GLOBAL ENVIRONMENTAL ISSUES AND LOCAL CONSEQUENCES:
EARTH SURFACE PROCESSES AND URBAN ENVIRONMENTAL QUALITY

CONFERENCE PROCEEDINGS AND FIELD GUIDE
EDITED BY
Nurdan S. Duzgoren-Aydin

GEOLOGICAL ASSOCIATION OF NEW JERSEY

XXXI ANNUAL CONFERENCE AND FIELDTRIP

OCTOBER 3– 4, 2014
THE RICHARD STOCKTON COLLEGE OF NEW JERSEY

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Atlantic City, NJ, after Hurricane Sandy, ABC Action News (10/31/2012)

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Thirteenth Annual Meeting - 1996
Dalton, Richard F., and Brown, James O., eds., 1996, *Karst Geology of New Jersey and Vicinity.*

Fourteenth Annual Meeting - 1997
Benimoff, Alan I., and Puffer, John H., 1997, *The Economic Geology of Northern New Jersey.*

Fifteenth Annual Meeting – 1998
Puffer, John H., ed., 1998, *The Economic Geology of Central New Jersey.*

Sixteenth Annual Meeting – 1999
Puffer, John H., ed., 1999, *New Jersey Beaches and Coastal Processes from a Geologic and Environmental Perspective.*

Seventeenth Annual Meeting – 2000
Harper, David P. and, Goldstein, Fredric L., eds., 2000, *Glacial Geology of New Jersey.*

Eighteenth Annual Meeting – 2001
Lacombe, Pierre, and Herman, Gregory, eds., 2001, *Geology in Service to Public Health.*

Nineteenth Annual Meeting – 2002
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Hozik, Michael J., and Mihalasky, Mark J., eds., 2003, *Periglacial Features of Southern New Jersey.*

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Twenty-seventh Annual Meeting – 2010**
Lacombe, Pierre, ed., 2010, *Geology of the Greater Trenton Area and Its Impact on the Capitol City*

Twenty-eighth Annual Meeting – 2011
Rainforth, Emma C., and Uminski, Alan, eds., 2011, *Environmental Geology of Central New Jersey*

Twenty-ninth Annual Meeting – 2012
Alexander, Jane, ed. *Geology and Public lands*

Thirteenth Annual Meeting- *2013*
Benimoff , Alan I., ed., *Igneous Processes During The Assembly And Breakup Of Pangaea: Northern New Jersey And New York City*

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SCHEDULE
Friday, October 3rd
The Richard Stockton College of New Jersey, Campus Center, Board of Trustees Room

11:00-4:30	Registration
11:30-12:30	Teachers' Workshop Experiential, Hands-On Learning: Applications of Portable X-Ray Fluorescence (XRF) Nurdan S. Duzgoren-Aydin, Ph.D., New Jersey City University and GANJ President
1:00-1:20	Welcoming Remarks Nurdan S. Duzgoren-Aydin, Ph.D., New Jersey City University and GANJ President Michael J. Hozik, Ph.D., The Richard Stockton College of New Jersey
1:20-1:45	Exploring New Jersey Climate Variability and Change David A. Robinson, Ph.D., Rutgers University and New Jersey State Climatologist
1:45- 2:10	GIS (Geographic Information System) Studies of Superstorm Sandy on Staten Island Alan I. Benimoff, Ph.D., William J. Fritz, Ph.D., and Michael Kress, Ph.D., College of Staten Island/CUNY
2:10–2:35	Urban Sprawl and 'Green' Remediation of Arsenic in Residential Soils Dibyendu Sarkar, Ph.D., Montclair State University
2:35- 3:00	Impact of Hurricane Sandy on Urban Soil Geochemistry in Jersey City, NJ Nurdan S Duzgoren-Aydin, Ph.D., New Jersey City University
3:00- 3:45	Poster Review and Break
3:45- 4.10	Climate Reality Project Presentation Amanda Nesheiwat, Climate Reality
4:10-4:35	Special Cost of Environmental Metrics: Representation and Challenges Melissa Harclerode, CDM Smith Inc and Montclair State University , Michael E. Miller, CDM Smith Inc., and Pankaj Lal, Ph.D., Montclair State University
4:35-5:00	Beach-Dune Recovery New Jersey Beach Profile Network Sites Following Hurricane Sandy Kimberly K. McKenna, and Stewart C. Farrell, Ph.D., Coastal Research Center-The Richard Stockton College of New Jersey
5:00- 6:00	Keynote Speaker Nicholas K. Coch, Ph.D., Queens College/CUNY The Damage Potential of a Hurricane Landfall in the NY-NJ Metropolitan Region: Lessons Learned from Hurricanes Irene (2011) and Sandy (2012)
6:00- 6.20	Closing Remarks and Award Announcements Nurdan S. Duzgoren-Aydin, Ph.D., New Jersey City University and GANJ President Michael J. Hozik, Ph.D., The Richard Stockton College of New Jersey
6.30- 8.30	Dinner and Business Meeting

Saturday, October 4th Field Trip
Long Beach Island Ocean County, New Jersey
8:00 am - 5:00 pm Meet at the Richard Stockton College, Campus Center

Table of Contents

PREVIEW

The overarching goal of the XXXI GANJ annual conference and field trip was to extend the professional opportunities for the geoscience community in New Jersey and New York City to improve recognition of the various means by which the Earth System Processes are being transformed by humans at different rates and scales. The title of this year's meeting "Global Environmental Issues and Local Consequences: Earth Surface Processes and Urban Environmental Quality" was selected to reflect this broad interdisciplinary theme focusing on the processes involved and challenges posed.

Global climate change is one of the most critical environmental problems the world community is facing today, and yet it remains to be one of the most controversial scientific topics. The issue of global climate change provides remarkable insights into the nature and workings of science. Past climate changes are induced by natural forcing agents, which played an important role in the evolution of life and the physical transformation of the planet. However, we are in an emerging era known as Anthropocene, i.e., an era in which human activities is expected to have growing and significant impact on natural processes. Humans are integral part of the biosphere and their interactions with their surroundings are inevitable. It is therefore imperative that we understand the consequences of our choices which may define the rates, scales and directions of the transformations resulting from these choices.

The New Jersey and New York metropolitan area, which is one of the most urbanized settings in the world, is extremely vulnerable to surface processes, particularly coastal erosion and flooding. The frequency and disruptive power of these processes are on the rise in recent decades. The extent and consequences of these processes will be examined during a field trip organized by Dr. Stewart C. Farrell (Richard Stockton College). The oral presentations include social, historical and environmental impacts of the surface processes with special emphasis on Hurricane Sandy and urbanization in the region.

For the first time, 2014 GANJ's executive committee integrated a poster session into the program, which particularly welcomes graduate and undergraduate students. The limited number of posters received for this introductory meeting had an impressively high quality overall. I would like to thank the executive committee, especially Dr. Michael J. Hozik (Richard Stockton College), for providing the tremendous logistic support needed for the realization of this meeting. I would like to extend my gratitude to all participants for their invaluable contributions, particularly our keynote speaker, Dr. Nicholas K. Coch (Queens College/CUNY), and invited guest speakers, Dr. David Robinson (Rutgers University), Dr. Dibyendu Sarkar (Montclair State University), Dr. Alan I Benimoff (College of Staten Island/CUNY), Kimberley K. McKenna (Richard Stockton College), Melissa Harclerode (CDM Smith, Edison and Montclair University), and Amanda Nesheiwat (Climate Reality).

Nurdan S. Duzgoren-Aydin, Ph.D.
President, 2014 GANJ
New Jersey City University

THE DAMAGE POTENTIAL OF A HURRICANE LANDFALL IN THE NY-NJ METROPOLITAN REGION: LESSONS LEARNED FROM HURRICANES IRENE (2011) AND SANDY (2012)

Nicholas K. Coch

School of Earth and Environmental Sciences Queens College of CUNY, 65-30 Kissena Blvd, Flushing, New York, and The PhD Program in Earth and Environmental Sciences CUNY. Graduate Center 365 5th Ave, New York, New York, 10016

Hurricanes making a landfall in the New York-New Jersey Metropolitan Area are infrequent but their consequences are considerably greater than those of similar Saffir Simpson Categories in the South. Damage prediction cannot be inferred from Saffir-Simpson category alone, but must consider nine other factors. For example, Hurricane Sandy was barely a Category 1 hurricane and yet its damage was enormous.

This damage amplification is the result of both the different characteristics of Northern Hurricanes as well as the unique geographic, geologic, oceanographic and demographic characteristics in the Northeast U.S.. Northern hurricanes move 2-3 times faster, have enlarged wind fields, and have a mostly coast-normal track that carries their more devastating right side hundreds of kilometers inland. A review of recent hurricane landfalls in the New York-New Jersey Metropolitan Area (NYNJMA) shows how they greatly amplify the damage from hurricane winds, storm surge and freshwater flooding.

The NYNJMA is now the most densely settled and developed hurricane prone urban coastal region in the United States of America. Coastal development policies and damage mitigation procedures will insure maximum damage in an inevitable future storm. The potential damage and economic dislocation from that storm will have national and international economic, and other consequences.

Key Words: *Hurricanes; damage mitigation; storm surge; inland fresh water flooding; beach erosion; surge amplification; surge barriers; sea level rise; Saffir Simpson Scale; New York-New Jersey Metropolitan Area.*

INTRODUCTION

The numerous landfalls of major hurricanes along the U.S. Gulf and South Atlantic shorelines in the last decade have heightened concern about this seasonal disaster. Hurricanes making a landfall in the New York New Jersey Metropolitan Area (NYNJMA) (Figure 1) are infrequent (Ludlum, 1963).

Consequently, most people in the NYNJMA feel that hurricanes are not a serious threat. Some of their misconceptions are these storms are rare events, only affecting eastern Long Island and are weakened by the colder waters North of the Gulf Stream. These are commonly held myths. Northern Hurricanes have very different characteristics than hurricanes hitting the South Atlantic and Gulf coasts. They do more damage than the same Saffir-Simpson category hurricane in the South. The greater damage potential of a Northern Hurricane landfall is a function of the nature of the Northern Hurricane itself as well as the unique oceanographic, geographic, geologic, meteorological, topographic, and demographic factors in the NYNJMA that amplify hurricane damage.

The unique nature of northern hurricanes, the factors that amplify hurricane damage, and what we have learned from recent hurricanes in the NYNJMA are the subjects of this paper.

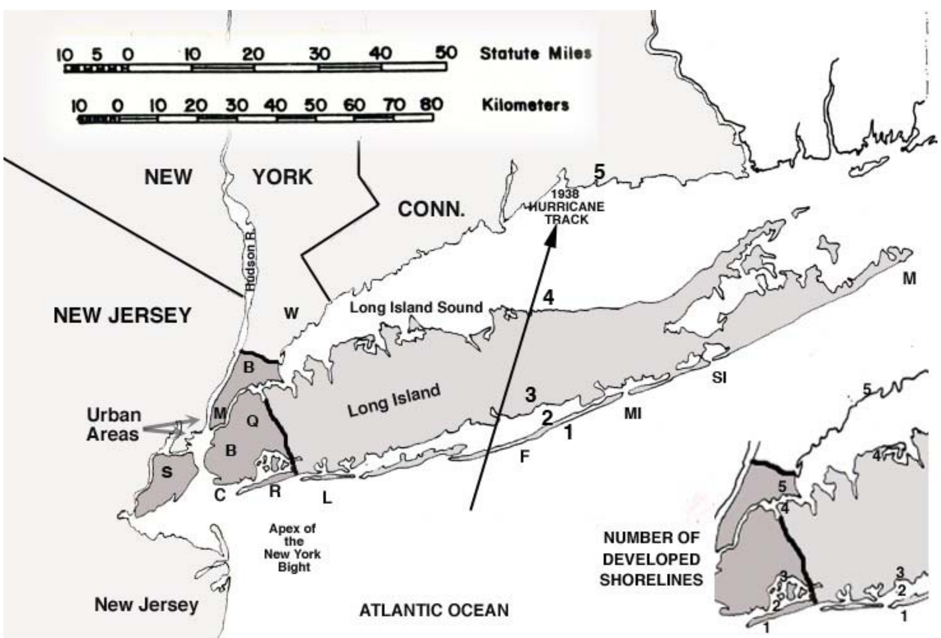

Figure 1. Map of the NYNJMA showing the locations referenced in the text and the number of shorelines a hurricane has to cross before it enters into New England. The locations are: C= Coney Island; R = Rockaway Beach; L = Long Beach F = Fire Island, MI = Moriches Inlet: SI = Shinnecock Inlet; M = Montauk: W = Westchester County; B = Bronx; M = Manhattan; Q = Queens: B = Brooklyn; S = Staten Island.

THE CHARACTERISTICS OF THE NORTHERN HURRICANE

Hurricanes making landfalls in the Gulf, the Southeast Atlantic and areas north of Virginia (Northern Hurricanes) have significantly different characteristics (Figure 2). However their destructive potential has been characterized by the insurance industry and emergency managers by their Saffir Simpson Category alone. The contrast in characteristics of hurricanes in these three basins are shown in Figure 2. It is vital that we consider both the regional differences in hurricanes (Figure 2) as well as other factors, and not just the Saffir Simpson Category alone, in estimating the damage in a future hurricane. The unique nature of the Northern Hurricane is described in detail in the following section.

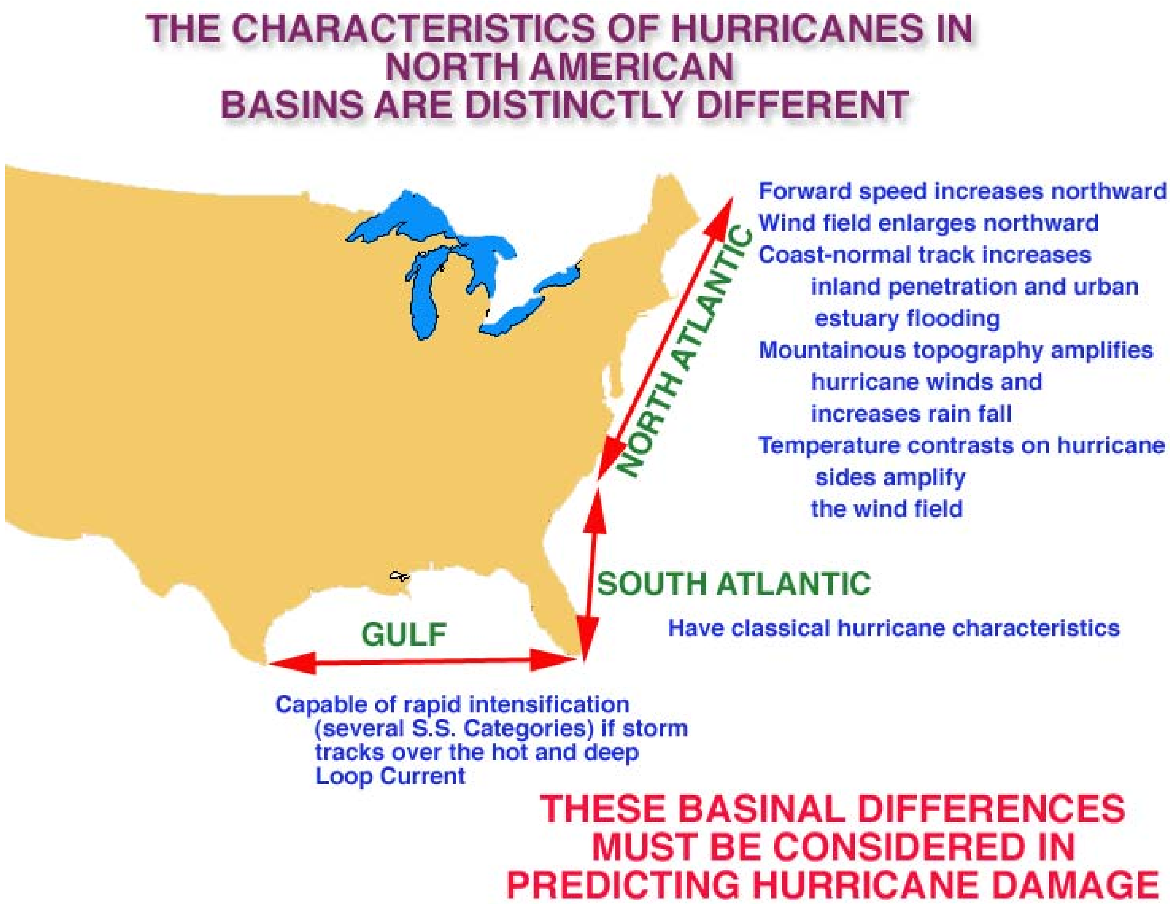

Figure 2. Generalized characteristics of hurricanes that make landfalls along different parts of the Gulf and Atlantic Coasts.

Translational velocity

Hurricanes move in the direction and at the speed of the steering winds in which they are imbedded. In the subtropical areas they are moved largely by the slower Northeasterly Trade Winds. These winds give Southern Hurricanes translational (forward) velocities of 16.1-24.1 km/hr (10-15 miles per hour). As hurricanes move north past the Carolinas, they become influenced by the Prevailing Westerlies that are stronger at upper levels. Translational velocities of northern U.S. Hurricanes are 2-3 times greater than that of southern hurricanes (Mayfield, 1995).

The average translational velocity of a northern Hurricane is 79.4 km/hr (36.1 miles/hr). On the right side of the hurricane (facing forward) there is a vectorial addition of the vortex velocity and some portion of the translational velocity. This raises the effective velocity on the right side of a hurricane, without changing its Saffir-Simpson category. In addition, Robert Sheets (1992, oral communication) stated that any hurricane with a translational velocity of greater than 77 km/hr (35 miles/hr) has sufficient momentum to override the cooler waters north of the Gulf Stream and hit New York City and/ or Long Island with undiminished force. Thus, the colder water south of the region does not protect the region from most northern hurricanes. The much faster translational velocity of a Northern Hurricane reduces the time available for evacuation.

Track direction relative to the coast

The angle that the eye track of a land falling hurricane intersects the coast is a major factor in its damage potential (Coch, 1994). Hurricanes with a coast parallel track along the East Coast have their weaker, left, sides against the coast and damage intensity drops off rapidly inland. However, the Long Island coast extends west to east and hurricanes move from south to north. This geographic setup guarantees that virtually every hurricane that that makes a landfall here has a coast-normal track that carries the more destructive right side far inland.

Wind field size and uniformity

The wind field of a hurricane is defined by its radius of maximum winds (R_{max}), the distance from the eye center to that place within the right eye wall where the winds are strongest. As hurricanes move northward their R_{max} increases (Mayfield, 1995). Thus, Northern Hurricanes spread their wind damage over a wider area.

A common misconception about hurricanes in the northeast is that they are just coastal events. Many people believe that the wind speed decreases steadily and uniformly out from the eye wall of a hurricane. However, satellite images and post-hurricane ground and aerial damage analysis indicate that the wind velocity and damage intensity is far more uneven. Wind velocity is greatest in the right eye wall, but in outlying areas there may be local areas of intense convective activity in the rain bands. These outlying convection centers were seen most recently in Hurricane Irene (2011) in the Northeast (Coch, 2012). As a hurricane moves inland, its sustained winds tend to decrease as a result of frictional effects and a weakening of the storm. However, studies done after Hurricane Hugo (1989) have shown that isolated convective centers inland can generate wind gusts as strong as the hurricane's earlier sustained winds at landfall (Powell et al., 1991). This can result in unexpectedly severe damage far inland from the coast. Coch (2012) showed that similar inland convection centers In New York and New England triggered orographic rainfall far ahead of the eye of Hurricane Irene. As the warm, moist air of Hurricane Irene was lifted up over the Catskill Mountains of New York and the Green Mountains of Vermont, the moist air condensed into heavy rainfall. The result was catastrophic riverine flooding (Coch, 2012).

Season of Landfall

The most active hurricane activity in the Northeast occurs in the late summer and early fall when Northern waters reach their maximum temperature. At that time, intrusions of polar air become more common.

These temperature contrasts intensified the wind field of the 1938 Long Island-New England Hurricane and enabled the storm to penetrate further inland at a high speed. As a result, the hurricane maintained a distinct eye deep into Southern Vermont. A similar effect occurred in Hurricane Sandy (Halverson and Rabenhorst, 2013). The contrast between a polar intrusion in the Midwest and Gulf Stream warmed air in the east energized the storm.

All severe northern hurricanes have made landfall in September or later in the fall. At that time, there is a greater possibility of such a hurricane encountering a polar air mass. If that occurs, the storm system can be energized. The most recent occurrence of this phenomenon was in Hurricane Sandy in 2012.

LOCAL FACTORS THAT INTENSIFY HURRICANE DESTRUCTION IN THE NYNJMA

Hurricane damage in the northeast is not only a function of hurricane characteristics (Figure 2), but also the geographic, topographic and geologic factors that are inherent in this region. The combination of meteorological and local factors increases the damage from any hurricane that makes a landfall here.

Coastal geography and bathymetry

Hurricane storm surge is the rise in water levels that occurs as winds blow nearshore waters landward through decreasing depths. The water surface rises into a broad dome on the right side of the storm. The level of storm surge can now be modeled by the SLOSH, Sea Lake and Overland Surge from Hurricanes. model of the National Hurricane Center/ Tropical Prediction Center (Jarvinen and Lawrence, 1985). An example is the SLOSH model for the New York Area (Figure 3).

