| Scale | Wind Estimate kph(mph) | Typical Damage |
|---|---|---|
| F4 | 333.1-418.8 (207-260) | Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated. |
| F5 | 420.0-511.8 ((261-318) | Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yds); trees debarked; incredible phenomena will occur. |

An update to the original F-scale by a team of meteorologists and wind engineers, implemented in the U.S. on 1 February 2007. The **Enhanced F-scale** still is a set of wind estimates (not measurements) based on damage. Its uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to the 28 indicators listed below. These estimates vary with height and exposure. Important: The 3-second gust is not the same wind as in standard surface observations. Standard measurements are taken by weather stations in open exposures, using a directly measured, "one-minute mile" speed. (SPC 2019)

Table G.3 Enhanced Fujita Tornado Damage Scale (adapted from SPC 2019)

| Fujita Scale | | | Derived EF Scale | | Operational EF Scale | |
|---|---|---|---|---|---|---|
| F Number | Fastest 1/4-mile kph (mph) | 3 Second Gust kph (mph) | EF Number | 3 Second Gust kph (mph) | EF Number | 3 Second Gust kph (mph) |
| 0 | 64-115 (40-72) | 72-126 (45-78) | 0 | 104-137 (65-85) | 0 | 104-137 (65-85) |
| 1 | 117-180 (73-112) | 127-188 (79-117) | 1 | 138-175 (86-109) | 1 | 138-177 (86-110) |
| 2 | 181-253 (113-157) | 189-259 (118-161) | 2 | 177-220 (110-137) | 2 | 178-217 (111-135) |
| 3 | 254-333 (158-207) | 260-336 (162-209) | 3 | 222-268 (138-167) | 3 | 218-265 (136-165) |
| 4 | 334-418 (208-260) | 338-420 (210-261) | 4 | 270-320 (168-199) | 4 | 267-321 (166-200) |
| 5 | 420-512 (261-318) | 421-510 (262-317) | 5 | 321-377 (200-234) | 5 | Over 321 (Over 200) |

**Severe Storms** (NOAA 2019b)

**Thunderstorms** — rain storms with lightning — can be dangerous by themselves and can cause destructive, deadly flooding. When they contain strong winds, hail and tornadoes they can turn violent. NOAA classifies a storm as "severe" when it produces wind gusts of at least 93 kph (58 mph) and/or hail one inch in diameter (about the size of a US coin quarter) or larger and/or a tornado.

**Lightning** is caused by the attraction between positive and negative charges in the atmosphere, resulting in the buildup and discharge of electrical energy. This rapid heating and cooling of the air produces the shock wave that results in thunder.

An AIChE Technology Alliance

CCPS

Center for Chemical Process Safety

# CCPS Monograph: Assessment of and planning for natural hazards

This monograph addresses the assessment of and planning for natural hazards. It is based on lessons learned by various CCPS member companies.

*The Center for Chemical Process Safety was established by the American Institute of Chemical Engineers in 1985 to focus on the engineering and management practices to prevent and mitigate major incidents involving the release of hazardous chemicals and hydrocarbons. CCPS is active worldwide through its comprehensive publishing program, annual technical conference, research, and instructional material for undergraduate engineering education. For more information about CCPS, please call (+1) 646-495-1371, e-mail ccps@aiche.org, or visit www.aiche.org/ccps.*



*Cover photo credits:*

*Upper left: Coffeyville Refinery, Coffeyville, Kansas, 2007*
*https://agriculture.ks.gov/divisions-programs/dwr/floodplain/resources/historical-flood-signs/lists/historical-flooding/coffeyville*

*Right: FEMA Flood Map*
*https://msc.fema.gov/portal/home*

*Lower: Lake Charles, Louisiana, 2005*
*Sanders RE. Expect the unexpected when thinking extreme weather. Process Safety Progress 2019; e12082. https://doi.org/10.1002/prs.12082*

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## TABLE OF CONTENTS

## 1 GENERAL

Natural disasters such as Hurricanes Katrina and Harvey, Superstorm Sandy, and various river flood events have made it clear to the upstream, refining and chemical industries that planning for such natural hazards is very important. The likelihood of such natural disasters occurring seems to be increasing. The U.S. Chemical Safety and Hazard Investigation Board (CSB) references a study by Swiss Re, an international insurer, covering the years 1970 to 2016, showing that North America has experienced increasing insured losses from disaster events with the highest losses in 2016. Most of the losses stemmed from hurricanes, hailstorms, thunderstorms, and severe flood events. (CSB 2018)

The American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS) member companies believe that sharing experiences and learnings is fundamental to reducing risk and improving performance. This monograph addresses the assessment of and planning for natural disasters. It is based on guidance provided by various government, insurance agencies, and CCPS, as well as lessons learned by various CCPS member companies. It is also aligned with the CCPS Risk Based Process Safety approaches of understanding hazards and managing risks. (CCPS 2007)

The reader is reminded that this monograph provides guidance and does not set a standard or expectation for performance or actions. Ultimately it is the responsibility of each company and its employees to act on their principles and available information to secure their site and protect their employees, the community, and the environment from harm. Also, where local regulations provide compliance requirements, those regulations should take precedent.

This monograph intends to provide basic information, an approach for assessing natural hazards, means to address the hazards, and emergency planning guidance. It applies to both new and existing facilities.

## 2 INTRODUCTION

Natural hazards include all types of naturally occurring events that have the potential for negative impact. These natural phenomena fall into two categories:

- Meteorological hazards are those that naturally occur due to the weather cycle or climactic cycles, and include flooding, temperature extremes, snow/ice storms, wild fire, tornado, tropical cyclones, hurricanes, storm surge, wind, lightning, hailstorms, drought, etc.
- Geological hazards are those occurring due to the movements of the earth and the internal earth forces, and include seismic events, earthquakes, landslides, tsunami, volcanic eruptions, and dam rupture.

## 3 IDENTIFY HAZARDS

The first step in preparing for a natural hazard event is to identify the natural hazards that could occur at the facility. The list of meteorological and geological hazards above could be considered as a primary screening list. When deciding if a natural hazard is relevant at a site, codes and standards, regulations, insurance reports, and site experience may be useful. Although a site, or the analyst compiling the list of hazards, may not have experienced a specific type of natural disaster, it is important not to discount its potential. An example site screening for natural hazards document format is provided in Appendix A.

## 4 GATHER DATA

Once the potential natural hazards relevant to a facility are identified, the next step is to gather data on the natural hazards. Data may also be available from third party, expert natural hazard consultants or from the facility's insurance carrier. Insurance carriers typically will have developed specific natural event reports. Other data sources may include the following.

- Federal Emergency Management Agency (FEMA) flood maps - https://msc.fema.gov/portal/home
- United States Geological Survey (USGS) seismic maps - https://earthquake.usgs.gov/hazards/designmaps/usdesign.php
- American Society of Civil Engineers (ASCE) seismic guide - https://hazards.atcouncil.org/#/
- National Oceanic and Atmospheric Administration (NOAA) tornado prediction - https://www.spc.noaa.gov/new/SVRclimo/climo.php?parm=allTorn
- ASCE Tornado Wind Prediction - https://hazards.atcouncil.org/#/
- National Hurricane Center (NHC) Storm surge maps - https://www.nhc.noaa.gov/nationalsurge/
- ASCE Wind prediction maps - https://hazards.atcouncil.org/#/
- ASCE Snow load - https://hazards.atcouncil.org/#/
- NOAA Hurricane center - https://www.nhc.noaa.gov/climo/

This data may be used in evaluating facility design in relation to natural hazards, assessing risks, and emergency planning. It is important that the data gathered from these sources is specific to each site location. This includes the probability of occurrence and the severity level (e.g. flood zone, water height, wind speed, seismic zone). For example, the facility may be subject to flooding of 1.52 meters (5 feet) at a frequency of 1 in 500 years. In addition to data from the above sources, it may be important to understand the specific site topography, as knowing the high and low spots may inform both increased risks and potential mitigation measures. A potential best practice used by one CCPS member company was to develop drone elevation maps of their site prone to river flooding. With this, they understand exactly what equipment will be impacted at a given river height, a value that is often forecasted days in advance.

The data gathered should be maintained along with other important raw data describing the conditions of the site. This site data should be maintained in a format that is accessible to those on site during a potential emergency and is also backed up and accessible remotely.

| Considering natural hazard data as "process safety information" is a good practice. |
|---|

## 5 IDENTIFY EQUIPMENT TO BE ADDRESSED IN NATURAL HAZARDS ASSESSMENT

Facilities include many pieces of equipment and systems which may be critical to supporting operations some of which may be important to protect from a natural hazard. For example, the emergency power system may be important for continued operation during a natural disaster, but the maintenance shop equipment may not be. Any equipment or operation that is required for safe operations or that, if compromised, could lead to a process safety event, harm to personnel the community, or the environment should be identified. Further examples of equipment that may be required for safe operation are: nitrogen generators, firewater pumps, cooling systems, process control and safety instrumented systems, and wastewater pumps.

This identification step should be documented as follows.

- For flood hazards, document the equipment/operation potentially impacted and its elevation, and the predicted 100-year and 500-year levels.
- For wind hazards, document the equipment/operation potentially impacted, the required wind design per local building code, and the existing wind design basis.
- For seismic hazards, document the equipment/operation potentially impacted, the required seismic design per local building code, and the existing seismic design basis.
- For other hazards such as temperature extremes, snow/ice storms, wild fire, tornado, tropical cyclones, hurricanes, storm surge, wind, lightning, hailstorms, drought, landslides, tsunami, volcanic eruptions, and dam rupture, document the equipment/operation potentially impacted, any design requirement and the existing design basis.

## 6 EVALUATE AGAINST DESIGN CRITERIA

Equipment and operations identified in section 5 should be evaluated compared to the natural hazard likelihood and severity data gathered in section 4. This comparison should be made for each type of natural hazard. Where the current or planned design falls below the design criteria (refer to section 6.1), then there is a gap that should be addressed.

One or more of the following approaches may be taken in addressing a gap.

1. Bring the equipment/operation up to the design criteria
2. Conduct a risk assessment to understand the risk and develop safeguards
3. Address the gap through emergency response plans.

The latter two options will be discussed in greater detail in the following sections. The process safety hierarchy should be kept in mind when deciding how best to close a gap. It is better to first eliminate the gap, then to engineer a solution, and then to provide emergency response.

A challenge in natural hazards response planning is that a number of important systems and pieces of equipment may be impacted by the same hazard at the same time, or in rapid succession. This may also include the layers of protection that have been installed to protect equipment. A common mode failure may be rising flood waters. For example, as the water level continues to rise, more and more equipment may be inundated and, eventually, even the equipment on “high ground” may also be flooded.

For meteorological hazards including wind (including hurricane), earthquake, tornado, snow/ice storm, and lightening, local building codes should be consulted for design criteria. For example, wind or seismic designs should be evaluated for tall structures such as distillation towers.

