ASSESSMENT OF LONG TERM HOUSING RECOVERY AFTER HURRICANE SANDY

by

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ABSTRACT

Disaster recovery, involving people and their properties, is considered to be a continuous process that spans from a very short time to years after the initial event depending on the severity of the damage. Recovery has many dimensions that include *repairing, restoring, rebuilding, and reshaping the physical, built, social, economic, and natural environment through pre-event planning and post-event actions* as mentioned by Smith & Wenger, 2007. Among all the fundamental issues, according to Peacock et al., 2007, reestablishing permanent housing is the most important one because it accelerates recovery process by helping households return in their normal regular activities. Hence the purpose of this thesis is to explore the progress rate in reconstruction/repair/reshaping of damaged buildings as an indicator of housing recovery in one of the Hurricane Sandy affected areas, Sea Bright, New Jersey, which is still experiencing recovery after two and half years.

The study focuses on the development of a methodological approach to (a) track housing recovery and (b) help in approaching quick recovery of the damaged area based on the condition of permanent houses. The effort uses several sources of data including questionnaire data from an ongoing project, FEMA damage data, airborne Light Detection and Ranging (LiDAR) data and remote sensing images. The data are analyzed quantitatively to fulfill the objective of assessing housing recovery rate over time. Geographic Information System (GIS) based image processing are done to delineate locations that have recovered, unrecovered or less recovered or

continuing recovery. Maps compare the status of damaged buildings (no damage, minor damage, major damage, affected, or destroyed) in disaster and repaired buildings in specified time intervals based on available data. Thus the study findings will help the policy makers, emergency management personnel, coastal managers, decision makers and relevant professionals to focus more on the identified location experiencing differential progress in reconstruction, rebuilding, and repairing of houses and take necessary actions to help those localities in accelerating their recovery process.

Chapter 1

INTRODUCTION

Hurricane Sandy, category 1 Hurricane, made landfall in Southern New Jersey on October 29, 2012 with high wind (speed of 80 miles per hour), storm surge and heavy rain that flooded many areas as well as creating significant debris accumulation (Blake, Kimberlain, Berg, Cangialosi, & Beven II, 2013; Cutter, Schumann, & Emrich, 2014). At landfall more than 23,000 people had evacuated to temporary shelters (FEMA, 2013b). According to the Federal Emergency Management Agency (FEMA, 2013a, p.1), ‘the storm caused tens of billions of dollars in damages, damaged or destroyed hundreds of thousands of homes, and killed at least 162 people in the United States’. Sandy impacted more than a dozen states, mainly in the mid-Atlantic region (FEMA, 2013b). The region is still going through the recovery process after two and half years of the event as communities work to restore their condition in similar status before disaster or improve their situation confronting future hazards. In the news bulletin ‘Sandy recovery continues over the holidays’ dated 23 December, 2014, FEMA describes continuing recovery and rebuilding work with help of state and local partners to make a strong resilient New Jersey to withstand future disasters (FEMA, 2014). Given the length and complexity of the post disaster recovery process, this thesis aims to develop a standard procedure for mapping the recovery progress using different type of available data at any time and identify aberrations, if any, for example, the areas still in the process of change, considering only the physical properties of the affected areas. To fulfill this purpose the borough of Sea Bright in Monmouth County, New Jersey is selected for detailed study.

1.1 Problem Statement and Motivation

The term recovery covers many dimensions of emergency management, involving people and the properties, and is considered to be a continuous process (Rathfon, Davidson, Bevington, Vicini, & Hill, 2013). This process starts after the initial event and continues over years depending on the severity of the event (Haddow, Bullock, & Coppola, 2007). Recovery involves the repairing, redevelopment, reconstruction, improvement of the damaged, destroyed or existing physical property with the social, economic and natural environment (Smith & Wenger, 2007) for the betterment of the community and to be prepared for future events. Among all the fundamental issues, reestablishment of permanent housing is considered most important because it accelerates the overall recovery process by helping households return in their normal regular activities (Peacock, Dash, & Zhang, 2007). Therefore the purpose of this research is to identify the progress rate of recovery in Hurricane Sandy affected areas, limited to the reconstruction or repairing of housing units or physical properties that are still experiencing recovery after two and half years.

Hurricane Sandy had significant impact with high storm surge, wind speed, low barometric pressure, flooding and extreme consequences on the vulnerable coastal zone with increased development to consider it as the largest disaster to affect New Jersey in more than 100 years (Cutter et al., 2014). In New Jersey, property damage cost more than $30 billion, 34 people died and 346,000 homes were destroyed or damaged. The severity of the impact has made the recovery process long, time consuming and costly (Blake et al., 2013; Cutter et al., 2014). The affected areas are still going through recovery to restore them to the original condition or improve the condition to be prepared confronting future disaster. This present situation motivates this research to identify geospatially the redevelopment, as well as improvements, over time. The product of this research has several applications as tool to identify location experiencing differential recovery progress. The identified location can be further investigated to find factors impacting the speed of recovery (socio-economic, insurance, financial assistance, policy implication, etc.) and help decision makers in solving those problems. The research outcome can be useful to compare geographic locations or coastal areas that have experienced hurricanes in the past or are vulnerable to disasters like hurricanes to help them be prepared considering the similarities and dissimilarities among the features and attributes of the community.

1.2 Defining Recovery

In disaster and hazard literature there is no cohesive theory of recovery (Cutter et al., 2014). It has considered to be most challenging and uncertain part in disaster management that begins after disaster response phase and continues for years, sometimes over decades (Haddow et al., 2007; Phillips, Neal, & Webb, 2011; Rathfon et al., 2013). Scholars have defined recovery in different ways. Recovery meant return back to normalcy in previous definitions, where modern term incorporates sustainability to minimize vulnerability (Smith & Wenger, 2007). According to the National Disaster Recovery Framework,

> Recovery process addresses complete redevelopment and revitalization of the impacted area, rebuilding or relocating damaged or destroyed social, economic, natural and built environments and a move to self-sufficiency, sustainability and resilience (FEMA, 2011, p. 81).

Also recovery can vary considering required time between short and long term recovery (Phillips et al., 2011). Among all these fundamental issues, “social, economic, natural and built environments” and the time frame, this research targets only the measurement of post-disaster housing recovery at any time. As the impacted areas are still recovering from the Hurricane Sandy damage, it is important to identify the reconstruction or rebuilding or repair of buildings to track progress and the rate of recovery.

1.3 Research Objective and Research Questions

The objective of this research is to develop a comprehensive assessment of post disaster housing recovery that reflects changes over time. The assessment will -

- Make use of available data from a variety of sources that may be available at different spatial scales and at different points in time.
- Reflect changes in the housing recovery over time using GIS methods.
- Be applied at a scale appropriate for the resources (data and computation effort) available.
- Develop a measurement scale to quantify damage and recovery.

This research addresses the following research questions:

1. How much has housing in a specific community recovered at any point in time after Hurricane Sandy?
2. How to use data from different sources to keep track of the progress of recovery based on physical damage to housing caused by disasters?

1.4 Overview of the Research Approach

In order to achieve the research objective and answer the research questions, the thesis has been framed to use a systematic research approach. Geographic data are utilized and analyzed to compare the scenario just after a disaster with the situations at different time intervals after the disaster for a specific study area. Thus a methodology is developed and tested to measure the progress in housing recovery in the long term. Remote sensing images (satellite and air borne) and LiDAR data are used to fulfill this purpose. In addition secondary data from a mail based questionnaire are used to support the findings with feedback from the residents of the affected community. Finally the results are used to develop several maps, tables and charts representing the ongoing recovery process with respect to the physical properties of the existing buildings.

1.5 Outline of Thesis

This thesis is comprised of several chapters starting from the introductory write up and ending with the concluding remarks. The thesis starts with Chapter 1 with an overview of the Hurricane Sandy and its impact in the affected areas, followed by the motivation behind selecting this topic considering the importance of recovery in emergency management. Recovery is a very complex issue in the disaster management field, even the term itself has no definite universal definition. The aspects of recovery are outlined and the scope of work in this master's thesis along with the research objective and questions to be answered are presented.

Chapter 2 summarizes the existing literature with theory and information in support of the recovery concept basically long term housing recovery in disaster or emergency management and methodology planned to accomplish the research objectives. Chapter 3 develops the research methodology with possible data sources and contains details on the case study area used for the research. The data used for the research and the findings from data analysis are discussed in Chapter 4 including relevant figures and tables that summarizes the progress and character of Hurricane Sandy long term housing recovery process for Sea Bright as the research results. The last chapter, Chapter 5, conclusions, presents the contributions, and the prospects for future research as well as addressing the limitations of this study. It also includes a summary discussion that provides insight into the whole research work. Finally references cited in the write up and the appendices appear at the end of the document. The appendices include information about the survey data, demographic information of the study area and some details on other secondary data that supported this work.

Chapter 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

This chapter includes relevant literature and existing theories in support of the study topic. It also provides background information clarifying basic concepts and outcomes from previous studies from published documents. The chapter starts with a review of past studies and relevant theories on housing recovery and then develops ideas supporting and directing this research work. The chapter concludes on developing the foundation for measurement of housing recovery that is used for this study.

2.1 Research on Recovery and Housing Recovery

The studies related to disaster recovery was very limited before 1970s (Barton, 1969; Smith & Wenger, 2007). The community level disaster recovery was first studied by Haas in the late 1970s and it received more attention by the mid-1980s (Olshansky, 2005; Quarantelli, 1995) when a case study at local level was considered to be the basis for describing the recovery process. Although a number of research studies (Becker & Stauffer, 1994; Berke, Kartez, & Wenger, 1993; May & Williams, 1986; Nigg, 1995; Ohlsen & Rubin, 1993; Olson & Olson, 1993; Olson, 2000; Peacock, Morrow, & Gladwin, 1997; Schwab, 1998; Smith & Wenger, 2007) represent different aspects of disaster recovery, for example, environmental (Cutter, 2001; Becker, 1994), social (Quarantelli,1999; Nigg, 1995; Cutter, 2014), economic (Comerio, 1998), political (Olson, 2000), housing (Peacock et al, 2007), sustainable recovery (Smith & Wenger, 2007) and many others, the recovery phase is still considered the least understood phase in the disaster management cycle with limited theory to explain it (Chang, 2010; Smith & Wenger, 2007, p. 234).

Researchers have applied a variety of measures or indicators to capture different dimensions of household or family recovery, such as psychological or perceptional measures related to stress, sense of loss, and regaining income, employment, household amenities, household assets, etc. (Peacock et al., 2007, p. 258). In areas with economic growth, post-disaster reconstruction was more important (Geipel, 1982). Rathfon et al. (2013) studied physical properties of permanent houses in the affected areas to measure the housing recovery as part of household recovery. Although there are many dimensions to disaster recovery, the thesis focuses on long-term permanent housing recovery as a critical element for household/family and community recovery, probably the least planned among all parts of disaster management cycle.

Quarantelli (1995) considered four key housing issues in disasters based on the movement of displaced people i.e. emergency shelter, temporary shelter, temporary housing and permanent housing sequentially over time. The affected households move from one stage to another based on the existing situation where the final stoppage is their permanent home. Rathfon et al. (2013) studied the physical condition of permanent residential buildings to explain housing recovery. The building may experience no damage, minor, moderate, severe or catastrophic damage and go through temporary protection, major or minor repair, reconstruction, demolished and rebuild considering mitigation measures before reuse or settle again. Also the land use can be changed after a disaster, the land may remain vacant (or unoccupied), or change from previous to another use. If the status of the plot can be monitored over time, it will show the progress rate in housing recovery over time.

2.2 Understanding Recovery

To better understand recovery in disaster management, the phases of recovery, measures of recovery, factors influencing recovery rate and the consequences of recovery are discussed in detail under the following sub sections.

2.2.1 Phases of Recovery

Recovery is best thought of as a continuous process without any logical order involving emergency period; restoration period; replacement and reconstruction period; and commemorative, betterment, and developmental reconstruction period (Kates & Pijawka, 1977; Phillips et al., 2011; Rubin, Saperstein, & Barbee, 1985). The recovery process does not always begin immediately and it requires *'balancing the more immediate need to return the community to normalcy and reduce vulnerability in the long term'* (Haddow et al., 2007). Post-disaster recovery is not *how soon to start but how long it will take* (Phillips et al., 2011). The recovery phase is divided in to two terms, short and long term, based on the time required to return to regular activities. Phillips et al. (2011) mentioned that local organizations are still working to rebuild hurricane affected private and public sectors in four states in 2010, though five years have passed since Hurricane Katrina. After two years of Hurricane Sandy, the impacted areas are still recovering from the damage.

2.2.2 Measuring the Recovery Rate

Different scholars have used different types of data sources in evaluating the speed and progress of housing recovery over time quantitatively, for example, data on building permit (permission for repair or demolish then rebuilt) (Comerio & Blecher, 2010; Rathfon et al., 2013; Stevenson, Emrich, Mitchell, & Cutter, 2010); tax appraisal, land-use change and census data (Zhang & Peacock, 2009); remote sensing satellite images and geo-referenced GIS maps (Brown et al., 2008; Rathfon et al., 2013); occupancy certificates, property appraisals, property sales, FEMA's temporary housing, and temporary roof installation (Rathfon et al., 2013).

The first challenge of recovery goes to assessment of damage (Phillips et al., 2011). Immediately after a disaster, the building's damage status can be classified as no damage, minor, moderate, severe, or catastrophic damage (Rathfon et al., 2013). Comparing the initial damage with the improvements over time, i.e. by defining the change from initial condition, the housing recovery rate can be computed.

2.2.3 Influences on Progress of Housing Recovery

There are many factors that impact the progress rate of recovery for example, *"the availability of undamaged housing, economic conditions, the disaster management system, local land use and building practices and, especially, the availability of financing"* (Wu & Lindell, 2004, p.64). In recovery and rebuilding process, the complications are finance, short time periods, racial mistrust and discrimination (Esnard & Sapat, 2014, p. 57; Olshansky, Johnson, & American Planning Association, 2010). Researchers have paid very little attention to the socio-political aspects of the long-term recovery process. The structure, available resources and capacity of a community or country's government impact the recovery speed and duration after major disasters and catastrophes (Esnard & Sapat, 2014, p.53). Foley (1980) described housing as a trickle down process in the United States where new housing is provided to the people who can afford it. Displaced people, excluding those voluntarily relocated or property owners who rebuilt, take more time to recover completely (Esnard & Sapat, 2014, p.53). Low income people and minority households face many challenges dealing with housing recovery. They ‘tend to suffer disproportionately higher levels of damage in disasters’ (Peacock et al., 2007). The institutional assistance gap is responsible for uneven recovery including mismatch between time and type of assistance, assisted people and people or organizations responsible for the help (Esnard & Sapat, 2014, p. 54). In another case, ownership patterns (owner occupied and rental housing, single family housing), financial resources (public and private funding), insurance coverage, etc. also impact permanent housing recovery (Peacock et al., 2007). According to Zhang & Peacock (2009), low-income households, the rental houses, and minority groups recover more slowly where the owner occupied houses and single family housing gets advantage in quick recovery.

2.2.4 Consequences of Recovery

Recovery has many positive and negative consequences over the affected community. These consequences have been focused on by many researchers (Haddow et al., 2007; Kates & Pijawka, 1977; Phillips et al., 2011) in the emergency management field. Recovery gives the opportunities to newly rebuild environmental friendly communities with proper planning (Phillips et al., 2011) and improve pre-disaster conditions (Kates & Pijawka, 1977). Also provides opportunity to the individual and community to be economically sustainable, safe, and improve their quality of life (Haddow et al., 2007). Recovery planning in the pre-disaster time increases the hazard mitigation process and improves the recovery process (Wu & Lindell, 2004).

2.3 Data used to Measure Recovery

For this research secondary source data have collected based on availability and as applicable to study area covering government, non-government, private, voluntary organizations involved in recovery from Hurricane Sandy with published documents. Free source remote sensing images (satellite and airborne), GIS based shape files and geodatabases, LiDAR point clouds (pre- and post-hurricane Sandy) data are collected from Federal Emergency Management Agency (FEMA), United States Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), New Jersey GIS data clearing house and other sources. One of the major source of data used in this research is mail based questionnaire data from an on-going project on Hurricane Sandy.

2.4 GIS as an Analysis Tool to Support Recovery

The local governments and emergency managers use Geographic Information System (GIS) increasingly to plan for hazards and disasters (Smith & Wenger, 2007, p. 241). Brown et al. (2008) and Rathfon et al. (2013) used remote sensing satellite images and geo-referenced GIS maps to quantitatively measure the post disaster housing recovery. GIS provides an important tool to compute spatially the differences and change in the physical properties in different time frame regarding previous and after situation. Thus it helps to distinguish areas demanding more attention regarding recovery or future preparedness or other plans in emergency management and concern relating policy issues.