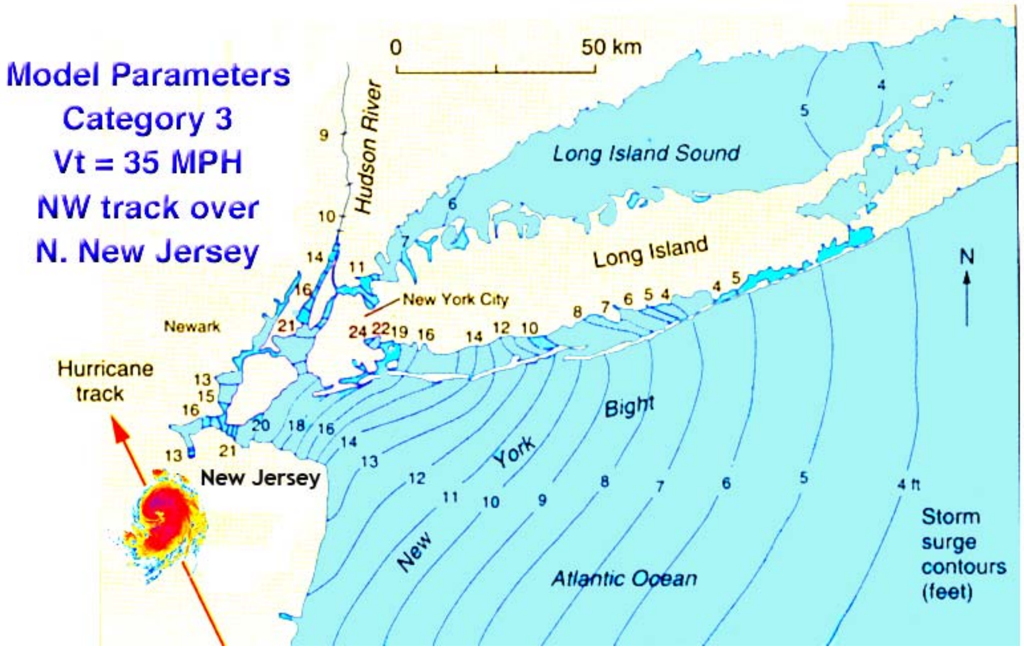

Figure 3. SLOSH map showing expected surge levels for a Category 3 Hurricane making landfall west of New York City. Surge contours are in feet. Note the marked surge level increase westward in the New York Bight Apex. Courtesy of Brian Jarvinene, National Hurricane Center [retired].

This model is based on a Category 3 hurricane moving 40 miles per hour to the northwest over northern New Jersey. In this scenario the right eye wall of the hurricane would be directly above Manhattan. The predicted water levels (feet) are represented by the contours. It is immediately apparent that the surge levels in the Apex of the New York Bight are much higher than those to be expected in a Category 3 hurricane elsewhere.

Why does the New York Bight Apex always experience abnormally high water levels in a storm? The right angle made by Long Island and New Jersey significantly increases storm surge levels wherever a hurricane has made a landfall in the New York Bight Apex (Figure 3). The easterly winds at the front of a land falling hurricane here drive the near shore waters westward where they are impounded in the right angle. The easterly winds at the front of the hurricane also drive the waters of Long Island westward toward New York City (Figure 4). This results in abnormally high surge levels in both the New York Bight Apex and in western Long Island Sound for any hurricane.

Field studies by Coch and Wolff (1991) have shown that a variety of mechanisms cause water damage at the coast. The force of the waves themselves exerts great pressure on structures. In addition, hurricane waters almost always contain debris that can have a battering ram effect. Waves passing under structures exert a vertical force that can lift houses off their foundations and float them away. Coch and Wolff (1991) also documented the role of engineering structures in amplifying wave damage. In Hurricane Hugo (1989) waves hitting groins were reflected to cause magnified damage to the structures adjacent to the groin. Thus, structures that can trap sand and build out beaches in calm weather can increase damage to adjacent structures in a hurricane.

The most effective protection against storm surge damage is high, wide and vegetated dunes (Coch and Wolff, 1991). Natural dune systems were common along the western Long Island shoreline and northern New Jersey until the last decades of the 19th Century. In the early 20th century, many dune systems were leveled to provide space for resort hotels and oceanfront homes. Pedestrian traffic over the remaining dunes eroded the protective vegetation, enabling wind to erode sand and create cuts through the dunes. Subsequent storm surge moved through and widened the cuts, removing more and more of the dunes in the process.

Multiple surge events

A hurricane hitting the NYNJMA will result in two separate surge episodes in New York City. The same hurricane winds that drives New York Bight Apex waters westward as a hurricane approaches the south shore of Long Island (Figure 4), also drive the waters of Long Island Sound westward (Figure 4). Long Island Sound is an east-west oriented funnel-shaped estuary opening to the east. Long Island Sound varies in width from 27 km near its eastern end to less than 3 km at its western end in New York City. The easterly winds at the front of the hurricane will drive the waters of the Sound westward, through a decreasing cross section, towards New York City as the hurricane approaches the south shore of Long Island. The surge levels will increase toward the west end of the Sound.

The 1938 hurricane had made landfall on the south shore of Long Island at 3:30 p.m. and moved inland at a translational velocity of 80-96 km/hr (50-60 mi/hr). However, the maximum storm surge in western Long Island and the East River in New York City was reached three hours later, at about 7:30 p.m. Rising surge waters flooded low-lying areas of the Borough of Queens in New York City and inundated hospitals and power plants on islands in the East River. The inundation of the power plant near Hell Gate in the East River plunged parts of the boroughs of the Bronx, and Manhattan into darkness, as well as brought parts of New York City's subway system to a halt. At this time (7:30 p.m.) the hurricane center was in southern Vermont (Bricker, 1988). For two hours the subways stopped and that part of the city (Manhattan above 59th Street and all of the Bronx) was dark. At that time, the hurricane was entering northern New England.

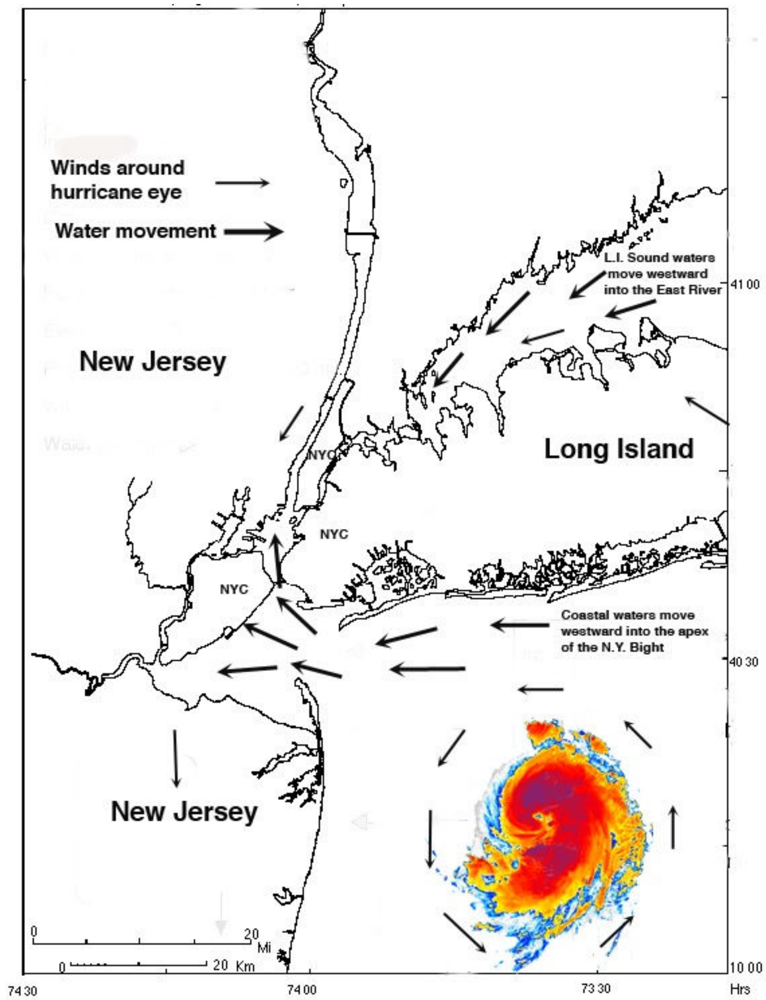

Figure 4. The winds at the front of any hurricane entering the New York Bight drive coastal waters westward into the right angle made by New York and New Jersey. This results in anomalously high surge levels in the apex of the New York Bight. As the hurricane continues northward, it drives the waters of Long Island Sound westward to flood New York City hours after initial landfall.

It is important to reiterate that the hurricane surge response in the NYNJMA is far different from most coastal segments in the United State. When a hurricane makes a landfall anywhere on Long Island, we can expect two surge sequences in the NYNJMA. The first will come along the South Shore when coastal waters are driven towards New York City. The second will come hours later as Long Island Sound waters are pushed into the East River (Figure 4).

Multiple shoreline exposures

Long Island, N.Y. has a unique multiple shoreline exposure to hurricane damage. A coast normal tracking hurricane must cross five developed shorelines before entering the mainland of New England (Figure 1). This is a unique hurricane damage scenario in the U.S. Each of those shorelines is densely developed and populated, and damage could be catastrophic.

Coastal topography and surface materials

Most of the U.S. Gulf and Atlantic coast is composed of low-lying sandy barrier islands and coastal plains. The first hilly topography and bedrock surface exposed along the Atlantic shoreline occurs at the southern part of New York City in the borough of Staten Island (Figure 1). The coastal areas to the south are underlain largely by sandy sediments (Figure 5).

Hurricane winds blowing over a gently sloping coastal plain with relatively low obstructions have a much smoother flow than when wind is forced upward and between hills. Two types of elevated topography characterize the NYNJMA; there are bedrock hills in Manhattan, Bronx, Staten Island and New Jersey and glacial topography rises up to a maximum of 100m (300 feet) on Long Island. Higher topography interacts with hurricane winds in two different ways. One is by wind channeling and the second is by increases in precipitation. As winds are confined in valleys in the bedrock topography or lower areas in the glacial moraine topography in the NYNJMA (Figure 1), the winds increase in velocity as a result of the Bernoulli effect. It can be summarized as follows: as the cross sectional area decreases, the velocity of a fluid flowing through it increases. Far greater wind damage can be expected in the lower areas of the bedrock topography.

Topography also affects rainfall in a hurricane. As warm, moist air is forced upwards over topographic barriers, it is cooled at upper altitudes and moisture condenses and falls as rain. This effect is most marked in hilly or mountainous bedrock areas, but recent research shows that there was a significant increase in rainfall on Long Island as storm winds encountered glacial hills only one hundred meters high. Cole and Yuter (2007) analyzed radar patterns to study precipitation as a tropical storm passed over the glacial hills on Long Island. Their conclusion was that the precipitation increased by 30-40% as a result of passing over the glacial hills. This effect would be significantly greater as moisture-laden tropical air is lifted over the higher bedrock topography of New York City, Westchester, and Rockland County and all of southern Connecticut. Coch (2012) detailed the effect of mountainous topography in triggering catastrophic flooding during Hurricane Irene (2011) in New York State and northern New England.

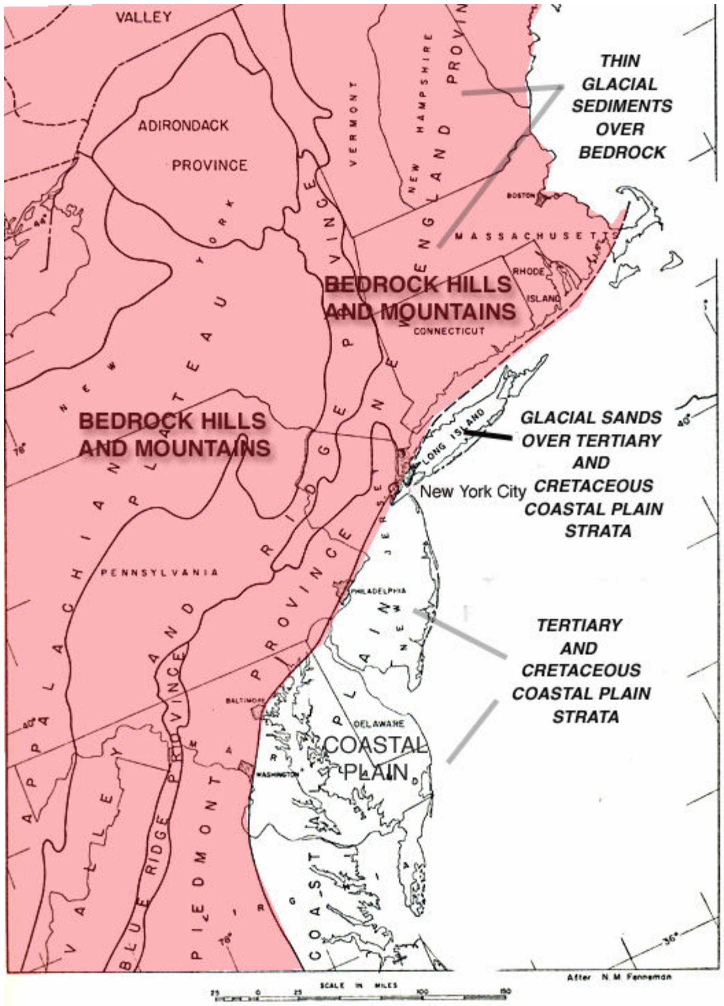

Figure 5. Map showing the surface materials in the eastern United States. Bedrock replaces sandy coastal plains north of New York City. This geologic change in surface materials and slopes has a great influence on inland freshwater flooding in a hurricane.

Urban topography

The original topography of the island of Manhattan has been greatly modified since colonial times (Sanderson, 2009). Hills have been leveled and low areas filled in during development and in the construction of the street grid. The great number of closely spaced skyscrapers has created a new urban topography. The dense clusters of high-rise buildings in many parts of the NYNJMA act in many ways like a low mountain range with respect to hurricane winds. Smoke dispersion studies in London have illustrated the flow complexities in such a field of urban skyscrapers (Wood et. al., 2009). Winds cause structural damage by their direct force, pressure effects, and the debris they carry.

Winds rushing across the edges of buildings or between them create zones of low pressure that lift off the outer parts of the structure (Sparks, 1991). Loss of the outer covering exposes surfaces that are less resistant to wind and rain, resulting in major wind and water damage to the interior of the building. In general, wind destruction increases with speed, altitude, exposure (lack of other buildings upwind), lack of integrity of the roofing materials, and their weak attachment to the frame (Robert Sheets, oral communication, 1992).

Wind stresses affect urban high-rise buildings depending on the wind direction relative to the outside of the structure. On the windward side of each, the wind will create a compressive stress, tending to break into the structure (Figure 6). Interaction of debris-laden hurricane winds and high-rise buildings will result in streets littered with broken window glass (Figure 6D). On the other three sides of the building, and the roof, the wind will exert a suction force (Figure 6A). The winds will be strongest at the edges of the structure where the velocity gradient is greatest. Suction forces led to loss of cladding in Hurricane Andrew in South Florida (Figure 6B) and windows in Houston skyscrapers in Hurricane Ike (Figure 6C).

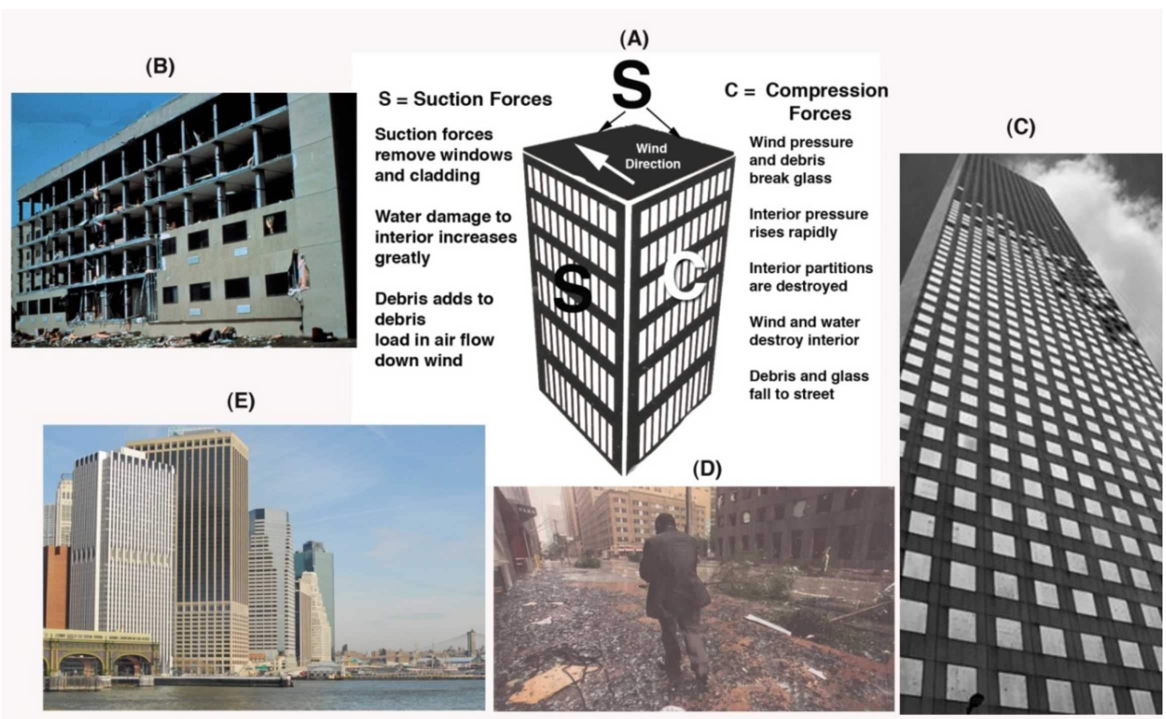

Figure 6. Wind effects on urban skyscrapers. A. Summary of the wind forces on different sides of a high-rise building. B. Cladding removed by suction forces in Hurricane Andrew in Florida. C. Window removal in Hurricane Ike in Houston. The window frames on the lower floors are replaced by plywood. The greatest damage was to the lower floors where the wind was compressed between lower buildings. D. Debris and broken glass in the streets of Houston after Hurricane Ike. E. The continuous line of glass-walled skyscrapers that line the East River shoreline in New York City will be the first structures to be hit by a hurricane.

The wind pressure on a structure increases with elevation. Inhabitants feel secure when told that the windows are rated for hurricane wind pressures. However, in a real storm, wind pressure is only part of the destructive force. Some modern high rise building windows may be rated for high velocity winds, but the abundant wind-borne debris can break windows at wind speeds lower than the window rating. Experience has shown that hurricane winds are always loaded with airborne debris. Debris will be blown from the streets and damaged structures, as well as from the destruction of water towers, large advertising signs, construction materials, and microwave towers. This will make urban hurricane winds far more destructive than would be expected from their velocity alone.

The modern skyline of New York City is quite varied. Many more high-rise structures of different heights, sizes, and construction make up the modern skyline. Winds being driven between them will speed up, increasing the damage to the buildings behind them. The interactions of the wind and the high-rise structures are very complex. In a smoke release experiment in Manhattan (Hanna et al, 2006), the investigators reported that winds hitting one building side are deflected down into the streets, whereas on the opposite side of the structure, the winds are directed upward from street level (Hanna et al, 2006, Fig. 18). The wind flow over and through a great number of skyscrapers of different heights, spacing, and shapes leads to extremely unpredictable wind behavior.

Development

The original land in the NYNJMA has been greatly modified since Colonial times. Most of the original drainage has been filled in. In the earliest stages, the Manhattan shoreline was extended into the Hudson and East Rivers as wetlands were filled in for development. The greatest land filling was in the period from 1924 to 1957 (Figure 7).

Major portions of the original shoreline have been filled in for development of business and residential areas. This makes greater areas vulnerable to storm surge flooding in a hurricane. The worst flooding from Hurricane Sandy was in the filled areas of New York City and the urban areas of New Jersey shown in Figure 7. High-rise buildings were built on the lower east side of Manhattan on land reclaimed from the East River. These were the sites of major New York City flooding in Hurricane Sandy.

Extensive filling of wetlands for development occurred all around Jamaica Bay (Figure 1) in the 20th Century. Wetlands were drained and fill was placed on the surface to provide a dry area for development. Tens of thousands of people now live in those Jamaica Bay communities, many with canals. Ongoing research by the author has documented that continuing land subsidence is occurring in these developments as a result of compaction of the subsurface from the weight of the added structures and fill. Recall from Figure 3 that future hurricanes will generate the highest surge levels in the Jamaica Bay area. Rising water and sinking land are a bad combination in an area where the SLOSH model (Figure 3) predicts the highest surge levels.

