ASPR
ASSISTANT SECRETARY FOR PREPAREDNESS AND RESPONSE

Healthcare and Public Health Risk Identification and Site Criticality (RISC) Toolkit

Threat/Hazard Assessment Module (THAM)

End-to-End Narrative Methodology

Preface

The Healthcare and Public Health (HPH) Sector encompasses organizations, facilities, information systems, and a skilled work force that are essential to maintaining the health of the American people. Disruptions to the HPH work force or critical physical and cyber assets, whether stemming from natural disasters, terrorism, or other intentional or accidental acts, may have a significant, negative effect on the Sector's ability to provide and sustain vital healthcare services. To help inform planning, preparedness activities, and resource investments to secure and enhance the resilience of the Sector's vital assets and work force, government and private sector partners within the HPH sector have engaged in the collaborative development of an all-hazards risk assessment methodology—including integrated threat/hazard, vulnerability, and consequence components—tailored to the Sector's unique operating environment. This methodology accounts for a wide range of threats and hazards, Sector complexity, dynamic infrastructure linkages/interdependencies, and stakeholder needs and inputs.

The first component of this methodology is the Threat/Hazard Assessment Module, also referred to as the "THAM." Utilization of the THAM as a common, yet tailorable assessment methodology will accomplish two goals: 1) enable the identification of a comprehensive list of threats and hazards common across the HPH Sector; and 2) inform the determination of the likelihood or probability of occurrence of each threat or hazard at a facility, system, coalition, and/or sector level.

The THAM is intended to support a wide range of potential users, ranging from those who currently do not perform formal threat/hazard assessments to those mandated to do so on a periodic basis under current Joint Commission on Accreditation of Healthcare Organizations (Joint Commission) rules, Centers for Medicare & Medicaid Services (CMS) rules, or other requirements. To that end, it provides users with objective, freely-accessible data sources and step-by-step instructions for rating the likelihood of a variety of threats and hazards, including intentional malicious acts, natural hazards, and unintentional manmade events. The threat and hazard ratings generated by the THAM process can be used alone or in conjunction with any existing vulnerability analysis tool to support current risk assessment and management practices. The THAM is an integral part of the HPH Sector Risk Assessment Methodology, which will ultimately help to produce a more complete picture of risk and support trend analysis at the system, coalition, subsector, and/or sector level.

The THAM Tool Kit consists of two complementary components. The primary component is the *THAM Automated Tool.* This Excel-based tool can be used to automatically calculate a Threat/Hazard Rating for numerous event types simultaneously, based simply on entry of the location of the facility/asset being assessed and a few facility characterization questions. For event types that are not location-based (or for which the format of the data is not compatible with the tool), the user is guided step-by-step through a series of questions to generate automated Threat and Hazard Ratings. Help text is provided throughout the tool to make data lookup and manipulation as simple as possible. The resulting ratings are recorded in the THAM Tool so that all assessment results can be stored in a single location. ***It is highly recommended that assessors utilize the THAM Automated Tool to simplify the assessment process.***

Accompanying the THAM Automated Tool is an "end-to-end" narrative description of the full THAM methodology, which includes 1) a comprehensive listing and description of the wide array of the manmade and naturally occurring threats and hazards facing the HPH Sector; 2) a discussion of the objective data sources and calculations used within the methodology to calculate individual Threat and Hazard Ratings by event type; and 3) a description of individual threat/hazard categories and an explanation of how the rating scales were derived for each event type. The data sources provided represent Internet-accessible, nationally scoped, authoritative data sources, and serve to complement local data sources and subject matter expert input that end-users may have privileged access to.

The THAM Tool represents a unique collaborative effort between government and private sector members of the HPH partnership. Your use of this tool is welcomed, as is feedback pertaining to its utility and ease-of-use. Please address all questions and comments to the Department of Health and Human Services Assistant Secretary of Preparedness and Response.

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1 Threat/Hazard Assessment Module (THAM) Overview

1.1 Assessing Risk within the Healthcare and Public Health Sector

The Healthcare and Public Health (HPH) Sector consists of physical, cyber, and human elements that are critical to the day-to-day health and safety of all Americans. A broad diversity of assets exists across the sector, including publicly-accessible direct patient care facilities, research centers, suppliers and manufacturers, laboratories, and vast and complex public-private information and communications technology systems. As part of a holistic risk management program, the HPH Sector is proposing the utilization of the THAM as described below to identify and assess threats and hazards to sector facilities, assets, and functions. The THAM can be used in a "stand-alone" assessment approach; however, its greatest value is in conjunction with existing sector approaches/tools such as the hospital-focused Hazard Vulnerability Assessment (HVA) required under Joint Commission on Accreditation of Healthcare Organizations (Joint Commission) or Centers for Medicare & Medicaid Services (CMS) rules.

Accurate, quantitative risk analysis is necessary to underpin investments in reducing vulnerabilities and building critical infrastructure resilience in any sector. Risk analysis includes determination of the probability that a given threat or hazard will occur, the extent to which that threat or hazard is able to impact performance of a facility, system, or function (i.e., vulnerability), and the consequences of facility, asset, or function degradation or failure, including cascading effects and key internal and external dependencies and interdependencies. The THAM provides a wide array of objective web-based data sources that can be accessed in a user-friendly and efficient way to support risk assessment activities.

Development of the THAM occurred through a collaborative effort between public and private sector organizations comprising the HPH Sector, and subject matter experts representing the following communities: intelligence, law enforcement, fire services, public safety, emergency management, meteorology, environmental health and safety, critical infrastructure protection, and medical syndromic surveillance.

1.2 All Hazard Threat Assessment: Purpose and Baseline Criteria

Execution of the Risk Management process is based on an assessment of the threat and hazard environment in which HPH Sector assets operate and key services are provided. The utilization of a common, yet tailorable Sector threat/hazard assessment methodology will accomplish two goals: 1) enable the identification of a comprehensive list of threats and hazards common across the sector; and 2) inform the determination of the likelihood or probability of occurrence of each threat or hazard identified at a facility, system, coalition, regional, and/or sector level. The threat-hazard assessment should: 1) be accomplished annually at a minimum; 2) be tailored to the local environment and facility operating characteristics; 3) be repeatable and provide comparable results across facility/asset types using a combination of data-driven and subject matter expert inputs; and 4) meet the needs of facility and asset owners/operators as well as sector-level public and private sector organizations under the National Infrastructure Protection Plan (NIPP) partnership framework.

The HPH Sector is very diverse, consisting of not only hospitals and other direct patient care facilities but also manufacturers and distributors of medical equipment or pharmaceuticals; research and testing laboratories; federal, state, and local public health agencies; blood banks; mortuary services; health insurance providers and payers; and other healthcare-related industries. The goal of the THAM is to provide a methodology that individual facility/asset managers across these various user groups can use to understand the threats and hazards that are relevant to them in a manner that is consistent across the entire

sector. The result of the THAM process is an understanding of the likelihood of any given threat or hazard occurring at a particular facility or grouping of facilities, which can be used in conjunction with any existing vulnerability analysis tool to produce a more complete picture of risk and support trend analysis at the system, coalition, subsector, and/or sector level.[1]

The THAM is intended to support a wide range of potential users, ranging from those who currently do not perform formal threat/hazard assessments to those mandated to do so on a periodic basis under current Joint Commission, CMS, or other requirements. With respect to those users currently operating under a variety of regulatory or government requirements, the THAM affords access to a wide array of Internet-based data that can be used to supplement or complement existing data sources and local subject matter expert input and bring more objectivity into the threat/hazard rating process. For example, a hospital currently using the Kaiser Permanente Hazard Vulnerability Assessment (HVA) tool or public health department using the Public Health Risk Assessment Tool (PHRAT) may find that the data sources or rating calculations provided in the THAM can help them in completing or adding objective detail to those assessments. The THAM can also be used in a tailored way to enable access to specific data to close information gaps relevant to a particular threat/hazard category where subject matter expert input alone may not provide a comprehensive picture of event likelihood. It may also be used to conduct a "deep dive" into data relevant to threat/hazard event types which may impact only certain regions of the country such as tsunamis, hurricanes, volcanoes, etc. Finally, the THAM is scalable in that users may elect to consider a smaller range of threat/hazard event types more relevant to them versus a more comprehensive walk through of all event types.

1.3 Threat and Hazard Categories

The first element of the THAM involves the identification of a common baseline of threats and hazards relevant to the HPH Sector. The THAM Methodology considers a wide array of manmade and naturally occurring threats and hazards as defined and discussed below.

Human Caused Intentional Threats. This category includes: information theft-related insider threats, malicious cyber actors, violent actors (including active shooters), domestic terrorists and homegrown violent extremists (HVEs), transnational terrorists, criminal activities (including property and violent crime, violent crime), and civil disturbances.

Hazards. This category includes: Natural Hazards and Unintentional Events. Each of these sub-areas is further described below.

- *Natural Hazards* – Geological, Meteorological and Biological – Geological categories include: tsunamis, earthquakes, sinkholes, landslides, and volcanoes. Meteorological categories include: hurricanes and tropical storms, tornados, drought, snow and ice storms, wildfires, lightning, hail, damaging winds, flooding, flash floods, extreme heat, extreme cold, storm surge, and space weather. The Biological category includes annual influenza epidemics.

- *Unintentional Events.* Unintentional events can cause disruption to the operation of individual facilities/assets and the key services they provide. Unintentional events can take many forms, such as those that result from human error as well as those events that are caused by technological failures. Examples of various types of unintentional events include, but are not limited to: aircraft mishaps; unintentional HAZMAT releases (fixed facility and transportation- related); and

1 The Department of Health and Human Services is currently developing a vulnerability assessment tailored to the HPH Sector to be used in conjunction with the THAM.

radiological exposure from nuclear power plant emergencies. These specific unintentional hazards are considered in the methodology; others may be added in future updates.

1.4 Threat and Hazard Probability Ratings and Numerical Weighting

Once a baseline of threats and hazards common across the sector has been identified, the next element included in the THAM involves an analysis of those threats and hazards on an individual basis to determine the likelihood or probability of occurrence of each. The THAM utilizes four standard categories of threat and hazard probability ratings (low, moderate, high, & very high) as illustrated in Figure 1 below. The use of these common ratings facilitates a standardized approach to assessing the likelihood or probability of any individual threat or hazard occurring. (Note: For purposes of the THAM, "probability" is defined as the estimate of the likelihood that a threat will cause an impact to a particular facility/asset and/or the key services provided by the facility/asset.) Numerical weights are also provided that correspond to each probability rating category, as detailed below:

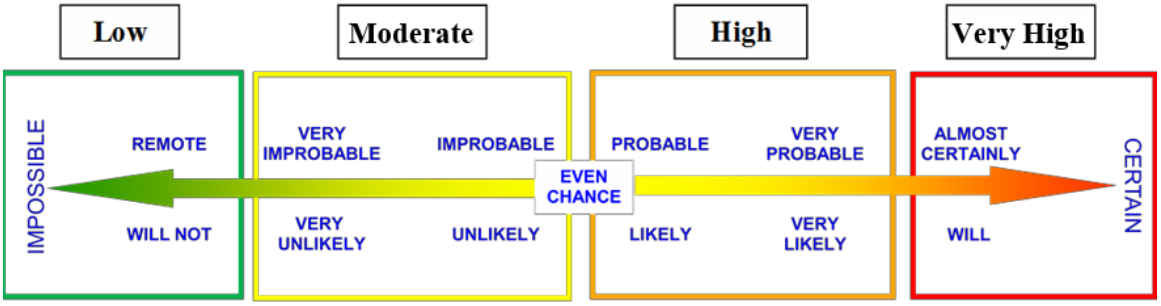

Figure 1. Probability/Likelihood Rating Categories.

Low (1). Indicates little or no credible evidence of a threat to the facility/asset or the immediate area where the facility/asset is located.

- For the identified threat, there is little or no credible evidence of capability or intent, and no demonstrated history of occurrence against the facility/asset or similar facilities/assets.

- For the identified hazard, there is a rare or no documented history of occurrence in the immediate area or region where the facility/asset is located.

Moderate (2). Indicates a potential threat to the facility/asset or the immediate area where the facility/asset is located. Also indicates there is a significant capability with low or no current intent (intentional threats), which may change under specific conditions, and there is low or no demonstrated history of occurrence.

- For the identified threat, there is some evidence of intent. There is little evidence of a current capability or history of occurrence, but there is some evidence that the threat could obtain the capability through alternate sources. Alternatively, the identified threat evidences a significant capability, but there is little evidence of current intent and little or no demonstrated history of occurrence.

- The identified hazard has a demonstrated history of occurring on an infrequent basis in the immediate area or region where the facility/asset is located.

High (3). Indicates a credible threat against the facility/asset or the immediate area where the facility/ asset is located.

- The identified threat has both the capability and intent, and there is a history that the facility/asset or similar facilities/assets have experienced the threat on an occasional basis.

- The identified hazard has a demonstrated history of occurring on an occasional basis in the immediate area or region where the facility/asset is located.

Very High (4). Indicates an imminent threat against the facility/asset or the immediate area where the facility/asset is located.

- The identified threat has both the capability and intent, and there is a history that the facility/asset or similar facilities/assets have experienced the threat on a frequent or recurring basis.

- The identified hazard has a demonstrated history of occurring on a frequent basis in the immediate area or region where the facility/asset is located.

Numerical Threat/Hazard Ratings by event type are the primary output of the THAM. These ratings provide a description of the likelihood of a specific threat or hazard occurring at a given facility/asset, relative to other facilities/assets within the sector and to other assessed threats and hazards. To calculate them, the threat/hazard ratings described above (numerical values 1 to 4) are modified by the national incidence of each event type. For example, a facility in Hawaii may have a base hazard rating of 4 for tsunami hazard because tsunamis in the U.S. are most likely to occur in Alaska and Hawaii; however, given the rarity of tsunamis in general (three events nationally in the past 20 years) the rating is scaled downward significantly to a 0.4. It should be noted that local/internal hazards (described in Section 2.6) are calculated on a separate scale and cannot be compared to the other threats and hazards. More detail on the rating calculations can be found in Appendix C.

The Threat/Hazard Ratings produced by the THAM also can be utilized to enhance any hazard vulnerability analysis currently in use within the HPH Sector. By providing likelihood ratings based on objective data sources, the outputs of the THAM can be entered directly into any tool that requires an assessor to determine the likelihoods of specific threats and hazards occurring. Determination of both categorical descriptions and numerical values provides versatility, so that the results of the THAM may be used in conjunction with both quantitative and qualitative vulnerability or risk assessments.

2 Threat and Hazard Probability Determination

The probability of occurrence of each identified threat or hazard is derived from analysis of refined analytical assessments and statistical data from various local, state, and federal government agencies, in conjunction with open source reporting and publicly accessible data sources. Each individual threat or hazard is assessed separately based on data available and is then given a specific threat/hazard rating. These ratings can be used in isolation to support threat-specific risk assessments or factored together to contribute to an overall picture of risk.

The sections below provide the objective data sources and calculations used to calculate individual Threat and Hazard Ratings, along with descriptions of each threat or hazard category and an explanation of how the rating scales were derived. The sources provided reflect easily accessible, nationally scoped data sources, but do not necessarily replace the local data sources users may have privileged access to. When

available, local data sources can always be preferentially used rather than the national data sources provided below.

To simplify the data collection process, the **THAM Automated Tool** is provided as a supplement to this narrative methodology document. This Excel-based tool can be used to automatically calculate a Threat/Hazard Rating for numerous event types simultaneously, based on the location of the facility/asset being assessed, and can calculate a Threat/Hazard Rating for all remaining event types based on user input to a short series of questions. The user can all also assess the threat or hazard based on the instructions presented below. The resulting ratings can be recorded in the THAM Tool so that all assessment results can be stored in a single location. The THAM Multiple Facility Comparison Viewer can be used to calculate Threat/Hazard Ratings for multiple facilities/assets simultaneously including those that form part of a broader healthcare coalition or cluster of facilities/assets within a healthcare system or geographically distributed corporation. **It is highly recommended that assessors utilize the THAM Automated Tool to simplify the assessment process and provide a means of documenting assessment results using a standardized report format.**

2.1 Intentional Threats

2.1.1 Information Theft-Related Insider Threat

2.1.1.1 Description of Threat

The potential for insider threats related to information theft exists in any industry or sector, with the threat increasing as the potential incentive for stealing information increases. The stolen information is generally sold to a competing foreign, criminal, or business interest. This activity, from insider threats to foreign intelligence entities, criminal interests, or business interests, that is typically motivated by a monetary incentive, is known as economic espionage. Prevention of this activity absorbs a large number of FBI resources annually.[2] The threat rating scale for this event type is partially based on the estimated monetary incentives possible from an insider selling the information found in their industry; the larger potential monetary gain, the greater the threat to the facility/asset. The estimated monetary incentive is based on the type of information a facility/asset maintains. In addition, the U.S. Computer Emergency Response Team (USCERT) Insider Threat Division released a report showing that within the HPH Sector, the majority of insider threat data loss is in the form of "fraud," or the unauthorized distribution of sensitive information such as personal health information (PHI).[3] Thus, the above scale is based both on past incidence data as well as estimated monetary incentive.

2.1.1.2 Rating Scale Determination

The Threat Rating Scale was determined as follows:

1. Open source literature was used to determine the historical incidents of information theft-related insider threat and the type of information that is historically targeted through such activity. This research provided a general notion that economic incentives are directly tied to the threat of an insider stealing information.

[2] Federal Bureau of Investigation. Counterintelligence Awareness: Teaching Industry How to Protect Trade Secrets and National Security. https://www.fbi.gov/news/stories/2012/november/teaching-industry-how-to-protect-trade-secrets-and-national-security/teaching-industry-how-to-protect-trade-secrets-and-national-security. Accessed 9/30/2015.

[3] Silowash G et al. (2012) Common Sense Guide to Mitigating Insider Threats, 4th Edition. Prepared for.

2. The majority of historical FBI resources have been dedicated towards stopping insider threat plots associated with stealing proprietary or sensitive information, thus implying that this data has a high monetary incentive and a high risk of insider threat plots.[4]
3. A report by a prominent cyber-security company denotes a recent increase in the collection and selling of medical and patient information, implying an increase in the monetary incentive for obtaining this information. Such personal health information (PHI) is highly valuable, and facilities/assets handling such information will receive the highest threat rating (Very High). Industries with patentable, propriety, trade secret, or sensitive information will be designated at a High threat rating.[5]
4. Facilities/assets that maintain personal information that could be sold for the purpose of identity theft are also addressed. This type of information has a lower monetary incentive than any of the previously described information types and, thus, was assumed to have lower threat potential.[6]
5. Facilities/assets that do not maintain any form of data with monetary incentive can also be targets of information theft. Due to the lack of monetary incentive, it is assumed that these types of facilities/assets will have the lowest information theft insider threat rating.

2.1.1.3 Threat Rating Table

Table 1. Insider Threat (Information Theft) Threat Ratings.

Rating Category	Threat Rating	Information Type Description
Very High	4	Facility/asset maintains Personal Health Information (PHI).
High	3	Facility/asset maintains proprietary, patented, or sensitive information, including trade secrets.
Moderate	2	Facility/asset maintains personal/personnel information (i.e. Social Security Number), not including PHI.
Low	1	Facility/asset maintains no data with an associated monetary incentive.

2.1.1.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Information Theft-Related Insider Threat are below.

