Raritan Bay and Sandy Hook Bay
Highlands, New Jersey
Coastal Storm Risk Management
Feasibility Study

Appendix C

Economics

July 2015

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July 2015

BOROUGH OF HIGHLANDS, NEW JERSEY
FEASIBILITY STUDY
INTERIM ECONOMICS SUBMISSION

U.S. Army Corp of Engineers **New York District**

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DISCLAIMER

This product is being released early in the planning process.
Feasibility level details will be identified during project optimization,
which is after public and agency review of the draft report.
Please be advised that this document
is subject to revision as the analysis continues.

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INTRODUCTION

REPORT PURPOSE AND SCOPE

1. This interim report was prepared to document procedures and results of the economic storm damage analysis for the Borough of Highlands, New Jersey Feasibility Study. This report presents the findings of economic assessments for the without-project future conditions.

2. Economic analyses include the development of stage versus damage relationships and annual damages over a 50-year analysis period, from year 2018 to year 2068. Damage assessments include tidal inundation and wave damages. The effect of interior flooding has not been incorporated into this submission.

CONDITIONS

3. Estimates of without-project damages are based on 2013 price levels and a 50-year project life, and reflect the economic condition of the Borough of Highlands as of the year 2013. Damages have been annualized over the 50-year project life using the 2015 fiscal year Federal water resource studies discount rate of 3.375 %.

4. Included in this interim economics report are:
    - Description of the Study Areas,
    - Identification of the without-project future conditions,
    - Summary of the flood damage analysis methodologies,
    - Summary of the wave damage analysis methodologies,
    - Summary of the report findings.

STUDY AUTHORIZATION

5. A combined beach erosion control and storm damage protection study for Raritan Bay and Sandy Hook Bay, New Jersey, including the Borough of Highlands, was authorized by a resolution of the U.S. House of Representatives Committee on Public Works and Transportation and adopted August 1, 1990. The resolution states that:

"Resolved by the Committee of Public Works and Transportation of the U.S. House of Representatives, that the Board of Engineers for Rivers and Harbors is requested to review the report of the Chief of Engineers on the Raritan Bay and Sandy Hook Bay, New Jersey, published as House Document 464, Eighty-seventh Congress, Second Session, and other pertinent reports, to determine the advisability of modifications of the recommendations contained therein to provide erosion control and storm damage prevention for the Raritan Bay and Sandy Hook Bay ."

6. The project, including incomplete construction, was re-authorized by the Water Resources Development Act of 1996 (Public Law 104-303, approved October 12, 1996, 110 Stat. 3658).

PRIOR STUDIES

7. The existing Federal project was authorized by the Flood Control Act of October 12, 1962 in accordance with House Document 464, Eighty-seventh Congress, Second Session. This project resulted in shore protection improvements in certain municipalities; however, improvements in the Borough of Highlands were not considered economically feasible and therefore, were not recommended.

8. A Reconnaissance Study Report for Raritan Bay and Sandy Hook Bay was completed in March 1993. The Raritan Bay and Sandy Hook Bay study area is a 21-mile stretch located between Sandy Hook and the mouth of the Raritan River. The area has been subject to storm damage and major flooding.

9. The purpose of the Reconnaissance Study was to identify and evaluate possible solutions to storm damage problems, to determine if there was local support for a potential project, to make recommendations with regard to the continuation of the study, and to develop a scope of study and cost estimate for a feasibility study.

10. The Reconnaissance Report focused on the community of Port Monmouth, a section of Middletown Township, and identified potential Federal interest for the communities of Middletown Township, Highlands, Union Beach, Keyport, and Cliffwood Beach. Considering the complexity of coastal processes and interior drainage in the area, and lack of

hard data, a pre-feasibility study within a greater level of detail was undertaken to verify interest in conducting feasibility level studies.

11. The pre-feasibility study for the Borough of Highlands was completed in February 1999 and determined that there likely was Federal interest in a storm damage reduction project. The State of New Jersey supported the findings and is participating as the local sponsor and cost share partner for the Feasibility Study.

DESCRIPTION OF THE STUDY AREA

LOCATION

12. The study area is contained within the Borough of Highlands in northeast Monmouth County in the State of New Jersey. The area consists of approximately 0.7 square miles located between the Sandy Hook Bay and the Navesink River. Monmouth County is located along the Atlantic Coastal Plain Physiographic Province and is bordered by four (4) counties: Middlesex to the north, Mercer and Burlington to the west and Ocean to the south. It is situated 26 miles south from New York City, with parts of Highlands Borough sitting on the highest point of land on the Atlantic coastline.

13. Overall, the Borough of Highlands is approximately 2,000 feet wide. It is characterized by primarily low, flat terrain. Although the topography is flat for about 1,500 feet inland from Sandy Hook Bay, the ground rises dramatically to an elevation of 240-feet NGVD. Shorelines in the eastern portion near Sandy Hook and the Shrewsbury River and in the southwestern portion near Middletown consist of low-lying marsh. The Highlands Borough business district as well as the central sections are protected by assorted public and private bulkheads, seawalls and revetments.

ACCESSIBILITY

14. Vehicle: The study area is convenient to major population centers, including New York City, through a network of modern highways, routes, tunnels and bridges. New Jersey State Route 36 runs east/west through Highlands providing direct access from the major corridors to the business district, shorefront and throughout the borough. Local routes connect with New Jersey State Highway Route 36, extending access to/from central Highlands and the shore points.

15. Rail and Bus: The community is serviced by New Jersey Transit (NJT) and Academy Bus Line which provide bus access to major commercial centers such as Philadelphia, Newark and New York City. The NJT buses provide connecting service throughout Monmouth County, to major airports, NJT Coast Line, Amtrak, Greyhound Lines, the Metropolitan Transportation Authority (MTA), Port Authority Trans-Hudson (PATH) trains, and the Port Authority of New York and New Jersey.

16. Ferry: The Highlands high speed ferry service provides water transportation from Highlands to New York City's Pier 11 (Wall Street) in 40 minutes and West 34th Street in 55 minutes. The passenger ferry service is operated by SeaStreak, a wholly-owned subsidiary of Sea Containers Ltd., and provides service on a daily basis. The Highlands Terminal is located at Conners Hotel on Shore Drive. Parking lots are available to ferry commuters with additional parking at the municipal parking lots located on Shore Drive and on South Second Street.

RECREATION AND TOURISM

17. Beaches: Highlands' beaches consist of three small recreational areas. Additionally, the nearby Gateway National Recreation Area at Sandy Hook is composed of long stretches of beaches and dune trails. South Bay Avenue Beach is situated along the Shrewsbury River in the Highlands while the Miller Street Beach is located along the bay coastline. Snug Harbor Beach is positioned along the bay and is the largest of the three beaches with approximately 150 feet of beachfront. Snug Harbor also offers courts for tennis, volleyball and basketball.

18. Restaurants and "Bed & Breakfast" Inns: Highlands boasts a variety of seafood restaurants; most located along Bay Avenue in the business district. Charter boats from the Borough provide locals and out-of-towners the ability to enjoy recreational fishing. Commercial fishermen catch clams, lobsters and salt-water fish, selling directly to wholesalers and retailers in the local fish markets. Historic homes have been converted into Bed & Breakfast Inns, attracting locals and tourists alike to the area.