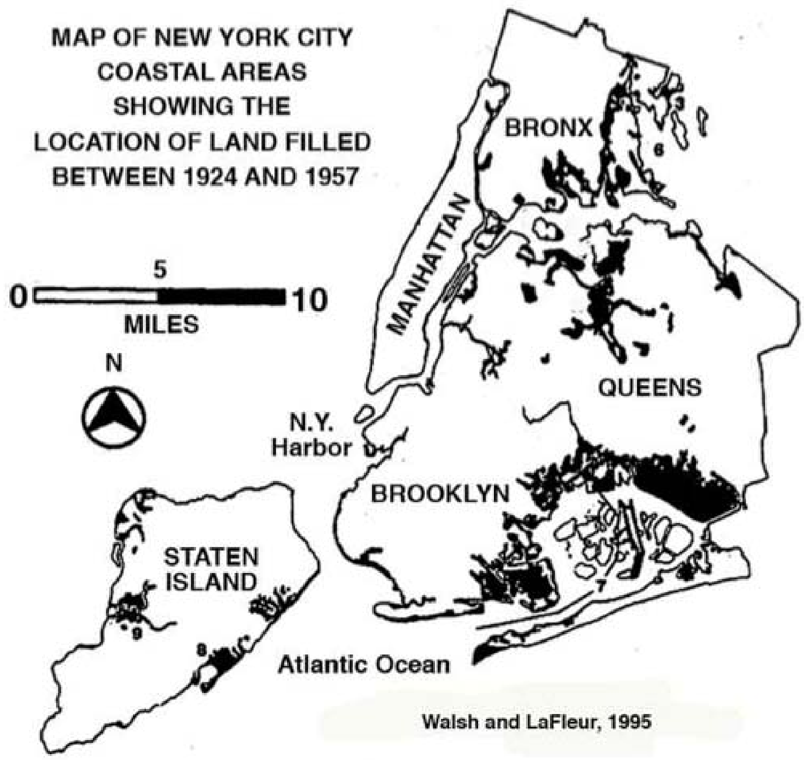

Figure 7. Map showing areas in New York City that have been filled in for development from 1924 to 1957. Major flooding occurred in most of the filled areas in Hurricane Sandy in 2012.

Geology and Flooding Potential

A hurricane hitting the NYNJMA will cause far more flooding than those that have hit coastal plain suburban or rural areas. Hurricanes making landfalls south of the NYNJMA produce heavy rains that fall on permeable coastal sediments (Figure 5). In the NYNJMA permeable glacial sediments are characteristic of Long Island, but not of most of New York City or urban New Jersey. Those areas are underlain by bedrock, which has a far lower infiltration rate than the sandy coastal plain or glacial sediments. In addition, many of the bedrock areas have steep slopes which favor flooding. In short, while the rainfall accompanying a hurricane may be the same in north and south urban coastal areas, infiltration is greatly reduced because streets, buildings, and parking areas are paved and many of the original drainage ways have been filled in during development. The combination of heavy hurricane rainfall and impervious surfaces will result in a short stream lag time and a significant increase in flash flooding.

It is important to understand that a hurricane wind field has many convection centers located far from the eye. These convection centers are foci of intense winds and rainfall. In Hurricane Irene (2011), the eye of the storm was at Annapolis, Maryland while high winds and heavy rain were occurring at convection centers in upper New York and New England

(Figure 8). We have focused on hurricane storm surge (saltwater), while the first urban damage might well be from flash flooding (freshwater) well in advance of the landfall of the hurricane eye.

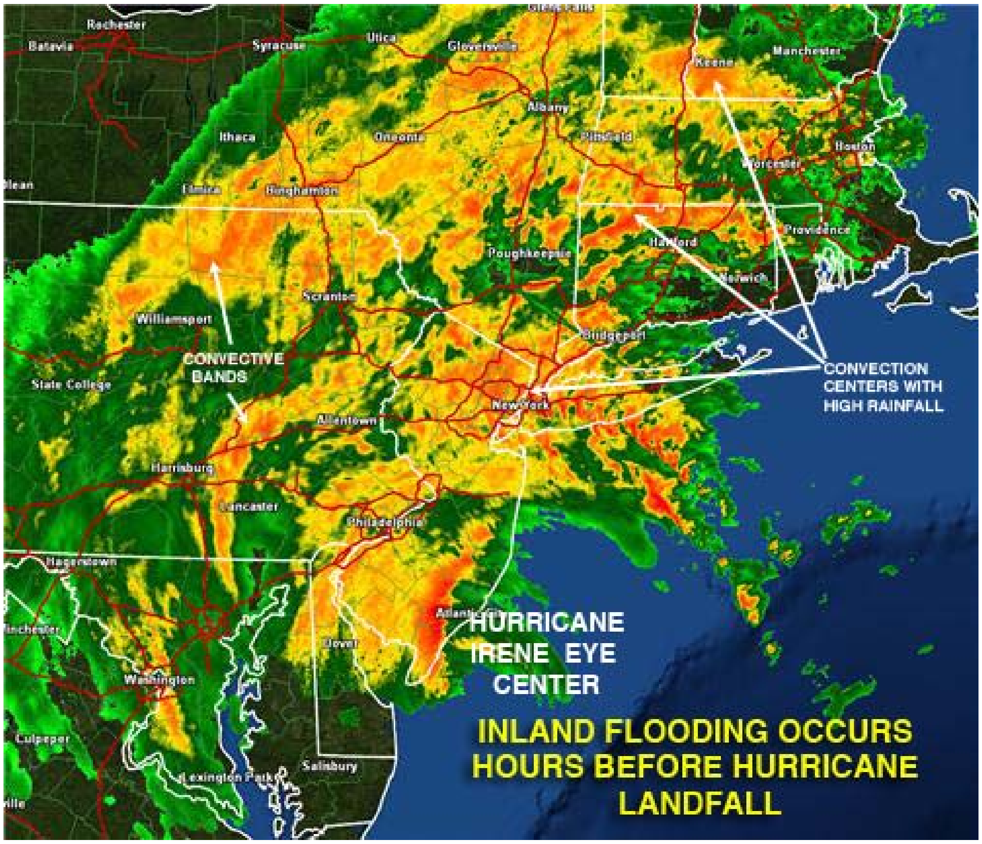

Figure 8. Radar image of Hurricane Irene (2011). While the eye of the hurricane was in Annapolis, Maryland, areas of high convection on the rain bands were causing flooding in the northeast.

Utilities Vulnerability

In small cities, suburban areas, and resort areas many of the telephone and power lines are overhead. A lesson was learned from the wind and snow of the Blizzard of 1888 that crippled the NYNJMA. It became obvious that dense arrays of overhead wires and elevated rail lines were very vulnerable in snowstorms. This led to the building of the largest subway system in the world and the relocation of utility lines, in the developed areas, to underground. In the most developed part of the region, the borough of Manhattan, power and communication lines now run underground. While this protects them from storm winds and snowstorms, it makes them more vulnerable to the fresh and salt water flooding that will accompany a hurricane landfall.

A major hurricane hitting the NYNJMA will raise abnormally high surge levels (Figure 3). The banking and communications centers in Lower Manhattan will be the first to be flooded. Fresh water commonly floods the subways in summer storms. Within a few hours, the system is pumped out and service resumes. The situation is quite different in a hurricane because salt water enters the system as storm surge drives bay waters into gratings and entrances in low areas. Salt water entering the subsurface systems will not only flood them but also corrode them. Such damage was extensive in Hurricane Sandy. The cost of reconstruction of the subsurface transportation (subway) and communication lines will be enormous and the reduction in work productivity will be extensive. It will take a long time for the region to recover. In addition, most of the vital infrastructure in the NYNJMA, such as arterial highways, sewage treatment plants, garbage transfer stations, power plants, airports, tunnel entrances, and major housing areas are within the surge levels of even a Category 2 Hurricane (U.S. Army Corps of Engineers, 1993). It is vital that these key facilities be protected from flooding in a future hurricane.

Evacuation Problems

Emergency planners define the *clearance time* for a given area as the time necessary for evacuees to reach safe shelter before the onset of gale force winds of 63 km/h (39 mi/h) and storm surge roadway inundation (U.S. Army Corps of Engineers, 1993). The edge of gale force winds may extend out 160-193 km (100-120 mi) from the eye of the storm. While the sustained winds at the end of clearance time may be 63 km/h (39 mi/h), expected gusts up to 92 km/h (57 mi/h) could be very dangerous to those attempting to evacuate at this late time (A. McDuffie, U.S. Army Corps of Engineers, personal communication, 1993). The *pre-landfall hazards time* is the period between the arrival of sustained gale force winds and the landfall of the hurricane eye (U.S. Army Corps of Engineers, 1993). During this time, roughly 3-4 hours for a northern hurricane, evacuation will be hazardous or impossible. For example, consider an area on the south shore of Long Island with a clearance time of 15 hours threatened by a Category 3 hurricane moving northward at 64 km/h (40 mi/h). Evacuation should be actively underway when the hurricane is 966 km (600 mi.) away, offshore of Charleston, South Carolina!

Evacuation of many northeastern coastal areas is a problem due partially to a lack of awareness of hurricane dangers, resulting in either dismissal of the danger or procrastination until it is too late to evacuate. In addition, many areas are difficult to evacuate due to geographic factors and population densities.

A major concern for local emergency planners in southern New York and New Jersey is how to evacuate vacation and year-round communities on the developed barrier islands (U.S. Army Corps of Engineers, 1993). Communities on the barrier islands of Long Island range from those in highly populated and urbanized areas of New York City (Coney Island and Rockaway Beach) and the city of Long Beach in Nassau County (Figure 1) to the numerous small barrier island vacation communities on Fire Island and elsewhere in Suffolk County (Figure 1). For example, clearance time for the city of Long Beach (Figure 1) is 14 hours.

Evacuation is a daunting problem in the most intensely populated coastal region in the U.S. Many people feel that it is impossible to evacuate the millions of people who live in the NYNJMA, and that is true. While the high bedrock topography in the NYNJMA intensifies wind destruction, it is actually an aid in evacuation. Fortunately, only a fraction of the population in the NYNJMA area need be evacuated from flood danger zones. High bedrock or glacial morainal areas are only a few miles away from most vulnerable flood areas. For example, residents of coastal areas below 30 feet on both the north and south coasts of Long Island can be easily moved to wind-resistant evacuation centers in the high central glacial morainal area of the Island. In a similar fashion, residents of low areas in the east and west sides of Manhattan Island can be moved to shelters in the high bedrock area of the center of Manhattan.

Problems in debris removal and management

The fall of the World Trade Center Towers on September 11, 2001, illustrated the problem with managing debris in the NYNJMA. The debris had to be removed rapidly to allow searches for survivors. The difficulty in getting the debris from this one site to the landfill on Staten Island provides a preview for what will happen after a major hurricane hits the NYNJMA. Today New York City has no operating landfills and solid waste is shipped out of the state. In addition, there are no open areas on which waste can be stored.

Some of the waste management options used after Sandy are illustrated in Figure 9. Solid waste from the Rockaway Peninsula and Coney Island were stored on the huge parking lot of Riis Park Beach (Figure 9). Over 250,000 vehicles were totally destroyed by saltwater flooding, impacts from floating debris (Figure 9), and impacts with other vehicles. Probably a similar number were damaged and needed repairs (Donald Hermanek, Insurance Auto Auctions, oral communication 2013). Where were all these vehicles to be stored prior to their removal for recycling or repairs? The answer was to use large parking lots and less active airfields for temporary storage (Figure 9). The damaged vehicles were stored on little used airfields such as the site at Calverton, N.Y. 70 miles from New York City (Figure 9). The Calverton site was only one of six such car storage sites (Donald Hermanek, Insurance Auto Auctions, oral communication 2013).

Figure 9. Debris management after Hurricane Sandy. A. Debris from the Rockaway and Coney Island areas stored on the large parking lot of Riis Park in Queens. B. Flooded car on Staten Island. C. Cars stored on an inactive airfield at Calverton, N.Y.

Anthropogenic induced shoreline erosion

After the 1938 Hurricane, coastal engineering structures, such as groins, sea walls, and jetties at inlets, were seen as a way to increase beach width to minimize storm damage and to stabilize storm-cut inlets to provide new access between bay communities and the ocean on Long Island (U.S. Beach Erosion Board, 1946). Hall (1939) recommended a combination of groins tied into a seawall, "so as build-up and preserve the protective beach in front."

Jetties were built to stabilize major storm-cut inlets along the Long Island and New Jersey coasts. These new stabilized inlets, along with groins and bulkheads soon began to seriously reduce the natural sand movement along the shore. The most heavily engineered coast in the NYNJMA is in northern New Jersey (Figure 10). The history of coastal erosion on the South Shore of Long Island, and its consequences, are discussed in detail by Coch (2009).

Figure 10. Seawalls and groins along the heavily engineered coast of northern New Jersey.

The lack of wide beaches and dunes led to massive coastal erosion in western Long Island in Hurricane Sandy (2013). Field studies have shown that groins can also cause serious local erosion during hurricanes. Coch and Wolff (1991) documented how amplification of surge within some groin compartments at Garden City, S.C resulted in elevated surge levels on the north side of those groins in Hurricane Hugo (1989). They reported that homes closest to the north side of the groins suffered heavy surge and wave damage. Some structures were washed back across the barrier island to collide with others, while some were over washed completely across the island and into the bay.

Coch and Wolff (1991) described the unexpectedly heavy storm surge damage in the community of Folly Beach, S.C., located on the weaker, left side of the eye of Hurricane Hugo (1989). They showed that the Folly Island beach erosion that occurred since the emplacement of massive jetties at the mouth of Charleston Harbor to the north (up drift) had reduced storm protection for this community. The absence of a wide beach and dunes caused major damage to the town, even though it was on the weaker, left side, of the hurricane.

COASTAL FLOOD AND DAMAGE MITIGATION MEASURES

A number of policies and structures are being considered to minimize future coastal flooding. Some protect only vital structures while others protect whole portions of New York City.

Surge barriers

The most extensive proposal for flood control would be to build a series of three surge barriers at the Narrows, East River and the south end of Staten Island (Figure 11). The details are given by Bowman et. al. (2004). These barriers are estimated to cost $20 billion and take ten years to complete. The most recent advocacy for this barrier system was presented by Hill (2012). This is not a valid solution to the problem for a number of reasons (Coch, 2012a). The most significant reason is that closing the gate across the Narrows would raise surge levels along the Jersey and Long Island shores. I feel it is more important to use available funds to correct chronic problems like flooding of mass transit tunnels and major arterial highways. This is the path New York City has chosen to take after a comprehensive study of Hurricane Sandy completed in 2013.

Flood walls and bulkheads

Critical areas along the shoreline can be protected by floodwalls. It is essential that the wall be higher than any flood of record and that it is strong enough to resist the forces of moving water, waves, and debris.

Dunes

An immediate mitigation for coastal flooding is the construction of ridges of sand referred to by contractors as "dunes". True dunes are *natura*l features that are built up slowly by wind and then stabilized by vegetation. Soon after Sandy, such sand ridges or berms were bulldozed up in some locations (Figure 12). Such engineered berms or ridges give homeowners a false sense of security. The arrangement of the sand particles in a bulldozed ridge or berm is quite different from a natural dune. Graton and Fraser (1935) pointed out that grains in a dumped or bulldozed pile have an open cubic arrangement, whereas those deposited under the shear force of air or water have a tighter, rhombohedral arrangement that is more resistant to erosion (Figure 13). Manufactured dunes do serve as a *temporary* solution until natural dunes with grass cover can be established. This process can take many years.

Figure 11. Sites of proposed surge barriers in the NYNJMA.

Figure 12. Construction of a sand berm along the northern New Jersey Coast after Hurricane Sandy (2012).

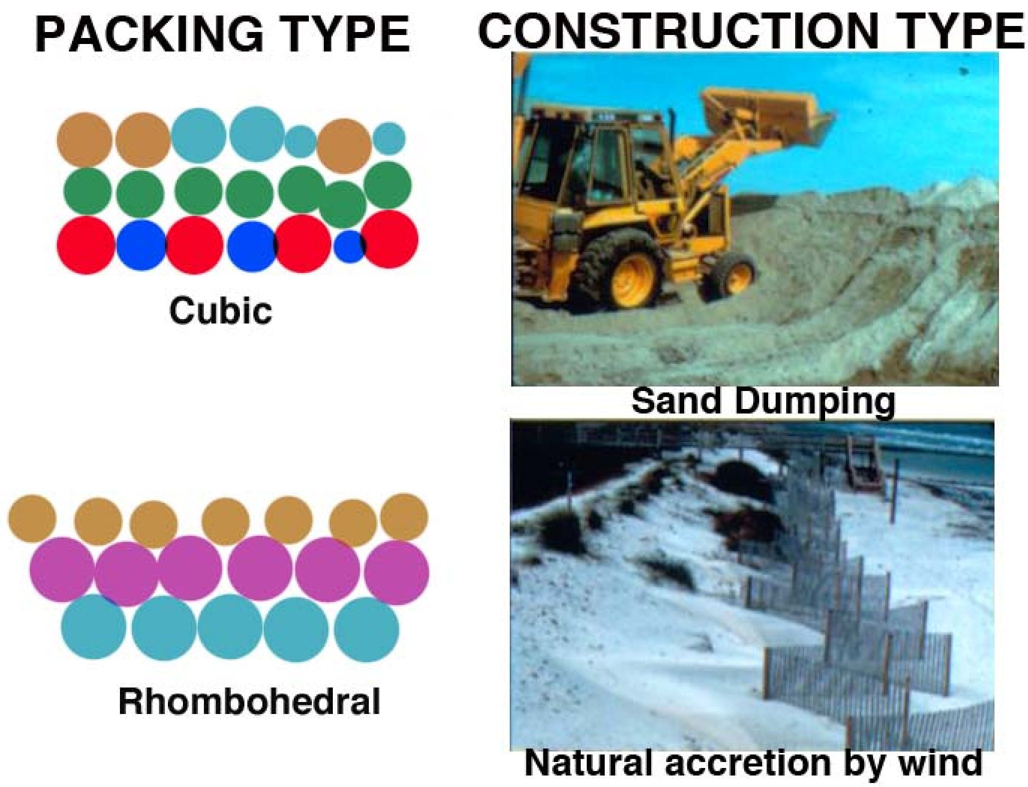

Figure 13. Arrangement of sand grains in a constructed berm and in a natural dune.

Structural Elevation

After Hurricane Sandy, new building regulations required structures that were rebuilt to be elevated on piers above flood levels. The idea is that future floods will move through the space under the house. However, there is a problem with that for protection of beachfront homes. Sea level is rising at a minimum rate of one foot per century (Rosensweig and Solecki, 2001). On our gently sloping coasts, a vertical rise of a foot translates into a lateral inland movement of the shoreline of anywhere between 100 and 400 feet (Figure 14). In a rising sea level barrier islands respond by erosion along the ocean side and deposition on the backside in the process of barrier rollover . As the beach front continues to erode inland, the elevated homes eventually wind up in the surf zone (Figure 14) and are subject to wave attack. Engineering structures such as bulkheads can delay the process but even those will fail and will have to be rebuilt further inland. The problem with structural elevation as a mitigation measure was discussed by Coch (2013b).

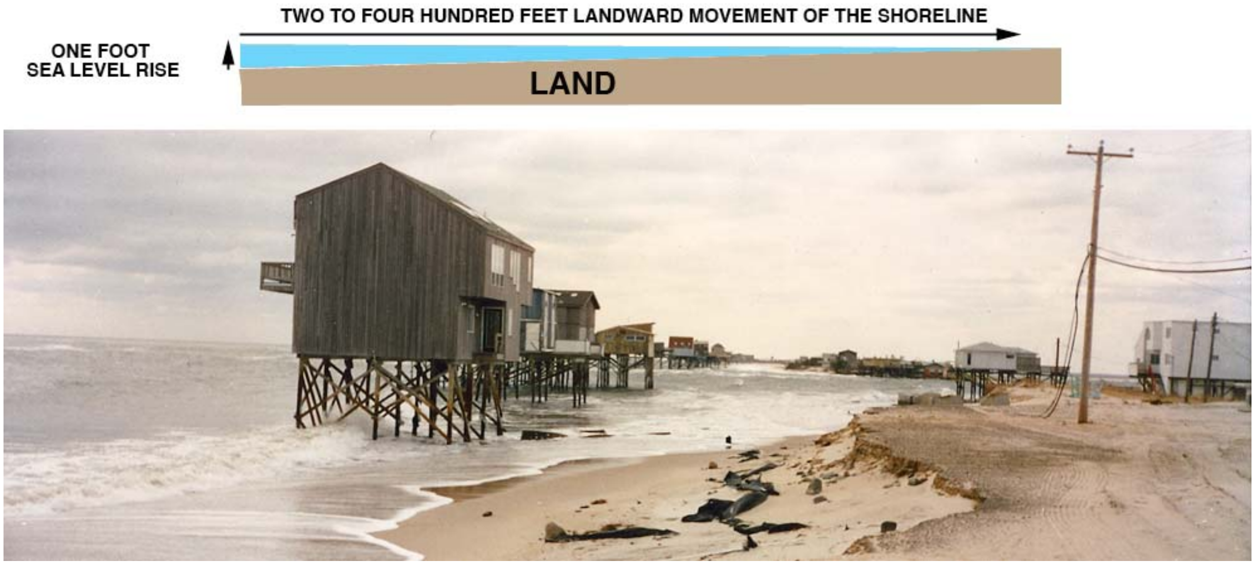

Figure 14. Effect of sea level rise on fixed structures. Top. On gently sloping sandy coasts a sea level rise of one foot can result in an inland translation of the shoreline of 200-400 feet. Bottom. The resulting erosion will eventually place elevated structures in the surf zone.