1. The CERT Insider Threat Center reports that 154 intentional malicious thefts of intellectual property (IP), and "over 150" unintentional IP thefts have occurred in the past 18 years. Thus, the

[4] Ibid.
[5] Helmick S. Raytheon|Websense® Labs Diagnoses State of Healthcare IT Security. http://community.websense.com/blogs/websense-news-releases/archive/2015/09/23/raytheon-websense-174-labs-diagnoses-state-of-healthcare-it-security.aspx. Accessed 09/30/2015.
[6] Shahani A. The Black Market For Stolen Health Care Data. http://www.npr.org/sections/alltechconsidered/2015/02/13/385901377/the-black-market-for-stolen-health-care-data. Accessed 9/30/2015.

THAM tool assumes approximately 304 Information Theft-Related Insider Threat events have occurred in the past 18 years (an event rate of 17 per year).[7]
2. The Insider Threat Information Theft event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.24. See Appendix C for a complete description of the process.

2.1.1.5 How to Calculate Threat Rating

The steps below describe how to calculate a facility's/asset's Threat Rating for information theft-related insider threats:

1. Determine which of the above data types are maintained by the facility/asset of interest.
2. Locate the selected data type maintained by the facility/asset on the information theft insider threat scale above in Table 1.
    a. If there is no data maintenance by the facility/asset corresponding to any of the categories identified in the table above, it is assumed that the facility/asset of interest will fall into the low insider threat category and rated as "no data with monetary incentive."
3. Multiply the threat rating by the relative modifier, 0.24.

2.1.1.6 How the THAM Tool Calculates the Threat Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Threat Rating for information theft-related insider threats:

1. On the Facility Characterization page, the user selects the type of information stored at the facility/asset as defined by the categories found in Table 1 above.
2. The THAM Tool outputs a Threat Rating following the guidelines presented in Table 1 above which is then multiplied by the relative modifier, 0.24.

2.1.2 Terrorism, Including Transnational Terrorists and Domestic Terrorists/Homegrown Violent Extremists (HVEs)

2.1.2.1 Description of Threat

The DHS Office of Intelligence & Analysis (I&A) has developed generalized terrorism threat ratings for states and metropolitan statistical areas (MSAs). This terrorist threat analysis considers specific, implied, and potential physical terrorist threats based on Intelligence Community (IC) reporting and FBI information. The analysis includes IC-disseminated threat reporting that revealed known and credible violent extremist plots, casings, threats, or aspirations. Threats considered include those derived from individuals and groups associated with or inspired by al-Qa'ida and other foreign terrorist groups or individuals. Also considered were those threats posed by other types of violent extremists—including domestic terrorists—that are inspired by ideologies espoused by al-Qa'ida or other extremist groups. This threat covers all potential forms of terrorist events (e.g, bioterrorism, Electro Magnetic Pulse (EMP) attack, chemical terrorism, etc.).

[7] The CERT Insider Threat Center. University SEICM. (2016) Common Sense Guide to Mitigating Insider Threats, Fifth Edition. Prepared for. http://resources.sei.cmu.edu/asset_files/TechnicalReport/2016_005_001_484758.pdf.

2.1.2.2 Rating Scale Determination

The definitions of the threat levels for this event type were determined by DHS I&A, and are designated *For Official Use Only*. To facilitate open access to this methodology, the descriptions of the different threat levels are not provided, but will be shared when a validated request for facility/asset-specific threat levels is initiated following the procedure outlined below.

2.1.2.3 Threat Rating Table

Table 2. Transnational Terrorists and Domestic Terrorists/Homegrown Violent Extremists (HVEs) Threat Ratings.

Rating Category	Threat Rating	MSA Threat Level	State/Territory Threat Level
Very High	4	Threat Level 1	Threat Level 1
High	3	Threat Level 2	Threat Level 2
Moderate	2	Threat Level 3	Threat Level 3
Low	1	Threat Level 4	N/A

2.1.2.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Terrorism/HVE-related events are below.

1. The Global Terrorism Database, managed by the University of Maryland, reported 555 terrorist events in the United States over the past 20 years (an event rate of 28 per year).[8]
2. The Terrorism event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.29. See Appendix C for a complete description of the process.

2.1.2.5 How to Calculate Threat Rating

Because information regarding the threat levels of specific MSAs, states, and territories cannot be made public due to its sensitive nature, the Department of Health and Human Services (HHS) Critical Infrastructure Protection (CIP) Office staff is maintaining this data with the permission of the DHS. State or MSA Threat Levels can be determined by making an information request to the HHS ASPR by emailing hphrisc@hhs.gov. ASPR will then verify identification of the requestor and validate need-to-know, and share the requested State or MSA Threat Level through a secure portal such as the Homeland Security Information Network (HSIN). The State or MSA Threat Level data provided will directly correlate to a Threat Rating as shown in Table 2. Multiply the threat rating by the relative multiplier of 0.29.

[8] START National Consortium for the Study of Terrorism and Responses to Terrorism. (June 2016) Global Terrorism Database. *Global Terrorism Database*. University of Maryland. http://www.start.umd.edu/gtd/. Accessed June 27, 2017.

2.1.2.6 How the THAM Tool Calculates the Threat Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Threat Rating for terrorism/HVE events:

1. After contacting the CIP office to validate need to know, and receiving the relevant Threat Rating for the facility, the user will select the assigned threat rating.
2. The THAM tool outputs a Threat Rating following the guidelines presented in Table 2 above which is then multiplied by the relative modifier, 0.29.

2.1.3 Active Shooter

2.1.3.1 Description of Threat

Active shooter events can happen anywhere and at any time, and specific factors useful for predicting a facility's/asset's relative likelihood of attack have not been identified in a formal data base. Because many of the active shooter incidents that have occurred in the past can be described as workplace violence (that is, the attacker has a professional relationship with the victim(s) and is acting in response to a perceived insult or injustice), they can occur in any professional environment (including health care facilities). Locations open to the public such as cafes and restaurants are also frequent locations for shootings. A preliminary attempt at estimating the likelihood of the active shooter threat is made below by examining past events.

The Federal Bureau of Investigation (FBI) released a study on 160 active shooter events that occurred from 2000 to 2013 and reported the incidence of occurrence based on facility/asset type. The threat scale for active shooter events is based on this report.[9] The FBI document classified active shooter event locations into seven primary categories; the three most relevant to the HPH Sector are described below.

1. **Commercial settings.** The most common location for active shooter events involves areas where commerce is conducted, accounting for 45.6% of the incidents documented in the FBI report. This category includes private office buildings, in which 14.4% of all attacks occurred, and public establishments such as malls, cafes, and restaurants, in which 31.3% of all incidents occurred. Many facilities/assets within the HPH Sector can be included in this category. If the facility/asset is better described by a more specific facility/asset category as identified below, select the more specific category. For example, a hospital is both a commercial setting as well as a health care facility, yet is better described as a health care facility for Threat Rating purposes. Conversely, the headquarters of a pharmaceutical manufacturer or a major retail outlet should be described as a commercial business.
2. **Institutions of education.** The second-most common location of active shooter events is schools—including elementary schools, high schools, and colleges or universities—which accounted for 24.4% of all incidents. Institutions of higher education specifically accounted for 7.5% of all incidents. Medical schools are an example of a type of HPH Sector asset that would be included in this category.
3. **Health care facilities.** Four active shooter events (2.5%) occurred at health care facilities over the timeframe of the report. The events specifically occurred at hospitals, although other HPH Sector assets within this category would include clinics, urgent care, hospice care, and retirement facilities.

[9] Blair JP, Schweit KW. (2014) A Study of Active Shooter Incidents, 2000-2013. Texas State University and Federal Bureau of Investigation, U.S. Department of Justice.

While the above source of data describes active shooter events that are obviously carried out through the use of firearms, the rating can be used to describe all ongoing violent acts regardless of the deadly weapon used, as the motivations behind the act are likely the same.

2.1.3.2 Rating Scale Determination

The Threat Rating scale was determined as follows:

1. Data from "A Study of Active Shooter Incidents in the United States Between 2000 and 2013," a report by the FBI Office of Partner Engagement, were analyzed to assess active shooter threat by facility/asset type.[10]
2. The facility types relevant to the HPH Sector were ranked based on the proportion of historical incidences of active shooter events that occurred at each facility/asset type.

2.1.3.3 Threat Rating Table

Table 3. Active Shooter Threat Ratings.

Rating Category	Threat Rating	Facility/Asset Description
Very High	4	Facility/asset is a **commercial businesses or office** that is either open or closed to pedestrian traffic (not including health care facilities).
High	3	Facility/asset is an **institute of higher education.**
Moderate	2	Facility/asset is a **health care facility.**
Low	1	Facility/asset does not match the description of any facility/asset type with historical active shooter events.

2.1.3.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Active Shooter events are below.

1. According to an FBI report of active shooter incidents in the United States, 214 active shooter events have occurred in the past 16 years (an event rate of 13 per year).[11]
2. The active shooter event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.22. See Appendix C for a complete description of the process.

[10] Federal Bureau of Investigation. Active Shooter Incidents. https://www.fbi.gov/about-us/office-of-partner-engagement/active-shooter-incidents. Accessed 11/19/2015.

[11] Federal Bureau of Investigation. 2000-2016 Active Shooter Incidents. Prepared for Federal Bureau of Investigation. https://www.fbi.gov/file-repository/activeshooter_incidents_2001-2016.pdf/view.

2.1.3.5 How to Calculate Threat Rating

The steps below describe how to calculate a facility's/asset's Threat Rating for active shooter events:

1. Determine which of the above facility/asset types best describe the facility/asset of interest.
2. Locate the selected facility/asset type on the active shooter threat scale above in Table 3 in the "Facility/Asset Description" column, and its associated threat rating.
    a. If there is no matching facility type description for the facility/asset of interest, it is assumed that the facility/asset of interest will have a Low Active Shooter Threat Rating.
3. Multiply the threat rating by the relative modifier, 0.22.

2.1.3.6 How the THAM Tool Calculates the Threat Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Threat Rating for active shooter events:

1. On the Facility Characterization page, the user will select a facility description from those presented above in Table 3 that best describes the facility.
2. The THAM tool outputs a Threat Rating based on the user's answer following the guidelines presented in Table 3 above which is multiplied by the relative modifier, 0.22.

2.1.4 Cyber

2.1.4.1 Description of Threat

The umbrella term "cyberattack" covers a wide range of attack patterns and methodologies as well as a variety of attack results. The Verizon Data Breach Investigations Report provides a thorough examination of data breach incidents that is recommended for review by several experts in the field of cyber security.[12] This annual report draws from hundreds of cyber partners and collects, analyzes, and curates data on the data breaches that businesses experience during the course of the year. The report provides a wealth of data, ranging from the cost of the data lost annually, to the number of attacks using a particular attack methodology. For data breaches occurring in the healthcare sector, the Verizon Report identifies seven cyberattack patterns: miscellaneous errors (32%), insider misuse (26%), physical theft/loss (16%), point of sale (12%), web app attacks (9%), cyber-espionage (4%), and crime-ware (1%).

While statistics such as these can provide direction for security managers as to the types of attacks that are most common, they do not necessarily present an accurate picture of the *threat* of cyberattacks. Data breaches are more often than not a product of opportunity, and their occurrence is intrinsically tied to the specific vulnerabilities that are unique to each facility/asset, and, therefore, cannot be used to estimate the likelihood of attack. In reality, any connected entity will experience a constant onslaught of untargeted probes and attempted breaches, in addition to numerous targeted attacks. Large organizations may see millions of attempts per day. Furthermore, the rate of cyberattacks is highly variable, and can fluctuate due to numerous factors unrelated to the intent of adversaries. The reality of the cyber threat landscape is that any networked facility has a very high likelihood of experiencing a cyberattack. Given the difficulties in assessing cyber threats, a more refined Threat Rating methodology could not be developed, and, instead, a facility's/asset's cyber risk should be determined primarily within the vulnerability section of

[12] Verizon. (2016) 2015 Data Breach Investigations Report.

the risk assessment methodology used to provide an aggregate risk picture for the facility/asset of interest.[13]

2.1.4.2 Threat Rating Scale Determination

The Threat Rating scale was determined as follows:

1. Connection of a facility to a network, or lack thereof, was used to determine cyberattack threat ratings.
    a. The Cyber Threat Rating is designed such that a facility/asset will be rated either 4 (connected to a network) or 1 (not connected to a network).

2.1.4.3 Threat Rating Table

Table 4. Cyber Attack Threat Ratings.

Rating Category	Threat Rating	Facility/Asset Description
Very High	4	Facility is connected to a network.
High	3	N/A (This Threat Rating is not used.)
Moderate	2	N/A (This Threat Rating is not used.)
Low	1	Facility is not connected to a network.

2.1.4.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of cyber attack events are below.

1. As stated above, cyber-attack attempts are almost constant, thus it is assumed that the rate of cyber events will at least be equivalent to the most frequently occurring threat or hazard.
2. The relative modifier of cyber-attack events is 1.0.

2.1.4.5 How to Calculate Threat Rating

The steps below describe how to calculate a facility's/asset's cyber-attack threat rating:

1. Determine if facility is connected to a network.
2. Multiply the identified threat rating by the relative modifier of 1.0.

[13] A state-level indicator of the potential for a cyber-attack on any U.S. government entity can be found using the Multi-State Information Sharing & Analysis Center (MS-ISAC) issued Cyber Alert Level. This data source is geared towards informing state and local government agencies of their potential cyber threat level, and is not directed specifically to the private sector. It may be particularly useful for public health departments and other state or local government agencies.

2.1.4.6 How the THAM Tool Calculates the Threat Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Threat Rating for cyber events:

1. On the Facility Characterization page, the user will select if the facility needs or uses a network to maintain function or conduct operations.
2. Depending on the facility's use of a network for functions, the THAM tool will output a Threat Rating based on the guidelines in Table 4 above which is multiplied by the relative modifier, 1.0.

2.1.5 Violent Crime

2.1.5.1 Description of Threat

The Threat Rating for this event type is based on the last five years of violent crime rates per 100,000 inhabitants for cities as reported in the FBI Uniform Crime Report (UCR). The rating category and Threat Rating for a specific city is based on the area's difference from the median rate of violent crime. The smaller the city's violent crime rate in comparison to the median violent crime rate, the lower the threat; conversely, the larger the city's violent crime rate in comparison to the median violent crime rate, the higher the threat.

2.1.5.2 Rating Scale Determination

The Threat Rating scale was determined using the following steps:

1. The last five years of violent crime data by city was downloaded using the annual UCR generated by the FBI.[14] This information was found in Table 8 of each annual UCR.
2. The median violent crime rate per 100,000 inhabitants from all city data available from the most recently published UCR (2014) was determined.
3. The smallest (minimum) and largest (maximum) violent crime rates per 100,000 inhabitants across all five years were identified. These values represented a Threat Rating of 0.01 and 1.00, respectively.
4. The violent crime rate was scaled linearly from the minimum to the maximum for Threat Ratings of 1 to 4.

2.1.5.3 Threat Rating Table

Table 5. Violent Crime Threat Ratings.

Rating Category	Threat Rating	Threat Occurrence Descriptor	Threat Occurrence Range
Very High	4	Frequent	A violent crime rate per 100,000 inhabitants greater than 2,900.
High	3	Occasional	A violent crime rate per 100,000 inhabitants from 1,901 to 2,900.
Moderate	2	Infrequent	A violent crime rate per 100,000 inhabitants from 1,001 to 1,900.
Low	1	Rare	A violent crime rate per 100,000 inhabitants less than or equal to 1,000.

[14] Federal Bureau of Investigation. Crime Statistics. https://www.fbi.gov/stats-services/crimestats. Accessed 11/19/2015.

2.1.5.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Violent Crime events are below.

1. The incidence of violent crime in hospital settings was used to determine the violent crime relative modifier.
    a. A 2017 Healthcare Crime Survey conducted by the International Association for Healthcare Security and Safety Foundation found that there was a rate of 10.3 violent crime events per 100 staffed beds in American hospitals.[15]
    b. This rate of 10.3 violent crimes per 100 beds was multiplied by the number of beds in U.S hospitals, 897,961 as reported by the American Hospital Association, resulting in an event rate of approximately 92,000 per year.[16]
2. The violent crime event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.99. See Appendix C for a complete description of the process.

2.1.5.5 How to Calculate Threat Rating

The steps below describe how to calculate a city's crime Threat Rating. This method can be used to collect data on violent crime and property crime simultaneously. The two crime rates should be used to calculate two separate Threat Ratings.

I. Baseline Crime Rate

1. Search for the crime rate of the city in which the facility/asset is located.
    a. Select the most recent complete year's Uniform Crime Rate from the FBI Uniform Crime Reporting Program.
    b. From the Offense Tables, select Table 8.
    c. Select the state in which the facility/asset of interest is located.
    d. For the city in which the facility/asset is located, calculate the violent crime rate as (# Violent Crimes ÷ Population) × 100,000.
2. For cities not listed in the UCR, determine the crime rate of the county in which the facility/asset is located.[17]
    a. From Table 8, record the number of violent crimes for each city in your county.
    b. Return to the Offense Tables and select Table 10.
    c. Record the number of violent crimes in the county in which the facility/asset is located.
    d. Return to the Offense Tables and select Table 11.

[15] IAHSS Foundation. (2017) 2017 Healthcare Crime Survey. Prepared for IAHSS Foundation. http://c.ymcdn.com/sites/www.iahss.org/resource/collection/48907176-3b11-4b24-a7c0-ff756143c7de/2017_Crime_Survey_-_IAHSS_Foundation.pdf?hhSearchTerms=%22crime+and+data%22.

[16] American Hospital Association. Fast Facts on US Hospitals 2017. http://www.aha.org/research/rc/stat-studies/fast-facts.shtml. Last Updated January 2017. Accessed June 27, 2017.

[17] There is no single source for county crime rate. Crime data reported by individual agencies, including city, county, and state police departments, must be sourced separately and added together. County population must be determined from the U.S. Census to calculate the crime rate.

e. Record the number of violent crimes in the county in which the facility/asset is located as reported by each agency listed.
f. Add together the number of crimes from step 2 (a), (c), (e).
g. Determine the county population for the same year as the reported crime data using the U.S. Census data at the American FactFinder.
h. Calculate the county crime rate as (# Crimes ÷ Population) × 100,000.

3. Correlate the county crime rate with the hazard rating providing in Table 5 above, then multiply by the relative modifier, 0.99.

II. Local Data Sources

Crime rates can vary greatly on a neighborhood level within a city. Therefore, additional local sources of data with a finer geographical resolution may be used to refine the crime rate for the immediate area around the facility/asset. Local police departments and their official websites may be consulted to obtain some of this information. Additionally, some commercial solutions may be used to obtain this type of local crime data. Two examples are provided below.

- CRIMECAST Provides a "CAP Index Score," which is an index based on crime rates of each census block within a certain radius of a specific location. Because proprietary calculations are used to determine the CAP Index, they cannot be directly related to crime rates, but can be used to determine relative increases or decreases in crime within defined local geographical areas. CRIMECAST can be tailored to a specific location.[18]
- Neighborhood Scout provides an online search tool that can be used to find state and city crime rates at no cost. Neighborhood-level detail can be obtained with a paid subscription.[19]

2.1.5.6 How the THAM Tool Calculates the Threat Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Threat Rating for violent crime events:

1. The user inputs the State, County, and City, and violent crime rates based on the location of the facility/asset. The tool pulls the crime rate based on the facility's/asset's city as entered on the Facility Characterization page.
2. Based on the crime rate for the facility's/asset's city, a Threat Scale is output based on the guidelines presented in Table 5 above which is then multiplied by the violent crime relative modifier, 0.99.

