Department of the Interior Strategic Sciences Group

# Operational Group Sandy Technical Progress Report

U.S. Department of the Interior

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# Operational Group Sandy Technical Progress Report

By Department of the Interior Strategic Sciences Group

## Executive Summary

### Introduction

Hurricane Sandy made US landfall near Atlantic City, NJ on 29 October 2012, causing 72 direct deaths, displacing thousands of individuals from damaged or destroyed dwellings, and leaving over 8.5 million homes without power across the northeast and mid-Atlantic. To coordinate federal rebuilding activities in the affected region, the President established the cabinet-level Hurricane Sandy Rebuilding Task Force (Task Force). The Task Force was charged with identifying opportunities for achieving rebuilding success while supporting economic vitality, improving public health and safety, protecting and enhancing natural and manmade infrastructure, bolstering resilience, and ensuring appropriate accountability.

The Department of the Interior (DOI) Strategic Sciences Group (SSG) was established in 2012 to provide interdisciplinary science-based scenarios for environmental crises affecting Departmental resources. In January 2013, the Secretary of the Interior directed the SSG to support the Department's participation in the Task Force. The SSG assembled a team of experts from government, academic institutions, and non-governmental organizations—Operational Group Sandy (OGS)—to develop scenarios for the impacts of Hurricane Sandy and future major storms on coastal communities and urban systems in the NY/NJ region. The OGS met in Park Ridge, NJ 3-7 March 2013 to complete this work.

This report documents results from the March 2013 deployment of the OGS. It includes: 1) background information on Hurricane Sandy and the federal response, 2) the OGS methodology, 3) scenarios for Hurricane Sandy's impact on coastal communities and urban systems, 4) potential interventions to improve regional resilience to future major storms, 5) a discussion of the scenario results, including key insights, and 6) lessons learned about the OGS process. Results of the OGS work are designed to be used primarily by the DOI in its role on the Task Force and more broadly by decision makers at the local, state, and federal levels and the scientific community.

### Methodology

The OGS used scenario-building methodology that was developed, peer-reviewed, and published by the Strategic Sciences Working Group during the Deepwater Horizon Oil Spill (Machlis and McNutt, 2010; Department of the Interior, 2010; 2012). These methods include defining relevant terms and scope of the scenarios, using a coupled human-natural ecosystem model as a conceptual framework, developing chains of consequences to illustrate the breadth of impact to the coupled human-natural system, assigning uncertainties to each element in each chain of consequences, and identifying possible interventions to mitigate adverse effects of the event.

DOI leadership directed the OGS to build scenarios focused on the most severely impacted region, extending from Montauk Point, NY to Cape May, NJ. The OGS defined and focused on two "regional types" for their scenarios: a) coastal communities and ecosystems and b) urban centers and ecosystems. The OGS developed a timeline of relevant events, extending from Hurricane Sandy to approximately five years into the future, when a hypothetical severe storm called "Hurricane 2018" was hypothesized to strike the NJ coast in mid-August, 2018. Using this framework, the OGS scenarios examine both the cascading consequences of Hurricane Sandy and potential interventions that could be taken during the next five years to build resilience of the NY/NJ region to future major storms.

A coupled human-natural system model was used as the foundation for the OGS scenarios to capture the impacts of Hurricane Sandy on the environmental, economic, and social systems of the affected region. Each scenario illustrates chains of consequences and each consequence is assigned a scientific level of uncertainty ranging from certain (or observed) to not known. Using the scenarios, the OGS developed interventions, defined as institutional actions that support recovery and increase the resilience of the coupled human-natural system to future major storms.

The OGS scenarios have several limitations. The scenarios depend on the expertise of the individual participants and information available at the time of

the scenario-building session. The OGS scenarios are aspatial and do not address geographically-specific features. Cascading consequences are not assigned an exact timeframe or duration during which they will occur. The results do not fully capture all possible linkages between each cascading effect. The assigned scientific uncertainties are subjective and conservative. OGS scenarios do not quantify the scale of the identified consequences.

## Results: Scenario 1a—Coastal Communities and Ecosystems

During the March 2013 session, the OGS worked on two scenarios: 1a) the impact of Hurricane Sandy on coastal communities and ecosystems; and 1b) the impact of Hurricane Sandy on urban communities and ecosystems. Scenario 1a was completed; Scenario 1b was not completed due to time constraints and is included as a work in progress in an appendix.

Results of this report focus on Scenario 1a, which identified 13 "first-tier" (primary) consequences that were a direct result of Hurricane Sandy:

- ecological change,
- changes in coastal geomorphology,
- atypical fresh/saltwater mixing,
- flood damage to the built environment,
- wind damage to the built environment,
- loss of electricity,
- disruption of commercial and recreational fishing,
- closure of outdoor recreation resources,
- altered storm preparedness and response activity,
- injury, stress, and loss of human life,
- altered perception of risk,
- increased voluntary activity, and
- altered beliefs and values.

Together, these consequences and their cascading impacts span a broad and complex range of environmental, economic, and social effects. For example, ecological consequences include changes in wildlife habitat, the disruption of migratory patterns, and the redistribution of invasive species. Changes in coastal geomorphology are marked by overwash and breaches of barrier islands and beaches, changes to coastal submerged areas, shoreline and profile change, and damage to iconic cultural resources. Further cascading consequences of each of these impacts range from changes in navigational hazards to changes in the availability and accessibility of dredge materials, where each consequence has different levels of uncertainty and additional cascading consequences.

Economically, flood and wind damage impacted a full range of infrastructure and services at different levels, from public utilities and transportation to communication facilities and recreation sites. The consequences of these impacts include loss of economic activity, exposure to health hazards, creation of debris, and changes in asset values, financing, and insurance, among other impacts. Compounded with the cascading consequences of flood and wind damage was the widespread loss of electricity, which precipitated the loss of refrigeration, interruption of communication systems, and the disruption of critical medical support equipment and other outcomes.

The OGS scenarios also identify Hurricane Sandy's impacts on the social system, including increased demand for medical treatment and use of social services, emotional trauma, and loss of household income. Scenario results suggest that volunteer activities responded to some of these challenges: many secular and faith-based civic groups increased the engagement of non-local volunteer groups in the affected area to collect goods and/or funding.

The consequences described above are only a few examples of Hurricane Sandy's impacts identified by the OGS. Each chain of consequences, with the level of uncertainty for each element, is illustrated in detail in the Results section of the report.

## Interventions

Using the scenarios, the OGS identified potential interventions, defined as institutional actions that support recovery and increase the resilience of the coupled human-natural system to future major storms. Each intervention was assigned an intervention value of High (H)/Medium (M)/Low (L), which is a subjective index of the potential return on investment and pervasive positive impact on the system. This technique was a new method introduced to the SSG scenario-building process during this deployment.

The proposed interventions and their assigned values have limitations: the evaluation of return on investment is subjective and qualitative; and, the intervention value cannot be used to determine rank order of the proposed interventions. The interventions are described in the report and an "interventions matrix" illustrates the pervasiveness of each intervention across the first-tier consequences. Interventions appear below and are *not* prioritized or in rank order.

- Prioritize, integrate, and implement both ecosystem-based *and* engineered risk-reduction projects on a regional basis to maximize ecological, economic, and social benefits. (H)
- Document and map key ecosystems that have storm protection benefits to inform a strategy for using public and private sector programs to invest in conservation and restoration of those systems. (H)
- Design, build, restore, monitor, and evaluate beach/dune/marsh ecosystem buffers that are self-sustaining and protective under normal perturbations. (H)
- Understand and address hazards of debris and environmental contamination (from both debris and outer sources, e.g., mold, lead, asbestos, released chemicals) through assessments, remediation, and education of workers, volunteers, homeowners, and building occupants. (H)
- Understand and develop predictive models of the complex interactions among networked infrastructure (such as water and waste systems) during storm events. (H)
- Build local, state and tribal government capacity to apply best-available data on current and future risk to expedite permitting review and implementation and evaluation of recovery projects. (H)
- Develop land valuation, tax incentives, and buy-out strategies to encourage land use that reduces risk, encourages environmental sustainability, and reduces government expenditure. (H)
- Apply best-available flood risk data from FEMA plus additional freeboard for all federal and federally-funded structures, and incentivize/support state, local, and tribal adoption of these data. (H)
- Assess current regulatory model codes and guidelines for building, land use planning, and zoning and revise them to reflect resiliency planning. Provide technical assistance to local municipalities to adopt these revisions. (H)
- Harden electrical distribution systems and increase distributed energy generation and the use of renewable energy. (H)
- Identify and build capacity of local civic groups to assist in emergency preparedness, response, and recovery. (H)
- Understand and develop strategies for hurricane hazard and risk education, communication, and actions that are effective across varying demographic and institutional types. (H)
- Conduct rapid and ongoing assessments and research on health care, mental health services, and social services, especially in high-impacted and underserved areas. (H)
- Identify vulnerable populations and create and maintain a “seek and find” registry for individuals and households needing special care during storm events. (M-H)
- Research consequences of long-term changes (such as population growth, population redistribution, and sea-level rise) on storm impacts and integrate findings into proposed interventions. (M-H)
- Collect, analyze and share critical regional data (particularly high-resolution LIDAR, land use/land cover and flood risk data) for asset risk management. (M-H)
- Develop and maximize market potential for repurposing materials and/or debris for community/public and private sector use. (L-M)

## Discussion

It is highly likely that future major storms—or even frequent smaller storms and/or other hazardous events—will have a significant impact on the Hurricane Sandy-affected region in the future, underscoring the importance of federal, state, and local governments to take steps towards bolstering the resilience of the coupled human-natural system as a whole. Many coastal communities in the mid-Atlantic and northeastern US face rising sea levels, which will exacerbate the impact of storm surge in both the built and natural environment.

The OGS developed a conceptual model to analyze the relationship between Hurricane Sandy rebuilding efforts and stress to the coupled human-natural system in the affected region. This model was derived from earlier work of the SSG (Department of the Interior, 2010; Machlis and McNutt, 2010; Department of the Interior, 2012). It describes the potential reaction of the system at different points over the scenario timeline such as during Hurricane Sandy and the hypothetical Hurricane 2018 (where stress peaks in response to both events) and during “blue sky” periods (where stress decreases and the system rebounds). Superimposed on the varying levels of system stress are different stages of response intensity such as the emergency phase (which peaks during the storms) and the rebuilding phase (which peaks as the system begins to return to pre-storm environmental, social, and economic conditions). Using this framework, results suggest that: a) system stress can accumulate over time, such that the system never fully returns to its pre-storm baseline conditions; and b) rebuilding efforts that begin *earlier* in the aftermath of an event

like Hurricane Sandy or hypothetical Hurricane 2018 may *decrease* system stress and give the system more time and opportunity to return to lower system stress.

Based on discussions during the OGS March 2013 session and the resulting scenarios and proposed interventions, key insights from this work show that:

- the consequences of Hurricane Sandy are complex;
- there are substantial uncertainties associated with both the consequences of the storm and potential interventions to improve resilience against future major storms and storm response activities should account for this uncertainty;
- resilience is best achieved when developed at the coupled human-natural system level rather than by applying measures only to individual units or infrastructures;
- both “gray” and “green” infrastructure are necessary for improving resilience; and,
- the speed and effectiveness of interventions may have substantial impact upon the capacity of the region to increase resilience to future major storms.

## Lessons Learned

For Hurricane Sandy, the SSG was deployed during the *recovery* phase of an event, enabling the SSG to assess its role and potential value during non-emergency situations. Earlier deployment of the SSG may have provided more immediate information to decision makers for assessing the cascading consequences caused by Hurricane Sandy. Future deployments of SSG teams may benefit from having a select set of remote subject matter experts “on call” to rapidly answer questions that arise during scenario-building discussions. The OGS process benefited from having a significant proportion of its participants from the affected area; this approach should be considered for future deployments. Other new understandings focus on ways to improve the logistics of the SSG deployment and the delivery of results to leadership. The SSG continues to identify lessons learned from this experience and from an independent external evaluation of the OGS completed in August 2013.

## Conclusion

The OGS scenario results identify interventions that may bolster recovery and resilience to future events and reveal the simultaneous positive impacts of each intervention on a range of first-tier consequences. The breadth of Hurricane Sandy’s impacts makes improving regional resilience an inherently complex challenge and much work needs to be done to enhance our understanding of the complex interactions between the social, economic, and environmental factors of the coupled human-natural system.

Rebuilding in the aftermath of Hurricane Sandy presents a unique opportunity to not only take actions to increase resilience of the coupled-human natural system, but also to test and monitor the long-term sustainability of these actions over time. It is highly likely that future major storms—or even frequent smaller storms and/or other hazardous events—will have a significant impact on the Sandy-affected region in the future, underscoring the importance of federal, state, and local governments to take steps towards bolstering the resilience of the system as a whole. The SSG’s strategic approach can provide unique insights into both the response and rebuilding phases of Hurricane Sandy and other environmental crisis.

### For further information, please contact:

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# Introduction

## Hurricane Sandy

In late October 2012, Hurricane Sandy advanced toward the eastern seaboard of the United States as one of the most severe storms to ever threaten the region. At the time of its US landfall near Atlantic City, NJ on 29 October, Hurricane Sandy measured over 1100 miles in wind-field diameter and was classified as a post-tropical storm with maximum sustained winds of 70 miles per hour (National Oceanic and Atmospheric Administration, 2012; Blake and others, 2013). Fueled by a coincident nor’easter and spring tides, Hurricane Sandy directly affected 17 states with storm surges of up to 8.57 feet, heavy snowfall (over three feet in parts of West Virginia and North Carolina) and historic flooding (Blake and others, 2013; US Geological Survey, 2013). The storm was directly responsible for at least 72 deaths in the region and thousands of individuals were displaced from damaged or destroyed dwellings (Blake and others, 2013). Over 8.5 million households lost power and the US sustained approximately $50-70 billion in damages, making Hurricane Sandy one of the

costliest storms to ever strike the US (Department of Energy, 2012; Blake and others, 2013, SwissRe, 2013).

## Federal Response

Since Hurricane Katrina in 2005 and the Deepwater Horizon oil spill in 2010, new federal policies have been created to promote interagency coordination for disaster response and recovery. These policies include the implementation of the National Disaster Recovery Framework (NDRF), which “provides guidance that enables effective recovery support to disaster-impacted States, Tribes, and local jurisdictions” and “focuses on how best to restore, redevelop and revitalize the health, social, economic, natural, and environmental fabric of the community and build a more resilient Nation” (Federal Emergency Management Agency, 2011). The NDRF complements the National Response Framework and is designed to facilitate coordination of expertise, information, and resources during the recovery phase of a disaster.

In response to the effects of Hurricane Sandy, on 7 December, 2012, the President established the cabinet-level Hurricane Sandy Rebuilding Task Force (Task Force) to coordinate federal rebuilding activities in the affected region (Appendix A). Chaired by the Secretary of Housing and Urban Development, Task Force members represent 24 federal agencies, offices, and departments, including the Department of the Interior (DOI). The Task Force is charged with identifying opportunities for achieving rebuilding success, consistent with the NDRF’s commitment to support economic vitality, enhance public health and safety, protect and enhance natural and manmade infrastructure, and ensure appropriate accountability. In addition, the Task Force is responsible for working to ensure that the federal government continues to provide appropriate resources to support affected state, local, and tribal communities to improve the region’s resilience, health, and prosperity by building for the future (Hurricane Sandy Rebuilding Task Force, 2013).

Since the establishment of the Task Force, multiple sub-groups have been convened to supply information directly to the Task Force and to support coordination among Task Force agencies. The Department of the Interior (DOI) Strategic Sciences Group is one of many bodies contributing to these government-wide efforts.

## DOI Strategic Sciences Group and Operational Group Sandy

The DOI Strategic Sciences Group (SSG) was established in 2012 by Secretarial Order 3188 to provide the Department with science-based assessments and interdisciplinary scenarios for environmental crises affecting Departmental resources, rapidly assemble teams of scientists to conduct such work, and provide the results to the Secretary and Departmental leadership to support decision-making during crises. The SSG Co-Leaders report to the Science Advisor to the Secretary. Under the Secretarial order, only the Secretary can activate the SSG by written directive.

In January 2013, the Secretary of the Interior directed the SSG to stand up a crisis science team to support the Department’s role on the Task Force, where its activities would support the National Park Service Director as the Secretary’s designated representative to the Task Force (Appendix B). In response, the SSG assembled a team of experts from government, academic institutions, and non-governmental organizations—Operational Group Sandy (see OGS roster in Appendix C)—to develop scenarios for the Task Force to examine the short- and long-term impacts of Hurricane Sandy and future major storms (such as another major hurricane) on the ecology, economy, and people of the affected region. The OGS met on 3-7 March 2013 in Park Ridge, NJ, to build the scenarios. The SSG co-leaders and staff delivered daily reports (Appendix D) to the Science Advisor to the Secretary and the DOI Task Force designee and later briefed DOI leadership, the Task Force, and others in March-June, 2013.

## Scope of this Report

This technical progress report documents results from the 3-7 March 2013 deployment of the OGS. During this session, the OGS developed scenarios focused on impacts to coastal communities and ecosystems and began work on analyzing impacts to urban communities and ecosystems. The report describes the scenario-building methodology, limitations, spatial and temporal scope of the OGS scenarios, and the cascading consequences of Hurricane Sandy on coastal communities in the affected region. Interventions—institutional actions that will improve resiliency to future storms—are presented and placed in the context of the OGS scenarios. The scenarios for the urban environment are shown as a work-in-progress in an appendix.

This document is a “progress report,” intended to capture the findings of the OGS during its March 2013 session and does not include extensive post-deployment analysis. Additional work may be requested by the DOI and would trigger the re-convening of an operational group.

Results of the OGS work are designed for use primarily by the DOI in its role on the Task Force and more broadly by decision makers at the local, state, and federal levels and the scientific community. This work is supported by the DOI and complements ongoing science response efforts as part of the federal Hurricane Sandy Rebuilding Task Force.

# Methodology

Scenario development is a common practice for the emergency, natural resource, and organizational management communities (e.g., Chermack and others, 2001; Alexander, 2002; Peterson and others, 2003). The OGS used scenario-building methodology developed, peer-reviewed, and published by the Strategic Sciences Working Group (SSWG) during the Deepwater Horizon Oil Spill (Department of the Interior, 2010; Machlis and McNutt, 2010; Department of the Interior, 2012). These methods include defining relevant terms and scope of the scenarios, using the coupled human-natural ecosystem model as a conceptual framework, developing chains of consequences to illustrate the breadth of impact to the human-natural system, assigning uncertainties to each element in each chain of consequences, and identifying possible interventions to mitigate adverse effects of the event.

## Definition of Terms

The OGS used several key terms to build and describe its scenarios. These are defined as:

- *Consequence:* an outcome or impact caused by Hurricane Sandy either directly or indirectly. Consequences can vary with time, space, and intensity. Drivers can be of all types (e.g., human, natural, or a combination thereof).
- *First-Tier Consequence*: These are broad-scale consequences which appear at the first level of a chain of consequences and typically lead to multiple cascading consequences.
- *Hurricane Sandy:* the weather event characterized by extreme rain, wind, waves, and storm surge coincident with spring high tides, which impacted the northeastern US from 27 October 2012 (roughly 48 hours prior to US landfall) until 31 October 2012 (approximate return to baseline weather conditions).
- *Hurricane 2018:* a hypothetical and plausible severe hurricane that strikes the New Jersey coast in mid-August, 2018. This storm would have more rain than Hurricane Sandy (e.g., from stalling over the region), less storm surge, and more uncertainty in its track.
- *Intervention:* an institutional action that supports recovery as defined by the Task Force and that increases the resilience of the coupled human-natural system to future major storms.
- *Intervention Value:* a subjective index of the potential return on investment *and* pervasive impact across the first-tier consequences. In the SSG scenarios, each intervention is assigned an intervention value which is designated as High (H)/Medium (M)/Low (L).
- *Resilience:* the OGS adopted the National Research Council's (NRC) definition of resilience from their 2012 report *Disaster Resilience: A National Imperative*: "the ability to prepare and plan for, absorb, recover from and more successfully adapt to adverse events" (National Research Council, 2012). Other definitions of resilience exist; see for example Walker and Salt, 2006 and Cutter and others, 2008.

**A**

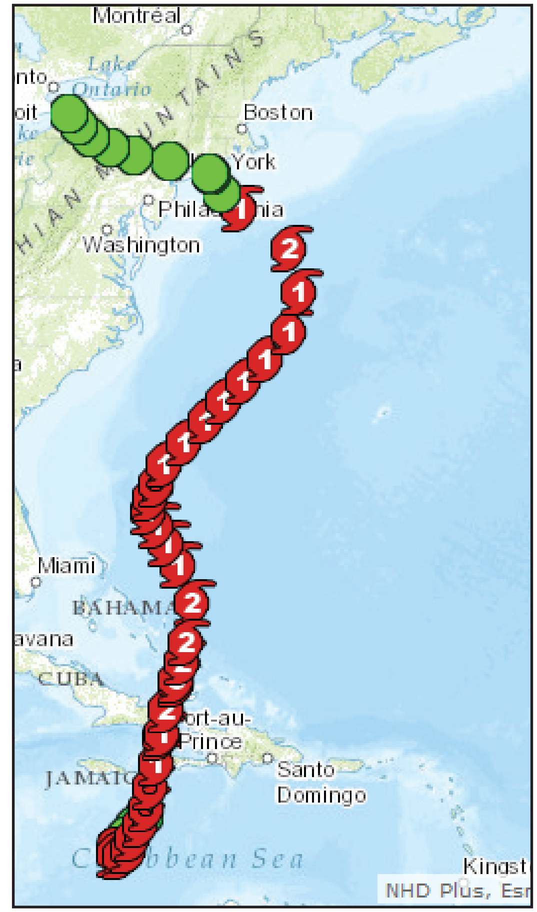



**Figure 1.** (*A*) Hurricane Sandy Storm Track. After developing on 22 October 2013 near Jamaica, Sandy swept through Cuba, destroying property as a Category 3 hurricane before turning northeast towards the Bahamas, then weakening to a tropical storm (Blake and others, 2013). On 28 October, Sandy re-organized and intensified, and turned northwest, aiming for the northeast coast of the US, making its US landfall near Atlantic City, NJ on 29 October 2013 and transitioning to an extratropical depression as it moved northwest (Blake and others, 2013). Sandy caused at least 147 direct deaths, including 72 in the northeastern and mid-Atlantic US. Red shows the storm as a hurricane (with Saffir-Simpson numerical rating), green shows the storm as an extratropical depression (Blake and others, 2013) (map courtesy National Hurricane Center, 2012).

***B***

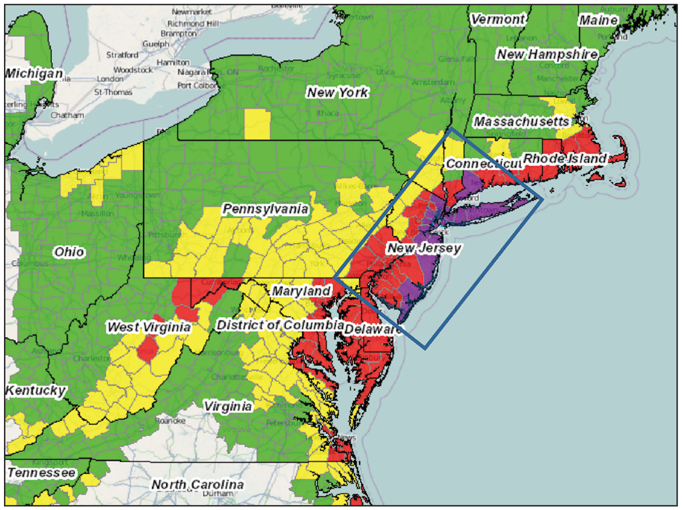



**Figure 1.** (*B*) OGS Study Area. The OGS scenarios focused on the region most severely-impacted by Sandy as defined by this FEMA Modeling Task Force impact assessment map. OGS scenarios apply to the region in the blue rectangle, extending roughly from Montauk Point, NY to Cape May, NJ. The FEMA impact assessment regions are based on modeling and observations. The colors represent a composite of surge, wind, and precipitation (rain and snow) impacts by county and surge is the primary driver of the severe impacts as a result of Hurricane Sandy. Purple areas have Very High impact, with >10,000 of the county population exposed to surge. Red areas are estimated High impact zones with 500-10,000 of the county population exposed to surge, or modeled wind damages of >\$100M, or high precipitation (>8″). Yellow regions experienced Moderate impact, with 100-500 of the county population exposed to surge, or modeled wind damages of \$10-100>, or medium precipitation (4′–8″). Green areas had estimated Low impact with no surge impacts, or modeled wind damages <\$10M, or Low Precipitation (<4″) (map courtesy Federal Emergency Management Agency, 2013).

***C***

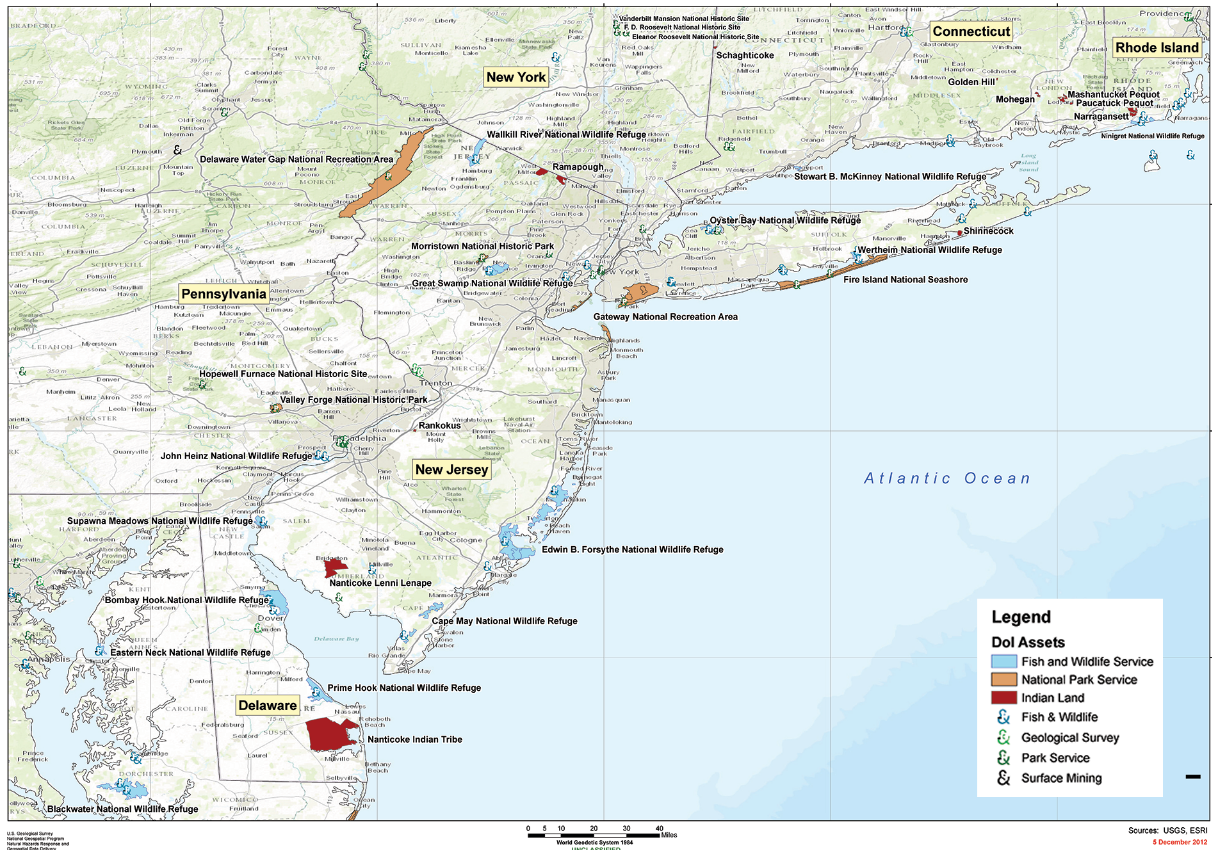



**Figure 1.** (*C*) Regional DOI Assets. The DOI has multiple assets in the affected region including National Park Service, Fish and Wildlife Service, and Tribal lands. Many of these were adversely and directly affected by Hurricane Sandy (map courtesy USGS).

## Scenario Scope

The SSG scenarios are designed to be built quickly in a very short period of time (days). For this reason, the scope of the SSG scenarios is defined at the outset of SSG deployment. For analyzing the impacts of Hurricane Sandy, DOI leadership, working with the SSG, defined the geospatial and temporal scope of their scenarios at the beginning of their meeting.

### Geographic Extent

Hurricane Sandy (Figure 1A) directly affected 17 states (Blake and others, 2013). The Federal Emergency Management Agency (FEMA) Modeling Task Force Sandy Impact Assessment Map (Figure 1B) was used to define the geographic scope of the OGS scenarios. This FEMA impact assessment is based on modeling and observations and shows *estimated* damage. The colors represent a composite of surge, wind, and precipitation (rain and snow) impacts by county, where surge was the primary driver of the severe impacts resulting from Hurricane Sandy. The region includes significant DOI assets (Figure 1C). DOI leadership directed the OGS to build scenarios focused on the most severely impacted zones, approximately the area extending from Montauk Point, NY to Cape May, NJ (blue rectangle, Figure 1B). This area is hereafter referred to as the "affected region" or the "OGS study area."

### Regional Types

The OGS defined two "regional types" for their scenarios to account for the geographic heterogeneity in the affected region (Figure 2). Coastal Communities and Ecosystems ("Coastal Communities") are areas that were completely or partially inundated during Hurricane Sandy and/or are within 0.25 miles of the coast (e.g., Fire Island, NY). Urban Communities and Ecosystems ("Urban Communities") are distinguished from Coastal Communities by high population density (>50,000 people/square mile), high building density, higher average building height, interconnected and underground infrastructure, "armored" shoreline (such as breakwaters and riprap); and high socioeconomic diversity (e.g., Manhattan). There is some overlap between these two regional types. Time constraints did not allow the OGS to explore impacts for inland suburban/rural areas (such as Park Ridge, NJ). These regional types are not comprehensive or mutually exclusive, and are meant to be a coarse tool to account for the environmental and socioeconomic heterogeneity of the region.