Zoning

The extreme coastal damage resulting from Hurricane Sandy forces us to re-examine our coastal development and management policies. In a time of rising sea level, the only answer is *abandonment* of the area closest to the shore. This can be accomplished by land zoning and aided by compensation from governmental agencies.

LESSONS OF HURRICANES IRENE AND SANDY

Recent hurricanes in the NYNJMA have provided valuable lessons for the future. The reader is referred to recent publications for specifics on these hurricanes. A summary of the lessons is given in Figure 15.

Hurricane Sandy was a very destructive event but it could have been far worse. Consider two additional possible scenarios (Figure 16). In the first scenario, Hurricane Sandy makes a turn to the west 100 miles to the north, and in the second scenario, Hurricane Sandy does not turn west or east but continues north along a projected path, into eastern Long island and southeastern New England.

WHAT HAVE WE LEARNED FROM HURRICANES IRENE (2011) & SANDY (2012)?

IRENE

- **Moisture-laden hurricanes can cause catastrophic flooding as they pass inland over rocky, mountainous terrain.**
- **When multiple states are hit by a hurricane, it is difficult for one to help another.**
- **We must consider inland (fresh water) flooding as a significant hurricane hazard and mitigate the danger.**

SANDY

- **Hurricanes can swing westward, as well as eastward, as they approach the Northeast.**
- **A hurricane turning 90 degrees in the apex of the N.Y. Bight will expose the whole NY and NJ coast to the maximum possible damage.**
- **The infrastructure in the NY-NJ Metropolitan region is highly vulnerable to storm surge flooding.**
- **Flooding of transit routes and businesses, power losses, fuel shortages and massive residential flooding and wave damage can bring even a major metropolis to a standstill**
- **Sandy was not the "Big One" but an unlucky confluence of tidal phase, jet stream interactions and unusual track. The "Big One" will be a Category 3 hurricane that will affect multiple urban centers in the Northeast,**

Figure 15. Summary of lessons learned from Hurricanes Irene (20111) and Sandy (2012).

If Hurricane Sandy had turned westward 100 miles to the north, the Category One hurricane would have had catastrophic consequences for the highly developed urban centers on New York and New Jersey. With an eye track heading toward Sandy Hook, the dangerous right side of the storm would have been over the most developed parts of New York and New Jersey. The power of the storm would have created much higher water levels in the apex of the New York Bight. The coastal destruction and urban flooding in New York City and New Jersey urban centers would have been catastrophic.

What if there had been no polar intrusion in the west? In that case, Hurricane Sandy would have continued north along its projected track (Figure 16). The consequences for New York and New Jersey would have been far less. However, the more dangerous right side of the storm would have had a major impact on urban centers in Providence, R.I and Boston, MA. These alternate scenarios make a valuable point. When *any* tropical storm reaches the New York-New Jersey Metropolitan Area, there is the potential for great damage whatever turns it takes.

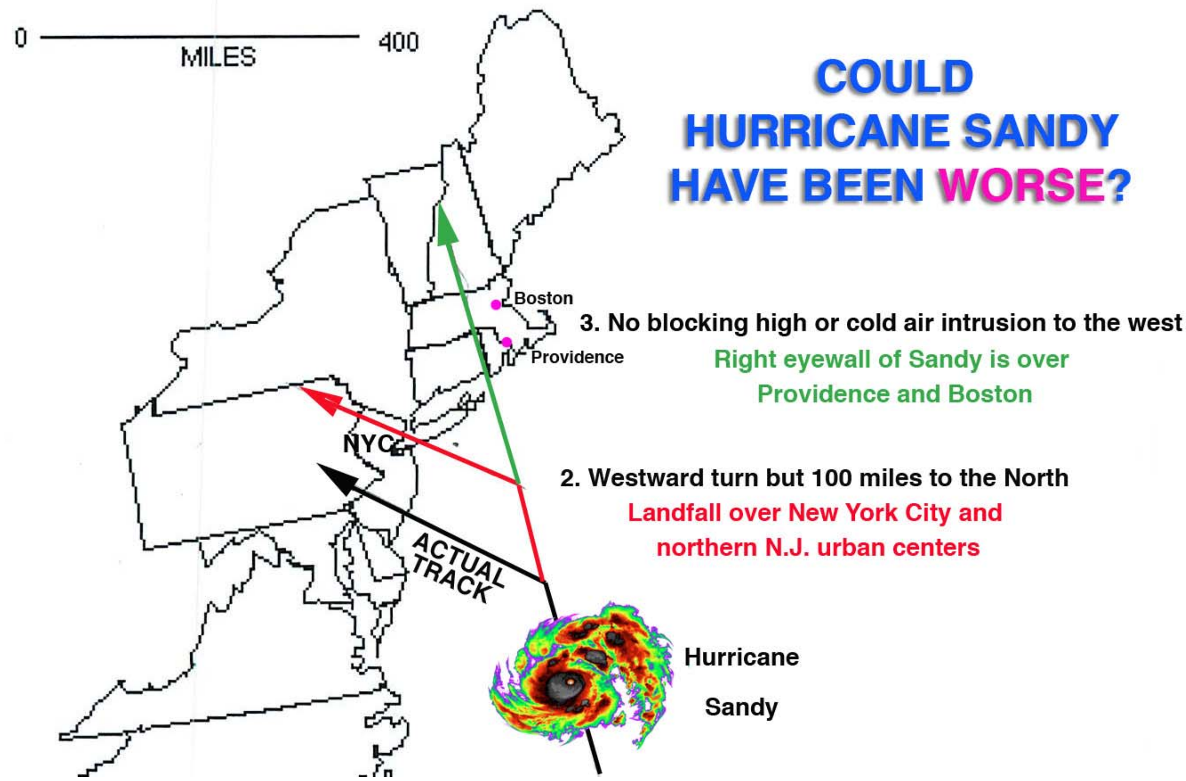

Figure 16. Alternative Hurricane Sandy track scenarios.

PREDICTING HURRICANE DAMAGE

Estimation of the potential damage of a hurricane, by the Saffir-Simpson Category (Simpson, 1974) alone, can seriously underestimate the actual damage that can result. This is especially true in the case of Northern Hurricanes. Insurance, re-insurance, risk management companies and emergency managers have a tendency to predict damage based solely on the Saffir-Simpson Category of an approaching storm. For example, Hurricane Sandy (2012) was a category 1 storm on the Saffir Simpson Scale. Based on the scale alone, damage should have been minimal. The Saffir Simpson Category is only one of ten factors (Figure 17) that determine hurricane destruction. Seven of these factors are the result of natural conditions and three of them are anthropogenic. Each of these factors is described briefly in the following section.

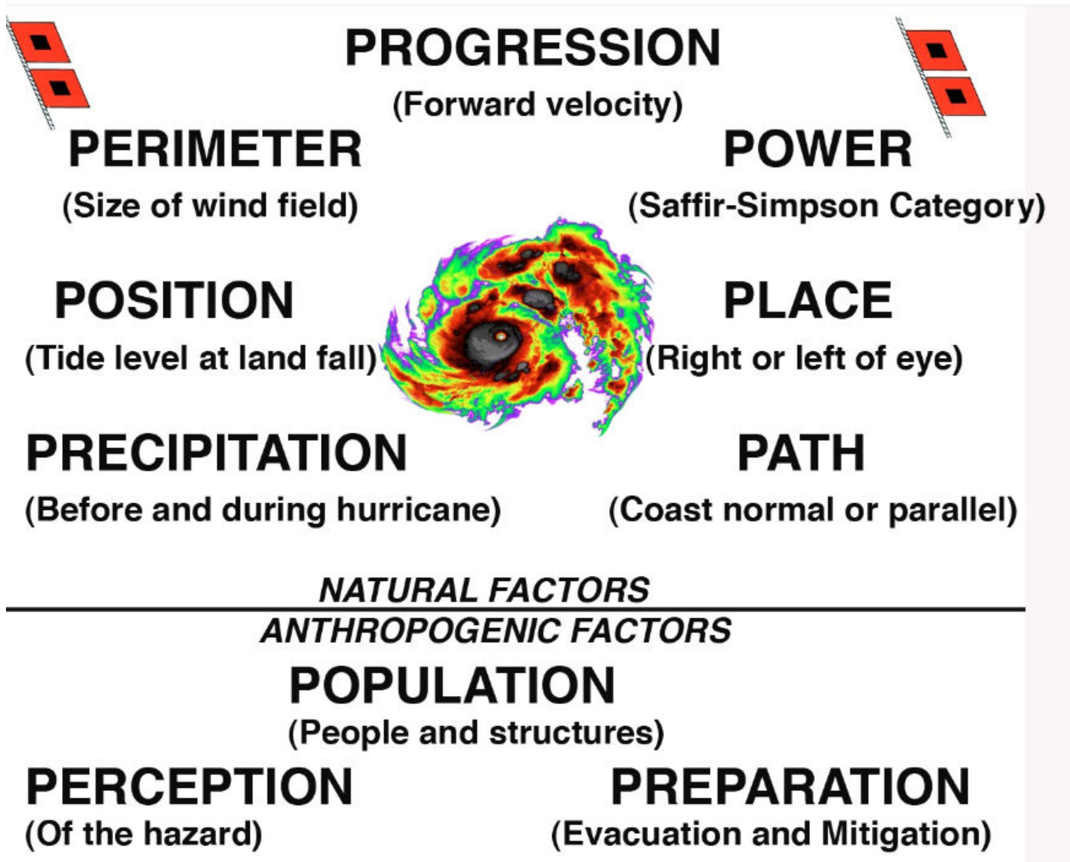

Figure 17. The 10 P's of hurricane destruction. Note that the Saffir Simpson Scale (POWER) is only one of the ten factors determining hurricane destruction.

The forward velocity (Progression) affects the velocity on the right side of the hurricane. Some portion of the translational velocity is added to the vortex velocity on the right side. Since northern hurricanes move faster, this increases the effective velocity on their right sides. The size of the wind field (Perimeter) indicates the area subject to wind damage. Since hurricanes expand their wind fields as they move north, this makes for a wider area of wind destruction. The wind velocity (Power) determines the wind damage and the surge height. The height of the tide (Position) at landfall affects the height of water damage. Whether an area is on the right or left of the eye (Place) determines destruction. The vectorial addition of the vortex and translational winds gives the right side stronger winds. The antecedent and hurricane rainfall (Precipitation) are important factors in both flooding as well as tree damage. If the soil is saturated, tree roots have less resistance to wind shear and can break, runoff increases and there is more danger from flash flooding. The track (Path) that a hurricane makes with the coast determines the depth of inland damage.

The three remaining are anthropogenic factors and determine the damage costs and the potential for injuries and deaths. How aware (Perception) are the inhabitants about the hurricane danger? How developed is the area (Population)? This will determine the damage costs and the costs for maintaining populations during the recovery process. The final factor (Preparation) is how well mitigation measures have been implemented and how effective is the evacuation process (Preparation).

Along with the 10 P's, we must also consider the hurricane basin (Figure 2) in which the storm makes a landfall. For example, a Gulf hurricane of Saffir Simpson Category 2 should not be dismissed because it can rapidly intensify if it crosses the very warm waters of the Loop Current. In a similar fashion, a Category 2 northern hurricane will develop a wide wind field and greater right side winds as it moves northward. These changes will amplify the possible damage.

THE FUTURE IN THE NYNJMA.

Some believe that Hurricane Sandy was the long awaited "Big One" for the Northeast. It was not. Hurricane Sandy resulted from an extraordinary confluence of weather and astronomic factors that will not reoccur for a long time. Major hurricanes hit the Northeast about every 100 years. The last was the 1938 Long Island-New England Hurricane. We are nearing the end of the time period for a reoccurrence.

All indications are that we face a stormy future along the Atlantic shoreline. Few would disagree that weather extremes have become more common. Ocean temperatures have been documented as rising. Scientists are debating whether rising ocean temperatures will cause more powerful and frequent hurricanes. That debate continues. Another possibility is that ocean warming will allow hurricanes to make a landfall further north. At the time of this writing, new evidence for that possibility was presented by Kossin et. al. et.al.(2014) (Figure 18). If this pattern continues major hurricane frequency in the northeast will increase in the future.

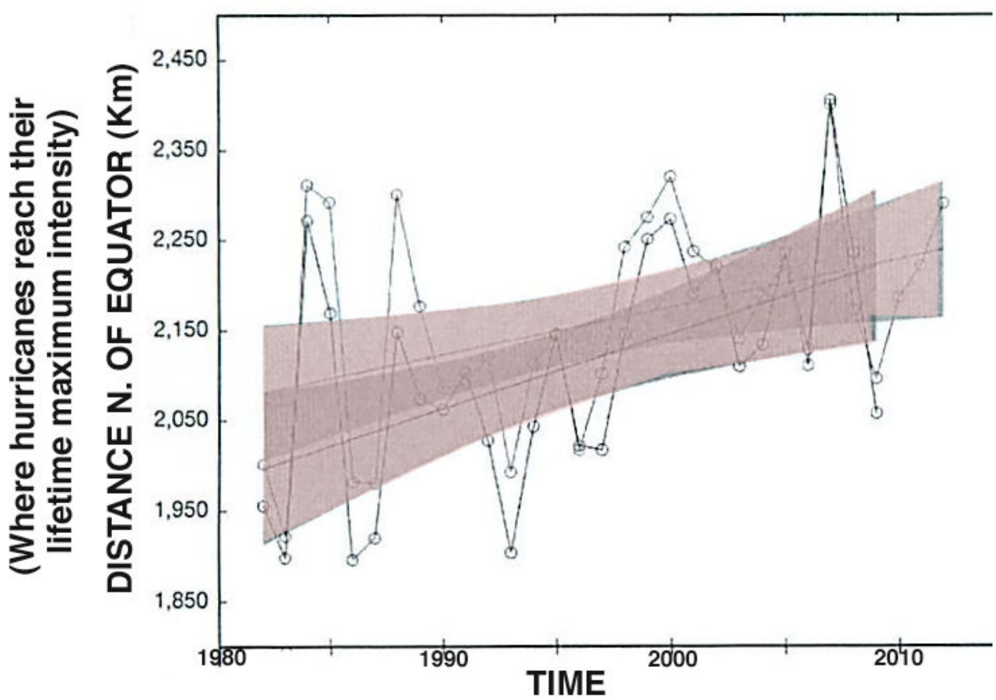

Figure 18. Evidence showing that hurricanes are reaching their maximum intensity further north each year. Modified from Kossin et al., 2014.

SUMMARY AND CONCLUSIONS

Major hurricanes making a landfall in the northeastern U.S are infrequent, but they have a damage potential far greater than storms of similar Saffir Simpson power in more southern latitudes. This is because meteorological, geographic, oceanographic, and anthropogenic characteristics in the northeast magnify storm damage. Hurricanes moving northward along the Atlantic Coast increase significantly in forward speed as they interact with northern air masses. This increase in storm center vortex velocity significantly increases wind and surge damage on the right side of the storm as it cuts a coast-normal swath across Long Island and deep into New England. Easterly winds on the hurricane fringe drive the waters of the New York Bight and Long Island Sound westward, greatly increasing storm surge levels in harbors. Damage will be increased markedly by the higher ocean surge generated by the right angle made by New York and New Jersey, the gentle slope of the continental shelf south of Long Island, the absence of protective dunes, and the lack of wide beaches along much of the shoreline. Fresh water flooding is more likely in the urban centers of the NYNJMA because of the extensive paved surfaces. Rather than tactical damage and flooding mitigation, we should develop strategic mitigation measures to eliminate, rather than restore, vulnerable sites.

Major damage from recent northeastern U.S. landfalling hurricanes was averted because several of the storms weakened as they passed over the cooler waters north of Cape Hatteras and also made landfall at low tide (Gloria in 1985). Gigi and Wert (1986) presented several theoretical scenarios for Hurricane Gloria under different conditions. If it had made a landfall at high rather than low tide, or if it had hit further to the west, the damage would have increased dramatically. Fortuitous avoidance of damage to major population centers in the Northeast has done little to raise the hurricane awareness in the region.

The regional devastation caused by the last great northeast storm- the 1938 Hurricane, has been described in many publications. However, few inhabitants of the northeastern U.S. today are aware of the catastrophic destruction caused by that storm.

Teams of the Federal Writers Project In The Northeast States did the first scientific study published on the 1938 storm. In the Epilogue of their publication they concluded:

> *"Here the ill wind may bring the proverbial good, once the communities have recuperated from their first shock. There are earnest proposals that the seaside resorts **pass zoning laws**. The New England Council hopes to persuade owners to **build cottages further inland** instead of at the shore edge. The open expanse of a century's hazardous building may now be rectified. The federal government is cooperating with local bankers to make funds available for reconstruction. There are plans for ocean driveways with underpasses from the settled colony to the broad, uncluttered sand dunes. Army engineers are surveying the beaches. They hope to build jetties in the waters off the coast so as to prevent future washouts. New sea walls will divert dangerous currents"*
>
> *-Federal Writers Project, Works Progress Administration, 1938, p.219-220.*

Much of what was suggested after the 1938 Hurricane (see italics above) has been forgotten or ignored and some proposed solutions such as building sea walls and jetties proved to be ineffective or even harmful.

Have we learned anything since the 1938 Hurricane? Unless we learn from past hurricanes and apply this knowledge in coastal planning and management, the consequences of landfall of another major hurricane in the northeastern U.S. will be major. The certainty of a future recurrence of a major hurricane landfall in the NYNJMA demands that we take steps to mitigate future damage. These measures include promoting natural beach and dune growth, upgrading existing building codes and zoning policies, developing adequate evacuation procedures, and increasing hurricane awareness in a region that has not experienced a major hurricane in over 80 years. Tropical meteorologists feel that we entered a multidecadal *c*ycle of greater hurricane frequency in 1995. The inevitable landfall of a major (Category 3+) hurricane in the most highly developed and populated coastal region in America could have catastrophic consequences that will have national, and, international implications.

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EXPLORING NEW JERSEY CLIMATE VARIABILITY AND CHANGE

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ABSTRACT

In recent years, New Jersey has experienced its wettest (2011) and warmest (2012) years since statewide averages began being compiled in 1895. Ten of the state's 15 warmest years have occurred since 1998. Extreme events have included Sandy, Irene and a record October snowstorm, each wrecking havoc over all or portions of the Garden State. Clearly something is happening to the region's climate regime. Potential drivers of these variations include solar or volcanic fluctuations, decadal variability in North Atlantic circulation, human impacts affecting our atmosphere and landscape, or perhaps these variations are occurring simply by chance. Climatologists recognize that natural variations or chance alone cannot fully account for recent global (not just NJ) anomalies. While human influences are significant, the climate system is chaotic enough that it remains difficult to quantify such forcings. This paper will bring the issue of global climate variability and change home to New Jersey, addressing where the state has been and where it may be headed. This will include a special look at Sandy, its potential relationship with climate change and whether more such storms may occur in the years ahead.

Key Words: *Earth's Climate System; Climate Variability: Global Climate Change; Extreme Weather Events; Natural Forcing; Human Impacts; Sandy; New Jersey*

INTRODUCTION

The Earth's climate system is remarkably complex. A myriad of external and internal forcings/interactions operate on time scales from seconds to millennia. New Jersey's middle-latitude location on the eastern edge of a continent with a major ocean to the east leaves the state directly exposed to most every climate variable imaginable. Even distant volcanoes and ice sheets play a role in determining NJ's climate and sea level. New Jersey has four relatively well-defined seasons, with clashes between cold and warmth that trigger occasional severe weather conditions over the course of any year. However, most of the threatening weather and climate events affecting New Jersey fail to reach the extremes experienced elsewhere. This is a result of New Jersey's proximity to the Atlantic Ocean that moderates winter cold and helps keep summer heat in check. The Atlantic Ocean also inhibits severe thunderstorms, and its waters are not warm enough to sustain strong hurricanes coming from the south. This does not mean that NJ cannot bear the brunt of major storms, this being abundantly evident with Sandy in October 2012. There is also the question as to whether the climate of the Mid-Atlantic region is changing, with new regimes of temperature and precipitation and changes in the strength and frequency of severe events perhaps already underway. This paper examines NJ's temperature and precipitation regime back to the late 19th century and discusses the meteorological and climatological conditions that made Sandy such a formidable event. It will conclude with some speculation as to what may occur in the decades ahead.

NJ TEMPERATURE AND PRECIPITATION: 1895 TO PRESENT

New Jersey has warmed in recent decades compared to earlier in the 20th century (figure 1). This applies to temperatures measured in instrument shelters approximately 5.5 feet above grassy surfaces. The growth of cities and suburbs and local warming associated with this development does not explain these changes. In fact, the more populated north warmed less than the south, based on a comparison of the 1971-2000 average to 1895-1970. Only a 0.3°F annual warming occurred in the north, while the south warmed 1.3°F. The early part of this century has been exceptionally warm statewide. Ten of the 15 warmest years since 1895 have occurred since 1998. The annual temperature trend is also manifested seasonally. In absolute terms, winter has warmed more than summer, which is expected given the wider variance in cold season temperatures. With 11 months exhibiting above average temperatures, 2012 was NJ's warmest year on record.

