North Shore of Long Island,
Asharoken, New York
Coastal Storm Risk Management
Feasibility Study

Appendix D

Economics

November 2015

Asharoken Feasibility Study

Economic Analysis for Storm Damage Reduction

Draft Benefits Report

November 2015

Contents

Tables

Figures

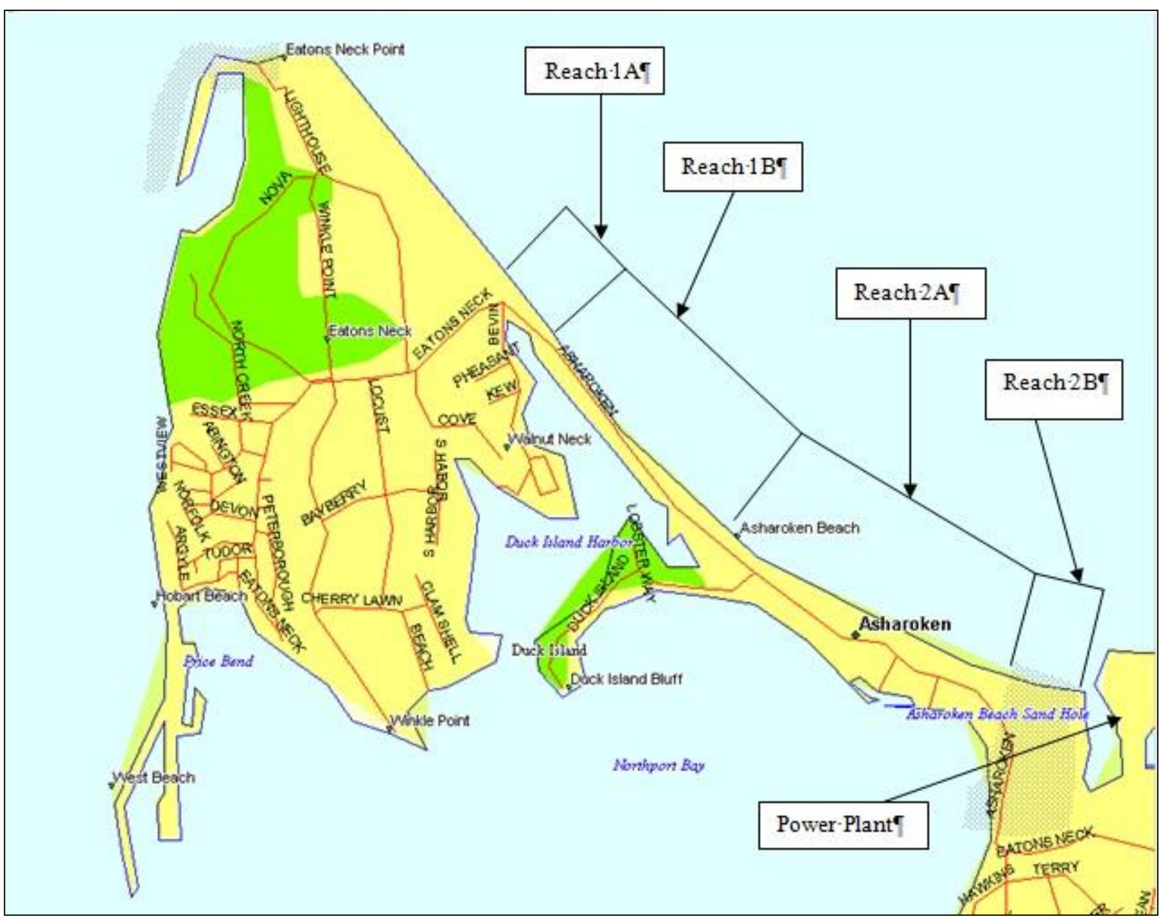
Asharoken, Suffolk County, New York
Economic Analysis for Storm Damage Reduction Feasibility Study

Draft Benefits Report

1. Introduction

Asharoken Village is located on the north shore of Long Island, within the Town of Huntington in Suffolk County, New York. Within the village, Asharoken Beach forms a tombolo (a sandbar connecting an island to the mainland) which provides the only physical connection between the Eatons Neck peninsula and the Long Island mainland. The tombolo is approximately 2.5 miles in length but in places less than 200 feet wide, and along its vulnerable northwestern portion consists of a narrow beach backed by dunes of variable condition. The road along the tombolo, known as Asharoken Avenue, forms the only access to and from the peninsula for residents of Eatons Neck and the western part of Asharoken Village and provides a service corridor for utilities.

Figure 1: Study Area Reach Map



This report assesses the benefits that may be realized by the implementation of various alternative measures to protect the vulnerable tombolo at Asharoken Beach. These benefits are derived from the avoidance of physical damage to the infrastructure links that make the Eatons Neck peninsula habitable, and the avoidance of costs associated with maintaining residents' safe access to and from the peninsula.

The Asharoken Beach tombolo stretches approximately 12,400 ft from Bevin Road at its northwestern end to the west jetty at the power plant (see Figure 1).

The study has included a review of data and methodologies from the following previous studies/reports and subsequent responses to them:

- Asharoken Beach: Section 14 Study, USACE, November 1988
- Asharoken Beach: Section 103 Study, USACE, November 1933
- North Shore of Long Island Reconnaissance Report, URS, September 1995
- Village Master Plan, Asharoken Village Planning Board, November 2002

2. Problem Identification

Sources of Damage

There are two major concerns associated with this study, of which the first is the current vulnerability of the road, utilities and existing coastal protection structures to storm-induced overtopping or breach at the northern end of the tombolo. The second concern is the vulnerability of residential structures to erosion at the southern end of the tombolo.

If measures are not implemented to protect Asharoken Beach (and hence the road) at the northern end of the tombolo, problems are anticipated in the following increments:

1. **Pre-overtopping**: erosion of beach material from the Long Island Sound side, leading to undermining of bulkheads and other existing protection.
2. **Still water overtopping**: periodic non-aggressive inundation of the tombolo by still water, hindering access but not resulting in significant damages to the road or utilities.
3. **Minor overtopping**: inundation of the road during minor storm events, resulting in access difficulties such as traffic delays, overwash of sand and debris, and the limited mobilization of emergency response teams.
4. **Major overtopping**: inundation by more serious storm events, resulting in blockage of the road, increased debris overwash, significant damage to the road surface, and major emergency response mobilization.
5. **Breach**: destruction or severance of the service and transport links that enable habitation of the peninsula; erosion of the tombolo resulting in loss of the roadway, roadbed, above ground and buried utilities, and complete isolation of the peninsula.