19. Parks: Highlands also has several recreational parks including the Mt. Mitchell Scenic Overlook Park and the nearby Hartshorne Woods Park. The Monmouth County Park System (MCPS) has incorporated the former Highlands Army Air Defense military reservation into its Hartshorne Woods Park. MCPS is currently considering restoration of the buildings and artillery gun batteries that were not intentionally destroyed when the site was abandoned by the U.S. government.

POPULATION

20. State, County & Borough: As shown in Table 1, the population for the Borough of Highlands increased from 3,916 in 1970 to 5,005 in 2010 (28%). This is lower than the county-wide growth rate of 36% during the same period.

TABLE 1 – HISTORICAL AND PROJECTED POPULATIONS BOROUGH OF HIGHLANDS, NJ

Area Name	Census 1970	Census 1980	Census 1990	Census 2000	Census 2010	Projected 2025
New Jersey	7,171,112	736,5011	773,0188	841,4350	8,791,894	9,446,200
Monmouth County	461,849	503,173	553,124	615,301	630,380	694,189
Highlands	**3,916**	**5,187**	**4,849**	**5,097**	**5,005**	**5,168**

Source: Monmouth County Division of Planning Aug 6, 2012

21. These population growth trends have slowed, with county-wide growth of 2.5% between 2000 and 2010, while the population has actually decreased in Highlands. The population of Monmouth County is expected to increase at a rate of 10.1% between 2010 and 2025. In comparison, the Borough of Highlands is expected to experience minimal growth (3.3%) through 2025.

22. Density: The Borough of Highlands is heavily developed with a population density nearly six times the state average. The population per square mile (2010, US Census) for the State of New Jersey is 1,195.5 persons. The Monmouth County density population is 1,344.7 persons per square mile, while the population density for the Borough of Highlands yields 6,522.8 persons per square mile.

23. Ethnicity: The racial composition of the Borough of Highlands consists primarily of White non-Hispanic inhabitants comprising the majority of the local population with a total of 4,653 persons (93.0%). Following are Asian and other non-classified groups comprising (1.92%) of the population, African-Americans comprising (1.6%), and Hispanics comprising (1.39%). This data is summarized in Table 2.

TABLE 2 – ETHNICITY STATISTICS, BOROUGH OF HIGHLANDS		
Ethnicity Composition	**Total**	**%**
White non-Hispanic	4,653	93.0
African Americans	81	1.6
American Indian and Alaska Native	14	0.3
Asian	65	1.3
Other	192	3.8
Total Persons:	***5,005***	***100***

Source- 2010 US Census

24. Age: Table 3 provides a comparison between the ages of Highlands, Monmouth County and New Jersey residents for census year 2010. The most notable difference is the low proportion of children and adolescents in Highlands (20.6%) in comparison to Monmouth County (37%). A higher than typical proportion of Highlands residents, 3,470 persons (68.1%), are within the ages of 20 to 64 years, classified as working age. The median age for Highlands is similar to the State and county values.

TABLE 3 - 2010 POPULATION AND HOUSEHOLD STATISTICS BOROUGH OF HIGHLANDS, MONMOUTH COUNTY, NEW JERSEY						
	Borough of Highlands		**Monmouth County**		**New Jersey**	
	Total	**%**	**Total**	**%**	**Total**	**%**
Total Population Sex and Age	5,005		630,380		8,791,894	
Male	2,522	50.3	306,654	48.6	4,279,600	48.7
Female	2,483	49.6	323,726	51.4	4,512,294	51.3
Under 5 years	252	5.0	34,755	5.5	541,020	6.2
5 years to 19 years	545	10.9	130,723	20.7	1,750,183	19.9
20 years to 64 years	3,564	71.2	378,211	60.0	5,665,670	64.4
65 years and over	644	12.9	86,691	13.8	835,021	9.5
Median Age	45.1		41.3		39.0	
Total Households	2,623		233,983		3,214,360	
Family Households	1,160	44.2	163,389	69.8	2,226,606	69.3
Non-Family Households	1,463	55.8	70,954	30.3	987,754	30.7

Source- 2010 US Census

25. Households: Family households make up a lower percentage of the total households in the Borough of Highlands than in the rest of the county or State. The average household size is 1.91 persons, compared to 2.79 for both the county and the State.

INCOME AND EMPLOYMENT

26. Income: Incomes in Highlands are low to moderate in comparison to Monmouth County. Even though the median household income level for the county ($82,265) is $12,454 higher than the State ($69,811), the Highlands has a higher proportion of residents below the poverty line. The medium value of owner-occupied housing units in the Borough of Highlands, as reported by the 2010 Census, was 11% less than in the State overall, and 25% less than for Monmouth County, as shown in Table 4.

TABLE 4 – COMPARISON OF INCOMES FROM 2010 CENSUS

Indicator	Highlands	Monmouth	New Jersey	United States
Per Capita Income	$42,737	$40,976	$34,858	$27,334
Median Household Income	$75,291	$82,265	$69,811	$51,914
Individual Below Poverty Line (% of Population)	12.3%	6.3%	9.1%	13.8%
Median Value of Owner Occupied Housing Unit	$319,200	$424,800	$357,900	$188,900

Source-2006-2010 American Community Survey 5-Year Estimates

27. Labor Force: As shown in Table 5, the Borough of Highlands' unemployment rate (13.9%) is higher than the unemployment rates for Monmouth County and for State of New Jersey. The total employed population over 16 years of age in the Borough of Highlands numbered 2,738, and 59.3% of this population was female. Educational, health and social services occupations employed 18.0% of the working population. Management professional, scientific administrative and waste management was the second largest employment sector (17.7%), followed by finance, insurance, real estate, rental and leasing (15.7%), and retail trade (9.5%). Construction accounts for 6.9% of employment, and farming and related occupations account for 0.4%.

TABLE 5 – 2011 EMPLOYMENT DATA, BOROUGH OF HIGHLANDS, MONMOUTH COUNTY, NEW JERSEY			
Employment Status	**Borough of Highlands**	**Monmouth County**	**New Jersey***
Population Aged 16 years or over	4,532	496,494	6,893,087
In Labor Force	3,121	334,260	4,596,702
Employed	2,739	333,552	4,230,560
Unemployment	382	25,569	356,690
% Unemployment	13.9%	7.7%	8.4%

Source-2007-2011 American Community Survey 5-Year Estimates

****Source-2006-2010 American Community Survey 5-Year Estimates***

ECONOMY AND LAND USE

28. The Borough of Highlands was incorporated in 1900. At that time the local economy was based around three main water-dependent industries: fishing, boating and clamming. In its early years the community supported a prosperous clamming industry. While overuse and pollution nearly devastated the industry, clamming recently began making a successful comeback. Although most of the clams harvested in the area of Raritan and Sandy Hook Bays are not fit for immediate consumption, clams may be purified at a depuration plant, or transplanted to cleaner water for a minimum of 30 days. The J. T. White depuration plant in Highlands is one of two facilities operating in Monmouth County.

29. The economy of Monmouth County has undergone extensive growth in recent years with much of the development concentrated along the major transportation routes. The majority of non-residential development has been for office and research facilities. According to the U.S. Census Bureau, there were 21 business establishments in the Borough of Highlands in 2012 with a total of 198 employees having an average annual payroll of $21,394.

30. With a total area of approximately 48 acres, the majority of land in the immediate project area contains residential (~70% of Borough area) and commercial and marine development (~30% of Borough area) within the low-lying areas along the Sandy Hook Bayshore (NJ Future 2014). Commercial development is concentrated along Route 36, Bay Avenue and Linden Avenue.