Significant variations in NJ precipitation have been observed over the past century (Figure 2). Both the north and south have become wetter in the past four decades compared to previous multi-decadal averages. In the north, the 1971-2000 average precipitation was over 5" (12%) greater than from 1895-1970. Autumn (September-November) is the season with the greatest increase, while summer shows the smallest rise. The south became about 2" (5%) wetter late in the 20th century through present. Autumn wetness in the south increased more than in other seasons, with summer showing no change. Considerable inter-annual variability in precipitation is common throughout the past 120 years. This is especially evident in recent decades, particularly with respect to the number of wet years with annual totals exceeding 55". Consecutive years with precipitation 5" or more below the long-term mean are uncommon, with the mid 1960s having three such years (1963-1966). Only once (1902-1903) have two consecutive years been 5" above average, while 2003-2011 saw four years in that category. A record wet August, due in large part to Tropical Storm Irene, led to 2011 being the wettest year on record.

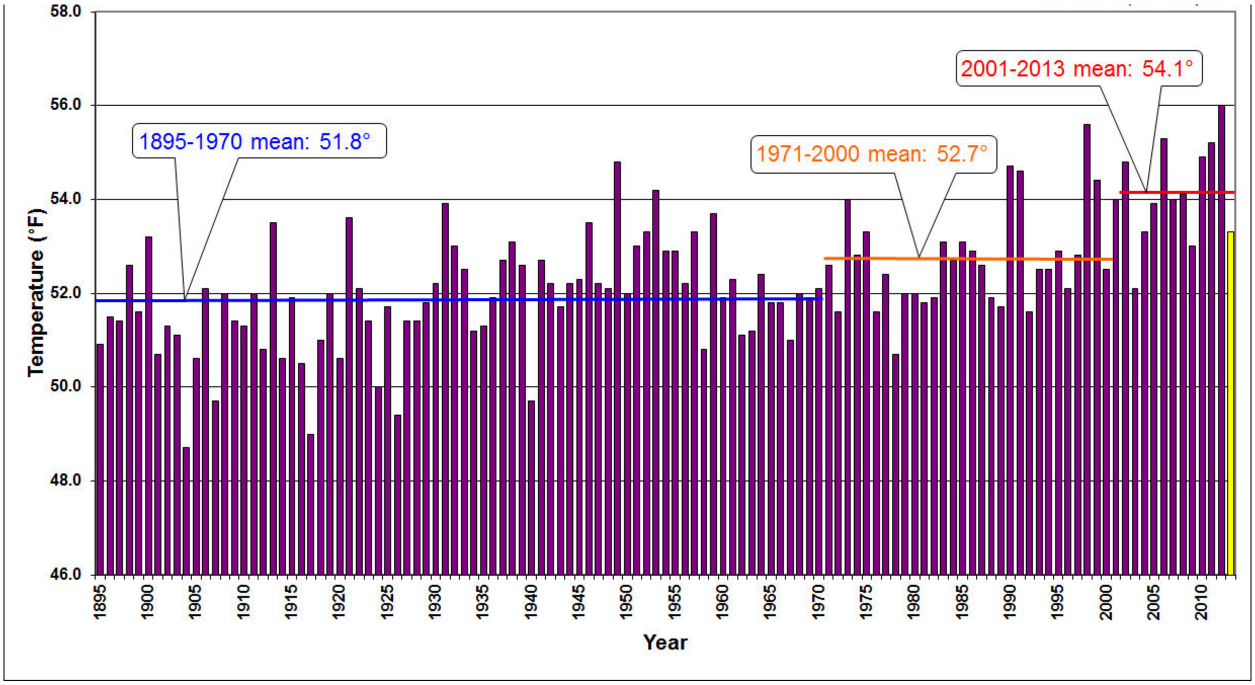

Figure 1. NJ annual temperatures from 1895-2013. Values are based on an average of several dozen stations located throughout the state (njclimate.org).

There is a general consensus in the climatological community that the warming of global surface air and ocean surface temperatures in the past three to four decades is primarily due to anthropogenic forcings (IPCC, 2013; Melillo et al., 2014). These include, for instance, emissions of greenhouse gases, land use changes and emissions of black carbon in the atmosphere and on snow and ice, all of which contribute to warming. This forcing is balanced to some extent by cooling attributed to anthropogenic atmospheric aerosols. This consensus is supported by theory, observations, and models. However one cannot fully dismiss inter-annual and decadal fluctuations that have resulted from natural fluctuations in ocean circulation, volcanic activity, and solar output, or simply by chance.

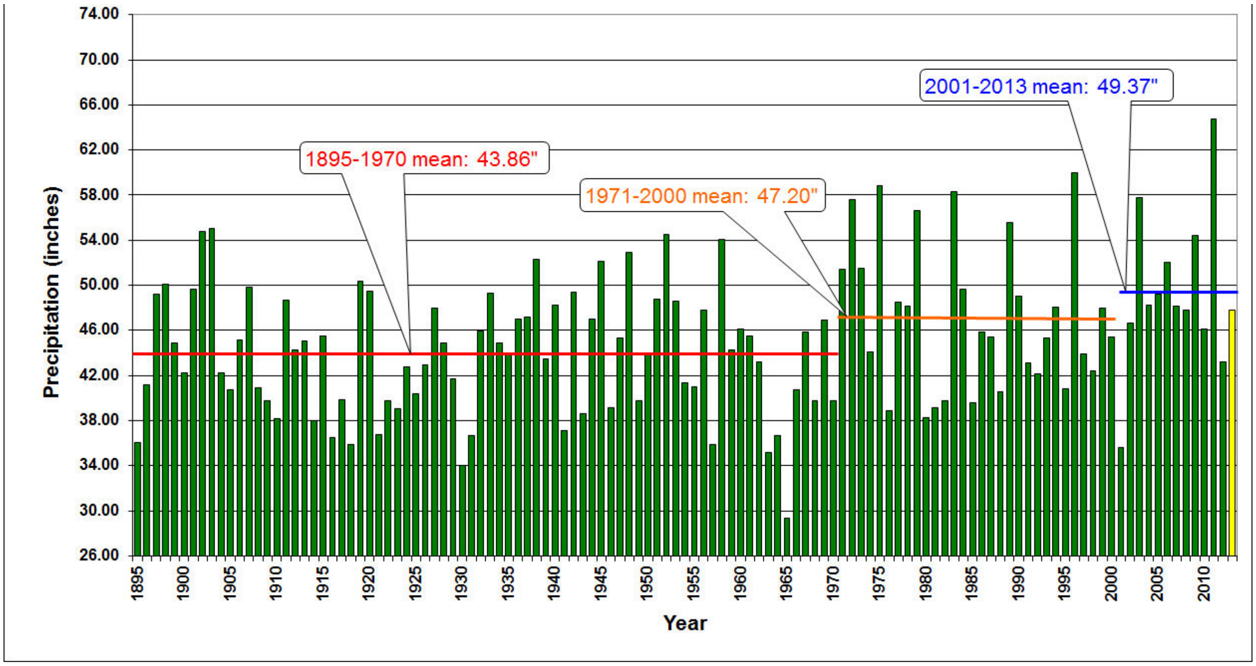

Figure 2. Same as figure 1, except for annual precipitation (njclimate.org).

SANDY

There is no better example of a New Jersey weather extreme than Sandy. The storm was a category one hurricane as it approached the NJ coast during the daytime hours of October 29, 2012 and a post-tropical cyclone as it came ashore near Atlantic City that evening. It dealt NJ and surrounding states a punishing blow. A unique combination of meteorological and climatological features brought post-tropical cyclone Sandy onshore. While Sandy's genesis in the Caribbean Sea a week earlier was not unusual, a combination of atmospheric and oceanic conditions subsequently combined to sustain the storm's strength and influence its trajectory such that it eventually made a rare New Jersey landfall soon after being declassified as a hurricane. Contributing to the strength of the storm as it headed toward NJ were above average sea surface temperatures, the result of an unprecedented 21 consecutive months of above average atmospheric temperatures in the Mid Atlantic and nearby environs. Atmospherically, a blocking high pressure system in the far north Atlantic prevented Sandy from taking a common path away from the East Coast and out to sea. Associated with the block was a sinuous jet stream with a trough or dip in the jet dropping into the eastern US. from Canada. The cold air in the trough clashed with the warmth off the coast to maintain Sandy's strength as it transitioned from a hurricane to an extratropical cyclone while approaching the coast. This jet stream pattern also helped draw Sandy westward toward the coast, a most unusual direction for any mid latitude storm. The result was a storm that brought record low barometric pressure to the southern half of NJ (lowest 27.92" in Brigantine), over ten inches of rain in Cape May County (maximum 12.71" in Stone Harbor), and winds gusting to as high as 91 mph (Seaside Heights) along the NJ coast and 70 mph inland over a several hour period (figure 3). Accompanying this atmospheric onslaught was a record-shattering coastal storm surge of over 9 feet above normal tidal levels along the northern coast and into nearby bays, rivers and harbors. This surge was made worse by landfall occurring close to high tide, a full moon, and sea level currently about a foot higher than a century ago.

Sandy caused damage that equaled or surpassed the worst coastal battering on record (figures 4 and 5). The surge at Sandy Hook exceeded the previous record by over 4 feet. Sandy joined the nor'easter of March 1962 and the hurricane of September 1944 as NJ's most destructive coastal storms of the past century. It is likely that inland winds had never been as strong or of a multi-hour duration in the modern era across central and northern areas; perhaps not since an 1821 hurricane ravaged the region. While precipitation was not excessive over most of the state, the worst of the southern deluge statistically happens no more than once every 200 years. Sandy was not the worst storm that could have hit any area along its path, however its exceptional size, unusual track and its target of one of the most populous portions of the United States made it an exceptionally memorable event.

LOOKING AHEAD

There have been a number of studies that have employed climate models to project future weather and climate conditions in the Mid Atlantic and Northeast (e.g. Jacobson et al., 2009, Union of Concerned Scientists, 2006, 2008). None have focused solely on New Jersey, in part due to the modest dimensions of the state relative to those of model grid cells. In all cases, model ensembles (averaged results from multiple models) were used to make projections, lending considerable strength to the results. The New York City Panel on Climate Change conducted a thorough regional study (Horton and Rosenzweig, 2009), the results of which can be considered generally representative for New Jersey. Models suggest that the next three decades (through 2030-2039) will see mean annual temperatures from 1.5° to 3°F warmer than during the last 30 years of the 20th century. This is within the range of warmer years experienced over the past century, particularly over the past decade (figure 1). The projections are for mean conditions, not extremes; still it is useful to place the projections into this sort of historical perspective. Once into the middle and latter portions of the century, as temperatures continue to rise, there are no analog years for mean temperatures of this magnitude.

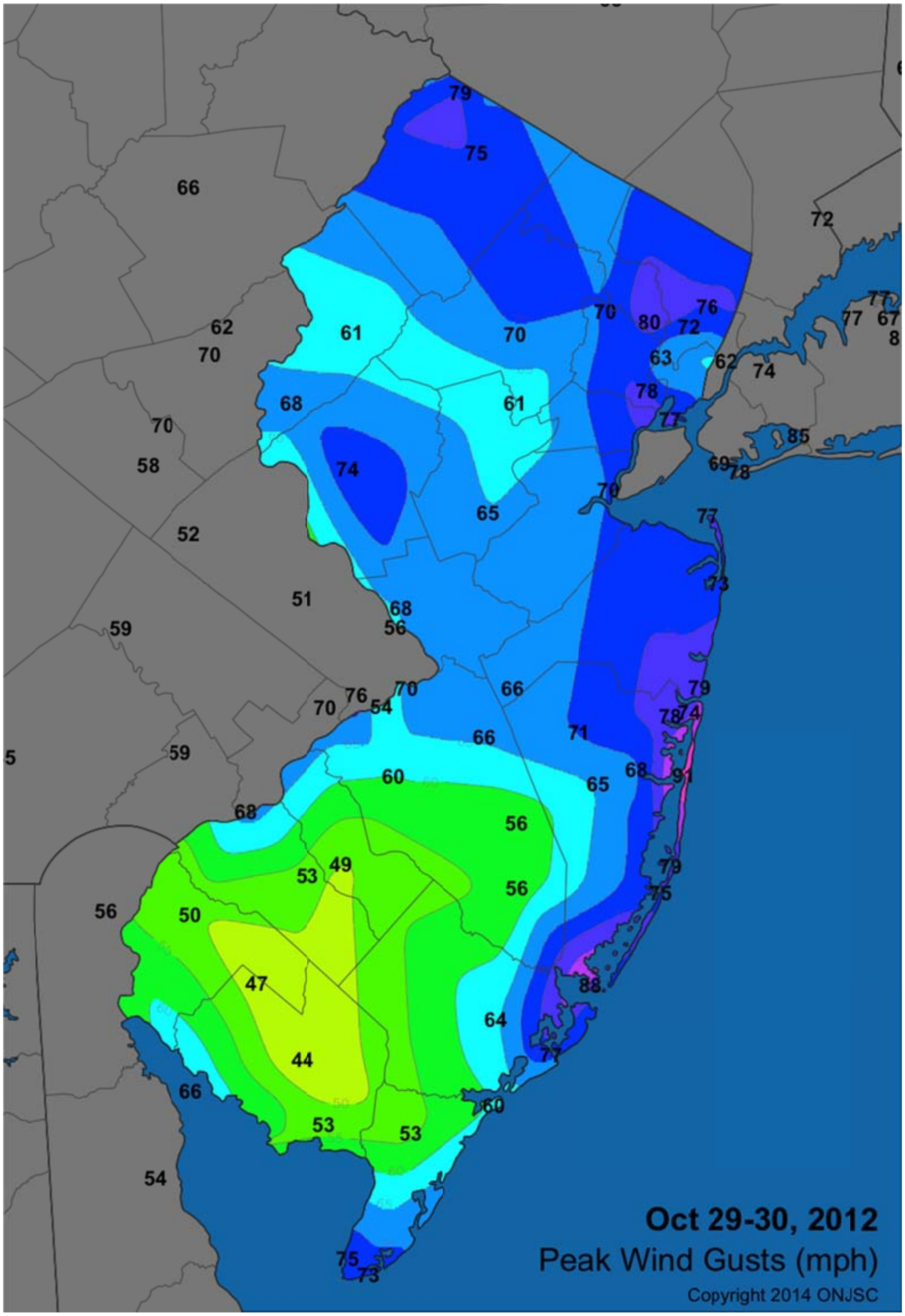

Figure 3. Maximum wind gusts associated with Sandy as observed at NJ Weather and Climate Network, NJ Community Collaborative Rain, Hail and Snow Network, and NWS Cooperative Observing Program stations (Office of the NJ State Climatologist).

Figure 4. Keansburg, NJ amusement park adjacent to Raritan Bay. Photo courtesy of Sonia Szczesna.

Figure 5. Holgate, NJ at the southern end of Long Beach Island. Photo courtesy of Will Randall-Goodwin.

It is expected that warming will be greater in winter than summer. However given that the range of summer temperatures is not nearly as wide as that in winter, summer warming of a lesser absolute magnitude than winter could be just as significant as more substantial winter increases. The key to winter warming is the freezing point. Since temperatures presently hover near that threshold in winter, considerable warming will likely produce a marked reduction in the frequency of sub-freezing temperatures and frozen precipitation. While temperatures will continue to fall below freezing quite often during the winter, they will become less common and cold days and runs of cold days are likely to become infrequent and less intense. Meanwhile, the number of hot days over 90°F is expected to rise considerably.

It is anticipated that as the 21st century continues, annual precipitation will remain steady and possibly increase from late 20th century values. End-of-century totals may be 10% higher. It is important to reiterate that the last 30 years of the 20th century were the wettest such interval during that century (figure 2). Late century increases from the previous 75 years ending in 1970 were similar to what is projected for the coming 90 years. Precipitation intensity is expected to increase as the century progresses. In other words, even should annual precipitation fail to increase, as seen recently, a greater percentage will likely occur in intense episodes. This would lead to more flash and river flooding. The recent National Climate Assessment (Melillo et al., 2014) suggests that such a pattern is already underway in the Northeast.

Precipitation totals, frequency, and intensity are not the only things that must be considered in evaluating the overall water budget. It is also critical to factor in the expected warmer temperatures and the cumulative impact of precipitation and temperature on evaporation. Infrequent, heavy rains that quickly run off or evaporate may become more commonplace as this century progresses. This could actually lead to more frequent droughts, even as intense events and total precipitation increases.

Might the future bring more extreme storms such as Sandy? With a warming atmosphere and ocean, and a resulting increase in atmospheric moisture, the climate system is increasingly primed for wetter, more intense storms. Of course there must be atmospheric disturbances, or triggers, to generate destructive events. However with sea level expected to rise another foot by mid century and three feet by 2100 (K. Miller, per. comm.), even lesser storms may be quite damaging. There is also speculation amongst atmospheric scientists that such “rogue” storms as Sandy may become more commonplace as climate change continues to impact surface conditions and atmospheric circulation in the Arctic and middle latitudes (Francis and Vavrus, 2012)

CONCLUSIONS

New Jersey is in lock step with the majority of the planet in seeing recent temperatures on average exceeding those of the previous century. So too has precipitation increased in the past several decades. A preponderance of evidence suggests that human impacts on the environment are largely responsible for the majority of these changes. This also includes a greater frequency of extreme precipitation events, which at times have been accompanied by severe flooding. It is also apparent that Hurricane/post tropical cyclone Sandy had a greater impact on New Jersey than might otherwise have been the case were the region not warming and sea level rising, each associated with anthropogenic climate change. Climate models suggest that the Mid Atlantic will continue to warm in future decades, precipitation will remain steady or possibly increase, and extremes, be they storms, drought or heat waves, will continue to increase in frequency and magnitude.

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INVITED TALKS (ABSTRACTS)

IMPACT OF HURRICANE SANDY ON URBAN SOIL GEOCHEMISTRY IN JERSEY CITY, NJ

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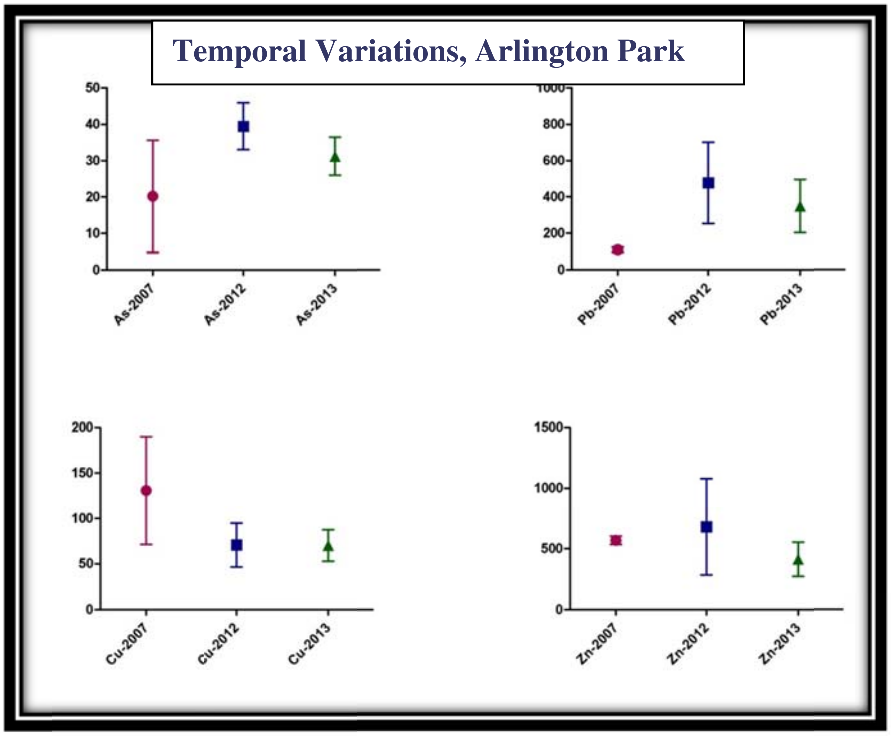
Urban environments as the densest human habitations are extremely vulnerable to anthropogenic and natural disasters. Hurricane Sandy was a powerful recent disaster, which devastated the US east coast (including New Jersey) in October of 2012. Such large-scale events may affect the overall geochemical characteristics (physical, chemical and mineralogical compositions) of urban soils which ultimately control surface environmental quality. To help improve our capacity for prediction and mitigation of potential environmental health effects from similar disasters, it was logical to investigate the magnitude and variability of the impact of Hurricane Sandy on urban soils in Jersey City, NJ, one of the most polluted cities in US.

Arlington Park, JC (2013). *Photo credit: Nurdan S Duzgoren-Aydin*

The on-going urban environmental monitoring program at the New Jersey City University provided a unique opportunity to establish the pre-Sandy urban-soil-baseline geochemistry. Based on this, it was possible to determine that there were no statistical differences between the concentrations of heavy metals in soils collected from the same urban setting before and after Hurricane Sandy. In addition, spatial distribution of heavy metal concentrations in the soil remained very similar. However, post-Sandy samples had a lower level of heavy metal concentrations with a narrower range of variations compared to those collected prior to Hurricane Sandy.



