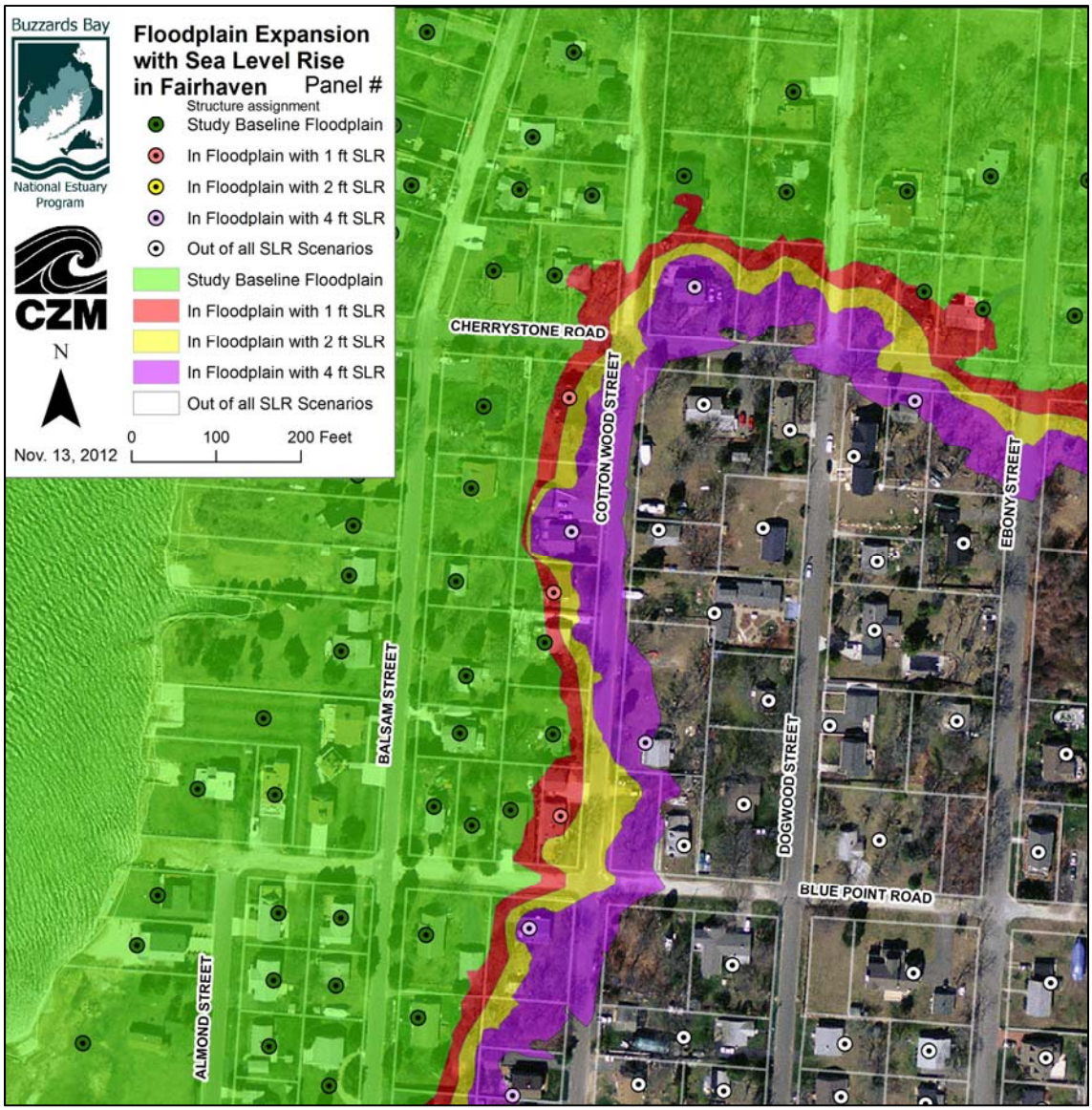
Projected Expansion of the Floodplain with Sea Level Rise in Fairhaven, Massachusetts

Buzzards Bay National Estuary Program and Massachusetts Office of Coastal Zone Management

Technical Report SLR12-1

Final November 13, 2012



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Summary
The Buzzards Bay National Estuary Program (BBNEP) and the Massachusetts Office of Coastal Zone Management evaluated the potential expansion of the rare storm event floodplain in Fairhaven, Massachusetts resulting from 1-foot, 2-foot, and 4-foot rises in sea level. A baseline condition flood zone was developed by adjusting the most landward extent of the 100-year floodplain as mapped by the Federal Emergency Management Agency (FEMA) in their 2009 digital Flood Insurance Rate Map (FIRM) coverages. This boundary was adjusted by matching the FIRM base flood elevations to a highly detailed elevation data set. This baseline conditions floodplain map was then expanded by adding, 1, 2, and 4-foot increases using the same detailed elevation data. Using a 2009 assessor's data set for the Town of Fairhaven, the number of buildings, their assessed values, and municipal structures were enumerated within these various floodplain expansion scenarios. This evaluation was not meant as a quantification of the impacts of storms with sea level rise, rather to define an approximate likely geographical expansion of the floodplain, a jurisdictional area used by many state, federal, and municipal agencies and boards for different purposes.

There are currently 1,198 built upon parcels in the Fairhaven 2009 assessors database within the baseline conditions floodplain. Of these, 210 (17.5%) were built after the issuance of the first floodplain maps for Fairhaven in 1973, and 134 (11.2%) were built after Hurricane Bob in 1991. Under the lesser sea level rise scenarios evaluated, there will be roughly a 4% increase in the number of homes and total structure value within the floodplain with each 1-ft increase in sea level rise and the baseline storm. However, in the case of a 4-ft rise in sea level, there will likely be a widespread and significant overtopping of the New Bedford/Fairhaven hurricane barrier as compared to the baseline storm scenario, resulting in a 180% increase in the number of properties that will be potentially affected. More specifically, in the 4-ft sea level rise scenario, an additional 1,637 parcels with existing structures could be added to floodplain in Fairhaven, with a total assessed structure value exceeding $264 million. The Fairhaven municipal wastewater treatment facility is at a high enough elevation in that it will not be directly affected in the baseline storm plus 4-ft sea level rise scenario, however a number of municipal buildings in the harbor waterfront area will be affected with the overtopping of the hurricane barrier, including town hall, several public schools, and the Millicent Library.

The maps resulting from this effort can be used as planning tools to assist municipalities on where to site and construct new facilities so that they are less likely to be affected in subsequent decades by sea level rise. The maps will also help illustrate to each level of government, how much additional area and existing structures (and existing values) may be included in the 100-year flood zone later in the century. These maps can also be used as a visual aid to educate municipal officials and the public about the potential impacts of sea level rise, and help set priorities for land acquisition and protection, and help define local climate adaptation strategies. The maps should not be used to determine which homes are now in the FEMA floodzone, and maps at FEMA.gov should be consulted instead.

1. Introduction

FEMA Flood Insurance Rate Maps (FIRMs) are the basis of federal, state, and local hazard mitigation planning, used to establish the regulatory requirements for mandated flood insurance, and are used by building inspectors, conservation commissions, and other local regulators to establish standards for the siting, construction, and maintenance of buildings, sea walls, and land alteration. In the coastal zone, FIRMs generally define the 1% storm flood zone (commonly called the "100-year storm") as being either in the Zone V (Velocity or V-zone); which are areas subjected to waves greater than 3 feet during a storm, or Zone A, which are areas subjected to waves less than 3 feet during a storm. Most typically, these two zones are defined as Zone VE or Zone AE, which indicates that the zones have been assigned a base flood elevation (BFE) which was defined by a model or some other analytical procedure. The BFE corresponds to the top of the wave crest during the projected 1% probability storm. The methodology for determining these elevations and their boundaries are described in the *Guidelines and Specifications for Flood Hazard Mapping Partners, Volume 1: Flood Studies and Mapping* (FEMA, 2003).

The predicted landward limit of the floodplain, as depicted in the FEMA FIRMs, corresponds to a specific real-world elevation as defined by the base flood elevation. The FIRMs prepared by FEMA are in fact an approximate depiction of which properties are in or out of the specified flood-zone elevation. While the FEMA FIRMs are generally good for broadly defining which homes are in or out of the jurisdictional flood zone, the maps are limited by the quality of topographic data that is available. Whether a particular structure near a mapped base flood elevation boundary is actually in the flood zone can only be determined definitively by actual field surveys. In fact, FIRMs can be amended based on such field investigations, and often are.

In 2009 and 2011, FEMA updated the FIRMs in Bristol and Plymouth counties based on recent LiDAR surveys, contracted by FEMA or United States Geological Survey (USGS), and limited new coastal engineering analyses[2]. The basis of the changes in the maps are summarized in Flood Insurance Studies for each county available on the FEMA website[3]. In many parts of Fairhaven, base flood elevations increased. Due to funding limitations, FEMA was unable to do new engineering analyses for all portions of each community. These new maps have increased precision and reliability, although like any data set, they are subject to errors in interpretation and processing of the elevation data as described below.

For this study, we considered only the landward most extent of the FIRM base flood (1% storm floodplain), and the published base flood elevation, to define the baseline flood zone used for this analysis. We then expanded this baseline flood zone by adding 1, 2, and 4-ft to the base flood elevation (whether A or V zone). The extrapolations were based on a digital data set of estimated bare earth elevations established by a 2007 aerial survey using LiDAR[4] technology that was obtained from FEMA and which was used in part to prepare the 2009 updated Bristol and Plymouth County FIRMs (CDM, 2008).

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[2] As part of FEMA's Map Modernization project, the 2009 Flood Insurance Rate Maps for Fairhaven have a new datum (=zero elevation, elevation[NGVD29] - 0.822 ft= elevation[NAVD88] in Fairhaven). In addition, the new maps show increased flood elevations in many areas that reflect improved flood hazard models, landscape changes, and better land elevation measurements.