HOUSING UNITS

31. As presented in Table 6, of the total residential housing units reported by the U.S. Census Bureau for 2010, there were 1,398 detached single family houses, 214 attached single family houses, 1299 multi-family units, and 128 mobile homes located within the Borough. About half of the units were built before 1969 (1,661 total) with some dating to 1939 and earlier. The next growth period in housing in this area was during the 1970's and 1980's, when 1,137 new units were built. Between 1990 and 2000, 94 new nits were constructed, and between 2000 and 2010, 147 new housing units were built in the Borough.

TABLE 6 –SUMMARY OF HOUSING UNITS-2006- 2010 HIGHLANDS, NEW JERSEY	
Land Use/Category	**Community Total Number**
Single Family Residential (detached)	1,398
Single Family Residential (attached)	214
Multi-Family Residential (2 to 4 units)	477
Multi-Family Residential (5 to 9 units)	139
Multi-Family Residential (> 10 units)	683
Mobile/Trailer Residential	128
Total Housing Units	**3,039**
Vacant /Seasonal Housing Units	605
Total Occupied Units:	***2,434***

Source: U.S. Census Bureau, 2010 Census

DESCRIPTION OF THE PROBLEM

32. The majority of development in the Borough of Highlands is located between the waters of Sandy Hook Bay or the Shrewsbury River, and a bluff extending up to 240 feet NGVD. Sandy Hook acts as a barrier preventing the Atlantic Ocean waves and storm surges from breaking on the shore of the Highlands. This low lying area is vulnerable to severe tidal inundation and wave damage. Most of the development is located below the 10-foot NGVD contour placing it within the regulated 100-year floodplain.

33. In addition to tidal inundation, the topography in the Highlands creates significant flooding due to the ponding of rainfall and runoff. In the center of the Borough, a topographic depression is developed as elevations slope gently away from the shoreline forming an area where floodwaters pond during periods of heavy rain. This problem is most pronounced when heavy rainfall coincides with abnormally high tides or storm surge. The Borough maintains numerous storm drains and two pump stations which help to reduce the severity of this interior flooding. Nevertheless, flooding in the Borough is pervasive, potentially affecting nearly all of the developed properties.

STORM HISTORY

34. A series of coastal storms have impacted the Borough of Highlands over the years, causing evacuations and extensive damage from both flooding and wave overtopping of low-lying bulkheads. According to the Federal Insurance and Mitigation Administration (FIMA), there are a total of 914 flood insurance policies in force within the Borough, with a total insured value of approximately $95,000,000.

35. Both extra-tropical storms (nor'easters) and hurricanes have impacted the Raritan and Sandy Hook bayshore areas. These storms produce wind and wave-driven surges that cause extensive flooding within the study area. Storm surges also frequently block existing storm water outlets, resulting in prolonged and extensive interior flooding.

36. Some of the most damaging storms that have impacted the Borough of Highlands include the following:

- <u>Hurricane of September 14, 1944</u> – This hurricane caused damage losses estimated at over $2,500,000 (1944 dollars) in the bayshore area. Peak tide height reached 8.4 feet NGVD in the area from Highlands to Keyport and 12.0 inches of rain were recorded in New Brunswick. At Highlands, the storm caused damage to streets, sewers, water lines and bulkheads. About 150 homes, 20 hotels, numerous stores and the sewage and water treatment facility were inundated. Several pavilions were also destroyed by waves.

- Extra-tropical Storm of November 25, 1950 - This storm, which produced tides of 9.1 feet NGVD at Keyport, caused over $2,000,000 (1950 dollars) of damage in the bayshore area. According to newspaper accounts, there were two deaths, one in Union Beach and another in Keansburg. Rainfall totaled approximately 2.5 inches. The accompanying high tide in the New York Harbor area was up to 2 feet above the previous maximum recorded during the 1944 hurricane.

  At Leonardo, Atlantic Highlands, and Highlands, boats and piers were severely damaged by tide and wave action in Sandy Hook Bay. The entire downtown section of Highlands was flooded resulting in the evacuation of residents and heavy damage to many commercial establishments. The beaches and many streets in the area were also damaged.

- Extra-tropical Storm of November 6-7, 1953 – Total estimated damage for this storm was estimated at $1,630,000 (1953 dollars). At Long Branch (Atlantic Coast), the strongest wind was measured at 78 miles per hour from the east. Total rainfall was estimated at 1.25 inches. Flooded tracks near South Amboy and other places resulted in loss of railway service along the entire north shore. The State Legislature of New Jersey organized the "Legislative Commission to Study Sea Storm Damage" as a result of the severe damage from the storm. The Commission found that direct damage to public property in the bayshore area was approximately $374,000 (1953 dollars).

- Hurricane Donna (September 12, 1960) – Total estimated damage for this Hurricane on the bayshore was $6,000,000 (1960 dollars). More than half of the total damages included damage to homes which were flooded or destroyed. Another one-third of the loss was the result of structural and stock damage to stores, restaurants and waterfront concession. Tides produced by the hurricane reached 8.7 feet NGVD with wind gusts up to 79 mph. A total of 4.5 inches of rainfall was reported at Morgan. In Highlands water was 4 to 5 feet deep on the main street and a large number of stores and homes were flooded. Newspapers carried reports of raw sewage floating in the streets. A recently constructed bulkhead was flanked by the tide and the street behind the bulkhead was washed out.

- Nor'easter of March 6-8, 1962 – During this storm, maximum water levels at the Battery and at Willets Point were 7.7 and 9.2 feet NGVD, respectively. Damage to beaches, bluffs, buildings, and erosion control structures on the bayshore were estimated at nearly $1,200,000.
- January 23, 1966 – Strong winds occurring during high tide caused flooding on the bay shore. Many residents had to be rescued from their homes during this event.
- November 11, 1977 – At the time of its occurrence, this storm was identified by many as the worst storm in recent history. The 7 inches of rain that fell in a 24 hour period caused homes to be flooded and left most local roadways closed.
- March 29, 1984. – This Northeaster caused widespread damage along the entire Mid-Atlantic coast. Water levels reached a peak of 7.14 feet NGVD at Sandy Hook, with a peak surge of 6.1 feet above predicted tides. Most of the low-lying streets of Highlands were under water through the day with water levels 3 to 4 feet above the roadways. More than 300 residents were evacuated, many by boat. The northern section of Highlands was most severely affected; the area bounded to the south by Bay Avenue was almost completely inundated. More than 80 cars were submerged.
- Nor'easter of December 11-12, 1992 – Gale force winds in combination with high tides caused the worst flooding in decades on the bay shore. Thousands of homes were damaged or destroyed and hundreds of residents were evacuated as floodwaters inundated local neighborhoods. A section of bulkhead at the end of Snug Harbor at Highlands was destroyed, possibly contributing to the severe inundation damages suffered by the low-lying town. Other bulkheads suffered moderate damage. In a garage attached to the second house on Water Witch Way, landward of the bulkhead, the water level reached 4 to5 feet above the ground elevation. This level of inundation appeared to be typical of all the homes in the town within five blocks of the water front. Widespread flooding resulted in vast amounts of furniture, debris and personal belongings stacked along the sidewalks awaiting removal. In one instance, flooding also prevented emergency response to a fire which destroyed a five-unit residential building.
- Nearly $5,300,000 in flood insurance claims were paid for damage within the Highlands as a result of the 1992 storm. Nearly 600 Highlands residents registered for emergency assistance and 249 housing assistance grants were issued. A total of 283 small business

administration loan applications were filed as the Borough struggled to recover from this major disaster.

