While they come by different names, research indicates major climate change and weather-related events like hurricanes and superstorms are coming stronger and more frequently than ever before in human history. In fact, there were 16 different natural disasters in 2017 that each led to more than a billion dollars in damage in the US not to mention tragic deaths and hardships for individuals affected.¹

Natural disasters can strike at any time, but public attention amplifies in August and September when hurricane season delivers some of its strongest mainland storms. While many can flee these storms in advance healthcare institutions must stay operational to serve those in need of care. This is no easy feat when one considers the magnitude of nature’s most powerful storms and recent results. Consider the following:

- When Hurricane Harvey hit the Houston, TX area in August 2017 dropping more than 60 inches of rain accompanied by relentless strong wind, 20 of the roughly 120 hospitals in the area had to close or evacuate according to the Texas Hospital Association (THA). Per the THA, the estimated disaster-related costs for reporting hospitals totaled $460 million spanning capital, operating, emergency work, uncompensated care and other costs.²
- According to a study from the U.S. Department of Health and Human Services after Superstorm Sandy hit the east coast in 2012, 89% of hospitals in the area had substantial challenges. These issues ran the gamut of infrastructure breakdown, power outages and critical resource struggles.³
- Hurricane Katrina’s devastation of the Louisiana area in 2005 forced 10 hospital evacuations of not just patients, but thousands of other people who had looked to hospitals as safe havens when their homes were destroyed.⁴
This modern history reveals that natural disasters are challenging and dangerous for hospitals in their path. Decisions to close facilities or evacuate patients can mean life or death for critical patients, not to mention millions in future repair and investment. Conversely, decisions to invest in resilient design strategies can not only enhance safety for patients and staff in the future, but also yield financial benefits. While CannonDesign data suggests resilient design measures usually lead to a 1.5 to 3% increase in initial construction costs (the variability is driven by project location, access to materials, etc.), the National Institute of Building Sciences Natural Hazard Mitigation Saves 2017 report concluded that every $1 invested in hazard mitigation saves $6 in future disaster-related and recovery costs.5

Knowing this, several health systems are taking bold steps to ensure their facilities are resilient to future storms and long-term climate change, and not susceptible to closure, power loss or other damages that could negatively impact their ability to deliver care. Specifically, our team has worked with Partners Healthcare, Texas Children’s Hospital, Mount Sinai Medical Center and the Department of Veterans Affairs among others on creative solutions to unique challenges. Case studies of these projects are published later in this document.

Resiliency Isn’t Just About Hurricanes and Superstorms

While major storms elevate resilient design solutions to mainstream attention, resiliency is about much more than being prepared for hurricanes and superstorms. Per the Resilient Design Institute, “resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption.”6

There are scores of disturbances or interruptions that can challenge health systems and hospitals. In our work, we most commonly see design responses that focus on resiliency challenges from the list below:

- Sea Level Rise: With evidence that climate change will continue to contribute to rising sea levels, how can hospitals be prepared for new realities 25, 50 and event 75 years into the future?
- Inland flooding: Numerous causes can lead to damaging inland floods. Hospitals need plans and protective design measures ready in advance.
- Wildfires: Both strategic natural landscape design and material selection can prove invaluable in the face of widespread fires.
- Extreme Temperatures: Our evolving climate promises more extreme weather patterns resulting in hotter and colder days than we’re used to (and more of them). Resilient design can ensure building envelopes are optimized for these extreme realities.
- Drought: In the absence of water, how can design strategies and systems ensure hospitals stay hydrated to serve their patients, staff and operations?
- Extended Power Loss: High winds and ice storms can cause the power to go out. Hospitals need a plan to ensure they can remain operable for business continuity without access to an outside power infrastructure. Current building code requires hospitals to have back-up power multiple days, but the utility service can be out for longer and it’s important for health systems to have fuel storage and a plan.

Again, these are just some of the most common and daunting threats to operations. Other weather events (heavy lake-effect snowstorms, for example) or weakened technology networks can all threaten a hospital’s operations, too.
What Defines a Resilient Hospital?

Just as there are numerous threats to resiliency, there is also a multitude of responses available to healthcare organizations. Every healthcare system and hospital requires its own strategic solutions, but there are common themes that will permeate the best responses regardless of geography, climate or specific threats.