### Timeline

The OGS developed a timeline of relevant events for framing the scenarios (Figure 3). Hurricane Sandy was defined as the time period that started 48 hours before US landfall ($T_1$) and ended when the storm left the affected region ($T_2$). This time period was chosen to reflect the many activities underway in advance of landfall including the mobilization of utility workers, stockpiling of supplies, sand-bagging buildings, etc. As a reference point, the time of the OGS session (early March, 2013) is defined as $T_3$. The hypothetical severe storm called "Hurricane 2018" is proposed to occur in mid-August, 2018 and is defined as $T_4$. The long-term future (tens of years) is defined as $T_N$.

The OGS scenarios for both Coastal and Urban Communities examine the cascading consequences of Hurricane Sandy from $T_1$ to $T_4$. The OGS developed interventions that could be taken during the next five years ($T_3$-$T_4$) to build resilience of the region to future major storms like the hypothetical Hurricane 2018.

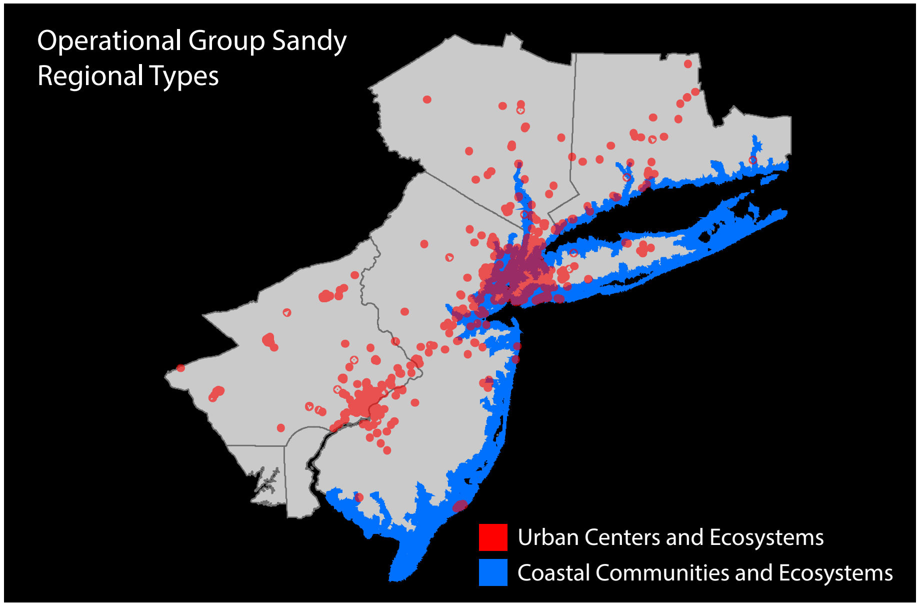



**Figure 2.** OGS Regional Types. The OGS scenarios focus on two regional types: Coastal Communities and Ecosystems (areas partially or completely inundated by Hurricane Sandy and within 0.25 miles of the coast) and Urban Centers and Ecosystems (areas characterized by >50,000 people/square mile and high infrastructure). (Map courtesy S. Spielman)

## Coupled Human-Natural Systems and Stress

In order to maintain a holistic, systems-based approach to building the scenarios, the SSG uses a coupled human-natural ecosystem model (Figure 4) as a conceptual framework to focus the scope of its scenarios. This model includes both biophysical and socioeconomic variables and flows of individuals, energy, nutrients, materials, capital, and information. All are essential components to consider when analyzing the short- and long-term effects of a natural disaster. Similar models have been applied to a variety of complex environmental challenges and are a valuable guide for the environmental, social, and economic complexity of disasters like Deepwater Horizon (Department of the Interior, 2010; 2012).

The coupled human-natural system model identifies specific variables that combined, reflect the complexity of such systems. For the SSG scenarios, stress to these systems is defined as heightened consequences, such as thirst in the face of lack of water, and/or increased requirement for adaptive responses, such as water conservation in the face of drought. Both heightened consequences and the increased requirement for adaptive responses are cumulative over time and can spread through multiple variables and flows within the coupled human-natural system.

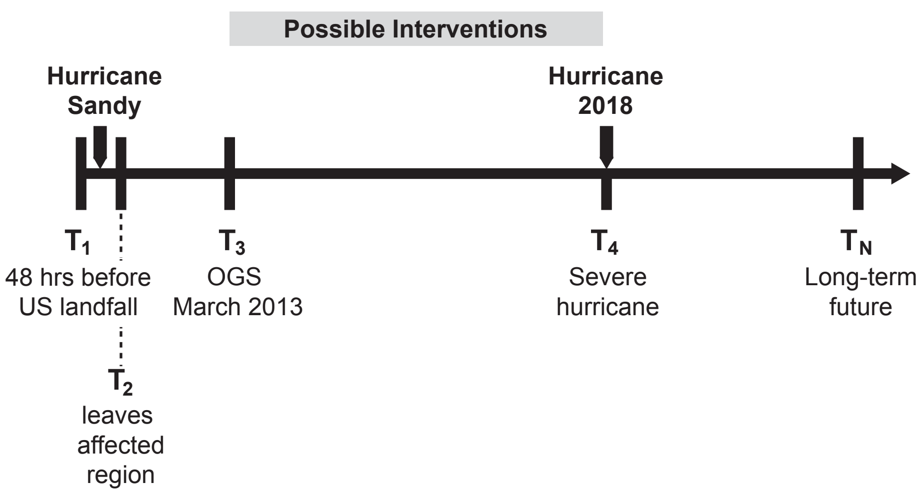



**Figure 3.** OGS Scenario Timline. The OGS developed a timeline of events to constrain the scope of the scenarios (note: not to scale).

## Scenario Building Process

To build the Hurricane Sandy scenarios, the OGS followed methods developed by the SSWG during the Deepwater Horizon oil spill (Department of the Interior, 2010; Machlis and McNutt, 2010; Department of the Interior, 2012). These methods include developing detailed scenarios to illustrate important cascading consequences, assigning a qualitative level of uncertainty to each consequence, and identifying potential interventions that would improve resilience of the coupled human-natural system to future natural hazards. Assigning a value to each intervention ("intervention value") was a new technique introduced for the OGS session.

### Chains of Consequences and Levels of Uncertainty

Each SSG scenario is a chain of consequences, illustrated as cascading effects stemming from an environmental disaster. Each effect has the potential to lead to another effect. During the scenario-building session, the amount of time spent "drilling down" one chain of consequences is generally constrained by time and/or expertise in the room. For example, participants may develop several levels of impact in one chain, but limited time dictates they have to move on to developing another chain. It is important to recognize that many consequences may be related to other consequences in other chains, but the SSG technique develops *chains* of consequences, not *webs* of consequences.

Each element in the chain is assigned a scientific level of uncertainty using a scale similar to one used by the Intergovernmental Panel on Climate Change and modified from Weiss (2003) (Figure 5). If there is doubt about the level of uncertainty, the precautionary principle is invoked and the next more conservative level of uncertainty is assigned. For the OGS scenarios, if individuals had first-hand knowledge of a consequence that had already occurred, it was rated 5, observed. If the OGS evaluated a consequence that was certain, it was also rated 5. Consequences that were not assigned levels of uncertainty by the OGS due to time constraints are shown as (--).

During the OGS session, scenario-building efforts focused on Coastal Communities because of DOI leadership's interest in this regional type. The OGS first identified first-tier consequences for Coastal Communities and then analyzed all first-tier consequences. Once this was completed, the OGS began the same task for Urban Communities, but left this scenario incomplete (Appendix E) to dedicate remaining time to developing interventions.

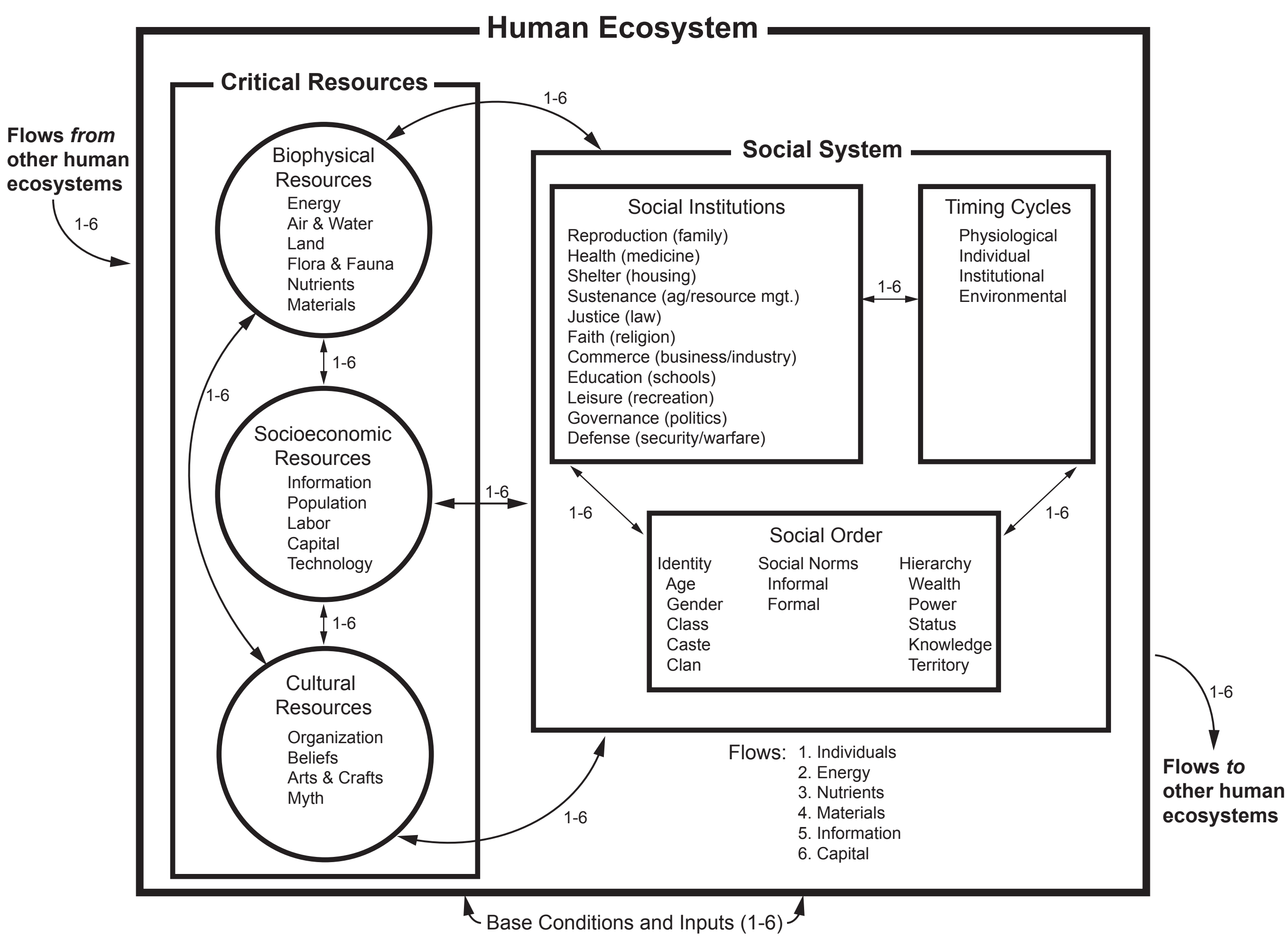



**Figure 4.** Coupled Human-Natural System. The coupled human-natural ecosystem model provides a useful conceptual framework for building interdisciplinary scenarios and this version was used as a guide for the OGS scenario-building session (adapted from Machlis and others, 1997).

## Anatomy of a Chain of Consequences

Figure 6 shows an annotated chain of consequences as a partial example of the SSG scenarios. In this chain, one of the consequences of Hurricane Sandy was evacuations. Evacuations resulted in the disruption of daily behavioral patterns, which led to mental and physical stress, heightened stress to local service providers, and ultimately to continued physical and mental health impacts. Hurricane Sandy and the hypothetical Hurricane 2018 are illustrated in the scenarios using dashed lines to show which consequences were effects of Hurricane Sandy (appearing below the Hurricane Sandy line) and which ones are potential effects of Hurricane 2018 (appearing below the Hurricane 2018 line). The distance between the dashed lines is not to be inferred as a time scale. In some chains, additional consequences are included—these are impacts that the OGS believed were important to communicate, but that did not fit the preceding chains. These items appear in italics in the scenario figures included in the *Results* section of this report.

**Levels of Scientific Uncertainty**

| | |
|---|---|
| **5** | Certain and/or Observed |
| **4** | Reasonably Certain |
| **3** | Probable |
| **2** | Plausible |
| **1** | Unlikely |
| **0** | Not Possible |
| **NK** | Not Known |
| **(--)** | Not Assessed |

**Figure 5.** Levels of Scientific Uncertainty. The SSG applies levels of scientific uncertainty to its scenarios, where each consequence in a chain is assigned a level using the scale above. This scale is based on a similar one used by the Intergovernmental Panel on Climate Change (adapted from Weiss, 2003).

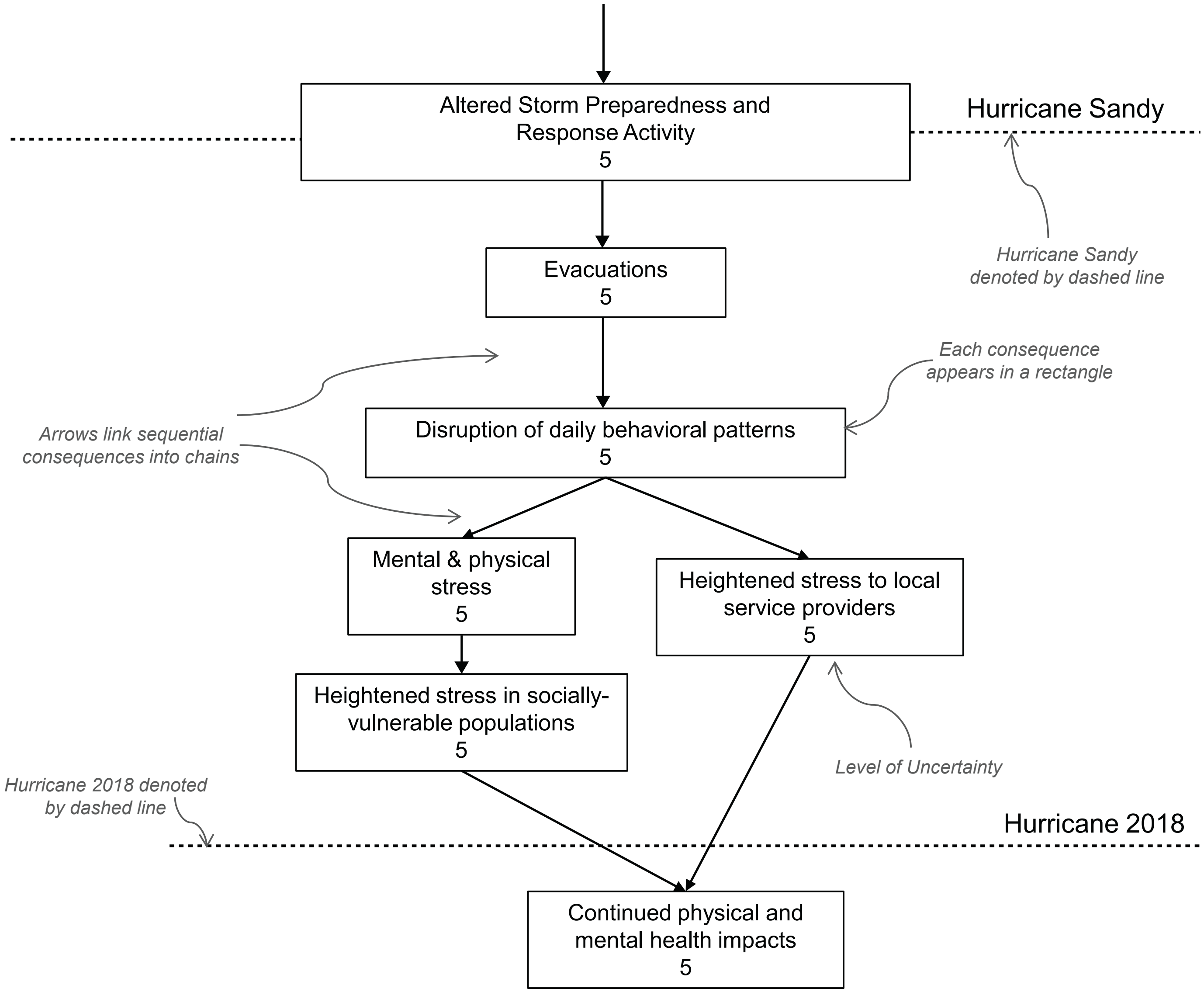



**Figure 6.** Schematic of SSG Scenarios. SSG scenarios illustrate cascading consequences, such as the effects of evacuations resulting from Hurricane Sandy. Each consequence is assigned a level of scientific uncertainty (numeric value below each consequence). Hurricane Sandy and hypothetical Hurricane 2018 are illustrated using dashed lines.

## Interventions

After the scenario building process was complete, the OGS developed interventions, defined as institutional actions that support the recovery as defined by the Task Force and that increase the resilience of the coupled human-natural system to future major storms. Each intervention was assigned an intervention value of High (H)/ Medium (M)/Low (L), which is a subjective index of the potential return on investment *and* pervasive impact on the system. Pervasiveness was defined as the number of first-tier consequences that are positively impacted by the intervention. This process is further detailed in the *Interventions* section of this report. The interventions are not illustrated in the chains of consequences, but listed separately (see *Interventions* section of this report).

## Scenario Limitations

Every scenario-building methodology has limitations. The OGS scenarios are limited in several ways, described below.

- The SSG scenarios inherently depend on the individuals participating in the session. The OGS scenarios were developed with input from the team of 15 individuals who assembled in New Jersey for the 3-7 March 2013 session (Appendix C). A different group of individuals would provide potentially different input on cascading consequences.
- The OGS scenarios are *aspatial* in nature: while the consequences are defined as those that occur for Coastal Communities and/or Urban Communities, they are not designed to answer questions about specific geographic areas or demographic groups. SSG scenarios are designed to be broad and strategic, and are not intended to be spatially specific.
- The OGS scenarios are limited with respect to *time* in the sense that the cascading effects are not assigned an exact timeframe or duration during which they will occur.
- Although the OGS used the coupled human-natural system model as the foundation for building their scenarios, the results do not fully capture *all* possible relationships between each cascading effect and are not comprehensive.
- The uncertainties assigned to each consequence are subjective; they are also conservative because the precautionary principle is applied if and when information provided by the OGS was inconclusive for determining an uncertainty level.
- The OGS scenarios do not include *severity* of impact. The scenarios highlight observed or potential consequences, but do not capture the magnitude of these outcomes.

There are also limitations to the proposed interventions and their assigned values:

- The intervention value is subjective and cannot be used to determine rank.
- The concept of return on investment is qualitative and based on subjective evaluation.

During the 3-7 March 2017 session, the OGS worked on two scenarios: 1a) the impact of Hurricane Sandy on Coastal Communities and Ecosystems from $T_1$ to $T_4$; and 1b) the impact of Hurricane Sandy on Urban Communities and Ecosystems from $T_1$ to $T_4$. Scenario 1b was not completed due to time constraints and is included in Appendix E as a work in progress. Results of this report focus on Scenario 1a.

# Results: Scenario 1a—Coastal Communities and Ecosystems

The OGS scenario of Hurricane Sandy's impacts on Coastal Communities and Ecosystems identified a total of 13 "first-tier" consequences that were a direct result of Hurricane Sandy in these regions (Figure 7). These consequences span a range of environmental, economic, and social effects, and include:

- Ecological Change
- Changes in Coastal Geomorphology
- Atypical Fresh/Saltwater Mixing
- Flood Damage to the Built Environment and Property
- Wind Damage to the Built Environment and Property
- Loss of Electricity
- Disruption of Commercial and Recreational Fishing
- Closure of Outdoor Recreation Resources
- Altered Storm Preparedness and Response Activity
- Injury, Stress, and Loss of Human Life
- Altered Perception of Risk
- Increased Voluntary Activity, and
- Altered Beliefs and Values.

Below, each of these first-tier consequences is presented by a short summary with illustrative examples in order from left-to-right in Figure 7, beginning with Ecological Change and continuing to Altered Beliefs and Values. Assigned levels of uncertainty are indicated using words from Figure 5 (e.g., certain, reasonably certain, etc.) in italics.

## Ecological Change

The ecological impacts of Hurricane Sandy vary across marine, estuarine, and terrestrial environments and include changes in wildlife habitat, changes in tree canopy and cover, the disruption of migratory patterns, saltwater intrusion, stream degradation, sediment burial of vegetation, the redistribution of invasive species, and creation of new habitat (Figure 8). Many of these consequences have cascading effects that are closely coupled with changes in the geophysical environment and pre- and post-storm human activity in the affected region.

One of the more unexpected outcomes of this cascade was the creation and possible later loss of new (novel) or additional habitat. Results show that new habitat would *certainly* be formed by a variety of natural forces, such as barrier island overwash, which may create new marine and/or terrestrial habitats. However, one *probable* outcome of this new habitat creation was the removal of storm-generated habitat by human activities. For example, if a barrier island overwash created new marine or estuarine habitat, this new habitat could be later lost through beach restoration and nourishment activities or property owners returning their property to a pre-storm condition.

## Changes in Coastal Geomorphology

There were four primary consequences of the changes in coastal geomorphology: overwash and breaches of barrier islands and beaches, changes to coastal submerged areas, shoreline and profile change, and damage to iconic cultural resources. Each of these phenomena was *observed*. As shown in Figure 9, each of these consequences had cascading effects impacting multiple dimensions of the environmental, social, and economic fabric of the region including observed changes in navigation hazards, probable changes in the availability of dredge materials, probable reduced tourism revenue, and plausible decreases in fisheries productivity.

For example, consequences of barrier island overwash and breaching include *observed* increased bay flooding, *observed* burial or partial burial of structure and road, and *observed* change in habitats. Cascading consequences include *certain* changes in bay circulation, *probable* impacts on navigation, and *probable* new habitat creation. An additional example includes one of the consequences to damages to iconic and cultural resources, which is the *reasonably certain* repair of these types of resource or more drastically, the *plausible* abandonment of these resources. Another example is the consequences of changes to submerged areas, where there are *probable* changes in the availability and accessibility of dredge materials, *plausibly* increasing the cost of dredge materials in the future. Sand is a much needed resource for not only beach nourishment, but is also a critical resource for many rebuilding efforts.

## Atypical Freshwater/Saltwater Mixing

Atypical freshwater/saltwater mixing was identified as an *observed* consequence of Hurricane Sandy that occurred in Coastal Communities where flooding, storm surge, sewage overflow, and dune erosion led to mixing in non-estuarine areas. The OGS did not complete cascading effects for this consequence and it is therefore a stand-alone item in Figure 7.

## Flood Damage to the Built Environment and Property

This particular chain encompasses a wide range of impacts and corresponding cascading consequences. Flood damage impacted public utilities, transportation, commercial centers, housing, communication facilities, health care facilities, coastal flood and erosion control structures (permanent and temporary), recreation and tourism sites, civic institutions, environmental monitoring systems, and iconic cultural resources (Figure 10). Combined, these impacts led to a loss of economic activity, exposure to health hazards, the creation of debris, degradation or loss of service functions, environmental harm, new opportunities and approaches for rebuilding, and changes in asset values, financing, and insurance—all of these consequences were *observed*.

Flood damage created both hazardous and non-hazardous debris. The OGS recognized that hazardous debris disposal could have multiple adverse effects including injury or death (*observed*), *certain* condemnation of buildings and properties, *probable* land abandonment, and *reasonably certain* litigation in the future. By comparison, non-hazardous debris disposal may lead to the *plausible* recycling of materials, increased recycling businesses, and the *probable* reduced capacity of landfills.

## Wind Damage to the Built Environment and Property

Similar consequences were observed for wind impacts as for flood damage, though these impacts were limited in their geographic extent within the affected region and were generally less severe. Wind had cascading consequences, with

*observed* impacts on public utilities, transportation, commercial centers, housing, communication, and recreation facilities, civic institutions, and cultural resources (Figure 11). One impact that was unique to wind damage and common to major storms was the *observed* loss of electrical power due to downed poles and trees. Other *observed* consequences included fuel shortages, loss of economic activity, and the creation of hazardous and non-hazardous debris.

## Loss of Electricity

One of the widespread impacts of Hurricane Sandy was loss of electricity—over 8.5 million homes across the eastern US were at one time without power (Blake and others, 2013). In Coastal Communities, loss of electricity led to the loss of refrigeration (and therefore *observed* food spoilage) and *observed* cascading consequences including the interruption of communication systems, disruption of heating and cooling systems, critical medical support equipment, water supply and sanitation facilities, other building mechanical functions, and government services (Figure 12).

Impacts such as the loss of lighting and security systems led to the *observed* increase in accidents and injuries and *probable* increased crime such as looting and robbery. Other consequences included *observed* investments in redundant power systems at the individual, household, and institutional level; and, the *reasonably certain* increase in contingency planning of individuals, households, and institutions in anticipation of future losses of power. Scenario results also suggest that there would be a *reasonably certain* adoption of alternate technologies that don't require a steady electrical source for some applications such as crank radios, manual toilets, and hand pumps.

## Disruption of Recreational and Commercial Fishing

Recreational and commercial fishing activities in coastal communities and ecosystems were *certainly* impacted by Hurricane Sandy (Figure 13). This led to several cascading events, including *reasonably certain* foreclosure on boats, the *probable* increased abundance of select species of fish and shellfish, and the *reasonably certain* bankruptcy of firms and or households who sustained severe loss of business and/or property as a result of the Hurricane Sandy-induced disruption to the industry.

## Closure of Outdoor Recreation Resources

Closure of outdoor recreation resources due to Hurricane Sandy impacts was identified as a first-tier consequence that could potentially have short- and long-term effects on the local economy and communities who depend on these resources (Figure 14). Although the OGS did not have time to examine this consequence in detail, the closure of outdoor recreation resources was *observed* and in some cases, would lead to the reopening of recreation resources with *reasonable certainty*.

## Altered Storm Preparedness and Response Activity (especially flood related- flood fighting, fortification, and planning)

Hurricane Sandy led to changes in storm preparedness and response activity, especially those that are flood-related. Cascading consequences include *reasonably certain* reduction and prevention of damages in the built environment, and *observed* enhanced preservation of communication networks, restricted access, increased expenditures at multiple levels, and evacuations (Figure 15).

Increased expenditures for preparedness at the instructional, commercial, and household levels will *certainly* lead to the pre-positioning of emergency personnel, critical equipment and supplies, and storm supplies and food for future major storms. Consequences of evacuations included the disruption of daily behavioral patterns, which precipitated *observed* heightened levels of stress to local service providers and mental and physical stress to the affected population, with *reasonably certain* more adverse effects on the socially-vulnerable such as the elderly, sick, young, or pregnant. The OGS results suggest that in the long term, these consequences will *probably* lead to physical and mental health impacts, which has implications for the coupled human-natural system during future major storms.

## Injury, Stress, and Loss of Human Life

Hurricane Sandy caused at least 72 direct deaths in the US (Blake and others, 2013). Hurricane Sandy's impacts to the social dimensions of the coupled human-natural system also included *observed* injury and stress (Figure 16). This led to multiple cascading consequences including the *observed* increased demand for medical treatment, services and supplies, increased health care costs, increased use of social services, *observed* emotional trauma on multiple levels (from household to community and institution), and loss of household income.

The increased demand for medical treatment and supplies has multiple cascading consequences. These include the *reasonably certain* diminishing but ongoing demand for treatment, supplies and services as the community recovers, and *probable new* demands for medical services as long-term health impacts of Hurricane Sandy emerge.

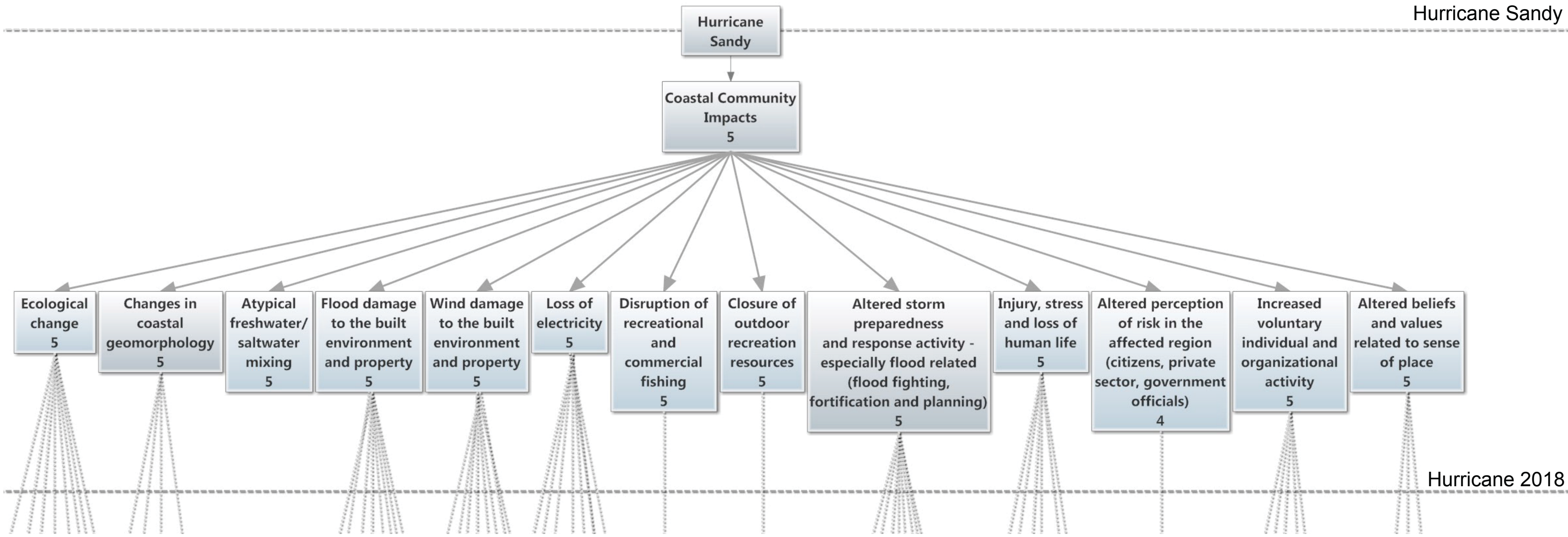



**Figure 7.** OGS Scenario 1a—First-Tier Consequences. Numbers in Figures 7–19 correspond to uncertainty levels shown in Figure 5.