[3] Go to: https://msc.fema.gov

[4] Light Detection And Ranging (also abbreviated LiDAR and LADAR) is an optical remote sensing technology that can measure the distance to a target by illuminating it with pulse of light from a laser.

The selected 1, 2, and 4-ft elevation increases in this study were chosen as convenient management elevation markers. The relative sea level rise rate documented for Woods Hole, MA has been 10.3 inches per century since 1930[5]. The IPCC (2007) consensus range for sea level rise, applied to this region, is 1 to 4.5 feet by year 2100. However, some other studies with alternative scenarios with more expanded Greenland and Antarctic glacier melting, or changes in the North Atlantic gyre may result in higher local sea level rise rates. We thus leave open ended how quickly the 1, 2, and 4-ft elevation increases may occur.

2. Methods

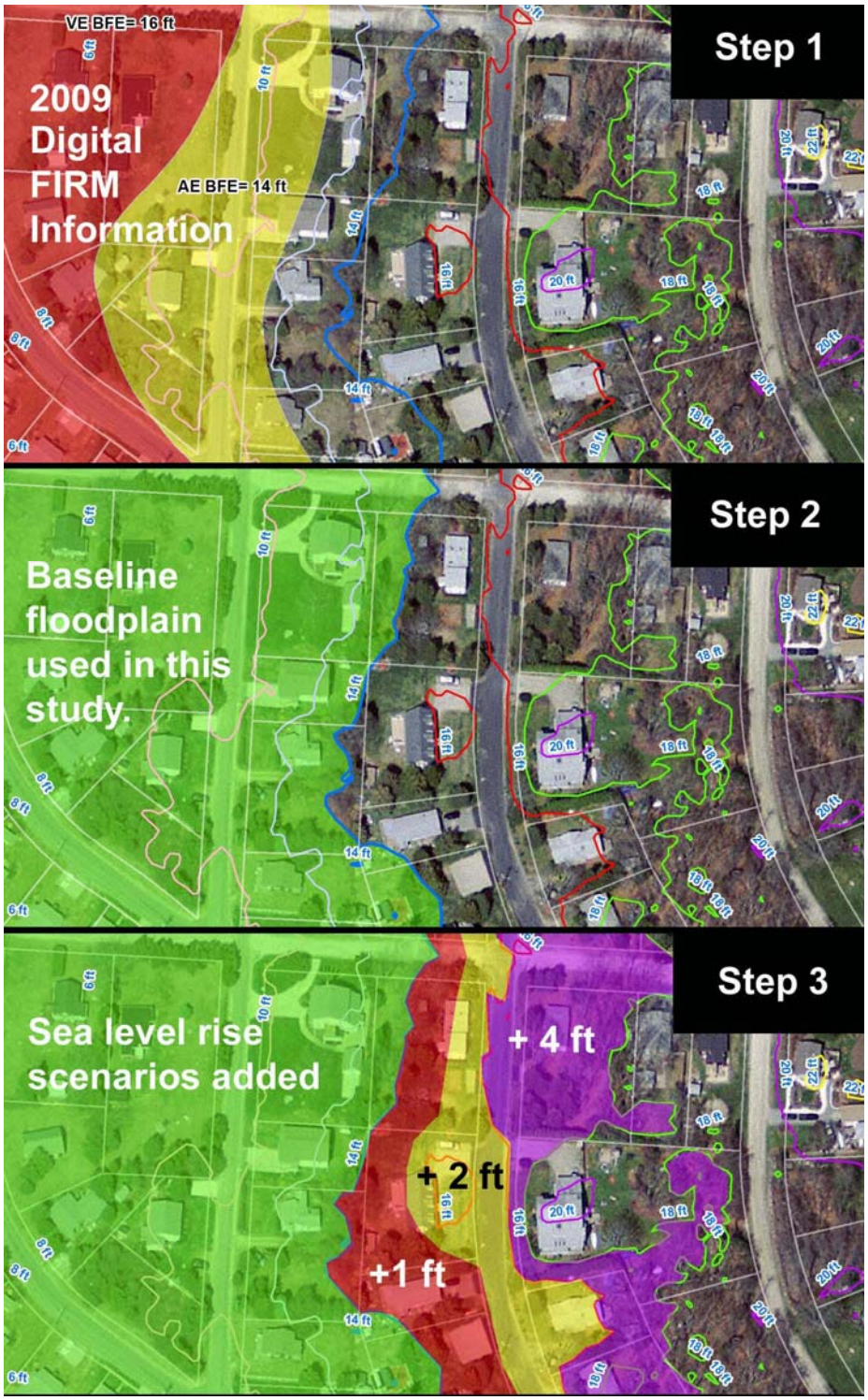
In this study, ArcMap GIS software (ArcView license) was used to manipulate the various existing digital data sets, with some additional analysis completed in spreadsheets using pivot table functions. No field collection of data or ground truthing was required for this analysis. We used a 2007 LiDAR study contracted by FEMA, and described in detail in CDM (2008). These LiDAR data were provided to the Buzzards Bay NEP as both 2-ft contour lines, and as digital elevation models (DEMs) in the form of Triangular Irregular Network (TIN) raster files. To a limited degree, for certain flood zone expansion areas we also used 2011 Northeast National Map LiDAR project data (unpublished[6]). In general, the precision of the LiDAR data is 1 cm, but the accuracy is approximately 6 inches over the entire southeast study area, and the relative accuracy over a small geographic area along the same flight path is considerably better (USGS, 2004).

The base flood elevations from the Flood Insurance Rate Maps (FIRMs) released by FEMA for Fairhaven in 2009 were overlain on the detailed LiDAR contour data (Fig. 1) and digital elevation models (Fig. 2). Because the flood zone delineations on the FIRMs do not exactly follow LiDAR contours for a number of reasons, this step was necessary to establish a detailed baseline floodplain that could be consistently expanded by the projected sea level rise scenarios. Typically, the LiDAR 2-ft elevation contour lines were adequate to estimate expansion or adjustments of the boundaries each of the sea level rise scenario. However, where land slopes were slight, and the base flood elevation was set to an odd-number value, then TIN raster images were often used to visually estimate the respective new flood zone boundaries, as in Fig. 2. In this way a baseline floodplain zone was defined which was used as the initial conditions for the purposes of this study and allow for more meaningful and precise comparisons among the sea level rise scenarios.

This baseline floodplain was then expanded to account for 1, 2, and 4-foot sea level rises by adjusting the boundaries to the LiDAR elevations that corresponded to the base flood elevations identified on the FIRMS (as in Figs. 1 and 2). Thus, if the base flood elevation on the FEMA FIRM was specified as 14 feet for a site, the boundary of the baseline floodplain would be expanded to the 18-ft LiDAR contour in the + 4-ft sea level rise scenario.

[5] Data available at http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8447930. This is the average rate for the period 1932 to 2006.

[6] LiDAR for the Northeast (ARRA LiDAR Task Order, USGS Contract: G10PC00026, Task Order Number: G10PD02143, Task Order Number: G10PD01027), project meets U.S. Geological Survey National Geospatial Program Base LiDAR Specification, Version 12, see USGS (2009).



Comments

The baseline floodplain developed for this study was based on the base flood elevations and other information contained in the 2009 FIRM digital data set. At this site, the base flood elevation of the AE Zone or the 100-year storm was designated as 14-ft.

To ensure consistency of comparisons among the data sets, a baseline floodplain was created for this study by precisely matching its boundary to the LiDAR contour elevations. In this case, the boundary was matched to the 14-ft LiDAR based contour line (blue line).

The process was continued for the +1-ft, +2-ft, and +4-ft sea level rise scenarios. If any portion of a house was in the new boundary, it was included in that sea level rise scenario. A house that crossed multiple boundaries was assigned to the lowest elevation.

Fig. 1. Summary of approach for defining expanding floodplains for each of the sea level rise scenarios. Step 1: The landward most base flood elevations for a 1% storm from 2009 digital FIRM data were compared to LiDAR contours (or digital elevation models). Step 2: A new baseline flood zone area was defined (shaded green) for the purposes of this study. Step 3: The baseline floodplain was expanded for the +1-ft (shaded red), +2-ft (shaded yellow), and +4-ft (shaded magenta) sea level rise scenarios.