2.5 Building on the Literature to Develop a Tool for Assessing Housing Recovery

From the literature review it is seen that recovery is the most uncertain and complex part in the disaster management cycle. It is very tough to define disaster recovery using specific parameters. Also it is hard to declare that an area, a community has or the individuals have fully recovered from the impact of previous disasters, unless the community starts working on a different phase or gets impacted by another disaster. So it is a never ending process that always goes on. Apparently, considering the physical properties of an area, if the damaged buildings are repaired, reconstructed or rebuilt, if the people restart their livelihood in their locality, the community starts functioning like before, it can be said the area is recovering and the process can be assessed to track the progress in one aspect - housing. Based on the findings the recovery or management plan could be changed, modified or updated to accelerate the recovery process or be better prepared for future disasters. Depending on the necessity of understanding the trend of recovery over time, this thesis emphasizes the development of a methodology that can be followed to identify the recovery progress rate in an area. The following chapter discusses the detailed research design and methods applied to fulfill the targeted objective and reach the research goal.

Chapter 3

RESEARCH DESIGN AND METHODS

The recovery rate of damaged structures or buildings or infrastructures in the affected area over time are studied based on quantitative methods with support of literature review. To explore the research questions and fulfill the objective, a detailed case study is developed based on the borough of Sea Bright in Monmouth County, New Jersey. The location with respect to surrounding states is shown in Figure 3.1. This section of the thesis discusses the overall research design and the methods chosen to complete the research.

3.1 Study Area

One community in New Jersey that has experienced massive devastation in Hurricane Sandy is thoroughly studied to understand housing recovery and answer the specified research questions posed in the thesis. More specifically, Sea Bright borough in New Jersey, the chosen study area, is still in the process of recovery from the destruction of Hurricane Sandy, and like other areas till rebuilding. In 2010, there were 1,412 residents with 1,211 homes (35% owner-occupied and 34.6% vacant). The median income was $74,550 with 94.6% white people according to Census data (http://www.census.gov). Appendix C includes detail data on the community profile of the study area according to Census 2010 and American Community Survey (ACS) 2011. Sea Bright's municipal budget relies heavily on local property taxes that are jeopardized by Hurricane Sandy (Ashman et al., 2013).

Figure 3.1: Geographic location of the study area, Sea Bright, New Jersey.

The reasons behind choosing this site are that Sea Bright is a barrier island with water bodies in two sides of the land as shown in Figure 3.1 with an area of approximately 0.64 square miles. The land is geographically vulnerable and historically susceptible to severe and recurrent coastal storm damage with regular flooding (Ash Wednesday storm of 1962, The Nor'easter of 1992; (Ashman et al., 2013). In Hurricane Sandy, Sea Bright was within 100 to 120 km buffer zone from the nearest trajectory of the hurricane eye. Figure 3.2 shows the image of the Hurricane path and the buffer zones for Sea Bright, New Jersey.

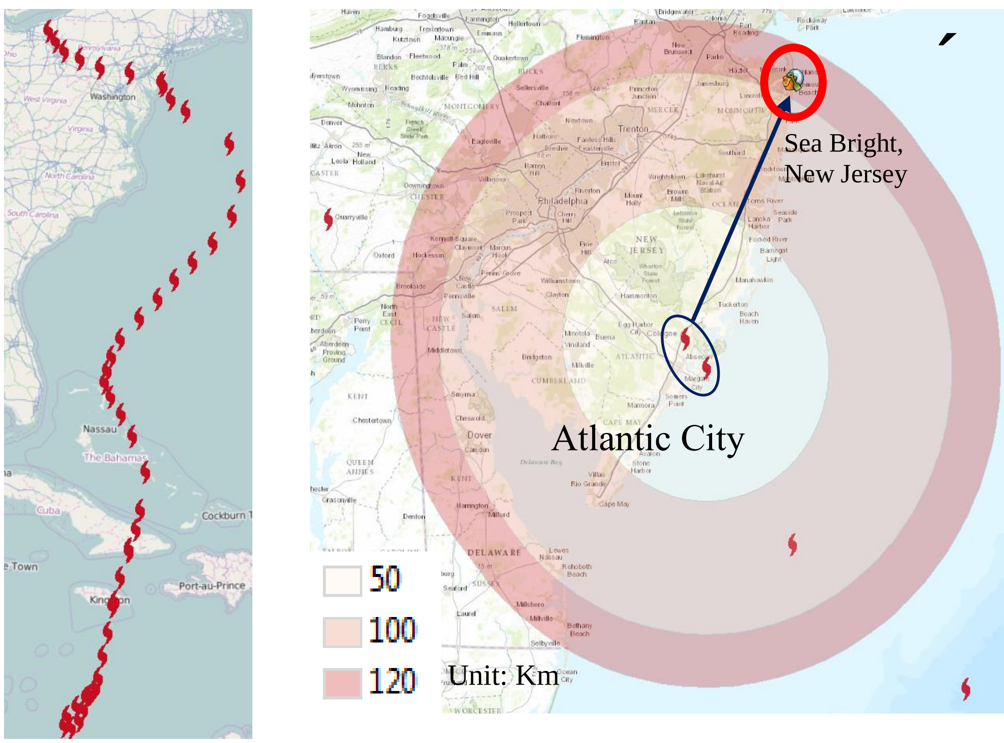

Figure 3.2: Hurricane Sandy path with buffer distance of the study area from neared eye of the hurricane.

In Hurricane Sandy 1,028 out of 1,126 housing units were damaged; assessed loss in property values of $72.1 million US dollar; immediate aftermath of hurricane there was 6 feet of sand on the main road Ocean Avenue; also many community facilities were destroyed. Hurricane Sandy had major negative impacts to homeowners, renters and the businesses. As of April 2013, approximately 50% of Sea Bright's residents were back (Ashman et al., 2013). FEMA records shows 759 structures damaged in Sea Bright (FEMA-MOTF, 2014). According to US Department of Housing and Urban Development (HUD), Hurricane Sandy damaged 720 structures in Sea Bright; the first floor of 376 buildings had 4 feet of flooding. Among the damaged property owners 92 persons had no insurance with 268 owners had insurance i.e. 25% without any insurance (HUD, 2014). There is inconsistencies in data from different sources that made this research more important to have a clear view on the actual scenario of recovery based on housing damage.

3.2 Measuring Housing Recovery

From the literature, it is apparent that there are various methods to measure the progress of housing recovery. In many studies on housing recovery, improvement or change in physical properties at a specific location are identified by comparing data over various time intervals. The data, over time, include GIS based maps, remote sensing satellite imageries, tax appraisal data, building permit data, land-use change and census data and so on. For this study, data satisfying the following criteria has collected to measure disaster recovery with respect to housing. The possible measures of damage and the attributes that may impact damage that are to be used in analysis of this research include:

- Scales of damage (no damage, affected, minor damage, major damage, or catastrophic damage i.e. destroyed)
- Damage estimates in monetary terms
- Ownership pattern (own/rent)
- Type of home (single-family/multi-family/apartment/condo/other)
- Occupancy type (Occupied/ unoccupied)

The measures of housing recovery is derived from these measures including measures of individual variables, multiple measures, and derived measures. Some measures are applied to a specific housing unit where others are applied to an area. Examples include:

- Single measures:
    - single measures for individual housing unit whether experienced damaged or non-damaged.
    - single measures by area that includes
        - Number (#) of housing units damaged.
        - Number (#) of housing units occupied or unoccupied.
        - Percentage (%) of housing units occupied or not.
        - Number (#) of housing units under repair.
        - Percentage (%) of area with a specified level of recovery.
- Derived measures:
    - derived measures with damage or recovery scale (say 1 to 4, or 1 to 10, or 1-damaged, 2-partially recovered, and 3-fully recovered).

3.3 Data Collection Techniques

Available data from secondary sources has been collected, and analyzed to fulfill the purpose of the research. The data includes mail based questionnaire, remote sensing images, GIS based data, air borne LiDAR data and so on.

3.3.1 Surveys and Interviews

The research has used data from an ongoing project on Hurricane Sandy titled 'Understanding the Relationships between Household Decisions and Infrastructure Investment in Disaster Recovery: Cases from Superstorm Sandy' funded by the Center for Advanced Infrastructure and Transportation (CAIT) at Rutgers University through the University Transportation Center Program (funded by US Department of Transportation, Grant Number DTRT12-G-UTC16.) Professors Sue McNeil and Joe Trainor are the Principal Investigator and Co-Principal Investigator respectively. Alex Greer, former research assistant and PhD student in Disaster Science and Management developed and implemented the survey that provides the data for this project. His dissertation 'Household Residential Decision-Making in the Wake of Disaster: Cases from Hurricane Sandy' also used the survey data source with the objectives of exploring the different factors that influence household decisions to stay and rebuild after a disaster, or to relocate (Greer, 2015).

In the ongoing project a mail based questionnaire was designed and implemented in 2014 to collect information related to damage from Hurricane Sandy and people's perception on issues related to recovery and resettlement. The questionnaire included 75 questions. In the first phase the questionnaire was sent to 1252 addresses followed by second and third round mailing that exclude completed and undeliverable addresses to encourage participation. Finally, 303 responses from the households were recorded from the survey, representing 29.8% response rate, here incorrect or unreachable addresses are not counted. In this proposed research, only data relevant to the research questions will be considered for analysis from the survey.

The data collection effort received Institutional Review Board (IRB) approval to deal with the human subject. The approval letter is enclosed in Appendix A where the survey instrument is included in Appendix B. According to IRB, the identity of survey respondents must be kept confidential. The secured questionnaire data in Statistical Package for the Social Sciences (SPSS) format is accessible for analysis of this research. The data are secured on DRC server in compliance with IRB and were utilized using the same storage device to fulfill the purpose of the current research. To hide the identity of the survey respondents, a separate identity number was used for each individual households.

The data covers the ownership of the property (own/rent), type of home, property status just after sandy and present condition (abandoned/repair completed/repair in progress/ rebuilt/ demolished/ property sold, etc.), mitigation measures applied in rebuilt properties, source of funds, damage estimates in dollars, and household income variation. In the questionnaire the respondents were asked to comment on the level of damage to their homes and their community in Likert scale ranging from ‘no damage’ to ‘very extensive damage’ on a four points base. They also provided numerical value for the damage estimates. Also asked information included the maintenance of flood insurance and its coverage at time of Hurricane Sandy. At the end of questionnaire two open ended questions were included to understand the housing recovery, for example, their experience, procedures and pitfalls during recovering.

In responses to the mail survey, some individuals agreed to participate in detailed interviews related to recovery issue. There were 15 interviews that can provide more detail on the present situation and help in addressing factors contributing to progress of recovery. For this research the interview data has not been explored. It can be used in future research to have more detail on support of the research objective.

3.3.2 LIDAR data

Airborne LiDAR data, as more accurate, high resolution and precise data, is used to provide geospatial information on housing condition both for pre and post disaster. At the initial stage of this research, these data were assembled by Professor Jie Gong, Assistant Professor, Department of Civil and Environmental Engineering, Rutgers, the State University of New Jersey for the purpose of academic research. He collected this conditional data from United States Geological Survey (USGS). At present the data is also publicly available from the National Oceanic and Atmospheric Administration (NOAA) coastal websites. So the after Hurricane Sandy LiDAR data only within the boundary of study area is downloaded from this free source and used for detailed analysis. The National Oceanic and Atmospheric Administration (NOAA) also conducted some aerial photography of the east coast Hurricane Sandy affected areas on the day after it hit these areas. These data at various time intervals have been assembled to spatially compare the damage scenario of physical properties as an element of housing recovery through change detection.

3.3.3 Data Summary

Table 3.1 summarizes the data sources with detail that are used in assessing housing recovery of Sea Bright, the scale at which the data is collected and the time frame for data collection.

Table 3.1: Summary of Available Data.

Data Source	Coverage	Scale	Time Frame	Measure
Survey Results	303 Households (29.8%)	Household	Summer 2014	Property Status: Abandoned; Repairs completed; Repairs in progress; Structure was or will be totally rebuilt; Structure was or will be demolished Condemned; Repairs completed; Repairs scheduled to begin; Property for sale or sold.
FEMA-MOTF data	100%	Projected Coordinate system	2012 Hurricane Sandy impact	Measures the damage level, inundation data and other impact data.
LiDAR data (USGS)	100%	Projected Coordinate system	Pre-Sandy and Post Sandy	Change in Elevation Indicates Structure Damage
Aerial Imagery (NOAA, FEMA)	100%	Projected Coordinate system	2010, 2012, 2013, 2014	Visual interpretation of the land use change comparing pre-sandy and post-sandy images.
Google-Earth images in time series	100%	Satellite image	2010, 2012, 2013, 2014	Visual interpretation of the land use change comparing pre-sandy and post-sandy images.
Census	100%	Block	2010	Demographics

Two problems arise regarding the data. First, the study area is very small and very little demographic and economic data are available. Second, the response rate from the mail survey is relatively low so there is insufficient information from the mail survey to cover the whole borough. Besides these data also present some interesting challenges, such as:

1. The LiDAR data represent elevations. Interpreting changes in elevation to indicate damage, or rebuilding requires assumptions, extensive data processing and local knowledge.

2. Parcel level data from the surveys must be handled in a way to maintain confidentiality.

3. The survey data are samples and the recovery measurements required assumptions to assist in their interpretation.

3.4 Analyzing the Data and Assessing Housing Recovery

There are several potential sources of data available for measuring housing recovery. The data are available in different time periods at different scales. One of the challenges is to integrate these disparate sources of data. ArcGIS software is used to prepare the maps and do spatial analysis based on sample data. The survey responses are geocoded to locate their position in field. After geocoding, the data from the survey is imported to an ArcGIS attribute table including individual household responses. Spatial analyst tools in ArcGIS are utilized with visual inspection to identify locations with damage and differential recovery progress of recovered, unrecovered or less recovered or continuing recovery and to compare recovery in certain time interval. The findings are presented in maps. Also the data are analyzed statistically using MS Excel by creating tables and graphs of comparative features. In the case of LiDAR data, the change detection is done using Quick Terrain Modeler software to identify the damage location with color codes and value in elevation change. Having LiDAR data at several distinct times after Hurricane Sandy would enable comparative analysis over time.

The maps produced using survey data, GIS and remote sensing data and LiDAR data are compared to find out the variation over time. In this case the maps are made in same scale and various geo-processing techniques like overlay or others are used for further analysis. In case of statistical analysis of the data, percentage change, change in numerical values are utilized to have more acceptable and reliable results. Finally the analysis result comes up with the number and percentage of houses repaired, rebuild or reconstructed to show the change over time to level recovery from the damage at that time of disaster to improved present situation.

The findings are presented in maps, charts, and tables to have a comparative view over time. A series of map at different points in time shows the area experiencing change in housing recovery to compare the progress. Several charts or graphs shows trend line with diminishing or increasing pattern considering the correlation between destroyed property and occupancy of the plot in later times with 2012 as base year of hurricane occurrence. The government and other organizations related to housing recovery can use these maps with identified location where more attention should be given to improve the situation based on factors contributing slow recovery from disaster.

Chapter 4

ANALYSIS, FINDINGS AND DISCUSSION

This chapter describes the data analysis and the findings from the data analysis in support of the research goal and objective. The research assembles and uses data from different sources and integrates them to document the recovery of damaged properties over time for the case of Hurricane Sandy. The data related to disaster housing recovery in different time periods has been identified, assembled and analyzed to track the improvements to the housing stock in Sea Bright, New Jersey.

To fulfill the objective of the study, available data covers three time frames: before the disaster, immediately after the disaster and about two years after the event. The data comes from secondary sources. These include:

1. A mail based questionnaire, as part of the on-going project titled 'Understanding the Relationships between Household Decisions and Infrastructure Investment in Disaster Recovery: Cases from Superstorm Sandy' sent in August 2014. The survey provides the information from residents impacted in Hurricane Sandy who responded to the survey.

2. Different aerial images of the study area in four time periods collected in 2010, 2012, 2013 and 2014, and Google Earth satellite images in different time periods used to compare the spatial change over time after Hurricane Sandy.

3. FEMA damage data in tabular, report and spatial format in GIS provides the data on immediate damage, inundation and other information.

4. LiDAR point clouds capture the immediate Hurricane impact. These data are compared to visually interpret the extent of the damaged site.