Given a sufficiently extreme storm event, breaches could be expected to occur at the narrowest and lowest sections of the tombolo, notably the 900 ft section immediately south of the intersection between Asharoken Avenue and Bevin Road at the northwestern end of the tombolo, where an emergency bulkhead was constructed in 1997. This section has been designated as Reach 1A. 5,300 ft section southeast of 1A to Duck lane designated Reach 1B. 5,000 foot segment from Duck Lane southeast to the last residential structure designated Reach 2A and extending from Reach 2A to the west jetty at the power plant designated Reach 2B.

The reaches covered by this study are described as follows:

Reach 1A: This reach consists of approximately 900 ft of shoreline with 80-100 ft of beach width on the Long Island Sound side, a bulkhead of elevation +12.5 ft NGVD with a 20 ft wide dune, and the paved road known as Asharoken Avenue immediately landward of the bulkhead and dune. A few residential properties are located on the harbor side of Asharoken Avenue. The shoreline in this reach is expected to recess at a rate of approximately 1 ft/yr. Without the implementation of protective measures, continued shoreline recession is expected to encroach on the structure toe and eventually lead to bulkhead failure and dune erosion. In addition, the existing bulkhead could fail under certain storm conditions, primarily due to wave overtopping. After bulkhead failure, erosion of the remaining dune would likely continue, with wave overtopping, overwash, inundation, and eventual breaching of the road.

Figure 2: Reach 1A – Aerial Photograph

Reach 1B: This reach consists of approximately 5,300 ft of shoreline with 100-150 ft of beach width on the Sound side backed by a 30 ft wide dune of average elevation +15.5 ft NGVD. For the majority of the length of this reach Asharoken Avenue lies to the landward side of the dune, but at its southern end a few residential structures have been built between the road and the dune. Residential structures have been built on the harbor side of the road over most of the length of this reach. The shoreline in this reach is expected to recess at a rate of approximately 1 ft/yr. The dune is expected to fail under certain storm conditions, primarily due to wave overtopping. After failure, dune erosion would continue with wave overtopping and overwash, inundation and breaching of the road.

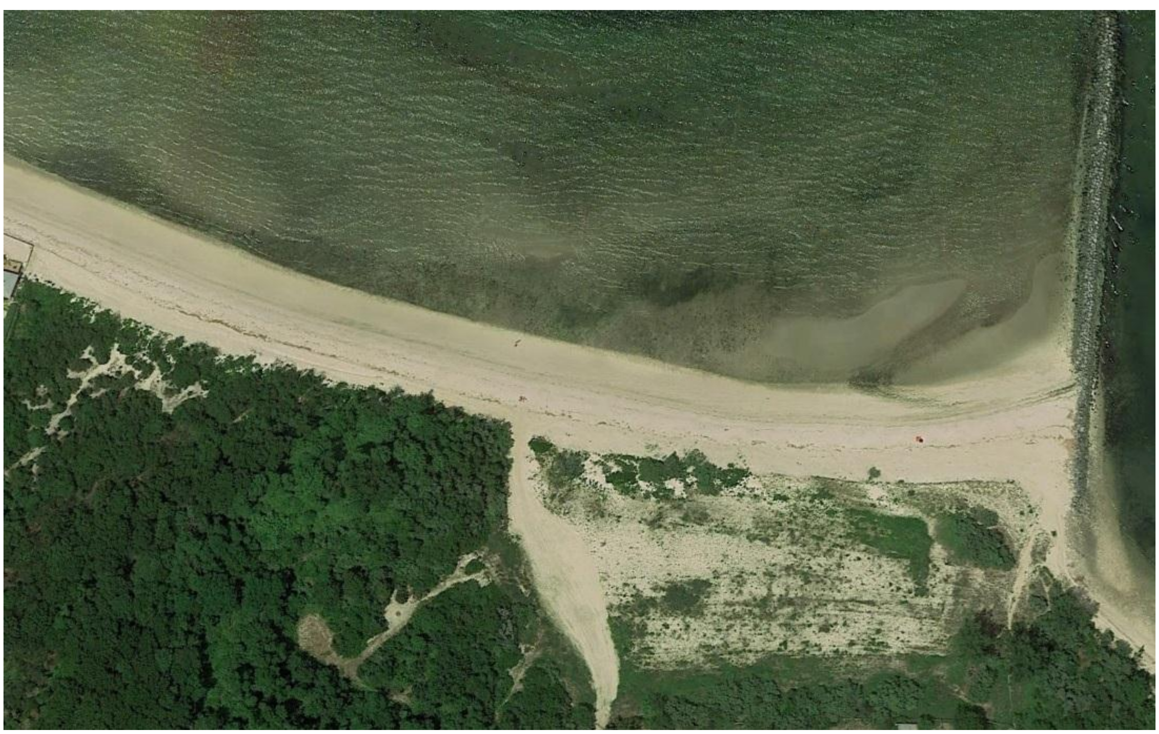
Figure 3: Reach 1B (Section) – Aerial Photograph

Reach 2A: This reach consists of approximately 5,000 ft of shoreline, a narrow beach on the Sound side, 4,000 to 4,200 linear feet of timber bulkhead with an average crest elevation of +14 ft. NGVD and average (13 ft. NGVD elevation behind the bulkhead) and 800 to 1,000 linear feet of dune with a crest elevation averaging +15.5 NGVD. The shoreline extends from Duck Island Lane southeast to the last residential structure on the Long Island Sound and is expected to recede at a rate of approximately 6 ft/yr.

Reach 2B: This reach consists of approximately 1,200 ft of shoreline extending from the last shorefront resident to the west jetty at the power plant. The shoreline is undeveloped with a large dune system having a +17 feet NGVD dune crest and an average ground elevation behind the dunes of approximately +14 ft NGVD. The average beach width is about 100 feet and erosion estimated to be 5 ft./year. Dune overwash and overtopping from waves is considered to be minimal in this reach due to the high dune elevations. Erosion is partially offset by the periodic placement of material dredged from the power plant cooling water intake channel.