- Hurricane Sandy October 29, 2012 – As the storm traveled up the Atlantic coastline after originating in the Caribbean, three weather systems combined to form a super storm. The storm became the largest Atlantic hurricane of record with winds spanning approximately 1,100 miles. The size and the energy of the storm caused unprecedented damage along the northern Atlantic coastline including damage to infrastructure, businesses and residences from flooding, wave action and erosion. The addition of the full moon tide over several tidal cycles caused damage to more than 40,000 residences in New Jersey.

  The 12-17 foot storm surge caused damage to approximately 1,200 of the 1,500 homes and almost all of the businesses in the downtown area. The preliminary evaluation estimated that approximately 800 of the 1,200 damaged structures would require being elevated almost 14 feet. The waterfront trailer park was wiped out by the storm surge and wave action.

  Widespread damage was also caused to many of the borough facilities and infrastructure including, Highlands Borough Hall, Highlands fire house, Highlands first aid building, the DPW garage, community center, pumping stations, electrical facilities, park facilities, and roadways. Preliminary estimates for repairs for damage to the municipal properties were in excess of $15 million.

WITHOUT-PROJECT FUTURE CONDITIONS

37. The Borough of Highlands without-project future conditions have been identified as:

    - worsening tidal flooding and wave impacts as continued sea level rise contributes to future storm damage; and
    - reconstruction of substantially damaged buildings to levels above the regulated Base Flood Elevation in accordance with floodplain management regulations.

38. It is expected that storms will continue to occur into the future, causing damage in this area. Tidal inundation is expected to increase gradually over time, in direct relation to the

anticipated rise in relative sea level. Based upon long-term trends measured at Sandy Hook, a 0.014-foot per year increase is anticipated, resulting in a 0.7-foot increase over the 50-year period of analysis for the project. In future years this will result in more frequent and higher stages of flooding.

39. According to the FEMA Flood Insurance Rate Map (FIRM), virtually all of Highlands Borough has been classified as a "Special Flood Hazard Area" inundated by the 100-year flood. In order to regulate land development in the floodplain, the Borough of Highlands has adopted and enforces various ordinances and regulations. Highlands Flood Damage Prevention Ordinance (0-99-11 Part 7, Article XXIV of the Zoning Ordinance, adopted August 18, 1999) has a primary purpose to prevent construction and development from increasing flooding as well as to ensure public safety and reduce property damage. The ordinances and regulations call for elevating buildings above the adopted Base Flood Elevation (BFE) for both new construction projects and substantial improvements to existing structures.

FLOOD DAMAGE

GENERAL

40. In order to address the storm damage problem in Highlands, various alternatives are being developed to provide additional storm damage reduction and shore protection. These alternatives are being developed in coordination with the New Jersey Department of Environmental Protection (NJDEP), the non-Federal Sponsor, and in conjunction with input from local municipalities and other interested parties.

41. The following basic steps were used in the analysis of inundation damage:
    - Assignment of evaluation reaches,
    - Inventory structures within the 500-year floodplain,
    - Estimate depreciated structure replacement costs,
    - Assign generalized stage vs. damage relationships to each structure,
    - Calculate aggregated stage versus damage relationships, and
    - Calculate average annual damages.

42. Flood damage calculations were performed using the Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) computer program. This program applies Monte Carlo Simulation to calculate expected damage values while explicitly accounting for uncertainty in the input data. HEC-FDA models were prepared for the existing without-project and future without-project conditions.

ECONOMIC REACHES

43. In order to conduct economic benefit analyses of alternative plans and to simplify the stage versus damage and subsequent interior drainage analyses, the study area was divided into seven (7) economic reaches. To more accurately define proposed levee and floodwall limits two economic reaches (five and seven) were further divided into additional sub reaches. Economic reach selection was determined by the criteria below. Reach description and structure counts are provided in Table 7.

    - Interior drainage areas: High ground between drainage areas was identified and the structures within these areas were assigned to reaches corresponding to the drainage areas. This delineation simplified the HEC-FDA stage versus damage modeling and will simplify corresponding alignment of the reaches with the interior drainage modeling.

- Existing protection features: Some structures along the shorefront are susceptible to wave attack damage in addition to flood damage during major storms. The existing shore protection structures provide varying levels of protection to these buildings. Reach boundaries were assigned at significant changes in the existing level of protection. These structures were assigned to be separate databases for analysis of wave damage.
- Potential protection limits: Certain areas of the community may be outside some of the proposed protection alignments. Identifying those areas as separate reaches facilitates eventual modeling of the benefit cost ratio (BCR) differences between the alternatives.

44. The study area has been divided into eleven economic reaches. To define these reaches, the study area was first divided into segments (typically about 100 feet wide) by overlaying Location Identifiers (LIDs), or 'stations,' upon the study area map. Beginning with LID 1 in Atlantic Highlands Corporate limits, LIDs were drawn at approximately 500-foot intervals eastward to Shrewsbury River Bridge, providing a total of 20 LIDs. Economic Reaches were further defined by its bounding LIDs.

45. By using LIDs to divide the study area into a series of smaller units, unique characteristics of individual segments of the study area can be taken into account during plan formulation. This allows for the evaluation of different levels of flood risk protection alternatives for different portions of the study area.

TABLE 7 – OVERVIEW OF ECONOMIC REACHES AND STRUCTURES IN STUDY AREA				
Economic Reach	**Description**	**Number of Structures**		
		Res.	**Non-Res.**	**Total**
1.0	Reach 1 – Station 0+00 to 1+00 The westernmost reach (approx. 500 feet) extended from Atlantic Highlands Corporate limits to Willow Street.	18	0	18
2.0	Reach 2 – Station 1+01 to 2+00 From Willow Street extending (approx. 285 feet) to east end of Bulkhead located in front of Bay view Garden Apartments.	58	2	60
3.0	Reach 3 – Station 2+01 to 3+00 Extended eastward (approx. 1,330 feet) from Bulkhead (Retaining Wall at Sta. 2+00) to West of Gravelly Point Road.	17	8	25
4.0	Reach 4 – Station 3+01 to 6+00 Reach extending (approx. 1,110 feet) from West of Gravelly Point Road to Snug Harbor Avenue.	113	2	115
5.0	Reach 5- Station 6+01 to 12+00 Reach extending (approx. 2,400 feet) from Snug Harbor Avenue to Sea Drift Avenue.	232	13	245
5.1	Reach 5.1- Station 12+01 to 13+00 Reach Extending (approx. 690 feet) from Sea Drift Avenue to Atlantic Street.	26	2	28
6.0	Reach 6 – Station 13+01 to 16+99 Reach extending (approx. 1.275 feet) from Atlantic St. to Miller St.	242	18	260
7.0	Reach 7 – Station 17+00 to 20+00 Reach extending (approx. 2,420 feet) from Miller Street to New Jersey State Highway 36 Highlands Bridge*.	*130*	*29*	*159*
7.1	Reach 7.1 – Station 18+00 to 19+00 North of Shrewsbury Avenue (approx. 930 feet) between Jackson Avenue and Smith Street.	*12*	*2*	*14*
7.2	Reach 7.2 – Station 20+00 Optional Line of Protection (approx. 480 feet) East of Veterans Memorial Park	*2*	*8*	*10*
7.3	Reach 7.3 – Station 20+00 End of Line of Protection (approx. 400 feet)	*0*	*3*	*3*
	Total:	***850***	***87***	***937***

*Excludes reaches 7.1, 7.2 and 7.3)

INVENTORY METHODOLOGY

46. To accomplish the damage analysis, the development of a structural data base was needed to assist in predicting flood damages. The structural base data was originally generated through inspection of structures in the project area obtained through a "windshield survey", which was conducted in late 2003. Topographic mapping with a 2-foot contour interval used as a base map. Table 8 (below) indicates the physical characteristics obtained for the building inventory during the windshield survey.