## Altered Perception of Risk in the Affected Region (citizens, private sector, government officials)

With *reasonable certainty*, the OGS scenarios show the altered perception of risk to be a first-tier consequence of Hurricane Sandy (Figure 17). Risk perception is likely to change at multiple levels within the coastal community population, including citizens, government officials, and across the private sector. For some, this may lead to a *probable* long-term shift in risk perception and for others, this may manifest into *probable* complacency in the face of risk. Within the business and built environment, changes in risk perception and the community's understanding of vulnerability to future major storms will *probably* lead to changes in property values and ultimately, *plausible* changes in demographic patterns as individuals, families, and officials make decisions about where they live based partially on their perception of risk.

## Increased Voluntary Individual and Organizational Activity

Hurricane Sandy resulted in increased voluntary activity (such as donating money or providing assistance) at both the individual and organizational levels (Figure 18). This led to *observed* changes in the use of social media, changes in the source and distribution of funding, changes in the missions of civic groups, increased corporate engagement from both local and non-local companies, and on a broad level, strengthened social cohesiveness.

During and after Hurricane Sandy, many secular and faith-based civic groups changed or added to their missions by forming new associations (*observed*), increasing the supply, demand, and type of services available from local organizations (*observed*), and increasing the engagement of non-local volunteer groups in the affected area (*observed*). Some non-governmental organizations (NGOs) and corporations repurposed themselves, leading to the *probable* incorporation of emergency response into volunteer group missions in the future, among other consequences.

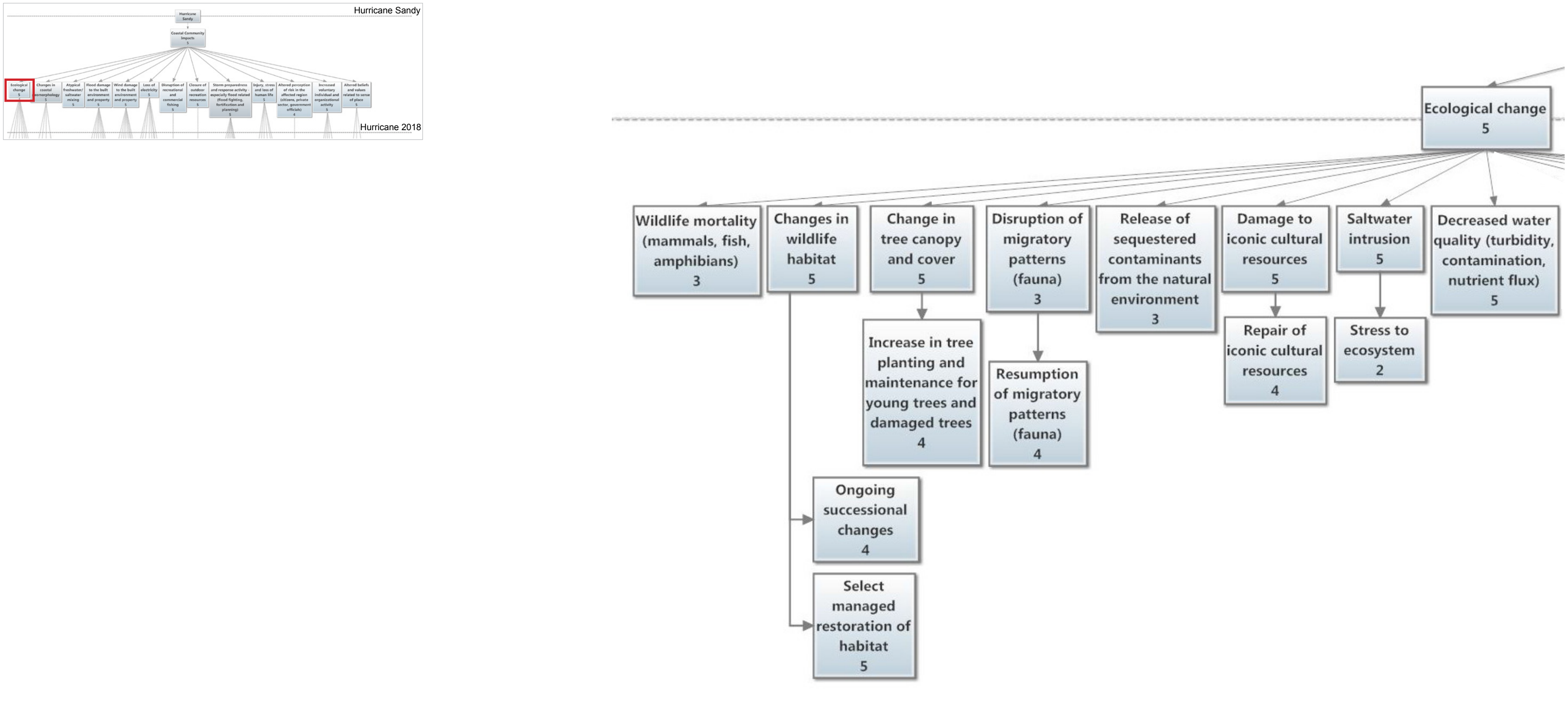
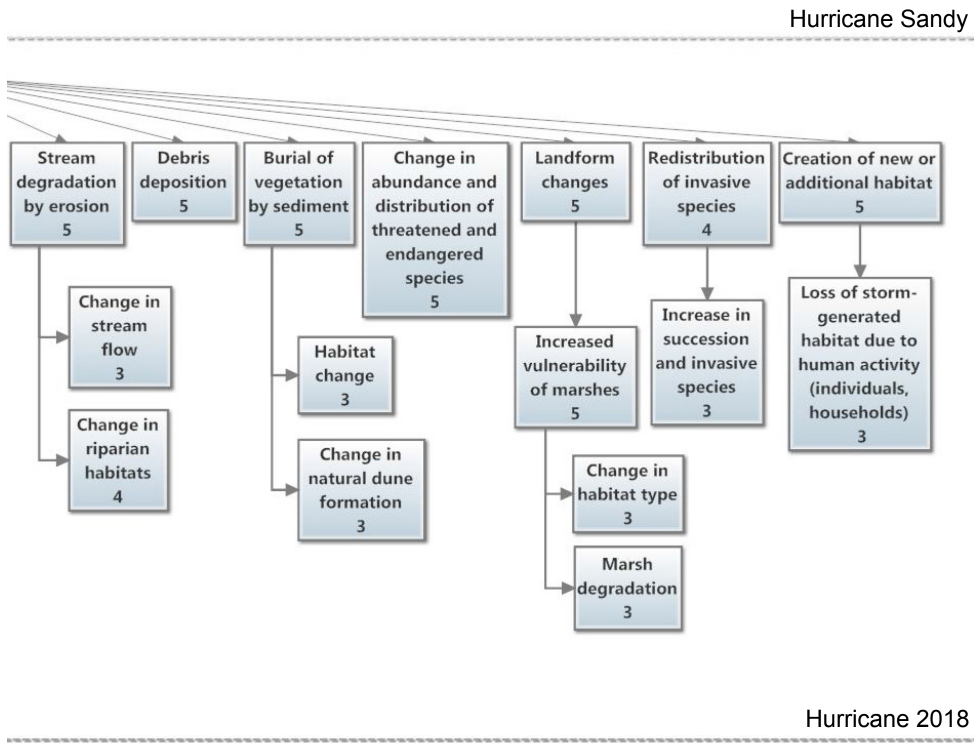



**Figure 8.** OGS Scenario 1a—Ecological Change.


Hurricane Sandy
Stream degradation by erosion 5
Debris deposition 5
Burial of vegetation by sediment 5
Change in abundance and distribution of threatened and endangered species 5
Landform changes 5
Redistribution of invasive species 4
Creation of new or additional habitat 5
Change in stream flow 3
Change in riparian habitats 4
Habitat change 3
Change in natural dune formation 3
Increased vulnerability of marshes 5
Change in habitat type 3
Marsh degradation 3
Increase in succession and invasive species 3
Loss of storm-generated habitat due to human activity (individuals, households) 3
Hurricane 2018

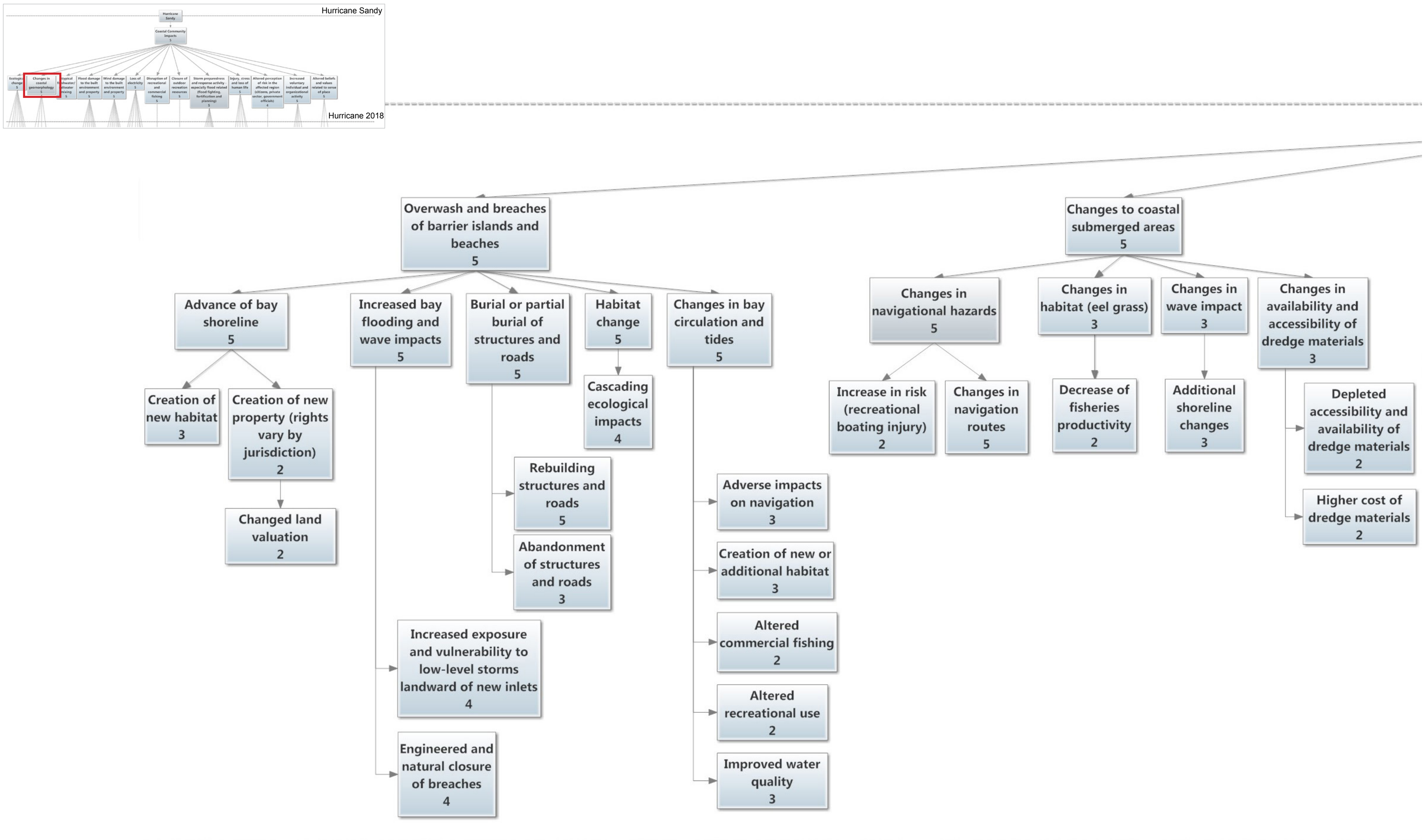
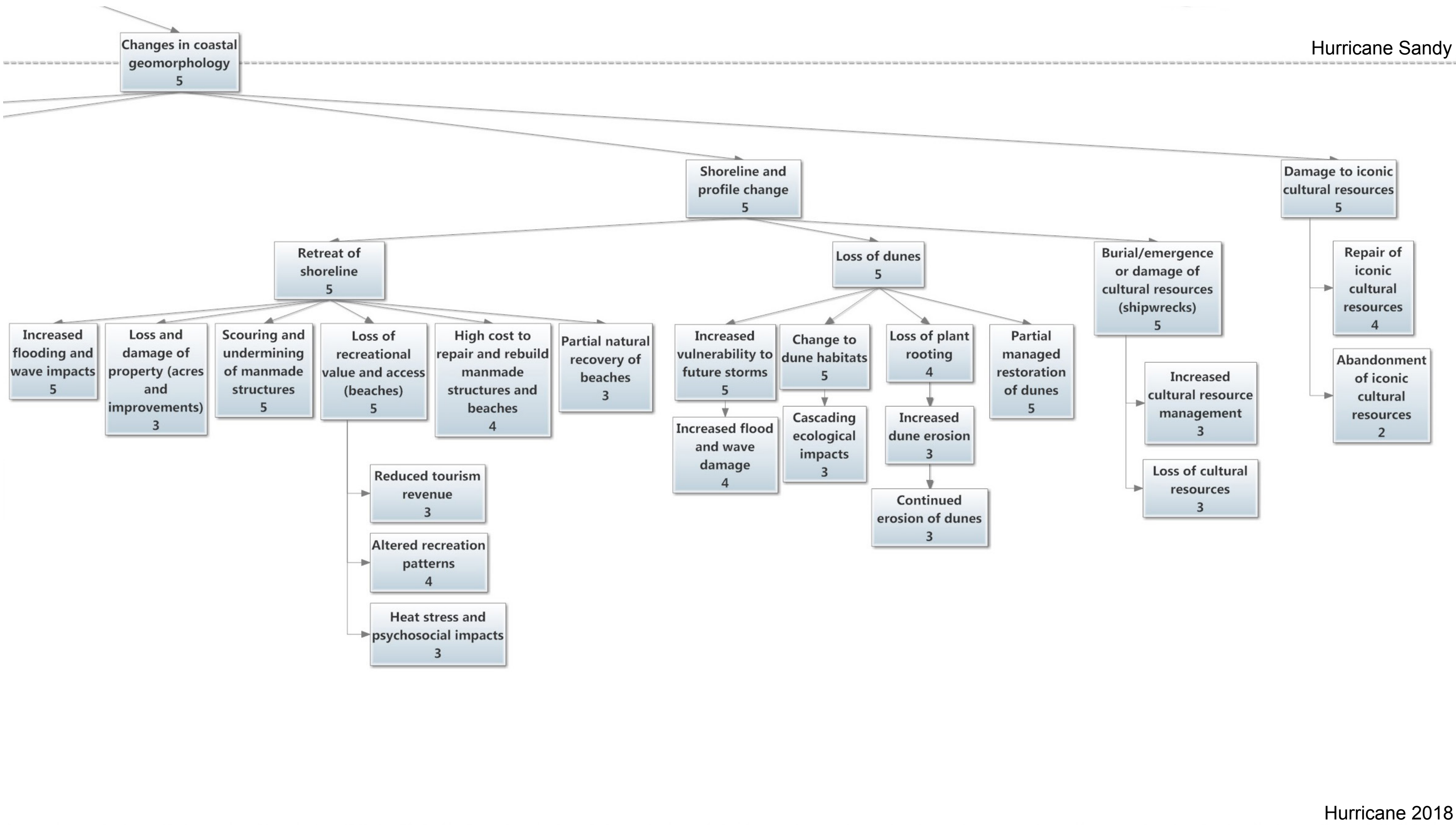



**Figure 9.** OGS Scenario 1a—Changes in Coastal Geomorphology.


Hurricane Sandy
Changes in coastal geomorphology 5
Shoreline and profile change 5
Damage to iconic cultural resources 5
Retreat of shoreline 5
Loss of dunes 5
Burial/emergence or damage of cultural resources (shipwrecks) 5
Repair of iconic cultural resources 4
Abandonment of iconic cultural resources 2
Increased flooding and wave impacts 5
Loss and damage of property (acres and improvements) 3
Scouring and undermining of manmade structures 5
Loss of recreational value and access (beaches) 5
High cost to repair and rebuild manmade structures and beaches 4
Partial natural recovery of beaches 3
Increased vulnerability to future storms 5
Change to dune habitats 5
Loss of plant rooting 4
Partial managed restoration of dunes 5
Increased cultural resource management 3
Loss of cultural resources 3
Increased flood and wave damage 4
Cascading ecological impacts 3
Increased dune erosion 3
Continued erosion of dunes 3
Reduced tourism revenue 3
Altered recreation patterns 4
Heat stress and psychosocial impacts 3
Hurricane 2018

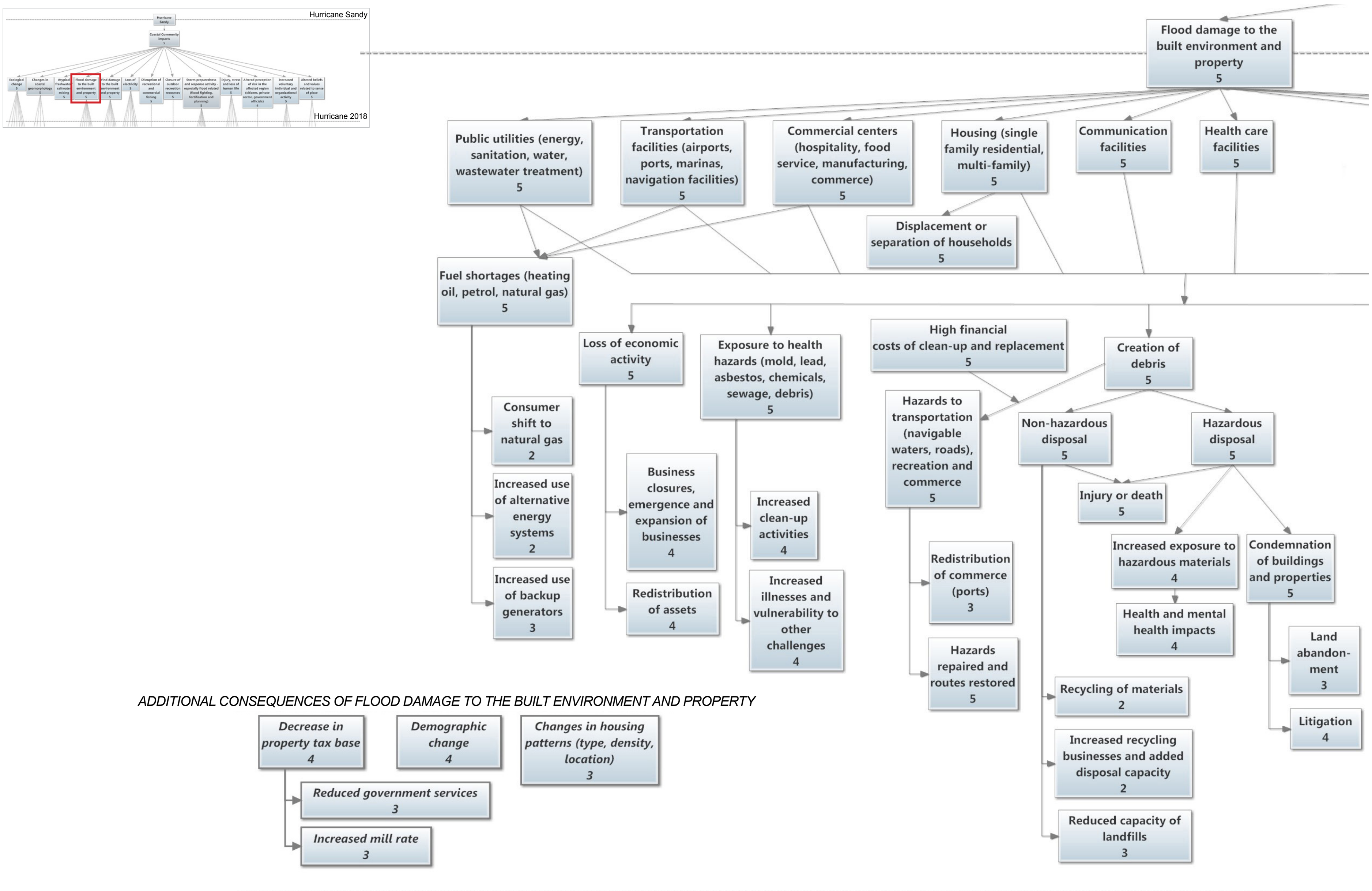
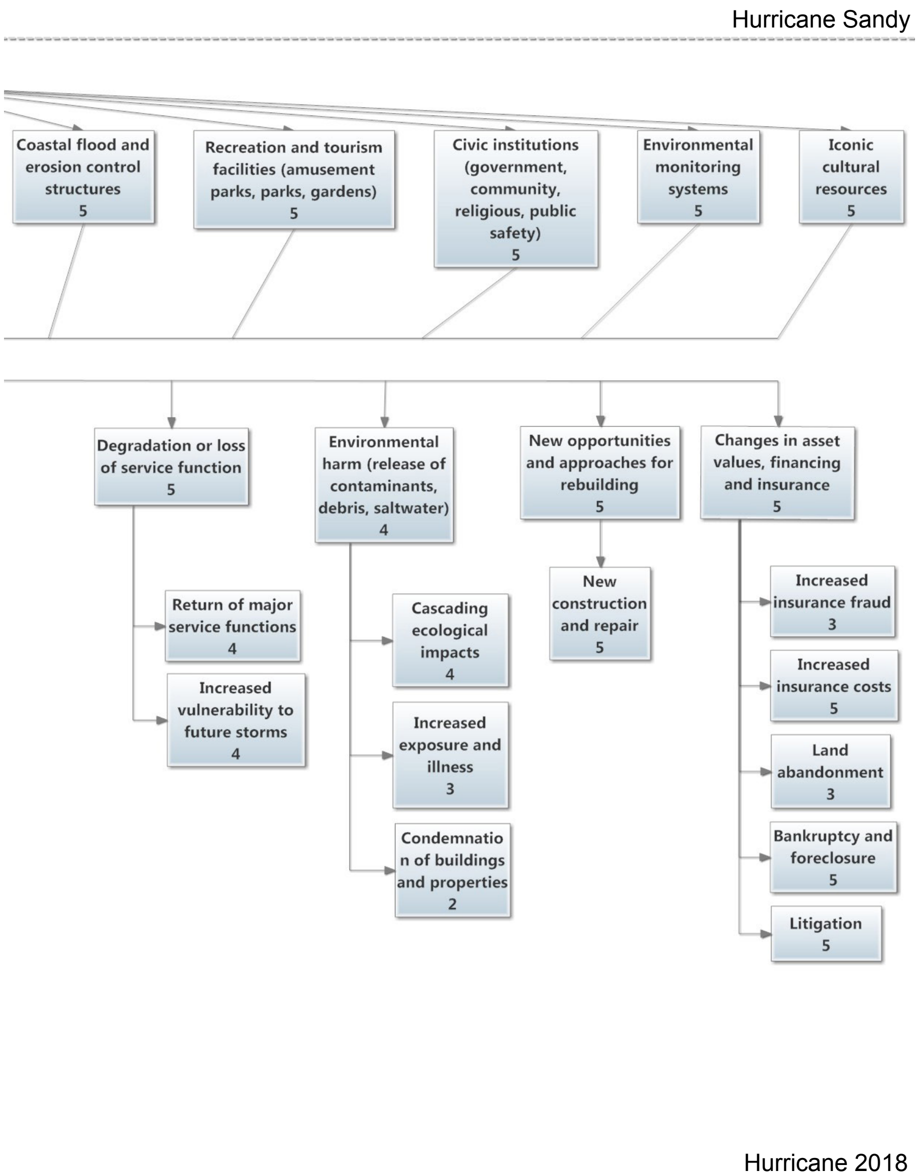



**Figure 10.** OGS Scenario 1a—Flood Damage to the Built Environment and Property.


Hurricane Sandy
Coastal flood and erosion control structures 5
Recreation and tourism facilities (amusement parks, parks, gardens) 5
Civic institutions (government, community, religious, public safety) 5
Environmental monitoring systems 5
Iconic cultural resources 5
Degradation or loss of service function 5
Environmental harm (release of contaminants, debris, saltwater) 4
New opportunities and approaches for rebuilding 5
Changes in asset values, financing and insurance 5
Return of major service functions 4
Increased vulnerability to future storms 4
Cascading ecological impacts 4
Increased exposure and illness 3
Condemnation of buildings and properties 2
New construction and repair 5
Increased insurance fraud 3
Increased insurance costs 5
Land abandonment 3
Bankruptcy and foreclosure 5
Litigation 5
Hurricane 2018

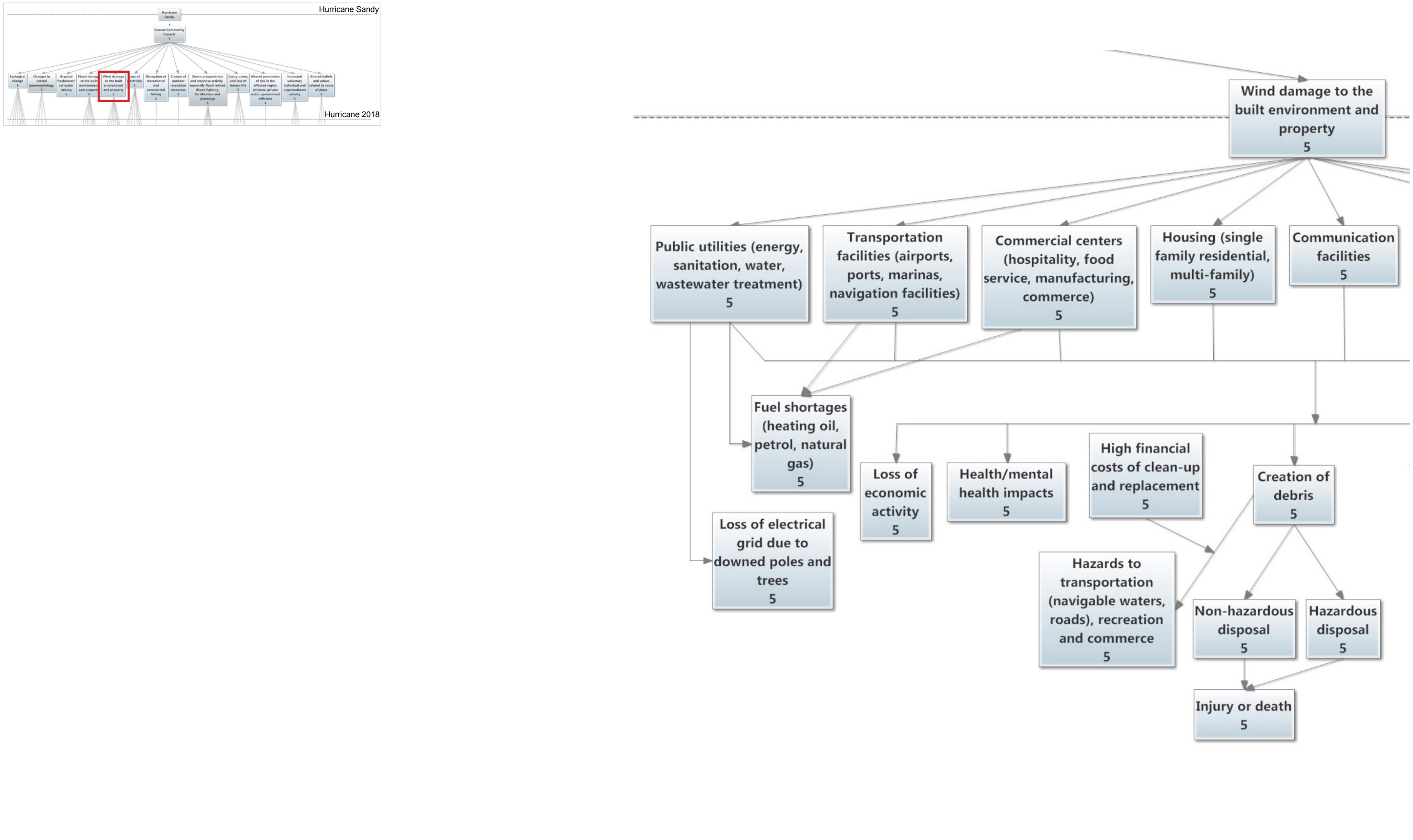
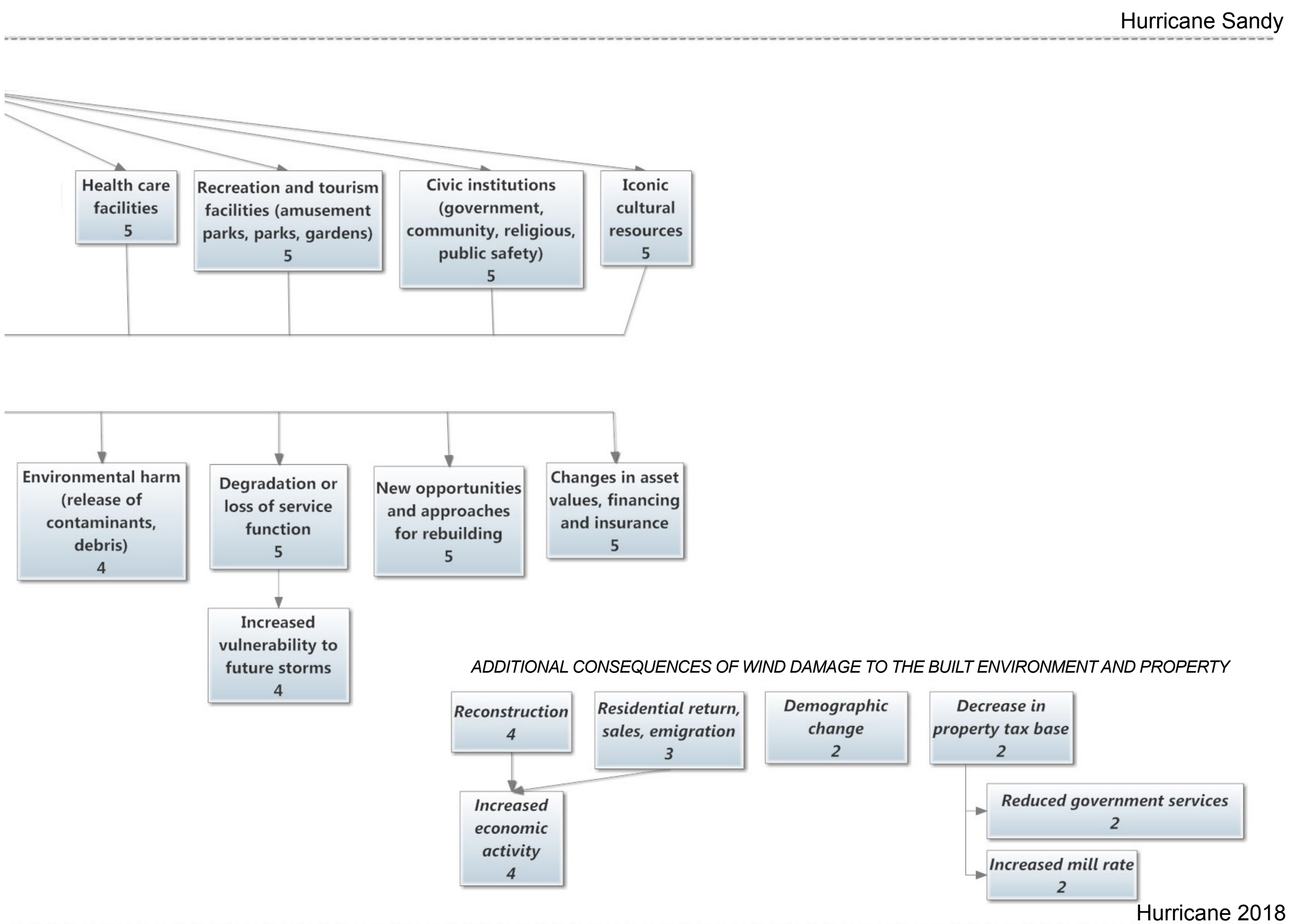