For geological natural hazards including wild fires, volcanic eruptions, landslides, droughts, and dam ruptures, there are likely no relevant design conditions defined. For these natural hazards, addressing the risk through emergency planning is appropriate.

For natural hazards of flooding and storm surge, there is frequency and severity data available from the sources listed in section 4 above, but the topic of applicable design criteria is not abundantly clear.

- FEMA defines a 100-year flood and 500-year flood area. (FEMA 2019a) A 100-year rainfall and a 100-year flood are not necessarily related as the flooding will be influenced by where the rain fell in the watershed, the soil saturation before the storm, and the storm duration as related to the watershed stream basins. (USGS 2019)
- Hurricanes are categorized using the Saffir–Simpson Hurricane Wind Scale (SSHWS) in categories 1 through 5 based on 1-minute maximum sustained wind speed. The SSHWS does not account for rain or storm surge – only wind.
- The National Hurricane Center defines storm surge levels with the highest level being greater than 9 feet. (NOAA 2019 a)

The information above does not clarify which of these flood zones and storm surge levels one should use as a design criterion. For example, the emergency power system deemed important in section 5 may be outside of the 100-year flood zone but within the 500-year flood zone. It is the owner's decision on which criterion to apply to new or existing equipment. Some points to keep in mind are the following.

- Hurricanes Ike, Katrina, and Hugo all generated storm surges well in excess of 9 ft. (NHC 2019a) which resulted in floodwater levels exceeding the base flood elevation by several feet. The FEMA flood maps are updated as new data and funding is available, but this can take decades.
- The Federal Emergency Management Agency (FEMA) states it is recommended that (FEMA 2014):
  - Critical facilities be protected to the greatest of the following flood elevations:
    - Base Flood Elevation (BFE) plus 0.61 meters (2 feet),
    - Locally adopted Design Flood Elevation (DFE), and
    - 500-year flood elevation (flood event having a 0.2% chance of being met or exceeded annually).
  - Emergency power systems within critical facilities and the equipment they supply should be protected to the greatest of the following flood elevations:
    - Base Flood Elevation (BFE) plus 0.91 meters (3 feet),
    - Locally adopted Design Flood Elevation (DFE) plus 0.3 meters (1 foot), and
    - 500-year flood elevation (flood event having a 0.2% chance of being met or exceeded annually) plus 0.3 meters (1 foot).

## 6.1 MEET DESIGN CRITERIA

Design criteria addressing natural hazards should be applied to new projects. It can also be used in designing upgrades for existing equipment. In addition to the criteria noted above in section 6, there is guidance and criteria provided in a number of sources including the following.

- ASCE Flood Resistant Design and Construction, ASCE 24 (ASCE 2014)
- ASCE Minimum Design Loads and Associated Criteria for Buildings and Other Structures, ASCE /SEI 7-16 (ASCE 2016)
- CCPS Guidelines for Safe Warehousing of Chemicals (CCPS 1998)
- CCPS Guidelines for Safe Storage and Handling of Reactive Materials (CCPS 1995)
- CCPS GL for Facility Siting and Layout (CCPS 2018)
- FM Global Property Loss Prevention Data Sheets 1-2 Earthquakes (FM Global 2012)
- FM Global Property Loss Prevention Data Sheets 1-11 Fire Following Earthquake (FM Global 2010)
- FM Global Property Loss Prevention Data Sheets 1-29 Roof Deck Securement and Above-Deck Roof Components (FM Global 2010a)
- FM Global Property Loss Prevention Data Sheets 1-34 Hail Damage (FM Global 2019)

- FM Global Property Loss Prevention Data Sheets 1-40 Flood (FM Global 2019a)

Any gaps identified in section 6 should be evaluated to determine if they can be modified to meet the design criteria. For example, ask the question, "could critical equipment be elevated to meet the company defined flood criteria or could a tall structure be reinforced to meet wind load criteria?"

> *Example*
> A company decides that its design criteria for flooding is a 1 in 500-year flood. The equipment evaluation step reveals that a firewater pump is located lower than the 1 in 500-year flood height. The first response should be to meet the design criteria and raise the pump above the 1 in 500-year flood height. The company conducts engineering studies, determines this is feasible, and proceeds with the project to elevate the fire pump thus meeting the company design criteria.

## 6.2 CONDUCT RISK ASSESSMENT

Guidance on risk assessment methods is provided in a number of CCPS texts including CCPS Guidelines for Chemical Process Quantitative Risk Analysis (CCPS 1999) and CCPS Guidelines for Developing Quantitative Safety Risk Criteria (CCPS 2009). The guidance in these texts can be used to determine the risks due to natural hazards. Quantitative methods can also be used and will require the company to have established risk criteria to determine if actions are required once the risk is determined.

> *Example:*
> Let's continue the example of the company with a firewater pump below their company design criteria for flooding. Let's say that the company conducts engineering studies to evaluate elevating the fire pump and determines that this *is not feasible*. They then continue the risk assessment to determine the consequences if the pump were to become flooded. They determine that the consequence of the loss of this fire water pump is limited to the loss of fire protection to a remote structure that does not contain flammables or combustibles but contains packaging materials. The company determines that the risk is 'tolerable' according to the company risk matrix, as there is no significant onsite or offsite consequence of loss of firewater to this structure. The company decides not to elevate the pump based on the combination of low consequence and the 1 in 500-year probability of flooding.

The risk assessment should include three phases. First, determine the damage the natural hazard could have on the facility. Second, determine the consequences imposed on the personnel, community, and environment as a result of the natural disaster. Finally, estimate the frequency or likelihood of the consequences. The risks for natural events may be similar, or completely different, from the risks posed by the facility during normal operations. It is also more efficient to focus on worst case consequences, as these will typically cover the lesser consequences as well.

It is important to document all of the natural hazards considered in the assessment and the outcome of this assessment. The assessment should list the consequences and the existing safeguards and actions to be taken. An example risk assessment is provided in Table 1. This example is qualitative; however, data such as the 100-year flood frequency could be used to enable a quantitative assessment. Facilities should develop their own consequences of concern, risk and abating actions specific for their specific situation. A company risk matrix can then be used to assign decision level and action criteria. The risk matrix could indicate that action should be taken, for example, to elevate critical equipment. The risk matrix could indicate that the risk is tolerable per the company's criteria, and the appropriate action is to address it in emergency response plans.

Table 1 Example Natural Hazards Risk Assessment
*H - high; M – medium; L – low; NA – not applicable

| Hazard | Damage | Consequence | Existing Safeguards | Likelihood* | Onsite Risk* | Offsite Risk* |
|---|---|---|---|---|---|---|
| Heavy rain leading to flood | A few inches of water in buildings. Minor. | Building damage. No process equipment damage. | None | H | L | NA |
| | Damage of control instruments, safety instrumentation, and/or communication equipment | Loss of process containment for hazardous chemicals. Loss of communication capabilities | Critical equipment is elevated | M | L | NA |
| | Elevation level of critical equipment exceeded. Major. | Loss of process containment for hazardous chemicals. Loss of communication capabilities. | Waterproof covering on all junction boxes, switchgear, electrical cabinets, and enclosures | L | H | M |
| Heavy snow | High weight load on structures and building roofs | Structural failure, roof collapse, possible injuries | Clear roof gutters and downspouts, check drainage routes | H | H | L |
| Hurricane force winds | Damage to tanks and vessels containing chemicals | Airborne or water borne pollutants Harm to people and the environment | Reduce all toxic chemical inventory to minimal levels and secure remaining supplies | L | H | M |

The risk assessment should be subject to technical and management approvals and be reviewed at a frequency similar to those completed for Process Hazard Analyses. A formal action plan for risk mitigation based on the gap analysis should be tracked to completion.

## 6.3 NATURAL HAZARD EMERGENCY RESPONSE PLAN

An FM Global report stated, "loss history has shown that facilities with well-organized flood emergency response plans have nearly 70-percent less damage, and resume operations sooner than those locations without a flood emergency response plan, or an inadequate one, in place." (FM Global 2004) It is clear that developing, training, and testing an emergency response plan for natural disasters is just as important as doing the same for other potential site emergencies.

Taking into consideration the assessments performed related to natural hazards, sites should develop a Natural Hazard Emergency Response Plan (NHERP) to define their steps in response to an event.

In addition to the information in this monograph, there are a number of resources available to assist in the development of natural hazards emergency response plans including the following.

- CCPS Guidelines for Technical Planning for On-Site Emergencies (CCPS 1995)
- FEMA Emergency Response Plan (FEMA 2014)
- FM Global Creating a Flood Emergency Response Plan (FM Global 2004)
- United Kingdom Environment Agency Preparing for Flooding – A guide for sites regulated under Environmental Permitting Regulations (EPR) and Control of Major Accident Hazards (COMAH) Regulations (UK EA 2015)

> The Natural Hazards Emergency Response Plan (NHERP) should document "who" is to do "what," "when," and "how" for all of the natural hazards relevant to the site. The plan should be developed well in advance of a potential natural disaster and should include actions to be taken before, during and after the potential natural disaster

The following sections comprise an example Natural Hazards Emergency Response Plan. Details on each section of this example NHERP are included in Appendix B.

1. Emergency Command Center(s)
2. Authority and responsibilities
3. Understand hazards
4. Warning systems
5. Activation prompts
6. Staffing assignments (including ride out crew)
7. Evacuation plans
8. Interdependency
9. Utility supplies
10. Communication systems and protocols
11. Protection of business-critical equipment and data
12. Inventory
13. Access and security
14. Safety

15. Supplies and logistics
16. Equipment checks
17. NHERP maintenance, quality assessment/quality control

Lists of example activities to be taken before, during and after the natural hazard event is provided in Appendix D. These lists can be used in conjunction with the site's NHERP, both in the developing of the plan and in its use.

Although the NHERP in Appendix B includes a section on communication, it is highlighted here as it applies to all phases of the planning and recovering from a natural hazard event. Plans should be made and executed for communication with the community, media, and local authorities before, during and after the event. All communication means (TV, radio, email, text and other social media avenues) should be considered to reach all potentially impacted people.

*Example:*
Let's continue the example of the company with a firewater pump below their company design criteria for flooding. Recall that the company conducts engineering studies to evaluate elevating the fire pump and determines that this *is not feasible*. However, in this alternative case, they decide that the consequence of a fire will lead to both on-site and off-site impacts. They decide that they can reduce the quantity of flammables and combustibles inside the structure by following their hurricane preparedness procedure. This action will help to mitigate the consequence to a lower level. They also identify that the local fire department can respond in a few minutes (from high ground) thereby mitigating the consequence with a firewater source independent of the plant firewater pump. They use the company risk management process, obtain approval address the potential fire pump flooding through emergency response planning. In addition to developing and implementing the NHERP, they meet with and make specific emergency response plans with the local fire department to provide firewater if needed.