TABLE 8 – PHYSICAL CHARACTERISTICS OBTAINED FROM BUILDING INVENTORY

1) Structure ID	
2) Map Number	10) Quality of Construction
3) Type	11) Current Condition
4) Usage	12) Ground Elevation*
5) Size	13) Main Floor Elevation
6) Story	14) Low Opening
7) Basement Type	15) Reach
8) Number of Garage Openings	16) Notes/Description (as required)
9) Exterior Construction	

*Note: * Ground elevations collected in NGVD.*

47. Each structure (or distinct usage type where multiple usages occur within a single building) was assigned a unique structure identification number (SRID) using Geographical Information System (GIS) database map. A GIS query was used to determine the structure footprint sizes which were adjusted for porches, decks, etc. according to observations in the field. The data collected was used to categorize the structure population into groups having common physical features. For each structure, data was also gathered pertaining to its damage potential including ground, main floor elevations, and lowest opening elevations.

48. Tables 9 and 10 summarize the finding of the structure inventory survey by structure type and the floodplain.

TABLE 9 – SUMMARY OF STRUCTURE INVENTORY BY STRUCTURE TYPE							
Economic (Damage) Reach	**Damage Categories**						**Totals by Reach**
	Apartment	**Commercial**	**Industrial**	**Municipal**	**Residential**	**Utility**	
1.0	0	0	0	0	18	0	***18***
2.0	0	2	0	0	58	0	***60***
3.0	5	3	0	0	17	0	***25***
4.0	0	2	0	0	113	0	***115***
5.0	0	12	0	0	232	1	***245***
5.1	0	2	0	0	26	0	***28***
6.0	1	9	4	3	242	1	***260***
7.0	1	26	3	0	130	2	***159***
7.1	0	2	0	0	12	0	***14***
7.2	0	5	3	0	2	0	***10***
7.3	0	3	0	0	0	0	***3***
Totals:	***7***	***66***	***7***	***3***	***850***	***4***	***937***

TABLE 10 – SUMMARY OF STRUCTURE INVENTORY BY FLOODPLAIN								
BUILDINGS WITH GROUND ELEVATIONS AT OR BELOW FLOODLEVEL								
Economic Project Reach	**2-YR**	**5-YR**	**10-YR**	**25-YR**	**50-YR**	**100-YR**	**200-YR**	**500-YR**
Reach-1	4	9	14	17	18	18	18	18
Reach-2	33	37	49	49	53	59	60	60
Reach-3	0	0	4	11	17	25	25	25
Reach-4	0	23	105	109	114	114	114	114
Reach-5	40	213	229	232	238	240	246	247
Reach-5.1	0	13	16	18	24	26	28	28
Reach-6	31	144	201	246	256	256	259	259
Reach-7	0	131	153	161	166	172	172	172
Reach-7.1	0	11	11	13	14	14	14	14
Reach-7.2	0	0	0	0	0	0	0	0
Reach-7.3	0	0	0	0	0	0	0	0
TOTAL All Reaches:	***108***	***581***	***782***	***856***	***900***	***924***	***936***	***937***

STRUCTURE VALUES

49. The depreciated replacement value of each building in the floodplain was updated from August 2003 to October 2014 price level utilizing a limited survey update of 300 structures randomly selected from the original structure inventory. Square foot building costs were then calculated for these structures using 2014 RSMeans.. The original analysis combined the physical characteristics obtained in the inventory with standard unit prices per square foot. Updated costs for the remaining structures in the inventory were determined based upon cost adjustment factors derived from the partial survey update. Depreciation was then calculated based on the quality and condition of each structure. The total depreciated replacement value of all structures within the study area is estimated to be $235,300,000. Depreciated structure values by economic reach are summarized in Table 11. The original inventory was also revised to remove buildings destroyed by Hurricane Sandy and those subsequently demolished, based on information provided by Borough officials and a review of publicly available information.

TABLE 11 –DEPRECIATED STRUCTURE REPLACEMENT VALUE BY ECONOMIC REACHES

Economic Reach	Depreciated Replacement Value
1.0	$1,800,000
2.0	$8,000,000
3.0	$26,900,000
4.0	$25,000,000
5.0	$52,900,000
5.1	$13,200,000
6.0	$55,800,000
7.0	$42,100,000
7.1	$3,700,000
7.2	$2,500,000
7.3	$3,400,000
TOTAL All Reaches:	***$235,300,000***

STAGE FREQUENCY DATA

50. Stage-Frequency curves were derived from all structure locations by the New Orleans District of the US Army Corp of Engineers, based on regional stage-frequency curves developed by FEMA through surge and wave modeling of a suite of synthetic design storms using the ADCIRIC + SWAN model. Since HECFDA does not allow the input of specific stage-frequency curves for individual structures, aggregate curves were created for each reach using the median stages at each frequency interval. Tables 12 and 13 summarize stage versus frequency data that was used in the analyses. All future year stages include 0.7 feet sea level rise, calculated in accordance with current guidance (EC 1165-2-2111). Note that the waves arrive at the shoreline at a 45-degree angle of incidence and waves are in a non-breaking condition at the shoreline. Accordingly non-wave setup is included in these still water flood levels.

TABLE 12 SUMMARY OF STAGE VERSUS FREQUENCY DATA EXISTING CONDITION

Economic Project Reach	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Reach-1	7.3	7.9	8.1	9.1	10.3	11.6	13.4	15.0
Reach-2	8.3	8.8	9.1	9.2	10.3	11.6	13.4	15.0
Reach-3	5.3	6.2	7.8	9.3	10.2	11.4	13.4	14.9
Reach-4	5.3	6.2	7.8	9.2	10.4	11.7	13.4	14.9
Reach-5	5.3	6.5	7.8	9.2	10.4	11.6	13.3	14.8
Reach-5.1	5.3	6.5	7.8	9.2	10.4	11.6	13.3	14.8
Reach-6	5.3	6.2	7.6	9.0	10.1	11.2	13.0	14.5
Reach-7	4.3	6.2	7.5	9.0	10.1	11.2	13.0	14.3
Reach-7.1	4.3	602	7.5	9.0	10.1	11.2	13.0	14.3
Reach-7.2	4.3	6.2	7.5	9.0	10.1	11.2	13.0	14.3
Reach-7.3	4.3	6.2	7.5	9.0	10.1	11.2	13.0	14.3

51. The frequency of exceedance of stages in the Sandy Hook Bay was originally developed from a simulation of recorded and possible storm tide conditions developed from the period 1933-2003; the 70 year period of record. This record length was used to construct

stage vs. frequency confidence bands based on the order statistics approach within the Hydraulic Engineering Center Flood Damage Assessment Program.