2.1.6 Property Crime

2.1.6.1 Description of Threat

The Threat Rating for this event type is based on the last five years of property crime rates per 100,000 inhabitants for cities as reported in the FBI Uniform Crime Reports (UCR). The rating category and Threat Rating for a specific city are based on the area's difference from the median rate of property crime. The smaller the city's property crime rate in comparison to the median property crime rate, the lower the threat; conversely, the larger the city's property crime rate in comparison to the median property crime rate, the higher the threat.

[18] CAP Index. http://capindex.com/. Accessed 11/10/2015.
[19] Neighborhood Scout. http://www.neighborhoodscout.com/. Accessed 11/10/2015.

2.1.6.2 Rating Scale Determination

The Threat Rating scale was determined using the following steps:

1. The last five years of violent crime data by city was downloaded using the annual UCR generated by the FBI. This information was found in Table 8 of each annual UCR.
2. The median property crime rate per 100,000 inhabitants from all city data available from the most recently published UCR (2014) was determined.
3. The smallest (minimum) and largest (maximum) property crime rate per 100,000 inhabitants across all five years were identified. These values represented a Threat Rating of 1 and 4, respectively.
4. The property crime rate was scaled linearly from the minimum to the maximum for Threat Ratings of 1 to 4.

2.1.6.3 Threat Rating Table

Table 6. Property Crime Threat Ratings.

Rating Category	Threat Rating	Threat Occurrence Descriptor	Threat Occurrence Range
Very High	4	Frequent	A property crime rate per 100,000 inhabitants greater than 12,400.
High	3	Occasional	A property crime rate per 100,000 inhabitants from 7,501 to 12,400.
Moderate	2	Infrequent	A property crime rate per 100,000 inhabitants from 4,101 to 7,500.
Low	1	Rare	A property crime rate per 100,000 inhabitants less than or equal to 4,100.

2.1.6.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Property Crime events are below.

1. The incidence of property crime in hospital settings was used to determine the rate of property crimes for relative modification.
    a. A 2017 Healthcare Crime Survey conducted by the International Association for Healthcare Security and Safety Foundation found that there was a rate of 12 property crime events per 100 staffed beds in American hospitals.[20]
    b. This rate of 12 property crimes per 100 beds was multiplied by the number of beds in U.S hospitals, 897,961 as reported by the American Hospital Association, resulting in an event rate of approximately 107,000 per year.[21]

[20] IAHSS Foundation. (2017) 2017 Healthcare Crime Survey. Prepared for IAHSS Foundation. http://c.ymcdn.com/sites/www.iahss.org/resource/collection/48907176-3b11-4b24-a7c0-ff756143c7de/2017_Crime_Survey_-_IAHSS_Foundation.pdf?hhSearchTerms=%22crime+and+data%22.

[21] American Hospital Association. Fast Facts on US Hospitals 2017. http://www.aha.org/research/rc/stat-studies/fast-facts.shtml. Last Updated January 2017. Accessed June 27, 2017.

2. The property crime event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 1.0. See Appendix C for a complete description of the process.

2.1.6.5 How to Calculate Threat Rating

The steps below describe how to calculate a city's crime Threat Rating. This method can be used to collect data on violent crime and property crime simultaneously. The two crime rates should be used to calculate two separate Threat Ratings.

I. Baseline Crime Rate

1. Search for the crime rate of the city in which the facility/asset is located.
    a. Select the most recent complete year's Uniform Crime Rate from the FBI Uniform Crime Reporting Program.
    b. From the Offense Tables, select Table 8.
    c. Select the state in which the facility/asset is located.
    d. For the city in which the facility is located, calculate the property crime rate as (# Property Crimes ÷ Population) × 100,000.
2. For cities not listed in the UCR, determine the crime rate of the county in which the facility/asset is located.[22]
    a. From Table 8, record the number of property crimes for each city in your county.
    b. Return to the Offense Tables and select Table 10.
    c. Record the number of property crimes in the county in which the facility/asset is located.
    d. Return to the Offense Tables and select Table 11.
    e. Record the number of property crimes in the county in which the facility/asset is located as reported by each agency listed.
    f. Add together the number of crimes from step 2 (a), (c), (e).
    g. Determine the county population for the same year as the reported crime data using the U.S. Census data at the American FactFinder.
    h. Calculate the county crime rate as (# Crimes ÷ Population) × 100,000.
3. Correlate the county crime rate with the hazard rating providing in Table 6 above, then multiply by the property crime relative modifier, 1.0.

II. Local Data Sources

Crime rates can vary greatly on a neighborhood level within a city. Therefore, additional local sources of data with a finer geographical resolution may be used to refine the crime rate for the immediate area in which the facility/asset is located. Local police departments and their websites may be consulted to obtain some of this information. Additionally, some commercial solutions may be used to obtain this type of local crime data. Two examples are provided below.

- CRIMECAST Provides a "CAP Index Score," which is an index based on crime rates of each census block within a certain radius of a specific location. Because proprietary calculations are used to determine the CAP Index, they cannot be directly related to crime rates, but can be used

[22] There is no single source for county crime rate. Crime data reported by individual agencies, including city, county, and state police departments, must be sourced separately and added together. County population must be determined from the U.S. Census to calculate the crime rate.

to determine relative increases or decreases in crime within defined local geographical areas. CRIMECAST can be tailored to a specific location.[23]

- Neighborhood Scout provides an online search tool that can be used to find state and city crime rates at no cost. Neighborhood-level detail can be obtained with a paid subscription.[24]

2.1.6.6 How the THAM Tool Calculates the Threat Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Threat Rating for property crime events:

1. The user inputs the State, County, and City, and property crime rates based on the location of the facility/asset. The tool pulls the crime rate based on the facility's/asset's city as entered on the Facility Characterization page.
2. Based on the crime rate for the facility's/asset's city, a Threat Scale is output based on the guidelines presented in Table 6 above which is then multiplied by the property crime relative modifier, 1.0.

2.2 Natural Hazards (Geological)

2.2.1 Earthquake

2.2.1.1 Description of Hazard

An earthquake is the perceptible shaking of the surface of the Earth, which can be violent enough to destroy major buildings and kill thousands of people. The severity of the shaking can range from barely felt to violent enough to displace people. Earthquakes result from the sudden release of energy in the Earth's crust that creates seismic waves. The seismicity, seismism, or seismic activity of an area refers to the frequency, type, and size of earthquakes experienced over a period of time. The hazard scale for this event type is based on earthquake probability ratings generated by the United States Geological Survey (USGS), using the USGS 2017 one year seismic hazard forecast. The USGS web site generated a map that displays the probability that an earthquake will induce a ground shake of a great enough magnitude to result in structural damage. This map describes probability for the contiguous United States, and data regarding non-continental United States is available.

2.2.1.2 Rating Scale Determination

The hazard rating scale was determined using the following steps:

1. The 2017 seismic hazard forecast from USGS was used to determine the scale of potential seismic probabilities.[25]
2. The hazard probability range provided by the forecast was scaled so that higher probabilities (>5%) were considered a "Very High" hazard rating, while the minimal probability (<1%) were considered a "Low" hazard rating.

[23] CAP Index. http://capindex.com/. Accessed 11/10/2015.

[24] Neighborhood Scout. http://www.neighborhoodscout.com/. Accessed 11/10/2015.

[25] USGS. Short-term Induced Seismicity Models. https://earthquake.usgs.gov/hazards/induced/index.php. Accessed June 272017.

2.2.1.3 Hazard Rating Table

Table 7. Earthquake Hazard Ratings.

Rating Category	Hazard Rating	Threat Occurrence Descriptor
Very High	4	A probability of 5% or greater for a structurally damaging magnitude earthquake within the next year.
High	3	A probability between 2% to 5% for a structurally damaging magnitude earthquake within the next year.
Moderate	2	A probability of 1% to 2% for a structurally damaging magnitude earthquake within the next year.
Low	1	A probability of less than 1% for a structurally damaging magnitude earthquake within the next year.

2.2.1.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Earthquake events are below.

1. Based on data from the USGS online Earthquake Catalog, a total of 974 earthquakes of magnitude 4.5 or greater have occurred in the contiguous US, Hawaii, and Alaska in the past 20 years (an event rate of 49 per year).[26]
2. The earthquake event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.33. See Appendix C for a complete description of the process.
3. The relative modifier of earthquake events is 0.3.

2.2.1.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's earthquake Hazard Rating:

1. Go to the USGS 2017 Short-term Seismicity Map for the contiguous United States, or below in Figure 2.
2. Identify the facility's county and associated annual earthquake damage probability. Using Table 7 above, determine the hazard rating using the annual earthquake damage probability then multiply by the earthquake relative modifier, 0.33.

2.2.1.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for earthquake events:

1. The Tool automatically looks up the damaging earthquake probability based on the county selected by the user on the Facility Characterization page.

[26] USGS. Search Earthquake Catalog. https://earthquake.usgs.gov/earthquakes/search/. Accessed June 27, 2016.

2. The Tool outputs a Hazard Rating using the guidelines in Table 7 above which is then multiplied by the earthquake relative modifier, 0.33.

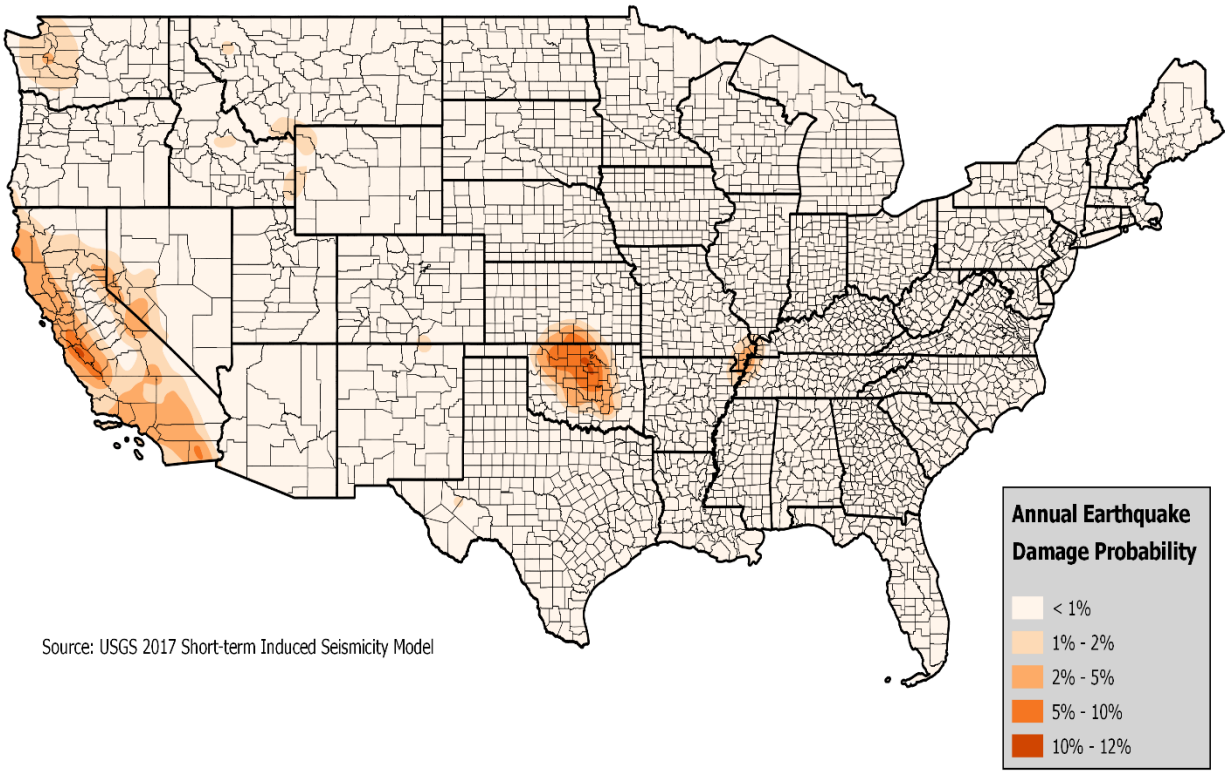

Figure 2. USGS 2017 Short-Term Induced Seismicity Model Map of the Contiguous United States.

2.2.2 Tsunami

2.2.2.1 Description of Hazard

A tsunami, colloquially known as a tidal wave, is a series of waves in a body of water caused by the displacement of a large volume of water, generally in an ocean or large lake. Earthquakes, volcanic eruptions, underwater explosions (including detonations of underwater nuclear devices), landslides, glacier calvings, meteorite impacts, and other disturbances above or below water all have the potential to generate a tsunami. In being generated by the displacement of water, a tsunami contrasts with a normal ocean wave generated by wind and with tides, which are the result of the gravitational pull of the moon and the sun on bodies of water.

The inundation of water from a tsunami is called a run-up event. Because tsunami run-ups in the U.S. and its territories are relatively rare events, recent historical records are not suitable for determining a hazard level. The National Tsunami Hazard Mitigation Program (NTHMP) has provided a tsunami hazard assessment, in which specific regions within the U.S. and its territories are identified with a relative hazard level. This hazard assessment is the basis for the Hazard Rating for tsunamis. Furthermore, according to NTHMP, tsunamis are not destructive greater than three kilometers inland or within three kilometers of a river that connects to the ocean.[27] The closer to the ocean or river, the more likely it is that

[27] National Tsunami Hazard Mitigation Program. Guidelines and Best Practices to Establish Areas of Tsunami Inundation for Non-modeled or Low-hazard Regions.

a location will be affected by the tsunami.[28] When tsunamis do affect rivers, generally only the first fifty miles of the river are affected.[29]

2.2.2.2 Rating Scale Determination

The Hazard Rating scale for tsunamis was determined using the following steps:

1. The Hazard Rating Categories were derived from the U.S. States and Territories NTHMP Hazard Assessment: Historical Record and Sources for Waves.[30]
2. The qualitative hazard levels as determined by NTHMP were correlated to Hazard Rating categories based on the following scheme:
    a. Very Low to Low = Low
    b. Moderate = Moderate
    c. High = High
    d. Very High = Very High
3. Within each rating category, Hazard Ratings were determined based on distance of a facility/asset from a coast or river.
4. All locations that were greater than three kilometers from a coast or river were assigned a Low (1) hazard rating.

2.2.2.3 Hazard Rating Table

Table 8. Tsunami Hazard Ratings.

Rating Category	Hazard Rating	Facility/Asset Location
Very High	4	**Alaska or Hawaii**, less than 3 km from the coast or from the first 50 miles of a river that connects to the ocean.
High	3	**U.S. West Coast, Puerto Rico, or Virgin Islands,** less than 3 km from the coast or from the first 50 miles of a river that connects to the ocean.
Moderate	2	**U.S. Pacific Island Territories**, less than 3 km from the coast or from the first 50 miles of a river that connects to the ocean.
Low	1	**U.S. Atlantic Coast or U.S. Gulf Coast, less than** 3 km from the coast or from the first 50 miles of a river that connects to the ocean OR **U.S. Inland** or greater than 3km from a coast or from the first 50 miles of a river that connects to the ocean (any region).

http://nws.weather.gov/nthmp/documents/Inundationareaguidelinesforlowhazardareas.pdf. Last Updated August 2011. Accessed 1/4/2015.

[28] Nicolsky DJ, Suleimani EN, Koehler RD. (2014) Tsunami Inundation Maps of the Villages of Chenega Bay and Northern Sawmill Bay, Alaska. Prepared for. http://pubs.dggsalaskagov.us/webpubs/dggs/ri/text/ri2014_003.pdf.

[29] Kalmbacher KD, Hill DF. (2015) Effects of Tides and Currents on Tsunami Propagation in Large Rivers: Columbia River, United States. *Journal of Waterway, Port, Coastal, and Ocean Engineering.*

[30] National Tsunami Hazard Mitigation Program. U.S. States and Territories NTHMP Hazard Assessment: Historical Record and Sources for Waves. http://nws.weather.gov/nthmp/publications.html. Accessed 11/19/2015.

2.2.2.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Tsunami events are below.

1. According to the NOAA Center for Tsunami Research, three tsunami events occurred in the US in the past 20 years (an event rate of 0.15 per year).[31]
2. The tsunami event rate was log-transformed and normalized according to the most frequent hazard. Because the resulting modifier value was less than the chosen minimum value, the modifier was set to 0.10. See Appendix C for a complete description of the process.
3. The relative modifier of tsunami events is 0.1.

2.2.2.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the region in which the facility/asset is located (Alaska or Hawaii; U.S. West Coast, Puerto Rico, or Virgin Islands; U.S. Pacific Island Territories; U.S. Atlantic Coast or Gulf Coast; or U.S. Inland).
2. For all regions except U.S. Inland, determine the distance of the facility/asset from a coast or river that connects to the ocean using any available map or mapping software.
3. Identify the Hazard Rating from Table 8 based on the region of the facility/asset and its proximity to a coast or river, then multiply by the tsunami relative modifier, 0.1.
4. Additional local data can be used to adjust the Hazard Rating. Local tsunami inundation maps can be found from the NTHMP. The Hazard Rating can be adjusted upward from the initial determination if the facility/asset is within an inundation area.

2.2.2.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for tsunami events:

1. The user will identify if the facility/asset is less than 3 km from the coast with a yes or no selection.
2. If the user answers that they are not less than 3 km from the coast, they will answer a follow up question to determine if they are less than 3 km from the first 50 miles of an ocean-connected river.
3. If the user answers yes to the follow up question, the model then determines where in the country the facility is located by the user entered state.
4. The THAM tool outputs the appropriate Hazard rating based on the guidelines presented in Table 8 above which was multiplied by the tsunami relative modifier, 0.1.

[31] NOAA Center for Tsunami Research. Recent and Historical Tsunami Events and Relevant Data. http://nctr.pmel.noaa.gov/database_devel.html. Accessed June 27, 2017.

2.2.3 Landslide (All Categories)

2.2.3.1 Description of Hazard

Landslides represent natural hazards that can occur on almost any sloped surface, regardless of the intensity of the slope. However, landslides present more of a hazard in certain areas than others. The hazard scale is based on a USGS survey observing landslide incidence and susceptibility in the contiguous U.S.[32] It should be noted that, while landslide hazard maps are an excellent starting point in the assessment of the hazard posed by landslides, they do not replace the accuracy of site-specific observations. For a more accurate assessment of the actual landslide hazards, facilities should invest in a geological site landslide assessment. Unfortunately, the data source cited does not include either Alaska or Hawaii and, therefore, cannot be used to estimate the landslide hazard present in those regions. Additional research is needed to identify appropriate sources of data for those locations.

Additional landslide hazard information can potentially be garnered at the state level. While landslides can occur anywhere, many states have a generally lower risk of landslides, and, therefore, don't typically expend the funds or efforts necessary to gather data on landslide incidence or susceptibility. Because of this disparity in landslide priority, only select states have researched landslide risks to the point at which they can be integrated into our proposed methodology. Ten states—Alabama, California, Maine, Maryland, Massachusetts, New York, Pennsylvania, Vermont, Virginia, and Utah—reported landslide susceptibility (without incidence) that could provide a more precise look at landslide risk for critical infrastructure sites within those ten states. These additional state level resources are presented below in Table 9.