Anticipate Future Environmental Conditions
Numerous tools, like the U.S. Climate Resilient Toolkit, help designers and health systems alike model how climate change will lead to new environmental conditions for any region in the world. These tools can predict future temperatures, sea levels, humidity, and rainfall among other factors. Consider, for example, that the prime development land of today could be the flood plain of tomorrow. How should this effect the placement of critical infrastructure or building entries?

Embrace Redundant Measures
Loss of power is always a threat to healthcare facilities; failing to design redundancies into power systems can leave health facilities without power for extended time periods or during severe weather events. Critical to any resilient design solution is the incorporation of multiple redundancies into a building’s power infrastructure via generators and on-site reserve fuel for these challenging moments.

Strategically Invest in Materials
It’s always important to focus on material selection for healthcare projects. Certain materials can inherently promote health in the building, reduce slips and falls and address other safety measures. In resilient healthcare facilities, designers must accommodate all these considerations while also ensuring they select materials that can withstand extremes – 150+ MPH winds, surging water, consistently strong heat waves, etc. Selecting materials for resilient health facilities requires careful consideration and planning to get it right and ensure safety when disaster strikes.

Ensure Maximum Adaptability
As indicated earlier in this document, it’s not just storms that threaten the endurance of buildings, but also time itself. The design community often talks of creating buildings that can thrive for 50-100 years, but that’s only achievable if we design them to accommodate the changes in technology and practice that will occur during their lifetimes.

Using a standardized structural grid provides one solution to the elusive goal of “future proofing” our facilities. A “universal grid” consisting of the optimum set of vertical and horizontal dimensions for a building’s structure can empower almost infinite adaptability – allowing hospital spaces to evolve over time and take on new programmatic purposes. A universal grid also enables these spaces to evolve from one programmatic purpose to another over time, while also enabling efficient configuration of structure, casework, lab equipment, lighting, power and HVAC.

Design Strategies for Sustainability and Resiliency
Many sustainable design strategies also strengthen resiliency. Here is a look at some of those strategies and the natural disasters they help guard against.

<table>
<thead>
<tr>
<th>Hurricanes and Tropical Storms</th>
<th>Storm Surge, Sea Level Rise and Flooding</th>
<th>Extreme Heat and Cold</th>
<th>Drought</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact-resistant glass</td>
<td>Locating power center and HVAC equipment above the storm surge elevation or floodplain levels</td>
<td>Strategic siting and shading of the building to reduce heat gain</td>
<td>Graywater recycling features</td>
</tr>
<tr>
<td>Water storage tanks</td>
<td>Landscape elements such as berms, swales and/or natural wetlands</td>
<td>Super-insulated building envelopes</td>
<td>Rainwater cisterns</td>
</tr>
<tr>
<td>Extra on-site backup power</td>
<td></td>
<td>Operable windows</td>
<td>Xeriscape with native trees and shrubs</td>
</tr>
</tbody>
</table>
Responding to Unique Challenges

Given the wide variety of challenges healthcare facilities can face, it’s key for every organization to ensure their buildings are uniquely ready to meet them. Over the final months of 2018 and early 2019, three buildings designed by CannonDesign are set to open in unique locations with unique resiliency stories. These case studies convey the variability in changes healthcare institutions can face.

A Hospital 30 Miles at Sea

Located 30 miles from mainland, Nantucket Island and its residents (11,000 permanent with summer seasonal influx of 50,000 additional visitors) face unique challenges. The island’s new 120,000 sf Nantucket Cottage Hospital (NCH) is a right-sized facility that transforms the patient experience and increases access to providers. Given its location in the Atlantic Ocean, NCH must regularly deal with inclement weather. The new hospital is designed to withstand potentially catastrophic conditions and provide all necessary services while "off-the-grid” when weather cuts off access to the mainland.

Prepared to be the “last building standing,” the facility is equipped with dual electrical and water supplies to provide backup redundancy, mechanical elements on its roof in case of severe flooding, materials to withstand 150 MPH hurricane winds, and operable windows for ventilation in the event the HVAC loses power.
Helping Health Systems Prepare for a Changing Climate

CannonDesign understands a growing number of owners are concerned with how their buildings will perform in the face of weather-related events and a changing climate.

To help our clients prepare their infrastructure, we are proud to offer the below services to help health systems design a more resilient future.

• Hazard Assessment and Resiliency Planning
  We use predictive models to forecast how regional climates and weather threats will evolve over the decades ahead. Using industry frameworks such as the RELi Resilience Action List, our design team works with clients to set goals and make informed decisions and investments for future resiliency.