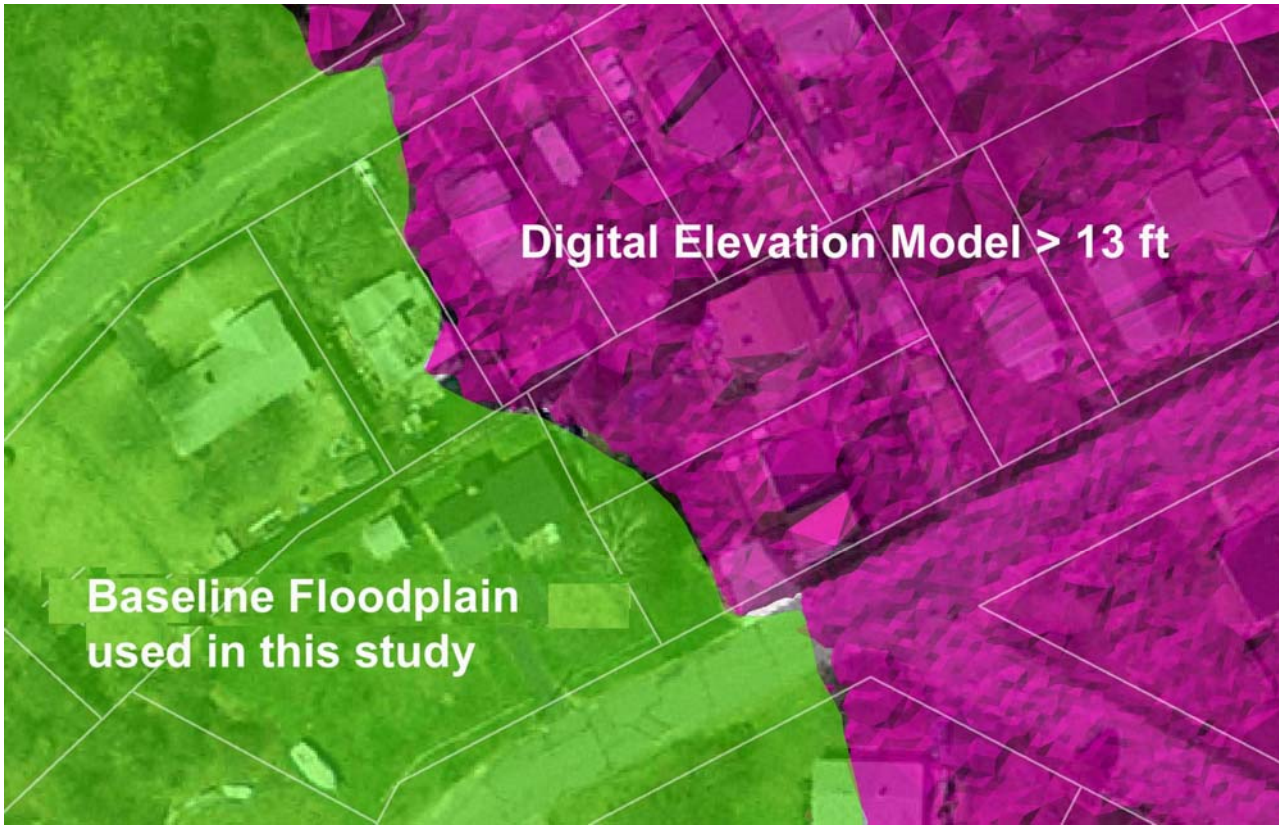


Fig. 2. In areas where the base flood elevation was set to an odd number value and elevation contours wide spaced, the TIN raster digital elevation model files were coded to match the same base flood elevation boundaries. In this image, the baseline floodplain used in this study (shaded green, left) was matched to the 13-ft lidar elevation in the elevation model (shaded magenta, right).

This is a simplified approach, and a more accurate approach would involve predictions of erosion and landform change, and detailed engineering analyses to determine how much the flood elevations would rise along the coast given the submergence of land in the 0-4-ft zone, but such an effort was beyond the scope of this study.

After the floodplain boundaries were created, assessor's data were joined to the GIS parcel data set. In the first step to approximate the locations of buildings, a centroid label point was created for each parcel to represent the location of each house. The position of these points, representing the vulnerability of the structures to sea level rise, was carefully examined on aerial photograph base maps for all parcels crossed by a sea level rise scenario. The positions of these points was moved to precisely coincide with the house footprint. If a house was crossed by several floodplain scenarios, the point was placed in the lowest elevation scenario as illustrated in Fig. 3 (note houses near Indian Way). Secondary or ancillary detached structures were ignored, and the property building value was assigned to the main structure, typically the primary residential structure. On some parcels, there are multiple detached dwellings units, but no parcels of this particular type were bisected by a flood zone in Fairhaven.

Once the position of structures was set relative to the sea level rise scenarios, and assigned assessed values for total building structures on the parcel linked to these points, this digital point

coverage was intersected with flood zone sea level rise scenario polygons. The resulting data set was processed in an Excel spreadsheet, and a pivot table was used to quantify building data using various classifications of structures by flood zone and inside or outside of the hurricane barrier.

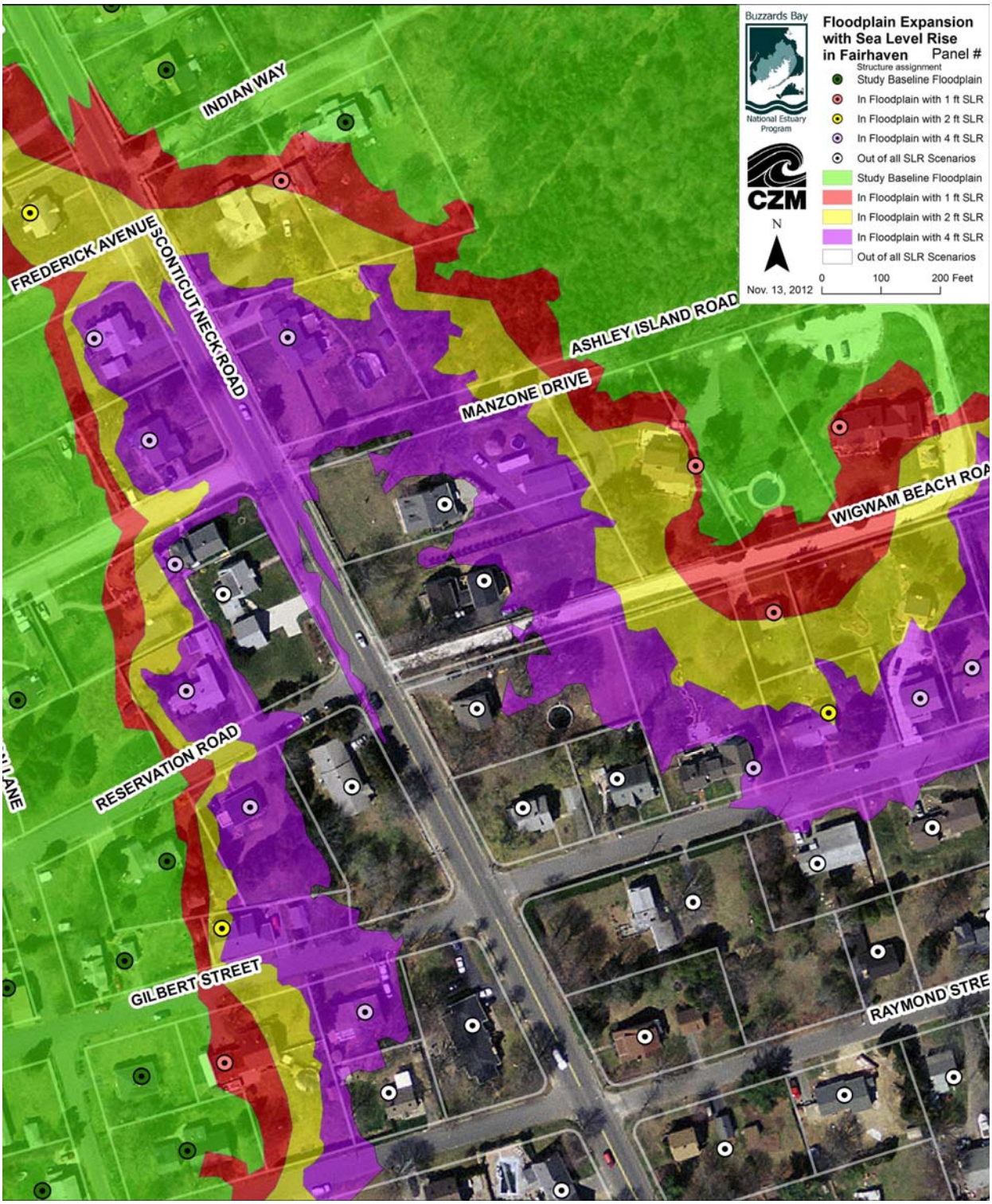


Fig. 3. Parcels (outlined in white) were converted to label points representing the position of

structures. The precise placement of these points is important only for properties near one of the flood zone scenario boundaries. If a house was crossed by several scenarios, the point location was adjusted to place the building in the lowest elevation zone.

Various quality control and data validation approaches were implemented to ensure the accuracy of the data following the protocols described above. These validation techniques included check sum approaches to ensure property counts and values and other data are not inadvertently double counted or omitted. Additional information on the methods, the QAPP, and the digital data sets related to this study area available at the Buzzards Bay NEP website: http://www.buzzardsbay.org/floodzone-expansion-slr.html

Hurricane Barrier Overtopping Assumptions

The potential overtopping of the US Army Corp of Engineers' New Bedford-Fairhaven Hurricane Barrier, which protects portions of Fairhaven, New Bedford, and Acushnet, has important implications for this study. The hurricane barrier consists of various segments (see Fig. 4). The barrier forms a seawall across the harbor (labeled a. in Figure 4, and Fig 5a.) which can be closed by a gate. An area on the eastern side of Fairhaven is protected by a dike just north of Boys and Girls Creeks in Fairhaven, which prevents flooding of the magenta shaded area nearest to the dike in Fig.4. Another dike segment protects an area behind Clarks Cove in New Bedford.

The elevation of the hurricane barrier (based on the LiDAR data) varies both by segment, and along portions of each segment (see Fig. 5). In the harbor hurricane barrier segments, the Fairhaven Harbor portions of the barrier (Fig. 5a, right) is mostly between 18 and 19 feet, whereas the New Bedford portion of the barrier (Fig. 6a, left) is somewhat lower, mostly between 17 and 18 feet, with a 60 foot stretch having elevations ranging from 15.5 and 17 feet. The dike segment north of Boys and Girls Creeks in Fairhaven is mostly between 17 and 18 feet elevation (Figs. 5b and 5c) , but with short stretches between 16 and 17 feet. There is an apparent anomaly in the LiDAR data that suggest a depressed 80-ft stretch between 12.5 and 15 feet elevation elevations. However, a site visit to the site determined that this was an artifact of processing the LiDAR data set.

The 2009 updated FIRMS show a V-Zone base flood elevation along the New Bedford side of the barrier of 17 feet, and 18 feet on the Fairhaven side the harbor hurricane barrier (Fig. 5). Along the dike near Boys and Girls Creeks, the V-Zone base flood elevation ranges from 15 to16 feet. In all areas, where there are AE zones near these sites, the base flood elevation is 13 or 14 feet, which can be considered close to the stillwater elevation.

The 2009 FIRM maps are based on the presumption that the hurricane barrier is adequately protective for the 100-year storm. However in the case of the 500-year storm, the hurricane barrier is presumed to be inadequate, and the 500-year floodplain on the 2009 FIRMs includes large areas of the inner harbor area roughly aligned with the 14-foot LiDAR data contour (and coincidentally equal to the current presumed stillwater elevation). A large portion of the inner harbor area of Fairhaven and area behind Boys and Girls Creeks is also inundated under the worse case storm scenario (category 4 Hurricane) in the ACOE SLOSH maps for Fairhaven.