Table 9. State Level Landslide Data Sources.

State	Link	Description
Alabama	Geological Survey of Alabama	Landslide susceptibility map reporting landslide susceptibility without historical incidence data
California	California Geological Survey	Landslide susceptibility map reporting landslide susceptibility without historical incidence data
Maine	Maine Geological Survey	Landslide susceptibility map relating slope intensity to landslide susceptibility
Maryland	U.S. Geological Survey	Landslide susceptibility map reporting landslide susceptibility without historical incidence data
Massachusetts	Massachusetts Geological Survey	Landslide susceptibility map relating slope intensity to landslide susceptibility
New York	New York Department of Homeland Security and Emergency Services	Landslide susceptibility map labelling counties with ranges of susceptibility and or incidence
Pennsylvania	Pennsylvania Department of Conservation and Natural Resources	Landslide susceptibility map labelling counties from low to highest landslide risk

32 Radbruch-Hall DH et al. (1982) Landslide Overview Map of the Conterminous United States.

State	Link	Description
Utah	Utah Geological Survey	Landslide susceptibility map reporting landslide susceptibility without historical incidence data
Virginia	Virginia Division of Geology and Mineral Resources	Landslide susceptibility map reporting landslide susceptibility without historical incidence data

2.2.3.2 Rating Scale Determination

The Hazard Rating scale for landslides was determined using the following steps:

1. The Landslide Overview Map of the Conterminous United States from USGS was identified as an interactive map.[33]
2. The seven possible landslide region designations were identified and are defined below
    a. No data – no data is reported for this region
    b. Sus-mod – region has moderate susceptibility to landslides and a low historical incidence of landslides
    c. Sus-high – region has high susceptibility to landslides and a low historical incidence of landslides
    d. Combo high – region has high susceptibility to landslides and a moderate historical incidence of landslides
    e. Low – region has both a low susceptibility to and historical incidence of landslides
    f. Moderate – region has both a moderate susceptibility to and historical incidence of landslides
    g. High – region has both a high susceptibility to and historical incidence of landslides
3. The landslide region designations were organized so that those with higher incidences and/or susceptibilities were considered a greater hazard.

2.2.3.3 Hazard Rating Table

Table 10. Landslide Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Landslide Region Designation Description
Very High	4	Frequent	Area has **high landslide incidence and susceptibility**. (High)
High	3	Occasional	Area has **moderate landslide incidence and susceptibility** (Moderate) OR Area has one of the following "**combination**" landslide incidence and susceptibility (Combo-high): • moderate incidence and high susceptibility; • high incidence and moderate susceptibility.

[33] Homeland Infrastructure Foundation-Level Data. Landslide Regions. https://hifld-dhs-gii.opendata.arcgis.com/datasets/6da35e43932b450f85511c52ce23aeed_0?geometry=-136.46%2C32.025%2C-63.379%2C42.486. Accessed November 22, 2016.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Landslide Region Designation Description
Moderate	2	Infrequent	Area has **high or moderate landslide susceptibility and low landslide incidence.** (Sus-high or Sus-mod)
Low	1	Rare or No Documented History	Area has **low landslide incidence and susceptibility** (Low) OR No landslide incidence or susceptibility data is reported.

2.2.3.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Landslide events are below.

1. No national database of landslide events could be identified, so total incidence was approximated as described below.
    a. Data from the USGS landslide susceptibility interactive map was used to estimate the percent of the total US land area assigned to each susceptibility rating. [34]
    b. The percent area in each susceptibility rating was converted into absolute land area based on the total land area of the Continental US, approximately 3,120,000 sq. mi.
    c. Each landslide susceptibility rating was assigned a percent of land that is assumed to have been impacted by landslides (e.g. 1% of the area of the US with a high landslide susceptibility has been impacted by landslides in the last 20 years).
        i. Literature on a region in Poland that is highly susceptible to landslides reported that less than 1% of the surveyed area was impacted by "recent" landslides. Thus, it is assumed that 1% of the total land area classified as high susceptibility has been impacted by landslides in the last 20 years.[35]
        ii. The percentage of total landslide area for each successive susceptibility category was reduced according to the following scheme:
            - Combo-hi: 0.7%
            - Mod: 0.35%
            - Sus-high: 0.1%
            - Sus-mod: 0.01%
            - Low: 0.001%
            - No data: 0%
        iii. The percentage of landslide area in each susceptibility category was multiplied by the total area of the category to determine absolute landslide area.
    d. The total area of landslides for each landslide susceptibility category was then divided by the average area of a landslide, 2 km^2, to achieve an estimate of the total number of landslides by landslide susceptibility rating. [36]

[34] Ibid.
[35] Sassa K, Canuti P, Yin Y. (2014) *Landslide Science for a Safer Geoenvironment: Volume 2: Methods of Landslide Studies*. Vol. Springer International Publishing.
[36] Ibid.

2. Using the described estimation, approximately 2,800 landslides occurred in the last 20 years (an event rate of 114 per year).
3. The landslide event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.41. See Appendix C for a complete description of the process.

2.2.3.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Go to the USGS Landslide Overview Map of the Conterminous United States Interactive Map.
2. Find the general location of the facility/asset of interest. Hover the mouse over the facility's region to see the pop-up card that describes the landslide region designation.
3. Identify the landslide region designation of the facility/asset in Table 10 above and its associated Hazard Rating, then multiply that value by the landslide relative modifier, 0.41.

2.2.3.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for landslide events:

1. The user will select from a drop down menu the landslide region designation of their facility.
2. The THAM Tool outputs the relevant Hazard Rating based on the user entered designation by following the guidelines presented above in Table 10, which is then multiplied by the landslide relative modifier, 0.41.

2.2.4 Subsidence (Sinkhole)

2.2.4.1 Description of Hazard

Subsidence is the slow sinking and caving in of surface soil, and sinkholes, resulting from the abrupt collapse of surface soil. It is the product of a loss of subsurface through the dissolution of dissolvable rock formations, known as karst, due to rainwater. Once karst formations dissolve, the negative space below the surface cannot hold up the surface weight, thus causing a collapse. All 50 U.S. states have some level of subsidence and sinkhole hazard based on the presence of underground karst formations. Sinkholes are dependent on the rate of annual precipitation and the presence of karst. Table 11 below presents the subsidence/sinkhole Hazard Rating as a function of the existence of karst formations and the rate of annual precipitation for a particular area.[37] Again, this methodology is an estimate of the subsidence/sinkhole hazard and cannot replace the accuracy of a site-specific survey of geologic hazards.

In addition to rainfall, subsidence and sinkholes can also occur due to the over-pumping of the aquafers for human or agricultural use. While this is a known cause of subsidence, no data sources could be found to reliably predict the likelihood of subsidence occurrence due to aquafer use. Local sources can be consulted to determine if this aspect of subsidence is of concern and can be included in the Hazard Rating.

[37] National Weather Service. Advanced Hydrologic Prediction Service. http://water.weather.gov/precip/. Accessed 11/19/2015.

2.2.4.2 Rating Scale Determination

The Hazard Rating for the subsidence/sinkhole rating scale was determined using the following steps:

1. The Karst factor was obtained via the USGS (United States: Digital Map Compilation and Database).[38]
2. Annual precipitation rates were determined from the National Oceanic and Atmospheric Administration (NOAA) historical readings of annual precipitation.[39]
3. The scale of precipitation found in the U.S. (< 1 inch to over 100 inches annually) is presented in 15 annual precipitation rate groups. These precipitation rate groups were organized into the four hazard categories with more annual precipitation equating to a higher hazard level.

2.2.4.3 Hazard Rating Table

Table 11. Subsidence/Sinkhole Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Precipitation Rate and Karst Presence Range
Very High	4	Frequent	Area has reported karst formations and has an annual precipitation measurement of greater than 70 inches.
High	3	Occasional	Area has reported karst formations and has an annual precipitation measurement of 41 to 70 inches.
Moderate	2	Infrequent	Area has reported karst formations and has an annual precipitation measurement of 11 to 40 inches.
Low	1	Rare or No Documented History	Area has no reported karst formations OR Area has an annual precipitation measurement of less than or equal to 10 inches.

2.2.4.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Subsidence events are below.

1. No national database of subsidence events could be identified, so total incidence was approximated as described below
    a. The USGS reports that 35% of the U.S is susceptible to subsidence.[40] This percentage was used to determine the absolute land area of the US that is susceptible to subsidence, using the total land area of the Continental US, approximately 3,120,000 sq. mi.

[38] Weary DJ, Doctor DH. (2014) Karst in the United States: A Digital Map Compilation and Database.
[39] National Weather Service. Advanced Hydrologic Prediction Service. http://water.weather.gov/precip/. Accessed 11/19/2015.
[40] USGS. Sinkholes. https://water.usgs.gov/edu/sinkholes.html. Last Updated Dec 9, 2016. Accessed June 27, 2016.

b. A state-wide land assessment in Florida, a state with a great number of subsidence events, reported 591 subsidence events.[41]
c. A percent area of subsidence was calculated by multiplying the total number of subsidence events in Florida by the average size of a subsidence event, 3.4 m^2, and dividing that product by the total land area of Florida (following the assumption that all land in Florida is susceptible to landslides).[42] This percentage was significantly less than 1% (1.45×10^{-6} %).
d. Assuming that the calculated rate of subsidence in Florida is comparable to the entirety of the subsidence-susceptible US land, the percent area of subsidence was multiplied by the subsidence-susceptible area of the US, and the resulting product was divided by the average area of a subsidence event to produce the national number of subsidence events.

2. Using the described estimation process, approximately 12,000 subsidence events occurred in the last 20 years (an event rate of 601 per year).
3. The subsidence event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.55. See Appendix C for a complete description of the process.

2.2.4.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's subsidence/sinkhole Hazard Rating:

1. Download the USGS karst formation map.
    a. The map can be downloaded directly as a .zip file, or can be found in the PDF Report on page 9. Selecting Figure 1 on page 9 will load a larger, higher resolution version of the map found in the document.
2. Determine if the location of the facility/asset is located in an area of karst.
    a. If the facility/asset is not in an area with karst formation, it is assumed that the facility/asset has a low hazard category with a rating of 1, and multiply by the subsidence relative modifier, 0.6.
3. If the facility's/asset's location coincides with a karst formation, determine the facility/asset surrounding area's average annual precipitation over the last 5 years from the Advanced Hydrologic Prediction Service.
    a. The Advanced Hydrologic Prediction Service reports precipitation annually; determine the annual precipitation for the last five years and take the average.
4. Find the closest annual precipitation in inches value in Table 11 and its associated Hazard Rating. Multiply this value by the subsidence relative modifier, 0.55.

2.2.4.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for subsidence events:

1. The user will first determine if their facility resides in an area that has geologic karst formations.
2. If the facility is located in a region with geologic karst, the user will then enter their average rainfall into the THAM Tool.

[41] Florida Department of Environmental Protection. Florida's Sinkholes. https://www.dep.state.fl.us/geology/geologictopics/sinkhole/florida_sinkhole_poster.pdf. Last Updated 2004. Accessed June 28, 2017.
[42] Zisman E. (2003) Sinkhole size. In *Sinkholes and the Engineering and Environmental Impacts of Karst*. 131-140.

3. The Tool outputs a Hazard Rating using the guidelines above in Table 11, and multiply by the subsidence relative modifier, 0.55.

2.2.5 Volcano

2.2.5.1 Description of Hazard

Volcanoes represent a class of hazard that is very difficult to predict, yet capable of producing extremely catastrophic impacts. Volcanic eruptions are not generally spontaneous; several geological indicators, such as seismic activity near the location of the volcano, can indicate activity and the potential for eruptions. Unfortunately, accurately determining the size and precise time of the eruption is difficult and inexact. Thus, the most representative indication of the hazard a volcanic eruption presents is based not on the historic activity of a particular volcano, but rather proximity to a volcano. Explosive volcanic eruptions can produce ash and sulfur dioxide clouds that can traverse continents, quick moving and destructive landslides, as well as damaging lava flows. The scale below relates the distance from an active volcano to a Hazard Rating based on the furthest reaching volcanic eruption hazard, the ash plume.

It should be noted that since this hazard scale is based on ash clouds, the scale below may not be precise or accurate for Hawaiian volcanic eruptions. Hawaiian volcanoes are generally not explosive and do not produce ash clouds. For a more accurate Hazard Rating for the Hawaiian Islands, please refer to local information sources on volcanic hazards such as the Hawaiian Volcano Observatory.[43]

2.2.5.2 Rating Scale Determination

The Hazard Rating scale for volcanic eruptions was determined using the following steps:

1. One of the largest and most well documented volcanic eruptions in the U.S. was the Mount St. Helens volcano eruption, occurring in 1980 in the State of Washington. The eruption generated an ash plume that caused blacked-out conditions in Spokane, Washington, 250 miles away, and major ash falls in central Montana approximately 600 miles from the point of eruption.[44] The major ash fall in central Montana represents the maximal distance (600 miles) that could reasonably be assumed to be affected by a volcanic eruption and represents a Hazard Rating of 1.
2. Lava flows represent the volcanic hazard component with the smallest range of impact, usually flowing for only 10 to 50 kilometers from the vent.[45,46] Thus, 10 kilometers, or 6 miles, represents the maximum Hazard Rating for volcanic eruptions as the probability of experiencing more than one impact from a volcanic eruption increases as you move closer to the eruption's epicenter.
3. The scale was then generated from 6 to 600 miles using a 0.05 increment, rounded to the nearest whole mile.

[43] United States Geological Survey. Volcanic Hazards on the Island of Hawai'i. http://hvo.wr.usgs.gov/hazards/. Accessed 11/19/2015.
[44] United States Geological Survey. Mount St. Helens - 1980 Cataclysmic Eruption. http://volcanoes.usgs.gov/volcanoes/st_helens/st_helens_geo_hist_99.html. Accessed 1/4/2015.
[45] United States Geological Survey. Volcanic Hazards on the Island of Hawai'i. http://hvo.wr.usgs.gov/hazards/. Accessed 11/19/2015.
[46] Trusdell FA. "Mauna Loa - History, Hazards, and Risk of Living With the World's Largest Volcano," USGS Fact Sheet. http://pubs.usgs.gov/fs/2012/3104/fs2012-3104.pdf. Accessed 11/19/2015.

2.2.5.3 Hazard Rating Table

Table 12. Volcano Hazard Ratings.

Rating Category	Hazard Rating	Proximity of Nearest Volcano
Very High	4	Facility/asset is 154 miles or less from a volcano.
High	3	Facility/asset is between 155 and 302 miles from a volcano.
Moderate	2	Facility/asset is between 303 and 451 miles from a volcano.
Low	1	Facility/asset is 452 miles or more from a volcano.

2.2.5.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Volcano events are below.

1. The U.S. Volcano Hazards Program, curated by the USGS, reports 70 volcanic eruptions in the past 20 years in the US (an event rate of 4 per year).[47]
2. The Volcano event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.11. See Appendix C for a complete description of the process.

2.2.5.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Go to the U.S. Volcano Hazards Program, curated by the USGS, to determine what volcano(s) are of interest to the facility/asset in question.
    a. When determining volcanos of interest include all classifications of volcanos, regardless of alert or activity levels. This means that historically inactive volcanos are included in this hazards assessment. This is due to the unpredictability of volcanic activity. Any of these historically inactive volcanoes could eventually develop activity.
2. Select the volcano that is closest to the facility's/asset's location.
    a. Distance from the volcano to the facility/asset can be determined using a mapping utility such as Google Maps.
    b. Enter the name of the volcano of interest or the latitude and longitude reported by the USGS on the volcano's page that is linked in the map into the Google Maps search bar.
    c. Right click the dropped pin and select the option of "Measure Distance."
    d. Click on the location of the facility/asset to determine the distance from the volcano of interest.
3. Using the steps described in 2.a through 2.d, determine the distance from the closest volcano to the facility/asset of interest.

[47] USGS, 2017. Volcano Hazards Program. http://volcanoes.usgs.gov/ Accessed 8/2/2015.

4. Find the Hazard Rating associated with the distance found in Step 3 in Table 12 above then multiply the identified Hazard Rating by the volcano relative modifier, 0.11.

2.2.5.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for Volcano events:

1. The user will enter the latitude and longitude of the facility in the Facility Characterization page of the Tool.
2. On the Volcano hazard page, the user will identify the closest volcano following the directions presented above or presented in the Tool itself and enter the latitude and longitude of the identified volcano.
3. The tool then calculates the distance between the two user-entered latitude and longitudes and outputs a Hazard Rating using the guidelines above in Table 12 which is then multiplied by the volcano relative modifier, 0.11.

2.3 Natural Hazards (Meteorological)

2.3.1 Damaging Winds

2.3.1.1 Description of Hazard

Damaging winds, as captured in this methodology, consist of winds of 35 knots (approximately 40 mph) or greater sustained for at least one hour, or 50 knots (approximately 58 mph) for any duration. High winds have the potential to cause structural damage and electricity blackouts through downed power lines. The data necessary for calculating the probability of Damaging Winds is located in the National Oceanic and Atmospheric Administration (NOAA) Satellite and Information Service Center's severe weather extremes database. This database maintains three damaging high wind categories that contain events that fulfill the above definition: strong winds, thunderstorm winds, and dust storms.

2.3.1.2 Rating Scale Determination

The Hazard Rating scale for damaging winds was determined using the following steps:

1. The NOAA Storm Events Database was used to determine the number of high wind *episodes*, including thunderstorm winds and dust storms, occurring in the past 20 years in each county within the continental U.S. [48]
2. A Hazard Rating of 4 was set at the 98th percentile county, which corresponded to 205 damaging wind episodes in a 20-year span.
3. The remainder of the Hazard Rating scaled was derived from linear interpolation from 205 to zero.

[48] National Oceanic and Atmospheric Administration. Storm Events Database. http://www.ncdc.noaa.gov/stormevents/. Accessed 8/2/2015.

2.3.1.3 Hazard Rating Table

Table 13. Damaging Wind Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	157 or more damaging wind episodes in the past twenty years in the county where the facility/asset is located.
High	3	Occasional	108 to 156 damaging wind episodes in the past twenty years in the county where the facility/asset is located.
Moderate	2	Infrequent	60 to 107 damaging wind episodes in the past twenty years in the county where the facility/asset is located.
Low	1	Rare or No Documented History	59 or fewer damaging wind episodes in the past twenty years in the county where the facility/asset is located.

2.3.1.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Damaging Wind events are below.

1. In the past 20 years 111,756 damaging wind episodes were reported in the NOAA storm events database (an event rate of 5,588 per year).[49]
2. The damaging wind event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.74. See Appendix C for a complete description of the process.

2.3.1.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of damaging wind *episodes* in the past 20 years for the state and county in which the facility/asset is located using the NOAA Storm Events Database.
    a. Count the number of high wind episodes, thunderstorm winds, and dust storms that occurred in the past 20 years in the county in which the facility/asset is located.
    b. Sum these three categories of wind episodes to determine a final damaging wind tally for the county in which the facility/asset is located.
2. Identify the Hazard Rating from the number of damaging wind episodes found using Table 13 above, then multiply by the damaging winds relative modifier, 0.74.

[49] Ibid.

2.3.1.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for damaging wind episodes:

1. The Tool automatically looks up the number of damaging wind episodes based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 13 which is then multiplied by the damaging winds relative modifier, 0.74.