Data are analyzed to distinguish the areas experiencing destruction during the Hurricane occurrence, and afterward how much of those areas, or how many properties have been repaired or rebuilt to measure trends in the recovery process over time. The analyses follow a step by step approach. First the FEMA damage data and the survey data are compared to interpret the present situation based on the status of the physical properties considering the repair of damaged properties. In parallel the aerial imagery from four time periods, 2010, 2012, 2013 and 2014, are compared to visually demark the areas with differential changes. In addition the LiDAR data identifies the location with changes in elevation that demarks the damage sites too. Later the data findings are compiled and compared to provide a clearer view of the damaged and redeveloped plots and determine the progress in the level of recovery for the study area.

4.1 Damage to Structures

4.1.1 Findings from FEMA-MOTF

In order to have a detailed idea of the damage after Hurricane Sandy and relevant information, publicly available data prepared by FEMA-MOTF (FEMA-Modeling Task Force) is used. This data was published in 2014. It is available in Web-GIS and downloadable GIS format in these web sites, respectively http://www.arcgis.com/home/webmap/viewer.html?webmap=307dd522499d4a44a33d7296a5da5ea0 and https://content.femadata.com/MOTF/Hurricane_Sandy/ (accessed on 3/26/2015).

The FEMA Modeling Task Force (MOTF), a group of modeling and risk analyst experts from FEMA Regions VIII (Denver) and IV (Atlanta), may be activated by the FEMA National Response Coordination Center (NRCC) for Level 1 events in support of disaster response operations. One of their responsibilities is to develop consensus for best estimates of impacts before, during, and after events coordinating data and hazard and modeling information from multiple variety of sources. During Hurricane Sandy, the MOTF deployed to the National Hurricane Center (NHC) to better and more expeditiously integrate NOAA-National Hurricane Center (NHC) modeling into MOTF situational awareness and impact assessment products.

The report (FEMA-MOTF, 2014) published by FEMA-MOTF in 2014 shows detail information on the damage during Hurricane Sandy. The data covers the latest Hurricane Sandy storm surge data (in feet); county wise impact assessment compiled from surge, wind, precipitation and snow impacts (very high, high, moderate, low); FEMA Individual Assistance (IA) Household Inspection to classify damage, and so on. For this research, only data related to Sea Bright is separated from the large data base and later compared with other data sources. According to FEMA-MOTF, surge is the primary reason of the severe impact in Hurricane Sandy and Sea Bright falls in the very high impact areas for Hurricane Sandy.

In FEMA-MOTF Hurricane Sandy Impact Analysis, the household damage has been classified in four categories based on the individual assessment. For example, FEMA inspectors estimate the amount of Personal Property (contents) Full Verified Loss (FVL), Real Property (home) FVL and a sum of both as Total FVL in field surveys initiated by a household's application for assistance. Applicant household's damage classifications is as follows:

1. Affected – Total Full Verified Loss (FVL) greater than \$0 to \$5,000
2. Minor – Total Full Verified Loss (FVL) \$5,000 to \$17,000

3. Major – Total Full Verified Loss (FVL) more than $17,000

4. Destroyed – If indicated by IA inspector

To determine the number of impacted residential building more accurately, FEMA-MOTF identified households in the same exact location as multi-family residential buildings and applied the maximum household damage classification for the entire building. Other criterion included in damage estimates are visible damage from aerial imagery and inundation based damage assessment that provides more comprehensive estimates besides considering households that applied for FEMA Assistance. The detailed criteria followed by FEMA-MOTF to classify property damage are shown in Appendix D.

The damage scenario for Sea Bright is summarized in Table 4.1 after extracting the data base from the large data of Hurricane Sandy impacted areas as reported by FEMA-MOTF. Some major types of information provided in the data include the following:

- DAMAGE: Damage level estimated based on visible aerial imagery
- INUNDATED: Presence or absence of inundation based on visible aerial imagery
- DAMAGETYPE: Indicates if damage was determined based on visible imagery or observed inundation or both.
- DMG_COMBO: Damage level based on the combination of visible imagery and water depth estimated at each structure point based on the FEMA-MOTF observed inundation products.
- DEPTH: The depth in feet of inundation at each structure point relative to the ground surface.

For further analysis and comparison, the data in type 'DMG_COMBO' are used as this data identifies damage based on both visible aerial imagery and inundation of each structures.

Table 4.1: Building damage information following the classification by FEMA-MOTF in Sea Bright, New Jersey.

Criteria of classification	Number of buildings with damage						
	Affected	Minor	Major	Destroyed	No Damage	No data	Total
Based on visible damage in aerial imagery only [DAMAGE]	46	40	11	18	625	19	759
Combination of visible damage in imagery, water depth and FEMA-MOTF observation [DMG_COMBO]	108 (14.23%)	252 (33.2%)	381 (50.2%)	18 (2.37%)	-	-	759 (100%)

Based on aerial imagery, only completely destroyed plots (18 plots) are clearly identifiable. Other damage to buildings are not easily recognizable to find their actual number. Here it is seen that the numbers increase a lot when the inundation and other observations are considered in the case of buildings affected and with major and minor damage. The data in Table 4.1 shows that 759 structures in Sea Bright experienced damage in Hurricane Sandy. Among the total damaged, 50% had major damage in Hurricane Sandy where 33.2% had minor damage, 14.23% were affected and only 2.37% fully destroyed structures.

The location of damage sites including affected, minor, major damage and destroyed plots are shown in Figure 4.1. The maps show that the damage is distributed all over the borough and the whole area has gone through a somewhat similar damage experience in Hurricane Sandy. The map shows the south part had experienced more damage regarding major, minor and destroyed structures than the north part where there are no destroyed buildings but rather the damage is not negligible because there are many major and minor damaged structures.

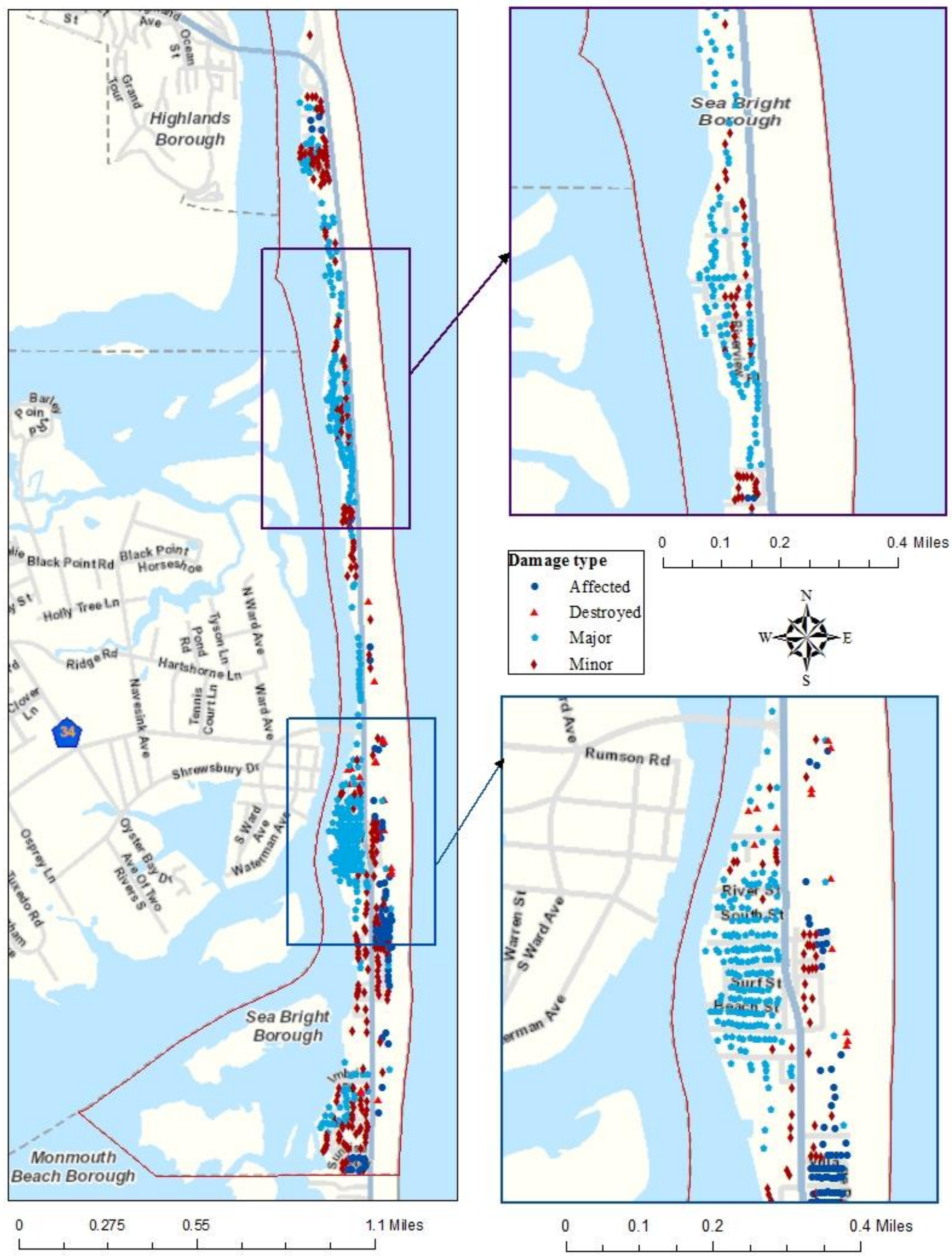

Figure 4.1: Spatial distribution of damaged structures by category based on FEMA-MOTF data.

The property inundation status with or without damage from FEMA-MOTF data is shown in Table 4.2. When the visible damage and observed inundation damage are combined [DAMAGETYPE], the information in Table 4.2 is found for all damaged points recorded by FEMA-MOTF.

Table 4.2: FEMA-MOTF data on inundation and damage of the plots.

Type	Number of structures				
	Damage & inundation	Inundation only	Damage only	No Data	Total
Affected	2	102	0	4	108
Minor	43	174	2	33	252
Major	46	269	4	62	381
Destroyed	18	0	0	0	18
Total	109 (14.36%)	545 (71.8%)	6 (0.8%)	99 (13.04%)	759 (100%)

From Table 4.3, it is apparent that for 71.8% of impacted structures the damage was due to inundation only, where other damage component and inundation covered 14.36% of the overall damaged structures. In the case of destroyed buildings, all of them had gone through inundation and massive damage to be destroyed in the Hurricane. For comparison only 0.8% of the damaged area in the borough faced damage without inundation.

The water depth in inundated structures after Hurricane Sandy is shown in Figure 4.2. Part of the map is zoomed out to make the damage more visible and show that inundated locations with high water height experienced more damage. The water height recorded in FEMA-MOTF ranges from approximately 0.04 feet to 12 feet. According to USGS survey data on high water marks in five location in Sea Bright, the water level was 4 to 5.1 feet high aboveground level (FEMA-MOTF, 2014). The data points are also shown in Figure 4.2.

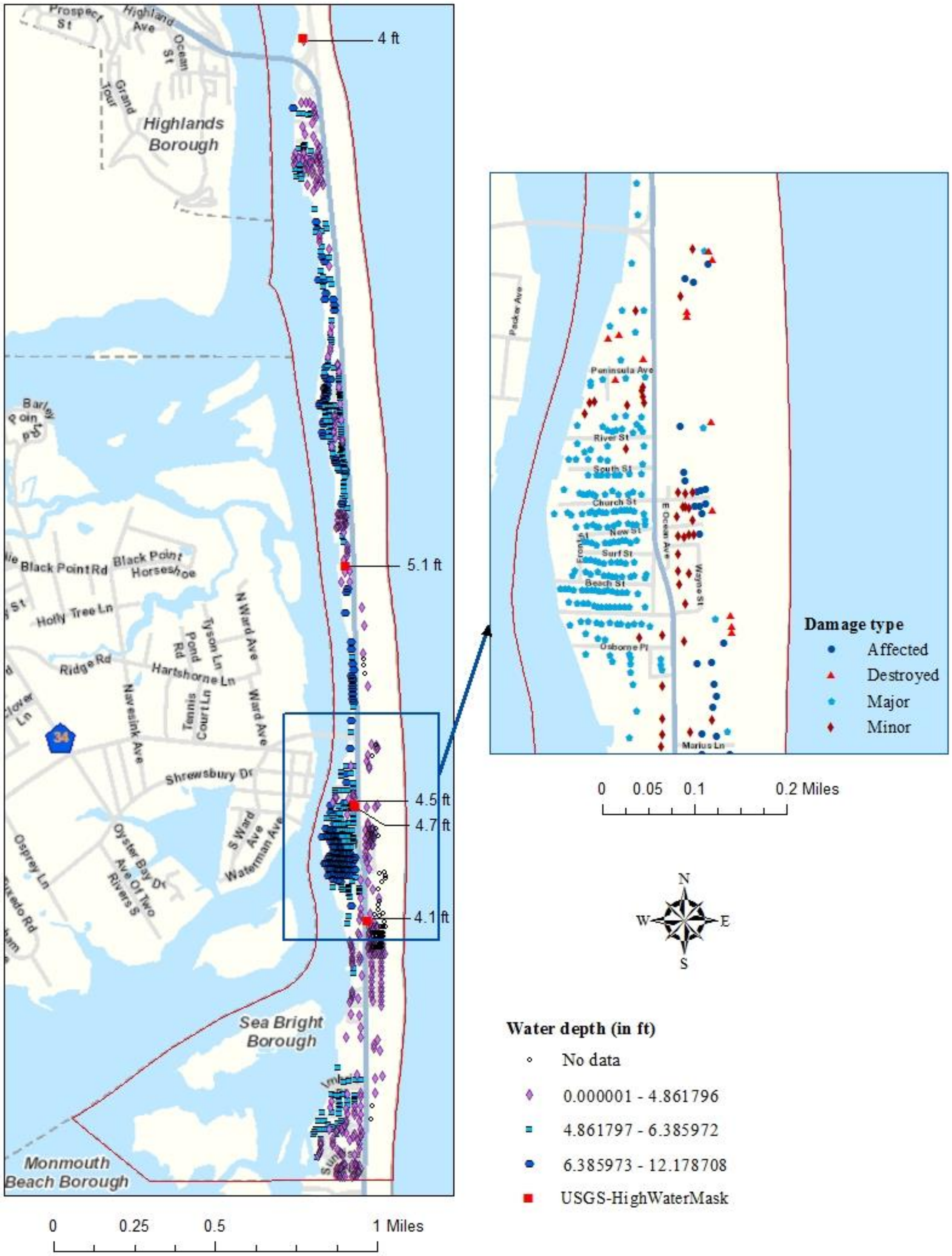

Figure 4.2: Image showing water depth in damaged structures with USGS high water mark data and inset view of damage in one part of Sea Bright.

4.1.2 Damage report from Questionnaire

The responses from the questionnaire survey have been geocoded to locate the position of the property within the study area. Knowing the location helps in analyzing data and comparison with other information from same or different sources. Accordingly 180 responses among 303 were found to be within the study area, the remaining 123 addresses were found to be outside Sea Bright because their property in the study area is used mostly as second home or they choose to use this address for postal purposes. After having the spatially georeferenced position of the survey responses, the FEMA-MOTF data on damages and inundation was merged with the survey information following a georeferenced map and matching corresponding locations spatially. The data findings after analysis are discussed in the following sections.

In the questionnaire, the respondents were requested to categorize the damage to their home as no damage, not very extensive damage, somewhat extensive damage and very extensive damage. Table 4.3 shows the result of their responses.

Table 4.3: Damage to home from survey responses and FEMA-MOTF data on respective location.

Damage Level	All Response from the survey		Response addresses located only in Sea Bright		Damage Level	FEMA-MOTF data corresponding the response in Sea Bright	
	n	%	N	%		n	%
No Damage	20	6.69	7	3.94	Affected	22	12.22
Not Very Extensive	73	24.42	46	25.84	Minor	86	47.78
Somewhat Extensive	113	37.79	68	38.20	Major	69	38.33
Very Extensive	93	31.10	57	32.02	Destroyed	3	1.67
Total	299	100	178	100	Total	180	100
Missing	4		2				

The survey shows 93 to 96% (considering 180 and 303 responses) of the Sea Bright borough experienced damage to some level from not very extensive to very extensive damage. From response of 303 households, it is found that 68.89% of the total area have gone through extensive damage (includes both somewhat and very extensive damage) while considering identified response within the study area (i.e. of 180 responses) it is 70.22%. However, comparing the damage condition to the FEMA-MOTF, data shows 87.78% of the damaged area had experienced minor to complete destruction. Figure 4.3 shows spatially the result from survey responses and FEMA data with respect to damage condition perceived by the households and as assessed by FEMA. Given different qualitative assessment of damage it is difficult to make a direct comparison of the survey data and the FEMA data.