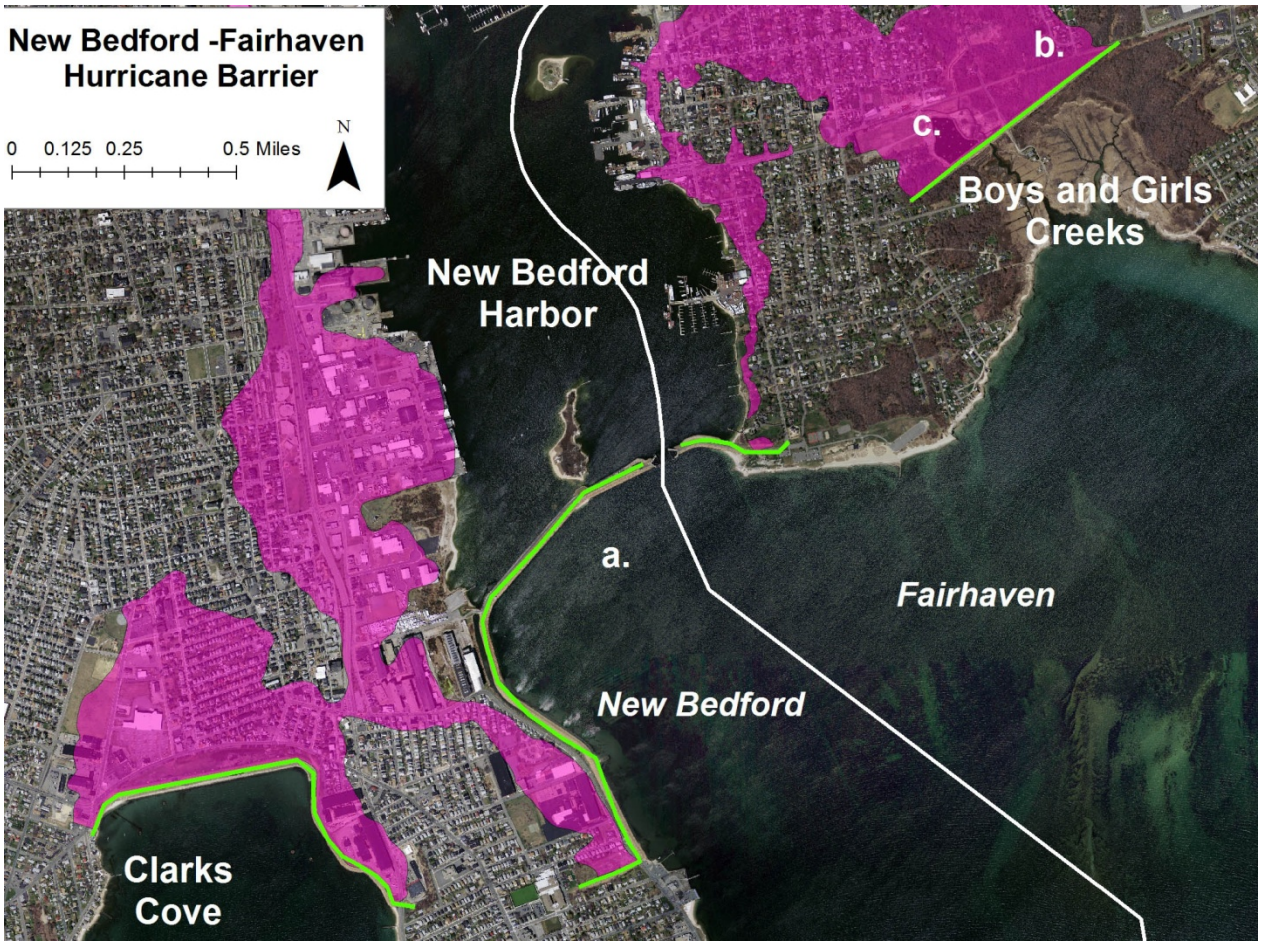


Figure 4. The New Bedford-Fairhaven Hurricane Barrier (green lines). The areas shaded magenta are in the 500-yr floodplain of the 2009 FIRMs and represent flooded areas with the overtopping of the barrier to roughly a 14-ft LiDAR elevation. Letters a., b., and c. refer to the panel numbers in Fig. 5.

For this study, we assume that the hurricane barrier will remain protective of the inner harbor under the +1-ft and +2-ft sea level rise scenarios. However, in the case of a future storm associated with the 4-foot sea level rise scenario, we assume a stillwater elevation of 18 feet will result in a broad overtopping of the hurricane barrier. In this + 4-ft sea level rise scenario, the floodplain in the harbor behind the hurricane barrier was created to match the 18-ft LiDAR contour.

Because of the various assumptions tied to overtopping the barrier with the 4-ft sea level rise, we break out this flooding separately from the structure number and values outside the hurricane barrier. The seriousness of the potential overtopping of the barrier points to the need for a more comprehensive and detailed model and engineering analysis of the potential flooding behind the hurricane barrier to better evaluate the impacts of the various sea level rise scenarios.

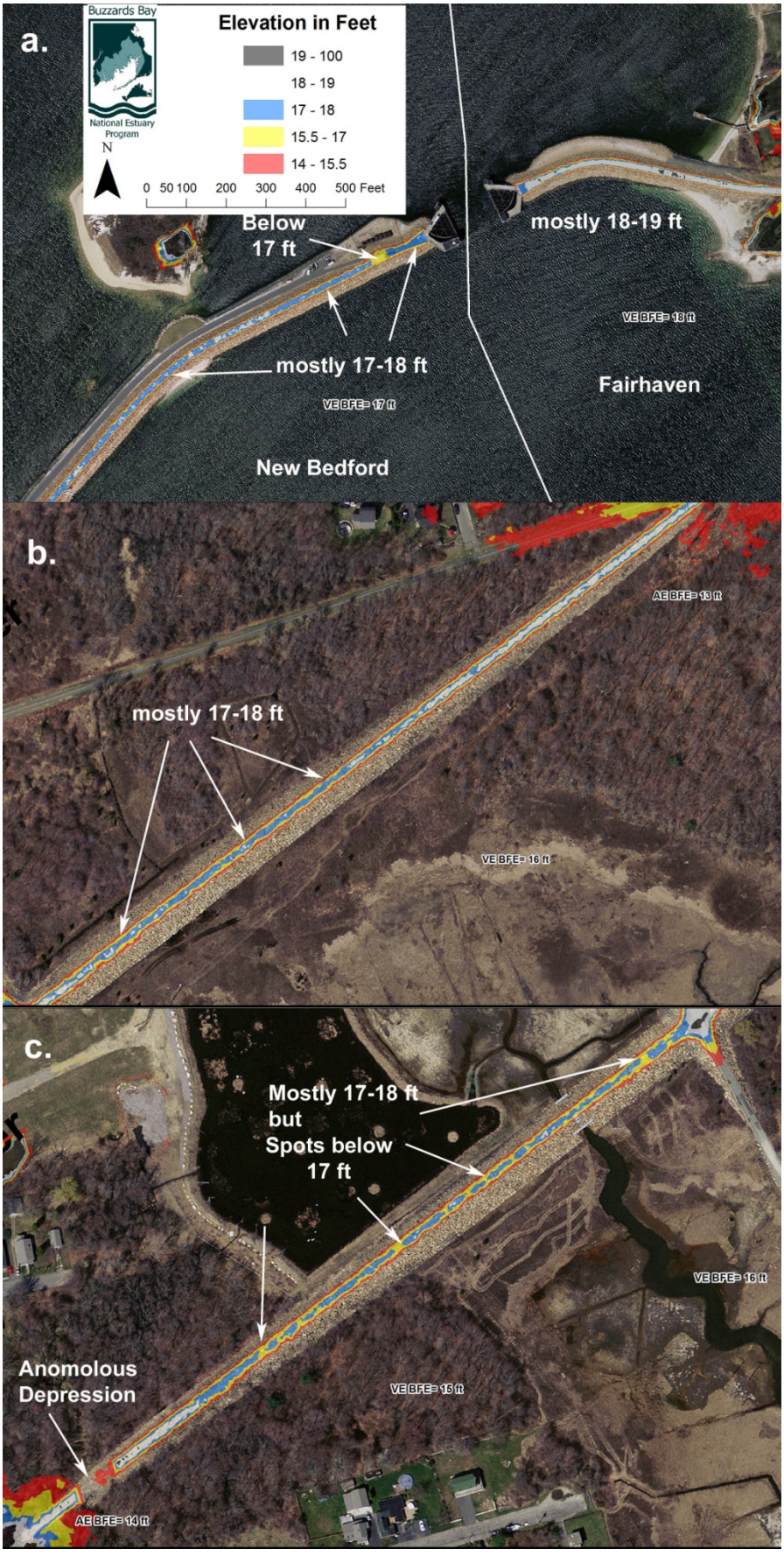


Fig. 5. Elevations of three portions of the New Bedford - Fairhaven Hurricane Barrier. For locations of panels a., b., and c., see Figure 5. The anomalous depression in panel c is an artifact in the LiDAR data set (see text for explanation).

3. Results

Fig. 6 shows the difference between the FIRM 1% floodplain and the baseline 1% floodplain used in this study. The two coverages were comparable, especially in developed areas, with a net 0.7% increase in the number of parcels with structures in the baseline floodplain.

Fig. 7 shows a town-wide overview of the boundaries under the various sea level rise scenarios. Appendix A includes additional detailed maps of this analysis. As shown in Table 1, using the baseline floodplain used in this study, there are 1,198 parcels with building structure values, out of a town wide total of 6,488, or 18.5% of the properties in town.

Table 1. Expansion of floodplain with different sea level rise (SLR) scenarios.