2.3.2 Drought

2.3.2.1 Description of Hazard

Droughts occur when an area does not receive the expected amount of precipitation. Severe droughts can cause water restrictions and crop losses. The above hazard scale is based off of historical drought data from 2011 to the present that is maintained in the U.S. Drought Monitor that reports the number of weeks a location experiences a drought. The data is restricted to impactful droughts of level D2 or higher. The greater the incidence of historical droughts, the larger the Hazard Rating.

2.3.2.2 Rating Scale Determination

The Hazard Rating scale for drought was determined using the following steps:

1. The U.S. Drought Monitor was used to determine the number of weeks of a level D2 drought or higher occurring in the past 5 years in each county within the U.S. A Hazard Rating of 4 was set at the 98th percentile county, which corresponded to 406 weeks of a D2 drought or higher in a 5-year span. [50]
2. The remainder of the Hazard Rating scaled was derived from linear interpolation from 406 to zero.

2.3.2.3 Hazard Rating Table

Table 14. Severe-Exceptional (Category D2-D4) Drought Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	214 or more weeks at a D2 or higher drought level in the past five years in the immediate area where the facility/asset is located.
High	3	Occasional	213 to 309 weeks at a D2 or higher drought level in the past five years in the immediate area where the facility/asset is located.
Moderate	2	Infrequent	117 to 213 weeks at a D2 or higher drought level in the past five years in the immediate area where the facility/asset is located.

[50] National Drought Mitigation Center USDoA, National Oceanic and Atmospheric Association. United States Drought Monitor. http://droughtmonitor.unl.edu. Last Updated 2016. Accessed 05/01/2016.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Low	1	Rare or No Documented History	116 or fewer weeks at a D2 or higher drought level in the past five years in the immediate area where the facility/asset is located.

2.3.2.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of drought events are below.

1. In the past 5 years, 4,162 instances of a level D2 drought or higher were reported in the United States Drought Monitor (an event rate of 832 per year). [51]
2. The drought event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.58. See Appendix C for a complete description of the process.

2.3.2.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of drought events in the past 16 years for the state and county in which the facility/asset is located using the US Drought Monitor.
    a. Select the category "Maps and Data Services" under the "Maps and Data" tab in the banner along the top of the website. From this new screen, select Statistical Data, then select Basic Statistics.
    b. Select County from the "Spatial Scale" dropdown.
    c. Adjust the start date to encompass the most recent five years.
    d. Select the appropriate county from the list and hit the Submit button above to generate a CSV file of the data.
2. Identify the Hazard Rating from the number of drought weeks at a drought level of D2 or higher using Table 14 above, then multiply by the drought relative modifier, 0.58.

2.3.2.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for drought events:

1. The Tool automatically looks up the number of drought events based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 14 which is then multiplied by the drought relative modifier, 0.58.

[51] Ibid.

2.3.3 Flash Floods

2.3.3.1 Description of Hazard

Flash floods, or high flowing water or inundation that begins within 6 hours of heavy rainfall, can occur anywhere in the U.S. Similarly to floods, a flash flood has the potential to cause damage or injury and generally occurs around existing water sources including coastlines. The NOAA Storm Events Database maintains data on flash flooding events from 1996 to the present and contains the data necessary to calculate the probability of flash flood events. Additional data may be found through the USGS Flood Inundation Mapping program. Furthermore, local sources may provide a more complete source of data, and, if available, should be used preferentially.

2.3.3.2 Rating Scale Determination

The Hazard Rating scale for flash floods was determined using the following steps:

1. The NOAA Storm Events Database was used to determine the number of flash flood *episodes* occurring in the past 20 years in each county within the continental U.S. [52]
2. A Hazard Rating of 4 was set at the 98th percentile county, which corresponded to 69 flash flood episodes in a 20-year span.
3. The remainder of the Hazard Rating scaled was derived from linear interpolation from 69 to zero.

2.3.3.3 Hazard Rating Table

Table 15. Flash Flood Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	54 or more flash floods in the past twenty years in the county where the facility/asset is located.
High	3	Occasional	37 to 53 flash floods in the past twenty years in the county where the facility/asset is located.
Moderate	2	Infrequent	21 to 36 flash floods in the past twenty years in the county where the facility/asset is located.
Low	1	Rare or No Documented History	20 or fewer flash floods in the past twenty years in the county where the facility/asset is located.

2.3.3.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having

[52] National Oceanic and Atmospheric Administration. Storm Events Database. http://www.ncdc.noaa.gov/stormevents/. Accessed 8/2/2015.

a relative modifier of 0.1. The steps and data used to determine the relative modifier of flash flood events are below.

1. In the past 20 years, 31,284 flash flood episodes were reported in the NOAA storm events database (an event rate of 1,564 per year).[53]
2. The flash flood event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.63. See Appendix C for a complete description of the process.

2.3.3.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of flash flood episodes in the past 20 years for the state and county in which the facility/asset is located using the NOAA Storm Events Database.
2. Identify the Hazard Rating from the number of flash flood episodes found using Table 15 above, then multiply the hazard rating by the flash flood relative modifier, 0.63.

2.3.3.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for flash flood events:

1. The Tool automatically looks up the number of flash flood episodes based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 15 which is then multiplied by the flash flood relative modifier, 0.63.

2.3.4 Floods

2.3.4.1 Description of Hazard

A flood is any high flowing or inundation of water that causes or has the potential to cause damage or injury. Flooding is generally due to rises in existing water sources, such as rivers and other watercourses, due to a causative event such as heavy rainfall. The hazard assessed in this methodology also includes coastal and lakeshore flooding. The data necessary for calculating the probability of flooding is located in the NOAA Satellite and Information Service Center's severe weather extremes database. Additional data may be found through the USGS Flood Inundation Mapping program. Furthermore, local sources may provide a more complete source of data, and, if available, should be used preferentially.

2.3.4.2 Rating Scale Determination

The Hazard Rating scale for floods was determined using the following steps:

1. The NOAA Storm Events Database was used to determine the number of flood *episodes*, including coastal and lakeshore floods, occurring in the past 20 years in each county within the continental U.S.[54]

[53] Ibid.
[54] Ibid.

2. A hazard Rating of 4 was set at the 98th percentile county, which corresponded to 70 flood episodes in a 20-year span.
3. The remainder of the Hazard Rating scaled was derived from linear interpolation from 70 to zero.

2.3.4.3 Hazard Rating Table

Table 16. Floods Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	54 or more floods in the past twenty years in the county where the facility/asset is located.
High	3	Occasional	38 to 53 floods in the past twenty years in the county where the facility/asset is located.
Moderate	2	Infrequent	21 to 37 floods in the past twenty years in the county where the facility/asset is located.
Low	1	Rare or No Documented History	20 or fewer floods in the past twenty years in the county where the facility/asset is located.

2.3.4.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of flood events are below.

1. In the past 20 years, 17,784 flood episodes were reported in the NOAA storm events database (an event rate of 889 per year).[55]
2. The flood event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.59. See Appendix C for a complete description of the process.

2.3.4.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of flood episodes, including coastal and lakeshore floods, occurring in the past 20 years for the state and county in which the facility/asset is located using the NOAA Storm Events Database.
    a. Count the number of floods, coastal floods, and lakeshore floods that occurred in the past 20 years in the county in which the facility/asset is located.
    b. Sum these three categories of flood to determine a final flood tally for the county in which the facility/asset is located.

[55] Ibid.

2. Identify the Hazard Rating from the number of flood episodes found using Table 16 above, then multiply the hazard rating by the flood relative modifier, 0.59.

2.3.4.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for flood events:

1. The Tool automatically looks up the number of flood events based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 16 which is then multiplied by the flood relative modifier, 0.59.

2.3.5 Hail

2.3.5.1 Description of Hazard

Hail generated by a thunderstorm can be life threatening and incur thousands of dollars of damage. Severe thunderstorms are capable of producing damaging hail, but it is not possible to accurately predict when storms will produce hail or how damaging the hail storm will be. Thus, the best representative predictor of future hail storms is a history of hail incidents. The NOAA Storm Events Database contains data from 1955 to the present on hail storms and is the foundation of the hazard scale provided below.

2.3.5.2 Rating Scale Determination

The Hazard Rating scale for hail was determined using the following steps:

1. The NOAA Storm Events Database was used to determine the number of hail *episodes* (≥ 0.75" in diameter) occurring in the past 20 years in each county within the continental U.S. [56]
2. A Hazard Rating of 4 was set at the 98th percentile county, which corresponded to 150 hail storms in a 20-year span.
3. The remainder of the Hazard Rating scaled was derived from linear interpolation from 150 to zero.

2.3.5.3 Hazard Rating Table

Table 17. Hail Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	115 or more qualifying hail episodes in the past twenty years in the county where the facility/asset is located.
High	3	Occasional	80 to 114 qualifying hail episodes in the past twenty years in the county where the facility/asset is located.
Moderate	2	Infrequent	44 to 79 qualifying hail episodes in the past twenty years in the county where the facility/asset is located.

[56] Ibid.

Rating	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Low	1	Rare or No Documented History	43 or fewer qualifying hail episodes in the past twenty years in the county where the facility/asset is located.

2.3.5.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of hail events are below.

1. In the past 20 years, 86,289 hail episodes were reported in the NOAA storm events database (an event rate of 4,314 per year).[57]
2. The hail event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.72. See Appendix C for a complete description of the process.

2.3.5.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of hail episodes in the past 20 years for the state and county in which the facility/asset is located using the NOAA Storm Events Database. Hail episodes can be filtered by size of the hail stones; only hail greater than or equal to 0.75" in diameter shall be included.
2. Identify the Hazard Rating from the number of hail episodes found using Table 17 above, then multiply this value by the hail relative modifier, 0.72.

2.3.5.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for hail events:

1. The Tool automatically looks up the number of hail events based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 17 which is then multiplied by the hail relative modifier, 0.72.

2.3.6 Ice Storm

2.3.6.1 Description of Hazard

Ice storms are defined as an accumulation of ice of ¼" or greater during a freezing rain event. The accumulation of ice can disrupt transportation and bring down electrical wires or trees. The data necessary to determine the probability of ice storms is maintained in the NOAA Satellite and Information Service

[57] Ibid.

Center's severe weather extremes database. Furthermore, local sources may provide a more complete source of data, and, if available, should be used preferentially.

2.3.6.2 Rating Scale Determination

The Hazard Rating scale for ice was determined using the following steps:

1. The NOAA Storm Events Database was used to determine the number of ice storm *episodes* (≥ .25") occurring in the past 20 years in each county within the continental U.S. [58]
2. A Hazard Rating of 4 was set at the 98th percentile county, which corresponded to eleven ice storms in a 20-year span.
3. The remainder of the Hazard Rating scaled was derived from linear interpolation from 11 to zero.

2.3.6.3 Hazard Rating Table

Table 18. Ice Storm Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	9 or more ice storms in the past twenty years in the county where the facility/asset is located.
High	3	Occasional	7 to 8 ice storms in the past twenty years in the county where the facility/asset is located.
Moderate	2	Infrequent	4 to 6 ice storms in the past twenty years in the county where the facility/asset is located.
Low	1	Rare or No Documented History	0 to 3 ice storms in the past twenty years in the county where the facility/asset is located.

2.3.6.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Ice Storm events are below.

1. In the past 20 years, 1,568 ice storm episodes were reported in the NOAA storm events database (an event rate of 78 per year).[59]
2. The ice storm event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.38. See Appendix C for a complete description of the process.

[58] Ibid.
[59] Ibid.

2.3.6.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of ice storm episodes in the past 20 years for the state and county in which the facility/asset is located using the NOAA Storm Events Database.
2. Identify the Hazard Rating from the number of ice storm episodes found using Table 18 above. Multiply the hazard rating by the ice storm relative modifier, 0.38.

2.3.6.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for ice storm events:

1. The Tool automatically looks up the number of ice storm events based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 18 which is then multiplied by the ice storm relative modifier, 0.38.

2.3.7 Snow Fall/Blizzard

2.3.7.1 Description of Hazard

Heavy snow has the potential to disrupt travel and transportation, cause structural damage to buildings, and cause injuries or fatalities. Heavy snow can come from any snow-producing storm, and includes lake-effect snow and blizzards (snow storms with high winds and reduced visibility). The data necessary for calculating the probability of snow is located in NOAA Satellite and Information Service Center's severe weather extremes database.

2.3.7.2 Rating Scale Determination

The Hazard Rating scale for snowfall/blizzards was determined using the following steps:

1. The NOAA Storm Events Database was used to determine the number of blizzard, heavy snow, and lake effect snow *episodes* occurring in the past 20 years in each county within the continental U.S. [60]
2. A Hazard Rating of 4 was set at the 98th percentile county, which corresponded to 147 snow episodes in a 20-year span.
3. The remainder of the Hazard Rating scaled was derived from linear interpolation from 147 to zero.

[60] Ibid.

2.3.7.3 Hazard Rating Table

Table 19. Snow Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	113 or more qualifying snow episodes in the past twenty years in the county where the facility/asset is located.
High	3	Occasional	78 to 112 qualifying snow episodes in the past twenty years in the county where the facility/asset is located.
Moderate	2	Infrequent	43 to 77 qualifying snow episodes in the past twenty years in the county where the facility/asset is located.
Low	1	Rare or No Documented History	42 or fewer qualifying snow episodes in the past twenty years in the county where the facility/asset is located.

2.3.7.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Snow events are below.

1. In the past 20 years, 15,746 snow episodes were reported in the NOAA storm events database (an event rate of 787 per year).[61]
2. The snow event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.57. See Appendix C for a complete description of the process.

2.3.7.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of blizzard, heavy snow, and lake effect snow episodes in the past 20 years for the state and county in which the facility/asset is located using the NOAA Storm Events Database.
    a. Count the number of blizzard, heavy snow, and lake effect snow episodes that occurred in the past 20 years in the county in which the facility/asset is located.
    b. Sum these three categories of snow events to determine a final snow fall/blizzard tally for the county in which the facility/asset is located.
2. Identify the Hazard Rating from the number of snow fall/blizzard episodes found using Table 19 above. Multiply the Hazard Rating by the snow relative modifier, 0.57.

[61] Ibid.

2.3.7.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for snow fall/blizzard events:

1. The Tool automatically looks up the number of snow fall/blizzard events based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 19 which is then multiplied by the snow relative modifier, 0.57.

2.3.8 Storm Surge

2.3.8.1 Description of Hazard

A storm surge occurs when a large rise in water is generated by a storm of tropical origin such as hurricanes, typhoons, or tropical storms. These high water events generally flood coastal regions and cause significant damage, although storm surges can occur in lakeshore areas as well. In the U.S., storm surges are associated with the coastal areas that experience hurricanes such as the southern Atlantic coast, although any body of water near a major ocean (e.g. Great Lakes) has the potential for storm surge events. The data necessary to calculate the probability of a storm surge event is located in the NOAA Storm Events Database.

2.3.8.2 Rating Scale Determination

The Hazard Rating scale for storm surge was determined using the following steps:

1. The NOAA Storm Events Database was used to determine the number of storm surge *episodes* occurring in the past 20 years in each county within the continental U.S. [62]
2. A Hazard Rating of 4 was set at the 98th percentile county, which corresponded to 5 storm surge episodes in a 20-year span.
3. The remainder of the Hazard Rating scaled was derived from linear interpolation from 5 to zero.

2.3.8.3 Hazard Rating Table

Table 20. Storm Surge Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	5 or more storm surge episodes in the past twenty years in the county where the facility/asset is located.
High	3	Occasional	4 storm surge episodes in the past twenty years in the county where the facility/asset is located.
Moderate	2	Infrequent	2 to 3 storm surge episodes in the past twenty years in the county where the facility/asset is located.
Low	1	Rare or No Documented History	0 or 1 storm surge episodes in the past twenty years in the county where the facility/asset is located.

[62] Ibid.

2.3.8.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Storm Surge events are below.

1. In the past 20 years, 383 storm surge episodes were reported in the NOAA storm events database (an event rate of 19 per year).[63]
2. The storm surge event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.25. See Appendix C for a complete description of the process.

2.3.8.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's Hazard Rating:

1. Identify the number of storm surge events in the past 20 years for the state and county in which the facility is located using the NOAA Storm Events Database.
2. Identify the Hazard Rating from the number of storm surge events found using Table 20 above, then multiply the hazard rating by the storm surge relative modifier, 0.25.

2.3.8.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for storm surge events:

1. The Tool automatically looks up the number of storm surge events based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 20 which is then multiplied by the storm surge relative modifier, 0.25.

2.3.9 Tornado

2.3.9.1 Description of Hazard

Tornados are a rotating column of air moving from 40 to upwards of 250 miles per hour. Tornados are capable of extreme destruction and can be generated anywhere if the weather conditions permit their formation. Severe thunderstorms can generate wind and weather conditions that promote cyclonic wind movement that could potentially progress to tornado formation. However, severe thunderstorm events do not guarantee tornado formation. In fact it is very hard to determine when severe thunderstorms will generate a tornado. Additionally, tornado formation occurs very rapidly. These components make predicting tornado weather events almost impossible. Due to the imprecise nature of predicting tornados, the frequency with which they form is the greatest predictor of future tornado events. Thus, the hazard scale presented below is based on the number of tornado events an area experiences; the more tornado

[63] Ibid.

events in an area, the greater the Hazard Rating. The data necessary for calculating the probability of thunderstorms is located in the NOAA Storm Events Database.

2.3.9.2 Rating Scale Determination

The Hazard Rating scale for tornados was determined using the following steps:

1. The NOAA Storm Events Database was used to determine the number of tornado *episodes* (of all strengths) occurring in the past 20 years in each county within the continental United States. [64]
2. A Hazard Rating of 4 was set at the 98th percentile county, which corresponded to 24 tornados in a 20-year span.
3. The remainder of the Hazard Rating scaled was derived from linear interpolation from 24 to zero.

2.3.9.3 Hazard Rating Table

Table 21. Tornado Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	19 or more tornados in the past twenty years in the county where the facility/asset is located.
High	3	Occasional	14 to 18 tornados in the past twenty years in the county where the facility/asset is located.
Moderate	2	Infrequent	8 to 13 tornados in the past twenty years in the county where the facility/asset is located.
Low	1	Rare or No Documented History	7 or fewer tornados in the past twenty years in the county where the facility/asset is located.

2.3.9.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of tornado events are below.

1. In the past 20 years, 14,238 tornado episodes were reported in the NOAA storm events database (an event rate of 712 per year).[65]
2. The tornado event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.57. See Appendix C for a complete description of the process.

[64] Ibid.
[65] Ibid.

2.3.9.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of tornado events in the past 20 years for the state and county in which the facility/asset is located using the NOAA Storm Events Database.
2. Identify the Hazard Rating from the number of tornado events found using Table 21 above. Multiply the identified hazard rating by the tornado relative modifier, 0.57.

2.3.9.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for tornado events:

1. The Tool automatically looks up the number of tornado events based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 21 which is then multiplied by the tornado relative modifier, 0.57.

2.3.10 Wildfire

2.3.10.1 Description of Hazard

Wildfires include any significant fire in natural land, including grasslands, forests, or rangelands, as well as wildland-urban interface fires. A significant wildfire is one that causes property damage or human injuries or fatalities. The data necessary for calculating the probability of Wildfires is located in the NOAA Satellite and Information Service Center's severe weather extremes database.[66] Forest fires smaller than 100 acres and rangeland or grassland fires smaller than 300 acres generally are not included in this database. Furthermore, local sources may provide a more complete source of data, and, if available, should be used preferentially.