Based on the damage estimates in survey responses, kernel density analysis is done in ArcGIS to create a continuous surface surrounding damage concentration. Here damage cost in dollars are the count or quantity to be spread across the landscape. Kernel calculates a magnitude per unit area using a kernel function to fit a smoothly tapered surface to each point or polyline. Figure 4.4 shows the result of such analysis. The analysis considered the 180 responses located in the study area, so the outcome is not very representative. The map highlights the area with more damage concentration based on people's perception. From this map it is clear that the south part of Sea Bright has more damage estimates than north part.

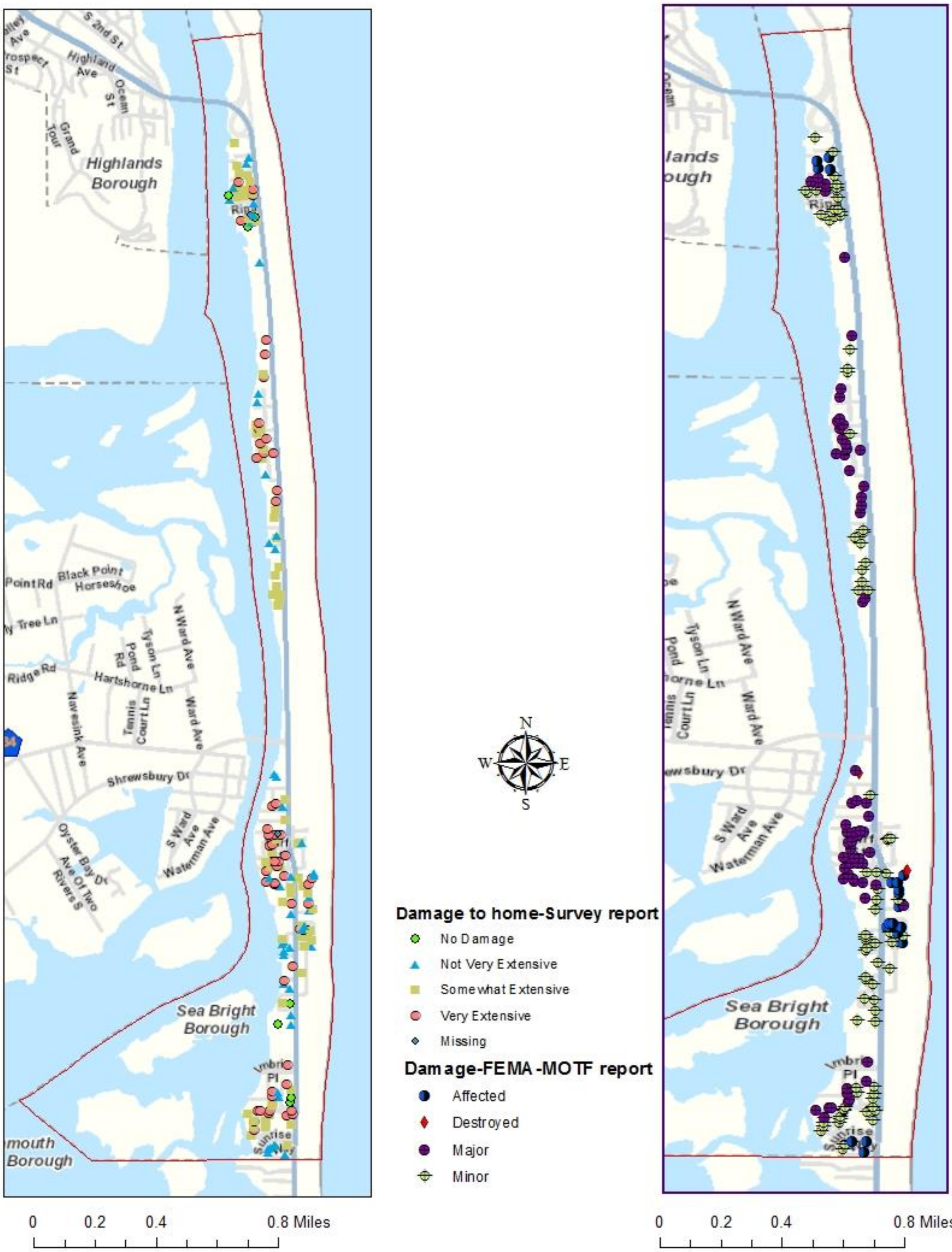

Figure 4.3: Damage condition recorded from questionnaire and FEMA-MOTF data.

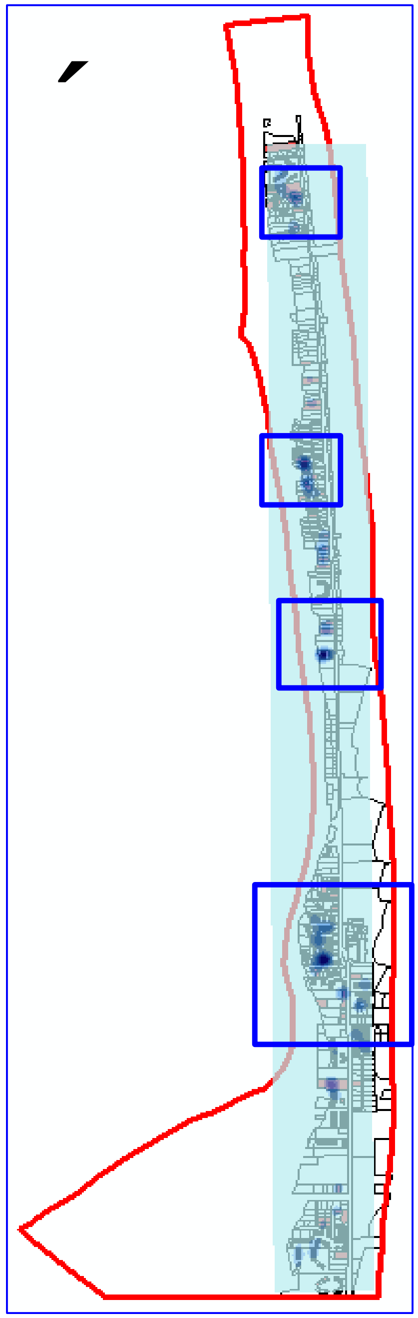

Figure 4.4: Findings from Kernel density analysis showing distribution of estimated damage from survey.

4.1.3 Scaling damage to the study area

To explore the range and variability in the data on damage, the damage categories are scaled to create a picture of on an 'average' scenario for the whole study area. The values were chosen arbitrarily but based on the severity of the damage such as 'only affected' has a value of 1, 'minor' and 'major' damage have values of 2 and 3 respectively, where 'destroyed' is assigned the largest value 4. For each category of damage, the product of the number in that damage type with their value divided by the number of total damaged properties represents the impact of damage. These resulting values are then summed to find the average damage value for the study area.

The weighted value with the number of structures under specific damage criteria are listed in Table 4.4 in order to compute the weighted damage in each level and finally their weights are added to quantify the damage level of the overall community of Sea Bright. Damage data from FEMA-MOTF for the entire locality and for location of the survey responses within Sea Bright are shown in parallel in this table and the grand total of weighted damage values in both case have found to be very close i.e. 0.241 and 0.229 respectively.

Table 4.4: Quantifying damaged property to estimate the damage level of the study area using FEMA data for whole area and survey responded location within study area.

Damage Type	No of Damaged Property		Scale	Impact of damage = (No of Property with specific damage x Weight) / Total damaged property	
	Survey location	Entire borough		Survey location	Entire borough
Affected	22	108	1	0.12	0.14
Minor	86	252	2	0.07	0.66
Major	69	381	3	1.15	1.51
Destroyed	3	18	4	0.96	0.09
Total	180	759		2.29	2.41

Next in Table 4.5 the weighted result considering the 279 responses (excluding no damage and missing data) from the questionnaire are summarized to determine the total weighted damage of the locality Sea Bright with the specific damage classification reported by the respondents. Here the weight of the damage have been readjusted as ‘not very extensive’ damage is weighted as 1, ‘somewhat extensive’ damage weights to 2.5 and ‘very extensive’ damage is given a weight of 4. The specific weighted value considering number of structures in each damage type is computed following the same computation rule in previous table. In this case the resulted average weighted value for the entire community has found to be 2.6.

Table 4.5: Quantifying damaged property to estimate the damage level of the study area using the total survey responses.

Damage Type	No of Damaged Property	Scale	Impact on properties
No Damage	20	0	0
Not Very Extensive	73	1	0.26
Somewhat Extensive	113	2.5	1.01
Very Extensive	93	4	1.33
Total	279 (excluding no damage)		2.6

The average value found from FEMA damage data for whole study area and for survey responses within study area along with damage data from overall survey are shown schematically in Figure 4.5. From this diagram it is obvious that on an average the whole community has gone through minor to major damage that represent significant importance for selecting Sea Bright as study area for assessing recovery over time.

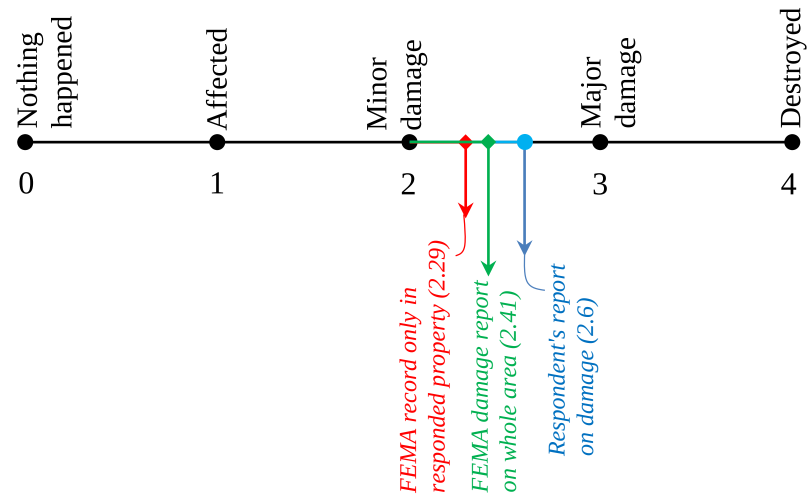

Figure 4.5: Schematic diagram showing the average damage from different data sources.

4.1.4 Visual interpretation from Aerial imagery

Open source, aerial images of the study area were found for four time frames: 1) before Hurricane Sandy image in 2010; 2) in 2012 the year Hurricane Sandy occurred; and 3) after Sandy impact in 2013 and 2014. The images of 4th July, 2010 and 30th July, 2013 are collected from publicly available National Agriculture Imagery Program (NAIP) imagery, downloaded from http://earthexplorer.usgs.gov/. The NAIP provides ortho imagery with 1-meter ground sample distance (GSD) and horizontal accuracy of +/- 6 meters to true ground.

The aerial image of 2012 has downloaded from the NOAA ‘Hurricane Sandy: Rapid Response Imagery of the Surrounding Regions’ data base (http://storms.ngs.noaa.gov/storms/sandy/). The airborne digital imagery were acquired by the NOAA Remote Sensing Division from a nominal altitude of 7,500 feet, using a Trimble Digital Sensor System (DSS) with approximate ground sample distance (GSD) of 35 cm (1.14 feet) in each pixel (http://ngs.woc.noaa.gov/storms/sandy/docs/sandy_metadata.htm). The images covering Sea Bright were captured on November 01, 2012 in Flight 1 (http://storms.ngs.noaa.gov/storms/sandy/).

The study area image for 2014 is clipped from the large data set of Ortho-rectified mosaic tiles in raster format that was created at 0.35m ground sample distance (GSD) for each pixel by the NOAA's Coastal Mapping Program (CMP) for the NOAA Integrated Ocean and Coastal Mapping (IOCM) initiative in Hurricane Sandy coastal impacted areas. The high resolution original images were acquired with Intergraph/Leica DMC Sensor Systems from January 01 to April 21, 2014. (http://coast.noaa.gov/dataviewer/ accessed on 5-10-2015).

These images are visually inspected to detect change and identify the locations with differential land use including man-made and natural features through overlaying them one above another in ArcGIS software and by swiping the target image over the base imagery, and thus the changes are identified. Figure 4.6 shows the full view of the study area with building locations and natural dunes where it differed from previous year. It also represents large view of a small part in those years to clarify the situation in the field.

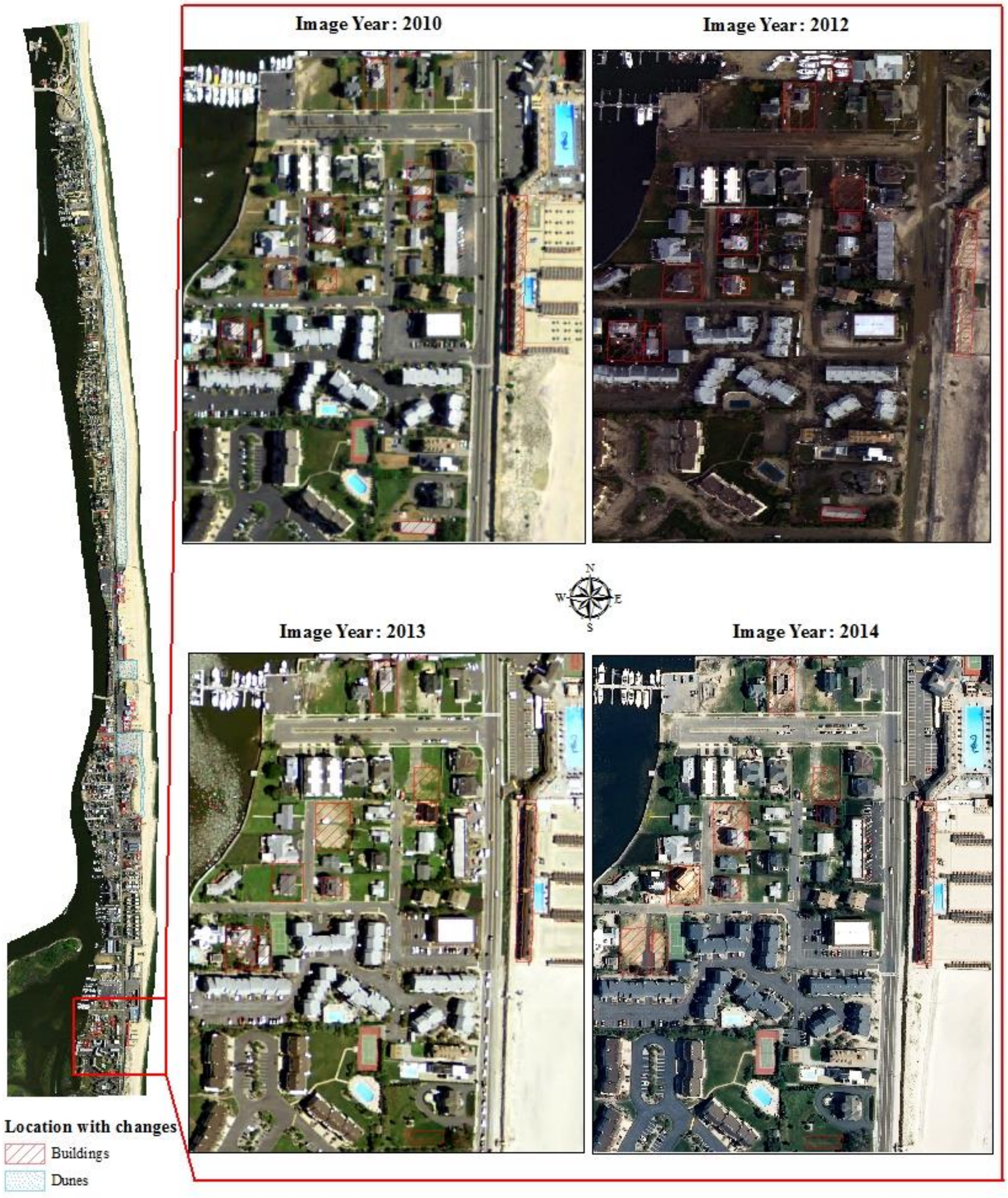

Figure 4.6: Visually identifiable change in structural (buildings) and natural (dunes) features over time after Hurricane Sandy impact in 2012.

From imagery the change in natural features like continuation of sandy dunes could be identified clearly. However, in the case of buildings, the difference could only be detected if the property was fully destroyed or demolished for rebuilding and after the space has been occupied again in the observed time interval. In the case of the sandy dunes that protect Sea Bright naturally, it is found that in Hurricane Sandy the dunes had been damaged in several places, which had not been repaired until 2014. Figure 4.7 shows a snap shot of this situation.