Flood Zone	parcels with structures	cumulative structures	% change from initial conditions	value of structure	cumulative value of structure	% change from initial conditions
Baseline	1,198	1,198		$146,278,900	$146,278,900	
+1-ft SLR	52	1,250	4.3%	$5,813,500	$152,092,400	4.0%
+2-ft SLR	47	1,297	8.3%	$5,590,100	$157,682,500	7.8%
+4-ft SLR	1,538	2,835	136.6%	$252,482,500	$410,165,000	180.4%
+4-ft SLR outside HB	[127]			[$14,588,100]		
Outside of flood zones	3,653			$648,114,218		
Grand Total	6,488			$1,058,279,218		

The +1 and +2-ft sea level rise scenarios each added about 4% more properties and 4% additional property value with each 1-ft rise in sea level (Table 1). However, in the case of the +4-ft scenario, the hurricane barrier was appreciably overtopped, adding more than 120% more properties and nearly more than 170% greater structure value over the plus 2-ft scenario. Overall, these increases added more than 1,637 parcels and $264 million in assessed value over the baseline floodplain used in this study.

4. Discussion

Of the 1,198 built upon parcels in the Fairhaven 2009 assessors database, 210 (17.5%) were built after the issuance of the first floodplain maps for Fairhaven in 1973, and 134 (11.2%) were built after Hurricane Bob in 1991. The greatest potential expansion of the number of structures in the floodplain with 1 and 2-ft sea level rise scenarios occurred on West Island along Cottonwood Street, some areas along the fringe of the existing flood zone off Sconticut Neck Road on central Sconticut Neck, and areas on upper Sconticut Neck in the general vicinity of Manhattan and Highland Avenues (Fig. 7, see also detailed maps in Appendix A).

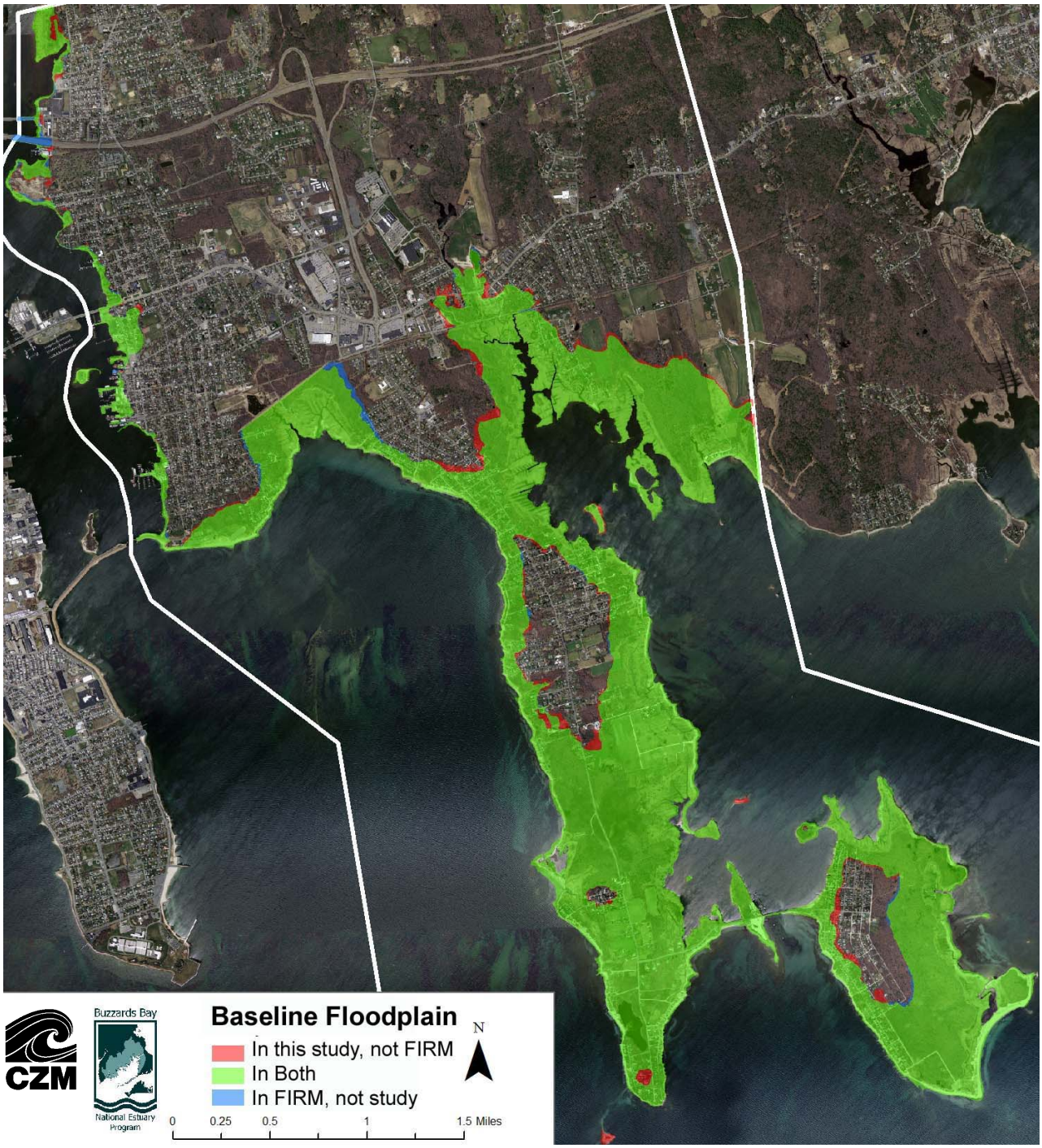


Fig. 6. Overview of the Town of Fairhaven showing the baseline floodplain conditions adopted in this study, and how it differed from the 2009 FIRMs 1% floodplain.

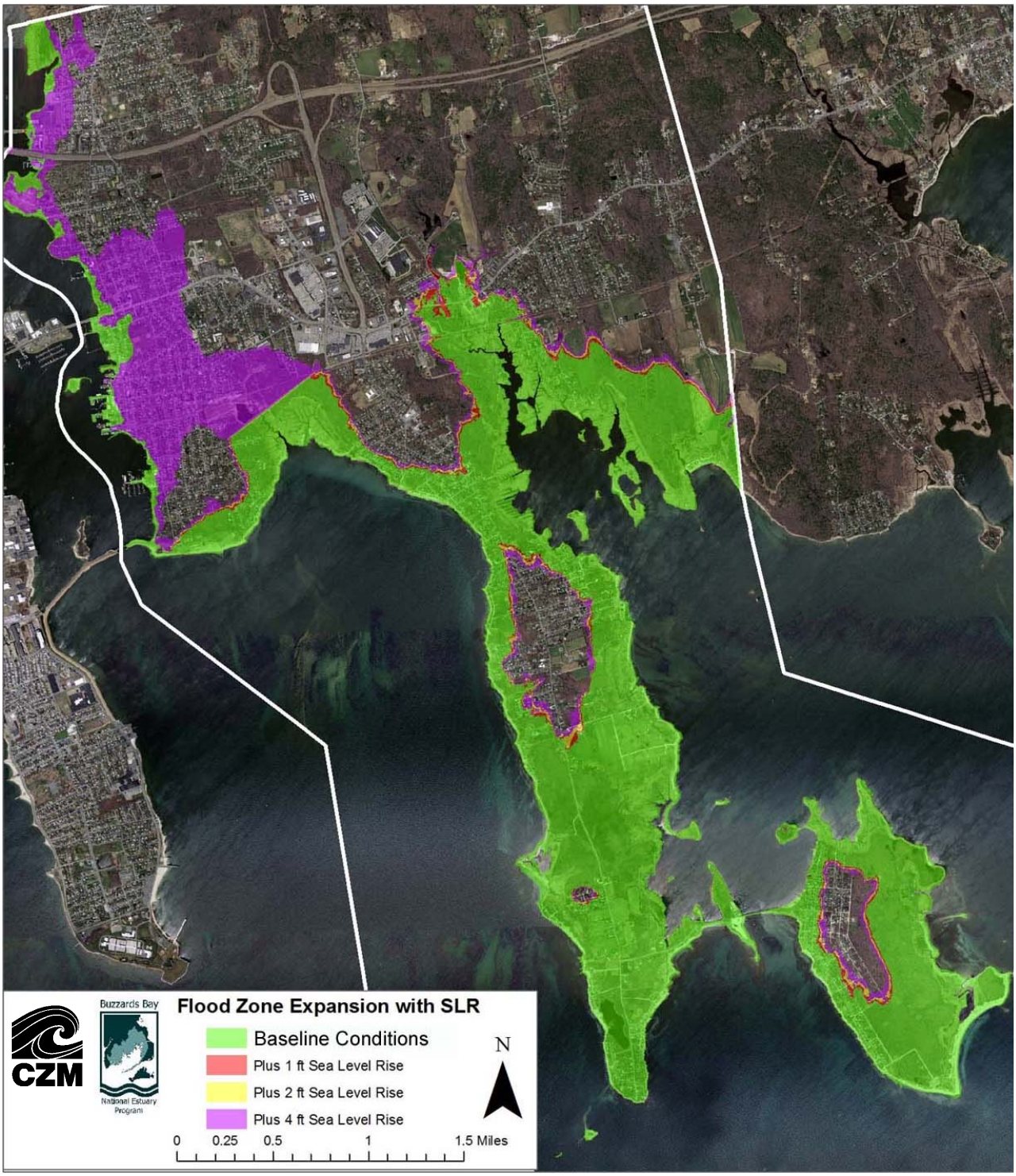


Fig. 7. Overview of the Town of Fairhaven showing changes in boundaries with various sea level rise scenarios over the baseline conditions flood zone.

The greatest cause of concern revealed by the study was that while there were areas on the top of the harbor hurricane barrier that will be topped in the plus 2-ft sea level rise scenario, it is the plus 4-ft sea level rise scenario where that barrier would appreciably overtopped across large lengths of the barrier. This would flood an additional 560 acres in the urban and industrial harbor front of Fairhaven (Fig. 7). In this area there are 1,538 built upon parcels with an assessed value of $252,482,500.