TABLE 13 SUMMARY OF STAGE VERSUS FREQUENCY DATA FUTURE CONDITION								
Economic Project Reach	**2-YR**	**5-YR**	**10-YR**	**25-YR**	**50-YR**	**100-YR**	**200-YR**	**500-YR**
Reach-1	8.0	8.6	8.8	9.8	11.0	12.3	14.1	15.7
Reach-2	9.0	9.5	9.8	9.9	11.0	12.3	14.1	15.7
Reach-3	6.0	6.9	8.5	10.0	10.9	12.1	14.1	15.6
Reach-4	6.0	6.9	8.5	9.9	11.1	12.4	14.1	15.6
Reach-5	6.0	7.2	8.5	9.9	11.1	12.3	14.0	15.5
Reach-5.1	6.0	7.2	8.5	9.9	11.1	12.3	14.0	15.5
Reach-6	6.0	6.9	8.3	9.7	10.8	11.9	13.7	15.2
Reach-7	5.0	6.9	8.2	9.7	10.8	11.9	13.7	15.0
Reach-7.1	5.0	6.9	8.2	9.7	10.8	11.9	13.7	15.0
Reach-7.2	5.0	6.9	8.2	9.7	10.8	11.9	13.7	15.0
Reach-7.3	5.0	6.9	8.2	9.7	10.8	11.9	13.7	15.0

INUNDATION DAMAGE FUNCTIONS

52. Based on the type, usage and value of each structure inventoried, Generalized Depth-Percent Damage functions were used to calculate inundation damage for each structure in the analysis. Using structure and ground elevation data these depth versus damage relationships were converted to corresponding stage (NGVD) versus damage relationships. Damages for individual structures at various stages were aggregated according to structure type (residential, apartment, commercial, etc.) and location (reach).

53. Two separately developed sets of damage functions formed the basis of the curves used in the analysis. The Passaic River Basin Study (PRB) damage functions were originally developed in 1982 as part of the Passaic River Basin Feasibility Study. The Functions were later updated in 1995. PRB functions were developed for specific residential and non-residential (commercial, industrial, municipal, and utility) structure types.

54. The U.S. Army Corps of Engineers (USACE or Corps), Depth-Percent damage functions were developed for residential structures with and without basements.

55. For a single family residential structure (except for bi-level and raised ranch residences) the USACE damage functions have been used. For all other single and multi-family residence structures, Passaic River Basin damage functions were assigned. Residential content values for the damage functions assigned were determined in accordance with current guidelines averaged 43.5% of the structure value, in accordance with guidance found in Engineering Manual EM 1110-2-1619.

56. Three categories of damage were considered. Other damage includes physical damage to landscaping and buildings, as well as physical cost, such as evacuation, cleanup and temporary housing. The PRB functions were used to calculate other damage.

57. In addition to damage to structures and associated contents, the study attempted to capture damages to motor vehicles left in the study area during flood events, using USACE guidance found in Economic Guidance Memorandum 09-04, "Generic Depth-Damage Relationships for Vehicles", June 22, 2009. To expedite this component of the analysis, of the following simplifying assumptions were made during the estimation of the number and value of vehicles likely to be present in the study area during flood events:

1. It was assumed that 1.5 vehicles are associated with each housing unit in the Borough of Highlands, based on U.S. Census bureau data.
2. The average depreciated value of a vehicle in the study area is $10,000, a value which has been accepted for use in similar studies for USACE elsewhere in the country.
3. Sedans were assumed to be the predominant vehicle type in the study area; hence the Sedan depth-damage function in Table 4 of EGM 09-04 was applied to all vehicles in the inventory.
4. The total number of housing units was estimated by assuming that each structure covered by one of the generic USACE residential depth-damage functions contained a single residential unit. For other residential structures, it was assumed that damage to motor vehicles is included in the "other" component of the assigned Passaic River Basin depth-damage functions.
5. The probability that vehicle owners would move their vehicles to higher ground before a flood was assumed to be 73%. In the absence of any specific information regarding local warning times in advance of flood events this figure was derived by taking an average of the percentages given in Table 5 of EGM 09-04.

6. It was assumed that no vehicles would remain outside non-residential structures during a flood event.

58. A summary of the assumed distribution and value of vehicles associated with single-family residential structures in the study area is presented in Table 14:

TABLE 14 DISTRIBUTION OF MOTOR VEHICLES IN STUDY AREA			
Reach	**Motor Vehicles (Assumed)**		
	Number	**Value**	**Modeled Value***
1.0	18	$180,000	$50,760
2.0	56	$560,000	$157,920
3.0	3	$30,000	$8,460
4.0	99	$990,000	$279,180
5.0	206	$2,060,000	$580,920
5.1	19	$190,000	$53,580
6.0	222	$2,220,000	$626,040
7.0	111	$1,110,000	$313,020
7.1	12	$120,000	$33,840
7.2	0	$0	$0
7.3	0	$0	$0
Project Total	*746*	*$7,460,000*	*$2,103,720*

*Value adjusted for the probability that vehicles will be removed by owners prior to a flood event.

AVERAGE ANNUAL INUNDATION DAMAGES

59. The 937 structures in the updated Highlands inventory were split into two data bases for analysis. A total of 870 structures were identified as outside of the wave damage area and were analyzed for flood damage only (the remaining 67 were analyzed for wave damage in addition to inundation). For these buildings, the stage versus damage data was combined with stage versus frequency data using the HEC-FDA program. The HEC-FDA program quantifies uncertainty in discharge-frequency, stage-discharge, and stage-damage functions and incorporates it into economic and performance analyses of alternatives. The process applies a procedure (Monte Carlo simulation) that computes the expected value of

damage while accounting for uncertainty in the basic value. The HEC-FDA program presents results for expected annual damages and equivalent annual damages.

60. Under current Corps' guidance, risk and uncertainty must be incorporated into flood damage reduction studies. The following areas of uncertainty were incorporated into the HEC-FDA program:

- stage frequency
- first floor elevation
- depreciated structure value
- content-to-structure value ratio
- other-to-structure value ratio

61. The HEC-FDA program allows uncertainty in stage-frequency to be calculated using equivalent record length, for which USACE Engineering Manual, EM 1110-2-1619, Table 4-5, was consulted. For the Borough of Highlands HEC-FDA models, an equivalent record length of 70 years was assumed.

62. A first floor standard deviation of 0.6 feet was selected based on recommendations in the USACE Engineering Manual, EM 1110-2-1619, Table 6-5, and the 2-foot contour intervals provided in the project topographic mapping.

63. The analysis recognizes that estimates of depreciated structure value based on windshield inventories contain inherent uncertainty. Structure values are assumed to have a coefficient of variation of 10%. Engineering Manual EM 1110-2-1619 suggests that in lieu of better site-specific information, content-structure value ratios based on large samples of Flood Insurance Administration (FIA) claims records can be used (Table 6-4 in Engineering Manual EM 1110-2-1619). A coefficient of variation of 25% was applied to the content to value ratio. Since the damage functions present other damage as a percent of structure value, the other-to-structure value ratio was estimated to have a coefficient of variation of 10%.

64. The economic analysis includes the existing protection afforded by high shorefront elevations and bulkheads. Since damages are limited until the storm surge overtops the existing bulkhead or high ground, the analysis of existing conditions considers a levee as part of existing conditions along the shorefront. This levee allows the existing level of protection to be taken into account when calculating project damages. The high ground

elevation along the shorefront varies, but inundation will occur when overtop the bulkheads at the lowest elevations, identified as 6 feet NGVD. Under existing conditions, it is assumed that no damages result until water levels exceed the crest of this structure.