Figure 4: Reach 2A (Section) – Aerial Photograph

Figure 5: Reach 2B – Aerial Photograph



Without-Project Future Conditions

In the absence of substantial investment in storm damage reduction measures along the tombolo (i.e. in the "without-project" condition), it is expected that future storms will continue to cause significant problems for the residents of Asharoken and Eatons Neck, and will continue to realize economically quantifiable damages. Two factors are expected to cause an increase in expected damages in future years:

Based on a study of_tidal records at the Battery, New York, and Montauk Point the rate of sea level rise ranged from 0.006 to 0.009 ft/year. Sea level rise at the north shore of Long Island was estimated at 0.008 ft/year or 0.8 feet in 100 years. This value represents a forecast based on observed historic changes at nearby gages. .

In Reach 1A, a factor affecting the future conditions and likely damages is the future actions to maintain or replace the existing bulkhead. The bulkhead in Reach 1A was repaired in 2013, and is currently assumed to provide protection from storm events of return periods up to and including 10 years and has a remaining life of seven years.

Following storm induced catastrophic failure of this bulkhead in any year, it is expected that the bulkhead will be replaced by local parties with a structure providing a similar level of protection.
In Reach 2A the bulkheads were constructed by individual property owners who are also responsible for any maintenance they may require. Following failure of the bulkhead line by wave overtopping or scour at the bulkhead toe the residential structures landward of the bulkhead will become vulnerable to erosion.

3. Economic and Social Base Study

Benefits that accrue from the implementation of measures to protect the tombolo may arise not only from the prevention of physical damage to the road, utilities and existing coastal protection structures, but also from the avoidance of responses to storm events and subsequent measures taken to ensure the safety and well-being of the residents of the Eatons Neck peninsula. The impact of a storm event on residents may range from minor inconvenience to a major threat to public safety, and in order to comprehensively assess the economic cost of all consequences of an event which obstructs or severs the tombolo, a socioeconomic study of the affected area and its population has been undertaken.

Of the two communities that lie within the area of interest to this study, the non-incorporated community of Eatons Neck lies wholly on the peninsula, while the incorporated Village of Asharoken is divided between the peninsula, the tombolo, and the mainland of Long Island. The only part of Asharoken Village within the study area is Northern Asharoken, which has been taken to be that part of the village which lies to the north of the most vulnerable section of the tombolo.

Apart from at its narrowest sections, the tombolo is heavily developed with residential properties, the great majority of which are inhabited throughout the year. The peninsula is comparatively sparsely developed, with heavily wooded parcels of undeveloped land rising to elevations of up to 150 feet. There is no commercial or other non-residential land use evident on the peninsula or the tombolo, apart from the Eatons Neck Fire Department and a US Coast Guard station on the northern tip of the peninsula. Commercial agricultural activity ceased on the peninsula in 1939, and the largest remaining parcel of undeveloped land was formerly the rural estate of Wall Street financier Henry Sturgis Morgan, founder of Morgan Stanley and grandson of J.P. Morgan. Most of the shoreline of the tombolo and the peninsula is privately owned, but there is one small publicly owned and accessible beach at the southwestern corner of Eatons Neck.

The most recent census data available is that for the 2010 census. Since census data is only available for discrete communities, an adjustment factor has been applied to raw data for Asharoken Village to determine the population and other socioeconomic data applicable to Northern Asharoken. This adjustment factor was calculated as the percentage of individual residential properties present on land to the northwest of the vulnerable section of the tombolo. This percentage was determined from a count of properties visible on high resolution aerial photographs of the Asharoken Beach area, assuming that socioeconomic factors such as household size and income are evenly distributed across the community. The adjustment factor was subsequently calculated to be 0.43. Table 1 presents key socioeconomic base data, incorporating the adjustment factor to derive figures applicable to the study area, and discussion of the key socioeconomic data follows.

Key Socioeconomic Data:

Population (including housing occupancy and number of households): Detailed studies of future population growth and other projections have not been undertaken. Modest population growth is projected over Suffolk County as a whole for the next 25 years, recent data indicates that the study area experienced an increase in population of 4.6% from 2000 to 2010.

From 1990 to 2000 there was an overall decline in population. The decrease in population in Asharoken was assumed by the Village Master Plan to result from several factors: Many of the children of families that moved to the area in the 80s and 90s had matured and moved away to college or were employed elsewhere and, because of the high cost of property, homes that were coming onto the market tended to be purchased by older people whose children no longer lived at home. The 2010 census data shows a 51.5% decrease in population for children under age 5, a 31% increase for 5 to 19 and 20 to 64 age groups and a 27% increase in the over age 64 . The population of Eatons Neck declined at a slower rate than Asharoken between 1990 and 2000. There was a decrease in people under 45 and an increase in people of retirement age during this time. From 2000 to 2010 the population of Eatons Neck increased by 1.3%. The overall increase included a 40.6% reduction in children under age 5 and 6.5% reduction in ages 20-64 along with a 21.1% increase in ages 5 to 19 and 28.4% increase over the age of 64. In light of this data which shows a demographic trend toward an older community, and probable resistance of the local community to significant further development, the study has not used projected future population levels in the analysis and has assumed 0% population growth over the project life.

The study also collected data relating to pet ownership and people with disabilities: emergency shelters and hotels are unlikely to accommodate residents' pets, and the cost of ensuring their suitable accommodation is not insignificant. Data from the Humane Society of the USA indicates that more than 800 cats and dogs may be resident in the study area. Census data indicates that more than 150 residents have disability status, and in the event of evacuation, special treatment for such people may tend to increase evacuation costs. However, due to the lack of precise data regarding the nature of these disabilities and the difficulty in quantifying the cost of special evacuation treatment, this data has not been included in the analysis.