**Figure 11.** OGS Scenario 1a—Wind Damage to the Built Environment and Property.


Hurricane Sandy
Health care facilities 5
Recreation and tourism facilities (amusement parks, parks, gardens) 5
Civic institutions (government, community, religious, public safety) 5
Iconic cultural resources 5
Environmental harm (release of contaminants, debris) 4
Degradation or loss of service function 5
New opportunities and approaches for rebuilding 5
Changes in asset values, financing and insurance 5
Increased vulnerability to future storms 4
ADDITIONAL CONSEQUENCES OF WIND DAMAGE TO THE BUILT ENVIRONMENT AND PROPERTY
Reconstruction 4
Residential return, sales, emigration 3
Demographic change 2
Decrease in property tax base 2
Increased economic activity 4
Reduced government services 2
Increased mill rate 2
Hurricane 2018

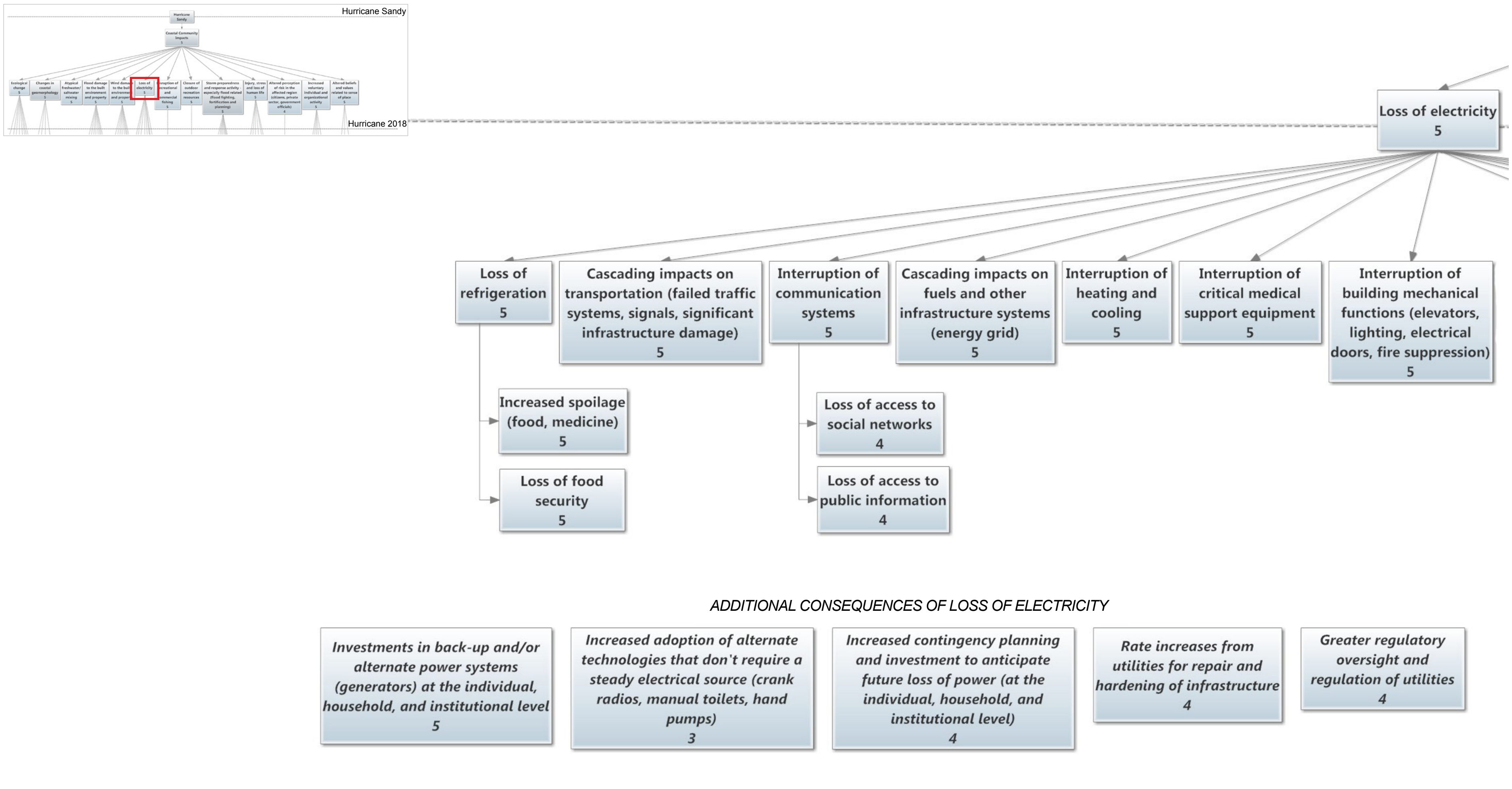
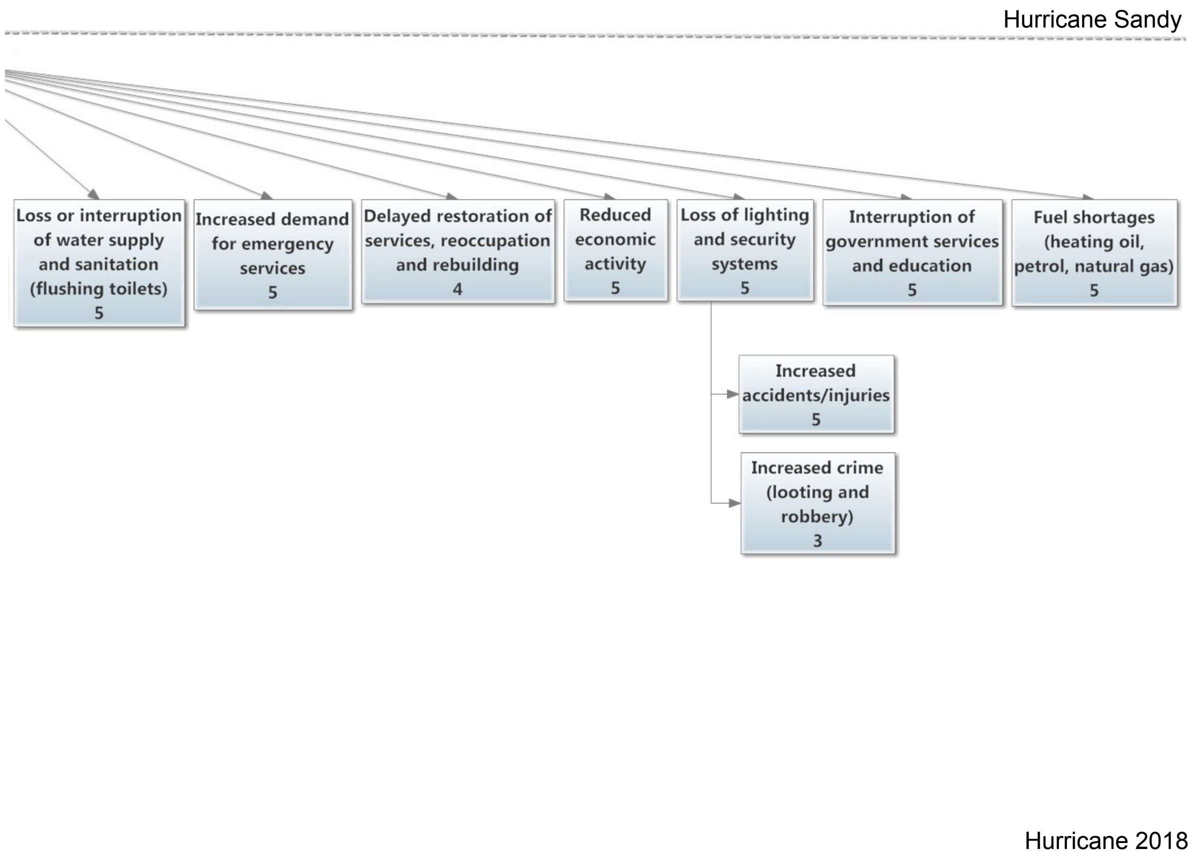



**Figure 12.** OGS Scenario 1a—Loss of Electricity.


Hurricane Sandy
Loss or interruption of water supply and sanitation (flushing toilets) 5
Increased demand for emergency services 5
Delayed restoration of services, reoccupation and rebuilding 4
Reduced economic activity 5
Loss of lighting and security systems 5
Interruption of government services and education 5
Fuel shortages (heating oil, petrol, natural gas) 5
Increased accidents/injuries 5
Increased crime (looting and robbery) 3
Hurricane 2018

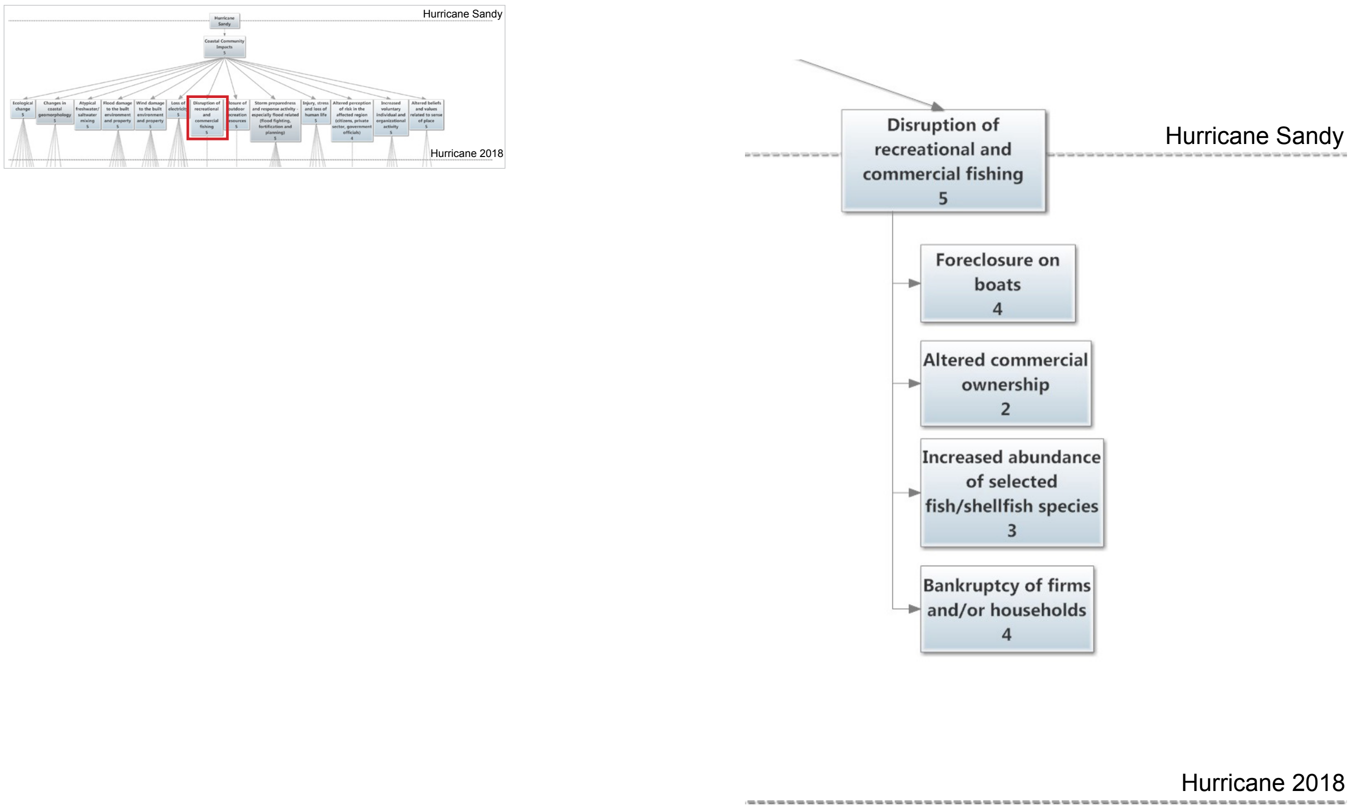



**Figure 13.** OGS Scenario 1a—Disruption of Recreational and Commercial Fishing.

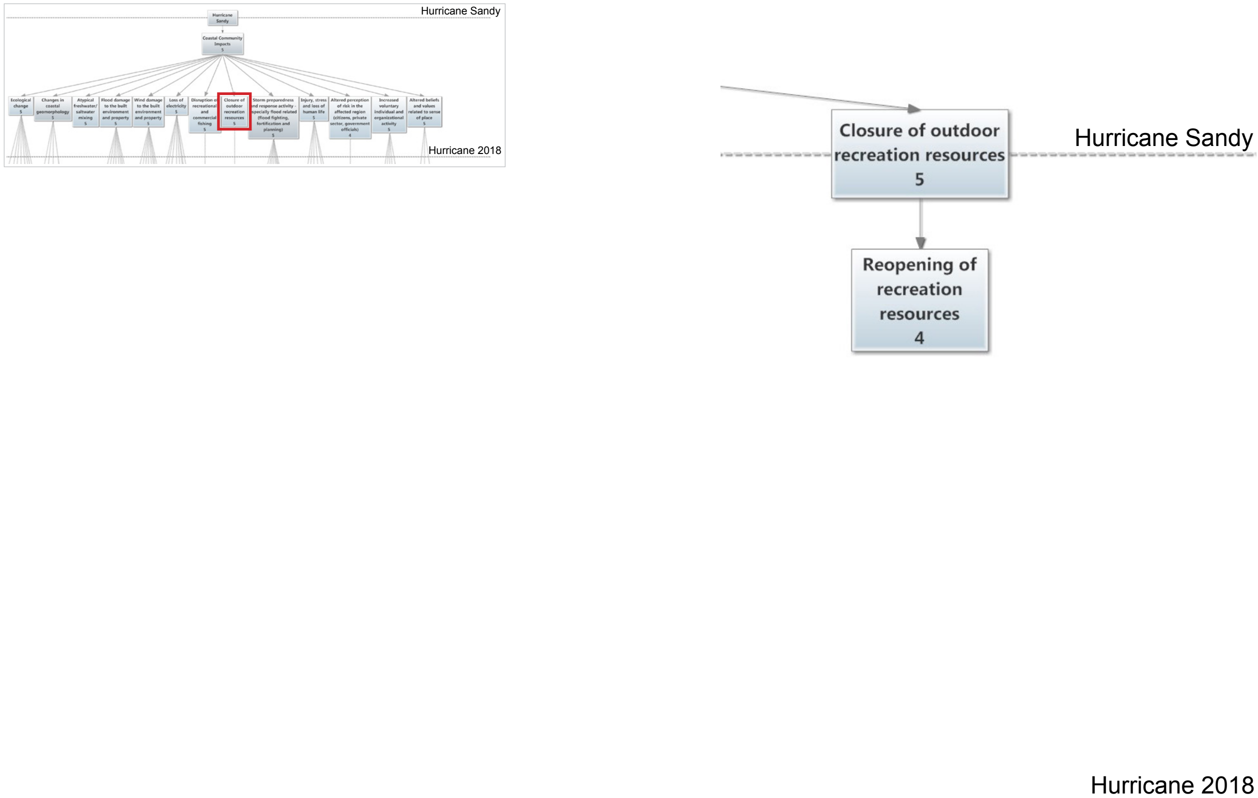



**Figure 14.** OGS Scenario 1a—Closure of Outdoor Recreation Resources.

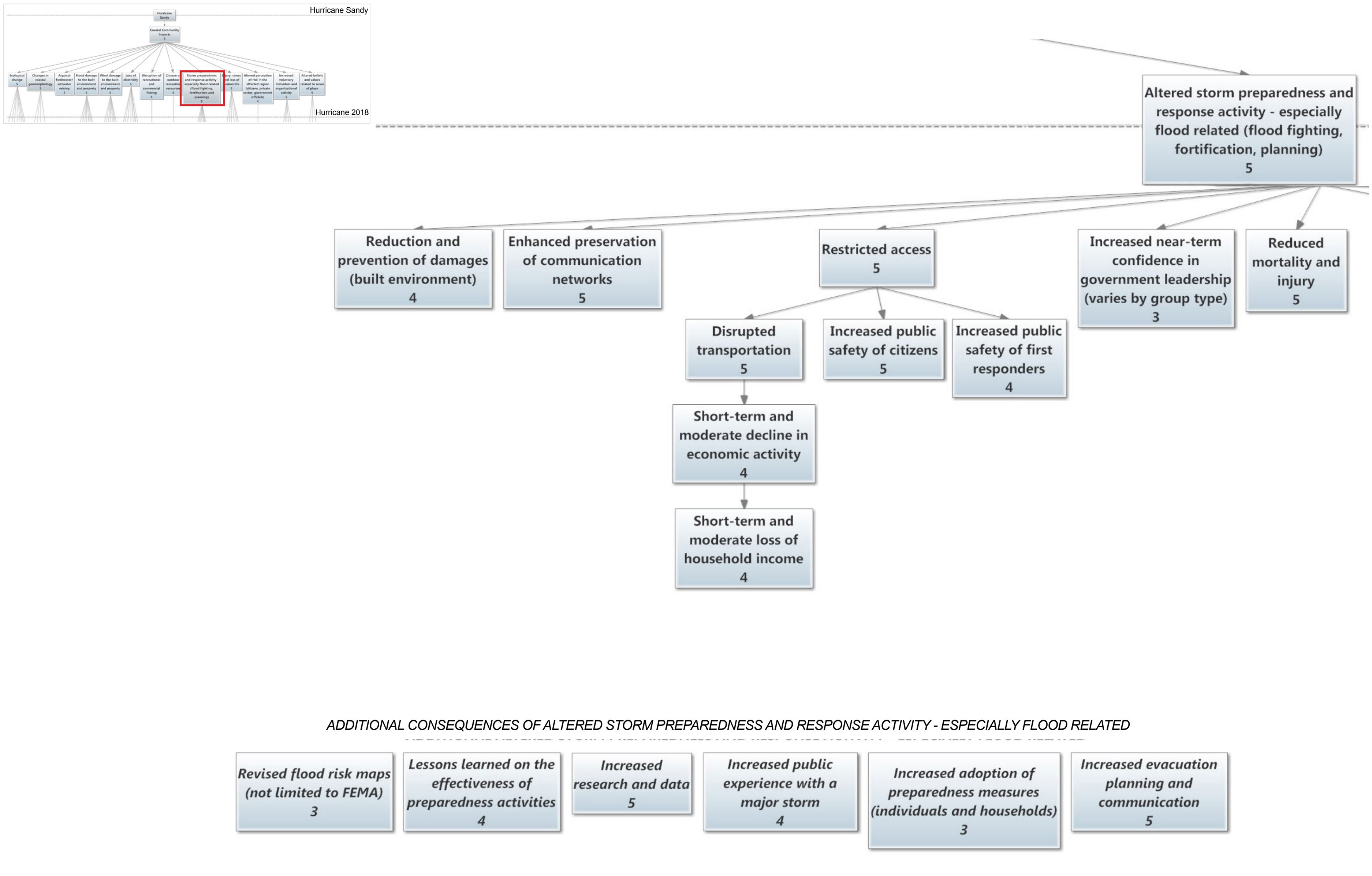
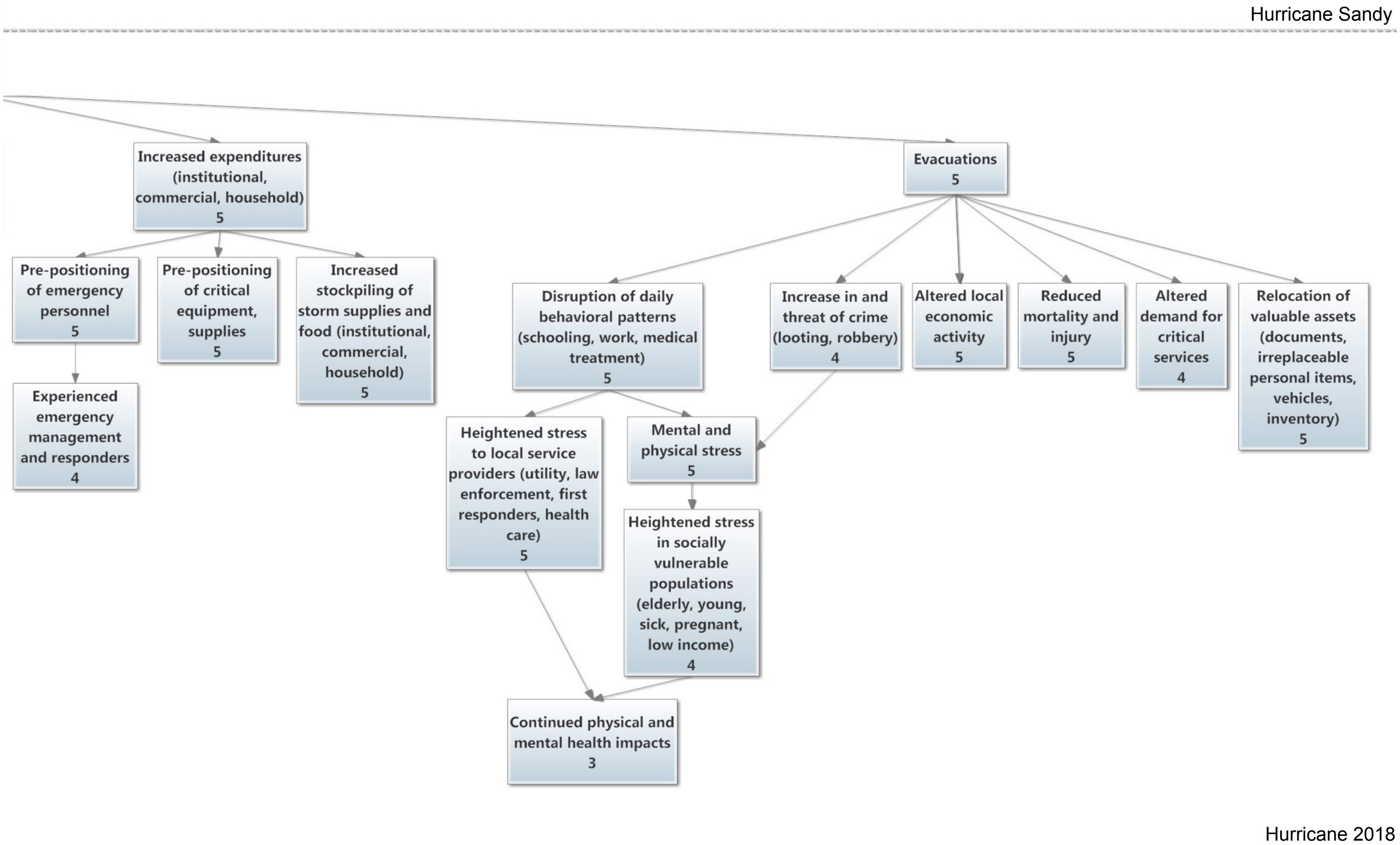
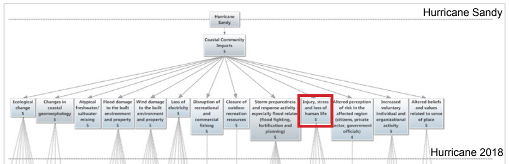



**Figure 15.** OGS Scenario 1a—Altered Storm Preparedness and Response Activity.


Hurricane Sandy
Increased expenditures (institutional, commercial, household) 5
Evacuations 5
Pre-positioning of emergency personnel 5
Pre-positioning of critical equipment, supplies 5
Increased stockpiling of storm supplies and food (institutional, commercial, household) 5
Disruption of daily behavioral patterns (schooling, work, medical treatment) 5
Increase in and threat of crime (looting, robbery) 4
Altered local economic activity 5
Reduced mortality and injury 5
Altered demand for critical services 4
Relocation of valuable assets (documents, irreplaceable personal items, vehicles, inventory) 5
Experienced emergency management and responders 4
Heightened stress to local service providers (utility, law enforcement, first responders, health care) 5
Mental and physical stress 5
Heightened stress in socially vulnerable populations (elderly, young, sick, pregnant, low income) 4
Continued physical and mental health impacts 3
Hurricane 2018