Chronologically, comparing the building structures from site images, it is found that 48 points had some change. Among them, in Hurricane Sandy, 18 locations were destroyed fully, 18 had major damage, 9 had minor damage and 3 buildings were affected in that disaster. Up to 2013 there was little activity on the destroyed properties with only four properties rebuilt. This number increased to seven in 2014, and the rest were still vacant plots. In 2013 eight major damaged plots were found vacant where building structures existed earlier. This number increased to 16 with two of those previous vacant location had houses reconstructed in 2014. The minor damaged sites also experienced demolition, for example, in year 2014, seven of these locations were found to be unoccupied. Affected buildings are not an exception of this scenario where three such plots were bare land in 2014. The damage sites going through reconstruction, and demolition with their damage condition in Hurricane Sandy are shown in Figure 4.8. From this figure it can be concluded through visual observation that the south part of Sea Bright area is still going through the recovery process in 2014 considering the number of unoccupied plots and change in use patterns from previous.

Figure 4.7: Condition of natural features (dunes) after Hurricane Sandy over years.

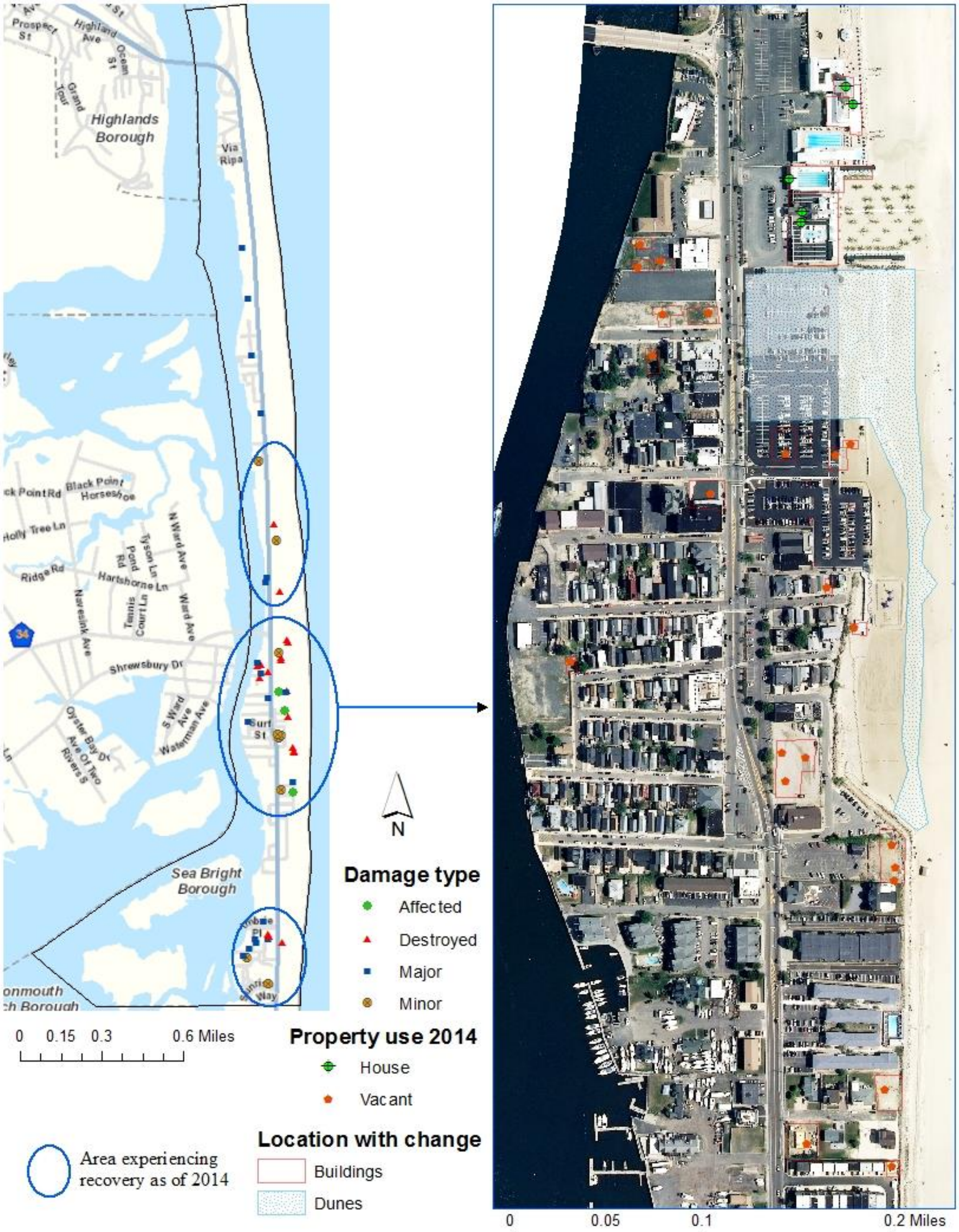

Figure 4.8: Location of 48 damage points that showed change in different time till 2014 after Hurricane Sandy, concentration identifies the area experiencing housing recovery.

4.1.5 LiDAR data findings

LiDAR data provides more detail and accurate data for any region. The U.S. Geological Survey (USGS) produced LiDAR point cloud data from remotely sensed, geographically referenced elevation measurements. They used second-generation Experimental Advanced Airborne Research Lidar (EAARL-B), a pulsed laser, in an aircraft to measure ground elevation, vegetation canopy, and coastal topography of the target area. The approximate travel speed and flight height was 55 meters per second and 300 meters respectively that resulted laser swath of approximately 240 meters with an average point spacing of 0.5 to 1.6 meters. Data acquisition dates were October 26, 2012 prior to Hurricane Sandy and on November 1, 2012 and November 5, 2012 just after landfall in New Jersey and the data published in 3 June, 2014. They initiated this project to produce accurate and highly detailed digital elevation maps serving the needs of researchers. (http://coast.noaa.gov/dataviewer/webfiles/metadata/2012_usgs_pre_sandy_nj_eaarlb_m3658_template.html; coast.noaa.gov/dataviewer/webfiles/metadata/2012_usgs_post_sandy_nj_eaarlb_m3657_template.html). The relevant data in geospatial data format (las for LiDAR multiple return points) is downloaded from free source of the NOAA Coast data (link: http://coast.noaa.gov/dataviewer/#) with UTM projection Zone 18N, horizontal datum 'NAD 1983' and vertical datum 'NAVD 1988' in unit meter. From the large data set only the information confining the geographic boundary of the study area has been segregated/separated for further analysis. In this subset of LiDAR data the point spacing in the pre-sandy LiDAR data is 1.948 meter, number of points are 1,071,985 having a minimum elevation of -1.099 meter (Z min) and maximum elevation of 22.92 meter (Z max) where average elevation is 2.595 m and standard deviation 2.881 m. In post-sandy the number of points are 1,415,180 having point spacing of 1.711 meter with Z min -0.818 meter and Z max 24.85 meter where elevation average is 2.246 m and standard deviation 2.792 m. In general comparison the difference in maximum elevation increased approximately by 1.93 meter and the minimum elevation difference is reduced by 0.281 meter from pre to post sandy elevation change representing debris accumulation or loss of land over the study area.

The Quick Terrain Modeler (QTM) software is used to produce 2 meter resolution digital surface model (DSM) based on point spacing in pre and post scenario. Here two meter is chosen to have a good result as it is more than point spacing in both data sets, and all points are covered in surface creation. The surface models created from pre and post sandy elevation are used to find out the location with differential change in elevation identifying loss or gain in elevation as an indicator of damage or debris accumulation in the area. To determine this change the analysis tool 'change detection map' in QTM software is used to create a continuous surface showing elevation difference. These maps are useful in visually identifying the areas with gain or loss in elevation due to impact of Hurricane Sandy. This type of LiDAR data analysis is effective in damage estimation of an area considering its physical properties. Figure 4.9 and Figure 4.10 respectively shows the visual interpretation from LiDAR data analysis of change detection in pre and post Hurricane Sandy in natural dunes and building structures.

Digital Surface Models in 2-meter

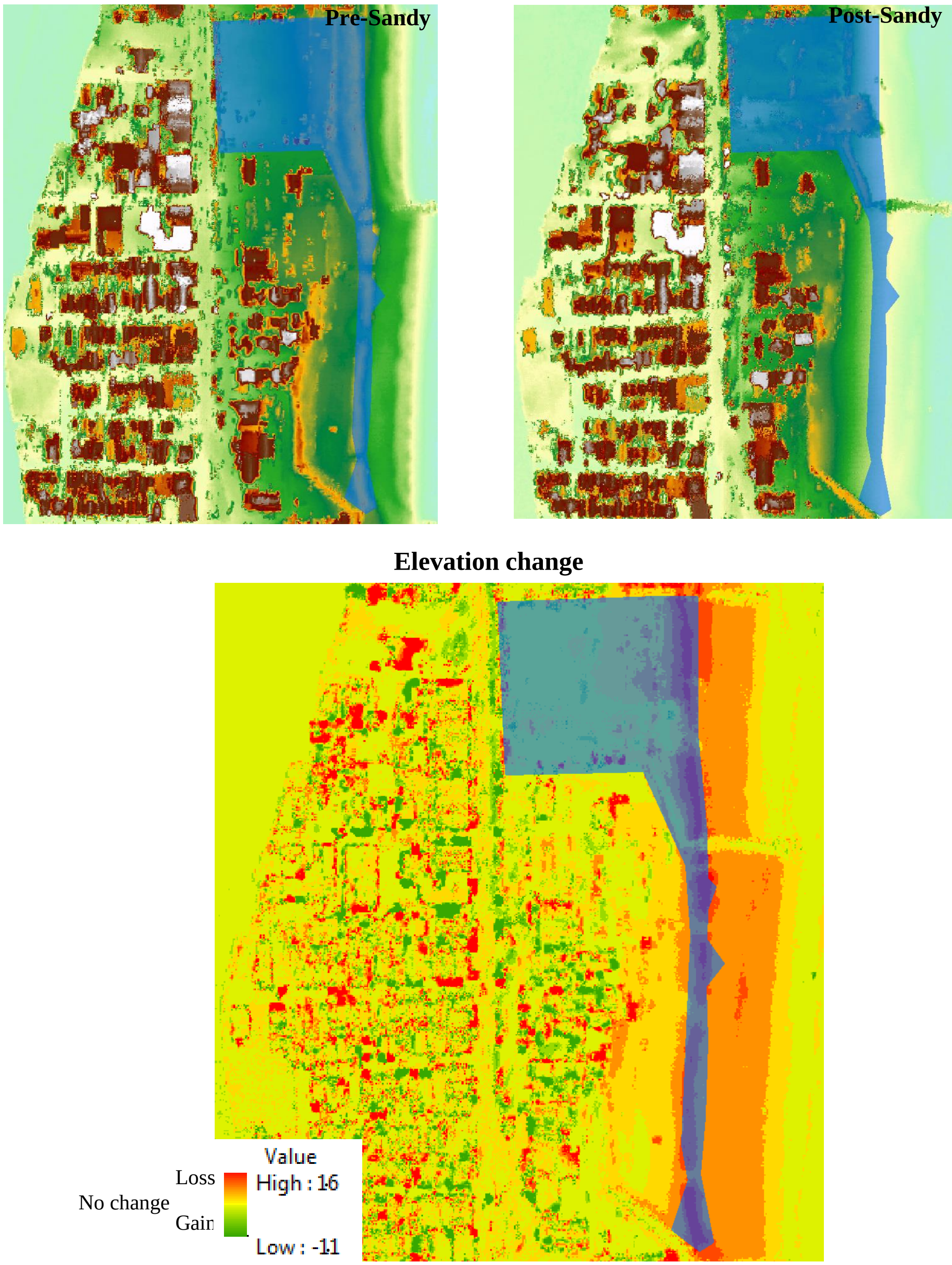

Figure 4.9: Change detection in dunes pre and post Sandy using LiDAR data.

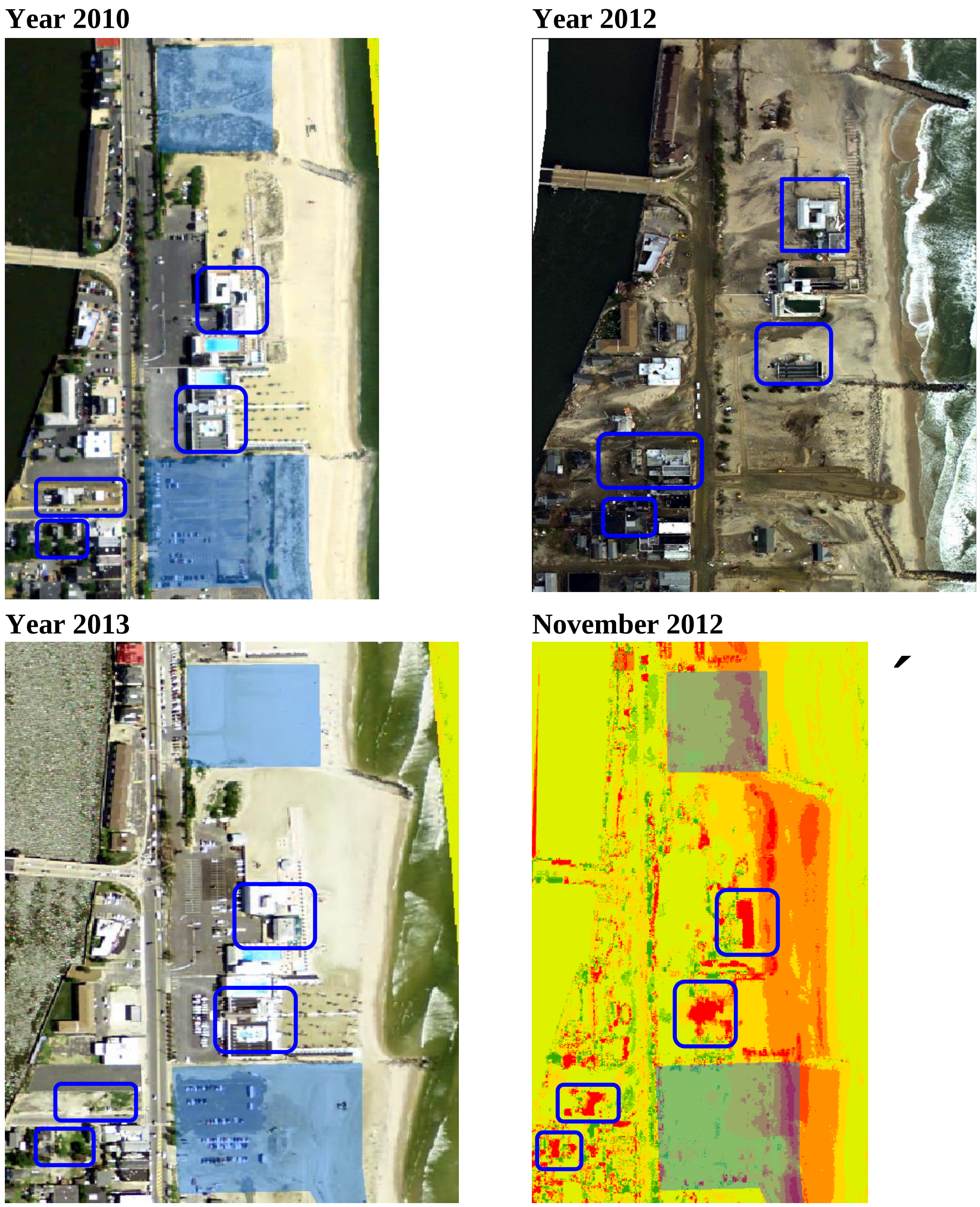

Figure 4.10: Change detection in building structures in pre and post Hurricane Sandy using LiDAR data.

4.2 Recovery Process

The recovery progress considers the changes in the number of damaged household properties. The main source of information to delineate progress is survey response on 'status of repair completed or not'. If the repair has been completed, it has been counted as complete recovery with respect to structural damage. The change in the status of destroyed properties in Hurricane Sandy could be studied for different time interval through visually noting the land use in those location from satellite images in Google Earth. The satellite images are available through April 2014. Also the properties with major or minor damage or affected in Hurricane Sandy that have been rebuilt after being demolished or are found to be demolished prior rebuilding can be identified by observing the images in different times.

4.2.1 Property status comparing survey data and FEMA damage data

The repair status of the buildings in the survey as of August, 2014 compared to the initial damage reported by FEMA is shown in Table 4.6.

Table 4.6: FEMA damage data (DMG_COMBO) with property status in August, 2014.