Commuters: In the sense that anyone who travels to a place away from their residence for a particular purpose on a daily/regular basis can be considered a commuter, commuters may include both those who travel to their place of work and those who travel to a place of education. This data forms the basis for estimating the number of residents who may be cut off from their homes by a significant storm event and who will require temporary accommodation. Economic losses also result from delays to commuters' work journeys. Census data records the use by residents of private and public transport: public transport is assumed to include railroad and bus services, and since the peninsula is not served by any scheduled public transport links, this study assumes that public transport refers to the bulk of the journey to the workplace and does not include journeys by other means (mostly by car) to reach transport nodes such as the Long Island Railroad Station in Northport. Since no schools exist on the peninsula, all residents in education are at risk from being cut off from their homes and may require temporary accommodation, hence their inclusion in the commuter data. Since residents must also leave the peninsula for all services and shopping, the number of people affected by blockage or severance of the tombolo road may be assumed to be more than just those who leave for work and school.

Income/Employment: Comparisons with local (County) and State statistics for household income and the value of owner-occupied housing units tend to suggest that the peninsula is a relatively affluent area, with median household incomes in the study area 50% higher than in the County as a whole, and median house values 2-3 times greater than the County median. The 2000 census also reported that only 8 families in the study area were living below the designated poverty level, and that unemployment in the study area was greater than the County figure but lower than the State average.

Table 1: Key Socioeconomic Data

Socioeconomic Criteria	Asharoken	Northern Asharoken*	Eatons Neck	Peninsula*
Total Population	654	281	1,406	1,687
Under 5 years	16	7	57	64
5-19 years	114	49	304	353
20-64 years	380	163	783	946
Over 64 years	144	62	262	324
Number of households	255	110	519	629
Number of families	199	86	412	498
Families with children <18	59	25	179	204
Housing Occupancy				
Total Housing Units	302	130	575	705
Owner Occupied	227	98	488	586
Renter Occupied	28	12	31	43
Seasonal/Occasional	36	16	41	56
Vacant	47	20	56	76
Household size (Owner Occ.)	2.59	2.59	2.75	2.72
Household size (Renter Occ.)	2.39	2.39	2.0	2.07
Pet Ownership (cats & dogs)	396	170	753	924
Employment				
Population over16 years	549	361	1,038	1,399
In Labor Force	296	127	625	752
Employed	281	121	578	699
Unemployed	15	6	47	53
Unemployed, %	2.7	2.7	4.5	4.17
Total Commuters	275	118	578	696
Motor vehicle (driver)	202	87	415	502
Motor vehicle (passenger)	6	3	50	53
Public transport	41	18	46	64
Pedestrian	0	0	21	21
Mean travel time (mins)	47.7	47.7	45	45.5
School enrollment Total	157	68	361	429
Preschool/kindergarten	16	7	13	20
Elementary school	83	36	238	274
High school	40	17	60	77
College/graduate school	18	8	50	58
Disability Status Total	71	30	123	153
5-20 years	10	4	7	11
21-64 years	31	13	83	96
Over 64 years	30	13	33	46
“go-outside-home” disability	22	9	16	25
Median Household Income	$131,563		$124,167	
Median Family Income	$173,611		$133,158	

*Peninsula: the study area, covering Eatons Neck and Northern Asharoken (assuming 43% of residences in Asharoken Village are in Northern Asharoken, hence located on the peninsula). – Sources: Census 2010, US Census Bureau (except for disability – Census 2000), and The Humane Society.

4. Storm Damage and Cost Criteria

In Reaches1A and 1B, any physical damage resulting from storm events or cost associated with emergency response to such events that may be prevented or reduced by the implementation of a project to protect the tombolo may be considered a benefit. In Reach 2A, erosion damage to residential structures following bulkhead failure is the only evaluated source of damage. Following the review of previous studies and consideration of the local area in some detail, a range of damage and cost categories for inclusion in the analysis were identified. The potential sources of damage or cost that have been considered for all reaches except Reach 2B are described as follows:

Reaches 1A and 1B

In reach 1, the primary sources of damage are bulkhead and dune restoration, evacuation of residents during natural emergencies and restoration of roads and utilities. As this reach lacks presence of residential structures, structural damage is not one of the sources of damages

(a) Coastal Protection Structure Repair

The cost of reconstructing or replacing the existing protection measures (i.e. the bulkhead along Reaches 1A and 2A and the dune along Reaches 1B, 2A and 2 B) following storm-induced failure is a significant source of damage. Estimated costs have been provided by the USACE for replacement bulkhead structures in Reach 1A with 5 and 15-year levels of protection.

(b) Utility Damage

The Eatons Neck peninsula is currently supplied with water, electricity, telephone, and cable television services, but both Asharoken Village and the Eatons Neck peninsula are entirely unsewered, the residential properties relying instead on individual septic systems. The electrical service to the peninsula has recently been buried along Asharoken Avenue, and water supplies to the peninsula are also buried, whereas telephone and cable TV supplies are pole mounted. At present almost a third of Asharoken properties are heated using utility gas, and the village hopes to extend the supply of gas to the whole community in the future (the gas supply is currently only available to properties at the mainland end of the tombolo, southeast of the most vulnerable section). To assess damages to these utilities, it is assumed that the length of buried and pole mounted services destroyed will match the length of any breach caused by a severe storm event. The cost per linear foot of replacing the various utilities has been estimated using RS Means Electrical Cost Data (36th edition) and Heavy Construction Costs, 27th Edition (2013).

(c) Road Repair and Replacement

It is assumed that some storm events will damage only the road surface, while progressively more extreme events will also damage the roadbed, and ultimately wash away the entire construction and the body of the tombolo itself. Costs for road repair and replacement have been based on standard current construction estimating techniques, assuming that Asharoken Avenue would be reconstructed on the same line following breach/washout. Road reconstruction costs have been estimated using RS Means Heavy Construction Costs, 27th Edition (2013).

(d) Cleanup/Debris Removal

It is assumed that these costs include labor, equipment and vehicle hire, fuel, and appropriate disposal of the debris, and also that cleanup and debris removal costs will still apply to some extent when complete washout of the road occurs. Assumptions have been made regarding the crews (labor plus equipment) required for cleanup and debris removal, and the subsequent costs have been based on crew rates from RS Means Heavy Construction Costs, 27th Edition (2013).