65. For this interim report, estimated storm damages are limited to structure, content and other damages at specific buildings. Public emergency costs have not yet been analyzed. Damages are represented by the output generated from the HEC-FDA models included in the attachments. Expected annual damages due to inundation only for the without-project/existing condition, and for the without-project/future year conditions for all 937 structures in the inventory are provided in Tables 15 and 16. Equivalent annual inundation damages are provided in Table 17.

TABLE 15 – SUMMARY OF WITHOUT-PROJECT CONDITION/BASE YEAR ANNUAL DAMAGE BY DAMAGE CATEGORIES AND DAMAGE REACHES

Damage Reach	Damage Categories							Total *
	Apartment	Commercial	Industrial	Municipal	Residential	Utility	Auto	
1	$0	$0	$0	$0	$82,400	$0	$4,180	$86,580
2	$0	$15,450	$0	$0	$663,940	$0	$26,550	$705,940
3	$107,170	$1,280	$0	$0	$151,290	$0	$150	$259,890
4	$0	$10,060	$0	$0	$635,110	$0	$19,290	$664,460
5	$0	$308,450	$0	$0	$1,784,790	$2,370	$60,600	$2,156,210
5.1	$0	$32,680	$0	$0	$120,680	$0	$3,880	$157,240
6	$24,250	$397,070	$44,150	$211,510	$1,801,370	$30	$43,980	$2,522,360
7	$23,740	$874,840	$0	$0	$1,457,720	$13,220	$29,070	$2,398,590
7.1	$0	$26,370	$0	$0	$52,720	$0	$2,320	$81,410
7.2	$0	$23,600	$4,370	$0	$30,270	$0	$0	$58,240
7.3	$0	$6,450	$0	$0	$0	$0	$0	$6,450
Total	*$155,160*	*$1,696,250*	*$48,520*	*$211,510*	*$6,780,290*	*$15,620*	*$190,020*	***$9,097,370***

** Does Not Include Wave Damage*

TABLE 16 - SUMMARY OF WITHOUT-PROJECT CONDITION/FUTURE YEAR ANNUAL DAMAGE BY DAMAGE CATEGORIES AND DAMAGE REACHES (0.7 FOOT SEA LEVEL RISE)								
Damage Reach	**Damage Categories**							**Total ***
	Apartment	**Commercial**	**Industrial**	**Municipal**	**Residential**	**Utility**	**Auto**	
1	$0	$0	$0	$0	$141,040	$0	$7,110	$148,150
2	$0	$25,720	$0	$0	$1,000,910	$0	$37,330	$1,063,960
3	$157,150	$1,860	$0	$0	$221,060	$0	$220	$380,290
4	$0	$14,210	$0	$0	$982,620	$0	$30,350	$1,027,180
5	$0	$482,030	$0	$0	$2,821,070	$3,780	$96,910	$3,403,790
5.1	$0	$47,860	$0	$0	$188,760	$0	$6,090	$242,710
6	$35,550	$672,480	$73,000	$360,290	$3,082,270	$40	$74,790	$4,298,420
7	$34,730	$1,281,670	$0	$0	$2,133,290	$19,440	$42,500	$3,511,630
7.1	$0	$38,760	$0	$0	$77,360	$0	$3,400	$119,520
7.2	$0	$34,700	$6,450	$0	$44,640	$0	$0	$85,790
7.3	$0	$9,510	$0	$0	$0	$0	$0	$9,510
Total	*$227,430*	*$2,608,800*	*$79,450*	*$360,290*	*$10,693,02*	*$23,260*	*$298,700*	***$14,290,950***

** Does Not Include Wave Damage*

TABLE 17 – SUMMARY OF WITHOUT PROJECT CONDITION EQUIVALENT ANNUAL DAMAGE (50-YEAR PERIOD OF ANALYSIS, 3.375 % INTEREST)								
Damage Reach	**Damage Categories**							**Total ***
	Apartment	**Commercial**	**Industrial**	**Municipal**	**Residential**	**Utility**	**Auto**	
1	$0	$0	$0	$0	$103,380	$0	$5,220	$108,600
2	$0	$19,130	$0	$0	$784,470	$0	$30,410	$834,010
3	$125,040	$1,490	$0	$0	$176,250	$0	$170	$302,950
4	$0	$11,540	$0	$0	$759,410	$0	$23,240	$794,190
5	$0	$370,540	$0	$0	$2,155,480	$2,880	$73,580	$2,602,480
5.1	$0	$38,110	$0	$0	$145,030	$0	$4,670	$187,810
6	$28,290	$495,580	$54,470	$264,730	$2,259,550	$0	$55,000	$3,157,620
7	$27,670	$1,020,370	$0	$0	$1,699,380	$15,440	$33,880	$2,796,740
7.1	$0	$30,800	$0	$0	$61,530	$0	$2,700	$95,030
7.2	$0	$27,580	$5,120	$0	$35,410	$0	$0	$68,110
7.3	$0	$7,550	$0	$0	$0	$0	$0	$7,550
Total	*$181,000*	*$2,022,690*	*$59,590*	*$264,730*	*$8,179,890*	*$18,320*	*$228,870*	*$10,955,090*

WAVE DAMAGES

GENERAL

66. Shorefront areas in the Borough of Highlands are exposed to waves which can break against some buildings with enough force to destroy the structure. The Flood Insurance Rate Maps (FIRMs) for Highlands at the time of the 2003 study identified approximately 218 structures within the V Zone, a designation reflecting potential high velocity wave impacts. These structures, plus an additional 28 front or second row buildings, were screened for possible wave attack damages. Of the 246 structures initially considered, 89 structures along the Highlands shoreline were originally deemed susceptible to wave attack based on current topography. Following the Post-Sandy inventory update, 67 structures remained from the original 89. The structures were subjected to a modified form of structural damage analysis that incorporated inundation damage with wave damage. This analysis used life-cycle simulation to account for the impact of regulatory rebuilding limitations, which reduces the potential for repetitive building failure.

WAVE FAILURE CRITERIA

67. The shorefront area of Highlands has historically been susceptible to attack by wind driven waves from Raritan Bay and Lower New York Harbor. In order to simplify the stage vs. damage analysis while accounting for waves from both sources, the wave heights in the analysis were all assumed to be depth limited. This means that the wave generation (or wave height) is limited by water depth. Therefore, using FEMA's "Ways of Estimating Wave Heights in Coastal Hazard Areas" (April 1981), wave height transmission beyond manmade structures were assumed limited by the water depth leeward of protective structures. Review of available wave data indicates that the depth limited waves at the buildings are typically smaller than the arriving waves, verifying the approach of using depth limited waves.

68. A controlling elevation was established to determine the limiting water depth between the bay and the structure. It was selected as the highest elevation that occurs in the path of the incoming wave from the shoreline to the structure. This lowest still water depth that occurs as a result of the controlling elevation will limit the wave height arriving at the structure. In some cases, bulkheads also limit wave impact areas. These structures were considered effective until overtopped by still water.

69. Several studies of wave damage and structural stability have related wave height to building failure. The analysis for the nearby Sea Bright to Ocean Township study calculated that a 2.2-foot breaking wave is sufficient to incur 100% damage to most structures. Building failure (100% damage) was found to occur at a minimum still water depth of 2.8 feet over the controlling elevation. This reflects the critical 2.2-foot breaking wave occurring at 78% of the still water depth.