FEMA damage record	Number of buildings damaged	From Survey result			
		Repair complete	%	Repair not complete	%
Affected	22	15	68%	7	32%
Minor	86	62	72%	24	28%
Major	69	34	49%	35	51%
Destroyed	3	1	33%	2	67%
Total	180	112	62%	68	38%

In the study area, based on responses from addresses located within Sea Bright, 62% of the total damaged area has recovered considering repair of the building, and

38% of the area are in the process of recovery. Among the affected properties, 68% have reported ‘repair complete’, still 32% are in the process of recovery. Significant improvement has found in minor damaged properties where 72% have repair completed. The major damaged sites along with the destroyed plots are experiencing slow recovery. As of August, 2014, data shows 51% of major damaged sites with 67% of the destroyed structures are still in the process of repair, two years after Hurricane Sandy.

According to the damage category reported in the survey, the recovery progress is shown in Table 4.7. To compare the recovery progress in damage sites, the sites with ‘no damage’ recorded (20 responses) was excluded from the count.

Table 4.7: Damage to home as reported from survey of residents.

Extensive damage to home	Repair complete		Repair not complete		Total damage	
	n	%	n	%	n	%
Not Very Extensive	44	60.27	29	39.73	73	100
Somewhat Extensive	90	79.65	23	20.35	113	100
Very Extensive	52	56	41	44	93	100
Missing status	2	50	2	50	4	100
Total	188	66.43	95	33.57	283	100

In the damaged area 66.43% have completed repair as shown in Table 4.6, while from FEMA damage category and response of household survey shows 68% area under ‘repair complete’ and considered full recovered. The values are close enough to suggest consistency in the results found in different ways. Significant progress in recovery with respect to repair completion happened in ‘somewhat extensive damage’ part as reported in response from the survey i.e. 79.65% of that damaged area. In comparison 44% of very extensive damage part are in process of recovery as reported in summer 2014 survey.

Figure 4.11 shows the distribution of survey result on ‘repair completion’ with location where repair is still needed. From the map it is apparent that there is no patterns in the progress of recovery based on location. Recovery has a mixed pattern throughout the borough. So it cannot be said definitely which part had fully recovered or had more recovery. In one block if some damaged properties have completed repair, others are waiting for repairing the damage.

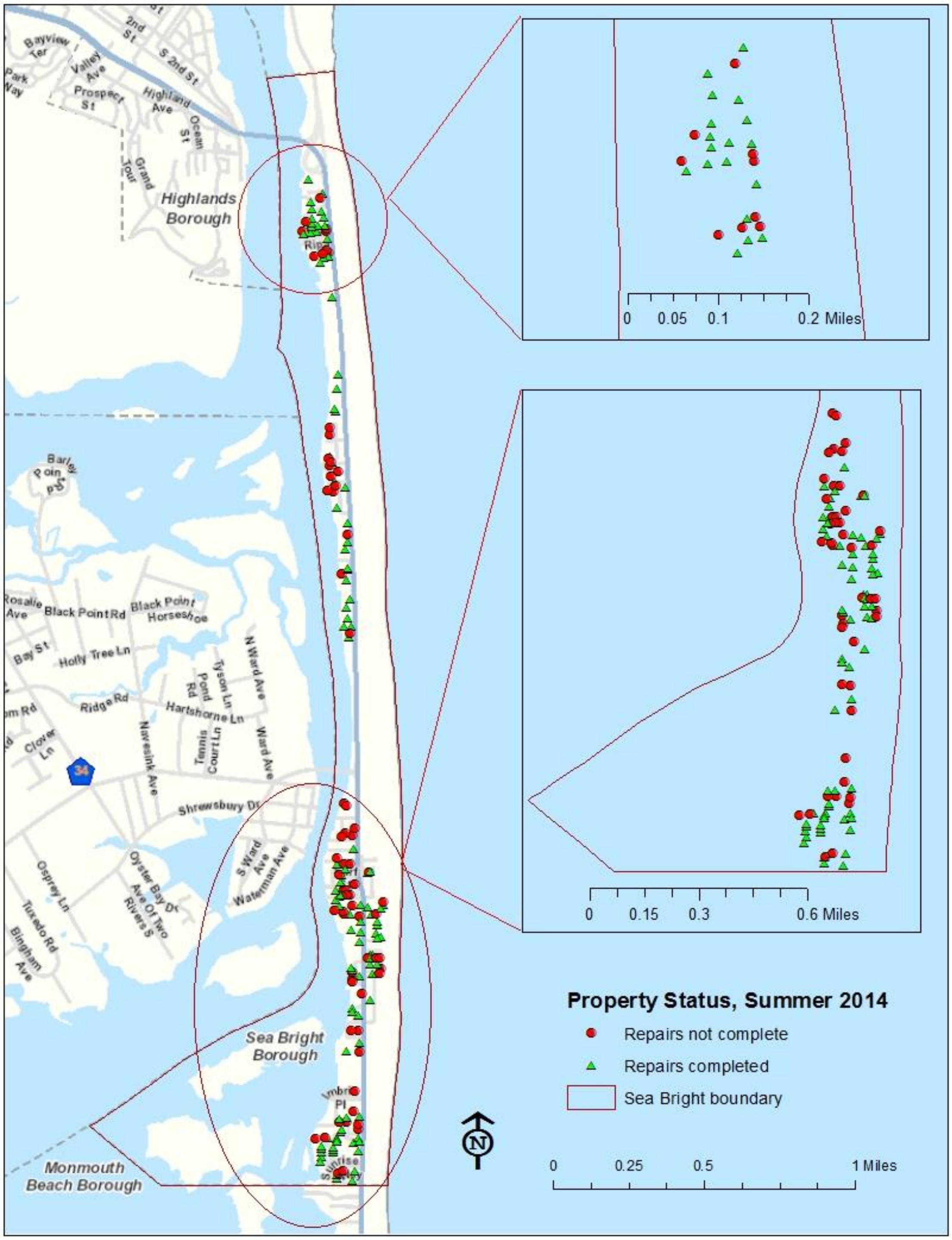

Figure 4.11: Recovery level of the study area based on repair status of the damaged buildings.

From the survey it is found that three of the major damaged (FEMA-record) properties are still abandoned where two experienced inundation. These properties are owner occupied single family houses, all have flood insurance, and as of August, 2014 they have not repaired yet. One of them will be rebuilt and is scheduled for repair. None of them was or will be demolished though the properties are not in good condition and faced very extensive damage as reported in the survey. Although this does not provide a quantitative assessment of recovery, a review of the responses provide some insight into the challenges in recovery, such as the statement of a property owner who was ‘not sure’ of the property status stated:

> We moved 4 times in 5 months. Spent the 1st week after the storm in same 2 sets of clothing. Overpaid for a rental large enough for a family, when we finally found a rental. The insurance process wasn't difficult, just depressing. We had a structural engineer report to the insurance company that we had major structural damage under our home, only to have them deny that part of the claim. They said my policy didn't cover the damage caused by "moisture". It was a flood, not moisture! We then hired a public adjuster who wrote a massive report on his findings. He said we are covered for the damage we had and escalated the findings up to FEMA. They also denied it. It was $26k worth of damage. Our last resort was to hire a lawyer who would take 40% of that money. We called a lawyer, but haven't done much else with it. So now we are working on RREM grant. We were told not to start the project or we could be disqualified for the grant. Bottom line - its been a mess from day one. All of it. I'm tired. My family living in a rental, our home sits rotting. The start of our project is no where in sight. I can't take another form to fill out or denial or having to prove we were victims of this storm. We run out of rental assistance Sept 1st and I am scared. We can't afford our rental, plus our home mortgage, taxes, insurances, and bills.

4.2.2 Recovery of destroyed property assessed from aerial and satellite imagery

The recovery of destroyed properties could be verified by visual inspection of sequential images in google earth. The georeferenced location of destroyed plots have been imported in google earth and their status was checked in available time series after Hurricane hit in October, 2012 until April, 2014. Figure 4.12 shows a time series of snap shots of a destroyed part of Sea Bright. In the upper left is the Shrewsbury river bridge that provides a landmark. The corresponding location is seen in each image. The images can be used to find the location with or without development to assess the recovery process of these type of damaged properties.

Comparing the recovery among the damaged properties it has been found that the destroyed properties are experiencing slow recovery; although this observation is based on a small sample only one destroyed plot out of three reported in the survey had completed repair. While from the satellite images from Google Earth in different time periods, it has seen that up to April 24, 2014, seven plots out of 18 destroyed plots are in use (i.e. 38.89%), the remaining are vacant with no use. Figure 4.13 shows the trend line with percentage of recovery progress over total destroyed structures considering the use of the land and also the bar shows the number of plots vacant after being destroyed in Hurricane Sandy.

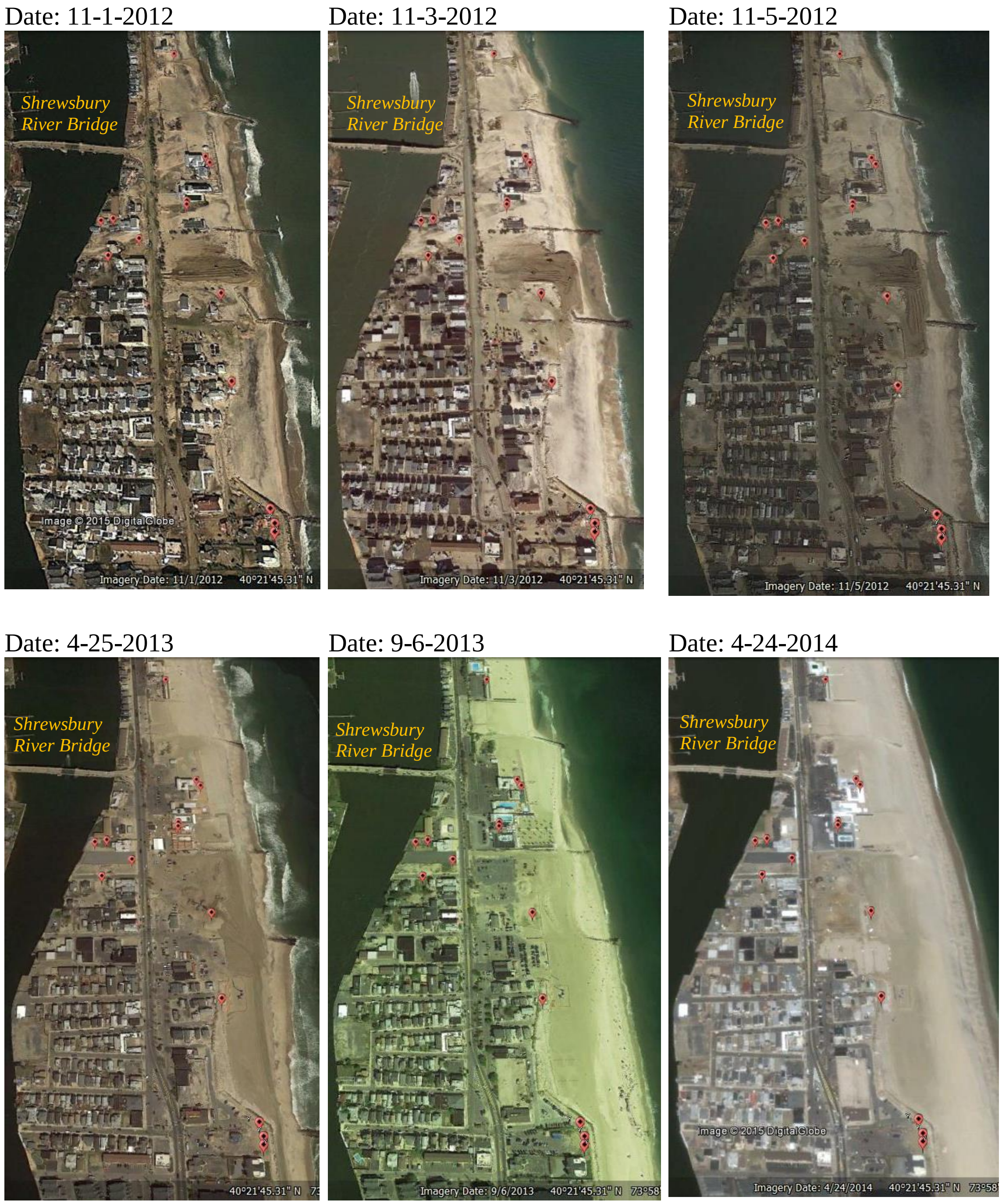

Figure 4.12: Google Earth images in several time to visually detect land use changes in destroyed plots.

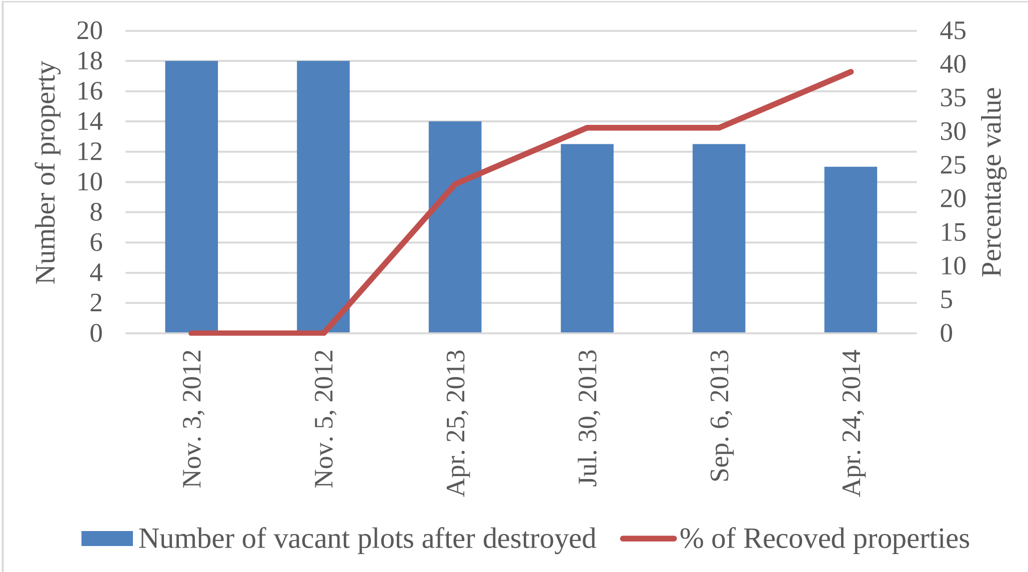

Figure 4.13: Recovery progress (%) of the destroyed property with their status (vacant) in different time period in Sea Bright after Hurricane Sandy.

4.2.3 Scaling recovery in the study area

The completion of the property repairs is given the same values as in Section 4.1.3 to assess the average recovery for the entire community. In this case the number of responses who have not completed repair has been quantified and the number is multiplied with the value of the specific damage category and then divided by the total number of damage structures to find out the impact in each damage group. All of the values are summed to give the average damage value for the whole study area. Table 4.8 shows the result from FEMA damage category of the responses located within Sea Bright and the cumulative value for the area is 0.93, so it is very close to 'affected'.

Table 4.8: Quantifying repair of the damaged property to estimate the recovery level of the study area.

FEMA damage record	No of Damaged property	Repair not complete	Scale	Value of properties =(No of Property still need repair with specific damage x Weight) / Total damaged property
Affected	22	7	1	0.04
Minor	86	24	2	0.27
Major	69	35	3	0.58
Destroyed	3	2	4	0.04
Total	180	68		0.93

The value according to the damage category specified by the residents who responded in the questionnaire is shown in Table 4.9. Here also the result shows very close proximity to 'not very extensive damage' of the entire community.

Table 4.9: Value recovery considering the repairing and damage recorded in questionnaire.

Extensive damage to home	No of Damaged property	Repair not complete	Scale	Impact
Not very Extensive	73	29	1	0.104
Somewhat Extensive	113	23	2.5	0.206
Very Extensive	93	41	4	0.588
Total	279	109		0.898

The figure 4.14 shows schematically the position of the weighted recovery level considering FEMA damage category and survey responses classification of damage. The responses related to repair completed or repair not completed has been weighted to find out the status of the area as a whole. It is seen from the weighted result in figure 4.7 that whole area is very close to 'affected'. It is assumed that when the value reaches '0' it can be said that the recovery is done for the moment considering the structural damage in the area.