(e) Emergency Personnel Costs
These costs are based on overtime worked by police and fire department officers, town highway department officials and medical personnel, and additional fuel and equipment if required. The affected population of the peninsula by itself is considered too small to warrant the use of the National Guard to assist in emergency response at this location, even in extreme events. Costs used in the analysis have been based on recorded costs for emergency personnel involved in recent flood response at other locations, with an appropriate adjustment factor to account for the different location.

(f) Accommodation for Full Evacuation
An extreme storm event likely to severely damage Asharoken Avenue, breach the tombolo completely or otherwise destroy the links that make the peninsula habitable will likely require the evacuation and temporary accommodation of the whole population of the peninsula for a duration depending on the length of the storm and the resulting recovery period. In the event of a breach this will be principally driven by the time required to reconstruct the road.

The Suffolk County Emergency Management Office (EMO) anticipates that an evacuation would be initiated in advance of an extreme storm event, and that residents would use their own transport to remove themselves to safety, with local emergency services providing transport for people with special needs or who are unable to provide their own transport. The Suffolk County EMO stressed that every possible effort would be made to ensure any evacuation is comprehensive, but any residents remaining on the peninsula after it has been completely isolated would be provided with shelter locally (in December 1992 the Eatons Neck Fire House was used), supplied with essentials once the storm has subsided, and given the option to relocate to temporary accommodation until access has been restored. The Suffolk County EMO anticipated that such supply and relocation would be carried out by the County Police Marine Division with Coast Guard assistance.

This study has used the current Federal per diem rate to cover the provision of hotel rooms and meals for evacuees, with additions to cover sundries including personal items not normally provided by hotels. It is assumed that virtually all residents will seek temporary accommodation in hotels rather than in Red Cross or other temporary shelters, which will have limited capacity.

Evacuation costs have also considered the transport and accommodation of residents' pets. It is assumed that when people are evacuated from their homes for several days or more, they will want to ensure their pets are also evacuated and suitable accommodation provided for them. Hotels will either not accommodate pets or charge extra for them, and Red Cross shelters are not able to provide appropriate facilities. Suffolk County Red Cross has limited arrangements with some local organizations to accommodate animals in an emergency, but residents are strongly encouraged to make their own arrangements as part of their individual emergency plans. Research suggests that the affected households may include more than 800 dogs and cats alone, and the analysis has used costs based on average boarding rates at local facilities.

(g) Accommodation for Temporarily Stranded Residents
It is assumed that some storm events that do not actually sever Asharoken Avenue will leave it inundated or otherwise temporarily blocked, and that there is a significant probability that this will isolate those residents of the peninsula in work and full-time education from their homes for short periods, requiring temporary accommodation to be provided for them.

Analysis of these costs has incorporated an assessment of the probability that such storm events occur during working days, and the relative affluence of the population, as evidenced by the socioeconomic data: as with full evacuation, it is assumed that commuters would probably seek out a hotel room rather than make do with the more basic temporary accommodation likely to be on offer, at Red Cross shelters or similar. Hence the analysis assumes that the daily cost to accommodate each stranded commuter will be similar to that for full evacuation, minus some of the extra costs for personal care items that would be incurred for a longer duration stay in temporary accommodation.

The fact that there are no retail stores or any other amenities on the peninsula makes it likely that as well as commuters, temporary accommodation would also have to be provided for other adult residents travelling off the peninsula for shopping or other services, and an uncertainty variable has been incorporated into the analysis to account for this possibility.

Since there are no educational establishments on the peninsula, all residents in full time education may also be counted as commuters, but these residents would be much more likely to be temporarily housed in shelters, the cost per person of which is around 10% of the cost assumed for adult commuters. Since the probability of a severe storm event occurring during school hours is much less than the probability of one occurring during the adult working day, the overall cost of sheltering stranded schoolchildren has been assumed to be not significant, and has not been included in the analysis.

(h) Traffic Delays

An economic loss (as a percentage of family income) can be attributed to delays experienced by commuters when they are forced to use longer alternative routes, or ordinary traffic patterns are disrupted by construction/repair work. Since there is no alternative route onto the peninsula other than Asharoken Avenue, costs due to lost work time are assumed to be realized when commuters find their progress across the tombolo slowed by cleanup operations, or are temporarily stranded on the peninsula. When evacuated or stranded on the mainland, it is assumed that temporary accommodation is likely to be found closer to centers of employment, and commuters may find they have a temporarily shorter commute, hence delay costs will not apply in these situations. The calculation of delay costs is based on guidance provided in ER 1105-2-100, *Planning Guidance Notebook*, and income data from the 2010 census.

(i) Recreation

There are currently no significant attractions or facilities for tourists on the Eatons Neck peninsula. Almost all the beaches are private, except for a small public beach and car park owned by the Town of Huntington at Hobart Beach on the southwestern tip of the peninsula. There is also a small wildlife preserve at Hobart Beach. The lighthouse at the Eatons Neck Coast Guard station is historically significant, but is not fully open to the public and does not generate significant numbers of visitors. Comments in the Asharoken Village Master Plan (VMP) suggest that the local residents would not welcome any further recreational development, and calculation of recreational benefits has not been included in this study.

(j) US Coast Guard Station

The Coast Guard Station at the northern tip of Eatons Neck is home to 45 personnel and dependents (according to the Asharoken Village Master Plan) and was considered for closure in the 1990s due to high operating costs. The station now seems likely to stay active for the foreseeable future, the USCG having assumed a more prominent role in the wake of 9/11. In the event of a storm severing Asharoken Avenue the station is likely to be self sufficient in terms of power and supplies, hence there are unlikely to be significant benefits derived from special measures to keep the station functioning while damage to the road is repaired. Therefore, costs associated with the Coast Guard Station have not been incorporated into the benefit analysis.

(k) Wetland Restoration

In the event of Asharoken Avenue being washed out over its most vulnerable section, or large amounts of sand from the Long Island Sound side being washed across the road, there is a strong possibility that large quantities of sand may be deposited over ecologically sensitive areas in the Duck Island Harbor area of Northport Bay. Such areas provide valuable breeding/nesting grounds for waterfowl and as such may have a National Ecosystem Restoration value. Potential benefits which may be realized by protecting these areas from sand intrusion are being assessed as part of a separate study.