2.3.10.2 Rating Scale Determination

The Hazard Rating scale for wildfires was determined using the following steps:

1. The NOAA Storm Events Database was used to determine the number of wildfire *episodes* occurring in the past 20 years in each county within the continental U.S. [67]
2. A Hazard Rating of 4 was set at the 98th percentile county, which corresponded to 23 wildfires in a 20-year span.
3. The remainder of the Hazard Rating scaled was derived from linear interpolation from 23 to zero.

[66] Ibid.
[67] Ibid.

2.3.10.3 Hazard Rating Table

Table 22. Wildfire Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	19 or more wildfires in the past twenty years in the county where the facility/asset is located.
High	3	Occasional	13 to 18 wildfires in the past twenty years in the county where the facility/asset is located.
Moderate	2	Infrequent	8 to 12 wildfires in the past twenty years in the county where the facility/asset is located.
Low	1	Rare or No Documented History	7 or fewer wildfires in the past twenty years in the county where the facility/asset is located.

2.3.10.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of wildfire events are below.

1. In the past 20 years, 4,514 wildfire episodes were reported in the NOAA storm events database (an event rate of 226 per year).[68]
2. The wildfire event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.47. See Appendix C for a complete description of the process.

2.3.10.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of wildfire events in the past 20 years for the state and county in which the facility/asset is located using the NOAA Storm Events Database.
2. Identify the Hazard Rating from the number of wildfire events found using Table 22 above, and then multiply the identified hazard rating by the wildfire relative modifier, 0.47.

2.3.10.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for wildfire events:

1. The Tool automatically looks up the number of wildfire events based on the county selected by the user on the Facility Characterization page.

[68] Ibid.

2. The Tool outputs a Hazard Rating using the guidelines above in Table 22 which is then multiplied by the wildfire relative modifier, 0.47.

2.3.11 Extreme Heat

2.3.11.1 Description of Hazard

Extreme heat can have dangerous health consequences, especially in children, the elderly, and people with chronic medical conditions. Facilities/assets located in areas that experience frequent high temperatures may be at risk of a reduced workforce or productivity during heat waves. Additionally, high temperatures can impact systems and infrastructure. Cooling systems, including HVAC systems and cold storage of biologicals and other sensitive materials, will be challenged and may fail during extreme high temperature events. Transportation systems, including roads and rail systems, can also be disrupted by long periods of high heat. The National Weather Service issues heat advisories for dangerously hot conditions when the heat index is greater than 100°F. [69] A temperature of 95°F with humidity greater than 40% corresponds to a heat index of 100°F.[70] Since the majority of the U.S. experiences humidity levels greater than 40% during the summertime, 95°F is used to define the threshold for extreme heat. To characterize the threat of extreme heat, locations are assessed for the average number of days exceeding 95°F per year.

2.3.11.2 Rating Scale Determination

The Hazard Rating scale for extreme heat was determined using the following steps:

1. Historical daily temperature data was downloaded from the NOAA National Centers for Environmental Information.[71] The daily high and low temperatures for all weather stations in the U.S. were collected for the period 5/1/2007 through 4/30/2016.
2. For each weather station with greater than 1,800 records, the number of days exceeding 95°F were counted, and divided by the number of years reported by the station.
3. A Hazard Rating of 4 was set to the 98th percentile of all weather stations assessed, which corresponded to an average of 96 days per year above 95°F.
4. The remainder of the Hazard Rating scaled was derived from linear interpolation from 96 to zero.

2.3.11.3 Hazard Rating Table

Table 23. Extreme Heat Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	An average of more than 77 days per year that reach above 95°F in the immediate area where the facility/asset is located.
High	3	Occasional	An average of 53 to76 days per year that reach above 95°F in the immediate area where the facility/asset is located.

[69] National Weather Service. Heat Watch vs. Warning. http://www.nws.noaa.gov/os/heat/ww.shtml. Accessed January 2016.

[70] National Weather Service. Meteorological Conversions and Calculations. http://www.wpc.ncep.noaa.gov/html/heatindex.shtml. Last Updated January 30, 2015. Accessed January 2016.

[71] National Oceanic and Atmospheric Administration. Climate Data Online: Dataset Discovery. http://www.ncdc.noaa.gov/cdo-web/datasets. Accessed 11/8/2015.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Moderate	2	Infrequent	An average of 30 to 52 days per year that reach above 95°F in the immediate area where the facility/asset is located.
Low	1	Rare or No Documented History	An average of 29 or fewer days per year that reach above 95°F in the immediate area where the facility/asset is located.

2.3.11.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of extreme heat events are below.

1. In the past 9.4 years, 3,239 incidences occurred of a weather station in the United States reporting a temperature greater than 95°F based on data from the NOAA National Centers for Environmental Information database (an event rate of 345 per year).[72]
2. The extreme heat event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.50. See Appendix C for a complete description of the process.

2.3.11.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's extreme heat Hazard Rating. This method can be used to collect data on extreme heat and cold simultaneously, although two separate Hazard Ratings should be calculated.

1. Visit the NOAA National Centers for Environmental Information.
2. Select the Daily Summaries dataset based on the county or zip code of the facility/asset.
3. Select a weather station that provides temperature data and includes recent data. If multiple stations are available, select the station that has records spanning the longest period of time while still covering recent data. Once the station is chosen select the "Add to Cart" button.
    a. It should be noted, that even though this websites requests that you put your selection in a cart, the website and data is free.
4. Download daily weather data as a CSV file for the most recent full year period (or longer, preferably a minimum of 5 years), if available. Select the "Continue" button, enter the email address at which the data can be sent to, and select the "Submit Order" button.
5. From the data file received, count the number of days that exceeded 95°F. Divide this by the number of years included in the dataset.
6. Match the number of days per year above 95°F to the Hazard Rating in Table 23 above. Multiply the hazard rating by the extreme heat relative modifier, 0.50.

[72] Ibid.

2.3.11.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for extreme heat events:

1. The Tool locates the nearest weather station based on the user-input facility latitude and longitude on the Facility Characterization page.
2. After the Tool identifies the closest weather station, it automatically pulls the number of extreme heat events.
3. The Tool outputs a Hazard Rating using the guidelines above in Table 23 which is then multiplied by the extreme heat relative modifier, 0.50.

2.3.12 Extreme Cold

2.3.12.1 Description of Hazard

Freezing temperatures can have a number of impacts on health and infrastructure. Besides the dangerous health affects people may suffer, including hypothermia and frost bite, frozen surfaces can cause dangerous falls and accidents. Additionally, freezing temperatures can impact systems and infrastructure. Transportation systems may be disrupted by extremely low temperatures. Facilities in regions with long cold spells are also more vulnerable to fuel shortages, as fuels are needed to provide heat both for human safety and to keep equipment functioning properly. To characterize the threat of extreme heat, locations are assessed for the average number of days where the temperature drops below 32°F per year, the same standard of extreme cold used by the New York City Panel on Climate Change. [73]

2.3.12.2 Rating Scale Determination

The Hazard Rating scale for extreme cold was determined using the following steps:

1. Historical daily temperature data was downloaded from the NOAA National Centers for Environmental Information.[74] The daily high and low temperatures for all weather stations in the U.S. were collected for the period 5/1/2007 through 4/30/2015.
2. For each weather station with greater than 1,500 records, the number of days below 32°F were counted, and divided by the number of years reported by the station.
3. A Hazard Rating of 4 was set to the 98th percentile of all weather stations assessed, which corresponded to an average of 217 days per year below 32°F.
4. The remainder of the Hazard Rating scaled was derived from linear interpolation from 217 to zero.

[73] NYC Panel on Climate Change. Climate Risk Information 2013: Observations, Climate Change Projections, and Maps. http://www.nyc.gov/html/planyc2030/downloads/pdf/npcc_climate_risk_information_2013_report.pdf. Last Updated June 2013. Accessed 1/4/2015.

[74] National Oceanic and Atmospheric Administration. Climate Data Online: Dataset Discovery. http://www.ncdc.noaa.gov/cdo-web/datasets. Accessed 11/18/2015.

2.3.12.3 Hazard Rating Table

Table 24. Extreme Cold Hazard Ratings.

Rating Category	Category Rating Range	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	An average of 167 days or more per year that reach below 32°F in the immediate area where the facility/asset is located.
High	3	Occasional	An average of 115 to 166 days per year that reach below 32°F in the immediate area where the facility/asset is located.
Moderate	2	Infrequent	An average of 63 to 114 days per year that reach below 32°F in the immediate area where the facility/asset is located.
Low	1	Rare or No Documented History	An average of 62 days or fewer that reach below 32°F in the immediate area where the facility/asset is located.

2.3.12.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of extreme cold events are below.

1. In the past 9.4 years, 2,079 incidences occurred where a weather station in the United States reported a temperature less than 32°F based on data in the NOAA National Centers for Environmental Information database (an event rate of 221 per year).[75]
2. The extreme cold event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.47. See Appendix C for a complete description of the process.

2.3.12.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's extreme cold Hazard Rating. This method can be used to collect data on extreme heat and cold simultaneously, although two separate Hazard Ratings should be calculated.

1. Visit the NOAA National Centers for Environmental Information.
2. Select the Daily Summaries dataset based on the county or zip code of the facility/asset.
3. Select a weather station that provides temperature data and includes recent data. If multiple stations are available, select the station that has records spanning the longest period of time while still covering recent data. Once the station is chosen select the "Add to Cart" button.
    a. It should be noted, that even though this websites requests that you put your selection in a cart, access to the website and data is free.
4. Download daily weather data as a CSV file for the most recent full year period (or longer, preferably a minimum of 5 years). Select the "Continue" button, enter the email address at which the data can be sent to, and select the "Submit Order" button.

[75] Ibid.

5. From the data file received, count the number of days that fall below 32°F. Divide this by the number of years included in the dataset.
6. Match the number of days per year below 32°F to the Hazard Rating in Table 24 above, them multiply this value by the extreme cold relative modifier, 0.47.

2.3.12.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for extreme cold events:

1. The Tool locates the nearest weather station based on the user-input facility latitude and longitude on the Facility Characterization page.
2. After the Tool identifies the closest weather station, it automatically pulls the number of extreme cold events.
3. The Tool outputs a Hazard Rating using the guidelines above in Table 24 which is then multiplied by the extreme cold relative modifier, 0.47.

2.3.13 Hurricane and Tropical Storm

2.3.13.1 Description of Hazard

Hurricanes (including tropical storms and depressions) consist of spiraling winds of greater than 64 knots (39 knots for tropical storms, 33 knots or less for tropical depressions) and are usually associated with heavy rains. Hurricanes and tropical storms/depressions can cause severe flooding and damage to structures, and areas in the path of a hurricane or tropical storm/depression are often evacuated. In the U.S., hurricanes, tropical storms, and tropical depressions primarily affect the southeastern coastal region, although island states and territories in the Pacific Ocean and the northern Atlantic coast can be affected as well. The data necessary for calculating the probability of tropical cyclones is located in the NOAA historical tracks database.

2.3.13.2 Rating Scale Determination

The Hazard Rating scale for hurricanes, tropical storms, and tropical depressions was determined using the following steps:

The NOAA Historical Tracks Database was used to determine paths of hurricanes and tropical storms/depressions making landfall in the U.S. and its territories. The region identified as having the highest occurrence is the coast of the Gulf of Mexico, where the most active locations experienced approximately 10 storms within a 65-mile radius in the past 20 years. [76]

1. A Hazard Rating of 4 was set at 10 hurricanes or tropical storms/depressions in a 20-year span.
2. The remainder of the Hazard Rating scaled was derived from linear interpolation from 10 to zero.

[76] National Oceanic and Atmospheric Administration. Historical Hurricane Tracks. https://coast.noaa.gov/hurricanes/. Accessed 8/2/2015.

2.3.13.3 Hazard Rating Table

Table 25. Hurricane Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	8 or more storms in the past twenty years where the eye has passed within sixty-five nautical miles of the location where the facility/asset is located.
High	3	Occasional	6 to 7 storms in the past twenty years where the eye has passed within sixty-five nautical miles of the location where the facility/asset is located.
Moderate	2	Infrequent	3 to 5 storms in the past twenty years where the eye has passed within sixty-five nautical miles of the location where the facility/asset is located.
Low	1	Rare or No Documented History	2 or fewer storms in the past twenty years where the eye has passed within sixty-five nautical miles of the location where the facility/asset is located.

2.3.13.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of hurricane events are below.

1. NOAA maintains a database recording the paths of Atlantic and Pacific Northwest hurricanes.[77] From this data, as well as a manual counting of hurricanes that contacted Alaska and Hawaii using the NOAA Hurricane Tracks Database, 82 hurricanes made land contact with the United states in the past 20 years (an event rate of 4 per year). [78]
2. The hurricane event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.12. See Appendix C for a complete description of the process.

2.3.13.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the number of hurricane, tropical storm, and or tropical depression events in the past 20 years for the state and county in which the facility is located using the NOAA Historical Hurricane Tracks Database by entering the city or county of the facility's location. Count the number of hurricane, tropical storm, and tropical depression events.
    a. The automatic span of time the data is pulled dates back to the year 1842, but the user can restrict the data by selecting Advanced Filters, and then holding the shift key and

[77] National Hurricane Center. HURDAT2. *HURDAT2*. NOAA. http://www.nhc.noaa.gov/data/#hurdat. Accessed June 28 2017.
[78] National Oceanic and Atmospheric Administration. Historical Hurricane Tracks. https://coast.noaa.gov/hurricanes/. Accessed 8/2/2015.

selecting the years that mark the end points of the 20 year span. The user must hit apply to update the list of hurricanes

2. Identify the Hazard Rating from the number of hazard events found using Table 25 above. Multiply the hurricane relative modifier, 0.12, by the identified Hazard Rating.

2.3.13.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for hurricane and tropical storm events:

1. The user inputs the number of hurricane and/or tropical storm events reported by the Storm Tracker database into the Tool.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 25 which is then multiplied by the hurricane relative modifier, 0.12.

2.3.14 Space Weather

2.3.14.1 Description of Hazard

Space weather refers to conditions and events occurring in the solar system that may affect conditions on Earth. Generally, space weather is caused by processes originating from the sun, including solar flares and coronal mass ejections. There are three main types of space weather: geomagnetic storms, solar radiation storms, and radio blackouts. The effects of these events include disruption of power grids, damage to satellites, and loss of navigation systems. While many space weather-caused disruptions are minor and may not ever be attributed to space weather, there is real potential for large-scale disruption, as evidenced by the March 1989 geomagnetic storm that caused a nine-hour blackout in Canada's Hydro-Quebec power grid.

A geomagnetic storm is a major disruption of the Earth's magnetosphere (the region of space surrounding the Earth which contains its magnetic field). These storms can cause power grid fluctuations and voltage controls problems which may be severe enough to cause power blackouts. Geomagnetic storms are of specific concern to the HPH Sector because of the potential for large-scale loss of power and potential damage to equipment that is connected to the power grid. There are many factors that influence the likelihood of geomagnetic storms, most of which are not understood well enough to allow for determination of relative likelihood among locations or facilities. There is, however, a clear effect of latitude on the intensity and frequency of geomagnetic storms, although efforts to quantify this relationship are still in development.

2.3.14.2 Rating Scale Determination

A Hazard Rating Scale was determined based on data published by Love et al. (2016).[79] The hazard rating is calculated relative to the latitude of the facility/asset being assessed; higher latitudes generally experience stronger geomagnetic storms. Using historical measurements of geomagnetic storms as recorded at observatories around the world, Love et al. calculated the magnitudes of 1-, 10-, and 100-year events and related them to the observatories' latitudes. The primary increase in storm magnitude occurred roughly between 40 and 60° north latitude.

[79] Love JJ, Coisson P, Pulkkinen A. (2016) Global statistical maps of extreme-event magnetic observatory 1 min first differences in horizontal intensity. Geophysical Research Letters. 43: 1-10.

Using the data for 10-year events, the range of magnitudes was divided into four ranges, representing low, moderate, high, or very high Hazard Ratings. The threshold between low and moderate hazard corresponds approximately to the 40th latitude parallel (for reference, this is the boundary between Nebraska and Kansas). The high hazard range is from approximately 50 to 55° latitude, with locations above 55° latitude constituting the very high hazard range. All of the continental U.S., its territories, and Hawaii are below 50° north latitude and thus are within the low or moderate hazard ranges. Alaska spans both the high and very high hazard ranges; the Aleutian Islands were chosen to constitute the high range, with the rest of Alaska comprising the very high range.

2.3.14.3 Hazard Rating Table

Table 26. Space Weather Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Facility/Asset Latitude Range
Very High	4	Frequent	Facilities/assets located in mainland Alaska.
High	3	Occasional	Facilities/assets located in the Aleutian Islands of Alaska.
Moderate	2	Infrequent	Facilities/assets in the continental United States located at or above 40° north latitude (below 50° north).
Low	1	Rare or No Documented History	Facilities/assets located below 40° north latitude.

2.3.14.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of space weather events are below.

1. According to a NOAA-maintained database of space weather events, managed by the Space Weather Prediction Center 99,663 space weather events occurred in the past 20 years (an event rate of 4,983 per year).[80]
2. The space weather event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.73. See Appendix C for a complete description of the process.

2.3.14.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Determine the location of the facility (continental U.S., Hawaii, U.S. territories, mainland Alaska, or Aleutian Island Alaska).
2. For facilities/assets outside of the continental U.S., determine the latitude of the facility/asset.

[80] Space Weather Prediction Center. Historical SWPC Products and Data Displays. *Warehouse*. ftp://ftp.swpc.noaa.gov/pub/warehouse/. Accessed June 28, 207.

3. Refer to Table 26 above to calculate a Hazard Rating based on the location or latitude of the facility. Multiply the hazard rating by the space weather relative modifier, 0.73.

2.3.14.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for space weather events:

1. The Tool uses the user-input facility latitude and longitude to determine where the facility is located.
    a. The Tool defines the latitude of the Aleutian Islands in Alaska as between 50º and 55º N.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 26 which is then multiplied by the space weather relative modifier, 0.73.

2.3.15 Thunderstorm (Lightning)

2.3.15.1 Description of Hazard

Thunderstorms present three major hazards: high winds, rain, and lightning. Because damaging winds and flooding are captured as separate hazards, this category focuses on the damaging effects of lightning. Lightning strikes can cause direct fatalities and injuries, damage to equipment and buildings, and may start structural fires. While lightning-producing storms can happen anywhere in the country, certain regions, like the Great Plains and the southeast U.S., are more prone. The data necessary for calculating the probability of lightning is based on the NOAA-supported Vaisala Inc. lightning density national map.

2.3.15.2 Rating Scale Determination

The Hazard Rating scale for damaging winds was determined using the following steps:

1. The Lightning Strike Density Map, was acquired from Vaisala Inc.[81]
2. The density scale from the strike map was adapted to the Hazard Rating scale via linear interpolation.

2.3.15.3 Hazard Rating Table

Table 27. Lightning Hazard Ratings.

Rating Category	Category Rating Range	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	20.1 lightning strikes per sq/mi annually or greater in immediate area of facility/asset location.
High	3	Occasional	6.1 to 20 lightning strikes per sq/mi annually in immediate area of facility/asset location.
Moderate	2	Infrequent	1.6 to 6 lightning strikes per sq/mi annually in immediate area of facility/asset location.