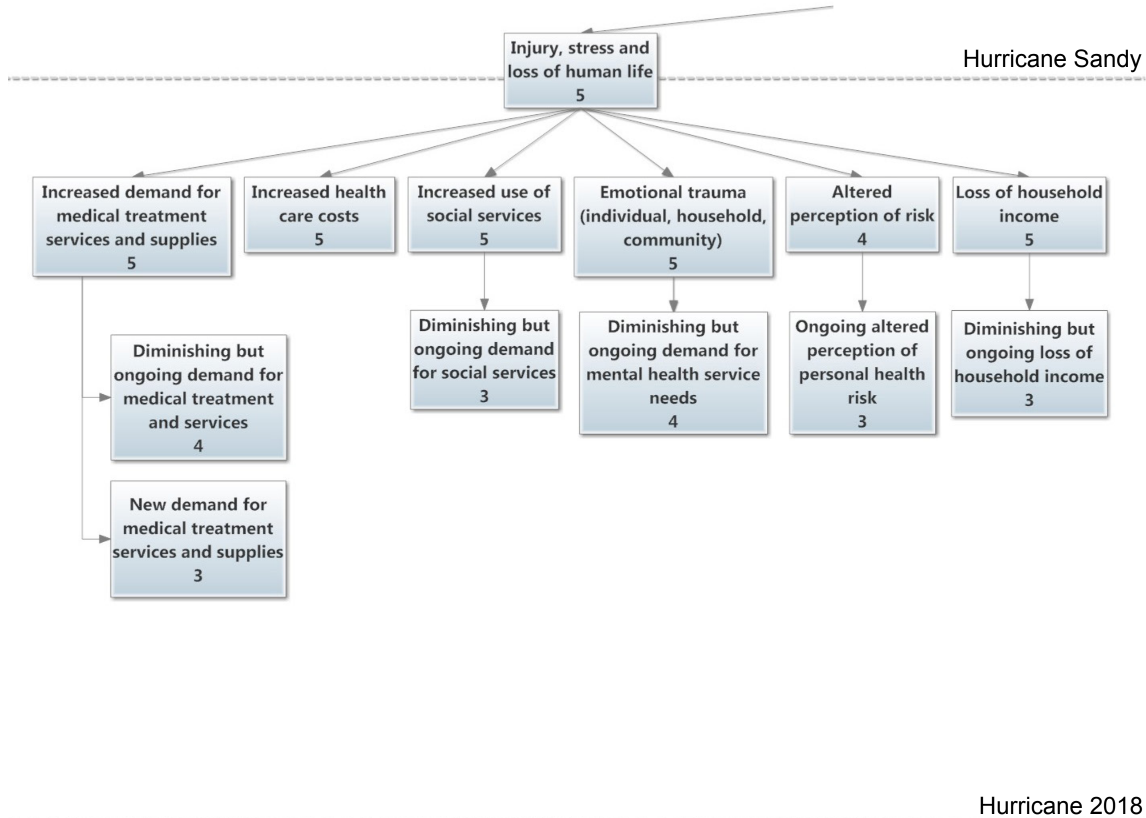




**Figure 16.** OGS Scenario 1a—Injury, Stress, and Loss of Human Life.

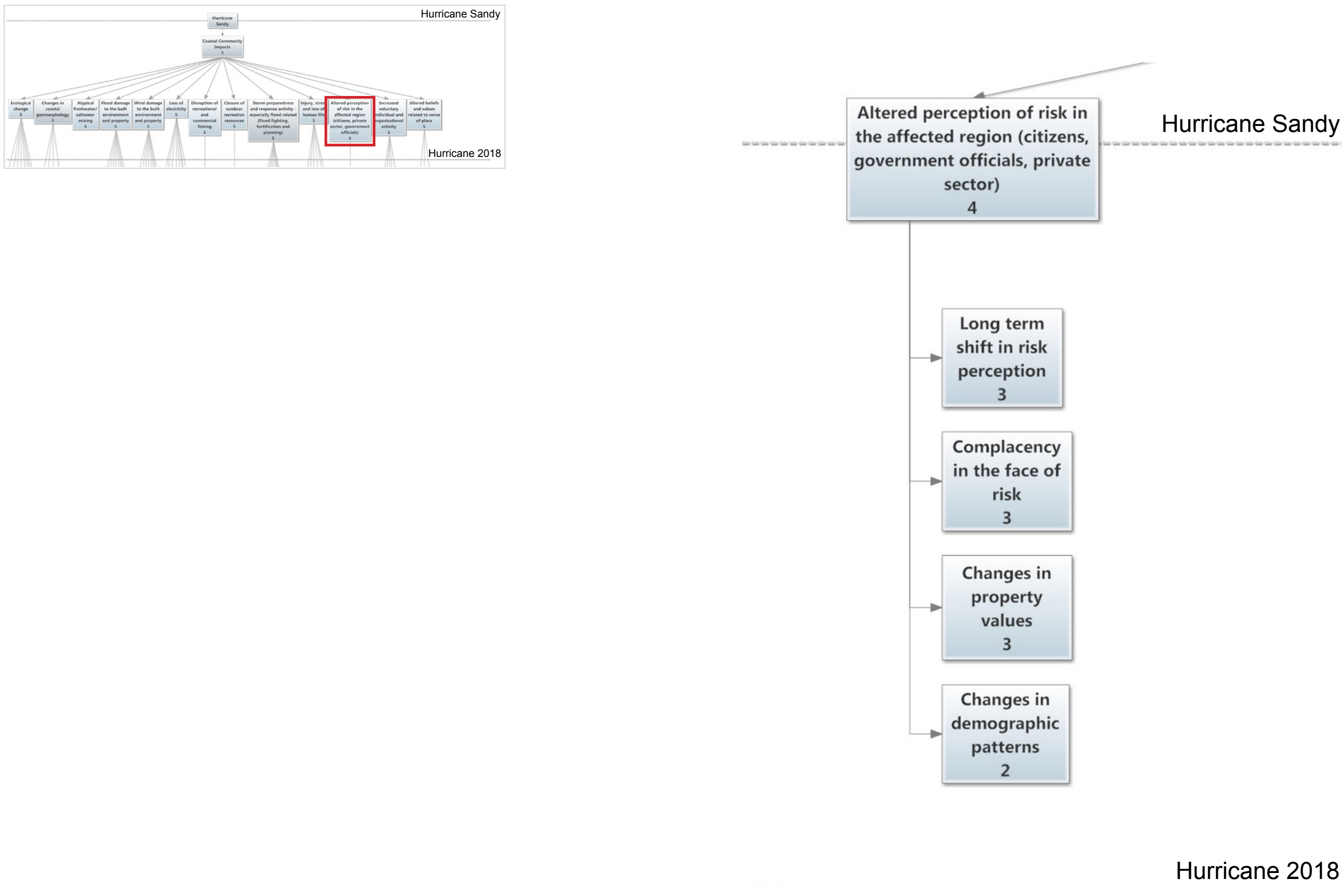



**Figure 17.** OGS Scenario 1a—Altered Perception of Risk.

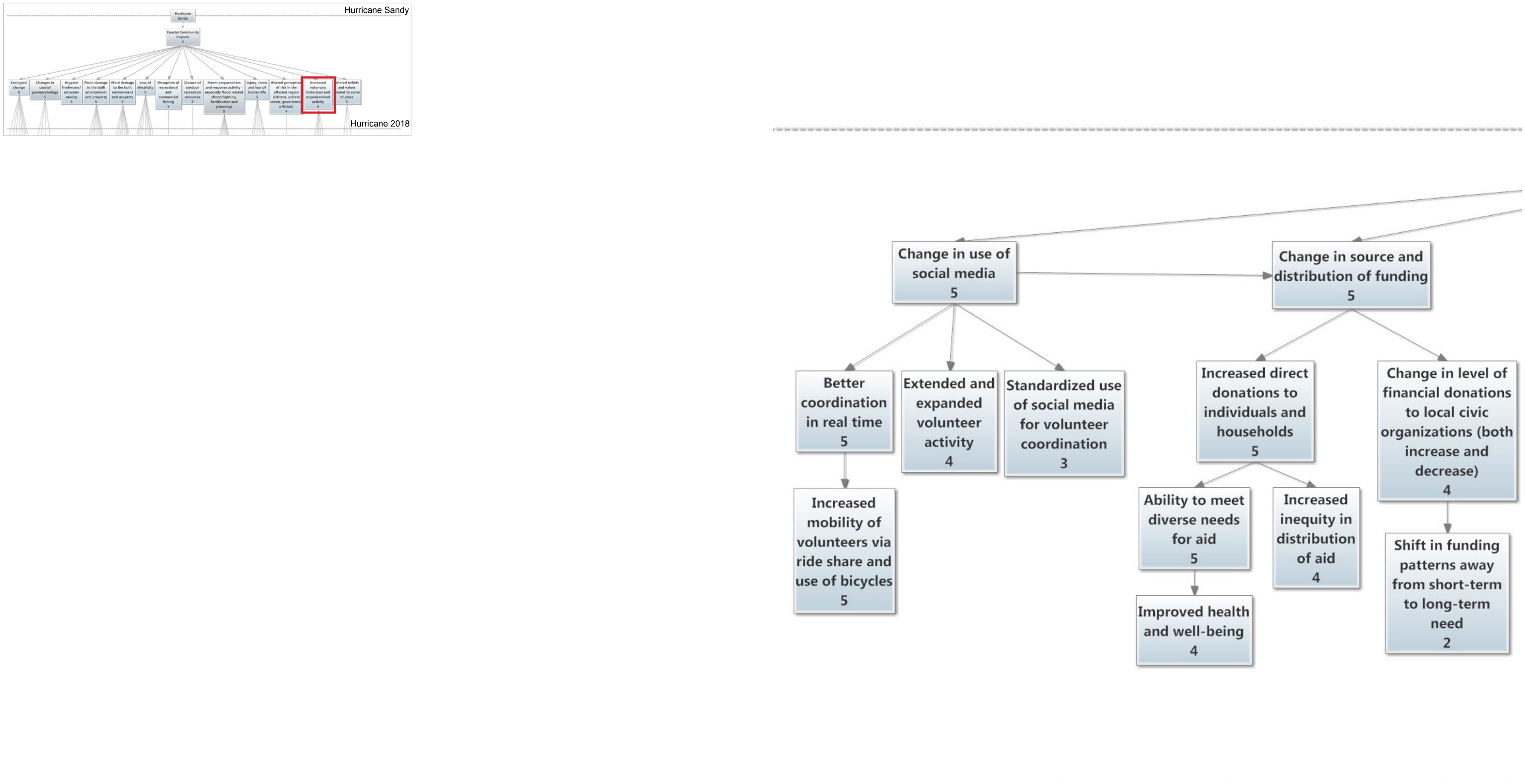
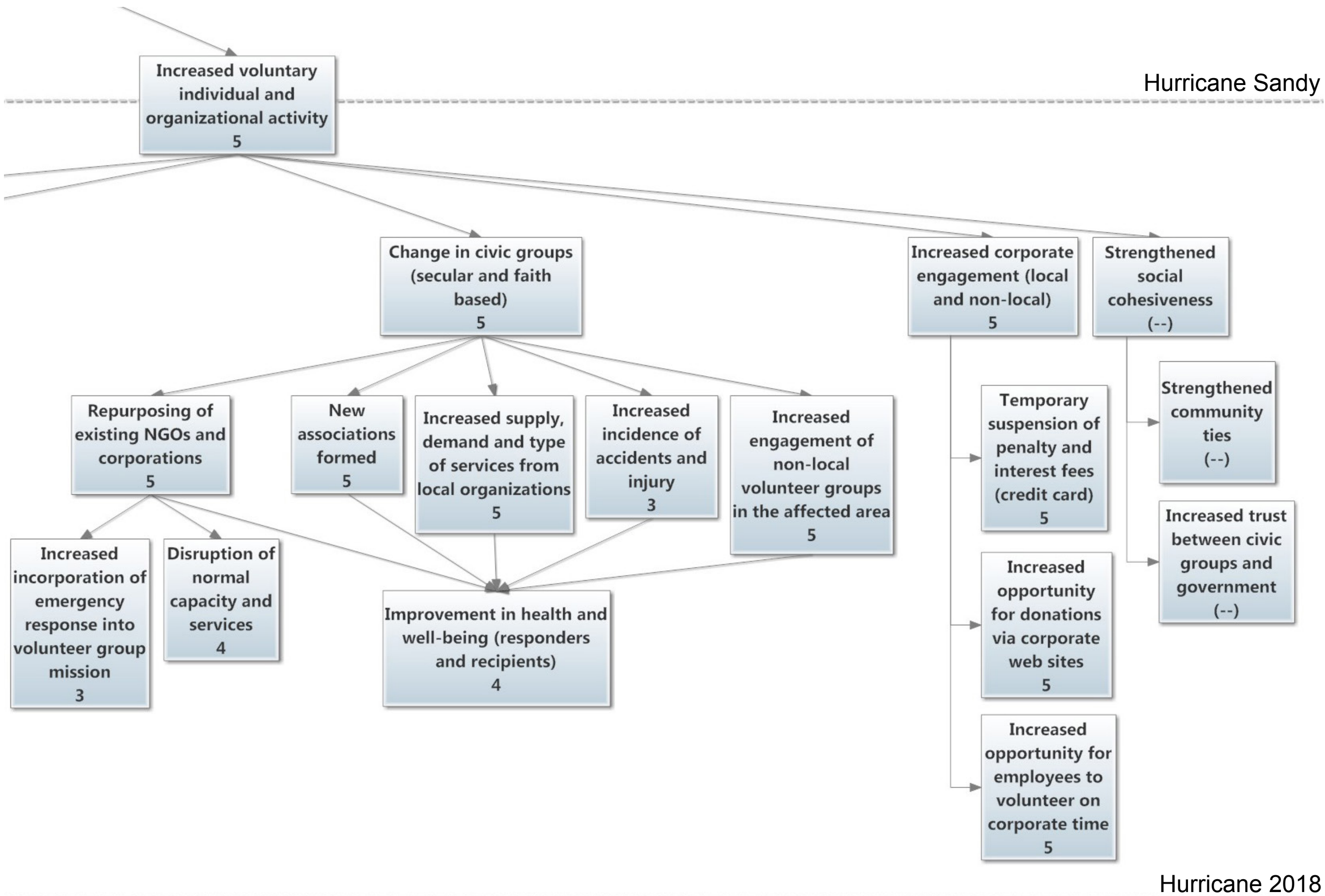



**Figure 18.** OGS Scenario 1a—Increased Voluntary Activity.


Hurricane Sandy
Increased voluntary individual and organizational activity 5
Change in civic groups (secular and faith based) 5
Increased corporate engagement (local and non-local) 5
Strengthened social cohesiveness (--)
Repurposing of existing NGOs and corporations 5
New associations formed 5
Increased supply, demand and type of services from local organizations 5
Increased incidence of accidents and injury 3
Increased engagement of non-local volunteer groups in the affected area 5
Temporary suspension of penalty and interest fees (credit card) 5
Strengthened community ties (--)
Increased trust between civic groups and government (--)
Increased incorporation of emergency response into volunteer group mission 3
Disruption of normal capacity and services 4
Improvement in health and well-being (responders and recipients) 4
Increased opportunity for donations via corporate web sites 5
Increased opportunity for employees to volunteer on corporate time 5
Hurricane 2018

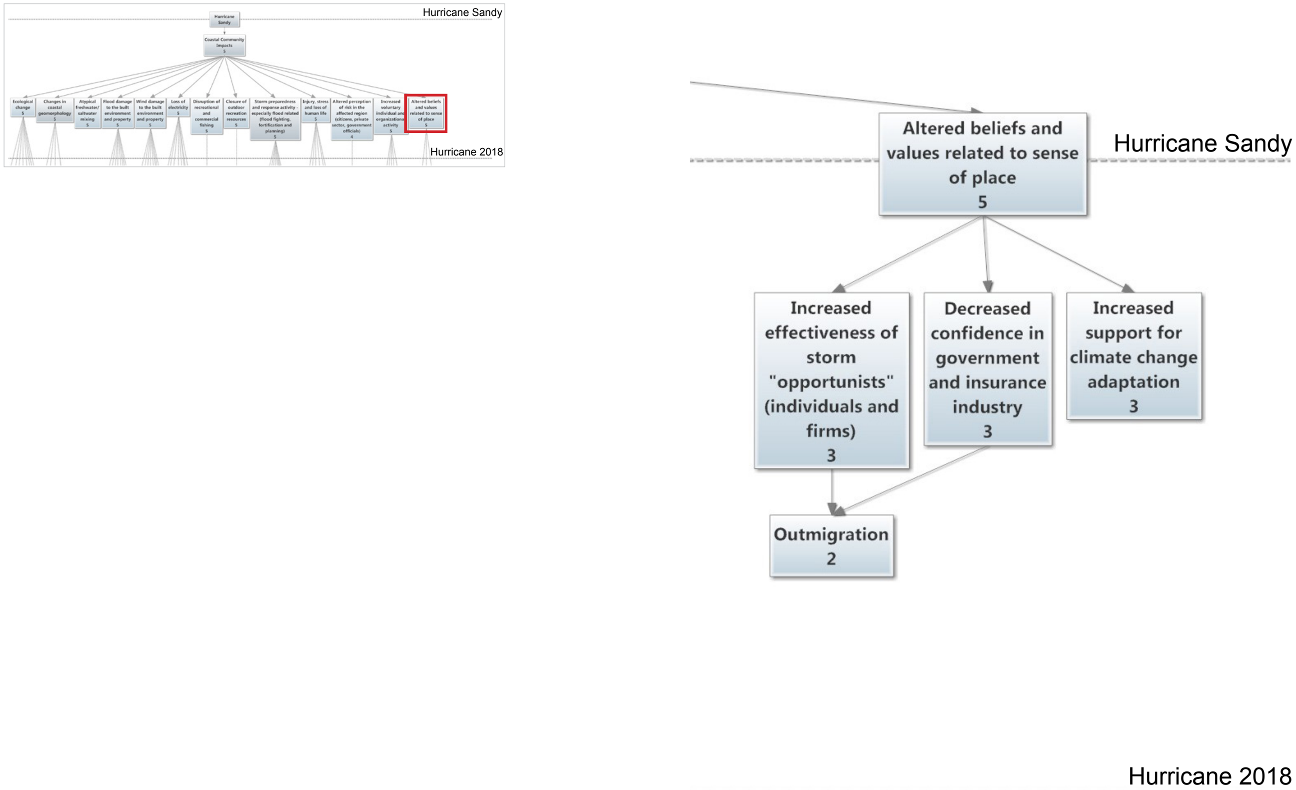



**Figure 19.** OGS Scenario 1a—Altered Beliefs and Values.

Emergence of new volunteer groups and efforts would with *reasonable certainty* lead to an improvement in the health and well-being of both responders *and* recipients. An example of increased volunteer activity has been the Occupy Wall Street effort morphing into Occupy Sandy (and later Occupy Sandy Recovery), where volunteers continue to actively use social media to organize groups and individuals and use the web to coordinate supply needs, donations, and distribution.

### Altered Beliefs and Values Related to Sense of Place

For many in the affected region, Hurricane Sandy resulted in altered beliefs and values related to sense of place (*certain*) (Figure 19). The OGS determined that this change could *probably* lead to increased effectiveness of individuals and companies taking inappropriate advantage of the storm and a collective decreased confidence in both the government and the insurance industry. Together, these events in the long-term may lead to an outmigration of individuals and families from the region (*plausible)*. The OGS scenarios suggest that Hurricane Sandy will *probably* lead to increased support for climate change adaptation and some early polls (e.g., Rutgers, 2013) suggest this change may already be underway.

## Interventions

The OGS developed 21 interventions, which were subsequently revised and refined by the SSG co-leaders and staff into 17 possible interventions for Coastal Communities and Ecosystems of the affected region that could improve short- and long-term regional resilience. Although the OGS focused on interventions to be taken in the next five years to improve the human-natural system's resilience to a storm like the hypothetical Hurricane 2018, many of the interventions may have long-term (e.g., decades) benefits and may bolster the coupled human-natural system's resilience to other hazards and adverse events.

Interventions are defined as institutional actions that support the recovery as defined by the Task Force *and* that increase the resilience of the coupled human-natural system to future major storms. Each intervention was assigned an "intervention value" of High (H)/Medium (M)/Low (L), which is a subjective index of the intervention's potential return on investment *and* pervasive impact on the system. Pervasiveness of interventions was assessed at the level of first-tier consequences.

Interventions are listed and discussed below and Table 1 illustrates the pervasiveness of each action throughout the scenario. Interventions appear in order of intervention value from high to low "value" and are *not* prioritized.

- **Prioritize, integrate, and implement both ecosystem-based** and **engineered risk-reduction projects on a regional basis to maximize ecological, economic, and social benefits. (H)** The OGS scenarios suggest that neither green nor gray infrastructure is individually sufficient for rebuilding more resilient coastal communities and ecosystems, and that both types of infrastructure are necessary. There are multiple definitions of gray and green infrastructure. This report adopts the Task Force's definition of green infrastructure, which is "the integration of natural systems and processes, or engineered systems that mimic natural systems and processes, into investments in resilient infrastructure" (Hurricane Sandy Rebuilding Task Force, 2013). In this report, gray infrastructure refers to engineered, man-made, and built systems that support community functions (e.g., wastewater treatment, communications, transportation, and commerce). Projects should be undertaken at a regional level to account for the interconnectedness of the human-natural system. Examples of potential green infrastructure include installing oyster beds to reduce storm impact (Piazza and others, 2005; Beck and others, 2012; Arkema and others, 2013), whereas examples of gray infrastructure include carefully designed artificial defenses such as seawalls and riprap to reduce storm impact. One report suggests that in many instances, green infrastructure can be more sustainable over time and has less continuous maintenance costs than gray infrastructure, although the latter has been more commonly used to date (Beck and Shepard, 2012).
- **Document and map key ecosystems that have storm protection benefits to inform a strategy for using public and private sector programs to invest in conservation and restoration of those systems. (H)** Considerable research has already been done to identify key ecosystems—such as oyster beds, mangroves, wetlands, dunes, and reefs—that provide substantial storm protection to coastal zones across the globe (e.g., Beck and Shepard, 2012; Arkema and others, 2013). The OGS scenario suggests coastal geomorphology is critical to regional resilience and ecosystem services. These ecosystem services are recognized for their ability to provide valuable storm surge protection in addition to providing unique habitats to flora and fauna, improved water quality, and popular tourism destinations. However, further research on the effectiveness of different techniques and use of GIS systems is needed to better quantify and map, on a regional basis, the long-term costs, benefits, and opportunities of both conserving and restoring these ecosystems. Monitoring, when combined with adaptive management strategies for adjusting restoration tactics, may be useful.

- **Design, build, restore, monitor, and evaluate beach/dune/marsh ecosystem buffers that are self-sustaining and protective under normal perturbations. (H)** Many natural storm barriers such as dunes and marshes were either destroyed or substantially damaged by Hurricane Sandy (US Geological Survey, 2013). These barriers provided protection to both coastal habitats and to the built environment including many coastal homes. In order to protect these vulnerable locations from future storms, significant effort should be placed on designing, building, and restoring these ecosystem buffers.
- **Understand and address hazards of debris and environmental contamination (from both debris and outer sources, e.g., mold, lead, asbestos, released chemicals) through assessments, remediation, and education of workers, volunteers, homeowners, and building occupants. (H)** Both flood and wind damage to the built environment created hazardous debris (Figures 10-11). In many cases, debris piles include mixed hazardous and non-hazardous materials. Significant work at the local and regional scales remains to be done in sorting and disposing the debris and educating individuals who may be exposed to different contaminants concerning potential long-term health impacts.
- **Understand and develop predictive models of the complex interactions among networked infrastructure (such as water and waste systems) during storm events. (H)** Within the OGS scenario, many of the problems encountered by residents of both coastal and urban communities in the aftermath of Hurricane Sandy resulted from complex and sometimes unexpected interactions of networked infrastructure, both above and below ground. Hurricane Sandy revealed the urgent need to improve predictive models of these interactions during storm events. For example, over 10 billion gallons of spilled sewage flowed into the waterways (and in some cases city streets) of eight states in the Hurricane Sandy-impacted region (Kenward and others, 2013). As reported by Kenward and others (2013), “in some cases, Sandy’s storm surge simply flooded treatment plants and pumping stations, while in other cases, a combination of power outages and flood conditions shuttered facilities or caused major diversions of sewage into receiving waters.” By creating maps, models, and a better understanding of how these systems interact during storm events, facility managers can be better prepared to assess pre-storm risk and post-event damage.
- **Build local, state and tribal government capacity to apply best-available data on current and future risk to expedite permitting review, implementation, and evaluation of recovery projects. (H)** The definition of risk depends on discipline and topic. The International Organization for Standardization defines risk as “the effect of uncertainty on objectives.” Local, state, and tribal governments do not routinely have access to best-available scientific data on current and future risk associated with major storms. Such data is essential for expedient and effective permitting review, as well as implementation and evolution of recovery projects. Building capacity includes decision-support and visualization tools, advanced training, modernized IT capable of handling large data sets, and protocols for data sharing among institutional partners. For efficiency, effectiveness, and lower cost, multi-institutional operations could be considered (such as several counties).
- **Develop land valuation, tax incentives, and buy-out strategies to encourage land use that reduces risk, encourages environmental sustainability, and reduces government expenditure. (H)** As one method to reduce risk from future disasters, FEMA has supported land and property buy-outs in disaster-prone areas since 1993. Land buyouts are administered by the state and local communities and the purchased property becomes public land that can be used to develop public parks, wildlife refuges, or other recreation areas. This strategy was used by some Gulf Coast communities who were hard hit by Hurricane Katrina in 2005. In the aftermath of Hurricane Sandy, the Governor of New York has proposed purchasing New York homes to turn land into permanent undeveloped flood zones near the coast (Kaplan, 2013). Land buyouts, in addition to new land valuation and tax incentives, could prove to be a useful tool for state governments to reduce long-term risk in the affected region, encourage sustainability, and reduce government expenditures.
- **Apply best-available flood risk data from FEMA plus additional freeboard for all federal and federally-funded structures, and incentivize/support state, local, and tribal adoption of these data. (H)** The OGS scenarios point to the need for the region’s structures to be re-built using the most current information on flood risk, both today and over the expect lifetime of these structures. This policy could be adopted for all federal and federally-funded structures. The Federal government should continue to mandate use of best-available flood risk data for federally funded Sandy recovery projects, and support state, local, and tribal governments in applying these data to their recovery efforts. Incentives such as premium discounts for flood insurance policyholders, tax breaks, credit systems, and other methods of support could be used across the state, local, and tribal levels to encourage residents and business owners to rebuild at higher elevations.

- **Assess current regulatory model codes and guidelines for building, land use planning, and zoning and revise them to reflect resiliency planning. Provide technical assistance to local municipalities to adopt these revisions. (H)** Revision of regulatory codes for building, land-use planning, and zoning require significant technical and legal expertise. Assessing current codes for potential revision would likely lead to improved resilience of the coupled human-natural system to severe storm events such as Hurricane Sandy. The Agricultural Extension Service model that includes federally-funded and locally deployed extension agents has significant potential to assist, accelerate, and improve revision of codes at the local and state level.
- **Harden electrical distribution systems and increase distributed energy generation and the use of renewable energy. (H)** Across 21 states in the northeast and mid-Atlantic, Hurricane Sandy left over 8.5 million homes without power when wind, surge, and precipitation-related flooding damaged out power lines, electrical networks, and substations. Loss of power led to food spoilage, damage or loss of medical services, interruption of commercial activity, disruption of building mechanical functions, and loss of heat among many other cascading consequences (e.g., Figure 12). To improve the resilience of the system to future major storms, electrical distribution systems could be hardened, energy generation facilities be spatially distributed and raised, and renewable energy be more broadly used. In some areas, this work is already underway [e.g., Consolidated Edison has committed $250 million to help harden New York City's electrical system (Wood, 2012)].
- **Identify and build capacity of local civic groups to assist in emergency preparedness, response, and recovery. (H)** The OGS scenarios identified an increase in voluntary activity at both the institutional and individual levels to be a significant consequence of Hurricane Sandy (e.g., Figure 18). These groups creatively employed both traditional means (e.g., neighborhood meetings, using churches as emergency supply distribution centers) and new technology (e.g. social media, new websites) to connect with their community. By identifying and recognizing the work of these civic groups and the communities they support, new paths for collaboration and coordination can be created to share resources, best practices, and expertise to strengthen these networks for future adverse events.
- **Understand and develop strategies for hurricane hazard and risk education, communication, and actions that are effective across varying demographic and institutional types. (H)** There is a significant need for broader outreach, engagement, and education concerning community risk and vulnerability both during "blue sky" periods and storm events. In addition, there is a need for integration and application of physical and social science research (both existing and new) on individual and community-level barriers to taking actions to reduce long-term risk. These research results would be useful in guiding communication and outreach strategies.
- **Conduct rapid and ongoing assessments and research on health care, mental health services, and social services, especially in high-impacted and underserved areas. (H)** Ongoing mental and physical health care will be needed in many parts of the affected area for years to come. It is important that both the short- and long-term impacts of Hurricane Sandy on personal and public health be researched to apply lessons learned to improve community resilience to future storms and extreme events.
- **Identify vulnerable populations and create and maintain a "seek and find" registry for individuals and households needing special care during storm events. (M-H)** Many of the individuals who suffered from loss of heat, medical services, and food shortages were individuals needing special care including the sick and the elderly. It may be useful to create a voluntary registry of these individuals to expedite aid-dispatch during hazard events. Such a registry could be used by individuals (e.g., children who register elderly parents, staff at nursing homes and other care facilities).
- **Research consequences of long-term changes (such as population growth and redistribution, sea-level rise) on storm impacts and integrate findings into proposed interventions. (M-H)** Across the natural and social sciences, research in climate change, geography, and human behavior has investigated the increasingly complex interactions between the natural and built environments. As population continues to increase and as the global climate continues to change, there is a growing need for integrated research in how long-term changes such as population growth and sea level rise act together or against one another in the face of hazardous events like Hurricane Sandy. To better understand and prepare for the environmental, social, and economic risks posed by long-term changes, it is important to invest in resilience research (across the coupled human-natural system) and to incorporate these findings into policy at the federal, state and local levels. This intervention is similar to the National Research Council's first recommendation in its 2012 *Disaster Resilience* report, which states "federal government agencies should incorporate national resilience as an organizing principle to inform and guide the mission and actions of the federal government and the programs it supports at all levels."

**Table 1.** Interventions Matrix.

[“X” indicates the intervention is applicable to the marked first-tier consequence.]

| Intervention |
|---|
| Prioritize and implement ecosystem-based and engineered risk-reduction projects on a regional basis to maximize ecological, economic, and social benefits. |
| Document and map key ecosystems that have storm protection benefits to inform a strategy for using public and private sector programs to invest in conservation and restoration of those systems. |
| Design, build, restore, monitor, and evaluate beach/dune/marsh ecosystem buffers that are self-sustaining and protective under normal perturbations. |
| Understand and address hazards of debris and environmental contamination (e.g., mold, lead, asbestos, released chemicals) through assessments, remediation, and education of workers, volunteers, homeowners, and building occupants. |
| Understand and develop predictive models of the complex interactions among networked infrastructure (such as water and waste systems) during storm events. |
| Build local, state and tribal government capacity to apply best-available data on current and future risk to expedite permitting review, implementation, and evaluation of recovery projects. |
| Develop land valuation, tax incentives, and buy-out strategies to encourage land use that reduces risk, encourages environmental sustainability, and reduces government expenditure. |
| Apply best-available flood risk data from FEMA plus additional freeboard for all federal and federally-funded structures, and incentivize/support state, loca, and tribal adoption of these data. |
| Assess current regulatory model codes and guidelines for building, land use planning, and zoning and revise them to reflect resiliency planning. Provide technical assistance to local municipalities to adopt these revisions. |
| Harden electrical distribution systems and increase distributed energy generation and use of renewable energy. |
| Identify and build capacity of local civic groups to assist in emergency preparedness, response, and recovery. |
| Understand and develop strategies for hurricane hazard and risk education, communication, and actions that are effective across varying demographic and institutional types. |
| Conduct rapid and ongoing assessments and research on health care, mental health services, and social services, especially in high-impacted and underserved areas. |
| Identify vulnerable populations and create and maintain a “seek and find” registry for individuals and households needing special care during storm events. |
| Research consequences of long-term changes (such as population growth and redistribution, sea-level rise) on storm impacts and integrate findings into proposed interventions. |
| Collect, analyze and share critical regional data (particularly high-resolution LIDAR, land use/land cover and flood risk) for asset risk management. |
| Develop and maximize market potential for repurposing materials and/or debris for community/public and private sector use. |

**Table 1.** Interventions Matrix.—Continued

[“X” indicates the intervention is applicable to the marked first-tier consequence.]

| Value | Ecological Impacts | Changes in Coastal Geomorphology | Atypical Fresh/Saltwater mixing | Flood damage to built environment | Wind damage to Built Environment | Loss of Electricity | Disruption of Commercial and Recreational Fishing | Closure of Outdoor Recreational Resources | Storm Preparedness and Response Activity | Injury, stress, and loss of human life | Altered Perception of Risk | Increased Voluntary Activity | Altered beliefs and values |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | x | x | x | x | x | x | x | x | x | x | x | x | |
| H | x | x | x | x | x | | x | | | x | x | | x |
| H | x | x | x | x | x | | | | x | | | x | |
| H | | | | x | x | | | x | x | x | x | | x |
| H | x | | | x | x | x | | | x | x | x | | |
| H | x | x | | x | x | | x | x | x | x | x | | x |
| H | x | x | | x | x | | | | x | x | | | x |
| H | x | | | x | | x | | | x | | x | | x |
| H | x | | | x | x | | | | x | x | x | | x |
| H | | | | x | x | x | | | x | x | | | |
| H | | | | x | x | | | | x | x | x | x | x |
| H | x | x | | x | x | x | x | x | x | x | x | | x |
| H | | | | x | x | x | x | x | x | x | x | x | x |
| M-H | | | | | | | | | x | x | x | x | |
| M-H | x | x | x | x | x | x | | | x | x | x | | x |
| M-H | x | x | | x | x | x | x | x | x | x | x | | |
| L-M | x | | | x | x | | | | x | x | | x | |

- **Collect, analyze and share critical regional data (particularly high-resolution LIDAR, land use/land cover and flood risk data) for asset risk management. (M-H)** Many federal agencies collected, analyzed and distributed regional data during and after Hurricane Sandy—examples include USGS high resolution coastal topography and bathymetry data, storm surge data, and aerial photography data which were uploaded to the USGS Hazards Data Distribution System; NOAA high-resolution aerial imagery and other photography collected by the Civil Air Patrol; and EPA air monitoring data. There is a need to disseminate and share these types of data over longer time frames to improve risk management practices during the recovery and rebuilding phase of Hurricane Sandy. Future response efforts may benefit from a central repository for both federal and non-federal science results and data.
- **Develop and maximize market potential for repurposing materials and/or debris for community/public and private sector use. (L-M)** Although much of the debris resulting from Hurricane Sandy's blow is a mix of hazardous and no-hazardous materials, some of this material could be sorted and reused for rebuilding the region. While some of these efforts are already underway (e.g., metal is being sorted from debris piles at Jacob Riis Park (Leonard, 2013), downed trees have been turned into mulch by several New Jersey municipalities (Izzo, 2013), and even driftwood has been turned into art and sold to benefit local reconstruction projects, this process could be expanded to the local and regional levels.