Pb: 477±223 mg/kg
Max: 793 mg/kg

Pb: 349±146 mg/kg
Max: 640 mg/kg

(Disclaimer: This presentation has been made elsewhere before)

SOCIAL COSTS OF ENVIRONMENTAL METRICS: REPRESENTATION AND CHALLENGES

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A complete sustainability assessment of a remediation project's life cycle would require evaluation of the costs borne by society in terms of environmental, economic, and community impacts. However, methods to evaluate societal impacts of a remediation project have not yet been established. The approach applied here assigned societal monetary values to the sustainability metrics generated from an environmental footprint analysis. The societal unit cost of each metric would ideally take into consideration a wide range of impacts on society. The greatest challenge was to identify the societal cost associated with each sustainability metric. A single source containing societal costs for all footprint analysis sustainability metrics does not exist. Furthermore the sources available often used different models for calculating the costs and present several cost options, such as the social cost of greenhouse gas emissions at 2.5 percent, 3 percent, or 5 percent discount rates. We present one possible methodology for evaluating the social costs of environmental metrics here, along with an economic analysis of some of the key parameters such as discount rates and carbon prices.

A cost benefit analysis (CBA) was conducted for a remediation project using existing engineering data and invoices. The CBA was extended to incorporate societal costs in terms of emissions (greenhouse gas, nitrogen oxides, sulfur oxides, and coarse particulate matter), as well as total energy used, in order to evaluate the social impact of remedial activities in terms of costs borne by society. Sensitivity analyses were conducted for several key social parameters to evaluate the impact of differing discount rates and carbon prices. For example, carbon prices were researched from a number of sources including work by United States Environmental Protection Agency and the United States Government Interagency Working Group on Social Cost of Carbon, as well as current market values of carbon drawn from the Western Climate Initiative and Regional Greenhouse Gas Initiative (RGGI).

Sustainability Metrics - SiteWise™

Site Characterization Alternatives	GHG Emissions	Total energy Used	NO_x Emissions	SO_x Emissions	PM10 Emissions
	metric ton	MMBTU	metric ton	metric ton	metric ton
Conventional	9.05	1.18E+02	2.00E-02	2.03E-03	6.34E-04
Phased Focused	5.84	7.31E+01	1.15E-02	1.20E-03	5.85E-04

Costs Borne by Society – 36% Savings for Phased Field Investigation

Site Characterization Alternatives	GHG Emissions	Total energy Used	NO_x Emissions	SO_x Emissions	PM10 Emissions
	metric ton	MMBTU	metric ton	metric ton	metric ton
Conventional	$19,912.77	$0.063	$615.32	$9.72	$1.32
Phased Focused	$12,849.79	$0.039	$353.81	$5.75	$1.22

The results of this research expand upon the cost borne by society methodology currently being developed to evaluate the social impacts of remediation. The social-CBA showed that greenhouse gas emissions contributed the most to the costs borne by society. The results of the sensitivity analysis illustrate that discount rate and source of the societal cost can significantly impact the overall costs borne by society. This research provides guidelines for the remediation sector on how to quantify the social impact of remediation. The remediation and redevelopment benefits and associated tradeoffs such as increase in property value and quality of life of neighboring communities has not been represented in this paper, giving rise to significant avenues for further research.

BEACH-DUNE RECOVERY AT NEW JERSEY BEACH PROFILE NETWORK SITES FOLLOWING HURRICANE SANDY

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The Coastal Research Center at the Richard Stockton College of New Jersey (CRC) has monitored shoreline trends for over 28 years at 105 locations for the state New Jersey Beach Profile Network (NJBPN). Within days following Hurricane Sandy's landfall (in Atlantic County on October 29, 2012), the CRC initiated a post-storm survey and assessment of the New Jersey shoreline to document how the beaches performed during the record event. Wave and storm surge elevations generated extensive beach and dune erosion along New Jersey's Atlantic shoreline, with beach-dune erosion and damages to developed areas generally increasing north of landfall. Measurements of wave run-up ranged from 14.5 feet (NAVD88) at Atlantic City in Atlantic County to 24.6 feet (NAVD88) in Long Branch in Monmouth County which suffered the greatest beach/dune volume losses of the stations within NJBPN. The extent of erosion of the beaches and dunes and damages to structures and infrastructure were dependent upon the elevation of the storm waters, volume and extent of the berm, elevation and width of the dune, and local shoreline management practices. Federally-designed shore protection projects with a design dune elevation at 22 feet NAVD88 completely protected landward structures from wave damage on Long Beach Island. Communities that suffered the greatest damages to structures and infrastructure were those where dunes were non-existent, or where elevations of the beaches and dunes were low or had narrow beach widths. The storm created a dramatic transfer of beach/dune sand volume out into the offshore region; creating sand bars all along the Atlantic coast. The amounts moved seaward ranged from 35 to 70 cubic yards per foot of shoreline (yds^3/ft.) and were deposited in eight to 22-foot water depths. Only the City of Cape May experienced beach accretion from the storm and that was due to its location and wave and tidal conditions with respect to landfall.

The survey data were analyzed to show changes in the location of the shoreline and sand volume changes for each of the four ocean-fronting counties. In the months after the storm, the CRC documented the shoreline recovery as sand moved from the offshore back onto the beach. Human intervention also played a part in shoreline recovery. Emergency storm protection efforts by the US Army Corps of Engineers (Philadelphia and New York Districts) in Monmouth, Long Beach Island (Ocean County), Atlantic and Cape May Counties produced extensive volume increases and large gains were documented between the spring 2013 and fall 2013 surveys when most of the emergency projects were completed. Ocean County experienced the most volume losses between the fall 2012 to spring 2013(-10.70 $yds^3/ft.$) due in part to the storm-induced breaches and overwashed sands that occurred in the northern portion of the county. The greatest volume gains during the summer recovery months (spring 2013 to fall 2013) were recorded in Atlantic County (33.14 $yds^3/ft.$) and are attributed to the Federal beach restoration projects. In Monmouth County, natural recovery returned over 60% of the amount of sand that was present prior to Hurricane Sandy and 61% in Ocean County.

NJBPN 153 – 1117 Ocean Avenue, Mantoloking

The November 5, 2012 (left) was taken within 300 feet from the temporary breach that opened during Sandy. The home at 1117 Ocean Avenue was completely removed from its location and the residence in the photograph was also destroyed. The photo on the right (September 20, 2013) shows the ridge of recovered sand from inland and dredged from Barnegat Bay.

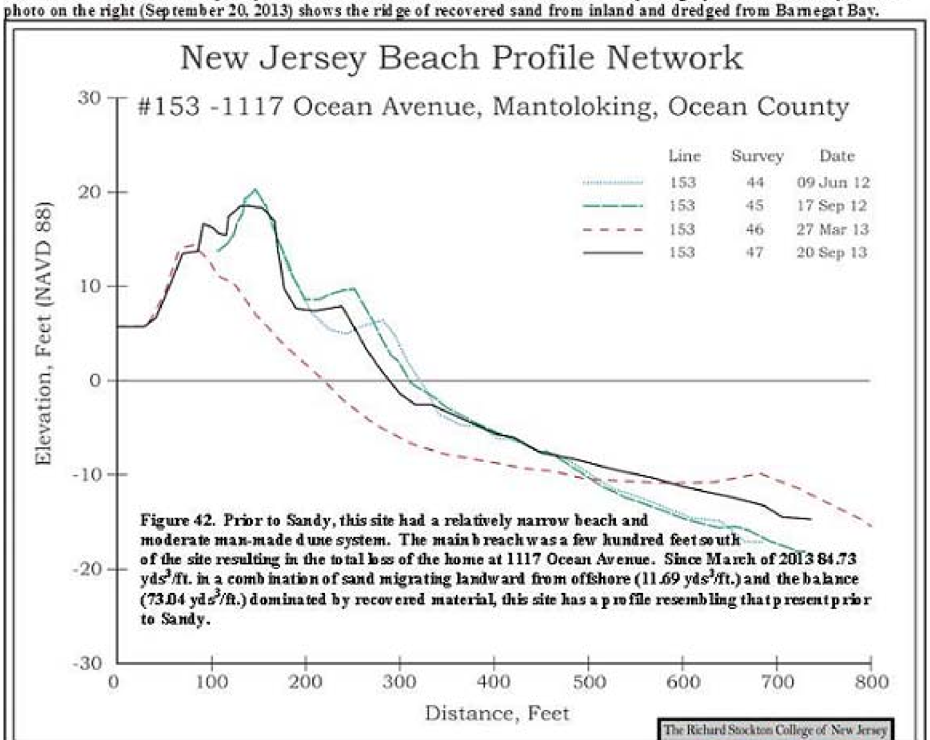

Figure 42. Prior to Sandy, this site had a relatively narrow beach and moderate man-made dune system. The main breach was a few hundred feet south of the site resulting in the total loss of the home at 1117 Ocean Avenue. Since March of 2013 84.73 $yds^3/ft.$ in a combination of sand migrating landward from offshore (11.69 $yds^3/ft.$) and the balance (73.04 $yds^3/ft.$) dominated by recovered material, this site has a profile resembling that present prior to Sandy.

URBAN SPRAWL AND "GREEN" REMEDIATION OF ARSENIC IN RESIDENTIAL SOILS

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Arsenical pesticides have been used extensively in agriculture until recently that has left a legacy of arsenic-rich soils in the farmlands. Widespread urban sprawl - particularly in the last three decades - converted a larger number of former farmlands to residential properties in many metropolitan areas in the United States. This change in land use from agricultural to residential has tremendously increased the potential of human exposure to soil arsenic, primarily via soil ingestion by hand-to-mouth activity in children. One of the more logical and cost-effective remediation methods for arsenic in residential scenarios is in-situ immobilization, which results in lowering arsenic bioavailability, hence, in reducing human health risk from chronic exposure to arsenic-rich soils. Drinking water treatment residuals (WTRs) promote soil immobilization of arsenic in a way that is both inexpensive and less ecologically disruptive.

Photo Credit: National Geographic

WTRs are by-products of the drinking water purification process that typically contain - depending on the treatment process - large amount of Al/Fe oxides that are largely amorphous and have high affinity for oxyanions due to both high specific surface and favorable pH dependent surface charge. We conducted short- and long-term, laboratory and greenhouse studies to investigate arsenic retention-release by Fe- and Al-based WTRs and WTR-amended soils. Arsenic bioaccessibility and in-vivo bioavailability were evaluated using in-vitro physiologically based extraction tests, and nude mice model, respectively. Aqueous and surface speciation of arsenic were studied, and risk analysis was performed. Although not yet tested in a landscape scale under natural conditions, incubation and greenhouse studies indicate that WTR amendment has the potential to develop into a cost-effective "green" remediation technology for arsenic enriched soils.

(Disclaimer: This presentation has been made elsewhere before)

STUDENT RESEARCH POSTERS
ABSTRACTS

*Undergraduate Student
** Graduate Student

HEAVY METAL CONCENTRATIONS IN COMMUNITY GARDEN SOILS, NORTHERN NEW JERSEY: PRELIMINARY SURVEY

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Urban community gardens or urban agriculture practices are becoming increasingly popular as a source of locally grown foods across downtown neighborhoods of major cities around the world. This trend creates a new urban land-use pattern that may alter exposure pathways of potentially toxic elements including heavy metals (such as As, Cu, Pb, and Zn). The consumption of vegetables and fruits grown in urban settings with elevated heavy metal contents may pose serious health risks. The heavy metals can be absorbed by the plants to various extents depending on several factors including type of plants, elements and their chemical speciation as well as physical and chemical characteristics of soils. Urban community gardens are often located on vacant lots in neighborhoods with historically elevated concentrations of heavy metal, especially Pb, primarily resulting from factors such as deteriorating housing and historical use of lead paint.

To be able to assess the health risk levels for individuals consuming locally grown food in urban settings, first step involves determining heavy metal concentrations in garden soils. During this preliminary study, limited numbers of garden soils from raised beds were collected in Weehawken, New Jersey (Fig.1), with a particular aim of relating their pH and particle size distributions to the heavy metal concentrations.

Compared to pH (5.4±1.1) values of Boonton Soil Series, which represent background soil properties in New York and New Jersey region, the sampled garden soils are slightly more neutral to alkaline (7.0±0.4). The garden soils were composed of 78% coarse- and medium-size particles (> 125 µm), whereas the background soils contain 16% fine-sand and 20% silt- and clay-size particles. Heavy metal concentrations in soils were determined by means of a portable Niton XRF (pXRF) using their fine-size fractions (< 63µm). Lead (52-364 µg/g), Zn (140-317 µg/g) and Cu (52-204 µg/g) concentrations in the garden soils varied significantly. However, the samples from an area near a parking lot and surrounded by residential buildings, consistently had higher levels of heavy metal concentrations, e.g., Pb (186±90), compared to those samples from an open area (82 ±15 µg/g). While Pb concentrations in the garden soils are lower than 400 µg/g (EPA, action level for Pb in residential soils), consumption of vegetables and fruits grown in these soils should still be considered to pose serious health risks, until the ability of these products for bioaccumulation of Pb and other potentially toxic elements are shown to be insignificant.

Fig.1. Community Gardens in Weehawken, NJ.

Photo credit: Nurdan S Duzgoren-Aydin

GLOBAL CHALLENGES AND LOCAL LEGISLATIONS: USING GIS MAPS AS AN EDUCATIONAL TOOL TO MOBILIZE LOW INCOME RESIDENTS AND BRING AWARENESS TO LOCAL LEGISLATORS-CASE STUDY

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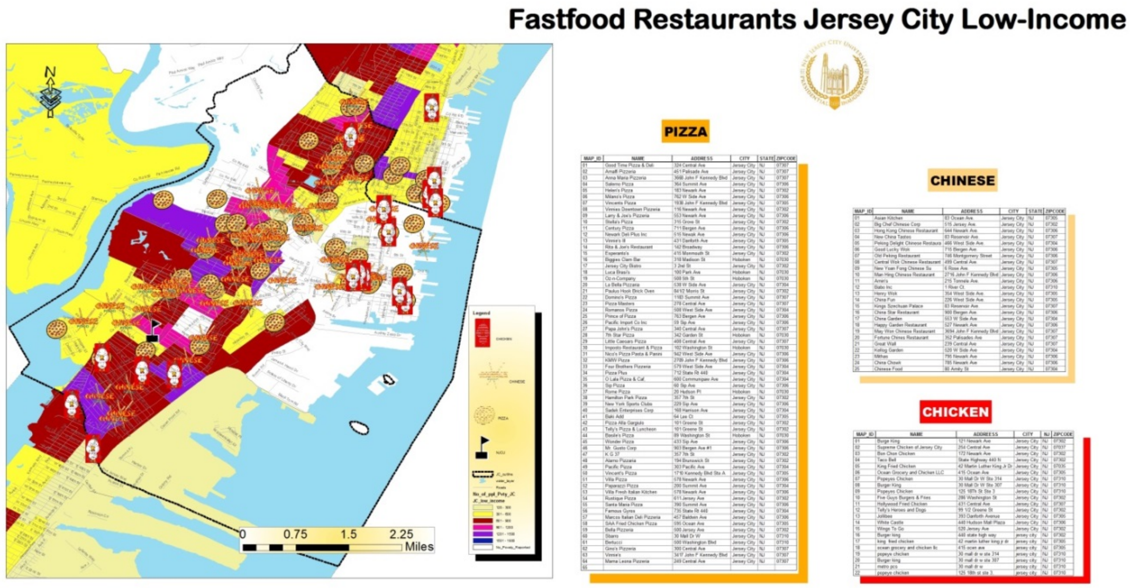
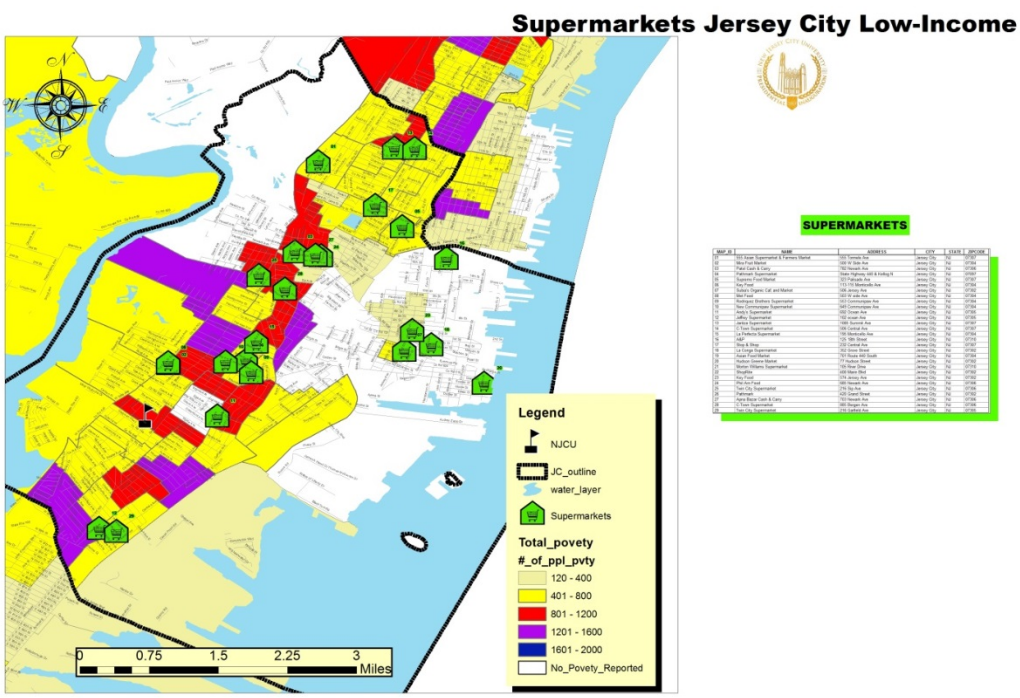
With approximately 870 million people of the 7.1 billion people in the world suffering from chronic undernourishment (FAO, 2012), alleviating hunger is imperative as it burdens societies economically, socially, and politically. Though the majority effected live in underdeveloped countries, there is a rapid rise in developed countries from 13 million in 2004 to 2006 to 16 million in 2012, reversing a steady decrease from 20 million in the early 1990s (FAO, 2012). In the U.S., movement to alleviate food scarcity for vulnerable populations (particularly women and children), has been on the forefront for public health policy since 1974 with the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). With the continuation of this federal mandate to ensure the well-being of the American underprivileged, local governments struggle to inform their communities on regularly revised WIC packets through education and community mobilization. Aiding needy populations through effective outreach and local policy is a great challenge, especially as there are expectations to do both simultaneously. In Jersey City, food insecurity is a global issue of current local focus where GIS mapping serves as an educational tool to spur both residents and legislators into advocacy

Jersey City's Department of Health and Human Services (JCDHHS) and undergraduate community health students from New Jersey City University implemented "Cooking Matters", a program designed to provide educational grocery store tours to low-income residents to increase access to healthy foods. The students employed GIS mapping to identify correlations between residents' levels of economic prosperity and local food distribution businesses. The maps were displayed at community health events for educational purposes. What was found was that the GIS maps assisted with communicating to both targeted residents and policy makers quickly and comprehensively to ultimately motivating advocacy in both parties. Due to maps' ability to transcend multiple barriers such as language and literacy, they have the capacity to deliver effective services consistently while easily explaining diverse and ever-changing complexities. One map can serve as multiple methods as an educational tool to showcase crucial patterns for community engagement and policy development.





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GLOBAL CHALLENGES: ACCESSIBILITY OF SUPERMARKETS TO SENIOR CENTERS IN JERSEY CITY USING GEOMAPPING TECHNOLOGY

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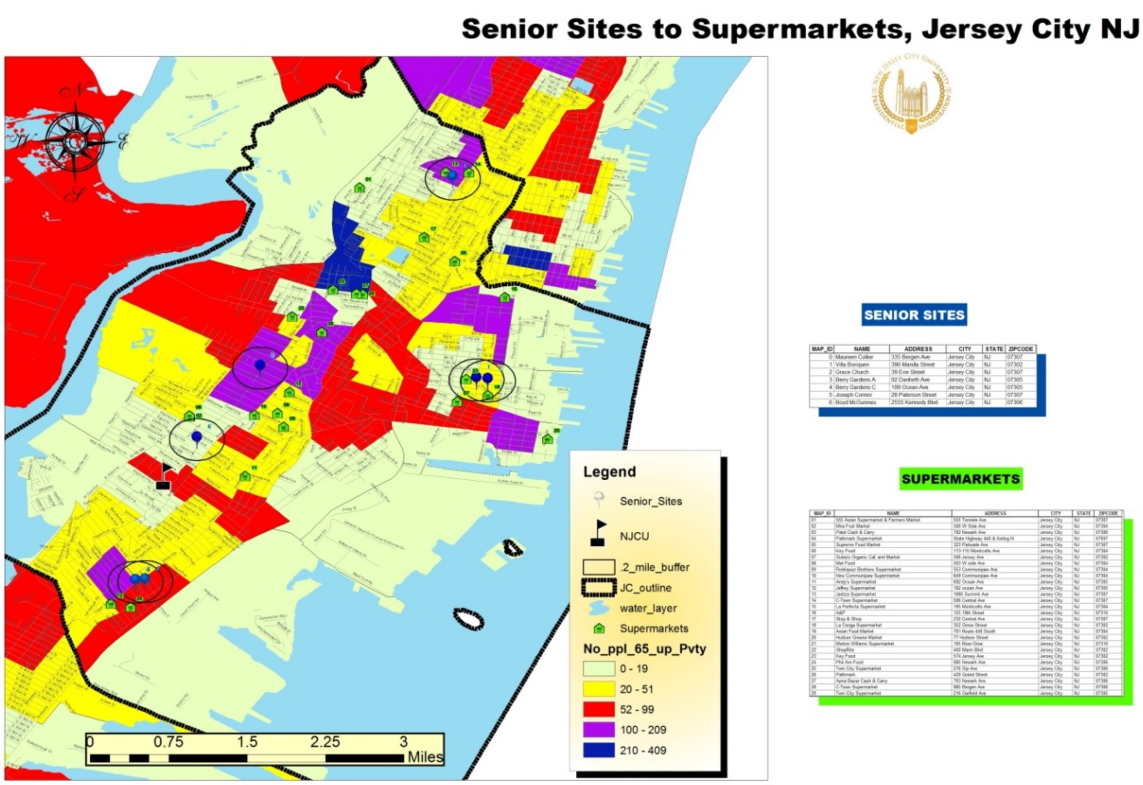
The NJ Hudson County Office on Aging has twenty-one senior congregate lunch sites in poor socio-economic urban areas. The agency, in conjunction with New Jersey City University (NJCU), has a grant which provides nutrition counseling, nutrition education, and fitness classes to 1,500 seniors a year. Approximately 36.7% of the 65 years and over population in Hudson County live below the poverty level (American Fact Finder, 2010). Seniors in Jersey City make up 9 percent of the population, 3.7 percent are males and 5.4 percent are females. Seniors account for 13% of the population in Jersey City. According to US Census (2010), Jersey City population was 247,597. It is the second largest city in New Jersey and ranks 17th in population density. There are 11,792.7 people per square mile. Jersey City population density is higher than the state (1, 007.95 people per square mile) and national average (81.32 people per square mile).