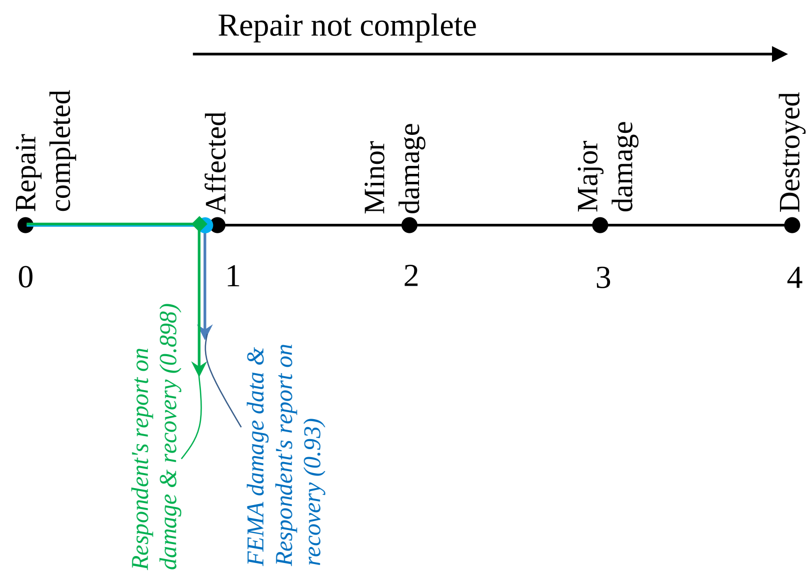

Figure 4.14: Schematic diagram showing the weighted recovery from different data sources

4.3 Discussion

This section summarizes the major findings from analysis presented in the above subsections. From data analysis it is found that the results are almost identical whether only 180 responses with postal address within Sea Bright are considered or all of the responses related to Hurricane Sandy are counted. Also the FEMA-MOTF data are consistent with the results found from survey data. The findings show the entire locality of Sea Bright has gone through minor to major damage as seen from average damage score based on a scale for specific damage categories. However considering the weighted value of recovery, the present condition of the area in 2014 is found to be in 'affected' level based on FEMA damage data and survey responses on repair. While comparing this value with respondent's damage category, the recovery of the study area is in 'not very extensive' damage level. One more step will move the community to full recovery considering the structural damage and repair completion. The survey data gives good results but the response size is small. It would have been better if more responses were obtained.

In contrast, the visual interpretation of satellite and airborne imagery shows very slow recovery progress in the completely destroyed plots. Only 39% of the destroyed sites have recovered regarding redevelopment of the property up to April, 2014. Therefore, the more severe the damage, the more challenging is the recovery. Again many of the major damaged plots and some of minor damaged and affected plots show as rebuilt starting approximately from mid-year of 2013 and such scenario is increasing significantly as identified by visual inspection of images. This indicates that the recovery process is going on and the recovery level of a community can be changed depending on the future condition of the area. The south part shows more damage as found using kernel density analysis of damage cost and also shows slower recovery than the north part of Sea Bright as found through analyzing data till 2014. So it is important to capture the time line in estimating the recovery level.

It is tough to handle a number of different types of data with several dimensions. The study struggled a lot in data management and processing before running analysis. LiDAR data needs intense processing before use. For the time being only the surface model is created using LiDAR data to identify damage in loss or gain through change detection in elevation.

Finally it is learned from this research that assessing recovery is a difficult task to do considering the different kinds of data with different measurement units, such as households versus structures.

Chapter 5

CONCLUSIONS

This chapter provides conclusions from this research as well the contributions and limitations of this work with proposals for future research. It starts by presenting the contributions of the thesis in section 5.1, then section 5.2 summarizes the limitations of the study and section 5.3 discusses the opportunities for future research.

5.1 Contributions

There has been limited research and literature that defines the term recovery in a concrete way. The term itself embraces many dimensions including the physical, social, economic, natural, cultural aspects of the impacted region along with the psychological recovery of the affected people. Targeted research can be done on each aspect of recovery, but even detailed study can cover a small part within the major sectors. This research contributes to the field of disaster recovery by considering the patters of damage and recovery of physical properties in a disaster affected area.

The research presents a data driven conceptual framework for assessment of post disaster damage and housing recovery and shows an example of how damage and recovery can be measured within a specific geographic boundary. Several dynamic data sets, ranging from a mail based survey of residents to geospatial information, are used to fulfill the objective of assessing long term housing recovery over time. Combinations of data from different sources results in a more comprehensive assessment of damages and recovery over time.

Recovery progress can be tracked over time starting just after the disaster impacts an area. The study develops a standard methodology, or standard format, to be followed in tracking the progress of housing recovery. Time series analysis of an area incorporating several types of information from different data sources is most challenging but comes up with more effective results in analysis. These multilayered data sets add complexity to the analysis. Therefore, it is difficult to manage the different patterns, and resolutions of data from different sources and unite them to generate new knowledge using appropriate methods and techniques in data processing and analysis drawn from remote sensing, image processing, and geospatial data analysis.

In this research four main types of data have been compiled and compared to understand the housing recovery over time. The data mapping followed the same projection system to ensure overlying and comparing data to each other represented the same location in the ArcGIS software. From the large data set of FEMA-MOTF Hurricane Sandy impact data the subset for Sea Bright area was separated. Similarly in the case of the LiDAR data and aerial images the part of study area was extracted following its geographic boundary. The mail survey data processing consumed more time to geocode and locate the respective response location in the field, incorporating the information from the resident’s response and merge these data with geospatial information for further interpretation. In the case of the LiDAR data the status of the point clouds with point spacing, x, y, z values with maximum, minimum and averages were checked to determine the resolution to create surface models representing pre and post Sandy conditions. A trial and error method was applied to find out the most representative outcomes with 1m, 2m and 3m resolution digital surface models. Later the minus tool in ArcGIS and change detection tool in Quick Terrain Modeler was used to identify damaged areas having loss or gain in elevation due to Hurricane Sandy impact. For visual interpretation of aerial images with the same projection in different time periods, it took more time to focus and concentrate carefully with zooming in as much as possible until it get distorted and thus finding out the areas with land use change and then digitize those locations. Finally using several data from different times, the research identifies the location on maps where damage happened. It also compares the condition of the site in subsequent time periods to outline the area going through the process of recovery and map the progress of recovery. Locations experiencing slow or rapid recovery can be identified and mapped.

The results can help concerned organizations to focus more on specific locations and plan to help the residents to speed up recovery. More attention should be given to those areas experiencing slow recovery, so that the victims can have more support in improving their condition. The findings from this study can also help policy makers to focus more on the areas with differential progress in reconstruction, rebuilding, and repairing of houses and take necessary actions to overcome the problem associated with the situation. Images are used for visual analysis of damage in the area. These images also help decision makers understand the situation in the field without physically travelling the site. Using the geospatial technologies, the framework developed in this thesis and available information, the decision makers can identify the damaged sites and locations where something is going wrong, or where the process is facing slow progress, or where recovery has completed. Armed with such tools and information, they can revise plans considering existing situation and also pre-plan the recovery work.

Finally this thesis approach can be applied to study multiple communities and other events and in the future to track disaster recovery. In addition, the findings can be used in other similar ongoing projects. The analysis presented in the thesis supports the objective of this research to develop a measure of post disaster housing recovery that reflects changes over time.

5.2 Limitations

Like many research studies the available data and resources presented some limitations to the research. To better understand the applicability of the results of this research, this section reviews some of these limitations which include the following:

- The lack of formal definitions of damage and recovery
- The small sample size
- Ambiguities in the survey questions and responses
- Missing or unavailable data, and
- A focus on quantitative data rather than qualitative information.

The remainder of this section elaborates on each of these limitations and the following section connects these limitations to areas for future research.

The literature on disaster recovery lacks specific criteria or guidelines to define a state or position or condition in the impacted area, as well as its residents, that can be used to declare the area as recovered from the past disaster. Also there is no universal measurement scale to declare an area to be fully recovered. In this study, considering the physical structures and housing condition, when the damaged property returns back in previous status after repair is completed or the destroyed property is occupied again, it is assumed that the property has recovered. Many other factors could be considered in modeling housing recovery. Here the survey responses from residents is the main input to assess the level of recovery. That is, if the respondent said repair is completed then that property is considered to be recovered.

In Sea Bright, only 180 responses with their postal addresses in Sea Bright could be located through geocoding. Other responses are from the same locality but could not be geocoded because the mail addresses were located outside the area. While geocoding some addresses did not match the exact location, for example, the residence was placed on a road or outside the boundary line for the township, so an approximate location within a nearby plot is assumed for those points. Thus in case of visual representation of the scenario in GIS maps only the responses (180) from identified locations are used for further analysis using geospatial technologies. Furthermore, the responses (303) to the mail based survey is very small compared with the overall number of houses in Sea Bright. Again, there are also some inconsistencies in the survey responses, for example, four respondents said no damage to their house but later they reported repair complete or repair not complete. If there is no damage there should not be any response regarding the question of repair completion. Similarly, the question asking the respondents to classify the level of damage to their homes was ambiguous. There was no specific guidance given respondents to define unique response categories: not very extensive, somewhat extensive and very extensive damage. So the result depends on people’s perception on how much damage they feel Hurricane Sandy caused to their homes.

Data limitations also hindered the time series analysis in many ways. For example, the building permit data is important for effective measurement of housing recovery and in combination of remote sensing analysis, it can show a more complete picture of recovery. While New Jersey has a standard building permit format and the data is intended to be publically available, building permits for Sea Bright Hurricane Sandy were not available for use in this study. In the case of the LiDAR data, the LiDAR data collected immediately after Hurricane Sandy in 2012 is the only publicly available data. More recent data, is not accessible and achievable for free. If recent LiDAR data as well as that for the time between now and Hurricane Sandy could be assembled that could provide more detailed information to make comparisons and assess changes over time. In addition the LiDAR data downloaded from NOAA are unclassified and includes only first return points with elevation data. It could not be used intensively for analysis as classified data can produce more details related to the study. Though LiDAR data and remote sensing images are a rich source of data these data require intense processing to produce useful outputs.

Sea Bright is a very small borough. The borough covers two census block that are merged in one census tract with other areas. Therefore significant demographic information was not available to be used in parallel with the damage and recovery scenarios to better understand the findings from this research.

The thesis considers the quantitative assessment of housing recovery. Qualitative measures can show more detailed insights based on the residents' responses. From the same secondary source of survey data (the on-going project at DRC) information from fifteen (15) interviews is available but for this study no qualitative analysis is done using this data.

The limitations, explained here, support ideas for work to be done in future as described in the next section.

5.3 Future Research

This research has identified many areas for additional research that would help to enhance or strengthen the findings from this research. The present data values can be supplemented with the future findings in order to demarcate recovery levels of an area more precisely and consistent. These proposed research topics include collecting additional survey data, accessing commercially available LiDAR data and publicly available building permit data, relating housing recovery to programs, policies and socio-economic variables, and using qualitative information to enhance the assessment of housing recovery. This section provides additional details related to these areas for future research.

The same type of mail-based survey could be repeated in the summer of 2015, one year after the last survey, to keep track on the recovery situation. In the follow up survey, better definitions of the status of the recovery effort can be provided. While few modifications can be done in question types and answers choices to maintain consistency, some questions will be retained and some other questions relevant to housing recovery can be added. Previous questions can be revised with appropriate phrasing to focus more on the research goal. If possible, field surveys can be done and buildings located using survey data can be inspected physically to check the real condition if needed. Another consideration could be the selection of study areas at county level to have more representative data and comparable findings over a large area. Relevant data on socio-economic, demographic and other characteristics can be easily accessible if large scale area is considered.

The study results can also be elaborated depending on available data through qualitative analysis and other quantitative analysis. Considering the information from the interviews done after the mail based survey in the Project, a qualitative analysis can be done to infer recovery level of the study area qualitatively.

Based on existing geospatial data more analysis can be done using tools in ArcGIS such as spatial analyst, raster calculator, and reclassify. The results of this analysis may include clusters or block centering the location with differential change. The airborne digital imagery can be tested in other ways. Building foot print can be drawn from high resolution images in different times and the changes can be identified comparing the present figure from previous through overlaying one above another. Also property use can be added to each building in each time. Thus a pattern can be shown in housing recovery measurement using trend line analysis considering land use change in each plot.

Depending on the data from the survey, more quantitative assessment can be done to provide insights on mitigation measures, insurance, and people’s perception on several aspects related of emergency management that will add more value to this research. In addition the data findings compiled in this thesis can be used in other ongoing research efforts.

In future, if the building permit data is available, it can contribute significantly to measuring the housing status over time and to delineate a trend line representing the recovery process considering reconstruction, rebuilding, redevelopment, and occupancy permits.

In this thesis, the LiDAR data is used to study the changes in elevation and detect the areas with debris accumulation or loss of land or buildings following the disaster. More analysis can be done using this data after classifying the first return points according to land use, for example, buildings, vegetation, bare earth, etc.

Specialized algorithms can be implemented to filter point cloud of last return elevations and determine the "bare earth" under vegetation. LiDAR data in different time intervals after Hurricane Sandy has been collected commercially. Having access to this data provides an opportunity to compare the scenarios from time to time. If data is available in sequence it can be analyzed to assess the extent of the repairs to damaged buildings through 3D observation of the building or by measuring the height difference. In 3D view structural damage will be apparent and the observation of the buildings in successive time periods will show the progress in repairing of the building. The building condition observed in different time periods can be useful in rating the recovery level. Thus housing recovery can be assessed with respect to building condition.

In other future research, problems impeding progress in community recovery considering housing damage in the identified location can be investigated so that initiatives can be taken to improve the existing condition and the recovery. These factors vary from location to location depending on the socio-economic, demographic, political and other characteristics of the community including availability of resources. The study could explore the programs that failed or worked for particular situations, the impact of contextual factors, and the relationship to the attributes of the community. In addition a relationship can be established between the housing recovery and the factors impeding or accelerating recovery in disaster affected areas. The results of this research could provide insights into plans and programs that should be repeated or avoided. The lessons learned from the case studies can also be applied for pre disaster recovery planning for other areas.

5.4 Summary

This thesis developed a comprehensive assessment of post disaster housing recovery that reflects changes over time. The measure used data from FEMA, a mail based survey of households, aerial images and LiDAR data to assess recovery from Hurricane Sandy in Sea Bright, New Jersey. Data was geocoded to reflect the specific locations. Using the geocoded data, GIS analysis was used to present maps and summary data.

Throughout Sea Bright the “average damage status” immediately after Sandy was found to be between minor and major damage based on a qualitative scale of not affected, slightly affected, minor damage, major damage, and destroyed. Using the survey data from August 2014, the “average damage status” is slightly affected suggesting significant recovery. However, further analysis suggested that the rate of recovery of destroyed properties is not as great. Spatial analysis of the data suggested that there is no discernible differences in recovery rates throughout the borough. Interestingly the latest aerial imagery of 2014 shows some affected and major or minor damaged plots started rebuilding after two and half years of the event. It represents that the areas are still recovering concerning the physical features. So the findings from recovery scale is not perfect to say the area is one step behind to be fully recovered regarding the housing properties, rather it looks like the recovery has started or it can be said that people are getting prepared to face the next disaster.

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Appendix A

INSTITUTIONAL REVIEW BOARD APPROVAL

UNIVERSITY OF DELAWARE

RESEARCH OFFICE

210 Hullihen Hall
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DATE:	October 14, 2013
TO:	Sue McNeil, PhD
FROM:	University of Delaware IRB
STUDY TITLE:	[523471-1] Understanding the Relationships between Household Decisions and Infrastructure Investment in Disaster Recovery: Cases from Superstorm Sandy
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	October 14, 2013
EXPIRATION DATE:	October 13, 2014
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # *6,7*

Thank you for your submission of New Project materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Appendix B

QUESTIONNAIRE OF THE MAIL SURVEY

1167 Ocean Ave. Sea Bright, NJ 07760 | (732) 842-0099 | Seabrightvolunteer@gmail.com

May 2014

Dear Sea Bright Resident:
This is our **third and final attempt** to ask for your participation in an important study about your experiences during and after Hurricane Sandy. It is critical that we receive feedback from the entire community on this significant issue. We are particularly interested in unique and different opinions. Let your voice be heard. Information from the original survey is included.

We are writing on behalf of the Borough of Sea Bright and the Disaster Research Center at the University of Delaware to ask for your participation in the following survey about your experiences during and after Hurricane Sandy. We are inviting every household in the borough to participate. The goal is to better understand how you have been making housing decisions after the storm and to create specific data your community can use for planning purposes.

The University will be collecting information specific to your home, but we will not publish or release information about individual households. The results will only be presented for neighborhoods or the whole community. Topics will include questions about your home, your community, the impacts of the storm, how you decided where to live after the hurricane, and basic information about yourself and your household. The goal is to use the experiences of Sea Bright residents to learn more about why residents rebuild in the same location or move after a disaster.

We expect that for most people the questions below will take about 20-30 minutes to complete. Participation in this study is voluntary and your decision to participate will have no bearing on your relationship with the University of Delaware or the community of Sea Bright.

Please have one of the heads of this household (age 18 or older) complete this survey and return it in the enclosed postage paid envelope. Please return the survey **as soon as you complete it**.