[81] Vaisala National Lighting Detection Network. Cloud-to-Ground Lightning Incidence in the Continental U.S. (1997 – 2014). http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/NLDN.aspx. Accessed 04/19/2016.

Rating Category	Category Rating Range	Hazard Occurrence Descriptor	Hazard Occurrence Range
Low	1	Rare or No Documented History	1.5 lightning strikes per sq/mi annually or less in immediate area of facility/asset location.

2.3.15.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Lightning events are below.

1. No national database of lightning strike incidences could be identified, so a total incidence was approximated as described below.
    a. The average strike density of the United States was identified to be 16 strikes per square mile per year. [82]
    b. The total number of lightning strikes was restricted to strikes hitting developed areas. The US Census Bureau reports that 3.5% of the US land area is developed.[83]
    c. The average strike density was multiplied by the total developed land area of the US to determine an approximate number of lightning strikes to developed areas of 109,000 strike events per year.
2. The lightning event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 1.0. See Appendix C for a complete description of the process.

2.3.15.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Identify the average flash density for the area in which the facility/asset is located using the Vaisala's National Lightning Detection Network Flash Density Map.
2. Identify the Hazard Rating from the flash density found using Table 27 above, then multiply rating value by the lightning relative modifier, 1.0.

2.3.15.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for extreme heat events:

1. The user inputs the identified lightning strike density following the directions of provided above and in the Tool.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 27 which is then multiplied by the lightning relative modifier, 1.0.

[82] Ibid.
[83] United States Census Bureau. U.S. Cities Home to 62.7 Percent of the U.S. Population, but Comprise just 3.5 Percent of Land Area. https://www.census.gov/newsroom/press-releases/2015/cb15-33.html.

2.4 Diseases That Impact Humans (Infectious Diseases)

2.4.1 Annual Influenza Epidemic

2.4.1.1 Description of Hazard

Infectious disease and pandemics are a continual annual occurrence, as evidenced by the influenza epidemic that occurs annually in the U.S. The hazard scale presented above is based on the amount of time a state maintains high influenza like illness (ILI) activity levels during the influenza season over the last five influenza seasons. The greater the number of weeks that a state stays at a high ILI activity level, the greater the hazard.

2.4.1.2 Rating Scale Determination

The Hazard Rating for the pandemics rating scale can be determined using the following steps:

1. The CDC reports state specific ILI activity levels for each week of the influenza season for the 2008-2009 influenza season through the current season. This ILI activity map and downloadable data can be accessed through the FluView tool.[84]
2. The average number of weeks a state spent at a high ILI activity level was counted for all seasons available in the database.
3. A Hazard Rating of 4 was set at the most flu burdened state, which corresponded to an average of approximately 10 weeks at high flu activity.
4. The remainder of the Hazard Rating scaled was derived from linear interpolation from 10 to zero.

2.4.1.3 Hazard Rating Table

Table 28. Annual Influenza Epidemic Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Influenza-Like Illness (ILI) Activity Range
Very High	4	Frequent	The state spends an average of 8 or more weeks of the flu season at a high activity level.
High	3	Occasional	The state spends an average of 6 – 7 weeks of the flu season at a high activity level.
Moderate	2	Infrequent	The state spends an average of 3 – 5 weeks of the flu season at a high activity level.
Low	1	Rare or No Documented History	The state spends an average of 2 or fewer weeks of the flu season at a high activity level.

2.4.1.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having

[84] Centers for Disease Control and Prevention. FluView. http://gis.cdc.gov/grasp/fluview/main.html. Accessed 11/19/2015.

a relative modifier of 0.1. The steps and data used to determine the relative modifier of Influenza events are below.

1. The FluView database was used to count the number of incidences of a state reporting high ILI activity, resulting in 1,148 days of high ILI activity (an event rate of 128 per year).[85]
2. The influenza event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.42. See Appendix C for a complete description of the process.

2.4.1.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's infectious disease Hazard Rating:

1. Download data for all available flu seasons from the CDC FluView tool.
    a. Select the Download Data button at the top right corner
    b. Select the "Custom Download" option, and make sure the "By Season" option is selected.
    c. Check the "Select All" box and select the "Download Data" button to generate a CSV file.
2. Determine the average number of weeks the state within which the facility/asset of interest resides had a high level of ILI activity over the last 5 influenza seasons.
3. Find the number of weeks at a high ILI activity level above in Table 28 and its associated Hazard Rating. Finally, multiply the Hazard Rating by the influenza relative modifier, 0.42.

2.4.1.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for infectious disease events:

1. The Tool uses the user-entered facility state location to automatically pull the average number of weeks of High ILI activity for that state.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 28 which is then multiplied by the influenza relative modifier, 0.4.

2.5 Unintentional Events

2.5.1 Aircraft Crash at Facility/Asset

2.5.1.1 Description of Hazard

The potential for a structure to be struck by a commercial, commuter, private, or military aircraft is theoretically present for any locality covered by unrestricted airspace; however, the likelihood of an aircraft crash increases as proximity to an airport or landing strip increases. The number of daily takeoffs and landings, as well as the size of the aircraft that operate from the airport or landing strip also represent key considerations. The rating category and Hazard Rating for a specific facility/asset is based on its distance, in nautical miles (NM)[86] to one or more airports or landing strips, as well as the volume of air traffic in terms of the number of arrivals and departures (operations). The exact distances needed for take-

[85] Ibid.

[86] A nautical mile (NM) is the approximate length of one minute of arc of the Earth's surface and is commonly used in sea and air navigation. One nautical mile is equivalent to 1.151 miles or 1,852 meters.

off, climb-out, and landing are determined by the length of the runway, wind speed and direction, the weight of the aircraft, and the air density. In general, aircraft conclude their climb-out within 5 to 10 nautical miles.

2.5.1.2 Rating Scale Determination

The Hazard Rating scale was determined using the following criteria:

1. Open source literature was used to determine the historical incidence of aircraft crashes and the incidence of crashes by phase of flight.[87,88,89] This research provided insight into crash risks based on phase of flight.
2. Data on fatal crashes indicates that approximately 13% occur during the take-off and initial climb phases of flight and 48% occur during the final approach and landing phases. The take-off and landing phases represent 7% and 24% of fatal crashes, respectively, and on average take place within 5 NM of the airport or landing site. The initial climbing and final approach phases account for 6% and 24% of fatal crashes, respectively, and generally take place within 10 NM of an airport.
3. The hazard contributed by an airport increases as the volume of traffic increases. The amount of air traffic at an airport can be measured by aircraft arrivals and departures.
4. The location of a facility near more than one airport increases the hazard of aircraft crashes. Location of multiple airports within 10 NM of the facility will have an additive effect on the Hazard Rating.

2.5.1.3 Hazard Rating Table

Table 29. Airport Ratings by Distance to Airport in Nautical Miles. Airport Ratings correspond to the Hazard Categories of Very High (0.76-1.0), High (0.51-0.75), Moderate (0.26-0.50), Low (0.00-0.25).

Total Operations (≤)	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
1,000,000	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
500,000	0.95	0.85	0.76	0.66	0.57	0.47	0.38	0.28	0.19	0.09
100,000	0.83	0.75	0.67	0.58	0.50	0.42	0.33	0.25	0.17	0.08
50,000	0.78	0.70	0.63	0.55	0.47	0.39	0.31	0.23	0.16	0.08
30,000	0.75	0.67	0.60	0.52	0.45	0.37	0.30	0.22	0.15	0.07
10,000	0.67	0.60	0.53	0.47	0.40	0.33	0.27	0.20	0.13	0.07
5,000	0.62	0.55	0.49	0.43	0.37	0.31	0.25	0.18	0.12	0.06
3,000	0.58	0.52	0.46	0.41	0.35	0.29	0.23	0.17	0.12	0.06
1,000	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
500	0.45	0.40	0.36	0.31	0.27	0.22	0.18	0.13	0.09	0.04
300	0.41	0.37	0.33	0.29	0.25	0.21	0.17	0.12	0.08	0.04
100	0.33	0.30	0.27	0.23	0.20	0.17	0.13	0.10	0.07	0.03
50	0.28	0.25	0.23	0.20	0.17	0.14	0.11	0.08	0.06	0.03

[87] National Transportation Safety Board. Aviation Statistics. http://www.ntsb.gov/investigations/data/Pages/aviation_stats.aspx. Accessed 10/1/2015.

[88] Ibid.

[89] Boeing Commercial Airplanes. (2015) Statistical Summary of Commercial Jet Airplane Accidents: Worldwide Operations 1959 – 2014. Prepared for. http://www.boeing.com/resources/boeingdotcom/company/about_bca/pdf/statsum.pdf.

2.5.1.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of Aircraft Crash events are below.

1. A database of National Transportation Safety Board aviation accident reports contained 10 crash events where the aircraft crashed into a building in the last 20 years (an event rate of 1 per year).[90]
2. The aircraft crash event rate was log-transformed and normalized according to the most frequent hazard. Because the resulting modifier value was less than the chosen minimum value, the modifier was set to 0.10. See Appendix C for a complete description of the process.

2.5.1.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's aircraft crash Hazard Category:

1. Find all airports within 10 NM of the facility/asset of interest. Determine the facility's/asset's distance from each airport and/or landing strip in nautical miles (1 NM = 1.151 mi). Airports and their distance to the facility can be identified using the AirNav Airports Search.
2. Look up the total number of operations for each nearby airport using the Airport IQ 5010 Airport Master Records and Reports Database.[91]
3. For each airport, determine an Airport Rating based on total operations (i.e. takeoffs and landings) and distance, using Table 29 or the following equation:

$$Airport\ Rating = \left(\frac{[\#Operations]}{1{,}000{,}000}\right) \times \left(\frac{11 - [Distance]}{10}\right)$$

4. OPTIONAL, SUBJECT TO AVAILABILITY OF LOCAL DATA. Consult local information sources to determine the location of the facility/asset relative to the major flight paths used for arriving and departing flights at each airport, and adjust each Airport Rating accordingly. This information can sometimes be found on the airport's website.
5. Add together all Airport Ratings and multiply by 4 to get the final Hazard Rating for the facility/asset (round Hazard Ratings up to the next higher integer). If the final Hazard Rating is greater than 4, use 4 as the Hazard Rating. After determining the Hazard Rating, multiply it by the aircraft crash relative modifier, 0.1.

2.5.1.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for extreme heat events:

1. Once the user enters all relevant airport codes and distances into the Tool, the Tool automatically pulls the number of operations for each airport.

[90] National Transportation Safety Board. (2017) Aviation Accident Reports. *Aviation Accident Reports*. National Transportation Safety Board. https://www.ntsb.gov/investigations/AccidentReports/Pages/aviation.aspx. Accessed June 28, 2017.
[91] AirportIQ 5010. Airport Master Records and Reports. http://www.gcr1.com/5010web/. Accessed 1/11/2016.

2. An individual Airport Rating is calculated for each airport using the following equation.

$$Airport\ Rating = \left(\frac{[\#Operations]}{1{,}000{,}000}\right) \times \left(\frac{11 - [Distance]}{10}\right)$$

3. The Tool then sums up the individual Airport Ratings to a maximum of 1 and multiplies the total by 4 to determine a final Hazard Rating. This value is then multiplied by the aircraft crash relative modifier, 0.1.

2.5.2 External Chemical HAZMAT Exposure, Facilities

2.5.2.1 Description of Hazard

Exposure to toxins or hazardous materials can result from such events as toxic air emissions, waste water discharge, and unintentional release of toxic chemicals by manufacturers or importers in the vicinity of the facility. While the likelihood of environmental release of chemicals or toxins is difficult to estimate, the number of nearby facilities that produce or use hazardous chemicals can be used to approximate the hazard. National databases keep records of the industrial and hazardous facilities across the nation. The number of these facilities within a county can be used to approximate the potential external Chemical HAZMAT exposure. The more facilities that handle hazardous materials in close proximity to a HPH sector facility/asset, the greater the hazard.

2.5.2.2 Rating Scale Determination

The Hazard Rating scale was determined using the following steps:

1. Using the Toxic Release Inventory, the Risk Management Plan Facilities list, Facility Response Plan Oil Facilities List, and the Resource Conservation and Recovery Act Treatment Storage and Disposal Facilities list, an approximately complete list of HAZMAT facilities in each county was compiled.
2. The Hazard Rating scale was set so that the top 2% of counties with the greatest number of HAZMAT facilities constituted a Hazard Category of very high. This resulted in a maximum Hazard Rating for counties with 148 or more facilities or more. The remainder of the Hazard Rating range was scaled linearly.

2.5.2.3 Hazard Rating Table

Table 30. Hazard Ratings for HAZMAT Incidents at External Facilities.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Occurrence Range
Very High	4	Frequent	112 or more HAZMAT facilities in the county where the facility/asset is located.
High	3	Occasional	75 to 111 HAZMAT facilities in the county where the facility/asset is located.
Moderate	2	Infrequent	38 to 74 HAZMAT facilities in the county where the facility/asset is located.

Rating	Hazard Rating	Hazard	Hazard Occurrence Range
Low	1	Rare or No Documented History	37 or fewer HAZMAT facilities in the county where the facility/asset is located.

2.5.2.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of External HAZMAT Facility Release events are below.

1. According to a US Chemical Safety Board-maintained database of current and completed chemical release investigations, 51 release events occurred in the last 20 years where the surrounding community was impacted (an event rate of 3 per year).[92]
2. The external HAZMAT facility release event rate log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.09. See Appendix C for a complete description of the process.

2.5.2.5 How to Calculate Hazard Rating

To determine a facility's/asset's HAZMAT accident Hazard Rating, the number of HAZMAT facilities must be quantified using four different databases: the Toxic Release Inventory, the Risk Management Plan Facilities list, the Facility Response Plan Oil Facilities List, and the Resource Conservation and Recovery Act Treatment Storage and disposal Facilities list. Each of these databases is mapped using the same DHS sponsored mapping tool and the steps below can be used for each of the four data bases. The steps below describe how to calculate a facility's/asset's highway HAZMAT accident Hazard Rating:

1. Use the EPA Emergency Response Toxic Release Inventory Facilities map to determine the number of HAZMAT facilities in the county in which the facility is located.
    a) Enter the county in which the facility is located into the search bar located on the map
    b) Select the "Table" tab below the generated map
    c) Select the "County Name" header to sort the facilities and count the number of facilities in in which the facility is located.
2. Repeat steps a) through c) above for the following three HAZMAT facility databases using the provided links.
    a) EPA Emergency Response Risk Management Plan Facilities
    b) EPA Emergency Response Facility Response Plan Facilities
    c) EPA Resource Conservation and Recovery Act Treatment Storage and Disposal Facilities
3. Sum the number of HAZMAT facilities in the relevant county.
    a) Be aware that the same facilities will be present in several databases; the assessor may wish to remove duplicate facilities from the count.

[92] U.S. Chemical Safety Board. (2017) Investigations. Investigations. U.S. Chemical Safety Board. http://www.csb.gov/investigations/current-investigations/?F_AccidentTypeId=14. Accessed June 26, 2017.

4. Look up the Hazard Rating in Table 30 based on the total number of HAZMAT facilities. Multiply the HAZMAT facility Hazard Rating by the external HAZMAT facility release relative modifier, 0.09.

2.5.2.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for external chemical HAZMAT events:

1. The Tool automatically looks up the number of HAZMAT facilities based on the county selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 30 which is then multiplied by the external HAZMAT facility release relative modifier, 0.09.

2.5.3 External Chemical HAZMAT Exposure, Highway

2.5.3.1 Description of Hazard

Chemical HAZMAT is commonly transported across the continental U.S. using roads and highways. Trucking accidents can result in the unintentional release of the hazardous material being transported. The past incidence of HAZMAT release due to a highway accident is indicative of the future likelihood. The above scale is based on the last 20 years of HAZMAT transportation accidents on the highways reported to the U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA). The rating category and Hazard Rating for a specific facility is based on the number of incidents that historically occurred in the city in which the facility is located. The more incidents occurring in the city in which the facility is located, the higher the Hazard Rating.

2.5.3.2 Rating Scale Determination

The Hazard Rating scale was determined using the following steps:

1. The PHMSA Incident Reports Database indicates that Texas was the state with the highest number of HAZMAT release incidents.[93]
2. The PHMSA Incident Reports Database Search was used to determine the number of HAZMAT release incidents that occurred in the last 20 years in Texas that were associated with highway transportation.
3. The smallest (0 incidents) and largest (> 550 incidents in Houston) number of highway HAZMAT releases in Texas cities were identified.
4. The majority of cities in Texas had very few or no historical incidence of highway HAZMAT release, and few had more than 50. Thus the hazard scale was set to allow for more resolution when considering 50 or fewer incidents.

[93] Pipeline and Hazardous Materials Safety Administration. Incident Statistics. http://phmsa.dot.gov/hazmat/library/data-stats/incidents. Accessed 1/13/2016.

2.5.3.3 Hazard Rating Table

Table 31. Hazard Ratings for HAZMAT Highway Incidents.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Frequency
Very High	4	Frequent	The city in which the facility/asset is located has had more than 50 HAZMAT highway incidents in the last 20 years.
High	3	Occasional	The city in which the facility/asset is located has had 11 to 50 HAZMAT highway incidents in the last 20 years.
Moderate	2	Infrequent	The city in which the facility/asset is located has had 1 to 10 HAZMAT highway incidents in the last 20 years.
Low	1	Rare	The city in which the facility/asset is located has had no HAZMAT highway incidents in the last 20 years.

2.5.3.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of HAZMAT Highway Release events are below.

1. The PHMSA Incident Report Database reported 45,758 Highway HAZMAT release events in the past 20 years (an event rate of 2,288 per year). [94]
2. The highway HAZMAT release event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.67. See Appendix C for a complete description of the process.

2.5.3.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's highway HAZMAT accident Hazard Rating:

1. Use the PHMSA Incident Reports Database Search to determine the number of HAZMAT highway release incidents in the state in which the facility is located.
    a. Restrict the search to the last twenty years in Step 3.
    b. Select the state in which the facility is located in Step 7.
    c. Check the "Highway" box in step 8 and the "In Transit" box in Step 9 to restrict the search results to only highway HAZMAT release incidents.
2. Download the search results by selecting the "Export to CSV" button.
3. Count the number of incidents occurring in the city in which the facility/asset is located.
4. Compare the number of HAZMAT highway releases to the Hazard Rating using Table 31 above. Multiply the identified Hazard Rating by the highway HAZMAT release relative modifier, 0.7.

[94] Ibid.

2.5.3.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for highway HAZMAT events:

1. The Tool automatically looks up the number of highway-based HAZMAT release events based on the city selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 31 which is then multiplied by the highway HAZMAT release relative modifier, 0.67.

2.5.4 External Chemical HAZMAT Exposure, Maritime

2.5.4.1 Description of Hazard

Chemical HAZMAT movement along waterways is a relatively less common mode of HAZMAT transport than either rails or highways, yet it poses a potential hazard. Release of hazardous material into the water system can have serious and far-reaching consequences to both humans and the environment. The past incidence of HAZMAT release during maritime transport is indicative of the future likelihood. The above scale is based on the last 20 years of HAZMAT transportation incidents using water transportation reported to PHMSA. The rating category and Hazard Rating for a specific facility/asset is based on the number of incidents that historically occurred in the city in which the facility/asset is located. The more incidents occurring in the city in which the facility/asset is located, the higher the Hazard Rating.