This paper reviews the vulnerability of the senior population and the physical environmental challenges, travel obstacles, and the need for community support to access supermarkets from senior centers as a central point in Jersey City. The GIS technology is used to map the city blocks, distance, and strategies for travel. More than half of the participating seniors in the nutrition and fitness program report being vulnerable, frail, and have an income below $11,490. These factors affect mobility in the older population by restricting their ability to walk, drive, or travel to supermarkets, and carry groceries in an environmentally safe community.

The GIS mapping was used as a tool to locate the distance and proximity of supermarkets to senior centers and discuss challenges to food accessibility, opportunities for travel, and community action needed to optimize nutritional options. A review of the literature shows how and when seniors are most likely to walk, drive, and use public transportation to enhance individual capacity. The focus groups conducted at various senior center sites will show how the built environment presents restrictions on the ability for seniors to walk in high-density areas and access food that is diverse and affordable at supermarkets. The GIS maps allow the service providers to assess the distance of the senior centers to supermarket while assisting seniors on how to negotiate the number of city blocks, traffic lights, street crossings, and public transportation. The GIS maps offer an opportunity to advocate on behalf of low-income seniors and present their need for various modes of transportation such as using senior housing vans, supermarket shuttles and simulating stress-free group walks to nearby supermarkets. Key to moving this agenda forward is to illustrate where supermarkets are located in reference to low-come areas and collaborate with community organizations, economic development planners, and other community partners in Jersey City to effect change.

USING GIS TO SUPPORT URBAN FOREST COMMUNITY AND HEALTH

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This project is being performed in support of the Hudson County Division. NJCU students and faculty are assisting in the creation of a Shade Tree Inventory, which is the first established goal of the *Urban Forestry Initiative*. We are using Leica mapping GPS receiver and collective information non-spatial attributes in addition X, Y NAD State Plane coordinates. Examples of attributes being collected include: tree species, age, health, and attributes that could interfere with community health and public safety (e.g. overgrown or broken tree limbs.)

Data collection has been collected in Bayonne; work continues in northern Hudson County. To date, we have inventoried approximately 898 trees. We estimate we are 14 percent completed at this time. One example of the benefits of this type of inventory has to do with carbon sequestration. For instance, we have identified a number of London Plane trees (Platanus acerifolia), that have been identified in a New York City survey as having the capacity to sequester up to 80 kg of Carbon per tree per year fully grown.

IMPROVING THE SUSTAINABILITY OF CLEANUPS THROUGH CONSERVATION AND REUSE OF REMEDIATED GROUNDWATER: A SURF INTIATIVE

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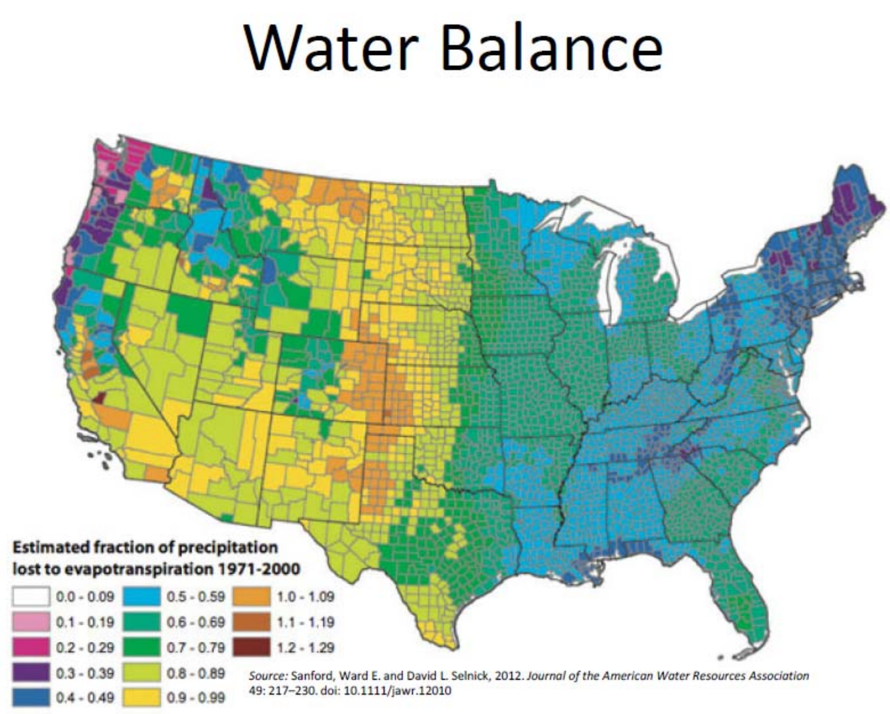
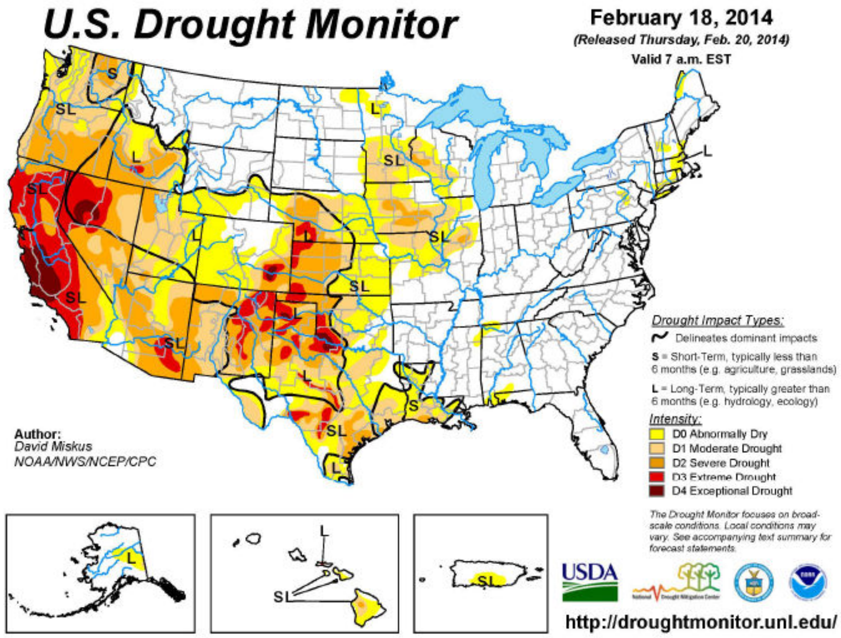
"Improving the Sustainability of Cleanups Through Conservation and Reuse of Remediated Groundwater: A SURF Initiative"

The Sustainable Remediation Forum (SURF) promotes the use of sustainable practices during implementation of remedial action activities with the objective of balancing economic viability, conservation of natural resources and biodiversity, and the enhancement of the quality of life in surrounding communities. As the global population and the demand for water continue to increase, the challenge of supplying potable water becomes more prominent, requiring us to manage this natural resource in a sustainable manner. In 2012 SURF undertook an initiative to improve the sustainability of remedies by encouraging a greater focus on conservation and reuse of remediated groundwater at cleanup sites. To that end SURF produced a document titled "Conservation and Reuse of Groundwater at Remediation Sites."



U.S. Drought Map



This document considers the impediments to conservation and reuse, and provides case study examples where reuse of treated groundwater from remediation sites was accomplished. The document also highlights examples of reuse from the municipal wastewater industry, focusing on situations where concerns similar to those associated with reuse of groundwater from remediation sites were successfully resolved.

Challenges such as water quality impacts, water balance and reliability, economics, public perception, and actual and perceived liabilities can hinder the successful conservation and reuse of groundwater during the design, implementation, and maintenance of remediation projects. Conservation and reuse efforts are encouraged by the increasing costs of water supply, but many appear to be motivated by the clear perception that water is inherently valuable. As evidenced by the case studies presented in the SURF document, there are efforts underway all across the United States, as well as in other countries, to increase the use of remediated groundwater. The case studies highlight the challenges mentioned above, as well as the approaches implemented to overcome those challenges.

EFFECT OF HYDRO-RAKING ON THE TROPHIC LEVEL OF LAKE WAPALANNE, NEW JERSEY: SHORT-TERM AND LONG-TERM STUDIES

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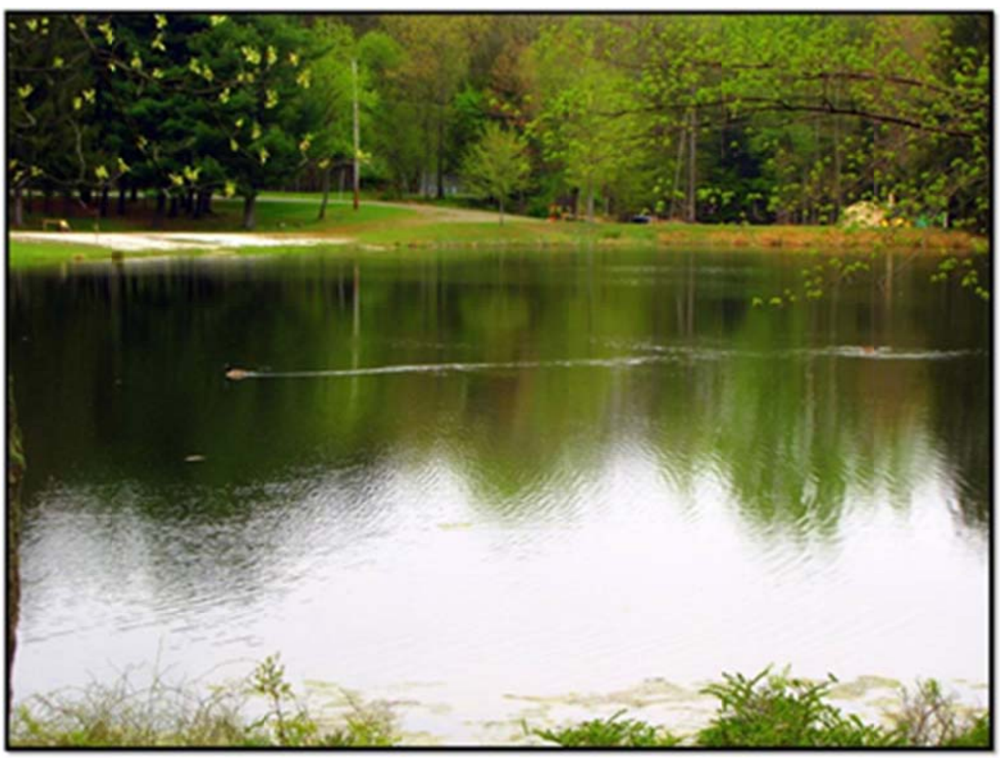
Lake Wapalanne, a man-made lake located in Sandyston, New Jersey, is surrounded by dense vegetation of the Stokes State Forest that receives significant input of phosphorus (P), which promotes algal growth. The lake consists of two distinct lobes, interconnected by a channel, with water flowing from south to north. Over the past few years, the south lobe of the lake became very shallow and started suffering from massive algal blooms. As a potential solution, hydro-raking was conducted in August, 2009 in the most severely affected sections of the south lobe of Lake Wapalanne. Hydro-raking is a technique for removal of aquatic vegetation and unconsolidated bottom debris, which sometimes results in accidental dredging of lake sediments. One of the major concerns associated with this partial dredging is release of bound P from the sediment, which is the primary internal source of P in lakes and rivers, thus causing further algal growth.



Lake Wapalanne, Photo Credit: Padmini Das

The current study determined the short term (11 months) and long term effects (4 years) of hydro-raking on trophic level in various sections of Lake Wapalanne, based on total P content. In addition, basic water quality parameters, such as pH, conductivity, and dissolved oxygen levels were also measured. Results showed that for water samples collected a month before hydro-raking (in 2009), the amount of P was higher than the level indicative of eutrophication at only one sampling location in the south lobe of Lake Wapalanne. Total P content of all samples collected from the north lobe, the intermediate channel, inlet and outlet streams were well below eutrophic level. Water samples collected after 11 months of hydro-raking (in 2010) were much higher in P content compared to those collected prior to hydro-raking. Total P levels indicated that several sections in the southern lobe and some in the northern lobe had become either eutrophic or supertrophic, resulting in further algal blooms. To prevent algal growth, periodic applications of inorganic algaecides were made in the lake since 2010. Analysis of water samples collected almost 5 years after hydro-raking (in 2014) revealed that the trophic level at the south lobe of Lake Wapalanne has gone down, as the dissolved P moved towards the north lobe, consistent with the direction of flow in the lake. As a result, the entire intermediate channel, north lobe, and the outlet stream now contain high amounts total P, more than three times higher than the P level that indicates eutrophication.

+ High School Student

GEOCHEMICAL INVESTIGATION OF THE IRON SPRINGS DISTRICT

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The Iron Springs District in Southern Utah hosts the second largest iron deposit in the United States. The main ore mineral is magnetite and it is unique for its rich iron content and large apatite inclusions. The district's main process of formation has yet to be identified despite its large size and economic importance. However, the presence of apatite suggests that the region was formed either from magmatic hydrothermal fluids or through silicate melt-oxide rich immiscibility. This study aims at addressing this question through geochemical microanalyses of the apatite, fluid inclusions, and possibly melt inclusions held within. Thin sections were made in order to study the petrography of the samples and subsequent electron probe microanalyses (EPMA) were conducted in order to determine the exact chemical composition of the apatite and magnetite. EPMA also yielded results concerning the trace elements found within the apatite crystal. The general fluid inclusion composition and minimum trapping temperature was determined using a USGS Fluid Inc. heating-freezing stage. Based upon the collected data, the formational environment and fluid inclusion geochemistry of the Iron Springs District has been determined.

GEOCHEMICAL FLUID VARIATIONS OF CLOSE-PROXIMITY PEGMATITES IN OXFORD CO. MAINE

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Pegmatites are coarse-grained intrusive bodies that form rapidly and generally represent fluid drainage of larger granitic bodies. Large mineral sizes indicate uniform distribution of material for nucleating crystals to grow as well as potentially liquid-liquid immiscibility (i.e. silicate melt-hydrothermal fluid). Pegmatites are economically important storehouses of gemstones (such as beryl and tourmaline), industrial minerals (such as quartz, muscovite, and feldspar), and REE-bearing phases (such as columbite, tantalite, and pollucite). This project focuses on examining the fluids of rare-earth type granitic pegmatites. Rare-earth pegmatites are typically categorized into NYF-type (Niobium, Yttrium, and Fluorine) and LCT-type (Lithium, Cesium, and Tantalum) pegmatites. The primary goal of this study is to examine geochemical variation within the pegmatite fluids over short distances within different "quality" quarries. Samples were collected from three geographically adjacent pegmatite quarries located in Oxford County, Maine. The quarries include Noyes (Harvard), Waisanan, and Tamminen quarries. These quarries belong to the Oxford pegmatite field, are within a 1 km radius, and are categorized as LCT-type pegmatites. Previous pegmatite work in this area has focused more on the descriptive mineralogy and/or geochemical analysis of specific minerals rather than on overall composition and fluid evolution. Fluid inclusions trap important information regarding geochemistry, and formation conditions. Therefore, fluid inclusions represent the exact fluid composition from which the host crystal formed. This study discusses fluid geochemistry and petrogenesis of fluids trapped in quartz, apatite, and tourmaline crystals collected from these pegmatites. Fluid inclusion freezing experiments were used to determine fluid compositions and salinity. The major and trace element composition of apatite and fluid inclusions were determined using laser ablation-inductively coupled plasma mass spectrometry (LA-ICPMS). The apatite geochemistry was determined using electron probe microanalysis (EPMA).

FIELD TRIP GUIDE

4 October 2014 Field Trip to Long Beach Island

Ocean County, New Jersey

FIELD TRIP TO LONG BEACH ISLAND OCEAN COUNTY, NEW JERSEY

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INTRODUCTION

Long Beach Island (LBI) is the first of eight barrier islands on the central and southern New Jersey coastline. The northern Ocean County shoreline is a long spit that begins at Bay Head that was a barrier spit historically, except when it became a barrier island for five days following Hurricane Sandy. LBI is the longest of the present crop of barrier islands (18 miles). Long Beach Island has been divided by storms into multiple islands that were recombined by man following each storm event. The last inlet breach that played out naturally occurred in January 1920 generating what came to be known as Beach Haven Inlet. The 1962 March storm cut two inlets that were closed by post-storm recovery efforts. Hurricane Sandy, in spite of countless points of direct wave overwash into Barnegat Bay, did not cut any ebb-flow channels.

Development went relatively slowly during the first half of the 20th Century since coming by rail required a measure of wealth because one did not stay for just one day. By 1950, the rail trestle was converted to a highway (two lanes) and enterprising developers commenced promoting home sales across the entire island. Following the 1962 northeast storm disaster, properties sold off cheaply for about 4 years, but after the storm faded into memory the value and pace of development soared.

The island's sand supply shows relative identity in terms of the heavy minerals present (garnet, zircon and glauconite) with sediments found further north indicating that material eroded from the Monmouth county bluffs had been transported as far south as Holgate on LBI (McMaster, 1954). A relatively coarser average grain size also fits with the northern beach sediments. South of LBI the mineralogy of the heavy minerals changes (mostly magnetite) and the average grain size decreases from 0.5 phi to 0.25 phi (1/2 to ¼ mm). The impact of these sand size parameters means a steeper offshore gradient and closer impact of storm waves to the development. It also did not help that the governing bodies back in the 1950's allowed oceanfront building to take place up to the crest of the existing dune field. Following the 1962 storm, the replacement oceanfront dunes were compressed into a narrow strip to allow the maximum use of the island for development. The officials turned to rock structures as well, and over the next 30 years 98 rock or rock and timber groins were built the length of the island (excepting the Holgate natural area & the extreme northern segment in Barnegat Light Borough). As erosion took its toll on the oceanfront, sand was trucked onto the island to plug the gaps that storms generated. The first large-scale truck-hauled beach fill occurred in 1994-1995 in Harvey Cedars and was co-sponsored by the State of New Jersey (465,000 cy). Large-scale Federal beach fill projects were initiated in 2006-2007 (Surf City-880,000 cy) and in 2009-2010 (Harvey Cedars-3,000,000 cy) (USACE, 2012). However, over the decades until 2007, Long Beach Township had several hundred thousand cubic yards of quarry sand hauled to the LBI beaches.

STOP #1; BARNEGAT INLET

Barnegat Inlet has been used by local fishing vessels for over 100 years. The inlet location has moved south by 3,000 feet since historical mapping began leading in 1933 to the construction of two inlet rock jetties to protect Barnegat Light. A combination of the southerly inlet migration and the seasonal mercurial channel positions produced the need for stabilization. Two designs emerged from the US Army Corps of Engineers - Philadelphia District (USACE); Plan A was for two parallel jetties about 350 feet apart extending south-southeast from the inlet narrows. Plan B was for an “arrowhead” design where the north jetty extended south- southeast, and the south jetty anchored at 10 Street and angled northeast to meet the tip of the north jetty with a 350-foot entrance (Figure 1A).

Plan B was selected, but over the years, constant dredging, rapid channel migration between the two jetties, and many vessel accidents prompted a review in the 1980’s leading to the re-adoption of Plan A. Construction started in 1988 and was completed in 1990 with a number of cost over-runs and complications due to strong currents and wave activity. The consequence of the new jetty configuration was a massive rearrangement of the ebb-shoals: the sand around the southern side of the inlet into the vast sand deposit we see today (Figure 1B). This is all public space with a development market value of over a billion dollars. Destined to become a maritime forest, the area extends the entire length of Barnegat Light Borough into Long Beach Township. The CRC cross section at 26th Street has advanced 425 feet seaward since 1992.

Figure 1A. 1972 view of Barnegat Inlet showing the original "arrowhead" design for the inlet jetties. Note the emergent shoal in the center of the inlet. One could leave the inlet one day with the navigation channel along the south margin only to find it along the north margin when you returned two days later. The red line approximates the location of the 1990 reconstruction of the south jetty. No old jetty rocks were removed, simply became buried in the fillet that deposited (photo-S. Farrell, 1972).