# 7 RECOVERY

After the disaster has passed, it is time to manage the aftermath and resume operations. There will likely be damaged equipment to repair, contamination to address, hidden or silent failures, new hazards associated with old equipment, and the typical startup challenges. At this time, it is critical to identify the concerns and needs driven by the unique situation. The workforce is likely dealing with damage to their homes and concerns for their families' welfare. Stress and distraction are of heightened concern in managing a safe return to operations. Additionally, workers new to the site (e.g., employees from other worksites, specialty contractors unfamiliar with the site/its processes) may be brought in to complete repair efforts. Management of any new workforce should be a focus area.

Stabilize and assess. First conduct the activities such as those suggested in the "After the natural hazard event" section of Appendix D. Assessing the situation is a key step. The site will likely look different, pose different hazards, and have safeguards disabled. In the effort to bring things back to normal, it is easy to overlook these points. Time should be taken to consider potential hazards and protect against them to avoid injury during this assess and stabilize stage.

Secure. As soon as services are available and it is safe to do so, activate as many of the security systems as possible—including lighting, video monitoring, motion detectors, gate locks, access authorization cards, and guards. Train guards for the type of situations they may encounter at this time such as dealing with media or questions from neighbors.

Repair. After critical emergency repairs are made, begin to compile and categorize the other damages that must be repaired before restart. Some damages will be obvious, but some will not. Consider dividing the repairs into categories such as obvious physical/mechanical damage, potential hidden damages, contamination, support services impairments, electrical outages, electronic/signal failures, and computer issues. Assign appropriate teams to investigate the extent of the damages and make repair decisions. Be sure those making repairs are qualified to do so and don't forget to do the paperwork which might include getting a certified inspector to approve the repair. Remember that some repairs may require Code stamps (American Petroleum Institute (API), European Pressure Equipment Directive (PED), American Society of Mechanical Engineers (ASME), American Society for Testing and Materials (ASTM), etc.) and/or worker certification of some type. Other repairs may have to conform to national codes (National Electrical Code or ATEX, for instance) or standards (International Society of Automation (ISA) or International Electrotechnical Commission (IEC) are examples) and others may require conformance to company standards.

This may be the time to make some upgrades previously planned. This decision should be properly reviewed using a management of change procedure to validate that it is appropriate to do so at this time and to obtain necessary permits.

Train. Remember to train (or refresher train) employees who will be recommissioning the facility. This includes operational, maintenance, safety, engineering and supervision. Training should focus on recognizing anomalies in the startup sequence and how to correct them. For mechanics, electricians, and instrument specialists, consider retraining them on recognizing early effects of contamination, electrical issues, and failed safety systems. Supervisors and engineers should be reminded of and retrained in the part they are to play in the startup, how they are to interact, and their specific responsibilities and authorities. Spend some training time on protocols for communicating requests for help, status reports, and concerns.

Consider training a process safety person (or team) to function as an "unbiased" advisor to give the startup team advice on potential responses to risks encountered. There will likely be frequent MOC situations due to abnormal condition, process sequencing driven by equipment availability, and equipment change due to lack of ability to replace in-kind. Consider setting up an advisory team to make those reviews work smoothly.

Consider training recommissioning personnel together so that they develop a team concept and are accustomed to working with each other. If contractors are involved, make them part of the retraining and recommissioning team. Customize the recommissioning training to the types of circumstances associated with the type shut down the facility went through and the type of natural disaster it experienced.

Provide everyone with refresher training on the basic safety procedures that may be used during startup. Pay particular attention to recognizing and responding to changes required and the facility MOC procedure. Remind startup personnel to pay particular attention to tripping, falling, cutting, and wildlife hazards. Remember that insects, fire ants, snakes, spiders, racoons, and even alligators may have been looking for a safe haven during the storm. Cautiously open equipment, panels, and drainage trenches.

Remind everyone to look before they reach. Also consider if personnel should be protected against hazards in the waste and debris by having tetanus or hepatitis shots.

Consider making a process safety expert(s) part of the recommissioning training and team with the specific purpose of helping the team identify and properly analyze risks.

Staff. Staffing the facility for emergency repairs, long term repairs, and eventual restart has several phases each with different needs. Staffing will include company employees and will likely include contractors as well. Develop a time line or sequence chart of what needs to be done and in what order. Match required expertise to the different tasks and then develop a staffing chart to match.

Locate employees. The NHERP should include a mechanism for employees to contact the company and a way for the company to contact and/or in some way get messages to employees and families of the ride out crew employees. Based on the staffing chart developed above, schedule identified employees to come back into the plant. This should be voluntary if at all possible. Recognize that some employees may not be available because of significant damages to their homes and/or family issues associated with the evacuation requiring their attention.

Lodging and transportation. To enable employees and contractors to return to site, they may need local housing and services which they may not be able to secure on their own. If you expect them to continue helping secure, repair, and start up the plant, you may have to provide housing and services for them. Consider contracting with a local hotel or motel to provide them. If that is not possible or if local services are damaged beyond use, consider installing temporary housing, laundry, kitchen, etc. onsite. Locate any temporary occupied buildings in a safe location. API RP 753 Management of Hazards Associated with Location of Process Plant Portable Buildings and API RP 756 Management of Hazards Associated with Location of Process Plant Tents provide guidance on locating occupied buildings. Also consider bringing in additional contractors to operate these temporary facilities and services. Transportation can be an additional issue. Both personal and facility vehicles may have been damaged in the event or may not be suitable given high water or debris remaining after the event.

It may be that your employees' homes were damaged, and their families have no place to stay. Consider making arrangements for them to be housed in surrounding areas not severely impacted by the disaster. It is important that you take care of your employees and their families during this time.

Supplies. It is important to have planned in advance on how to purchase things to enable the recovery. Key staff should have appropriate spending authorization or purchasing cards. Consideration should also be given to accessing cash if electronic systems are disabled.

## 8 RECOMMISSIONING

The recommissioning plan for a facility following a natural disaster must be at least as comprehensive as that for the initial start-up of a new facility. Before starting operations, those responsible for the startup should be properly trained, it should be verified that the equipment is ready to receive the chemicals and utilities, and all operational and safety systems should be functional. CCPS Guidelines for Performing Effective Pre-Startup Safety Reviews (CCPS 2007) and CCPS Risk Based Process Safety (CCPS 2007) section on operational readiness provide guidance on this topic.

Recommissioning involves preparing equipment and personnel again for all of the tasks associated with operating the facility. A recommissioning plan should be developed for recovery from the specific natural hazard impacts such as wind and water damage. Things that may have worked properly before the disaster may not work after it. Don't assume that equipment will perform as expected. Confirm it.

Equipment, instrumentation in particular, may have sustained hidden damages, lost calibration, or been contaminated. For instrumentation, step through the process one stage at a time and check configurations and responses, ensuring that each item is performing as designed. Check for responses to out-of-acceptable or operational-range conditions to ensure that the process controls and safety instrumented systems will bring the process back under control or to a safe configuration. Carefully check (functional check preferred) each safety device or system:

- Basic process controls
- Preventative safety systems: active and passive systems
- Mitigative safety systems: active and passive systems

Do not forget that your distributive control system(s) (DCS) may be the hub of most of these instrumented systems, so check functionality all the way from field instruments through the DCS.

For processing equipment, check for damages and contamination and confirm that each is ready to receive materials. Pay particular attention to storage tanks that may have been emptied or filled with water during the disaster. Look for displacement and damage to foundations or to tankage due to floating. Verify the integrity of equipment including secondary containment systems such as dikes. Also look for piping damage due to tankage displacement, tie-down damage, or impacts from flying debris. Look for damage to piping connected to tanks that might have floated or been displaced. Conduct leak testing to ensure tightness of the system. Technologies such as IR cameras for leak detection and drones for damage assessment may aid in assessing equipment.

After verifying the equipment integrity, start resupplying inventory based on the startup plan. Auxiliary systems, such as lubrication, compressed air, inerting, and fuel supply systems should be carefully checked for contamination and product quality. Bearings and seals may have been compromised. Check them for contamination including grease/packing and local lubrication supply systems. If uncertain regarding contamination, assume it to have occurred and flush/replace lubrication systems and supplies. Function test equipment. Look for blockages (for instance in relief valve discharge pipes) and debris that might impair the functionality of equipment (for instance a piece of debris prohibiting a valve from stroking). If strong winds or flooding where equipment may have broken loose and impacted other equipment were involved, look for debris-impact damage such as missing insulation, broken tubing and wiring, dented piping, and bent structural supports. There may be a greater need than in normal operations for Civil Engineering expertise to conduct damage assessment and remediation. Pay particular attention to sensitive or fragile instrumentation systems.

Recommissioning could highlight changes that may be needed to compensate for missing and/or damaged equipment. It will also allow for identification of repairs made during the natural hazard event. Use the MOC process and Prestart-up Safety Review process. See Section F for a more complete description of how to conduct PSSRs after a disaster.

Staging the recommissioning of systems is key. There will be an appropriate order, given the damage, the equipment, and the facility design, to support a safe recommissioning. For example, establish the ability to assess the process condition through the DCS view. Then operationalize critical safety systems from individual critical devices to critical systems such as the flare and the firewater system. Next address utilities such as nitrogen, instrument air and cooling water. After all this is successfully completed, then the process itself can be started up.

Startup may be contingent on integration from others for electrical power or water supply. Recognize that the facility may be called on to give a service associated with interdependencies with another company before you can receive a service from them. When developing recovery and recommissioning plans, consider the interdependencies identified and address in the interdependency section of the NHERP. Communicate what services you need and explain how those services will enable your facility to provide services to others. Follow through on your "promises" by providing services to others as outlined in the NHERP.

Approach emergency response and governmental agencies for help in recovery. They may be able to provide expedited routes for repair materials, some security assistance, technical expertise, and establish communication mechanisms.

Improving the NHERP, recovery and recommissioning will come from documenting and sharing what went well, what didn't go so well, what was unanticipated, and what could be improved. This should be done as soon as possible after the natural disaster so that memories are fresh. If possible, involve site partners, neighboring facilities, interdependent facilities, and the civic authorities who participated in managing the disaster and/or response to participate in this process.