It is worth stressing that the inundation area we define for the hurricane barrier overtopping is somewhat conservative in that we presume that the overtopping will occur for a long enough time to completely fill the area behind the barrier. However, this approach appears consistent with both FEMA's 500-year floodplain (the X-Zone area, Fig. 4), which assumes a broad flood area to the 14 foot contour inside the hurricane barrier (our flood zone is to 18 feet with the +4-ft sea level rise). Our overtopping inundation area is also consistent with the ACOE "SLOSH" maps which also show extensive flooding behind the barrier for the worse case storm scenarios, similar to the boundaries shown here. In fact, under existing sea level and storm conditions, the ACOE notes, "The New Bedford Hurricane Barrier is designed to provide complete flood protection during the vast majority of hurricanes that can be sustained in New England's meteorological climate. The SLOSH model indicates, however, that certain Category 3 and 4 hurricanes, which landfall on critical storm tracks coincident with high astronomical tide, may exceed the barrier's minimum top elevation."[7]

With respect to public properties, no public properties with structures were added to the flood zone with the plus 1 and 2-ft sea level rise scenarios. However, in the case of the +4-ft rise scenario, additional public properties were added, mostly within the hurricane barrier protected area. Table 2 shows a complete list of public properties and their building values in the existing baseline condition flood zone as defined by this study, and the +4-ft sea level rise. As shown, the most prominent public buildings to be affected by a 4-ft sea level rise and overtopping of the hurricane barrier will be the Fairhaven Housing Authority property on Ash Street, the Huttleston Avenue School, Town Hall at 40 Center Street, the Bridge Street School, the Pleasant Street School, and the Millicent Library.

There is one additional limitation to the forgoing analysis not previously mentioned. First, if future storms are more severe the actual extent of inundation of municipalities in Buzzards Bay could be greater. Second, this analysis did not consider the elevation of the landscape or elevation of the buildings. Buildings near the elevational margins of a flood zone tend to have minimal flooding compared to properties close to shore and at lower elevations. For these reasons, the maps should be used as general planning tools by public officials and residents about where to construct future structures to minimize their susceptibility to storms with sea level rise. They also can help identify areas that may subsequently enter the jurisdictional regulated area known as the 100-year floodplain that is used by many agencies. In this way, municipal officials and the public could also use these maps to identify sites for open space and habitat protection rather than for construction public facilities. Other ways this data can be used is described in the Massachusetts Climate Change Adaptation Report (EEA, 2011).

[7] Text from the 1994 Commonwealth Of Massachusetts Hurricane Evacuation Study Inundation Map for Fairhaven, MA. Compare also the model of the Hurricane of 1938 as presented in RMSI (2008).

Table 2. Public Structures in the baseline flood zone and within the +4-ft sea level rise scenario.	
Public properties with structures in the baseline flood zone	**Building Assessed Values**
Town of Fairhaven, 11 Causeway Road	$22,400
Town of Fairhaven, Bernese Street	$13,000
Town of Fairhaven, Bridge Street	$7,600
Town of Fairhaven, Middle Street	$14,100
Town of Fairhaven, Pilgrim Avenue	$21,600
Town of Fairhaven, Taber Street	$41,300
Town of Fairhaven, C/O Edmund Dinis Dba Wjf 37 Railroad Way	$25,300
Town of Fairhaven, Conservation property 55 Goulart Memorial Drive	$27,100
Town of Fairhaven, Town Possessions Abbey Street	$35,800
Town of Fairhaven, Town Possessions Manhattan Avenue	$31,400
United States of America Department of Public Works 1 Old Fort Road	$435,500
Total structure value in Existing Flood Zone adjusted to LiDAR data:	**$675,100**
Public Properties with structures in +4-ft Sea Level Rise Scenario:	
Fairhaven Housing Authority Ash Street Apartments	$531,500
Town of Fairhaven, 1 South Street	$35,400
Town of Fairhaven, Whitfield-Manjiro Friendship House, 11 Cherry Street	$132,500
Fairhaven High School, 12 Huttleston Avenue School	$9,201,500
Town Hall, 40 Center Street	$3,085,500
Fairhaven property, 56 Bridge Street	$1,125,100
Town of Fairhaven, 9 Washington Street	$21,900
Town of Fairhaven Rogers School, 90 Pleasant Street	$2,556,300
Town of Fairhaven, Cushman Park	$25,300
Town of Fairhaven, Spring Street	$91,800
Town of Fairhaven, Millicent Library 45 Center Street	$2,191,700
Riverside Cemetery 1 River Avenue	$231,300
United States Post Office 13 William Street	$333,100
Veterans of Foreign Wars of Fairhaven Inc 109 Middle Street	$172,800
Woods Hole Marthas Vineyard Nantucket Steamship Auth, 2 Water Street Warehouse	$792,700
Total structure value in existing flood zone +4-ft sea level rise scenario:	**$20,528,400**

Acknowledgments
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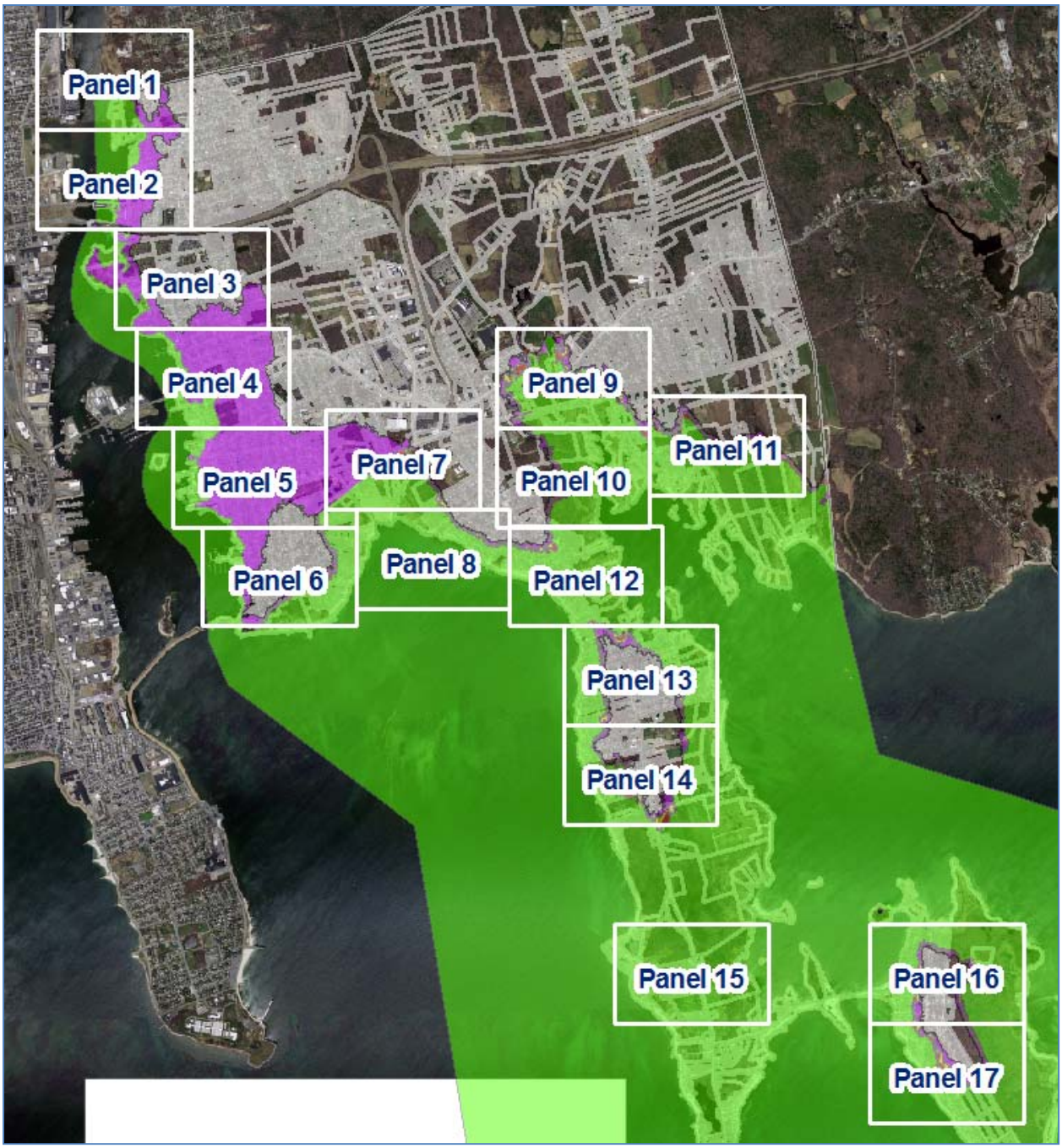
Appendix A. Detailed maps showing the expanded flood zone boundaries under the various sea level rise scenarios.

The locations of the detailed panel maps can be determined using the key below.