The basic reference costs that have been assumed for damages to infrastructure and for the cost of emergency actions for the increments of damage in Reaches 1A and 1B (see Table 4) are summarized in Table 2.

Table 2: Infrastructure Damages and Emergency Costs

Damage Category	Most Likely Value	
	Reach 1A	Reach 1B
15-Yr Bulkhead reconstruction following failure	$1,467,800	N/A
Dune reconstruction/backfill cost per foot erosion	$27,000	$45,000
Traffic delays due to still water flooding and minor overtopping	$13,600	$1,200
Emergency services - major overtopping	$9,200	$9,200
Emergency services - breach	$41,400	$32,600
Emergency services - minor overtopping or still water flooding	$1,100	$1,100
Cleanup - major overtopping	$36,000	$59,900
Cleanup - breach	$47,900	$79,900
Cleanup - minor overtopping or still water flooding	$18,000	$30,000
Total emergency services & cleanup - major overtopping	$45,100	$69,100
Total emergency services & cleanup - breach	$89,300	$112,400
Total emergency services & cleanup - minor overtopping or still water	$19,100	$31,100
Replace road surface	$36,400	$82,300
Damage to road base & bedding	$111,100	$277,700
Road reconstruction (drainage etc)	$52,500	$131,200
Damage to utilities total	$150,900	$377,300
Total utility and road damage - breach	$350,900	$868,500
Housing costs - major overtopping	$104,000	$7,500
Evacuation and housing costs - breach	$3,500,000	$2,500,000

Sources: USACE Planning Guidance Notebook (ER 1105-2-100), RS Means Heavy Construction Data, RS Means Electrical Cost Data, http://www.irs.gov/publications.

<u>Reaches 2A and 2B</u>

Structure Damage

In Reach 2A reduction of erosion damage to 71 residential structures is assumed to be the only source of potential benefits. The shoreline in Reach 2A extends from Duck Island Lane southeast to the last residential structure on the Long Island Sound and is expected to recess at a rate of approximately 1 ft/yr. The existing bulkheads are expected to fail under certain storm conditions, either due to wave overtopping or scour of the toe and subsequent shoreline recession is expected to approach the residential structures. There are no residential structures vulnerable to erosion in Reach 2B and no existing shoreline structures such as bulkheads. A summary of the principal characteristics of the residential structures potentially at risk is presented in Table 3.

Table 3: Vulnerable Residential Structure Characteristics

Structure Characteristic	Average	Minimum	Maximum
Depreciated Replacement Value	$347,000	$151,000	$682,000
Stories	2	1	3
Total Square Footage	4,400	1,400	11,900
Setback distance from Bulkhead (Ft)	50	13	138

The total depreciated structure replacement value of the 71 potentially vulnerable residential structures is estimated to be $24,600,000, and for the purpose of these analyses content value has been assumed to be equivalent to 50% of the structure value.

The damage experienced by the structures due to erosion is based on the depreciated replacement value and setback distance of each structure. Erosion damage is assumed to increase linearly from zero at the point immediately before undermining starts, to 100% (when 50% of the structure footprint has been undermined). Uncertainty has been incorporated by allowing the setback distance and total value of the structures to vary via normal distributions with standard deviation input by the user.

Quantification of Storm Damages and Costs

As noted in the discussion of each potential damage or cost criteria, the actual quantification of data has been based on publicly available sources: Census 2010, USACE planning guidance, information from local authorities and the Red Cross, and industry standard construction cost estimating techniques (in particular RS Means Heavy Construction Costs, 27th Edition, 2013). Since emergency response plans in this area are well established, this study did not incorporate interview or mail surveys with the potentially affected community members to determine in detail their options and plans in the event of an emergency. Such an effort may result in a refinement of the data derived from census information and may clarify some uncertainties or assumptions (such as how many stranded commuters would expect to use hotel rooms in preference to the basic shelter offered) but would not be expected to radically alter the current assumptions. Therefore, the additional effort was not undertaken.

5. Attribution of Storm Damages and Costs

The assumed relationships between categories of storm damages or costs in Reaches 1A and 1B, and the damage increments that give rise to them are summarized in Table 2.

Table 4: Attribution of Damage and Cost Categories, Reaches 1A and 1B

Damage / Cost Category	Damage Increments				
	1 Pre OT	**2 Still Water Flood**	**3 Minor OT**	**4 Major OT**	**5 Breach**
Emergency services & cleanup		√	√	√	√
Traffic delays for commuters		√	√		
Temporary stranding of residents away from homes				√	
Damage to coastal protection				√	√
Damage to road surface				√	√
Damage to roadbed					√
Damage to utilities					√
Evacuation of population					√
Physical Damage to Buildings				√	√

Other theoretical sources of potential damage or cost that have not been included in the analysis at this stage are those associated with recreational opportunities, the operation of the Eatons Neck Coast Guard Station, damage to residential structures on the tombolo, and the restoration of wetlands adjacent to a breach in the tombolo.

6. Analytical Methodology

The choice of analytical approach to estimate benefits for this study has been ultimately determined by the nature of the problem and the degree of accuracy or certainty with which data values can be realistically estimated. For previous studies at this location, a deterministic approach was used: average annual expected damages were calculated from the area under a damage-frequency curve, derived from relating absolute values of damage (assuming some of the same criteria as described in Section 4) to storm events with assumed frequencies of occurrence. This approach is no longer considered suitable at this location, since the physical and socioeconomic consequences of each different storm event are not so easily defined. Therefore a probabilistic analytical method is required that can incorporate the uncertainty within the data to the greatest extent possible. This assessment has used a risk-based approach to model the potential damages from simulated series of storm events.

An Excel spreadsheet model was compiled for each reach under consideration in which infrastructure or buildings are assumed to be vulnerable to damage. Each model simulates the occurrence of storm events over the project life and quantifies the resulting damages.

The model consists of an Excel spreadsheet with a series of individual worksheet tabs containing inputs, calculations, and outputs. Simulations are performed using the @RISK (Palisade Corporation) add-in to Excel. @RISK allows various inputs, such as the value of vulnerable structures, to be input as probability distributions rather than a single value. It will repetitively recalculate the spreadsheet, allowing each of the uncertain inputs to vary independently (or in accordance with defined correlation coefficients), collect the results from each lifecycle iteration, and report the mean values and other statistics such as the distribution of results.