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## APPENDIX A: EXAMPLE SITE SCREENING FOR NATURAL HAZARDS

| Site Screening for Natural Hazards | | | | |
|---|---|---|---|---|
| **Natural Hazard** | **Applicable to Site** | | **References/Sources** | **Actions** |
| | Yes | No | | |
| **Meteorological** | | | | |
| Flood/Storm Surge | | | | Complete Flood Hazard Table |
| Hurricane/Tropical Cyclone | | | | Complete Flood Hazard and Wind Hazard Tables |
| Extreme Temperature | | | | |
| Snow/Ice Storm | | | | Determine snow load design for building |
| Hail Storm | | | | |
| Wildfire | | | | |
| Tornado | | | | Complete Wind Hazard Table |
| Straight-line Winds | | | | Complete Wind Hazard Table |
| Drought | | | | |
| **Geological** | | | | |
| Earthquake | | | | |
| Landslide | | | | |
| Tsunami | | | | |
| Volcanic Eruption | | | | |
| Dam Rupture | | | | |
| Review Conducted By: | | | | |
| Date: | | | | |

**APPENDIX A: EXAMPLE SITE SCREENING FOR NATURAL HAZARDS, continued**

| **Flood Hazard Table** | | | | | | |
|---|---|---|---|---|---|---|
| Critical Equipment / Building Impacted | Estimated 500-year Flood Level (m)(ft) | Estimated 100-year Flood Level (m)(ft) | Elevation (m)(ft) | Elevation Gap: 500yr/100yr (m)(ft) | Safeguards | Action: (one or more)<br>• Close Gap<br>• Assess Risk<br>• Emergency Response |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

| **Wind Hazard Table** | | | | | |
|---|---|---|---|---|---|
| Critical Equipment / Building Impacted | Wind design required per code (kph)(mph) | Existing Wind design basis (kph)(mph) | Wind Design Gap: (kph)(mph) | Safeguards | Action: (one or more)<br>• Close Gap<br>• Assess Risk<br>• Emergency Response |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

| **Earthquake Hazard Table** | | | | | |
|---|---|---|---|---|---|
| Critical Equipment / Building Impacted | Seismic design required per code | Existing Seismic design basis | Seismic Design Gap: | Safeguards | Action: (one or more)<br>• Close Gap<br>• Assess Risk<br>• Emergency Response |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

| **Other Hazard Table** | | | | | |
|---|---|---|---|---|---|
| Building Name | Snow Load design required per code | Storm Surge design basis | Extreme Temperature design basis | Other design basis: | Action: (one or more)<br>• Close Gap<br>• Assess Risk<br>• Emergency Response |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

## APPENDIX B: EXAMPLE CONTENTS OF A NATURAL HAZARD EMERGENCY RESONSE PLAN

This is an example. A facility should use this example in developing a plan specific to their needs.

1. **Emergency Command Center(s).** The emergency command center coordinates all activities and serve as communication hubs.

   It is advisable to create an offsite Emergency Command Center remote from the disaster's effects. Its function is to coordinate all emergency response, recovery and restart type activities, arrange for assistance and repairs, and respond to needs of the manufacturing facility or employees therein. It is critical to plan and drill the set-up and operation of this offsite Emergency Command Center in advance of any natural hazard emergency.

   The *onsite* Emergency Command Center, if it is appropriate to create one, should be staffed by a small crew with specialized expertise and specific assignments. Their function is to monitor the effects of the disaster on the facility and resultant effects on the surroundings so that appropriate and timely actions can be taken to minimize risks, on and offsite impacts, keep the facility in a safe state, and return the facility to service as soon as is practical and safe to do so. For the onsite staff to determine the effects of the disaster on the facility they will need to monitor and observe the facility throughout the disaster. This may entail installing instrumentation specific to the natural hazard expected (e.g. wind speed and direction, water level). This onsite Emergency Command Center should be located in a safe location with respect to the potential natural hazards. If there is not such a location readily available, then consider building such a location in advance of any natural hazard event. For example, if the hazard is flooding, it should either be located outside of flood potential areas or it should be elevated sufficiently and adequately provided for the occupants' safety if they are inundated (e.g. boats to access the building, food, hygiene provisions). Also, special provision may be required so that the occupants can see out of the Emergency Command center since normal doors and windows may be inaccessible or blocked. Because of its purpose, the command center may be relatively air tight if not properly ventilated. Special safety precautions should be taken to ensure that the atmosphere is not contaminated by equipment and/or depleted. Consider installing several battery-operated oxygen sensors with low oxygen alarms and organic vapor (LEL) analyzers.

2. **Authority and responsibilities.** The decision should be made, and it should be clearly documented in the NHERP, as to who has the authority to activate the plan, redirect resources, shut down operations and make other key decisions. Responsibilities for each of the activities in the NHERP should be assigned to specific individuals/roles and clearly stated in the NHERP (e.g. testing of equipment, charging of backup batteries, acquiring supplies). Appendix C provides a simplified example of a document listing authority and responsibilities for specific natural hazard response activities and decisions.

3. **Understand hazards.** The NHERP should include the information compiled as described in sections 3, 4, 5, and 6 above so that it is clear what the hazards are, what the specific impact may be on the overall site and specific important equipment and operations on the site. Whereas it might not be appropriate to design equipment to withstand all conceivable situations (e.g. Hurricane Harvey's 1.52-meter (60-inch) rainfall totals (USGS), the NHERP should address all conceivable situations. This should include recognizing that one natural hazard mitigation measure may fail or there may be common cause failures that may disable a number of systems and mitigation measures simultaneously.

**APPENDIX B: EXAMPLE CONTENTS OF A NATURAL HAZARD EMERGENCY RESPONSE PLAN, continued**

4. **Warning systems.** Systems to be used to identify impending natural hazards (e.g. weather predictions, flood warnings) should be identified. The NHERP should include station numbers, radio frequencies, website addresses and other location information. It should also address the provisions for if these systems are lost in the course of a natural disaster, which is often the case.

5. **Activation prompts.** The NHERP may address activities from protecting equipment to evacuating the site as a natural disaster escalates. It is important to determine the prompts (e.g. rainfall amount, river levels, flood warnings) which will be used to initiate predefined actions (e.g. shutting down operations, isolating equipment, or evacuating personnel) and document this in the NHERP. For example, flood defenses may be put in place at the onset of a flood warning, sensitive equipment isolated at a given water level, and the site evacuated at a higher water level. It is also important to recognize the time needed for personnel to perform the activities and take that into account in determining the prompts. It may be helpful to define prompts based on T-minus times, e.g. for a storm in the Gulf, 72 hours to landfall, 48 hours to landfall, etc.

6. **Staffing assignments**. The NHERP should document if there is to be a "ride-out crew" that will remain on-site during a natural disaster or if the entire facility should be evacuated. There should be a valid reason, such as significant risk management, for keeping people on-site. If the facility is to be staffed, by whom should it be staffed and what are the activities they are to perform and when? Identify staff based on the skills needed. For example, is an operator needed or is a board operator for a specific unit that is certified with controls required? Request volunteers with the needed skills; don't assign an unwilling person. Recognize that this team of volunteers may have a different order of command and authority than during normal times. Choose volunteers who understand that potential change and can live with it, working together in isolation for several days. Clearly define staff roles prior to, during, and after the natural disaster. Analyze each task you expect them to perform and establish appropriate safety and health procedures they should follow.

   If the decision is to staff the facility during the natural disaster, primary staff and alternates should be named, trained, and educated as to their assignments, performance expectations, and reporting scheme. Particular attention may be required for the families of those who will staff the facility during this time. For this staff to perform as needed, it is important that they know that their families are safe. Plans must be in place to assure that their families are protected and/or evacuated. And that the company keeps the families up to date on the safety of the ride out crew.

7. **Evacuation plans.** The NHERP should address removing non-required staff and other personnel before the disaster with consideration given to allowing time for these staff to make personal preparations. Emergency evacuation (should the need arise) of those remaining in the facility during or shortly after the disaster may be dependent on local emergency response providers in which case the potential for and method of rescue should be discussed with the local, regional, and national emergency response agencies when developing the NHERP. Consider the need for and availability of vehicles with high road clearance to transport personnel in and out if the roads start flooding but the winds aren't too high.

**APPENDIX B: EXAMPLE CONTENTS OF A NATURAL HAZARD EMERGENCY RESPONSE PLAN, continued**

8. **Interdependency.** Interdependency is the relationship of how your facility depends on and influences other things around it and how those things depend on and influence your facility. Interdependencies should be communicated to any and all agencies and/or organizations that might benefit from that knowledge. A plan for the effective use of interdependencies to facilitate disaster recovery should be developed, shared with, and agreed upon by all affected parties.

   Electrical power is an interdependency example. A manufacturing facility may have a cogeneration facility onsite capable of supplying the power needed to operate the facility. The local commercial power generating company serves as the backup. The manufacturing facility is dependent on the local commercial power generating company for power when its cogeneration system goes down. It also needs power from them to start up the cogeneration system; and, it needs them to take any excess power generated. The local commercial power generating company in turn operate a certain number of generators because they are expecting the manufacturing facility to normally consume a minimal amount of power or even supply some power back into the grid. They are impacted by what happens at the manufacturing facility and vice versa. In other words, they are interdependent.

   The NHERP should include all interdependencies that a facility has. Particular attention should be given to those interdependencies that would play a major role during or after an emergency. Make sure that those who will be making disaster recovery decisions, particularly the regional and national agencies, know about and understand the interdependencies in your area. See Appendix E for an example list of interdependencies.

9. **Utility services.** Identify critical utilities for the safe operation and/or shut down of the facility. This may include means of operating safety critical equipment and means to safely relocate personnel and protect sensitive equipment, chemicals or operations. Ensure that electricity (including on-site transformers and substations), gas, steam, heating, cooling, and water supply systems can withstand the natural disaster or can be safely isolated or switched off before flooding. As the loss of utilities may be for an extended period, consider the installation of backup systems for critical equipment.

   Electrical power supply is likely to be interrupted. Consider interdependencies as this may apply to inbound electrical services and outbound services cogeneration excess electricity. Do not assume that it is lower risk to discontinue all services. Determine what items in the facility must have electrical power to meet the functions described in your NHERP. If the facility is shut down there will be a significant reduction in electrical power needs. Delineate what will need emergency power back up and determine how the onsite emergency electrical supply system should be configured. It may be appropriate to have a few large generators, or several smaller generators may be the best option. Either way, consider holding in reserve a few small generators that use little fuel for servicing critical systems such as your communication systems, ventilations systems, battery chargers, and alarms, in case a primary generator fails. They may be needed if fuel supplies are almost exhausted and/or if large generators fail. Be sure that these smaller generators can easily “plug in” to the critical electrical circuits.

**APPENDIX B: EXAMPLE CONTENTS OF A NATURAL HAZARD EMERGENCY RESPONSE PLAN, continued**

10. **Communication systems and protocols.** Communications before, during, and after an emergency or disaster are essential. Planning your communication strategy is a key ingredient in ensuring its reliability and effectiveness. An Emergency Response Coordination Center should be established as the communication center for managing the natural disaster response. To function effectively, it must have the ability to gather and disseminate information. This facility or system should be located so that it is not directly impacted by the disaster itself. It should be able to communicate in all available modes—land line telephone, Government Emergency Telecommunications Service (GETS), cell phones, satellite telephones, e-mails, CB radios, etc. Since it will function as the hub of most communications, it should have an up to date list of contacts, telephone numbers and e-mails.