Buzzards Bay

National Estuary Program

CZM

Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 1

Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

N

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Nov. 13, 2012

Panel 1

BEECH STREET
WILLIAM STREET
APLE STREET
CHARD STREET
SIVIGNY STR
LAURA KEE AVENUE
WILLOW STREET
FAIR
PORTER STREET
FRANCIS STREET
SOUTH MAIN STREET
MULBERRY STREET
BURR AVENUE
BERNA
PLEASANT STREET
SPRINGHILL STREET
NICHOLAS STREET
HASTE STREET
ALDEN ROAD
DAVIS STREET
CLARK STREET
MILTON STREET
PHILLIP STREET
SARATOGA STREET
HARDING ROAD
JESSE STREET
DEERFIELD LAN
DANIEL STREET
SYCAMORE STREET
SAINT MARYS STREET
MAIN STREET
HAWTHORNE STREET
MAGNOLIA AVENUE

Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 2

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Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

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Nov. 13, 2012

MAGNOLIA AVENUE
VERANDA AVENUE
CLIFFE AVENUE
MOZART STREET
MAIN STREET
BLACKBURN STREET
MAITLAND STREET
NEWBURY AVENUE
ALPINE AVENUE
WOODSIDE AVENUE
DUDLEY STREET
DOVER STREET
GLENHAVEN STREET
MORGAN STREET
WINSOR STREET
RYLE STREET
LIVESEY PARKWAY
MORTON STREET
MORTON STREET
PARKER STREET
HOPKINS STREET
DEANE STREET
ADAMS STREET
HOWLAND ROAD
BROWN STREET
SHARON ST
MANUEL'S
BEACH STREET
RIVER AVENUE
OAK STREET
SYCAMORE STREET
GARRISON STREET
SPRUCE STREET
HOULE STREET
WILDING STREET
BURGESS AVENUE
INTERSTATE 195
INTERSTATE 195

Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 3

Buzzards Bay National Estuary Program

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Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

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Panel 3

INTERSTATE 195

INTERSTATE 195

RIVER AVENUE

WOOD STREET

BUTTONWOOD STREET

CENTURY DRIVE

KACY LANE

TABER STREET

HEDGE STREET

CHERRY STREET

MAIN STREET

COOKE STREET

JARVIS AVENUE

LONG ROAD

ADAMS STREET

NORTH STREET

BIRCHFIELD STREET

HICKS STREET

OXFORD STREET

ROBERT STREET

CASTLE AVENUE

MAYFLOWER STREET

NORTH GREEN STREET

PLYMOUTH AVENUE

FRANCIS STREET

MASSASOIT AVENUE

WILLOW STREET

LAFAYETTE STREET

WEST STREET

PILGRIM AVENUE
MASSASOIT AVENUE
ELM AVENUE
SCHOOL STREET
HICKORY STREET
ASH STREET
BELLEVUE STREET
LINDEN AVENUE
CASTLE AVENUE
ACADEMY AVENUE
HOPE AVENUE
LARCH AVENUE
WINSLOW COURT
NORTH GREEN STREET
MAIN STREET
HUTTLESON AVENUE
BRIDGE STREET
FRANCIS STREET
BRIDGE COURT
JEFFERSON STREET
ELLIOT LANE
PARK AVENUE
GREEN STREET
MIDDLE STREET
LOGAN COURT
COWEN STREET
CHRISTIAN STREET
MULBERRY STREET
SPRING STREET
TERRY STREET
PLEASANT STREET
ADAMS STREET
CHESTNUT STREET

Panel 4

Buzzards Bay
National Estuary Program

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Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 4

Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

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Nov. 13, 2012

Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 5

Buzzards Bay National Estuary Program

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N

Nov. 13, 2012

Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

0 100 200 300 400 Feet

PEASE STREET
SPRING STREET
RODMAN STREET
WATER STREET
WALNUT STREET
CENTER STREET
GREEN STREET
LAUREL STREET
CHESTNUT STREET
ADAMS STREET
FRIENDLY STREET
Panel 5
UNION STREET
MIDDLE STREET
MAIN STREET
WILLIAM STREET
MORSE STREET
FERRY STREET
SOUTH STREET
FORT STREET
CHURCH STREET
WRIGHT STREET
ATLAS STREET
VINCENT STREET
PLEASANT STREET
ALLEN STREET
LAWTON STREET
ABBEY STREET

Panel 6

FARMFIELD STREET
PARADISE DRIVE
REYNOLDS DRIVE
LAUREL STREET
CHESTNUT STREET
IVY LANE
PLEASANT STREET
ATLAS STREET
TYLERS WAY
GIFFORD STREET
WASHBURN AVENUE
COTTAGE STREET
FARMFIELD COURT
MOREY LANE
MAPLE AVENUE
CEDAR STREET
COE STREET
THOMPSON STREET
BAKER AVENUE
TURNER AVENUE
STETSON AVENUE
HARBOVIEW AVENUE
CARLETON AVENUE
ELLIS AVENUE
JAMES STREET
PHOENIX STREET
GREEN STREET
FORT STREET
DOANE STREET
OLD FORTE ROAD

Buzzards Bay
National Estuary Program

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Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 6

Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

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Nov. 13, 2012

Buzzards Bay
National Estuary Program

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Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 7

Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

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Nov. 13, 2012

SUNSET LANE
WASHINGTON STREET
E PLACE
MANOR DRIVE
ELIZABETH STREET
EGYPT LANE
PLAZA WAY
ALDEN ROAD
DAVID A DROWN BOULEVARD
HARBOR MIST DRIVE
MARILANE
JOHN STREET
SCONTICUT NECK ROAD
HILLER AVENUE
JAMESON STREET
SEBEC STREET
BRAE ROAD
HACKER STREET
CASCO STREET
PRESTON STREET
SCOTT STREET

Panel 7
Panel 5


HACKER STREET
HIGHLAND AVENUE
MANHATTAN AVENUE
YALE STREET
DAY ST
Panel 10
GROVE STREET
HARVARD STREET
CHANEY AVENUE
BAY STREET
BAY VIEW AVENUE
Panel 8
HAWAY STR
COVE STR
Panel 12
Buzzards Bay
National Estuary Program
Floodplain Expansion with Sea Level Rise in Fairhaven
Panel 8
Structure assignment
Study Baseline Floodplain
In Floodplain with 1 ft SLR
In Floodplain with 2 ft SLR
In Floodplain with 4 ft SLR
Out of all SLR Scenarios
Study Baseline Floodplain
In Floodplain with 1 ft SLR
In Floodplain with 2 ft SLR
In Floodplain with 4 ft SLR
Out of all SLR Scenarios
CZM
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0 100 200 300 400 Feet
Nov. 13, 2012

Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 9

Buzzards Bay National Estuary Program

CZM

Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

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0 100 200 300 400 Feet

Nov. 13, 2012

MEADOW

EDDY STREET

PRINCE STREET

MILL ROAD

HUTTLESON AVENUE

SLOCUM STREET

WELCOME STREET

ALPHONSE DRIVE

DARTMOUTH STREET

COOLIDGE ST

BABBITT STREET

STUDLEY STREET

JENNA DRIVE

STEPHEN S

Panel 9

ARSENE STREET

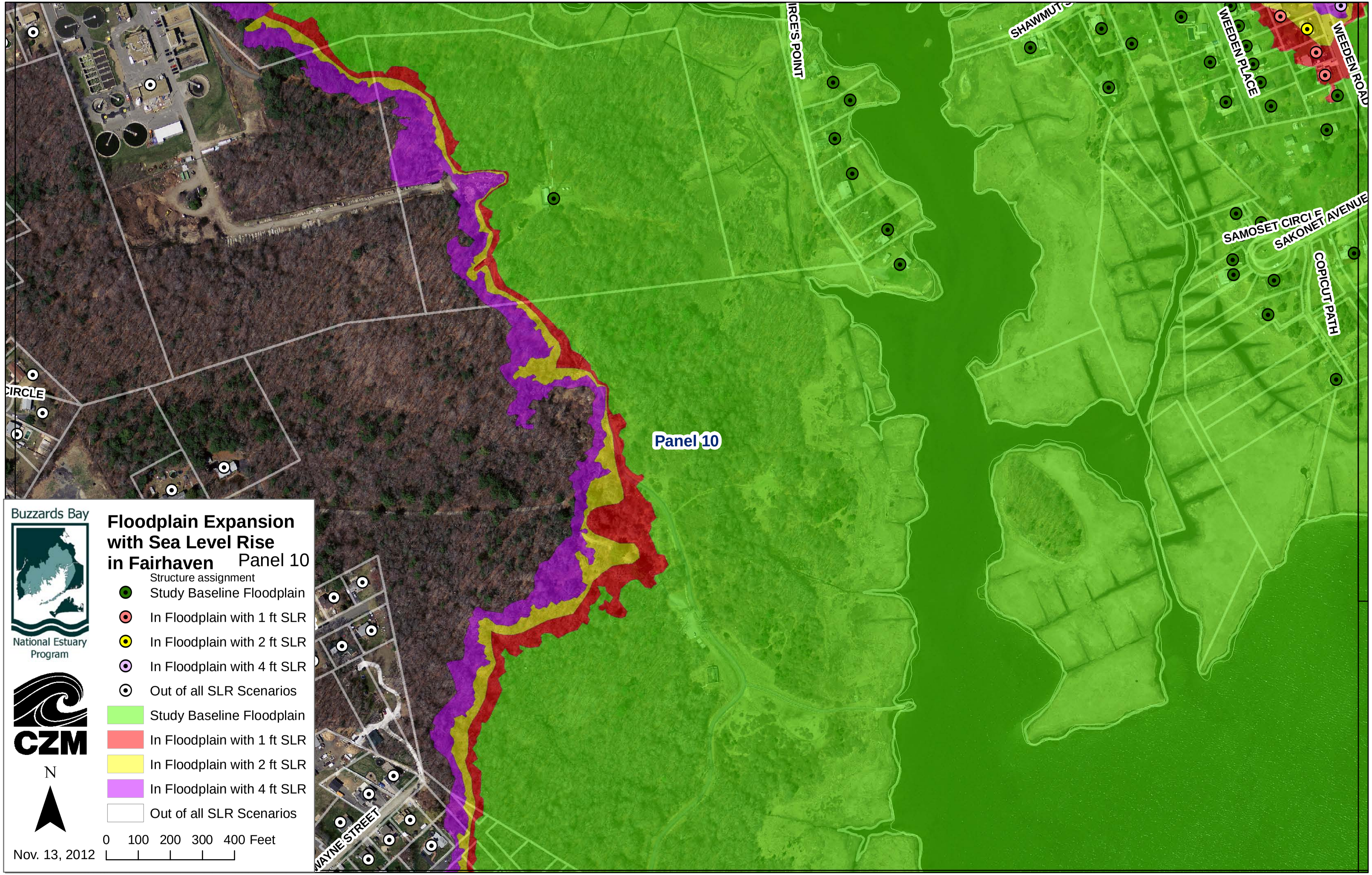
PEIRCE'S POINT

MARK DRIVE

WEEDEN ROAD

WEEDEN PL

Panel 11


Panel 10
IRCE'S POINT
SHAWMUT
WEEDEN PLACE
WEEDEN ROAD
SAMOSET CIRCLE
SAKONET AVENUE
COPICUT PATH
CIRCLE
WAYNE STREET
Buzzards Bay
National Estuary Program
CZM
Floodplain Expansion with Sea Level Rise in Fairhaven
Panel 10
Structure assignment
Study Baseline Floodplain
In Floodplain with 1 ft SLR
In Floodplain with 2 ft SLR
In Floodplain with 4 ft SLR
Out of all SLR Scenarios
Study Baseline Floodplain
In Floodplain with 1 ft SLR
In Floodplain with 2 ft SLR
In Floodplain with 4 ft SLR
Out of all SLR Scenarios
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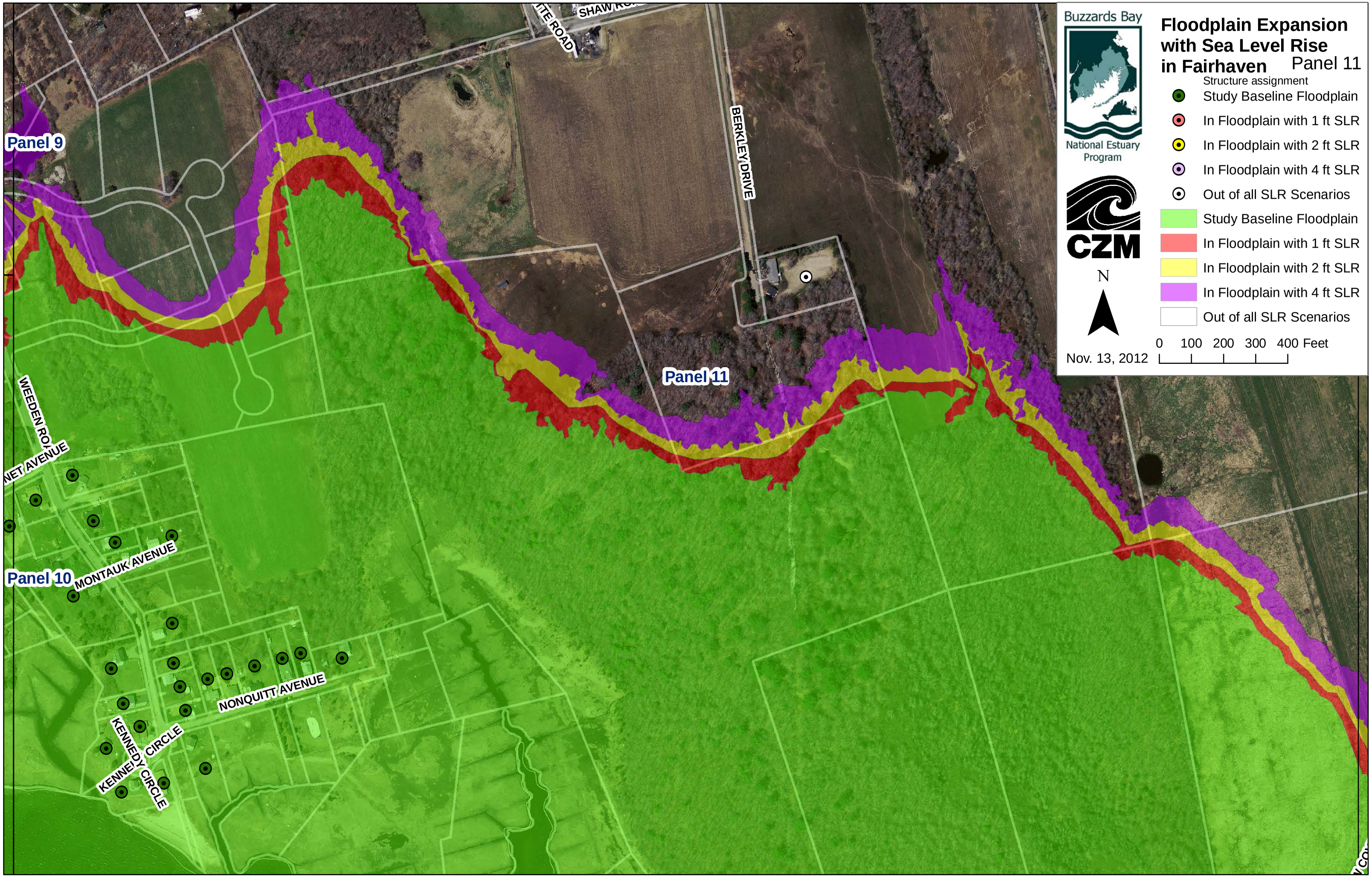
Nov. 13, 2012


Panel 9
Panel 10
Panel 11
BERKLEY DRIVE
WEEDEN ROAD
NET AVENUE
MONTAUK AVENUE
NONQUITT AVENUE
KENNEDY CIRCLE
KENNEDY CIRCLE
Buzzards Bay
National Estuary Program
CZM
Floodplain Expansion with Sea Level Rise in Fairhaven
Panel 11
Structure assignment
Study Baseline Floodplain
In Floodplain with 1 ft SLR
In Floodplain with 2 ft SLR
In Floodplain with 4 ft SLR
Out of all SLR Scenarios
Study Baseline Floodplain
In Floodplain with 1 ft SLR
In Floodplain with 2 ft SLR
In Floodplain with 4 ft SLR
Out of all SLR Scenarios
N
0 100 200 300 400 Feet
Nov. 13, 2012


PLANTE
WAYNE
HARVARD STREET
GOLF STREET
GROVE STREET
HATHAWAY STREET
BAY STREET
ORCHARD STREET
GRAPE STREET
EDGEWATER STREET
BEACHWOOD STREET
POINT STREET
BONNEY STREET
COVE STREET
Panel 8
Panel 12
ROCKLAND STREET
DELMONT STREET
STATE STREET
BUIST AVENUE
AUSTRIA AVENUE
MORAVIA AVENUE
BAXTER AVENUE
EMERSON AVENUE
SCONTICUT NECK ROAD
EMERSON AVENUE
INDIAN WAY
WAMPANOA
Buzzards Bay
National Estuary Program
Floodplain Expansion with Sea Level Rise in Fairhaven
Panel 12
Structure assignment
Study Baseline Floodplain
In Floodplain with 1 ft SLR
In Floodplain with 2 ft SLR
In Floodplain with 4 ft SLR
Out of all SLR Scenarios
Study Baseline Floodplain
In Floodplain with 1 ft SLR
In Floodplain with 2 ft SLR
In Floodplain with 4 ft SLR
Out of all SLR Scenarios
CZM
N
0 100 200 300 400 Feet
Nov. 13, 2012

Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 13

Buzzards Bay National Estuary Program

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Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

N

0 100 200 300 400 Feet

Nov. 13, 2012

Panel 13

FREDERICK
ASHLEY ISLAND ROAD
MANZONE DRIVE
WILLYS WAY
RESERVATION LANE
WIGWAM BEACH ROAD
RESERVATION ROAD
GILBERT STREET
WAMPANOAG DRIVE
SUNRISE COURT
TREASURE BAY LANE
RAYMOND STREET
CRESCENT DRIVE
CAPEVIEW STREET
BERNESE STREET
CHASE ROAD
SUMMIT DRIVE
HOLIDAY DRIVE
SCONTICUT NECK ROAD
GROVER STREET
SHORE DRIVE
SEAVIEW AVENUE
SMITH STREET
RESERVATION ROAD
OCEAN AVENUE
GRANDVIEW AVENUE
TORRINGTON ROAD
WAYBRIDGE ROAD
BRIERCLIFF ROAD
REMARSH BEACH ROAD

Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 14

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N

Nov. 13, 2012

0 100 200 300 400 Feet

Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

WAYBRIDGE ROAD
EATON ROAD
BRIERCLIFF ROAD
TORRINGTON ROAD
SEDGEWICK ROAD
CALUMET ROAD
JERUSALEM ROAD
WIDEMARSH BEACH ROAD
SMUGGLERS BEACH DRIVE
Panel 14
MELPEN WAY
EDWARD WAY
SUNSET BEACH ROAD
LEEWARD WAY
SCONTICUT NECK ROAD
CAMEL STREET
HENRY STREET
CLUB STREET
DIAMOND STREET
WAPATMA LANE
WINDSWEPT DRIVE
CHAMBERS STREET
SHORESIDE

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Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 15

Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

N

0 100 200 300 400 Feet

Nov. 13, 2012

Panel 15

WINONA AVENUE
TECUMSEH AVENUE
WINSEGANSETT AVENUE
WHISPER LANE
WHISPER LANE
MURRY STREET
WAMSUTTA STREET
SIPPICAN STREET
MONONDACK AVENUE
SCONTICUT NECK ROAD

Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 16

Buzzards Bay National Estuary Program

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Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

N

0 100 200 300 400 Feet

Nov. 13, 2012

Panel 16

CHERRYSTONE ROAD
COTTON WOOD STREET
DOGWOOD STREET
BLUE POINT ROAD
FIR STREET
ALMOND STREET
CAUSEWAY ROAD
EBONY STREET
BALSAM STREET
ALDER STREET
LITTLE NECK ROAD

ALDER STREET
FISHERMAN S ROAD
EBONY STREET
FIR STREET
GULL ISLAND ROAD
DOGWOOD STREET
BALSAM STREET
MISTY BAY ROAD
COTTON WOOD STREET
CKY POINT ROAD

Panel 17

Buzzards Bay
National Estuary Program

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Floodplain Expansion with Sea Level Rise in Fairhaven

Panel 17

Structure assignment

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

- Study Baseline Floodplain
- In Floodplain with 1 ft SLR
- In Floodplain with 2 ft SLR
- In Floodplain with 4 ft SLR
- Out of all SLR Scenarios

N

0 100 200 300 400 Feet

Nov. 13, 2012