Reaches 1A and 1B

The five damage increments listed in Section 2 and in Table 4 have been related to a range of water surface elevations, overtopping rates and erosion distances, using available topographic information and hydraulic and hydrological data relating water surface elevation and frequency of occurrence for existing conditions and proposed alternatives. The principal elements of the spreadsheet model for Reaches 1A & B are summarized below as follows.

Simulation: The model randomly generates a storm event in each year of the project life, and returns corresponding water surface elevations (on both sides of the tombolo), overtopping rates, and erosion distances, taking into account the effects of sea level rise and shoreline change due to yearly erosion. These are compared to existing topography, threshold overtopping rate for failure, and erosion distance required for a breach, to determine which damage increment has been triggered.

Damages: For every year in the assessment period the damages corresponding to the highest damage increment occurring in that year are recorded, converted to a present value and totaled, from which average annual damages are calculated.

Lookup Tables: The model makes use of one set of lookup tables for water surface elevations, overtopping rates, and erosion distances, and another for estimated damages. The damages lookup table also incorporates the uncertainty inherent in the data by calculating minimum, maximum and most likely values of the damages and the assumed shape of their distribution.

Summary: Draws together average annual damages from the without-project condition and the with-project alternatives for any single set of simulated storm events, and calculates the benefits of each alternative as the reduction in storm damages and costs.

Reach 2A

The spreadsheet model that compiles damages in Reach 2A is conceptually similar to the Reach 1 models in that it randomly generates a storm event in each year of the project life, and returns corresponding water surface elevations, overtopping rates, and erosion distances. The principal elements of the spreadsheet model for Reach 2A are summarized below as follows.

Simulation: A storm event probability is randomly generated for each lifecycle year, for which erosion distances and ocean water levels are retrieved from *Lookup* tab, enabling total erosion distances and wave heights to be calculated. Erosion up to and through the vulnerable structures is only possible following failure of the bulkhead line due to toe scour or wave action. Erosion damages associated with the total erosion distance (storm erosion plus long term shoreline change) are retrieved from the *Damages Lookup* tab and are refined by linear interpolation between low/high damages when the erosion distance falls between the 10 foot increments in the erosion-damage curve.

Interpolation and Lookup: Specific set of curves for each condition modeled (i.e. for the without-project condition and for each with-project alternative) are input and stage and erosion values are interpolated for all intermediate frequencies for which data has not been provided. The Interpolated data is formatted into a lookup table to be referenced by *Simulation* tab.

Damages Lookup: This component is a lookup table of the aggregated erosion-distance relationship generated by the *Building Inventory* tab, to be referenced by the *Simulation* tab. The assumed replacement cost of bulkheads is also input here.

Building Inventory: This tab calculates the damage experienced by each structure due to erosion as the structure is undermined in increments of 10 feet, based on the depreciated replacement value and setback distance of each structure.

The spreadsheet model forms the basis of the risk-based benefits analysis using @RISK for Excel. Having defined for each variable upper and lower bounds, most likely values, and the most appropriate distribution (e.g. normal, triangular), as well as a method of sampling from the chosen distribution, @RISK uses an iterative process to calculate definitive average annual damages, reporting results after a specified number of iterations have been performed or when the results converge to within a specified degree of accuracy.

7. Variation of Damage Parameters

Judgements have been made regarding the damages and costs that will be realized by each problem increment, and the source of any uncertainty that affects them. Uncertainty surrounding the occurrence of storm events during the 50 year project life is incorporated in the analysis by the use of randomly generated sequences of storm events, but uncertainty in the damages realized by these events has been considered separately.

The principal factors influencing the variation of the economic damages and costs resulting from storm events are considered to be the length of the tombolo that experiences severe damage or breach, the length of failed bulkhead that must be reconstructed in Reach 1, and the number of residents affected. The principal assumptions regarding the variation of these parameters are presented in Table 5.

Table 5: Variation of Key Damage Parameters

Damage Parameter	Minimum	Maximum	Most Likely	Distribution
Reach 1A Breach length (ft)	250	650	400	Triangular
Reach 1B Breach length (ft)	500	5,000	1,000	Triangular
Reach 1A Bulkhead Failure Length (ft)	300	900	600	Triangular
Reach 1B Dune Failure Length (ft)	500	5,000	1,000	Triangular
Evacuation Population	1,629	1,687	1,803	Triangular
Reach 1A Commuters (trips/week)	25% Coefficient of Variation		7,500	Normal
Reach 1B Commuters (trips/week)	25% Coefficient of Variation		500	Normal
Reach 1A Stranding (trips/week)	25% Coefficient of Variation		3,750	Normal
Reach 1B Stranding (trips/week)	25% Coefficient of Variation		250	Normal
Reach 2A Structure Value	10% Coefficient of Variation		*	Normal
Reach 2A Structure Setback	5 Ft Standard Deviation		*	Normal

*Varies by structure.

Any breach resulting from the most extreme events will vary in length, although for any single event the breach can be expected to remain relatively stable and not expand significantly once the storm has subsided: High flow velocities would not be expected through a breach since there is no significant tidal phase lag between the Long Island Sound and Harbor sides of the tombolo. The length of breach will have consequences for the cost of road/utility repair and reconstruction work, and will also dictate the length of time over which the road is closed and the peninsula inaccessible, which in turn determines the duration of affected residents' stays in temporary accommodation. Following lesser storm events, the length of any damaged section will influence the time and resources and hence the cost of repair, cleanup and debris removal operations.

In Reach 1A, restoration of the protection structures post-breach will require the construction of a replacement bulkhead and some erosion backfill, whereas in Reach 1B only backfilling of the eroded dune will be required. In Reach 1A it has been assumed that the length of breach will usually be less than the length of failed bulkhead, and in this reach separate assumptions have been made regarding the bulkhead reconstruction costs, based on the variation in failure length. The simulation model currently assumes that any replacement bulkhead in Reach 1A will be of a similar design featuring the same level of protection as the failed structure, but the model retains the capability to model the effect of reconstructing bulkheads of different levels of protection at different times, should there be any change to the most likely future without project conditions.