    All communications modes should be tested including these communication protocols in table top exercises and drills. This also gives the agencies the opportunity to understand the NHERP plan.

    Conventional communication equipment (e.g. land lines, cell phones) may not work during a natural disaster. Have a plan should communications fail. Consider backup systems such as the following.

    - The United States Government Emergency Telecommunications Service supports federal, state, local, and tribal government, industry, and non- governmental organization personnel in performing their National Security and Emergency Preparedness missions. GETS provides emergency access and priority processing in the local and long-distance segments of the Public Switched Telephone Network when regular telephone service is congested. (DHS)
    - A NOAA Weather radio, with a battery backup can provide warning tones and information in emergency command centers.
    - Increase the chance of connecting with a cell telephone service by subscribing to several different providers.
    - Purchase or rent satellite telephones and a base station. Satellite phones are more complicated to operate than cell phones so train several people in their use. They also require a relatively unobstructed path to the satellite. Plan on using them outdoors or connected to a remote antenna.
    - Internet communication systems: Computer, cell phones, and smart devices may continue to work if the wireless service and the site equipment is not compromised. Having an "emergency use computer" not routed through your company's firewall and spam filters, which may hinder or completely block use during an emergency, may be an option.
    - Citizen Band (CB) Radios: CB's, or shortwave radio, have long been recognized and used as emergency use communication devices. Have a CB base station and an appropriate number of portable units in the emergency command center. CB operators must be licensed and may need training on the equipment. There may be licensed CB operators already working at the facility who would volunteer to staff the equipment in an emergency.
    - Two Way Radios: These will generally allow you to communicate with staff at the plant during the emergency although they may not reach outside the facility. Make sure that your emergency command center has the ability to use it (perhaps add a second base station in the command post) and that extra radios are available. Keep a stock of charged batteries available and put the battery chargers on your emergency power supply.

## APPENDIX B: EXAMPLE CONTENTS OF A NATURAL HAZARD EMERGENCY RESPONSE PLAN, continued

Communication protocols are just as important as communication systems.

- It is important that regional and national Emergency Service Providers be able to communicate with the facility Emergency Response Center and the facility being impacted by the natural disaster (if it is staffed). To facilitate this, establish and agree on communication protocols with each agency and exchange lists of telephone numbers and people to call. Agree on who calls whom and when. Call prompts might be agreed upon periodic (every hour, for instance) updates or when there are significant changes in risks or circumstances.
- Your neighbors will be interested in the facility's status and it may be important to contact them, for example, to evacuate or to shelter in place. Plan in advance when and how to make these communications and develop a back-up plan if normal communication systems are disabled.
- Employees may be displaced by the disaster. Establish a way for them to contact the Emergency Response Coordination Center and for the Center to contact them. An option is to establish a toll-free line to enable personnel to hear messages, leave messages or speak to someone about their status. Another option is creation of an internet address that can send and receive emails. Ensure personnel are aware of and know how to use the system.
- Communication refresher training and education effort should be prompted in advance of the natural disaster. Employees and their families should be given up to date information so that they can take care of themselves and help take care of the facility. It is important that the families of employees who will remain onsite to help are safe and that the employee knows it.
    - Ensure that employees understand that taking care of their families is a first priority and offer assistance if needed. Tell the employees who will remain onsite the contact numbers and methods that are expected to be available for contacting their families and for their families to contact them. Remind each employee of the part they are to play in securing the plant site for the natural disaster and conduct overview/refresher training sessions. If special equipment, such as satellite phones, is to be used, conduct refresher training on where it is, how to access it, and how it is to be used.
    - Ensure that families are informed. Send disaster preparedness pamphlets to each employee's home informing them on how to properly prepare their home for the disaster, gather supplies and plan their evacuation mode and route should they choose to leave the area. Pamphlets are available from the U.S. Department of Homeland Security, FEMA, and other agencies. These publicly available pamphlets should be supplemented with site specific information such as local emergency agencies and contact information. Communicate with families that have special need to ensure their safety. Include Emergency Response Coordination Center contact information so that employees offsite can let the company know where they are and find out what you want them to do. Also include information for families who will have a family member remaining at the site to contact the company for information about the site and their family member.

**APPENDIX B: EXAMPLE CONTENTS OF A NATURAL HAZARD EMERGENCY RESPONSE PLAN, continued**

11. **Protection of business-critical equipment and data.** The NHERP should address the protection of this data. Data protection falls in to two broad categories—onsite or offsite. Onsite data protection requires the recognition of the difference between volatile data and fixed data. Volatile data requires continuous power if it is to be retained whereas fixed data does not (e.g. data saved to a hard drive). In a distributive computer control system (DCS), some of the data may be volatile and should be protected via emergency power supply—even when the system is not functionally controlling the facility. Each facility should analyze where their critical data resides, what type of memory contains it and then establish secure systems to protect that data during all type of service interruptions. Make copies of and securing Distributive Control Systems (DCS) and other critical computer systems configuration data just in case memory and all power, including emergency and battery power, fails.

    Some data may already reside offsite having been transferred via the internet, the cloud or other physical or electronic transfer modes. This data may inherently be protected from local natural disasters simply because of its remoteness and redundancy. Other onsite data can be collected and sent offsite to secure locations via those same routes or simply by making electronic copies and sending via a variety of modes. Plan what data needs to be monitored during the natural disaster and how that data is to be preserved, accessed, or transferred. Develop a protection scheme, and then put that scheme into action prior to the onset of the natural disaster. Also consider data stored in physical or paper form and its storage location to prevent potential damage or loss.

    Key data that could be needed during or after the emergency includes RMP plan, dispersion models, electrical drawings, P&IDs, inventory levels, etc. The NHERP should consider providing any hard copies at the emergency command center so that they can be accessed by the ride out crew. Ideally the data should be digitalized so that it can be accessed by experts offsite for support or in the event that the site has to be evacuated.

12. **Inventory.** A key activity in emergency response is the handling of flammable and toxic inventories. The decision process should consider the risks associated with leaving the inventories (feed stocks/raw materials, in-process materials, and finished goods) at normal levels verses decreasing them.

    For example, a tank containing a flammable liquid could suffer a loss of containment and pollute waterways. Removing the inventory from the tank and leaving the empty tank could result in the tank floating away or suffering wind damage. Inventories can be managed (typically at a height equal to the dike wall) such that the tank will not float in flood waters. Another option may be to fill the tank with water (where the chemical is compatible with water) to prevent float off. In this case, preparing the chemicals in the tank (with latent water) for use after the natural disaster should be considered. An inventory plan should be made for each vessel of concern. It may be possible to move some inventories off site. This may require appropriately license drivers and identification of an appropriate temporary site. These plans should be enacted during the early stages of preparing for the disaster, for example, before a hurricane makes landfall.

    Also consider the inventory stored offsite at tollers warehouses, and terminals and how to protect that inventory.

**APPENDIX B: EXAMPLE CONTENTS OF A NATURAL HAZARD EMERGENCY RESPONSE PLAN, continued**

13. **Access and security.** It is important to ensure the site (including onsite and offsite employees and non-employees, facilities, chemicals, equipment, etc.) are properly protected from intruders (e.g. unwanted visitors, observers, the media) while being accessible to key employees and other specialists before and after the disaster. Contact local, regional, and national authorities to understand who may need access to the site during a natural disaster, who will be controlling access to the impacted areas, what roads will be used for emergency travel, and what credentials will be needed to travel those roads. Make sure that the right people have the right credentials by having the issuing authorities validate them. Employees remaining at the site should be aware of who may be coming into the site during or after the natural disaster as they may be called to provide access.

    Area access may be restricted before the disaster hits. Develop a plan for emergency access credentials for employees who will be coming in to staff the plant during the emergency. Do not count on employees being able to get in just because the disaster had not yet occurred. Local emergency officials may have already closed roads to all travelers without appropriate credentials.

    Determine if special passes are required for ride-out crews (or first returning recovery crews) to be allowed past checkpoints or road blocks implemented by local authorities. Ensure this is part of engagement with community authorities.

    Include the use of emergency access and credentials in drills to train your employees to bring them and to “condition” authorities to expect requests for entry using these documents.

    The media has the right to document and report on the news. They do not have the right to come onto private or company property without permission or to endanger others and/or the safety and security of your facility or the chemicals onsite. If they request access before this, explain that safety checks are not yet complete and, therefore, no visitors are allowed in yet. Also tell them that access to the site can be granted only by senior management located in the offsite command center. If already on the property, escort them off the property being polite but firm. Again, explain and emphasize that safety checks are not yet complete and, therefore, no visitors are allowed in yet. As it is likely that these interactions will be recorded, it is best if staff trained in media relations handle these interactions. It may be appropriate to train the ride out crew leaders in media relations.

    If looters and scavengers enter the site, ask them to leave. Have the Emergency Response Command Center notify law enforcement. If safe to do so, take their picture for law enforcement follow-up, but do not try to apprehend them yourself. Personnel safety may be jeopardized by apprehending them without proper training and experience.

14. **Safety.** Safety of personnel is vital. Require all onsite personnel to have first aid training. The importance of safety during the event should be emphasized as seemingly heroic actions can lead to unnecessary risks and injuries.

**APPENDIX B: EXAMPLE CONTENTS OF A NATURAL HAZARD EMERGENCY RESPONSE PLAN, continued**

It may be appropriate to modify or create new safety procedures for during and immediately after the natural disaster. This is not a lessening of safety, but rather an adaptation to the special circumstances. Recognize that there will be pressure to quickly approve MOCs necessitated by plant damage, unusual equipment configuration, and/or the rush to return to normalcy. Changes must be reviewed thoroughly and with special attention to hidden consequences. PSSRs must be done with critical diligence since there may be many potential anomalies and hidden hazards. Make arrangements for potentially not having the usual personnel available for checking and authorizing certain safety procedures, such as MOCs or lock outs. To manage this risk, ensure that those who will be involved in authorizing safety permits have the proper training and experience to do so and that they fully understand their role and responsibilities. Use the management of change procedure to uncover any unrecognized unwanted consequences of modified safety procedures.

15. **Supplies and logistics.** Having materials located where they are safe but can be accessed quickly is a key component of planning that minimizes ongoing damage and facilitates recovery faster after a disaster. The two broad groups to be considered are 1) disaster and recovery: assistance, materials and supplies, and 2) manufacturing materials: raw materials and products. Identify what supplies will be needed, where they will be stored and how they will be accessed. This includes supplies for operations and personnel on-site. As power and internet may be down, use of credit and debit cards may be challenging. Remember to have cash available. Make arrangements with the local, regional, and national agencies that will control access to the disaster area so that your people and materials will be allowed into the impacted area when needed. An example list of supplies is provided in Appendix E.