WAVE TRANSMISSION

70. The landward limit of the wave damage analysis was determined based on the depth limited arriving wave height and wave transmission beyond the first row of buildings. The wave transmission was calculated using procedures described in using FEMA's "Ways of Estimating Wave Heights in Coastal High Hazard Areas." The density of the number of structures per reach fronting the shoreline was used to determine the transmission coefficient. This coefficient was applied to the incoming first row wave heights to determine the wave heights approaching the second row of structures. From the resulting calculations, it was established that no second row structures are likely to fail from wave attack.

DEPTH VS. DAMAGE FUNCTIONS

71. After considering limits on wave transmission, it was determined that 43 of the 89 structures in the wave zone database are subject to failure within the expected range of still water elevations. Custom damage functions were developed for each of the 43 buildings to blend inundation functions with the wave failure results. The Depth-Percent Damage functions were adjusted to transition from partial inundation damage to 100% damage at the failure depth (relative to main floor) for the remaining 27 affected buildings.

72. The wave failure point used to modify the inundation damage curves assumes 100% damage when still water surface elevations exceed 2.8 feet above the controlling ground elevation. Controlling elevations were identified and used to calculate the resultant still water level at which failure would occur due to wave attack. The depth versus damage curves for each of the affected structures were then modified to reflect the 100% damage depth. The data was imported into the HEC-FDA program to aggregate stage damage relationships by reach and to calculate average annual damage.

EXISTING CONDITIONS DAMAGES

73. Existing without project condition damages were calculated using both the inundation only and the combined inundation and wave attack depth damage functions for each affected structure. Total existing condition base year average annual damage to structures in the area susceptible to wave damage is calculated to be $1,128,000. Of this total, $706,000 is attributable to inundation, and $422,000 is attributable to wave damage. The most significant center of wave damage is Reach 7, with $217,000 of average annual structure damage attributable to waves. The remaining reaches in the study area containing wave-vulnerable structures are Reaches 4 and 5, each with approximately $95,000 in annual wave damage to structures.

FUTURE CONDITIONS DAMAGES

74. In both with and without project future conditions, structures that experience substantial damage as defined by the National Flood Insurance Program must be rebuilt to meet V-Zone requirements, which generally results in elevation of the structure such that the lowest horizontal structural member is at or above the applicable base flood elevation plus the freeboard stipulated in the local floodplain management ordinance. This will reduce the potential for repetitive building failure and future damages. Conversely, continued sea level rise will increase the potential for future damages.

75. Previous flood risk reduction studies for the Borough of Highlands project area were conducted prior to Hurricane Sandy and included a risk-based lifecycle analysis to determine equivalent annual damages due to waves taking into account changes in development conditions due to potential future storms and the effects of sea level rise. A total of four post-storm developments and two sea level conditions were evaluated to simulate the combined effect on future annual damage.

76. For the current study, it has been assumed that Hurricane Sandy represented a worst-case wave damage scenario, and since the updated structure inventory reflects all structures demolished or elevated following the storm, the assumption that the number of structures susceptible to future wave damages will change over time is no longer considered valid. Therefore, the future wave damages and equivalent annual damage for structures in the wave zone may be computed using the current inventory in HEC-FDA and the risk-based lifecycle model is no longer required.

77.

The wave damage results generated by HEC-FDA are presented in Table 18, along with a summary of the total structure value in each reach. The effects of baseline sea level rise were incorporated by projecting the current historic rate of sea level rise to the future year, in accordance with the current guidance as per the calculation of inundation damages for structures outside the wave zone, as described above.

TABLE 18 SUMMARY OF ANNUAL EQUIVALENT DAMAGES WITHIN THE WAVE ATTACK ZONE

Reach	Number of Structures	Total Depreciated Structure Replacement Value	Equivalent Annual Damage*
1	0	$0	$0
2	0	$0	$0
3	7	$14,174,970	$0
4	10	$4,314,460	$112,210
5	19	$3,051,880	$109,940
5.1	1	$2,025,550	$0
6	19	$3,469,820	$16,410
7	11	$6,226,090	$256,440
TOTALS:	***67***	***$33,262,770***	***$495,000***

*Damage attributable to wave damages, above the inundation damages presented in Table 17.
3.375% Discount Rate, 50-year Project Life

78. Of the $495,000 in equivalent annual wave damages, $265,000 (53.5%) is attributed to non-residential structures, while the remaining $230,000 (46.5%) is attributed to residential buildings. Of the 27 remaining structures in the wave damage zone for which custom depth-damage functions were assigned, only three are non-residential, while the rest are residential. However, these three non-residential structures are responsible for 45% of the total value of wave-vulnerable structures.

INTERIM REPORT SUMMARY

79. This interim report was prepared to document the procedures used to determine without-project damages and to assist in determining what alternatives may be economically viable.

80. This document has presented the finding of economic analyses including development of stage versus damage relationships and expected annual damages in the base year and future years. Assessments included tidal inundation and wave damage within the limits of the study area. Preliminary without project damages estimates are summarized in Table 19. Table 20 summarizes the residual damages under the with-project conditions; and Table 21 summarizes the net benefits of the project.

TABLE 19 WITHOUT PROJECT SUMMARY OF TOTAL EQUIVALENT ANNUAL DAMAGE			
Reach	**Inundation Damage**	**Wave Damage**	**Total Damage**
1	$108,600	$0	$108,600
2	$834,010	$0	$834,010
3	$302,950	$0	$302,950
4	$794,190	$112,210	$906,400
5	$2,602,480	$109,940	$2,712,420
5.1	$187,810	$0	$187,810
6	$3,157,620	$16,410	$3,174,030
7	$2,796,740	$256,440	$3,053,180
7.1	$95,030	$0	$95,030
7.2	$68,110	$0	$68,110
7.3	$7,550	$0	$7,550
TOTALS:	***$10,955,090***	***$495,000***	***$11,450,090***

3.375% Interest Rate, October 2014 price level

TABLE 20 WITH PROJECT SUMMARY OF TOTAL RESIDUAL EQUIVALENT ANNUAL DAMAGE			
Reach	**Inundation Damage**	**Wave Damage**	**Total Damage**
1	$16,000	$0	$16,000
2	$67,100	$0	$67,100
3	$167,910	$0	$167,910
4	$196,650	$39,820	$236,470
5	$420,330	$49,410	$469,740
5.1	$53,760	$0	$53,760
6	$448,370	$6,930	$455,300
7	$384,410	$125,900	$510,310
7.1	$22,200	$0	$22,200
7.2	$68,110	$0	$68,110
7.3	$7,550	$0	$7,550
TOTALS:	***$1,852,390***	***$222,060***	***$2,074,450***

3.375% Interest Rate, October 2014 price level

TABLE 21 SUMMARY OF TOTAL EQUIVALENT ANNUAL BENEFITS			
Reach	**Inundation Damage**	**Wave Damage**	**Total Damage**
1	$92,600	$0	$92,600
2	$766,910	$0	$766,910
3	$135,040	$0	$135,040
4	$597,540	$72,390	$669,930
5	$2,182,150	$60,530	$2,242,680
5.1	$134,050	$0	$134,050
6	$2,709,250	$9,480	$2,718,730
7	$2,412,330	$130,540	$2,542,870
7.1	$72,830	$0	$72,830
7.2	$0	$0	$0
7.3	$0	$0	$0
TOTALS:	***$9,102,700***	***$272,940***	***$9,375,640***

3.375% Interest Rate, October 2014 price level