If you have any questions about this survey, please contact Frank Lawrence at (732) 842-0099, extension 44 or the Principal Investigator at the University, Sue McNeil, at (302) 831-6618. Alternatively if you have any questions about your rights as a participant in this study, you can also contact the University of Delaware Institutional Review Board at (302) 831-2137. We appreciate your assistance, and look forward to learning more about you and your experiences with Hurricane Sandy.

Sincerely,

University of Delaware Disaster Research Center **Borough of Sea Bright**

First, we would like to ask you about the home you lived in at the time Hurricane Sandy occurred and the community of Sea Bright.

1. Do you own or rent the property addressed on the envelope of this survey?
   ☐ Own
   ☐ Rent (Please go to question 4)

2. Which of the following describes how you use this property? Mark all that apply.
   ☐ Primary residence
   ☐ Second home
   ☐ Rental property
   ☐ Other___________________
   ☐ Prefer not to answer

3. How long has this residence been owned by your family? Please answer in years.

   _____________ years

4. What type of home is this?
   ☐ Single-family home
   ☐ Multi-family home
   ☐ Apartment
   ☐ Condo/Townhome
   ☐ Other___________________
   ☐ Don't know

5. When did you move into or take ownership of this house, apartment, or mobile home? Please provide the calendar year (for example, 2001).

   ____

6. In total, how many years have you lived in Sea Bright?

   ____

Now, we would like you to answer a few questions about Sea Bright. Please tell me how strongly you "agree" or "disagree" with the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
7. I feel Sea Bright is a part of me.	☐	☐	☐	☐	☐
8. Being in Sea Bright says a lot about whom I am.	☐	☐	☐	☐	☐
9. I am very attached to Sea Bright.	☐	☐	☐	☐	☐
10. No other place can compare to Sea Bright.	☐	☐	☐	☐	☐
11. Sea Bright is the best place for what I like to do.	☐	☐	☐	☐	☐
12. The things I do at Sea Bright I would enjoy doing just as much at some similar community.	☐	☐	☐	☐	☐

You have two sections completed already. To understand how you saw your community prior to Hurricane Sandy, we would like to learn about your favorite and least favorite parts of your community **before the hurricane hit**.

13. Please list three things you **liked most** about Sea Bright **prior to Hurricane Sandy**.
    1. ____________________
    2. ____________________
    3. ____________________

14. Please list three things you **liked least** about Sea Bright **prior to Hurricane Sandy**.
    1. ____________________
    2. ____________________
    3. ____________________

In this section, we would like to ask you some questions about your home **at the time that Hurricane Sandy occurred**.

15. Which of the following describes the status of that property now? Has it been: (Mark all that apply)

☐ Abandoned
☐ Condemned
☐ Repairs completed; not elevated
☐ Repairs completed; elevated
☐ Repairs in progress
☐ Repairs scheduled to begin
☐ Structure was or will be totally rebuilt
☐ Property for sale or sold
☐ Structure was or will be demolished
☐ Prefer not to answer
☐ In good condition (did not require repairs)
☐ Not sure (please explain)

____

____

16. Following Hurricane Sandy, have you invested in any of the following mitigation measures for future storms? (Mark all that apply)

☐ Installed storm shutters
☐ Elevated utilities
☐ Purchased additional insurance
☐ Installed roof fasteners
☐ Elevated your home
☐ Installed new pilings
☐ Installed hurricane windows
☐ None of the above
☐ Strengthened attachment to foundation
☐ Prefer not to answer
☐ Other (please explain)

____

____

17. If you selected any of the options above, how did you pay for it? (Mark all that apply)

☐ Personal funds/savings
☐ Loans from a financial institution
☐ Insurance
☐ Government support
☐ Borrowed from friends/family
☐ Did not select anything
☐ Non-profit assistance/aid
☐ Prefer not to answer
☐ Other (please explain)

____

____

18. Do you plan to invest in any of the following mitigation measures for future storms? (Mark all that apply)

☐ Install storm shutters
☐ Purchase additional insurance
☐ Elevate your home
☐ Install hurricane windows
☐ Strengthen attachment to foundation
☐ Other (please explain)
☐ Elevate utilities
☐ Install roof fasteners
☐ Install new pilings
☐ None of the above
☐ Prefer not to answer

____

____

19. If you selected any of the options above, how do you plan to pay for it? (Mark all that apply)

☐ Personal funds/savings
☐ Insurance
☐ Borrow from friends/family
☐ Non-profit assistance/aid
☐ Other (please explain)
☐ Loans from a financial institution
☐ Government support
☐ Did not select anything
☐ Prefer not to answer

____

____

Now we would like you to answer questions about damage from the hurricane to your home and to your community.

20. How much damage did your home sustain related to Hurricane Sandy? Please estimate in dollars.

$_______________

☐ Don't know (due to renter status)

21. Did you have flood insurance at the time that Hurricane Sandy occurred?

☐ Yes
☐ No (Please go to question 24)

22. What amount of this damage did flood insurance cover?

$__________________

23. What did you base your estimate on?

____

____

	No Damage	Not Very Extensive	Somewhat Extensive	Very Extensive
24. How extensive was the damage **to your home** due to Hurricane Sandy?	☐	☐	☐	☐
25. How extensive was the damage **to Sea Bright** due to Hurricane Sandy?	☐	☐	☐	☐

This section asks you about travel disruptions resulting from Hurricane Sandy, both within and outside of Sea Bright.

26. At any time did the disruption from Hurricane Sandy affect your ability to travel **within** Sea Bright for everyday activities (go to work, church, the post office, the grocery store, etc.)?
    - ☐ Yes
    - ☐ No (Please go to question 28)

27. **How long** did the disruption from Hurricane Sandy affect your ability to travel **within** Sea Bright for everyday activities (go to work, church, the post office, the grocery store, etc.)?
    - ☐ Less than a week
    - ☐ Two to four weeks
    - ☐ Two to six months
    - ☐ Seven to twelve months
    - ☐ More than a year

28. Did the disruption from Hurricane Sandy affect your ability to travel **outside** Sea Bright at any time?
    - ☐ Yes
    - ☐ No (Please go to question 30)

29. **How long** did the disruption from Hurricane Sandy inhibit your ability to travel **outside** Sea Bright?
- ☐ Less than a week
- ☐ Two to four weeks
- ☐ Two to six months
- ☐ Seven to twelve months
- ☐ More than a year

Following a disaster, people have many decisions they have to make about living in a community or leaving it. For this next set of questions, we would like to ask you about where you currently live.

30. Do you still live **in the same community** as you did at the time of Hurricane Sandy?
- ☐ Yes
- ☐ No

31. Do you still live **at the same address** as you did at the time of Hurricane Sandy?
- ☐ Yes
- ☐ No (Please share your new address on the lines below)

____

____

32. How long do you plan to live at your current residence?
- ☐ Less than one year
- ☐ One to five years
- ☐ More than five years

For this next set of questions, please indicate how important each element was when making your decision about where to live after Hurricane Sandy.

	Not Important At All	Not Very Important	Somewhat Important	Very Important
33. The likelihood of a hurricane	☐	☐	☐	☐
34. Concerns over sea level rise	☐	☐	☐	☐
35. Being close to family	☐	☐	☐	☐
36. Being close to friends	☐	☐	☐	☐
37. Being close to employment opportunities	☐	☐	☐	☐
38. Being close to the beach	☐	☐	☐	☐
39. Access to affordable housing	☐	☐	☐	☐

	Not Important At All	Not Very Important	Somewhat Important	Very Important
40. Family history in the area	☐	☐	☐	☐
41. Opinions of neighbors	☐	☐	☐	☐
42. Concerns about going into debt	☐	☐	☐	☐
43. Changes in where homes can be built	☐	☐	☐	☐
44. Changes in insurance rates	☐	☐	☐	☐
45. Changes to the building code	☐	☐	☐	☐
46. Ability to travel easily within Sea Bright	☐	☐	☐	☐
47. Ability to travel easily outside of Sea Bright	☐	☐	☐	☐
48. Financial incentives to rebuild your home in the same community from the government (aid programs)	☐	☐	☐	☐
49. Financial incentives to build your home in a new location from the government (aid programs)	☐	☐	☐	☐
50. Help from other organizations (such as a local church or civic group)	☐	☐	☐	☐
51. Trustworthiness of community leaders	☐	☐	☐	☐

52. Were there any other important factors that influenced your decision about where you lived that were not listed? If so, what were they?
____
____
____

53. Please list three things you like **most** about where you currently live **after** Hurricane Sandy.
1. ____
2. ____
3. ____

54. Please list three things you like **least** about where you currently live **after** Hurricane Sandy.
1. ____
2. ____
3. ____

Now, we would like to ask you how you feel about the chances of a future event like Hurricane Sandy affecting Sea Bright.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
55. An event of similar magnitude to Hurricane Sandy is likely to affect Sea Bright in the next **five years.**	☐	☐	☐	☐	☐
56. An event of similar magnitude to Hurricane Sandy is likely to affect Sea Bright in the next **ten years.**	☐	☐	☐	☐	☐
57. An event of similar magnitude to Hurricane Sandy is likely to affect Sea Bright in the next **twenty years.**	☐	☐	☐	☐	☐
58. An event of similar magnitude to Hurricane Sandy is **never likely to affect Sea Bright again**.	☐	☐	☐	☐	☐

This section asks you to imagine that if there were such an event within the next ten years, what sort of impacts you would expect.

	Not Likely At All	Not Very Likely	Somewhat Likely	Very Likely
59. Likelihood of major damage to your home.	☐	☐	☐	☐
60. Likelihood of injury to you or members of your household.	☐	☐	☐	☐
61. Likelihood of health problems to you or members of your household.	☐	☐	☐	☐

Lastly, we would like to ask you some questions about yourself, your household, and for some closing comments.

62. What is your age (in years)?

_____________ years old

63. What is your job or profession?

____

64. How many **adults** live in your home (individuals over the age of 17)?

____

65. How many of those adults are **seniors** (individuals over the age of 64)?

____

66. How many **children** currently live in your home (individuals 17 years old or younger)?

____

67. What was your total household income before taxes for **the year 2011** (the year prior to Hurricane Sandy)?

☐ Less than $20,000
☐ $20,000-$39,999
☐ $40,000-$59,999
☐ $60,000-$79,999
☐ $80,000-$99,999
☐ $100,000-$199,999
☐ $200,000 and up

68. What was your total household income before taxes for **the year 2013** (the year after Hurricane Sandy)?

☐ Less than $20,000
☐ $20,000-$39,999
☐ $40,000-$59,999
☐ $60,000-$79,999
☐ $80,000-$99,999
☐ $100,000-$199,999
☐ $200,000 and up

69. What is your sex?

☐ Male
☐ Female

70. What is your race?

☐ White
☐ Black or African American
☐ Asian
☐ American Indian
☐ Other (please specify)____________________________________

71. What is the highest degree or level of school you completed? If currently enrolled, mark the previous grade or highest degree received.

☐ Kindergarten through 8th grade
☐ 9th grade through 11th (no diploma)
☐ High school diploma or GED
☐ Technical School
☐ Some College or Associates Degree (AA)
☐ Bachelor's Degree (BS, BA, etc.)
☐ Master's Degree (MS, MA, etc.)
☐ Professional Degree (MD, JD, etc.)
☐ Doctoral Degree (PhD)

75. What sort of problems or pitfalls, if any, did your household encounter in the process? An example may be problems acquiring insurance money or finding affordable housing.

72. Would you like a copy of the completed results?
☐ Yes (Please provide an e-mail address on the lines below)
☐ No

____

____

73. The researcher may contact me for a follow-up interview.
☐ Yes (Please provide contact information on the lines below, e-mail or phone preferred)
☐ No

____

____

For our last two questions, we would like to learn more about the housing recovery process you navigated following Hurricane Sandy. A number of researchers have found that this process has a number of steps, ranging from time in temporary shelters, moving, working with their insurance companies and other organizations, applying for aid, and moving into a home.

74. For your household, what were the steps you went through in this process?

Appendix C

COMMUNITY PROFILE

Community Profile of the Study area, Sea Bright Borough, NJ according to Census 2010, American Community Survey 2011

Total Population: 1,412; Male: 729 (51.63%); Female: 683 (48.37%)

C.1 Housing Status

Total Housing Unit: 1,211

Occupied: 792 (65.40%)

Owner-occupied: 433 (35.76%)

Households with individuals under 18: 106 (8.75%)

Vacant: 419 (34.60%)

Vacant for rent: 67 (5.53%)

Vacant for sale: 12 (0.99%)

C.2 Population by Age

Age group	Number	Percent
Under 18	160	11.33
18 & over	1,252	88.67
20 – 24	58	4.11
25 – 34	212	15.01
35 – 49	361	25.57
50 – 64	400	28.33
65 & over	205	14.52

C.3 Population by Race

Race	Number	Percent
White	1,335	94.55
African American	11	0.78
Asian	32	2.27
American Indian and Alaska Naïve	0	0
Native Hawaiian and Pacific Islander	0	0
Other	21	1.49
Identified by two or more	13	0.92

C.4 Educational Attainment

Education	Number	Percent
Less than 9th grade	10	0.90
9th to 12th grade, no diploma	7	0.60
High school graduate (includes equivalency)	182	16.50
Some college, no degree	245	22.30
Associate's degree	69	6.30
Bachelor's degree	386	35.10
Graduate or professional degree	202	18.30
Total	1,101	100

C.5 Income

Median household income*: 78,550; Mean household income*: 139,847

Household Income*	Number	Percent
Less than $10,000	6	1.80
$10,000 to $14,999	4	1.20
$15,000 to $24,999	14	4.30
$25,000 to $34,999	11	3.40
$35,000 to $49,999	24	7.40
$50,000 to $74,999	27	8.30
$75,000 to $99,999	96	29.50
$100,000 to $149,999	36	11.10
$150,000 to $199,999	30	9.20
$200,000 or more	77	23.70
Total	325	99.90

* Data from American Community Survey 2011

Income in 2011 inflation-adjusted dollars

Due to size constraints, a census tract was not used for Sea Bright Borough, NJ.

Appendix D

FEMA-MOTF DAMAGE CRITERIA

Table: Detail criteria of damage classification used in FEMA-MOTF data (FEMA-MOTF, 2014 p.5)

FEMA DAMAGE CLASSIFICATION		VISIBLE IMAGERY BASED CLASSIFICATION				INUNDATION ASSESSMENTS
DAMAGE LEVEL	OBSERVED DAMAGE	Roof Covering	Roof Diaphragm	Collapsed Walls	Other Consideration	
Affected	Generally superficial damage to solid structures (loss of tiles or roof shingles); some mobile homes and light structures damaged or displaced	Up to 20%	None	None	Gutters and/or awning; loss of vinyl or metal siding	Field Verified Flood Depth (or Storm Surge): > 0 to 2 feet relative to the ground surface at structure. Depth damage relationships may vary based on building or foundation type, as well as duration or velocity of flood event.
Minor	Solid structures sustain exterior damage (e.g., missing roofs or roof segments); some mobile homes and light structures are destroyed, many are damaged or displaced.	>20%	Up to 20%	None	Collapse of chimney; garage doors collapse inward; failure of porch or carport Mobile homes could be partially off foundation	Field Verified Flood Depth (or Storm Surge): 2 to 5 feet relative to the ground surface at structure. Depth damage relationships may vary based on building or foundation type, as well as duration or velocity of flood event.

FEMA DAMAGE CLASSIFICATION		VISIBLE IMAGERY BASED CLASSIFICATION				INUNDATION ASSESSMENTS
DAMAGE LEVEL	OBSERVED DAMAGE	Roof Covering	Roof Diaphragm	Collapsed Walls	Other Consideration	
Major	Wind: Some solid structures are destroyed; most sustain exterior and interior damage (roofs missing, interior walls exposed); most mobile homes and light structures are destroyed		> 20%	Some exterior walls are collapsed.	Mobile home could be completely off foundation – if appears to be repairable.	Field Verified Flood Depth: Greater than 5 feet, modeling observed, relative to the ground surface at structure, and not high rise construction. Depth damage relationships may vary based on building or foundation type, as well as duration or velocity of flood event.
	Storm Surge: Extensive structural damage and/or partial collapse due to surge effects. Partial collapse of exterior bearing walls.			Some exterior walls are collapsed.		Major is the general category where the onset of Substantial Damage (>50% of building value) as defined by the national Flood Insurance Program (NFIP) may occur.
Destroyed	Wind: Most solid and all light or mobile home structures destroyed.			Majority of the exterior walls are collapsed.		
	Storm Surge: The structure has been completely destroyed or washed away by surge effects.			Majority of the exterior walls are collapsed.		