Figure 1B. By 1995 the new jetty was complete and the sand was accumulating along the south side of the south jetty to create what we see today. The dunes and vegetation will change slowly over time into a maritime forest that should protect Barnegat Light Borough for decades into the future (photo-S. Farrell, 1995).

The impact of Hurricane Sandy on Barnegat Light Borough was strictly limited to back bay tidal flooding. There was absolutely no wave damage, overwash or dune scarping. The wide beach, gradual slope up to the dunes absorbed everything Sandy could generate. Plus the shoreline orientation was more southeast than the normal coastal alignment making wave attack more glancing than direct in approach. Storm waves washed into the dunes adding sand, not eroding it. The beach berm was flattened out with cross shore and littoral transport significant. The net impact of the storm on the residents was some bayside tidal flooding, but the waves just made for a bad beach day.

It is 2,500 feet to the shoreline from the lighthouse parking lot, up from about 100 feet in 1988, so use the guidebook photos to survey the landscape, because time will not allow for an excursion out to the shoreline here. In another 35 years, the maritime forest should appear making this one of the prime natural areas along the NJ coast.

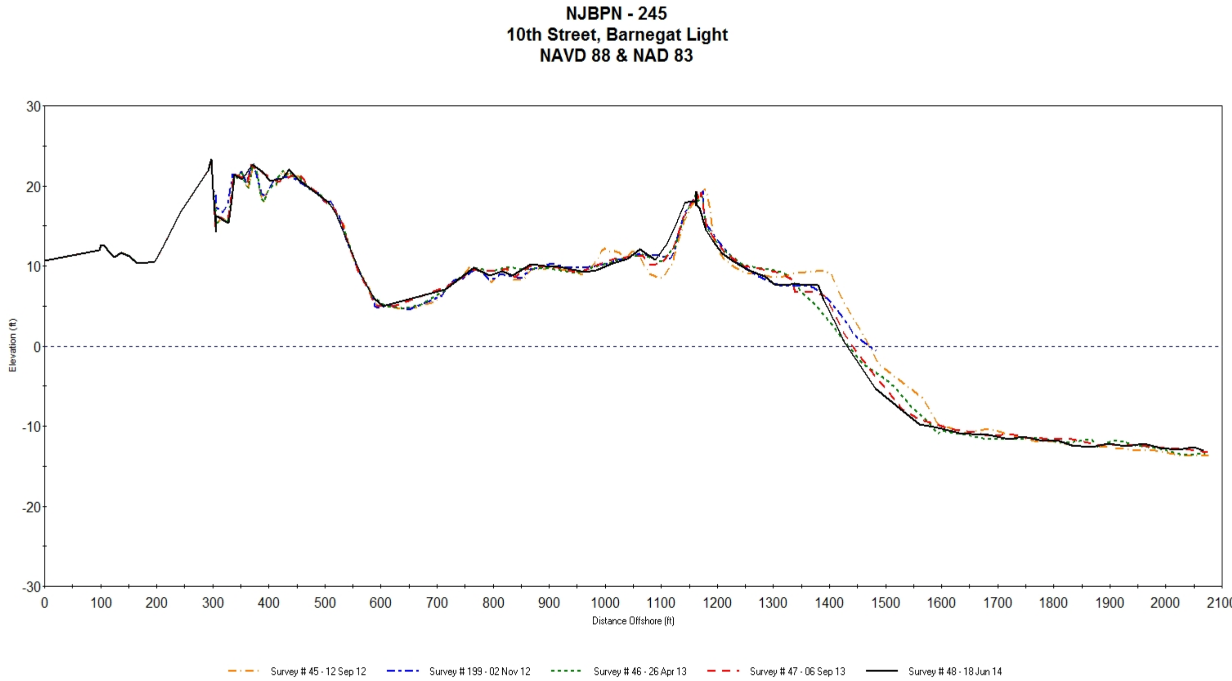

Figure 1C. The pre- vs. post-Sandy profiles at 10th Street in Barnegat Light Borough provide the evidence that nothing much happened during Sandy to this oceanfront shoreline. The berm has retreated about 40 feet since Sept 2012.

STOP #2; 73RD STREET IN HARVEY CEDARS

Harvey Cedars is the next incorporated Borough on LBI. The 1995 NJ State fill can still be found if one digs into the beach north of the boundary to find the yellow-orange sand. In 2009 the initial federally sponsored Shore Protection Project started in Harvey Cedars following a long period of difficulty obtaining property easements from individual owners. Historically, many governing bodies on LBI never purchased or claimed the beach/dune system as public land. Therefore the developers simply sold oceanfront lots that extended to the Mean High Water line (NJ State policy). The NJ State/Federal partnership for the shore protection project requires that a prescriptive easement to allow the beach restoration work be obtained for every property on which the project will occur. These easements are in perpetuity since the project has a 50-year life. Oceanfront owners are generally reasonably well off so there were a myriad of objections and requests for large payments for these easements. Many objections were spurious as they could be, but believed fervently by some owners. Others simply objected to any form of “taking” especially when it came to obstructing the view by the 22-foot elevation dune crest in the project design .

The initial work was completed in Surf City and a portion of Ship Bottom in 2007. Harvey Cedars obtained nearly all the easements and took the remainder by condemnation so they were ready to proceed by 2009. While the project was under construction a residential owner sued

Harvey Cedars over the lost view. The NJ Supreme Court record can be viewed at the following link. Details will be provided on the trip.

http://caselaw.findlaw.com/nj-supreme-court/1637874.html

At 73rd Street the project was complete and performing well. The 22-foot dune also was 25-feet wide at that elevation before descending at a 5:1 slope to the beach. The success in resisting Hurricane Sandy came from BOTH the wide beach AND the dune. Erosion carved away half the sand volume placed on the beach and cut 1/3rd into the dune. Debris was deposited to the crest, but little water ran down the landward slope. There were no direct wave damages done landward of the project. The USACE has since received funding (PL 113-2) to restore all constructed projects in NJ to their design specifications.

Figure 2A. In 2006, prior to the USACE project, the dunes were inconsistent in elevation and width. The low areas at pedestrian access paths were points where Hurricane Sandy's waves may have been able to penetrate and move sand and water landward. (photo-CRC, 2006)

Figure 2B. In 2010, prior to Hurricane Sandy this view to the north shows the new, consistent elevation dune with its plants in place. The 22-foot crest elevation was not so great as to block water views as owners initially feared. This was because many dune crests approached 20 feet in elevation if only in spots. Note the vastly greater dune width after the project. (photo-CRC, 2010)

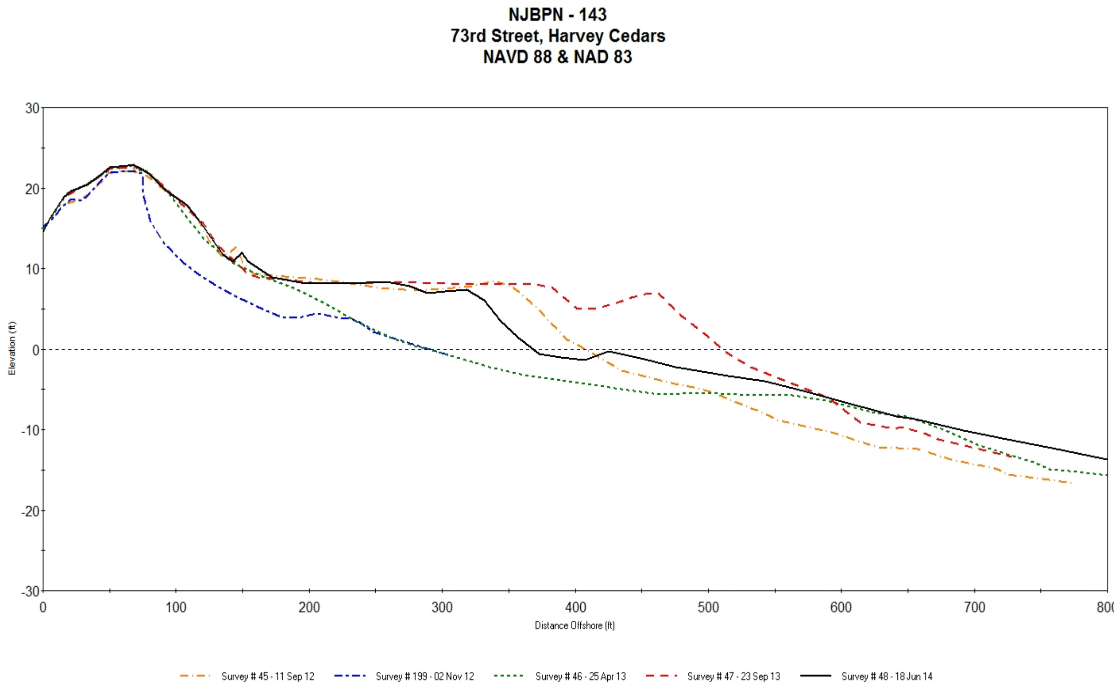

Figure 2C. The pre- and post-Sandy surveys show the impact the storm had on the Harvey Cedars project. The beach was decimated and the dune cut by about 1/3rd of its constructed volume. The feature held, however, and saved the homes landward from wave inundation and damage. The restoration was complete by September 2013 with shoreline adjustment occurring between then and June 2014.

STOP #3; WEBSTER AVENUE; LONG BEACH TOWNSHIP

The USACE work continued in 2009 completing Harvey Cedars, then in 2012 the majority of Brant Beach in Long Beach Township was finished. This left the entire Beach Haven Borough and the southern segment of Long Beach Township without the Federal project in place when Hurricane Sandy struck.

http://www.nap.usace.army.mil/Missions/Factsheets/FactSheetArticleView/tabid/4694/Article/6447/new-jersey-shore-protection-barnegat-inlet-to-little-egg-inlet-long-beach-islan.aspx

The link above is to the District fact-sheet page on the LBI project.

There were dunes established all along LBI, but the base width seldom exceeded 50 feet and the elevation ranged between 14 and 16 feet (NAVD88) with a few up to 20 feet in elevation. Individuals or small groups of owners took it upon themselves to augment dunes with plants, fencing and generate the best dune the narrow beach widths could support. This was painfully visible along this part of the post-Sandy shoreline where remnants of dunes had served to save the home landward from the full fury of overwash. We will pass by one overwash deposit on your right that buried an undeveloped segment of back island flats with new sand stripped off from the beach/dune system. The picture below (Figure 3A) is of the stop area two days after Hurricane Sandy. The overwash fan is evident and is presently the issue with a proposal to build single family homes in the area affected by the overwash deposition and now no longer tidal wetlands.

Figure 3A. November 2012 view of Webster Avenue and the largest sand overwash deposit within the developed section of Long Beach Island. The Nov 3rd view shows the extensive bulldozer work going on to remove up to 4.0 feet of sand from the boulevard and push something back to the beach to form a meager dune. In the time since Sandy, a proposal has been introduced to the NJ DEP to construct single family homes on the newly deposited sand since it no longer is protected salt water wetlands. (photo-Google, Nov. 3, 2012)

Recovery involved excavating up to 4-foot thick deposits on, first the streets and roads, and later from private property and returning it to the beach. Large barrel sieves were employed to extract debris (mostly landscape plants and paving blocks). The oceanfront homes were all constructed on pilings according to NFIP policy, but many owners had walled and filled the grade level area among the house pilings with everything imaginable. Washers, dryers, golf carts, barbeque grills, air conditioning units, freezers, refrigerators, bicycles, stoves, and a few automobiles all were distributed across the island and into Barnegat Bay. Natural gas was venting everywhere, so the CRC staff stuck to the beach to avoid triggering anything bad while the post-storm surveys were conducted.

The current dune you are viewing was created out of recovered sand from inland. Excavation of the sand that buried storm-water outfall pipes in the bay was added to this material over a three month time. The good news is that all of Beach Haven and Holgate owners have now signed the easements so that the next phase of the Federal project can proceed that will include the entire shoreline to the Holgate wildlife area.

Figure 3B. View to the south in June 2012 showing the variation in the dunes along the Holgate shoreline. The homes crowd into the landward dune slope reducing its total width. The beach in 2012 was wider than usual, but not sufficient to provide enough protection. (photo-CRC, 2012)

Figure 3C. Following Sandy (Nov 5th) the beach was flat and extended straight across the island to the bay. The vast majority of the dunes and everything placed under the buildings were removed and deposited landward. A CRC colleague's family home had debris (including a boat on its trailer) piled into the double garage to the floor joists and very little of it was theirs. Note the dune remnant in the distance that served a pair of homeowners extremely well because their landscaping was still intact. (photo-CRC, 2012)

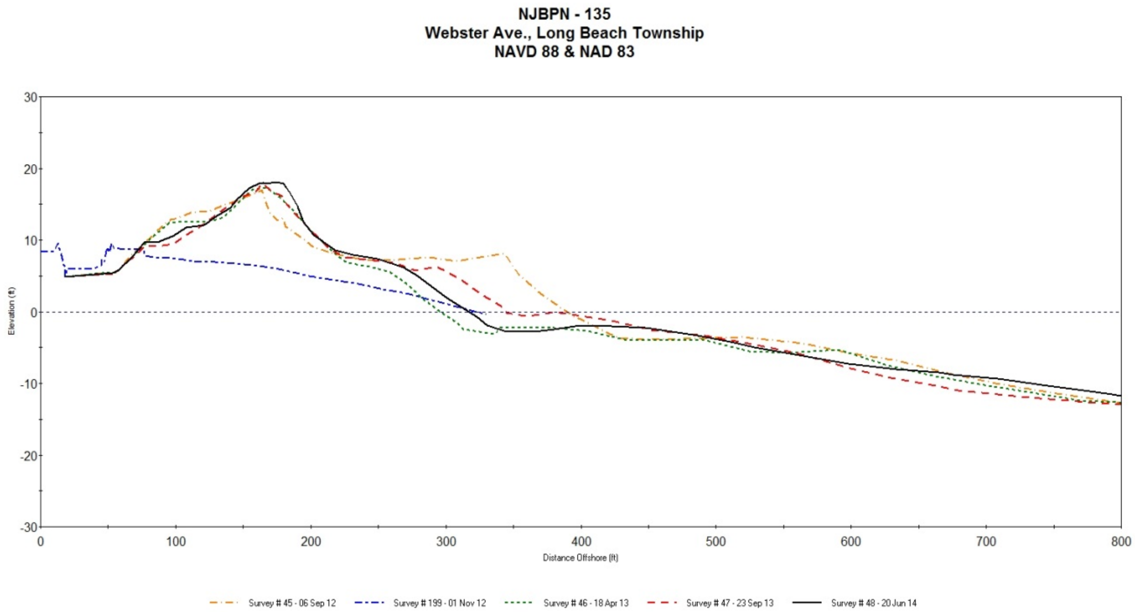

Figure 3D. The cross sections show the excavation that had already taken place in the road, but extended landward as a 4+foot thick wedge of overwash material. The biggest problem was removing it from the private lots among all the homes.

STOP #4; THE HOLGATE UNIT OF THE FORSYTHE WILDLIFE REFUGE

Development stopped at the boundary with the Forsythe Wildlife Refuge leaving the final two miles of LBI as a natural area. Extremely popular with fishermen and naturalists, this area has been an on-going contest between wildlife needs and the desires for recreation. The access by vehicle has been the biggest sticking point. The terminal rock groin in Holgate has acted as a sand retention structure and deprived this natural area of material somewhat. In addition the existing sand supply is free to move landward as often and as rapidly as storms can move it, so the shoreline has moved over 700 feet landward of the 1975 position. Sandy blew through the parking lot all the way to the bay and completely overwashed everything to the south. The final profile was moved landward with no trace of the small dune remaining. The final picture was taken November 5, 2012 and shows both the overwash and the devastation of the Holgate development.

Figure 4A. Five days after Hurricane Sandy the CRC had the entire NJ coast flown yielding this photograph of the overwash and dune erosion in the Forsythe Wildlife Refuge plus the chaos that was existing on the Holgate section of Long Beach Township. In the upper middle right is a white patch of sand that represents one of the many overwash fans deposited on an undeveloped part of the island. The yellow sand is the fill material originally brought in to fill under the oceanfront homes and provide additional lot elevation. This was being moved back onto the beach. (photo-T. Kingston, 2012)

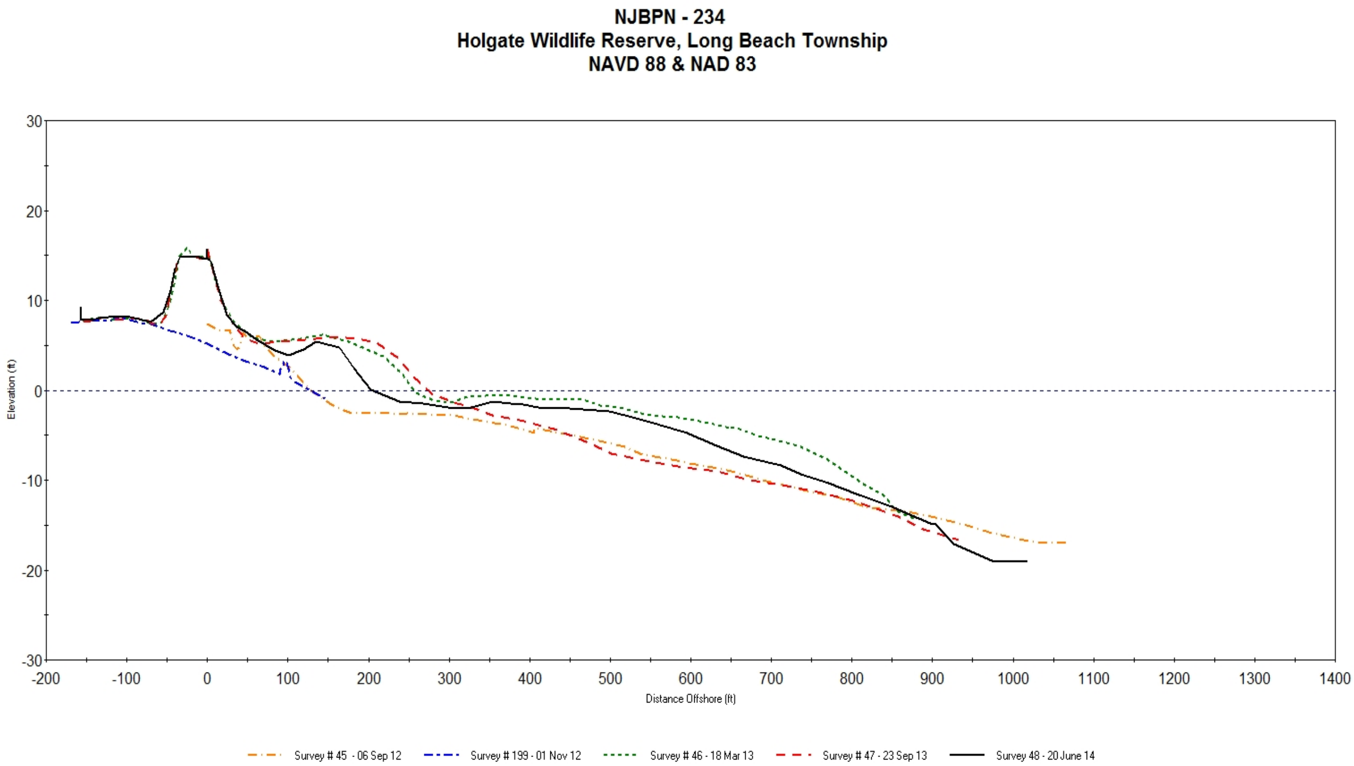

Figure 4B. Site 234 is positioned about 700 feet south of the terminal groin on LBI. This site has seen repeated bouts of retreat with the latest round moving the reference monument about 260 feet landward.

CONCLUSIONS

Long Beach Island has an 18-mile long shoreline that is a popular shore destination and home to over a billion dollars in development. Federally authorized shore protection projects, co-sponsored by the USACE (Philadelphia District) and the State of New Jersey, commenced in 2007 and proved successful in protecting homes during Hurricane Sandy. Acceptance of the easement requirements for continued maintenance has been established especially following the NJ supreme court's mandate regarding Kahan vs. Harvey Cedars where the lawsuit should be retried and take into consideration the shore protectionproject value to both the landward neighbors and to the Kahans themselves.

The island had been developed with too narrow a beach and dune system in the first place. Together with sea level rise, serious management of the coastal barrier is both essential and economically valid to maximize longevity for major recreational and ocean enjoyment.. Since landward relocation of the developed part of the island is unlikley, the only way forward to protect the structures lies with aggressive beach maintenance.

Changes to the Barnegat Inlet jetty system had un-anticipated consequences of providing an substantial deposit of sand making the Borough of Barnegat Light the most storm-proof community in New Jersey. This protection fades to the south into the Loveladies section of Long Beach Township, so the Federal project is needed to widen the beach and raise the dune elevation to a consistent value to the southern limit of development.

Finally, the progressive march landward at the Holgate section of the Forsythe Wildlife Refuge will mean the chance of the reappearance of "Beach Haven Inlet" yet again in the future. The 1920 breach was the third in a series documented by historical mapping, so if the offset between the developed shoreline and this natural area grows too large, an inlet is ever more likely.

REFERENCES

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