    - Disaster and Recovery: People with specialized skills and expertise may be needed during or immediately after an emergency to minimize safety hazards and address onsite or offsite damage. Identify these experts in advance, advise them of the potential need, and include their contact information in the NHERP for use by the Emergency Response Coordination Center.

    - Materials and supplies (such as food, water, clothing, shelter, first aid, repair materials, extra communication equipment, etc.) should be staged and stored in a secure area. Materials for use during the event should be accessible to those needing it. Materials for use in the recover should be stored in a location not expected to be impacted by the disaster, but readily available to replenish exhausted or damaged onsite supplies. Have a delivery system predesigned and ready to respond as the need arises and flexible enough to gather additional items if not already stocked.

    - Manufacturing Materials: The section on inventory addressed storage of feed stocks and finished products onsite or offsite. Using this information, develop a staging plan, if one is needed, for feed stocks/raw materials and finished goods. Check with suppliers to confirm that they can delay/hold/store materials at their unimpacted sites. Make informed risk-based decisions regarding offsite storage/staging of materials. Make arrangements well in advance of any need (e.g. at the beginning of the hurricane season) with suppliers, customers, and owner/operators of potential storage locations for use prior, during and after a natural disaster. Consider the ability to transport product through via roads, docks, and pipelines where damage may have occurred to the infrastructure.

**APPENDIX B: EXAMPLE CONTENTS OF A NATURAL HAZARD EMERGENCY RESPONSE PLAN, continued**

16. **Equipment checks**. Equipment should be checked to make sure it is in good working order. Checks may include refreshing battery packs and testing equipment that is not in routine use. Checks could be scheduled, for example, two weeks before the beginning of the monsoon season in south Asia, one month before the official start of the hurricane season in the US Gulf coast and Atlantic coast, and two times a year for earthquake prone regions.

17. **NHERP maintenance, quality assessment, and quality control.** The NHERP should be kept up to date, accurate, and appropriate for the types of natural hazards identified. This includes periodic review, training, drills and after-action critiques plus "Lessons Learned" from others. It is critical that the drills are conducted on a routine basis on a frequency and schedule appropriate for the facility. When conducted seriously they act as refresher – both for personnel and equipment. New additions to the team will witness the full details first hand and past participants will be able to refresh their roles and also be able to identify areas of improvements. Make your drills as realistic and comprehensive as possible. Ensure that everyone has the opportunity to ask questions relative to their roles and expected actions. Of particular importance to validate/test during the drill are communications effectiveness, whether the participants knew when and what actions to take, were actions taken safety, and was access and security managed to plan. If it is impossible or impractical to conduct a full involvement drill, start to finish, consider conducting staged or topic drills. For instance, focus the drill on the period of time before, during, or after the natural disaster or focus the drill on communications or access and security. Drills are good training and usually generate improvement suggestions. It is important to involve resources external to the site in the drills. Update the NHERP as needed. Redistribute the updated plan and conduct training if needed per updated plan.

**APPENDIX C: EXAMPLE LIST OF AUTHORITY AND RESPONSIILITIES FOR NATURAL HAZARD EMERGENCY RESPONSE**

This is an example. Each site should develop their own list specific for their hazards, organization and needs. For many rainfall and tropical cyclone events, there may be knowledge of the impending event days in advance. The "when" column below envisions these instances. In some cases, however, the storm system develops quickly, and it may be necessary to compress this timeline into fewer days, even hours.

| Action/Decision | Made By | Whe | Tasks |
|---|---|---|---|
| Activate the Natural Hazards Emergency Response Plan | Plant Manager | First warning of event | As described in the plan |
| Accommodations for response and recovery staff | Human Resources | First warning of event | Secure accommodations |
| Supplies and logistics | Purchasing | First warning of | Formal alert notification to suppliers and customers to gather/store response and recovery supplies |
| Manage facility chemical storage inventories | Production Manager | 1 week before event | Initiate storage tank de-inventory plan<br>Close watertight doors and windows<br>Relocate sensitive chemicals to higher ground or temporary storage location |
| Manage facility tankage inventory | Production Manager | 1 week before event | Survey all empty tankage and add tie-down security if needed<br>Decide to leave empty or fill with water / other liquids |
| Manage interdependencies | Production Manager | 1 week before event | Notify agencies and interdependent companies<br>Review interdependencies with each and protocol for activation |
| Increase storm water capacity | Tankage/ Utility Area Managers | 1 week before event | Align drainage systems, empty retention ponds.<br>Verify drainage systems are free of dirt and vegetation. |
| Cogeneration shut down | Plant Manager | 3 days before event | Notify commercial utility company<br>Initiate cogeneration total shutdown |
| Activate and staff Emergency Response Command Center(s) | Plant Manager | 3 days before event | Initiate Natural Hazard Emergency Response Plan<br>Notify personnel |
| Shut down process facility | Plant Manager | 3 days before event | Initiate total shutdown<br>Notify personnel<br>Defer shipment of raw materials |
| Electrical power | Utilities Manager | 1 day before event | Shut down and isolate potentially exposed electrical equipment |

## APPENDIX D: EXAMPLE ACTIVITY LIST FOR BEFORE, DURING, AND AFTER THE NATURAL HAZARD EVENT

1. **Shortly before the natural hazard event**

   Prepare the facility and ensure it is as ready as possible for the natural hazard expected. Potential activities include the following.

   - Inspect the Emergency Command Center and ensure all equipment is working and that there is proper ventilation and access/egress.
   - Check supplies, including food and water for the ride-out crew, and confirm that they are accessible. Address any shortfalls quickly. See Appendix E for suggested supply lists.
   - Conduct last minute tests of backup systems.
   - Secure the facility. Look for anything that will impose a hazard in high winds or rising water. Review housekeeping. Identify items that might become missiles in high winds and remove, store them, or tie them down. Look for any chemicals stored in drums or buckets and store them in a secure location to prevent spillage. Remove unnecessary vehicles from roads, empty truck beds of loose items, pick up loose tools, materials, signs, etc.
   - Enact the inventory plans.
   - Test and confirm adequacy of all modes of communication. Confirm two-way radios, cell phones and satellite phones work, are charged, and charged backup batteries are available.
   - Bring storm equipment onsite, including boats or other means to move materials.
   - Stage flood equipment, such as pumps, hoses, and sandbags.
   - Fill fuel tanks for backup generators.
   - Dismiss non-required personnel leaving only those employees designated to remain onsite during the event. Activate the access and security controls.
   - Review storm scenarios and actions with members of the ride-out crew.
   - Reduce the level in waste water treatment equipment in preparation for the heavy rain.
   - Fill waste disposal containers (e.g. dumpster, skip) with water to prevent them from floating or remove them to an offsite location.
   - Dismantle and remove any tents.
   - Anchor temporary buildings, container boxes (conex), etc.

2. **During the natural hazard event**

   During the natural hazard event, the NHERP should be used to direct activities. Main activities during this time period include the following.

   - Ensure personnel safety and monitor personnel location at all times.
   - Monitor and record the disaster's effect on the facility. Observe and understand what damage is being done, the effect on the facility safety and security, and any potential offsite impacts.
   - Abate damages, spills, releases and unsafe and/or environmentally damaging conditions if able to do so without endangering personnel
   - Periodically communicate conditions to the offsite Emergency Response Command Center along with requests for assistance, if needed, advance notice of repairs and repair personnel needed after the disaster, and potential offsite damages due to debris and/or loss of containment of chemicals.
   - Notify the offsite Emergency Command Center of any damages affecting security systems so they can make plans for repairs as soon as circumstances allow this to be done safely. If complete repairs are not possible in the short term, consider temporary repairs and/or alternate arrangements.

**APPENDIX D: EXAMPLE ACTIVITY LIST FOR BEFORE, DURING, AND AFTER THE NATURAL HAZARD EVENT, continued**

**3. After the natural hazard event**

Immediately after the disaster there will be a strong desire to get outside to assess the damages. Resist that urge until it is assured that the danger has passed, and it is safe to venture outside of the Emergency Response Command Center. Use the appropriate personal protective equipment (PPE) (e.g. dielectric boots, rubber gloves) when venturing outside until monitoring proves it is safe. Communicate personnel status to the offsite Emergency Response Command Center and let them know that you are going outside. Consider sending a small team out first to validate that the site is safe. Then follow up with more people in small groups, keeping the groups separate from each other so that each can function as a rescue team for the other. Always keep at least one person in the Emergency Response Command Center. All teams should carry portable communication equipment and stay in touch with the other teams and the Emergency Response Command Center. Survey the site for the following potential hazards.

- Chemical releases. Care should be taken because some caustic chemicals and some acids look like water. Some float on top of the water and some are heavier than water so the water floats on them.
- Damage to electrical equipment. Beware of electrocution hazards, especially when the power is on and flood waters are present. If the electrical power is off, electrical hazards may not be apparent until the power is turned back on. If the power to the site was lost, isolate the main circuit breakers to enable power to be restored in a controlled manner. Resurvey for electrical hazards after the power has been restored.
- Physical damage. These are often observable, but some can be hidden. Take special care when walking under equipment or structures as they may be damaged or have debris on them that could fall off. Be aware of sharp and jagged edges, broken glass, tripping and slipping hazards. Categorize damages by those that can be addressed with resources currently onsite and those that will require additional resources. Drones may be helpful in surveying damage and will require a pilot to be available for their operation. Communicate needs to the offsite Emergency Command Center so that they can send people and equipment to the site with appropriate expertise. If possible, take pictures to document the damages as they are before remediation. Do not make repairs and/or modifications without analyzing the consequences of actions and inactions using the MOC process.
- Wildlife. As they try to escape from the hazard, they may find refuge in the facility. Depending on where the facility location, this may include insects, fire ants, raccoons, snakes, and alligators. Specialist assistance may be to rescue some wildlife safely.
- Releases to air and water. Monitor the air and water and collect samples for environmental reference. Report any losses to authorities as required.
- Site security issues. Any issues caused by media attempting to gain access. Uninvited visitors including scavengers, looters, curious citizens, terrorists, opportunists, or people who are lost or injured.
- Fence damage. Since a fence around the facility is a basic form of security, have it repaired as soon as possible.
- Deceased. On a somber note, locate any human and animal bodies and enact plans to remove them as soon as possible. Be cautious as corpses may be laden with pollutants, insects, disease, and animals.