# Discussion

Approximately 39% of the US population lives in the Nation's coastal counties, with approximately 80% of the US population inhabiting cities and highly urbanized areas (US Census Bureau, 2011; National Oceanic and Atmospheric Administration, 2013; Cutter and others, 2013). Many coastal communities in the mid-Atlantic and northeastern US face rising sea levels, which will exacerbate the impact of storm surge in both the built and natural environment (Titus and others, 2009; National Research Council, 2011; Horton and others, 2013). It is likely that rainfall in the region will become heavier over time, and hurricanes are projected to be more intense, although they may be less frequent (Solomon and others, 2007; Kunkel and others, 2013; Walsh and others, 2013). It is highly likely that future major storms—or even frequent smaller storms and/or other hazardous events—will have a significant impact on the affected region in the future, underscoring the importance of federal, state, and local governments to take steps towards bolstering the resilience of the system as a whole.

## Conceptual Framework of System Stress and Response and Recovery Activity

To begin to assess the effect of Hurricane Sandy rebuilding efforts on system stress, the OGS developed a conceptual framework showing stress in the coupled human-natural system in the affected region over the scenario timeline (Figure 20). This framework was derived from earlier work of the SSG (Department of the Interior, 2010; Machlis and McNutt, 2010; Department of the Interior, 2012). In this framework, the x-axis denotes the OGS timeline, extending from Hurricane Sandy ($T_1$-$T_2$) to the long-term future ($T_N$). The y-axis is a qualitative scale of stress to the coupled human natural system, from low to high. The black lines indicate stress experienced by the system over time and the red lines show potential response intensity (including time, personnel, and resources). This framework provides a tool for formulating hypotheses about the relationship between system stress and emergency response and rebuilding activities. Key characteristics of the framework include:

- In general, before $T_1$, the system was experiencing moderate stress caused by forces including increasing urbanization, coastal development, and rising sea level.
- Between $T_1$-$T_2$, stress to the system quickly escalated as Hurricane Sandy moved through the region. Coincident with this stress was a peak in emergency response intensity (red line), which tapered quickly as rebuilding activities began.
- Between $T_2$ and $T_4$, system stress (black line) potentially decreases as rebuilding activities increase, accelerate, and accumulate. At the time of the hypothetical Hurricane 2018, the system experiences a second spike in stress. The system never returned to the original baseline it had before Hurricane Sandy. Hence, the hypothetical Hurricane 2018 impacts the region before the system has fully recovered, leading to increased response efforts (and likely costs), as shown in red.
- Similar to Hurricane Sandy, at $T_4$ Hurricane 2018 causes elevated system stress in a short period of time while simultaneously hindering and/or interrupting rebuilding efforts as response efforts focuses on the emergency.
- Sometime after $T_4$, system stress begins to decline as rebuilding efforts (red) begin again and continue.

Many of the OGS-proposed interventions could result in a *decrease* in system stress (lowering the black curve towards pre-storm baseline values) and/or a *decrease* in the response intensity curves—for example, hardening the electrical infrastructure in the next five years (between $T_3$-$T_4$) would potentially increase resiliency of

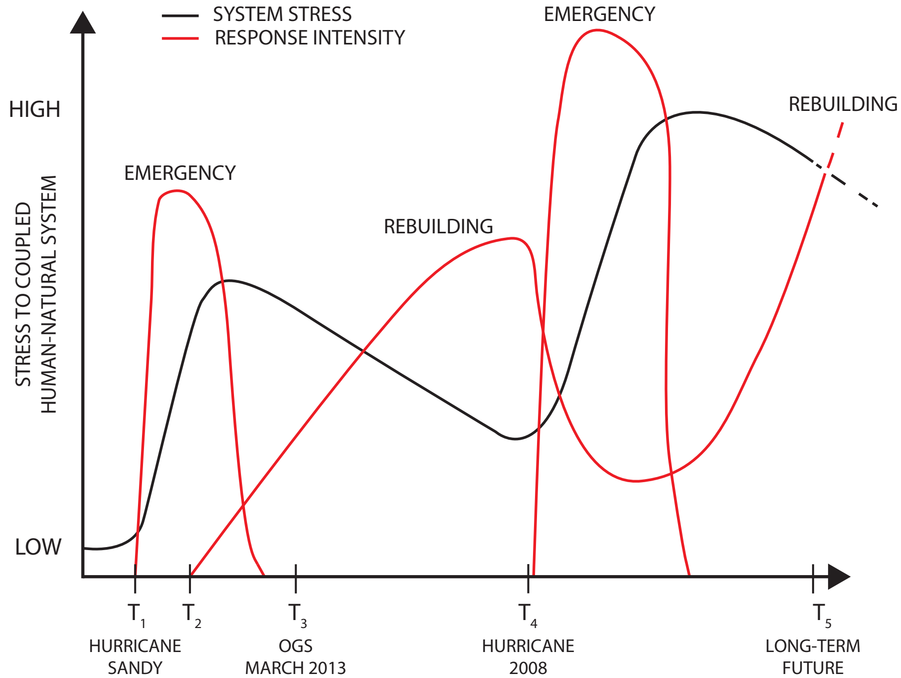



**Figure 20.** Conceptual Model for Stress to the Coupled Human-Natural System over Time. Please see text for full explanation.

the system to a storm like the hypothetical Hurricane 2018, bringing the emergency response activity curve after $T_4$ down, and also decreasing system stress. As a second example, if the local, state, and tribal government capacity is supported to apply the best available data on current and future risk expediting review, implementation, and evaluation of recovery projects, the rebuilding curve between $T_3$-$T_4$ would steepen, increasing resilience, and decreasing system stress.

If rebuilding efforts are begun earlier, this may result in a phase shift of the rebuilding curve. Using this framework, rebuilding efforts that begin earlier in the aftermath of an event like Hurricane Sandy or hypothetical Hurricane 2018 may decrease system stress and give the system more time and opportunity to return to lower stress baseline conditions.

## Key Insights

In the fall of 2012, the National Research Council (NRC) released a report entitled "*Disaster Resilience: A National Imperative*." In the report, the NRC defined resilience as "the ability to prepare and plan for, absorb, recover from and more successfully adapt to adverse events" (National Research Council, 2012). The OGS adopted this definition for scenario-building and results suggest that interventions that bolster resilience and simultaneously have a positive impact on many dimensions of the coupled-human natural system would be strong actions towards improving the resilience of the entire region to both future storms and other hazardous events.

However, the breadth of Hurricane Sandy's impacts makes improving resilience an inherently complex challenge. Little research is available to quantify the return on investment of actions such as building capacity among volunteer networks or evaluating the long-term efficacy of hybrid green-gray infrastructure. Much work needs to be done on fully understanding the complex interactions between the social, economic, and environmental factors of the system as a whole. Rebuilding in the aftermath of Hurricane Sandy presents an opportunity to increase resilience of the system, but also to test and monitor the long-term sustainability of these actions over time.

Based on discussions during the March, 2013 session and the resulting scenarios and proposed interventions, key insights include:

- the consequences of Hurricane Sandy are complex;
- there are substantial uncertainties associated with both the consequences of the storm and potential interventions to improve resilience against future major storms and storm response activities should account for this uncertainty;
- resilience is best achieved when developed for the coupled human-natural system rather than by applying measures only to individual units or infrastructures;
- both "gray" and "green" infrastructure are necessary for improving resilience; and,
- the speed and effectiveness of interventions may have substantial impact upon the capacity of the region to increase resilience to future major storms.

## SSG Scenarios and the Hurricane Sandy Rebuilding Task Force

Upon completion of the OGS scenarios, the SSG staff briefed Task Force representatives, DOI leadership, White House staff, and officials in the affected region. DOI has since used OGS findings to inform the prioritization of $300 million in supplemental mitigation investments to enhance regional resilience. On 19 August 2013, the Hurricane Sandy Rebuilding Task Force released its report detailing a rebuilding strategy for the Hurricane Sandy-affected region. The report includes 69 policy recommendations, some of which have already been adopted. The recommendations focus on resilient rebuilding; ensuring coordination across local, regional, and federal entities; providing safe and affordable housing; supporting small businesses and revitalizing local economies; addressing insurance challenges; and building local governments' capacity for rebuilding and emergency planning (Hurricane Sandy Rebuilding Task Force, 2013). In addition, the report references the work of the SSG.

## Further Scenario Building

Further scenario building is possible and should benefit from careful evaluation of this first session. Such evaluation should include, at a minimum, input from staff and participants in the OGS, and if possible, input from decision makers and other users of the OGS results. There are several actions the OGS could take during an additional session. First, it could complete the scenario for Hurricane Sandy's impact on urban communities and ecosystems (the partially-completed scenario is available in Appendix E). Second, it could develop a scenario focusing on the long-term cascading consequences of Hurricane Sandy (from $T_1$ to $T_N$) to evaluate the efficacy of the interventions and the impact of the hypothetical Hurricane 2018. Third, the OGS could identify potential gaps in its intervention analysis and refine these to include factors such as tourism, international/national economic implications, cultural resources, volunteer activities, and storm surge barriers. Finally, a second OGS session could examine interventions that could specifically be considered and implemented by the DOI to build the resilience of its resources and assets in the affected region.

# Lessons Learned

The activation of the SSG to respond to Hurricane Sandy was the first time the SSG has been deployed since it was formalized by Secretarial Order in early 2012. As stated in its operational plan, the SSG uses the following "triggering criteria" for identifying crises for which it may be deployed:

- An acute event of immediate, significant impact and of relatively defined duration;
- An event for which the SSG can add value, using a strategic approach of scenario development to assist decision makers;
- Unanticipated, improbable events with multiple, synergistic or cascading environmental, economic, and social consequences; and,
- Events with a potential high degree of risk or loss (social/economic/environmental).

Hurricane Sandy met these criteria, and SSG staff discussed deployment with DOI leadership in December, 2012, leading to the OGS session in March, 2013. Unlike the Deepwater Horizon deployment of the SSWG during the height of the *emergency* phase of the environmental crisis event, the OGS was deployed during the *recovery* phase of an event, enabling the SSG to begin assessment of its role and potential value during non-emergency situations. The SSG continues to identify lessons learned from this experience—some of these are included below (not ranked). Additional insights from the OGS participants will be gained in an independent external evaluation report currently in preparation.

## Lessons Learned

- The SSG could have been activated sooner (e.g., November 1) to provide more immediate response to assessing the cascading consequences caused by Hurricane Sandy and in identifying interventions.
- Scenario boundary conditions (e.g., time, scope) should be defined as clearly as possible before all participants meet in person. If local knowledge is needed to inform these definitions, the SSG should consider using regional expertise. A pre-session conference call may be useful.
- The OGS had an adequate mix of expertise from multiple relevant areas of research including coastal oceanography, engineering, social science, public health, and ecology to address the complex impacts of Hurricane Sandy. However, it could be useful to have a select set of remote subject matter experts "on call" to rapidly answer questions that arise during scenario-building discussions. This could be facilitated by notifying select individuals with specific expertise of the SSG meeting time frame and response time needs in advance of deployment.
- Ensuring that approximately half of the participants came from the affected area was a substantial benefit in collecting and using local knowledge to build the scenarios.

- The development of interventions would benefit from more time (at least one to two additional days). Hurricane Sandy proved to be highly complex across the social, economic, and environmental impacts to the region. The process would benefit from additional time and analysis.
- The SSG is working to maintain rosters of scientists who may be included as members of crisis science teams. In a parallel effort, the SSG may benefit from developing a network of universities and training centers with critical facilities (internet access, cell service, access to nearby food and lodging) to be used as venues for future scenario-building sessions to reduce costs and speed deployment.
- When the SSG is deployed during recovery phases of events or working in the absence of a centralized incident command system, briefings to senior leadership should be delivered within two weeks of deployment. To expedite delivery of results, it may be useful to pre-schedule these briefings to the degree possible.
- Within the SSG scenarios, consequences with low levels of uncertainty (e.g., in the range of NK-2) may be valuable indicators of promising areas of future research.

### External Evaluation

In keeping with the SSG operational plan, a third party external evaluation of the OGS process and deployment has been completed. Led by colleagues at the Natural Hazards Center at the University of Colorado-Boulder, this evaluation captures insights from the OGS participants and the OGS session in NJ. The report will be shared with the SSG co-leaders, the Science Advisor to the Secretary, and other DOI leadership.

## Conclusion

The SSG was notified in January, 2013 to stand up a crisis science team to support the DOI's role on the Hurricane Sandy Rebuilding Task Force. In response, the SSG assembled the OGS to develop scenarios to examine the short- and long-term impacts of Hurricane Sandy and future major storms (such as another major hurricane) on the ecology, economy, and people of the affected region. The OGS identified 13 first-tier consequences of the storm and multiple cascading consequences of the storm's impact and devised 17 interventions that local, state, and federal decision makers can consider for improving the resilience of the affected region to future storms.

Multiple federal, state, and local authorities continue to debate the best paths forward to rebuild the Hurricane Sandy-affected region in ways that enable the area to quickly rebound and that simultaneously bolster the region's resilience to future storms, rising sea level, and other hazardous events. Proposed changes have included land buyouts and planned retreat, green and gray infrastructure fortifications and design competitions, and new social services and volunteer coordination networks. Hurricane Sandy has helped re-ignite the national conversation on how the country should adapt to rapid urbanization and changes in global climate to better prepare and protect its citizens, infrastructure, and natural resources for the future. Considerable resources will be invested in the recovery from Hurricane Sandy and it will be important to frequently assess their short- and long-term effects on the region's resilience.

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# Appendices

# Appendix A: Executive Order Creating the Hurricane Sandy Rebuilding Task Force

**Executive Order -- Establishing the Hurricane Sandy Rebuilding Task Force**
**EXECUTIVE ORDER**
**- - - - - - -**

**ESTABLISHING THE HURRICANE SANDY REBUILDING TASK FORCE**

By the authority vested in me as President by the Constitution and the laws of the United States of America, it is hereby ordered as follows:

**Section 1.** Purpose. Hurricane Sandy made landfall on October 29, 2012, resulting in major flooding, extensive structural damage, and significant loss of life. A dangerous nor'easter followed 9 days later causing additional damage and undermining the recovery effort. As a result of these events, thousands of individuals were displaced and millions lost power, some for an extended period of time. Over 1,600 stores were closed, and fuel distribution was severely disrupted, further complicating the recovery effort. New York and New Jersey -- two of the Nation's most populous States -- were especially hard hit by these storms.

The Federal Emergency Management Agency (FEMA) in the Department of Homeland Security is leading the recovery efforts to assist the affected region. A disaster of Hurricane Sandy's magnitude merits a comprehensive and collaborative approach to the long-term rebuilding plans for this critical region and its infrastructure. Rebuilding efforts must address economic conditions and the region's aged infrastructure -- including its public housing, transportation systems, and utilities -- and identify the requirements and resources necessary to bring these systems to a more resilient condition given both current and future risks.

This order establishes the Hurricane Sandy Rebuilding Task Force (Task Force) to provide the coordination that is necessary to support these rebuilding objectives. In collaboration with the leadership provided through the National Disaster Recovery Framework (NDRF), the Task Force will identify opportunities for achieving rebuilding success, consistent with the NDRF's commitment to support economic vitality, enhance public health and safety, protect and enhance natural and manmade infrastructure, and ensure appropriate accountability. The Task Force will work to ensure that the Federal Government continues to provide appropriate resources to support affected State, local, and tribal communities to improve the region's resilience, health, and prosperity by building for the future.

**Sec. 2.** Establishment of the Hurricane Sandy Rebuilding Task Force. There is established the Hurricane Sandy Rebuilding Task Force, which shall be chaired by the Secretary of Housing and Urban Development (Chair).

(a) In addition to the Chair, the Task Force shall consist of the head of each of the following executive departments, agencies, and offices, or their designated representatives

(i) the Department of the Treasury;

(ii) the Department of the Interior;

(iii) the Department of Agriculture;

(iv) the Department of Commerce;

(v) the Department of Labor;

(vi) the Department of Health and Human Services;

(vii) the Department of Transportation;

(viii) the Department of Energy;

(ix) the Department of Education;

(x) the Department of Veterans Affairs;

(xi) the Department of Homeland Security;

(xii) the Environmental Protection Agency;

(xiii) the Small Business Administration;

(xiv) the Army Corps of Engineers;

(xv) the Office of Management and Budget;

(xvi) the National Security Staff;

(xvii) the Domestic Policy Council;

(xviii) the National Economic Council;

(xix) the Council on Environmental Quality;

(xx) the Office of Science and Technology Policy;

(xxi) the Council of Economic Advisers;

(xxii) the White House Office of Public Engagement and Intergovernmental Affairs;

(xxiii) the White House Office of Cabinet Affairs; and

(xxiv) such other agencies and offices as the President may designate.

(b) The Chair shall regularly convene and preside at meetings of the Task Force and determine its agenda as the Task Force exercises the functions set forth in section 3 of this order. The Chair's duties shall also include:

(i) communicating and engaging with States, tribes, local governments, Members of Congress, other stakeholders and interested parties, and the public on matters pertaining to rebuilding in the affected region;

(ii) coordinating the efforts of executive departments, agencies, and offices related to the functions of the Task Force; and

(iii) specifying the form and subject matter of regular reports to be submitted concurrently to the Domestic Policy Council, the National Security Staff, and the Chair.

**Sec. 3.** Functions of the Task Force. Consistent with the principles of the NDRF, including individual and family empowerment, leadership and local primacy, partnership and inclusiveness, public information, unity of effort, timeliness and flexibility, resilience and sustainability, and psychological and emotional recovery, the Task Force shall:

(a) work closely with FEMA in the coordination of rebuilding efforts with the various intergovernmental activities taken in conjunction with the NDRF;

(b) describe the potentially relevant authorities and resources of each member of the Task Force;

(c) identify and work to remove obstacles to resilient rebuilding in a manner that addresses existing and future risks and vulnerabilities and promotes the long-term sustainability of communities and ecosystems;

(d) coordinate with entities in the affected region in efforts to:

(i) ensure the prompt and orderly transition of affected individuals and families into safe and sanitary long-term housing;

(ii) plan for the rebuilding of critical infrastructure damaged by Hurricane Sandy in a manner that accounts for current vulnerabilities to extreme weather events and increases community and regional resilience in responding to future impacts;

(iii) support the strengthening of the economy; and

(iv) understand current vulnerabilities and future risks from extreme weather events, and identify resources and authorities that can contribute to strengthening community and regional resilience as critical infrastructure is rebuilt and ecosystem functions are restored;

(e) prior to the termination of the Task Force, present to the President a Hurricane Sandy Rebuilding Strategy (Strategy) as provided in section 5 of this order;

(f) engage local stakeholders, communities, the public, Members of Congress, and other officials throughout the areas affected by Hurricane Sandy to ensure that all parties have an opportunity to share their needs and viewpoints to inform the work of the Task Force, including the development of the Strategy; and

(g) communicate with affected tribes in a manner consistent with Executive Order 13175 of November 6, 2000, regarding the consultation and coordination with Indian tribal governments.

**Sec. 4.** Task Force Advisory Group. The Chair shall, at his discretion, establish an Advisory Group to advise the Task Force and invite individuals to participate in it. Participants shall be elected State, local, and tribal officials and may include Governors, Mayors, County Executives, tribal elected officials, and other elected officials from the affected region as the Chair deems appropriate. Members of the Advisory Group, acting in their official capacity, may designate employees with authority to act on their behalf. The Advisory Group shall generally advise the Task Force as requested by the Chair, and shall provide input on each element of the Strategy described in section 5 of this order.

**Sec. 5.** Hurricane Sandy Rebuilding Strategy. (a) Within 180 days of the first convening of its members, the Task Force shall prepare a Strategy that includes:

(i) a summary of Task Force activities;

(ii) a long-term rebuilding plan that includes input from State, local, and tribal officials and is supported by Federal agencies, which is informed by an assessment of current vulnerabilities to extreme weather events and seeks to mitigate future risks;

(iii) specific outcomes, goals, and actions by Federal, State, local, and tribal governments and the private sector, such as the establishment of permanent entities, as well as any proposed legislative, regulatory, or other actions that could support the affected region's rebuilding; and

(iv) a plan for monitoring progress.

(b) The executive departments, agencies, and offices listed in section 2(a) of this order shall, as appropriate and to the extent permitted by law, align their relevant programs and authorities with the Strategy.

**Sec. 6.** Administration. (a) The Task Force shall have a staff, headed by an Executive Director, which shall provide support for the functions of the Task Force.

(b) The Executive Director shall be selected by the Chair and shall supervise, direct, and be accountable for the administration and support of the Task Force.

(c) At the request of the Chair, other executive departments and agencies shall serve in an advisory role to the Task Force on issues within their expertise.

(d) The Task Force may establish technical working groups of Task Force members, their representatives, and invited Advisory Group members and elected officials, or their designated employees, as necessary to provide advice in support of their function.

(e) The Task Force shall terminate 60 days after the completion of the Strategy described in section 5 of this order, after which FEMA and the lead agencies for the Recovery Support Functions, as described in the NDRF, shall continue the Federal rebuilding coordinating roles described in section 3 of this order to the extent consistent with the NDRF.

**Sec. 7.** General Provisions. (a) For purposes of this order, "affected tribe" means any Indian tribe, band, nation, pueblo, village, or community that the Secretary of the Interior acknowledges to exist as an Indian tribe pursuant to the Federally Recognized Indian Tribe List Act of 1994 (25 U.S.C. 479a), located or with interests in the affected area.

(b) To the extent permitted by law, and subject to the availability of appropriations, the Department of Housing and Urban Development shall provide the Task Force with such administrative services, facilities, staff, equipment, mobile communications, and other support services as may be necessary for the Task Force to carry out its functions, using funds provided from the Disaster Relief Fund by agreement with FEMA and any other available and appropriate funding.

(c) Members of the Task Force, Advisory Group, and any technical working groups shall serve without any additional compensation for their work on the Task Force, Advisory Group, or technical working group.

(d) Nothing in this order shall be construed to impair or otherwise affect:

(i) the authority granted by law to an executive department, agency, or the head thereof, or the status of that department or agency within the Federal Government; or

(ii) the functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(e) This order shall be implemented consistent with applicable law, and subject to the availability of appropriations.

(f) This order is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

BARACK OBAMA
THE WHITE HOUSE, Washington, December 7, 2012.

# Appendix B: Memo Activating SSG for Hurricane Sandy

THE SECRETARY OF THE INTERIOR
WASHINGTON

JAN 09 2013

**Memorandum**

To: Director, U.S. Geological Survey and Science Advisor to the Secretary

From: Secretary Ken Salazar

Subject: Activating the Strategic Sciences Group Crisis Science Team for Hurricane Sandy

Secretarial Order 3318 established the Department of the Interior Strategic Sciences Group (SSG) to conduct science-based assessments and interdisciplinary scenarios during environmental crises affecting Department of the Interior resources. Section 4(c) of the Order authorizes the Secretary to direct the SSG, in writing, to activate a Crisis Science Team, including scientists from government, academic institutions, non-governmental organizations, and the private sector, as appropriate. The SSG mission is to conduct such assessments and to provide the results of this work to the Secretary and Departmental leadership to support decisionmaking.

This Memorandum directs the SSG to stand up a Crisis Science Team in support of the Department's role on the Hurricane Sandy Rebuilding Task Force. Its activities should support National Park Service Director Jon Jarvis as my designated representative to the Task Force, and follow the SSG operational plan.

The SSG Co-Leaders are responsible for forming the temporary Crisis Science Team, which shall be organized, engaged, and then dissolved when its tasks are complete. The SSG should engage the best available scientific experts with a diverse set of talents appropriate to the SSG mission.

The Crisis Science Team will be formally dissolved by the SSG Co-Leaders, as determined by the Co-Leaders in consultation with the Secretary's Science Advisor and representative to the Task Force.

cc: Jon Jarvis, NPS Director
Gary Machlis, Strategic Sciences Group Co-Leader
David Applegate, Strategic Sciences Group Co-Leader
Pam Haze, Deputy Assistant Secretary, Policy, Management and Budget
Kim Thorsen, Deputy Assistant Secretary, Policy, Management and Budget

# Appendix C: Operational Group Sandy Team Members

**David Applegate, Ph.D.**
*Associate Director for Natural Hazards and Co-Leader, DOI Strategic Sciences Group*
*U.S. Geological Survey*

**Jessie Braden**
*Director, Spatial Analysis and Visualization Initiative*
*Pratt Institute*

**Morgan Grove, Ph.D.**
*Social Ecologist*
*USDA Forest Service, Baltimore Field Station*

**Maria Honeycutt, Ph.D., CFM**
*Coastal Hazards Specialist*
*NOAA Coastal Services Center*

**Radley Horton, Ph.D.**
*Associate Research Scientist*
*Center for Climate Systems Research*
*Columbia University*

**Jennifer L. Irish, Ph.D., P.E., D.CE**
*Associate Professor of Coastal Engineering*
*Virginia Tech University*

**Kristin Ludwig, Ph.D.**
*AAAS Science & Technology Policy Fellow*
*Natural Hazards Mission Area, U.S. Geological Survey*

**Gary Machlis, Ph.D.**
*Science Advisor to the Director and Co-Leader, DOI Strategic Sciences Group*
*National Park Service*

**Aubrey Miller, M.D., M.P.H.**
*Senior Medical Advisor*
*National Institute of Environmental Health Sciences*

**Regan Nelson**
*Ph.D. Student, Ecology and Environmental Sciences*
*Montana State University*

**Glenn E. Plumb, Ph.D.**
*Chief Wildlife Biologist*
*National Park Service*

**Eric W. Sanderson, Ph.D.**
*Senior Conservation Ecologist*
*Wildlife Conservation Society*

**Christine C. Shepard, Ph.D.**
*Scientist, Global Marine Team*
*The Nature Conservancy/University of California-Santa Cruz*

**Seth Spielman, Ph.D.**
*Assistant Professor of Geography*
*University of Colorado, Boulder*

**Erika S. Svendsen, Ph.D.**
*Research Social Scientist*
*USDA Forest Service, Northern Research Station*

# Appendix D: Operational Group Sandy Daily Briefing Statements

DOI STRATEGIC SCIENCES GROUP—OPERATIONAL GROUP SANDY
Daily Briefing Statement, 10:00pm EST, 4 March, 2013

## Background

The Department of the Interior (DOI) Strategic Sciences Group (SSG) was established by Secretarial Order 3188 in 2012 to provide the Department with science-based assessments and interdisciplinary scenarios of environmental crises affecting Departmental resources; rapidly assemble trained teams of scientists to conduct such work during environmental crises; and, provide the results of this work to the Secretary and Departmental leadership to support decision-making during crises.

On January 9, 2013, Secretary Salazar directed the SSG to stand up a science team to support the Department's role on the Hurricane Sandy Rebuilding Task Force. In response, the SSG assembled a team of experts - Operational Group Sandy (OGS) - to develop scenarios for the Task Force. The OGS is meeting in Park Ridge, NJ March 3-7, 2013 to develop scenarios analyzing the cascading effects of Sandy and another Sandy-like storm on the coupled human-natural ecosystem of the affected region. This work is supported by the DOI and complements ongoing science response efforts as part of the federal Hurricane Sandy Rebuilding Task Force.

## Activities

OGS Leader Machlis introduced participants to the basic concepts and approach of the SSG.

The Group established the assumptions and conditions for the OGS scenarios:

- **Scenario 1** will assess the short term cascading consequences of Hurricane Sandy. **Scenario 2** will analyze the cascading consequences of another Sandy-like storm occurring in the future.
- The affected region is shown in the map at right.
- Because the affected region is heterogeneous, the scenarios will focus on three **community/ecosystem types** to explore through the scenario building process: coastal communities (such as Long Beach, NY); intense urban centers and ecosystems (such as Manhattan); and inland suburban/rural communities and ecosystems (such as Edison, NJ). These types are not comprehensive.

The Group began work on the first scenario by examining the cascading consequences of Hurricane Sandy on coastal communities and ecosystems.

## Science Insight

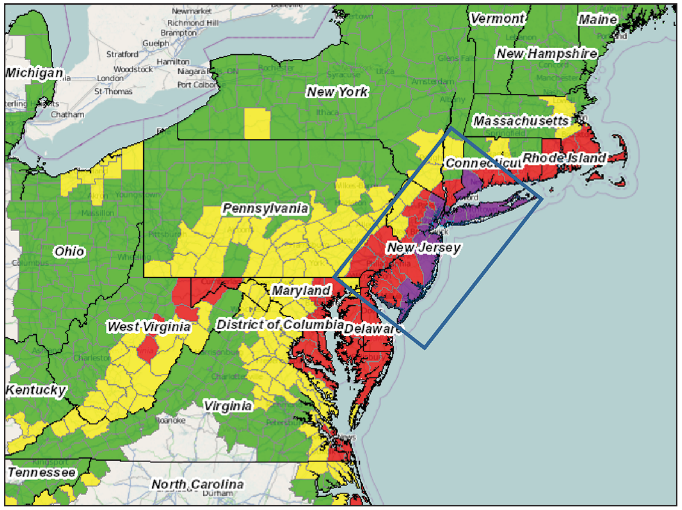
OGS participants pointed out that many factors were already in motion beginning well in advance of landfall (such as the mobilization of utility workers, stockpiling supplies, sand-bagging buildings, etc.). Hence, for the purpose of the scenarios, Hurricane Sandy was defined as beginning 48 hours before the hurricane made landfall.

## Next Steps

The Group will continue building out Scenario 1. Once Scenario 1 is complete, the Group will begin to develop Scenario 2, the impacts of another Sandy-like storm on the affected region.

**For further information, please contact:**

Dr. Gary Machlis, DOI Strategic Sciences Group Co-Leader, 202-746-8877, gary_machlis@nps.gov




Map of SSG-OGS affected area used for scenarios (blue rectangle).