• Passive Survivability Modeling
  Our team utilizes computer simulations to understand building performance and occupant conditions during loss of power or water utilities.

• Existing Building Resiliency Assessment
  We provide comprehensive facility assessments to identify a building’s vulnerabilities and hazard priorities. The assessment enables clients to create a prioritized list of mitigation strategies with associated costs and timelines for investment.

• Emergency Power Testing
  We verify critical facility backup and emergency power systems, generator and transfer switchgear operation, and performance of all connected critical systems like HVAC.

• Post-Event Assessment and Recovery
  After a weather event occurs, our team helps owners evaluate the scope of damage and develop plans to respond ASAP while improving future resiliency.

1 PMEL Tsunami Forecast series: Vol. 8 – Nantucket, Massachusetts;
2 Sea Level and Storm Surge Flooding Forecast – Nantucket, Massachusetts;
3 Historical Hurricane Tracks Relative to Nantucket, Massachusetts
A Safe Haven on Miami’s Coastline
Mount Sinai Medical Center (MSMC) is set to transform its health campus in Miami Beach, FL with the creation of a new surgical tower and emergency department (ED). The expansion effort brings new spaces to the campus and enhances Mount Sinai’s ability to deliver leading-edge care to its patients and community. Located along Miami’s coastline, the facility offers stunning views of Biscayne Bay.

As the only hospital and emergency services provider located on Miami Beach and the barrier islands, MSMC acts as a safe haven for the community during catastrophic weather events. Given its location on the ocean, the hospital is able to withstand winds in excess of 185 mph, 100-year flood water levels, and extended power outages. Infrastructure systems – including electricity, gas lines, water, telecom, and storm water – have been upgraded for redundancy. Critical patient care units are located on upper floors to avoid potential flooding, and the ED ambulance entry and canopy can accommodate an influx of emergency vehicles.
Texas Children’s Hospital has long ascribed to leading-edge and stringent resilient design strategies to prepare itself for future storms given their Houston location (in the path of 2017’s Hurricane Harvey and 2001’s Tropical Storm Allison). Across its campus, Texas Children’s Hospital has implemented a site design that mitigates excessive run-off and long-term land subsidence via increased permeable surfaces, elevated ground level openings for passive flood protection, previous vulnerable openings are equipped with flood gates and all critical utility components are elevated and sealed on upper levels. Texas Children’s also relies on wind studies and associated design responses to ensure all buildings on campus can withstand strong winds.

Rapid Recovery for the VA Manhattan
After Superstorm Sandy in 2012, the Manhattan VA Medical Center (VAMC) had to close for months due to storm damage. The VA used this challenging time to make several key updates to its facility, including the construction of a permanent floodwall to protect sides of the hospital exposed to future flood-level waters.

Additional upgrades included the renovation of the medical-surgical inpatient services on the 4th and 8th floors and VAMC’s inpatient behavioral health clinic on the 17th floor. The VAMC also invested in a raised generator building and switchgear room to replace underground fuel tanks and several other infrastructure and system components. This VAMC improvement effort demonstrates how health organizations can turn challenges related to weather into opportunities to prepare for a more resilient future. All of these new features uniquely equip the hospital to stay operable and treat patients in the event of another storm.
In addition to creating resilient buildings, design teams should advocate for response and recovery plans that help organizations fully think through how space, systems and resources can ensure continuity of service. These plans should be refreshed and revised annually.

New research continues to indicate that Mother Nature’s storms may grow even more powerful in the years ahead. This means resilient design will become more important for healthcare organizations in the future. Pulling inspiration from leading-edge examples across the country, every health system should take resilient design seriously to create hospitals and care spaces that can deliver for patients, staff and communities even in the worst of times.

About the Authors

Mike Cavanaugh is CannonDesign’s sustainability leader and works with client organizations to align goals and further integrate sustainability strategies - big and small - throughout the design process.

Brett Farbstein is CannonDesign’s commissioning services leader and also acts as the firm’s resilient design subject matter expert. He is a tireless advocate for developing industry standards and community resiliency resources.

About CannonDesign

CannonDesign is an integrated global design firm that unites a dynamic team of architects, engineers, industry experts and builders driven by a singular goal – to help solve our clients’ and society’s greatest challenges.

Contact Information

For more information please visit cannondesign.com.