**APPENDIX E: EXAMPLE LIST OF INTERDEPENDECIES**

This is an example list of interdependencies. Each facility should develop its own list specific for the facility.

| Interdependency | With Whom | Contact / Phone No. | Notes |
|---|---|---|---|
| Electric power | Local Commercial Power Supply | | Need electrical power from local supplier to start cogeneration unit running. After startup, facility can supply electrical power back in to public grid. |
| Steam and Fuel | Local Gas Company | | If facility steam boilers and facility cogeneration plant are running, facility can supply steam to ABC who, in turn, can supplement facility fuel supply by sending facility the off-gas from their steam heaters. |
| Nitrogen | Local Inert Gas Supplier | | Needed for purging prior to recommissioning of equipment |
| Communications | Local Telecoms Company | | Facility supplies power to local telecoms company and they operate facility communications systems |
| Firefighting emergency response and mutual aid | Local Fire Department | | Local Fire Emergency Response Company supplies mobile firefighting equipment and personnel. Facility supplies the fire truck and personnel. |
| Waste water treatment | Next door Operating Plant and Municipal Sewage Treatment Plant | | Site receives waste water from Next Door Operating Plant. Facility in turn, send facility's discharge to the Municipal Sewage Treatment Plant. |

## APPENDIX F: EXAMPLE LIST OF SUPPLIES

This is an example list of supplies for those remaining onsite. It does not include quantities. Each facility should develop its own list and quantities specific for the expected needs.

### Medical and First Aid Supplies

| Item | Quantity | Item | Quantity |
|---|---|---|---|
| Prescription medication | 2 weeks | Antacids | |
| Blood pressure kit | | Anti-diarrhea medication | |
| Automatic External Defibrillator (AED) | | Anti-nausea medication | |
| Glucometer for monitoring blood sugar | | Laxative | |
| CPR breathing barrier | | Cold medicine | |
| Burn blanket | | Cough medicine | |
| EpiPen | | Toothache medication | |
| Snake bite kit | | Aspirin | |
| Scissors | | Non-aspirin pain relievers | |
| Tweezers | | Antibiotics – topical & oral | |
| Knife | | Antihistamine | |
| Magnifying glass | | Antiseptic ointment | |
| Small Mirror | | Insect bite ointment | |
| Small flashlight | | Hydrogen peroxide | |
| Needle | | Rubbing alcohol | |
| Thermometer | | Iodine | |
| Tongue depressors | | Petroleum jelly | |
| Medical grade non-latex gloves | | Gauze | |
| Cold pack | | Cotton pads | |
| Adhesive tape | | Cotton swabs | |
| Salve for wounds | | Bandages | |
| Eye wash and eye wash cup | | Feminine hygiene supplies | |
| Eye drops | | Contact lens supplies | |
| Eye patches | | Mouthwash | |
| Nail clippers | | Insect repellant | |
| Nail file | | Suntan lotion | |
| Safety pins | | Disinfectant soap | |
| | | Hand sanitizer | |

**APPENDIX F: EXAMPLE LIST OF SUGGESTED SUPPLIES – continued**

**Food Supplies**

| Item | Quantity | Item | Quantity |
|---|---|---|---|
| Salt | | | |
| Pepper | | Ice | |
| Cooking oil | | Bottled sports drinks | |
| Flour | | Fruit juices | |
| Sugar | | Soft drinks | |
| Eggs | | Coffee | |
| Bread | | Tea | |
| Rice | | Milk | |
| Seasonings | | Milk that does not require refrigeration | |
| Peanut butter | | High-energy bars | |
| Jelly | | Crackers | |
| Ramen Noodles | | Cookies | |
| Canned soups | | Cereal | |
| Canned vegetables | | Chips | |
| Canned beans | | Nuts | |
| Canned Chili | | Cooking utensils | |
| Spaghetti sauce | | Multivitamins | |
| Spaghetti/pasta | | Paper plates and plastic utensils | |
| Hot dogs | | Plastic wrap | |
| Hamburger meat | | Aluminum foil | |
| Packaged sliced meats | | Zip lock type bags in varying sizes | |
| Macaroni & Cheese kits | | Paper towels | |
| Ready-to-eat canned meals, meats, fruits, and vegetables | | Pots and pans | |
| Fresh fruit—Apples, oranges, grapes, bananas, pears, etc. | | Can opener—non-electric | |
| Dried fruit—raisins, plums, prunes, etc. | | Bottled water - 2 gallons / person per day | |
| Canned fruit and sauces—applesauce, etc. | | | |

Note: Keep in mind any dietary restrictions or food allergies of the onsite staff.

**APPENDIX F: EXAMPLE LIST OF SUGGESTED SUPPLIES – continued**

**Clothing and Personal Effects:**

| Item | Quantity | Item | Quantity |
|---|---|---|---|
| Combs | | Men's shirts | |
| Toothbrushes | | Men's jeans/slacks | |
| Toothpaste | | Men's underwear | |
| Mouthwash | | Women's shirts | |
| Deodorant | | Women's jeans/slacks | |
| Disposable razors | | Women's underwear | |
| Shaving soap or cream | | Women's sports bras | |
| Tissues | | Tee shirts | |
| Shampoo | | Socks | |
| Soap | | Raincoats | |
| Sanitizing soap | | Gloves | |
| Lotion | | Dielectric gloves | |
| Towels | | Boots | |
| Washcloths | | Dielectric boots | |
| Pre-moistened | | Sleeping bags | |
| Toilet paper | | Pillow | |
| Reading glasses, varying strengths | | Cots | |
| | | Blankets | |
| | | Sheets | |

**APPENDIX F: EXAMPLE LIST OF SUGGESTED SUPPLIES – continued**

**Tools and Supplies:**

| Item | Quantity | Item | Quantity |
|---|---|---|---|
| Chain saw and fuel | | Fire extinguishers | |
| Hand saw | | Flashlights | |
| Mechanics box of tools | | Battery operated radio | |
| Hammers and nails | | Battery operated fans | |
| Heavy duty Staplers | | Batteries in all voltages | |
| Plywood and nails for boarding up | | Two-way radio batteries | |
| Tarps | | Cell phone batteries and chargers | |
| Plastic sheets | | Candles | |
| Rope | | Lanterns | |
| Duct tape | | Brooms | |
| Adhesive tape | | Mops & buckets | |
| Lubricant (e.g. WD-40) | | Squeegee | |
| Oil absorbents | | Rags | |
| Tire repair materials | | Plastic garbage bags | |
| Spare tires | | Large leaf bags | |
| Electrical contact cleaner spray | | Burlap Bags | |
| Insect killer—bees, wasps, etc. | | Thermos bottles | |
| Lighters and matches | | Cash—coins and currency | |
| Gasoline tanks in vehicles | | Charcoal | |
| Propane stoves | | Charcoal lighter fluid | |
| Small propane tanks--full | | Water (for flushing toilet, | |
| Cooler filled with ice until needed | | | |

## APPENDIX G: EXPLANATION OF TERMS

The **Beaufort wind scale** is a system used to estimate and report wind speeds when no measuring apparatus is available. It was invented in the early 19th Century by Admiral Sir Francis Beaufort of the British Navy as a way to interpret winds from conditions at sea. Since that time, the scale has been modernized for effects on land. (Weather 2019)

Table G.1 Beaufort Wind Scale (adapted from Weather 2019a)

| Force | Speed | | Description | Specifications for use at sea |
|---|---|---|---|---|
| | kph (mph) | knots | | Specifications for use on land |
| 0 | 0-1.6 (0-1) | 0-1 | Calm | Sea like a mirror. |
| | | | | Calm; smoke rises vertically. |
| 1 | 1.6-4.8 (1-3) | 1-3 | Light Air | Ripples with the appearance of scales are formed, but without foam crests. |
| | | | | Direction of wind shown by smoke drift, but not by wind vanes. |
| 2 | 6.4-11.3 (4-7) | 4-6 | Light Breeze | Small wavelets, still short, but more pronounced. Crests have a glassy appearance and do not break. |
| | | | | Wind felt on face; leaves rustle; ordinary vanes moved by wind. |
| 3 | 12.9-19.3 (8-12) | 7-10 | Gentle Breeze | Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses. |
| | | | | Leaves and small twigs in constant motion; wind extends light flag. |
| 4 | 20.9-29.0 (13-18) | 11-16 | Moderate Breeze | Small waves, becoming larger; fairly frequent white horses. |
| | | | | Raises dust and loose paper; small branches are moved. |
| 5 | 30.6-38.6 (19-24) | 17-21 | Fresh Breeze | Moderate waves, taking a more pronounced long form; many white horses are formed. |
| | | | | Small trees in leaf begin to sway; crested wavelets form on inland waters. |
| 6 | 40.2-49.9 (25-31) | 22-27 | Strong Breeze | Large waves begin to form; the white foam crests are more extensive everywhere. |
| | | | | Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty. |
| 7 | 51.5-61.2 (32-38) | 28-33 | Near Gale | Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind. |
| | | | | Whole trees in motion; inconvenience felt when walking against the wind. |
| 8 | 62.8-74.0 (39-46) | 34-40 | Gale | Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind. |
| | | | | Breaks twigs off trees; generally impedes progress. |

| Force | Speed kph (mph) | Speed knots | Description | Specifications for use at sea / Specifications for use on land |
|---|---|---|---|---|
| 9 | 75.6-86.9 (47-54) | 41-47 | Severe Gale | High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility |
| | | | | Slight structural damage occurs (chimney-pots and slates removed) |
| 10 | 88.5-101.4 (55-63) | 48-55 | Storm | Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes on a white appearance. The tumbling of the sea becomes heavy and shock-like. Visibility affected. |
| | | | | Seldom experienced inland; trees uprooted; considerable structural damage occurs. |
| 11 | 103-115.9 (64-72) | 56-63 | Violent Storm | Exceptionally high waves (small and medium-size ships might be for a time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected. |
| | | | | Very rarely experienced; accompanied by wide-spread damage. |
| 12 | 115.9-133.6 (72-83) | 64-71 | Hurricane | The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected. |
| | | | | see Saffir-Simpson Hurricane Wind Scale |

The **Fujita Tornado Damage Scale** categorizes a tornado based on estimated wind speed. It is no longer used in the U.S. (SPC 2019)

Table G.2 Fujita Tornado Damage Scale (adapted from SPC 2019)

| Scale | Wind Estimate kph(mph) | Typical Damage |
|---|---|---|
| F0 | < 117.5 (73) | Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged. |
| F1 | 117.5-180.2 (73-112) | Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads. |
| F2 | 181.9-252.7 (113-157) | Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground. |
| F3 | 254.3-331.5 (158-206) | Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown. |

| Scale | Wind Estimate kph(mph) | Typical Damage |
|---|---|---|
| F4 | 333.1-418.8 (207-260) | Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated. |
| F5 | 420.0-511.8 ((261-318) | Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yds); trees debarked; incredible phenomena will occur. |

An update to the original F-scale by a team of meteorologists and wind engineers, implemented in the U.S. on 1 February 2007. The **Enhanced F-scale** still is a set of wind estimates (not measurements) based on damage. Its uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to the 28 indicators listed below. These estimates vary with height and exposure. Important: The 3-second gust is not the same wind as in standard surface observations. Standard measurements are taken by weather stations in open exposures, using a directly measured, "one-minute mile" speed. (SPC 2019)