DOI STRATEGIC SCIENCES GROUP—OPERATIONAL GROUP SANDY
Daily Briefing Statement, 5 March 2013, 9:00pm EST

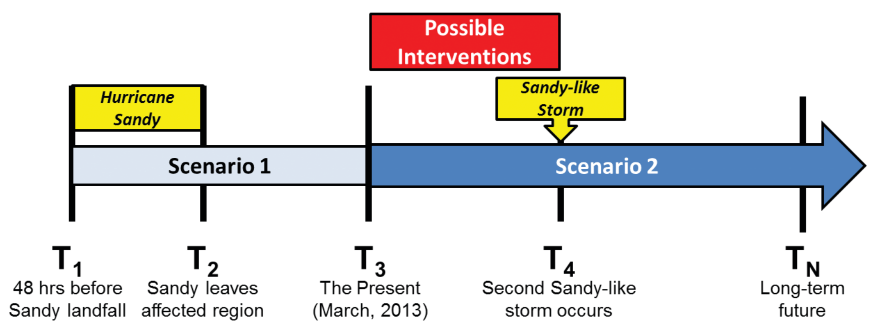
## Background

The Department of the Interior (DOI) Strategic Sciences Group (SSG) was established by Secretarial Order 3188 in 2012 to provide the Department with science-based assessments and interdisciplinary scenarios of environmental crises affecting Departmental resources; rapidly assemble trained teams of scientists to conduct such work during environmental crises; and, provide the results of this work to the Secretary and Departmental leadership to support decision-making during crises.

On January 9, 2013, Secretary Salazar directed the SSG to stand up a science team to support the Department's role on the Hurricane Sandy Rebuilding Task Force. In response, the SSG assembled a team of experts - Operational Group Sandy (OGS) - to develop scenarios for the Task Force. The OGS is meeting in Park Ridge, NJ March 3-7, 2013 to develop scenarios analyzing the cascading effects of Sandy and another Sandy-like storm on the coupled human-natural ecosystem of the affected region. This work is supported by the DOI and complements ongoing science response efforts as part of the federal Hurricane Sandy Rebuilding Task Force.

## Activities

The Group discussed a modified structure and timeline for framing the two scenarios. The framework is illustrated in the figure below. Scenario 1 examines the cascading consequences of Hurricane Sandy from 48 hours before the storm made landfall ($T_1$) to the present ($T_3$). Scenario 2 will build the cascading consequences of Sandy from the present ($T_3$) to the long-term future ($T_N$), assuming a second Sandy-like storm occurs five years from the present. The Group will assess interventions between $T_3$-$T_4$; interventions are actions that support the recovery as defined by the Task Force and increase the resilience of the region's coupled human-natural systems to future major storms.




SSG-OGS Scenario Structure and Timeline.

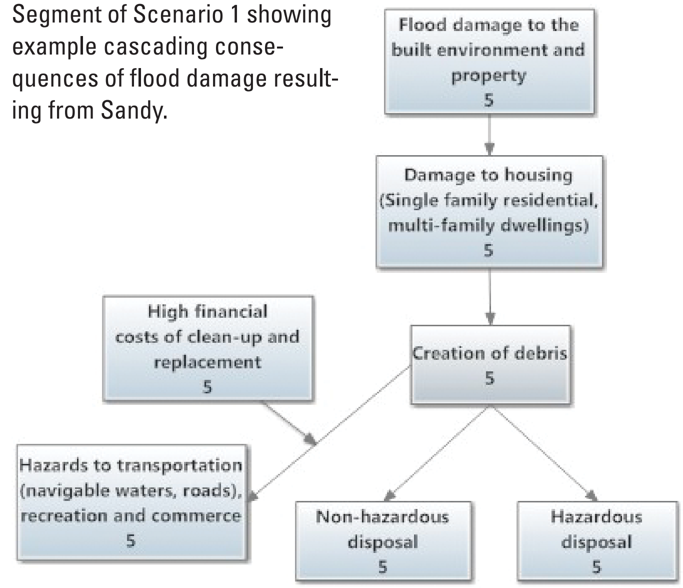
Scenario 1 was completed for coastal communities and ecosystems. Over 15 first-level consequences of Sandy were identified and assigned a level of uncertainty. The Group explored subsequent chains of consequences such as flood and wind damage to the built environment, changes in geomorphology, ecological impacts, and economic loss.

The Group began Scenario 1 for urban centers by discussing the major differences between coastal communities and urban centers and identifying consequences unique to urban centers.

## Science Insight

One of the cascading consequences of Hurricane Sandy in coastal communities was flood damage to the built environment. This led to multiple cascading effects, including damage to housing. The figure below shows a sample segment of Scenario 1. The segment shows only a small portion of the scenario.

Segment of Scenario 1 showing example cascading consequences of flood damage resulting from Sandy.




## Next Steps

The Group will complete Scenario 1 for urban centers and will begin to develop Scenario 2, the impacts of another Sandy-like storm on the affected region.

**For further information, please contact:**
Dr. Gary Machlis,
DOI Strategic Sciences Group Co-Leader,
202-746-8877, gary_machlis@nps.gov

DOI STRATEGIC SCIENCES GROUP—OPERATIONAL GROUP SANDY
Daily Briefing Statement, 6 March 2013, 10:00pm EST

## Background

The Department of the Interior (DOI) Strategic Sciences Group (SSG) was established by Secretarial Order 3188 in 2012 to provide the Department with science-based assessments and interdisciplinary scenarios of environmental crises affecting Departmental resources; rapidly assemble trained teams of scientists to conduct such work during environmental crises; and, provide the results of this work to the Secretary and Departmental leadership to support decision-making during crises.

On January 9, 2013, Secretary Salazar directed the SSG to stand up a science team to support the Department's role on the Hurricane Sandy Rebuilding Task Force. In response, the SSG assembled a team of experts - Operational Group Sandy (OGS) - to develop scenarios for the Task Force. The OGS is meeting in Park Ridge, NJ March 3-7, 2013 to develop scenarios analyzing the cascading effects of Sandy and another Sandy-like storm on the coupled human-natural ecosystem of the affected region. This work is supported by the DOI and complements ongoing science response efforts as part of the federal Hurricane Sandy Rebuilding Task Force.

## Activities

Discussion focused on defining the differences between coastal communities and urban centers for the OGS scenarios. The figure at right illustrates the two OGS regional types *Coastal communities and ecosystems* (blue) were completely or partially inundated during Hurricane Sandy and are within 0.25 miles of the coast. *Urban centers and ecosystems* (red) are characterized by high infrastructure and have >50,000 people/square mile. Urban centers are distinguished from coastal communities by high population density, high building density, higher average building height, interconnected and underground infrastructure, "armored" shoreline (e.g., breakwaters and riprap); and high socioeconomic diversity. These characteristics proved important when the Group analyzed various social, economic, and environmental impacts of Sandy on this regional type. The Group completed Scenario 1 for urban centers.

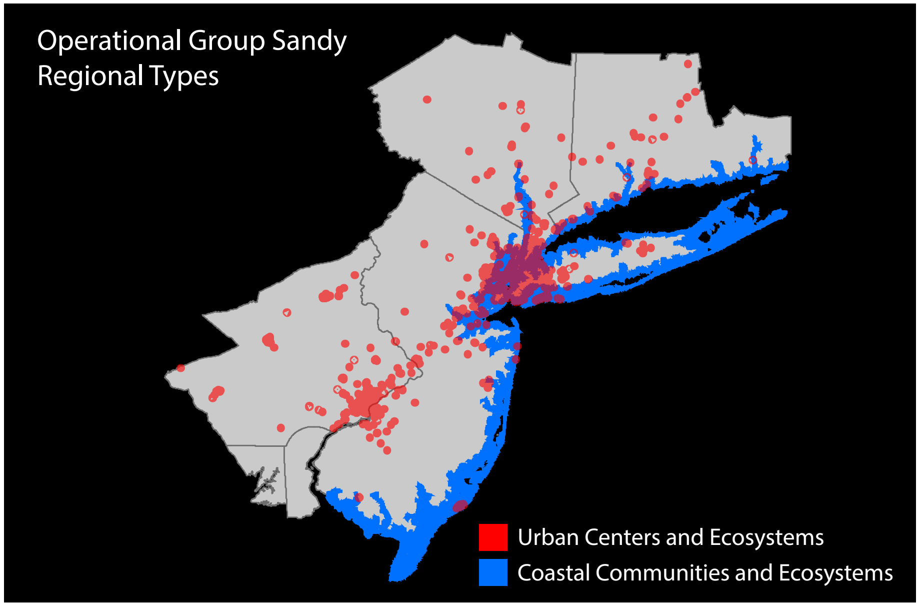
The Group began developing Scenario 2. OGS Scenario 2 analyzes the cascading consequences of Sandy over the next five years, when another Sandy-like storm occurs. For this scenario, the second storm is identified as a hurricane making landfall on the New Jersey coast in August, 2018. The purpose of Scenario 2 is to evaluate the vulnerability of the coupled human-natural ecosystem post-Sandy to this second storm and to test the impact of possible interventions.

## Science Insight

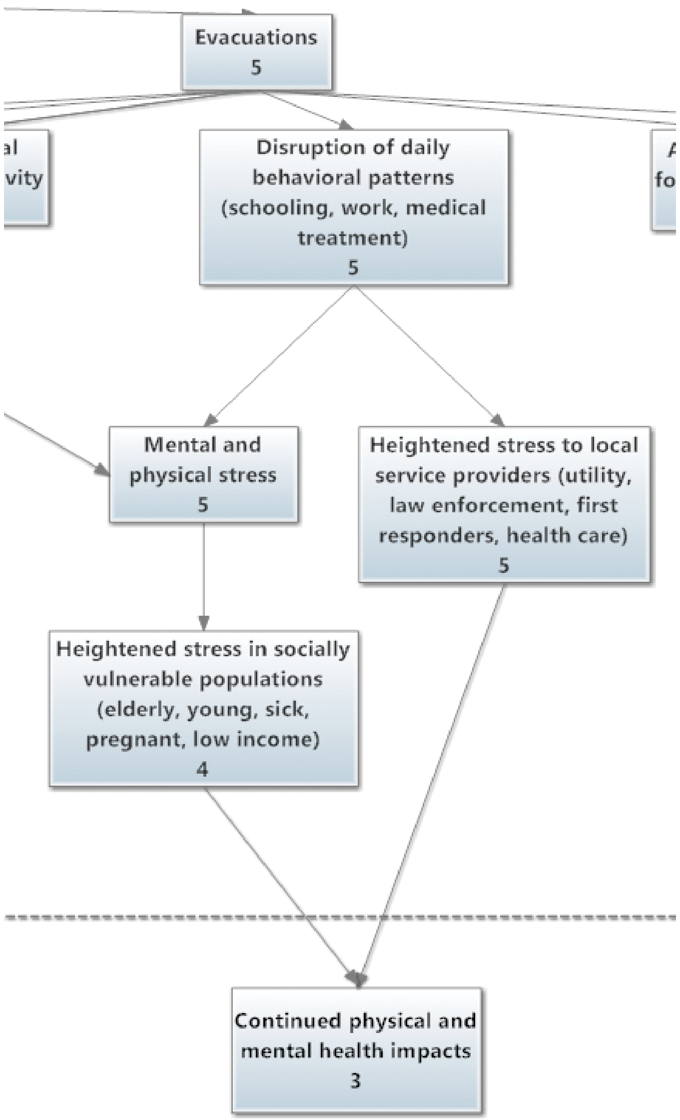
In coastal communities, one of the consequences of Sandy was evacuations. This led to a disruption of daily behavioral patterns, and heightened stress between the time of 48 hours before landfall up to the present. Further cascading effects over the following five years were identified, as illustrated in the sample segment shown in the figure on the following page.

## Next Steps

The Group will complete Scenario 2 for coastal communities and identify and assess possible interventions. The Group will conclude the meeting by discussing next steps for the technical report.




SSG-OGS Regional Types. (Data source: 2010 US Decennial Census, US Census Bureau 2010 TIGER Boundary files).




Segment of Scenario 2 showing example cascading consequences of evacuations caused by Hurricane Sandy from 48 hours before landfall to five years after the present time.

**For further information, please contact:**
Dr. Gary Machlis, DOI Strategic Sciences Group Co-Leader,
202-746-8877, gary_machlis@nps.gov

DOI STRATEGIC SCIENCES GROUP—OPERATIONAL GROUP SANDY
Daily Briefing Statement, 7 March 2013, 6:00pm EST

## Background

The Department of the Interior (DOI) Strategic Sciences Group (SSG) was established by Secretarial Order 3188 in 2012 to provide the Department with science-based assessments and interdisciplinary scenarios of environmental crises affecting Departmental resources; rapidly assemble trained teams of scientists to conduct such work during environmental crises; and, provide the results of this work to the Secretary and Departmental leadership to support decision-making during crises.

On January 9, 2013, Secretary Salazar directed the SSG to stand up a science team to support the Department's role on the Hurricane Sandy Rebuilding Task Force. In response, the SSG assembled a team of experts - Operational Group Sandy (OGS) - to develop scenarios for the Task Force. The OGS is meeting in Park Ridge, NJ March 3-7, 2013 to develop scenarios analyzing the cascading effects of Sandy and another Sandy-like storm on the coupled human-natural ecosystem of the affected region. This work is supported by the DOI and complements ongoing science response efforts as part of the federal Hurricane Sandy Rebuilding Task Force.

## Activities

Scenario 2 for coastal communities and ecosystems was completed. The Group spent the remainder of the session identifying interventions to be implemented over the next five years that would support the recovery of the affected area as defined by the Task Force and that increase the resilience of the coupled human-natural system to future major storms. Each intervention was assigned an intervention value, defined as a subjective index of the return on investment and the pervasive positive impact of the intervention on the coupled human-natural system. All proposed interventions were matched to first-tier (major) consequences to show which chains of consequences they would affect.

The Group concluded the session by discussing next steps for reviewing the technical report.

## Science Insight

Changes in coastal geomorphology were identified as one of the first-tier (major) consequences of Hurricane Sandy in coastal communities and ecosystems. This precipitated further cascading effects such as changes in habitat, navigational routes, and fisheries.

## Next Steps

An independent evaluation of the OGS is being conducted; interviews with participants will be held in the near future. Briefing materials will be prepared for the Task Force. SSG staff will draft the technical report for review by OGS members; revision, and peer review (managed by USGS).

**For further information, please contact:**
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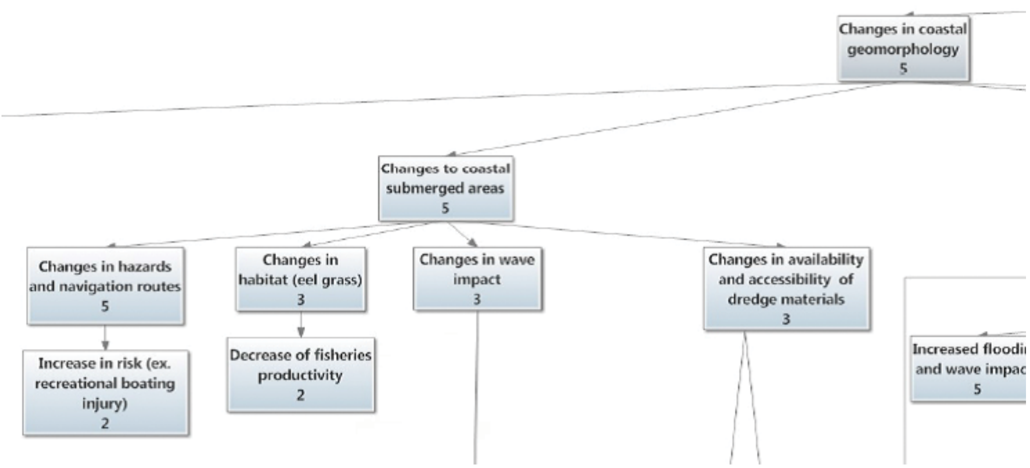


Segment of scenario 2 for coastal communities showing cascading consequences of changes in coastal geomorphology.

# Appendix E: Progress on OGS Scenarios for Urban Communities and Ecosystems

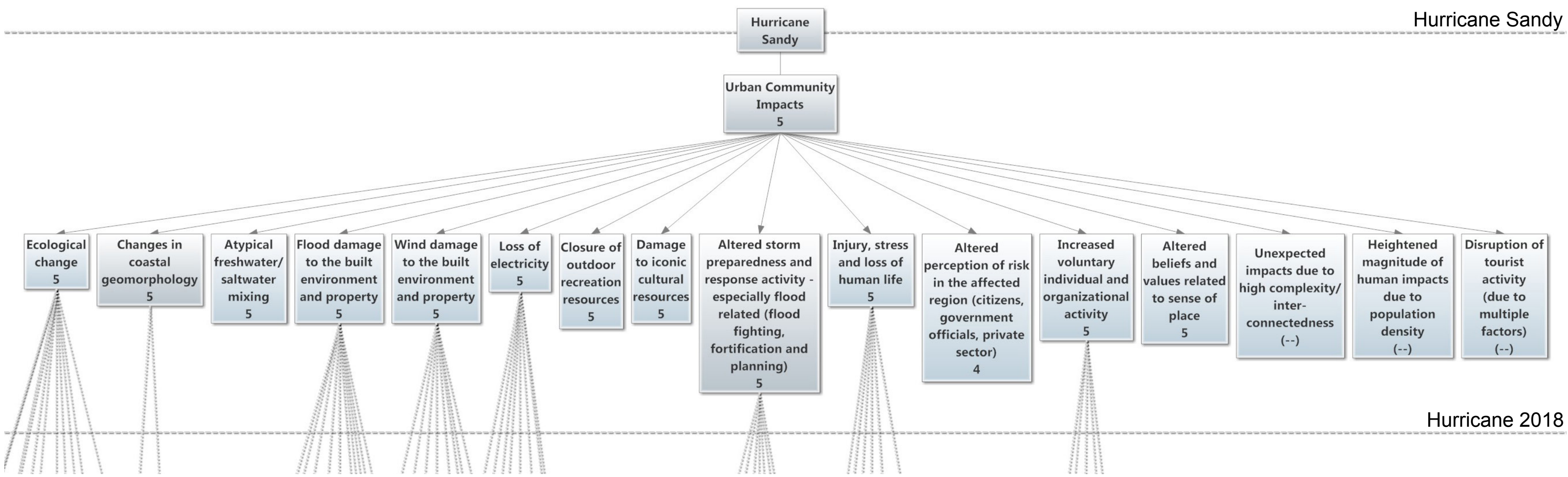


**Figure E–1.** Hurricane Sandy Urban Communities - First Tier Consequences - Partial Scenario.

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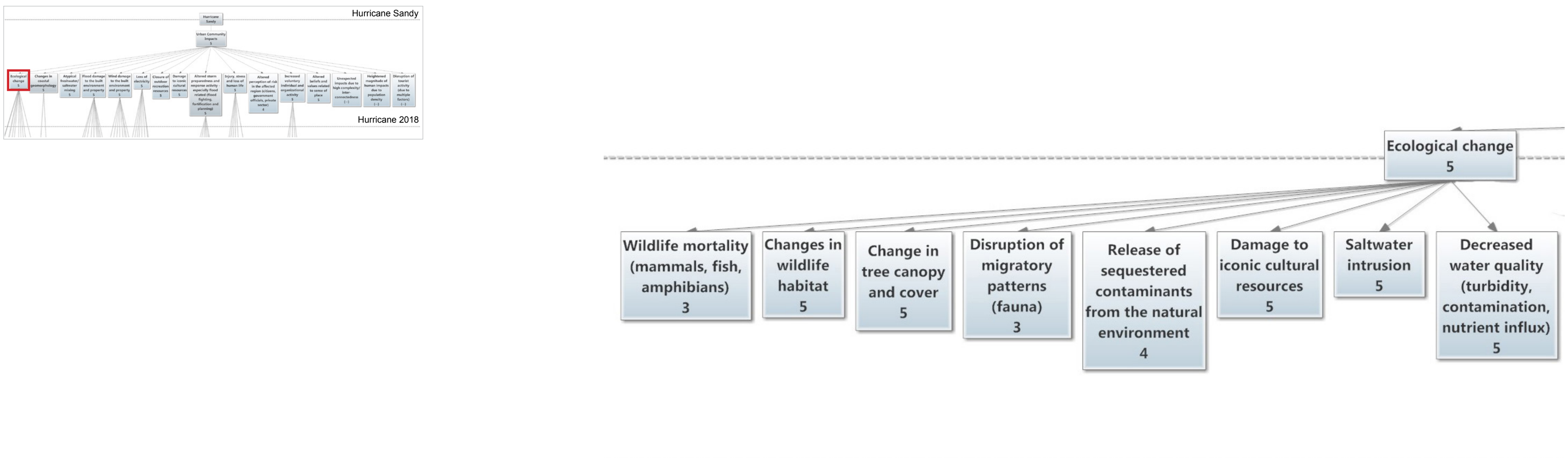


**Figure E–2.** Hurricane Sandy Urban Communities - Ecological Change - Partial Scenario.

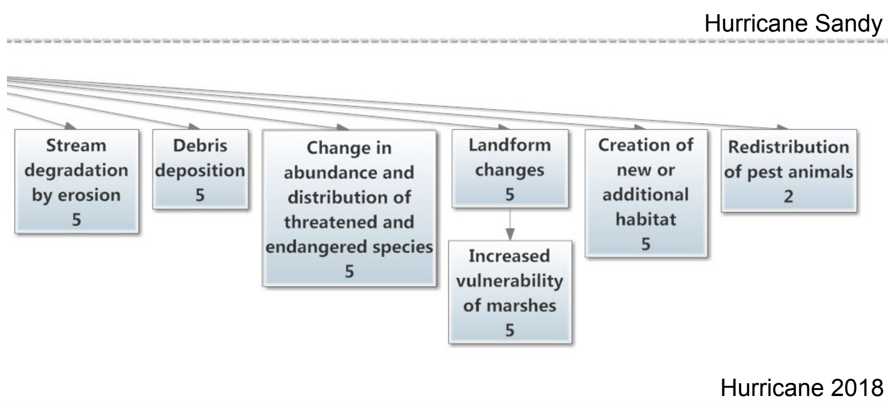
Hurricane Sandy
Stream degradation by erosion 5
Debris deposition 5
Change in abundance and distribution of threatened and endangered species 5
Landform changes 5
Increased vulnerability of marshes 5
Creation of new or additional habitat 5
Redistribution of pest animals 2
Hurricane 2018

Figure E-3: Hurricane Sandy Urban Communities - Changes in Coastal Geomorphology - Partial Scenario

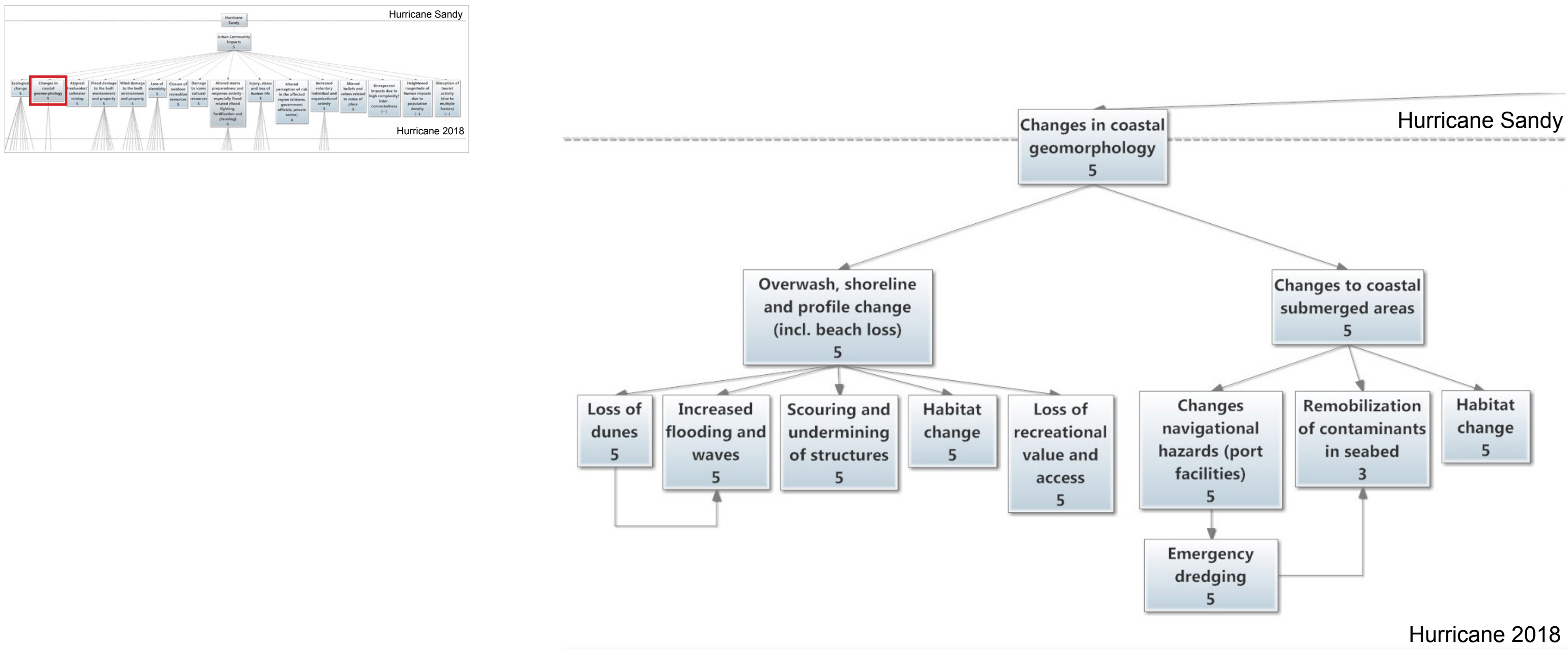


**Figure E–3.** Hurricane Sandy Urban Communities - Changes in Coastal Geomorphology - Partial Scenario.

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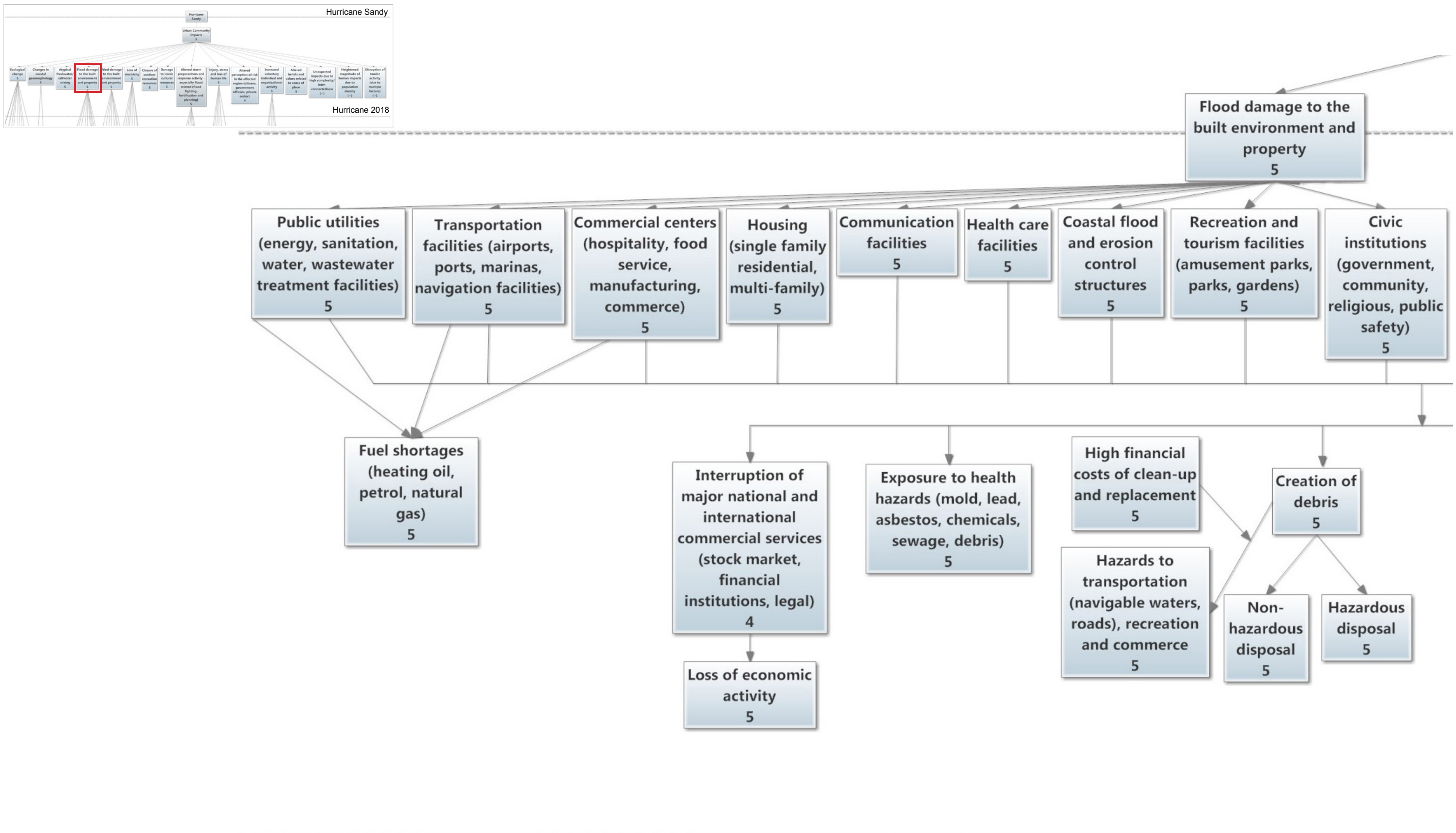
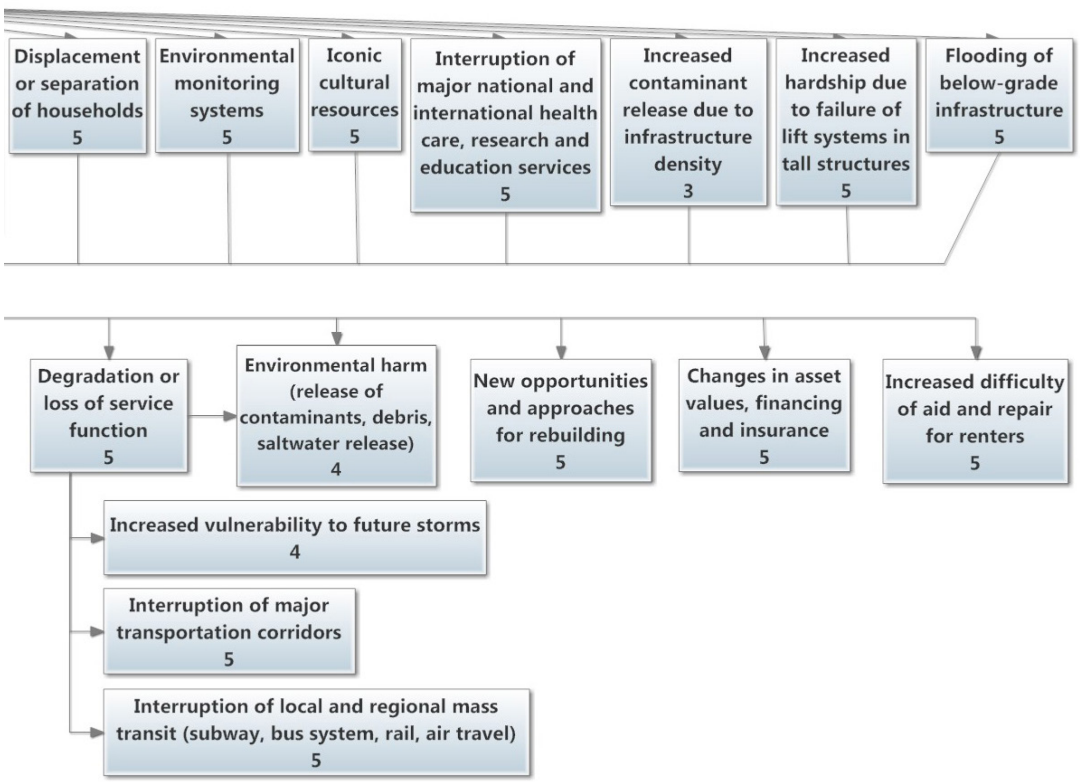



**Figure E–4.** Hurricane Sandy Urban Communities - Flood Damage to the Built Environment and Property - Partial Scenario.