Uncertainty surrounding the population of the study area and those away from their homes at any given time will influence the cost of evacuations, strandings, and traffic delays. While Census 2010 provides the most likely base population data, the minimum and maximum ranges have been based on data regarding the additional presence or absence on the peninsula of college students who may be home during vacations and the seasonal/occasional occupancy of vacation homes from the Asharoken Village Master Plan.

Census 2010 provides the most likely base data for commuters, but without conducting detailed surveys on the peninsula, the maximum and minimum number of residents who may be away from their homes when a storm event strikes is more difficult to determine, hence a coefficient of variation from the most likely value and a normal distribution have been assumed for damage values relating to stranding and traffic delays.

Care has been taken to avoid potential double-counting of evacuation, stranding, and traffic delay costs. In the simulation, under existing conditions breaches occur more frequently in Reach 1A, (but generally over greater lengths in Reach 1B) and Reach 1B breaches are caused by storm events which have already breached Reach 1A. A storm event that breaches Reach 1A will prompt the evacuation of the whole peninsula, and an additional breach in Reach 1B will extend the period of time for which these people will require temporary accommodation because it is assumed to take longer to reconstruct the road following breaches in both reaches. Stranding and traffic delay damages arise from inundation of the road rather than breach, and inundation of Reach 1 will always occur before inundation of Reach 1B due to their relative topography. Inundation of Reach 1 affects the whole peninsula, and any inundation of Reach 1B is assumed to additionally affect only the small number of people who live on the tombolo itself.

8. Results of Benefits Assessment

The results of the Excel/@RISK models are presented in Tables 6, 7, 8 and 9. Table 6 presents a summary of equivalent annual damages in each reach for the Without-project Condition.

Table 6: Without-Project Equivalent Annual Damages by Category

Damage Category	Reach		
	Reach 1A	**Reach 1B**	**Reach 2A**
Bulkhead/Dune restoration	$235,000	$67,900	$726,500
Emergency/Cleanup	$8,200	$3,600	N/A
Road and Utility Reconstruction	$29,000	$9,000	N/A
Traffic Delays	$500	$0	N/A
Stranding	$1,000	$300	N/A
Evacuation	$318,000	$3,500	N/A
Structure Damage	N/A	N/A	$1,357,400
Reach Totals	**$591,700**	**$84,300**	**$2,083,900**
Project Area Total			***$2,763,200***

Price Level February 2015, FDR 3.375%, Project Life 50 years

The evaluated potential project alternatives for reach 1A, 1B and 2A are based on berm widths of 30 ft, 50 ft and 70 ft.

Table 7, 8 and 9 presents the with-project equivalent annual damages break up by category for the three reaches for three different alternatives respectively.

Table 7: With-Project Equivalent Annual Damages by Category: Alternative 1, 30 ft berm width

Damage Category	Reach		
	Reach 1A	**Reach 1B**	**Reach 2A**
Bulkhead/Dune restoration	$80,300	$43,900	$246,600
Emergency/Cleanup	$4,200	$1,200	N/A
Road and Utility Reconstruction	$2,600	$2,600	N/A
Traffic Delays	$900	$0	N/A
Stranding	$6,700	$100	N/A
Evacuation	$0	$0	N/A
Structure Damage	N/A	N/A	$107,800
Reach Totals	**$94,700**	**$47,800**	**$354,400**
Project Area Total			***$490,600***

Price Level February 2015, FDR 3.375%, Project Life 50 years

Table 8: With-Project Equivalent Annual Damages by Category: Alternative 2, 50 ft berm width

Damage Category	Reach		
	Reach 1A	**Reach 1B**	**Reach 2A**
Bulkhead/Dune restoration	$57,800	$1,000	$121,200
Emergency/Cleanup	$5,800	$1,200	N/A
Road and Utility Reconstruction	$1,900	$2,600	N/A
Traffic Delays	$1,000	$0	N/A
Stranding	$5,000	$100	N/A
Evacuation	$0	$0	N/A
Structure Damage	N/A	N/A	$2,500
Reach Totals	**$71,500**	**$4,900**	**$123,700**
Project Area Total			***$192,300***

Price Level February 2015, FDR 3.375%, Project Life 50 years

Table 9: With-project Average Annual Damages by Category: Alternative 3, 70 ft berm width

Damage Category	Reach		
	Reach 1A	**Reach1B**	**Reach 2A**
Bulkhead/Dune restoration	$52,100	$1,000	$112,000
Emergency/Cleanup	$5,800	$1,200	N/A
Road and Utility Reconstruction	$1,900	$2,600	N/A
Traffic Delays	$1,000	$0	N/A
Stranding	$5,000	$100	N/A
Evacuation	$0	$0	N/A
Structure Damage	N/A	N/A	$0
Reach Totals	**$65,800**	**$4,900**	**$112,000**
Project Area Total			***$175,300***

Price Level February 2015, FDR 3.375%, Project Life 50 years

Table 10 presents a summary of the with-project equivalent annual damages for each alternative.

Table 10: With-project Average Annual Total Damages

Reach	W/O Project	Alt 1 30 ft	Alt 2 50 ft	Alt 3 70 ft
1A	$591,700	$94,700	$71,500	$65,800
1B	$84,300	$47,800	$4,900	$4,900
2A	$2,083,900	$354,400	$123,700	$112,000
Total	**$2,763,200**	**$490,600**	**$192,300**	**$175,300**

Price Level February 2015, FDR 3.375%, Project Life 50 years

Table 11 presents a summary of the total annual benefits arising from implementation of the project alternatives over Reaches 1A, 1B and 2A.

Table 11: With Project Average Annual Benefits over Reach 1A, 1B and 2A

Reach	Alt 1 30ft	Alt 2 50 ft	Alt 3 70 ft
1A	$497,100	$520,200	$525,900
1B	$36,500	$79,400	$79,400
2A	$1,729,500	$1,960,200	$1,971,900
Total	**$2,272,600**	**$2,570,900**	**$2,587,900**

Price Level February 2015, FDR 3.375%, Project Life 50 years

The benefits presented above do not include those arising from ecological restoration or any storm damage to structures in Reaches 1A and 1B.