Table G.3 Enhanced Fujita Tornado Damage Scale (adapted from SPC 2019)

| Fujita Scale | | | Derived EF Scale | | Operational EF Scale | |
|---|---|---|---|---|---|---|
| F Number | Fastest 1/4-mile kph (mph) | 3 Second Gust kph (mph) | EF Number | 3 Second Gust kph (mph) | EF Number | 3 Second Gust kph (mph) |
| 0 | 64-115 (40-72) | 72-126 (45-78) | 0 | 104-137 (65-85) | 0 | 104-137 (65-85) |
| 1 | 117-180 (73-112) | 127-188 (79-117) | 1 | 138-175 (86-109) | 1 | 138-177 (86-110) |
| 2 | 181-253 (113-157) | 189-259 (118-161) | 2 | 177-220 (110-137) | 2 | 178-217 (111-135) |
| 3 | 254-333 (158-207) | 260-336 (162-209) | 3 | 222-268 (138-167) | 3 | 218-265 (136-165) |
| 4 | 334-418 (208-260) | 338-420 (210-261) | 4 | 270-320 (168-199) | 4 | 267-321 (166-200) |
| 5 | 420-512 (261-318) | 421-510 (262-317) | 5 | 321-377 (200-234) | 5 | Over 321 (Over 200) |

**Severe Storms** (NOAA 2019b)

**Thunderstorms** — rain storms with lightning — can be dangerous by themselves and can cause destructive, deadly flooding. When they contain strong winds, hail and tornadoes they can turn violent. NOAA classifies a storm as "severe" when it produces wind gusts of at least 93 kph (58 mph) and/or hail one inch in diameter (about the size of a US coin quarter) or larger and/or a tornado.

**Lightning** is caused by the attraction between positive and negative charges in the atmosphere, resulting in the buildup and discharge of electrical energy. This rapid heating and cooling of the air produces the shock wave that results in thunder.

Strong winds are often called **"straight-line" winds** to differentiate the damage they cause from tornado damage. Most thunderstorm winds that cause damage at the ground are a result of outflow generated by a thunderstorm downdraft.

**Hail** is a form of precipitation that occurs when updrafts in thunderstorms carry raindrops upward into extremely cold areas of the atmosphere where they can freeze into balls of ice. Hailstones can grow to several inches in diameter and may fall at speeds greater than 100 mph.

A **tornado** is a narrow, violently rotating column of air that extends from the base of a thunderstorm to the ground. About 1,200 tornadoes occur in the U.S. annually. The most destructive and deadly tornadoes come from rotating thunderstorms called supercells and can have winds estimated at more than 200 mph.

**Flooding** is an overflowing of water onto land that is normally dry. Floods can happen during heavy rains, when ocean waves come on shore, when snow melts too fast, or when dams or levees break. It is a threat all over the United States and occurs nearly every day.

A **100-year storm** refers to rainfall events that have a one percent probability of occurring at that location in that year. Encountering a "100-year storm" on one day does not decrease the chance of a second 100-year storm occurring in that same year or any year to follow. In other words, there is a 1 in 100 or 1% chance that a storm will reach this intensity in any given year. Likewise, a 50-year rainfall event has a 1 in 50 or 2% chance of occurring in a year. (NRCS 2019)

The term **100-year flood** is used in an attempt to simplify the definition of a flood that statistically has a 1-percent chance of occurring in any given year. The actual number of years between floods of any given size can vary because the climate naturally varies over time. Large floods or rain events can occur in successive or nearly successive years. It should be noted that not every 100-year rainfall event leads to a 100-year flood. (NRCS 2019)

A 100-year storm does not always cause a 100-year flood. This relationship is influenced by the extent of rainfall in the watershed, the soil saturation before the storm, and the size of the watershed and stream basin. Consequently a 100-year flood may not, and a smaller storm may, cause a 100-year flood. (USGS 2019)

FEMA identifies flood hazard areas on the **Flood Insurance Rate Map** (FIRM) as a Special Flood Hazard Area (SFHA). SFHA are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. Moderate flood hazard areas, labeled Zone B or Zone X (shaded) are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood. The areas of minimal flood hazard, which are the areas outside the SFHA and higher than the elevation of the 0.2-percent-annual-chance flood, are labeled Zone C or Zone X (unshaded). (FEMA 2019a)

Flood hazards are dynamic and can change frequently because of a variety of factors, including weather patterns, erosion, and new development. FEMA, through the Risk MAP program, works with communities to collect new or updated flood hazard data and periodically updates flood maps to reflect these changes. (FEMA 2019b)

The **Modified Mercalli (MM) Intensity Scale** assigns a value to an earthquake intensity that ranges from imperceptible shaking to catastrophic destruction. It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects. The Modified Mercalli Intensity value assigned to a specific site after an earthquake has a more meaningful measure of severity to the nonscientist than the magnitude because intensity refers to the effects actually experienced at that place. The lower numbers of the intensity scale generally deal with the manner in which the earthquake is felt by people. The higher numbers of the scale are based on observed structural damage. Structural engineers usually contribute information for assigning intensity values of VIII or above. The following is an abbreviated description of the levels of Modified Mercalli intensity. (USGS 2019b)

Table G.4 Modified Mercalli Intensity Scale (USGS 2019b)

| Intensity | Shaking | Description/Damage |
|---|---|---|
| I | Not felt | Not felt except by a very few under especially favorable conditions. |
| II | Weak | Felt only by a few persons at rest, especially on upper floors of buildings. |
| III | Weak | Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated. |
| IV | Light | Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. |
| V | Moderate | Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop. |
| VI | Strong | Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. |
| VII | Very strong | Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. |
| VIII | Severe | Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. |
| IX | Violent | Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. |
| X | Extreme | Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. |

A **monograph** is a learned treatise on a small area of learning; a written account of a single thing. (MS 2019)

The **Richter magnitude scale** is a mathematical device to compare the size of **earthquakes**. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. Adjustments are included for the variation in the distance between the various seismographs and the epicenter of the earthquakes. On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value. (USGS 2019c)

The **Saffir-Simpson Hurricane Wind Scale** (SSHWS) is a 1 to 5 rating based on a hurricane's sustained wind speed. This scale estimates potential property damage. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and damage. Category 1 and 2 storms are still dangerous, however, and require preventative measures. In the western North Pacific, the term "super typhoon" is used for tropical cyclones with sustained winds exceeding 241 kph (150 mph). (NOAA 2019d)

Table G.5 Saffir-Simpson Hurricane Wind Scale (adapted from NOAA 2019d)

| Category | Sustained Winds | Types of Damage Due to Hurricane Winds |
|---|---|---|
| 1 | 119-153 kph<br>64-82 kt<br>74-95 mph | Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap, and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days. |
| 2 | 154-177 kph<br>83-95 kt<br>96-110 mph | Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks. |
| 3<br>(major) | 178-208 kph<br>96-112 kt<br>111-129 mph | Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes. |
| 4<br>(major) | 209-251 kph 113-136 kt<br>130-156 mph | Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted, and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months. |

| | | |
|---|---|---|
| 5<br>(major) | 252 kph or higher<br>137 kt or higher<br>157 mph or higher | Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months. |

A **storm surge** is the abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide. The surge is caused primarily by a storm's winds pushing water onshore. The amplitude of the storm surge at any given location depends on the orientation of the coast line with the storm track; the intensity, size, and speed of the storm; and the local bathymetry. (NOAA 2019e)

Storm surge maps are available that show potential storm surge levels of less than 0.9 m (3 ft), greater than 0.9 m (3 ft), greater than 1.8 m (6 ft), greater than 2.7 m (9 ft), and a leveed area. (NOAA 2019 a)

A **storm tide** is the total observed seawater level during a storm, resulting from the combination of storm surge and the astronomical tide. Astronomical tides are caused by the gravitational pull of the sun and the moon and have their greatest effects on seawater level during new and full moons—when the sun, the moon, and the Earth are in alignment. As a result, the highest storm tides are often observed during storms that coincide with a new or full moon. (NOAA 2019e)

A **subtropical storm** is **a subtropical cyclone** in which the maximum sustained surface wind speed (using the U.S. 1-minute average) is 63 kph (34 kt or 39 mph) or more. (NOAA 2019f)

A **cyclone** is an atmospheric closed circulation rotating counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. https://www.nhc.noaa.gov/aboutgloss.shtml

A **tropical cyclone** is a rotating low-pressure weather system that has organized thunderstorms but no fronts (a boundary separating two air masses of different densities). Tropical cyclones with maximum sustained surface winds of less than 62.7 kph (39 mph) are called **tropical depressions**. Those with maximum sustained winds of 62.7 kph (39 mph) or higher are called **tropical storms**. (NOAA 2019d)

A **hurricane** or **typhoon** is a **tropical storm** with maximum sustained winds of 119 kph (74 mph) or greater. The Saffir-Simpson Hurricane Wind Scale is used to categorize hurricanes. The SSHWS does not account for rain or storm surge – only wind. (NOAA 2019c) The term hurricane is used for Northern Hemisphere tropical cyclones east of the International Dateline to the Greenwich Meridian. The term typhoon is used for Pacific tropical cyclones north of the Equator west of the International Dateline. (NOAA 2019f)

**Tsunamis** are giant waves caused by earthquakes or volcanic eruptions under the sea. Out in the depths of the ocean, tsunami waves do not dramatically increase in height. But as the waves travel inland, they build up to higher and higher heights as the depth of the ocean decreases. The speed of tsunami waves depends on ocean depth rather than the distance from the source of the wave. Tsunami waves may travel as fast as jet planes over deep waters, only slowing down when reaching shallow waters. (NOAA 2019g)

**APPENDIX H: ACRONYMS**

| | |
|---|---|
| CCPS | Center for Chemical Process Safety |
| AIChE | American Institute of Chemical Engineers |
| CSB | U.S. Chemical Safety and Hazard Investigation Board |
| FEMA | Federal Emergency Management Agency |
| USGS | United States Geographic Survey |
| ASCE | American Society of Civil Engineers |
| NOAA | National Oceanic and Atmospheric Administration |
| SSHWS | Saffir-Simpson Hurricane Wind Scale |
| BFE | Base Flood Elevation |
| DFE | Design Flood Elevation |
| EPR | UK Environmental Permitting Regulations |
| COMAH | UK Control of Major Accident Hazards Regulation |
| NHERP | Natural Hazard Emergency Response Plan |
| API | American Petroleum Institute |
| PED | European Pressure Equipment Directive |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| ATEX | French Appareils destinés à être utilisés en ATmosphères EXplosives |
| ISA | International Society of Automation |
| IEC | International Electrotechnical Commission |
| MOC | Management of Change |
| DCS | Distributive Control System |
| PSSR | Pre Start-up Safety Review |
| GETS | Government Agency Telecommunications Service |