Hurricane Sandy




Hurricane 2018

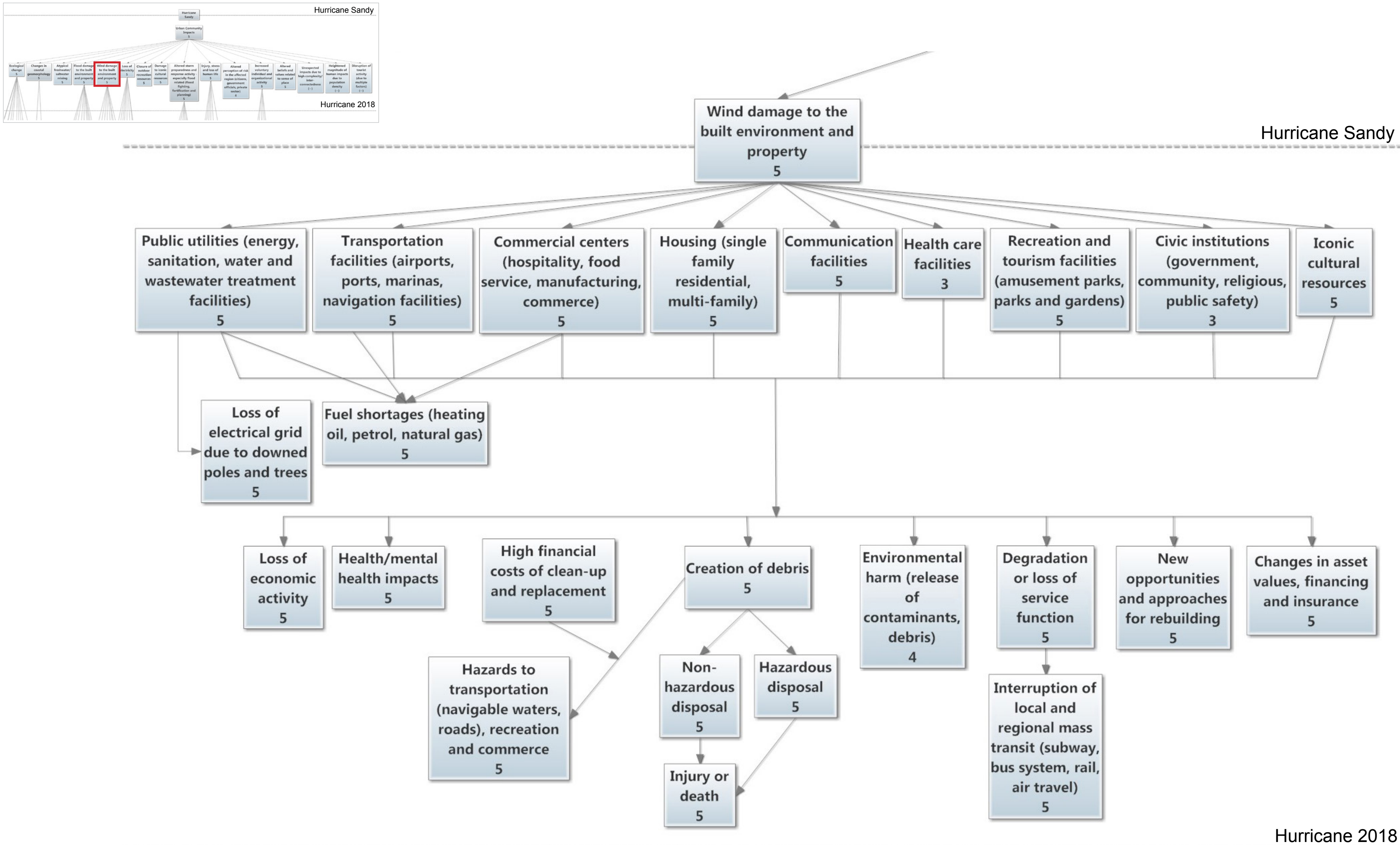



**Figure E–5.** Hurricane Sandy Urban Communities - Wind Damage to the Built Environment and Property - Partial Scenario.

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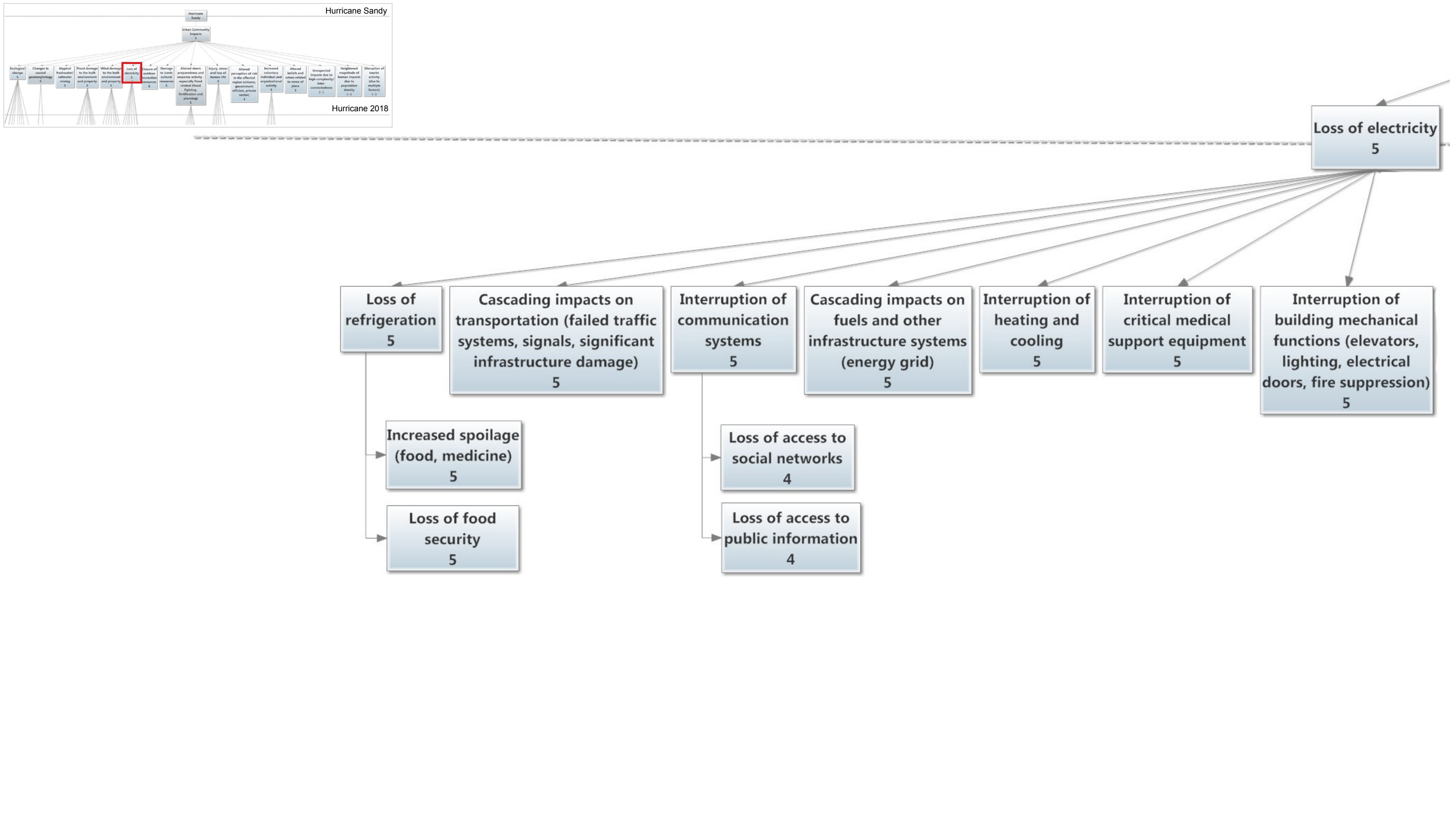
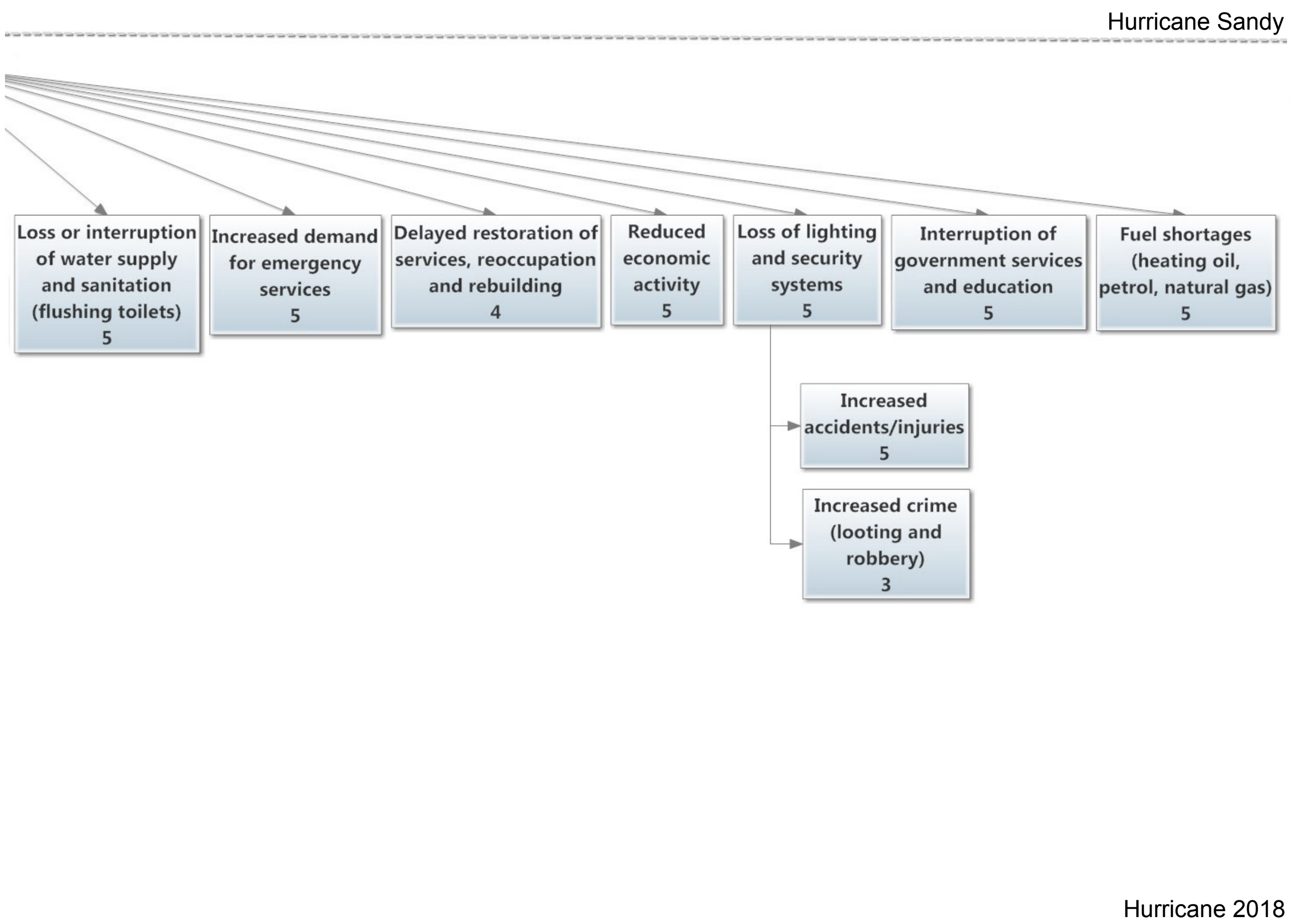



**Figure E–6.** Hurricane Sandy Urban Communities - Loss of Electricity - Partial Scenario.


Hurricane Sandy
Loss or interruption of water supply and sanitation (flushing toilets) 5
Increased demand for emergency services 5
Delayed restoration of services, reoccupation and rebuilding 4
Reduced economic activity 5
Loss of lighting and security systems 5
Interruption of government services and education 5
Fuel shortages (heating oil, petrol, natural gas) 5
Increased accidents/injuries 5
Increased crime (looting and robbery) 3
Hurricane 2018

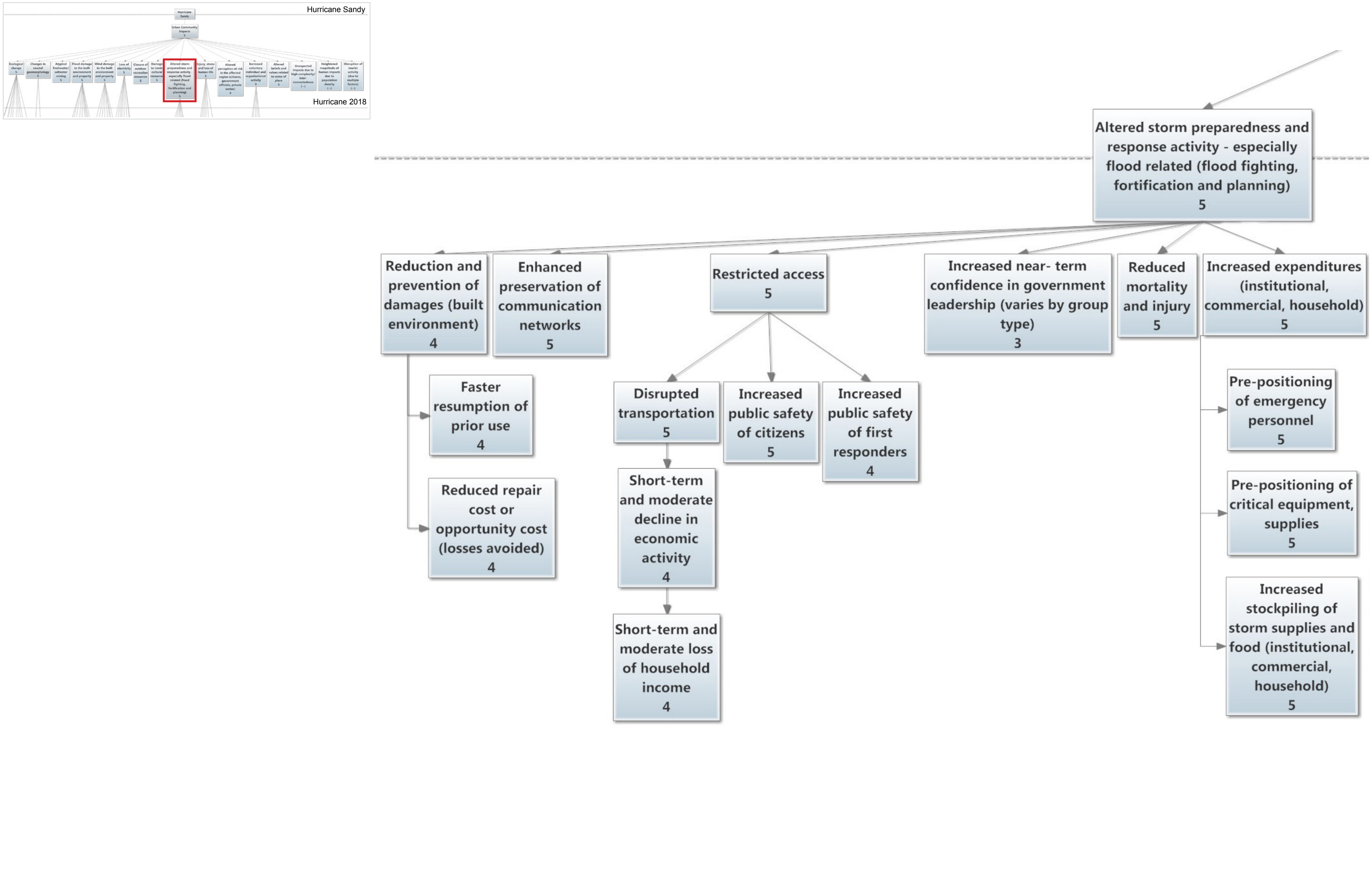
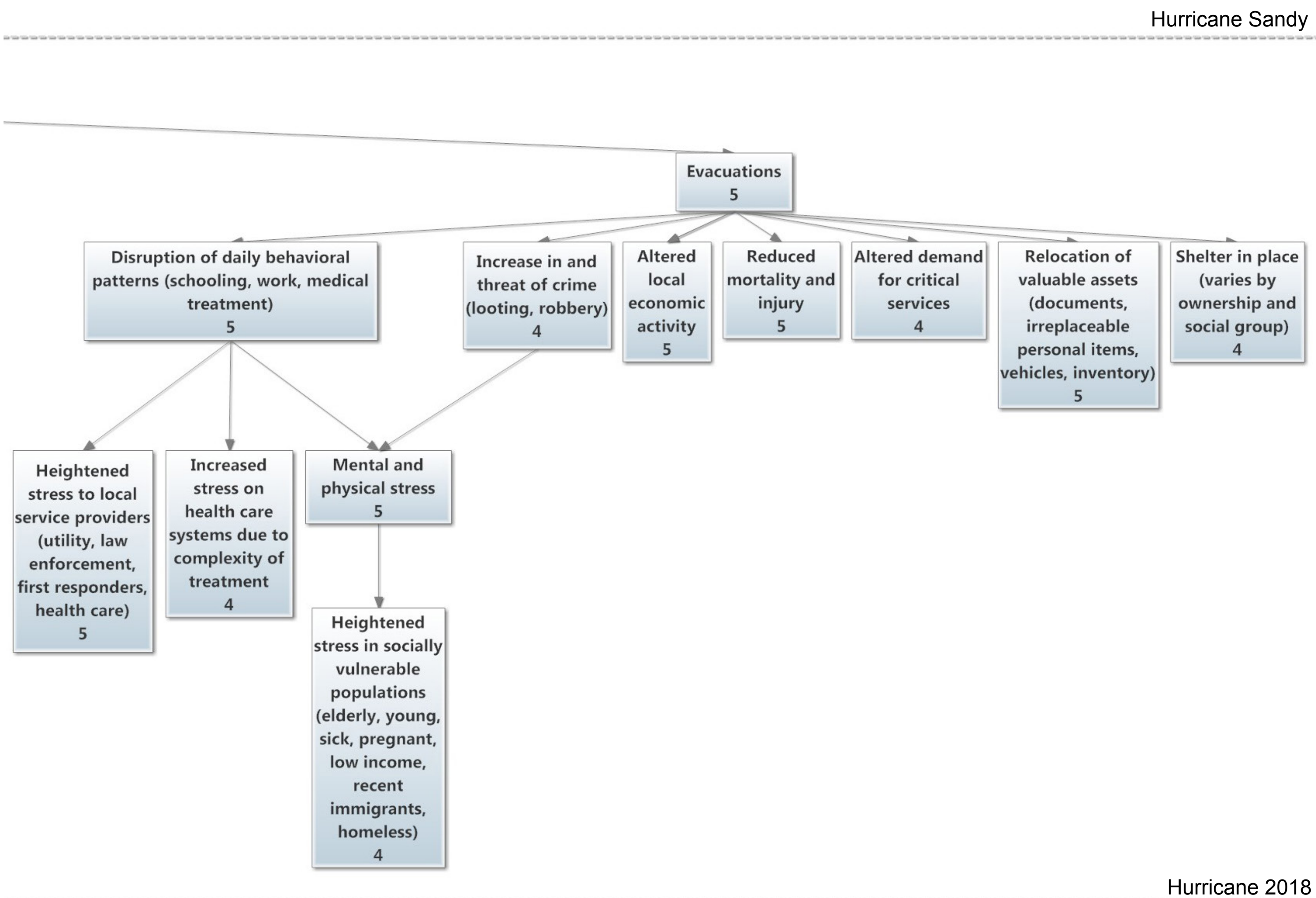



**Figure E–7.** Hurricane Sandy Urban Communities - Altered Storm Preparedness and Response Activity - Partial Scenario.


Hurricane Sandy
Evacuations 5
Disruption of daily behavioral patterns (schooling, work, medical treatment) 5
Increase in and threat of crime (looting, robbery) 4
Altered local economic activity 5
Reduced mortality and injury 5
Altered demand for critical services 4
Relocation of valuable assets (documents, irreplaceable personal items, vehicles, inventory) 5
Shelter in place (varies by ownership and social group) 4
Heightened stress to local service providers (utility, law enforcement, first responders, health care) 5
Increased stress on health care systems due to complexity of treatment 4
Mental and physical stress 5
Heightened stress in socially vulnerable populations (elderly, young, sick, pregnant, low income, recent immigrants, homeless) 4
Hurricane 2018

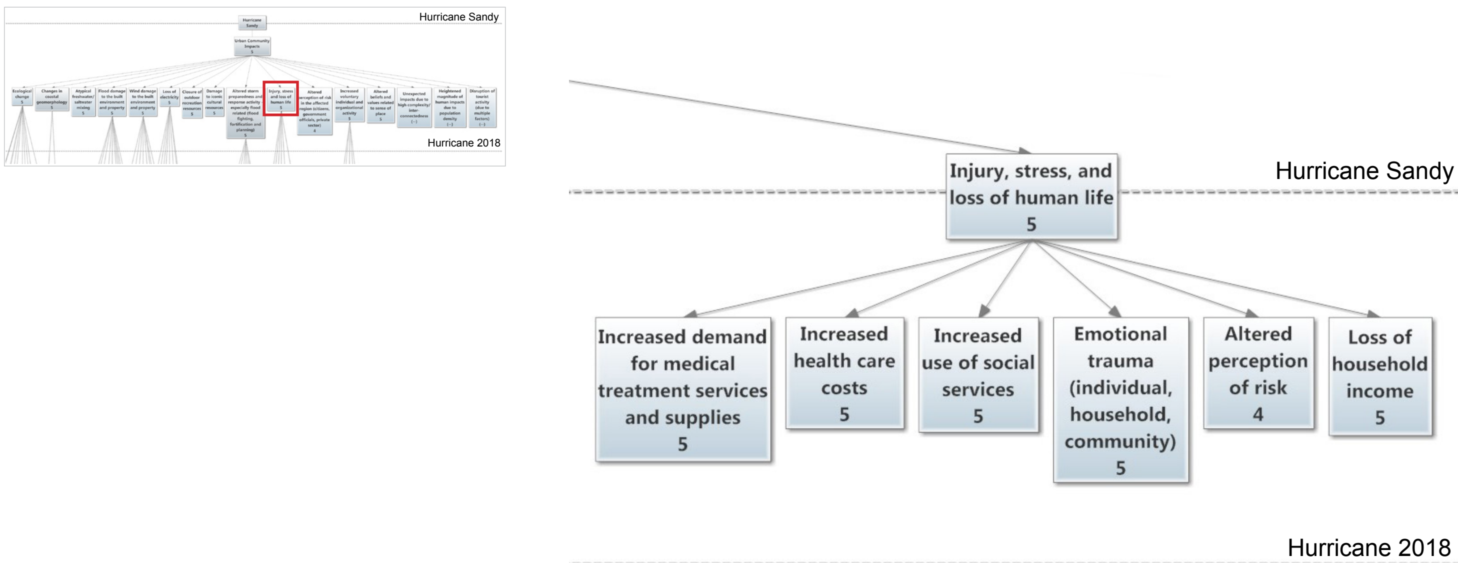



**Figure E–8.** Hurricane Sandy Urban Communities - Injury, Stress and Loss of Human Life - Partial Scenario.

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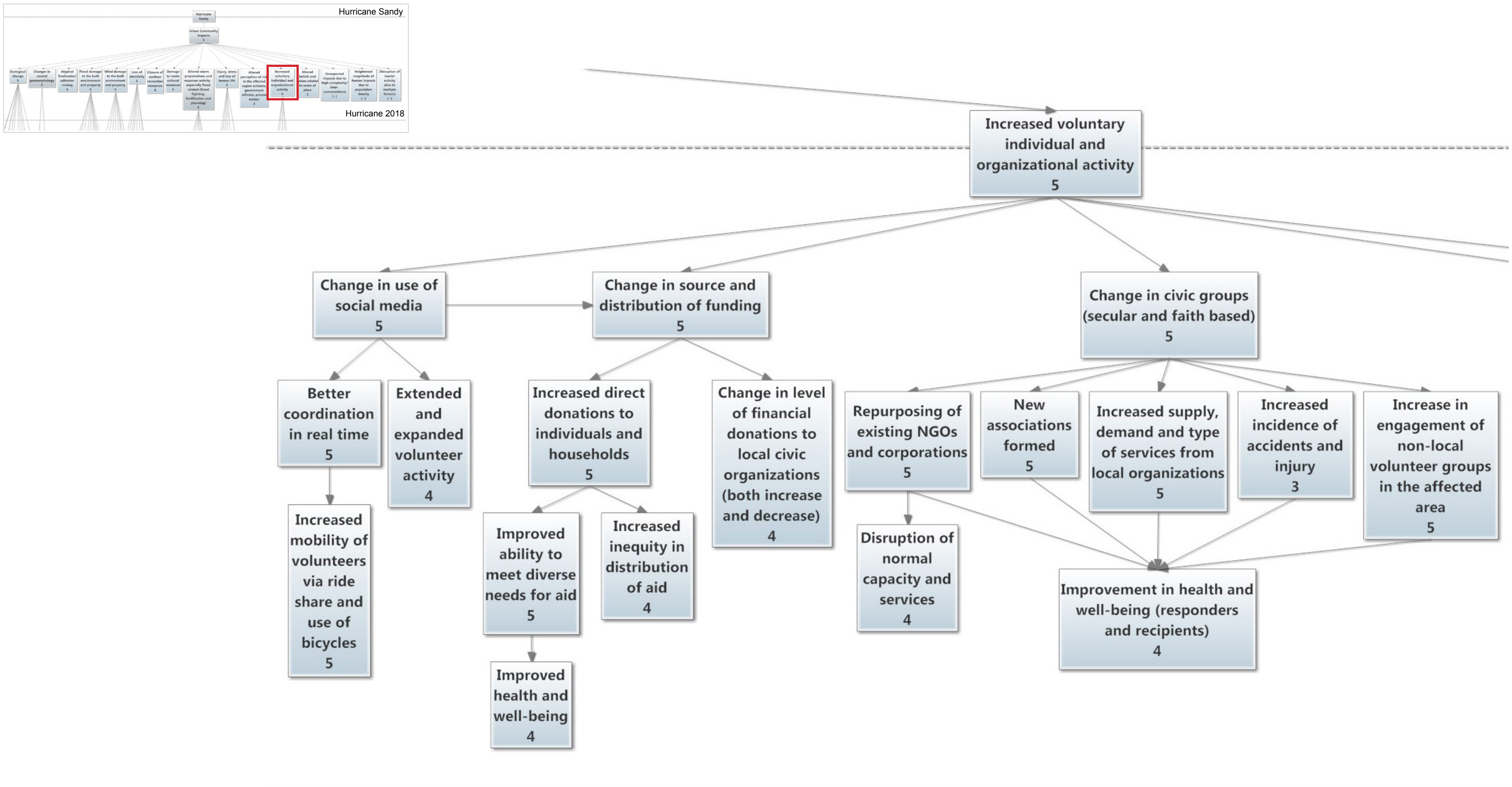
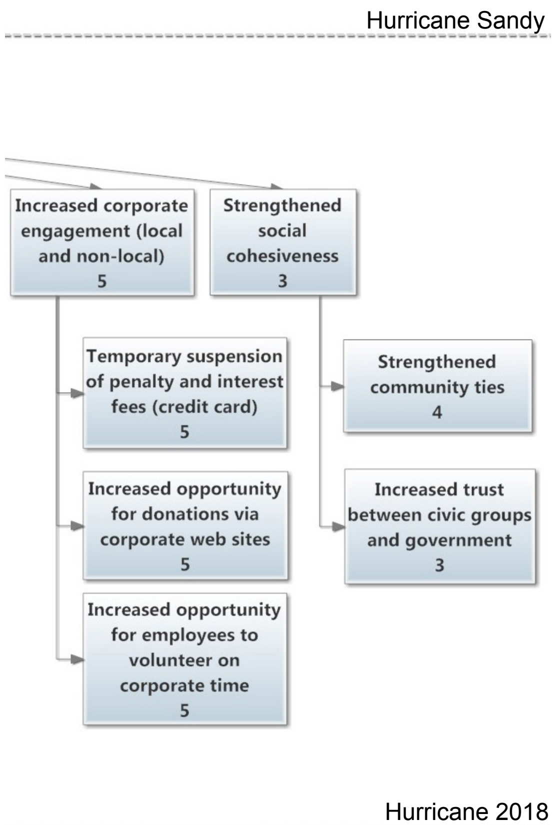



**Figure E–9.** Hurricane Sandy Urban Communities - Increased Volunteer Activity - Partial Scenario.


Hurricane Sandy
Increased corporate engagement (local and non-local) 5
Strengthened social cohesiveness 3
Temporary suspension of penalty and interest fees (credit card) 5
Increased opportunity for donations via corporate web sites 5
Increased opportunity for employees to volunteer on corporate time 5
Strengthened community ties 4
Increased trust between civic groups and government 3
Hurricane 2018