2.5.4.2 Rating Scale Determination

The Hazard Rating scale was determined using the following steps:

1. The PHMSA Incident Reports Database was used to determine that Alaska was the state with the highest number of maritime HAZMAT release incidents. [95]
2. The PHMSA Incident Reports Database Search was used to determine the number of HAZMAT release incidents occurred in the last 20 years in Alaska that were associated with maritime transportation.
3. The smallest (0 incidents) and largest (> 166 incidents in Anchorage) number of maritime HAZMAT releases in Alaska cities were identified.
4. The majority of cities in Alaska had very few or no historical incidence of highway HAZMAT release; only Anchorage had more than 50. Thus the hazard scale was set to allow for more resolution when considering 50 or fewer incidents.

[95] Ibid.

2.5.4.3 Hazard Rating Table

Table 32. Hazard Ratings for HAZMAT Maritime Incidents.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Frequency
Very High	4	Frequent	The city in which the facility/asset is located has had more than 50 HAZMAT maritime incidents in the last 20 years.
High	3	Occasional	The city in which the facility/asset is located has had 6 to 50 HAZMAT maritime incidents in the last 20 years.
Moderate	2	Infrequent	The city in which the facility/asset is located has had 1 to 5 HAZMAT maritime incidents in the last 20 years.
Low	1	Rare	The city in which the facility/asset is located has had no HAZMAT maritime incident in the last 20 years OR the facility/asset is not near the coastline or an inland waterway.

2.5.4.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of HAZMAT Maritime Release events are below.

1. The PHMSA Incident Report Database reported 640 maritime HAZMAT release events in the past 20 years (an event rate of 32 per year). [96]
2. The maritime HAZMAT release event rate log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.30. See Appendix C for a complete description of the process.

2.5.4.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's maritime accident Hazard Rating:

1. Use the PHMSA Incident Reports Database Search to determine the number of HAZMAT maritime release incidents in the state the facility resides in.
    a. Restrict the search to the last twenty years in Step 3.
    b. Select the state in which the facility/asset is located in Step 7.
    c. Check the "Water" box in step 8 and the "In Transit" box in Step 9 to restrict the search results to only maritime HAZMAT release incidents.
2. Download the search results by selecting the "Export to CSV" button.
3. Count the number of incidents occurring in the city the facility/asset of interest resides in.

[96] Ibid.

4. Compare the number of HAZMAT maritime releases to the Hazard Rating using Table 32 above, then multiply the Hazard Rating by the maritime HAZMAT release relative modifier, 0.30.

2.5.4.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for maritime HAZMAT events:

1. The Tool automatically looks up the number of maritime-based HAZMAT release events based on the city selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 32 which is then multiplied by the maritime HAZMAT release relative modifier, 0.3.

2.5.5 External Chemical HAZMAT Exposure, Railway

2.5.5.1 Description of Hazard

Chemical HAZMAT can be transported across the continental U.S. using the U.S. railway system. Derailments and other accidents can result in the unintentional release of the hazardous material being transported. The past incidence of HAZMAT release incidents on a railway is suggestive of the future likelihood. The above scale is based on the last 20 years of HAZMAT transportation accidents within the U.S. rail system that were reported to PHMSA. The rating category and Hazard Rating for a specific facility is based on the number of incidents that historically occurred in the city in which the facility/asset is located. The more incidents occurring in the city in which the facility/asset is located, the higher the Hazard Rating.

2.5.5.2 Rating Scale Determination

The Hazard Rating scale was determined using the following steps:

1. The PHMSA Incident Reports Database was used to determine that Texas was the state with the highest number of railway HAZMAT release incidents.[97]
2. The PHMSA Incident Reports Database Search was used to determine the number of HAZMAT release incidents that occurred in the last 20 years in Texas that were associated with rail transportation.
3. The smallest (0 incidents) and largest (> 450 incidents in Houston) number of railway HAZMAT releases in Texas cities were identified.
4. The majority of cities in Texas had very few or no historical incidence of railway HAZMAT release, and few had more than 50. Thus, the hazard scale was set to allow for more resolution when considering 50 or fewer incidents.

[97] Ibid.

2.5.5.3 Hazard Rating Table

Table 33. Hazard Ratings for HAZMAT Railway Incidents.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Frequency
Very High	4	Frequent	The city in which the facility/asset is located has had more than 50 HAZMAT rail incidents in the last 20 years.
High	3	Occasional	The city in which the facility/asset is located has had 6 to 50 HAZMAT rail incidents in the last 20 years.
Moderate	2	Infrequent	The city in which the facility/asset is located has had 1 to 5 HAZMAT rail incidents in the last 20 years.
Low	1	Rare	The city in which the facility/asset is located has had no HAZMAT rail incident in the last 20 years.

2.5.5.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of HAZMAT Railway Release events are below.

1. The PHMSA Incident Report Database reported 15,306 railway HAZMAT release events in the past 20 years (an event rate of 765 per year).[98]
2. The railway HAZMAT release event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.57. See Appendix C for a complete description of the process.

2.5.5.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's HAZMAT railway accident Hazard Rating:

1. Use the PHMSA Incident Reports Database Search to determine the number of HAZMAT railway release incidents in the state the facility/asset resides in.
    a. Restrict the search to the last twenty years in Step 3.
    b. Select the state in which the facility is located in Step 7.
    c. Check the "Rail" box in step 8 and the "In Transit" box in Step 9 to restrict the search results to only highway HAZMAT release incidents.
2. Download the search results by selecting the "Export to CSV" button.
3. Count the number of incidents occurring in the city in which the facility/asset is located.
4. Compare the number of HAZMAT railway releases to the Hazard Rating using Table 33 above. Multiply the identified Hazard Rating by the railway HAZMAT release relative modifier, 0.57.

[98] Ibid.

2.5.5.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for railway HAZMAT events:

1. The Tool automatically looks up the number of railway-based HAZMAT release events based on the city selected by the user on the Facility Characterization page.
2. The Tool outputs a Hazard Rating using the guidelines above in Table 33 which is then multiplied by the railway HAZMAT release relative modifier, 0.57.

2.5.6 External Chemical HAZMAT Exposure, Pipeline

2.5.6.1 Description of Hazard

Hazmat pipelines carry hazardous materials such as natural gas, crude oil, ethanol, and other liquids that are highly volatile, explosive and/or flammable. These pipelines are found across the U.S. If they rupture, they can cause serious damage including explosions and oil spills. The National Pipeline Mapping System (NPMS) allows the general public to see the number and location of pipelines and pipeline release incidents at the county level.[99] The pipelines and corresponding release incidents are color-coded based on whether they carry natural gas or liquid hazardous materials (including crude oil, ethanol). It can generally be assumed that the threat of a pipeline rupture is related to the number of pipeline release incidents in a given area. Therefore, the scale used to facilitate the calculation of the Hazard Rating for this event type is based on the number of pipeline release incidents in a given county, as determined by consulting the NPMS database.

2.5.6.2 Rating Scale Determination

The Hazard Rating scale was determined using the following steps:

1. County pipeline mapping data from the NPMS maps was used to determine the number of pipelines incidents within U.S. counties.
2. Texas was identified as the state with the most pipeline HAZMAT release incidents.
3. The smallest (0 incidents) and largest (>100 incidents in Harris county) number of pipeline HAZMAT releases incidents were identified.
4. The majority of counties had very few or no historical incidence of pipeline HAZMAT release, and few had more than 50. Thus, the hazard scale was set to allow for more resolution when considering 50 or fewer incidents.

2.5.6.3 Hazard Rating Table

Table 34. Hazard Ratings for HAZMAT Pipeline Incidents.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Frequency
Very High	4	Frequent	The county in which the facility/asset is located has had more than 50 HAZMAT pipeline incidents in the last 20 years.
High	3	Occasional	The county in which the facility/asset is located has had 6 to 50 HAZMAT pipeline incidents in the last 20 years.

[99] National Pipeline Mapping System. NPMS Public Map Viewer. https://www.npms.phmsa.dot.gov/PublicViewer/index.jsp. Accessed 1/13/2016.

Rating Category	Hazard Rating	Hazard Occurrence Descriptor	Hazard Frequency
Moderate	2	Infrequent	The county in which the facility/asset is located has had 1 to 5 HAZMAT pipeline incidents in the last 20 years.
Low	1	Rare	The county in which the facility/asset is located has had no HAZMAT pipeline incidents in the last 20 years.

2.5.6.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of HAZMAT Pipeline Release events are below.

1. According to a PHMSA-maintained database of pipeline releases of hazardous materials, 2,684 pipeline HAZMAT release events occurred in the past 20 years (an event rate of 134 per year).[100,]
2. The pipeline HAZMAT release event rate was log-transformed and normalized according to the most frequent hazard, resulting in modifier value of 0.42. See Appendix C for a complete description of the process.

2.5.6.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's HAZMAT release hazard rating:

1. Access the NPMS database.
2. Select your state and then your county from the drop down menus.
3. On the generated map, de-select the "Gas Transmission Pipelines" and "Hazardous Liquid Pipelines" map layers, and select the "Accidents (Liquid)" and "Incidents (Gas)" map layers.
4. Count the number of incident markers located in your county then compare this number to the hazard rating using Table 34 above, then multiply the Hazard Rating by the pipeline HAZMAT release relative modifier, 0.42.

2.5.6.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for pipeline HAZMAT events:

1. Once the user enters the number of pipeline release incidents, the Tool uses that number to output a Hazard Rating based on the guidelines in Table 34 above.
2. The Hazard Rating is then multiplied by the pipeline HAZMAT release relative modifier, 0.42.

[100] Pipeline and Hazardous Materials Safety Administration. (2017) Gas Distribution Incident Data. Gas Distribution Incident Data - March 2004 to December 2009. https://www.phmsa.dot.gov/pipeline/library/data-stats/distribution-transmission-and-gathering-lng-and-liquid-accident-and-incident-data. Accessed June 27, 2017.

2.5.7 Radiologic Exposure, External

2.5.7.1 Description of Hazard

The potential for a facility/asset to be impacted by a radiological release from a nuclear power plant is directly relatable to the distance that such a facility/asset is located from a nuclear power plant. The U.S. Nuclear Regulatory Commission (NRC) defines zones of impact, called Emergency Planning Zones, based on distance from a nuclear power plant. The NRC denominates two major zones, the Plume Exposure Pathway (PEP) and the Ingestion Exposure Pathway (IEP), when planning for a nuclear emergency. These two zones encompass the short term (PEP) and long term (IEP) consequences of a radiological release. Every nuclear power plant in the U.S. has developed specifically defined zones based on the geography and demographics of their specific area; however, the general guidelines associated with the NRC emergency planning zones provide the foundation of the above hazard scale.[101]

Research reactors were also considered as a potential source of external radiological exposure, but were found to not present a hazard as they are considerably smaller than nuclear power reactors, are self-contained, and operate on limited schedules with limited amounts of radioactive material.[102] Some research reactors are not even capable of melting down because they do not produce enough energy to do so.[103] Many emergency planning zones for research reactors only involve the building in which they are located with a maximal emergency zone limit of 0.5 miles.[104]

2.5.7.2 Rating Scale Determination

The Hazard Rating scale was determined using the following steps:

1. The NRC emergency planning zones provide a guideline for emergency preparedness plans for a radiological release event. The NRC presents a recommended zone of evacuation in a 2-mile ring around the nuclear power plant. As this ring is the closest to the radiological release and is guaranteed to be evacuated in case of an emergency, those facilities/assets located within 2 miles of a nuclear power plant are associated with the largest Hazard Rating of 4.
2. The NRC further recommends evacuating 5 miles downwind from the release. Due to the unpredictability of winds, a second ring 5 miles from the radiological release represents the second highest Hazard Rating; any facility/asset located between 2 and 5 miles from a nuclear power plant will receive a Hazard Rating of 3.
3. The 10 mile radius that delineates the Plume Exposure Pathway marks the limits of the immediate effects due to a radiological release. At this distance from the release, it is at the responders' discretion to evacuate the citizens. Since this is not a distance that will guarantee an evacuation, it represents a moderate hazard level; any facility/asset located between 2 and 5 miles from a nuclear power plant will receive a Hazard Rating of 2.
4. The ingestion exposure pathway defines the furthest locations impacted by a radiological release and thus represents the low Hazard Rating; any facility/asset located between 2 and 5 miles from a nuclear power plant will receive a Hazard Rating of 1.

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[101] United States Nuclear Regulatory Commission. Emergency Planning Zones. http://www.nrc.gov/about-nrc/emerg-preparedness/about-emerg-preparedness/planning-zones.html. Accessed 11/19/2015.

[102] United States Nuclear Regulatory Commission. Backgrounder on Research and Test Reactors. http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/research-reactors-bg.html. Last Updated August 5, 2015. Accessed January 2016.

[103] Reed College. Reed Research Reactor. http://reactor.reed.edu/faq.html. Accessed January 2016.

[104] Norris M. Emergency Preparedness on a Smaller Scale: Research Reactors. http://public-blog.nrc-gateway.gov/2013/05/10/emergency-preparedness-on-a-smaller-scale-research-reactors/. Last Updated May 10, 2013. Accessed 1/16/2016.

2.5.7.3 Hazard Rating Table

Table 35. Hazard Ratings for External Radiologic Exposure.

Rating Category	Hazard Rating	Distance from Hazard
Very High	4	Facility/asset is less than or equal to 2 miles from a nuclear power plant.
High	3	Facility/asset is between 2 and 5 miles from a nuclear power plant.
Moderate	2	Facility/asset is between 5 and 10 miles from a nuclear power plant.
Low	1	Facility/asset is greater than 10 miles from a nuclear power plant.

2.5.7.4 Relative Modifier

The threat/hazard rating is modified by the national incidence of the event type in comparison to the incidence of all other event types. The most frequent event will have a relative modifier equivalent to one (i.e., no change), while the less frequent events will be scaled down, with the least frequent events having a relative modifier of 0.1. The steps and data used to determine the relative modifier of External Radiological release events are below.

1. No external radiological releases events could be identified that required the evacuation of the surrounding community. Therefore, the THAM assumes that there have been 0 external radiological release events in the past 20 years.
2. The external radiological release event rate was log-transformed and normalized according to the most frequent hazard. Because the resulting modifier value was less than the chosen minimum value, the modifier was set to 0.10. See Appendix C for a complete description of the process.

2.5.7.5 How to Calculate Hazard Rating

The steps below describe how to calculate a facility's/asset's Hazard Rating:

1. Go to the U.S. NRC List of Power Reactor Units to identify the nuclear power plants that function in the state in which the facility/asset is located.
2. Determine the closest nuclear power plant from the U.S. NRC List of Power Reactors and determine the distance between the facility/asset and the power plant.
3. Find the Hazard Rating associated with the identified distance found in Step 3 in Table 35 above, then multiply the identified Hazard Rating by the external radiological release relative modifier, 0.10.

2.5.7.6 How the THAM Tool Calculates the Hazard Rating

The steps below describe the inputs the THAM tool uses and how it calculates a facility's/asset's Hazard Rating for external radiological exposure events:

1. Once the user enters distance to the closest nuclear power reactor, the Tool uses that distance to output a Hazard Rating based on the guidelines in Table 35 above.
2. The Hazard Rating is then multiplied by the external radiological release relative modifier, 0.10.

2.6 Hazards Assessed Using Local Data Sources

The threats and hazards described above are a representative, but not comprehensive, list of possible concerns for HPH facilities and assets. A number of hazards, including facility/asset-level accidents, hazmat releases, technological failures, power disruptions, cyber outages, etc., can only be assessed based on locally held information. The hazards listed in this section do not have corresponding national data sources that can be used to determine Hazard Ratings, but, nonetheless, should be considered when completing the THAM. Once appropriate local data is identified, oftentimes through subject matter expert input, the general methods below can be used to calculate a Hazard Rating for each individual locally-based hazard type. It should be noted that the hazard ratings of the local hazards can be compared to each other, but cannot be compared to the non-local hazards assessed above.

2.6.1 Local/Internal Technological Hazards

2.6.1.1 Description of Hazard

Local/Internal technological hazards are unintentional events that typically effect mechanical, power, electronic, or other systems at a facility/asset level. These events may be caused by larger-scale hazards—intentional, unintentional, or natural—including those described in sections above. Technological hazards may also occur due to local or internal conditions such as the design, age, or maintenance history of the system or stresses put upon it through normal usage. Because of the myriad factors that may contribute to such localized failures, the best data from which to assess technological hazards is local historical data.

2.6.1.2 Rating Scale Determination

A hazard rating scale for localized events was determined that incorporates the historical frequency of occurrence of specific hazards, principally based on local subject matter expert input. The frequency of occurrence is translated to a hazard category (Very High, High, Moderate, or Low) in accordance with the World Health Organization's (WHO's) Vulnerability Analysis, a component of the WHO Health Care Facilities Toolkit.[105]

2.6.1.3 Hazard Rating Table

Table 36. Technological Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Description	Hazard Occurrence Range
Very High	4	Frequent	At least once per year.
High	3	Occasional	At least every 5 years.
Moderate	2	Unlikely	At least every 20 years.
Low	1	Rare	More than 20 years between occurrences.

2.6.1.4 How to Calculate Hazard Rating

1. For each of the facility/asset-level hazards below, identify how often the hazard has occurred at the facility/asset in the past 20 years using local data sources. See Appendix B for a definition of each hazard.

[105] World Health Organization. (2008) Vulnerability in Health Care Facilities: Risk Reduction in Hospitals.

a. Electrical Failure
b. Generator Failure
c. Transportation Failure
d. Fuel Shortage
e. Natural Gas Failure
f. Water Failure
g. Sewer Failure
h. Steam Failure
i. Fire Alarm Failure
j. Communications Failure
k. Medical Gas Failure
l. Medical Vacuum Failure
m. HVAC Failure
n. Information Systems Failure
o. Fire, Internal
p. Flood, Internal
q. Supply Shortage
r. Structural Damage
s. Heliport Accident
t. Dam Inundation
u. Other

2. Using Table 36 above, determine a Hazard Rating based on the frequency of the hazard occurrence.

2.6.1.5 How the THAM Tool Calculates the Hazard Rating

The THAM tool uses the user selected rate of occurrence for each of the Technological hazards, corresponding to a Hazard Rating in Table 36 above as the Hazard Rating.

2.6.2 Local/Internal Human Hazards

2.6.2.1 Description of Hazard

Local/internal human hazards are intentional acts by individuals or groups of people that may cause disruption to a facility's/asset's operations. Some human hazards may be directed at the facility/asset itself (e.g., chemical theft) or at persons located proximate to the facility/asset (e.g. infant abduction, hostage situation). Others involve activities unrelated to a specific entity in the HPH sector but are disruptive nonetheless due to close proximity to the facility/asset (e.g., civil disturbance, labor action). Human hazards are inherently difficult to predict and depend on a number of factors specific to the facility and region in which they occur. As such, the best data from which to assess facility/asset-level human hazards is local historical data.

2.6.2.2 Rating Scale Determination

A hazard rating scale was determined that incorporates the historical frequency of occurrence of specific human hazards. The frequency of occurrence is translated to a hazard category (Very High, High, Moderate, or Low) in accordance with the WHO's Vulnerability Analysis, a component of the WHP Health Care Facilities Toolkit.[106]

[106] Ibid.

2.6.2.3 Hazard Rating Table

Table 37. Human Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Description	Hazard Occurrence Range
Very High	4	Frequent	At least once per year.
High	3	Occasional	At least every 5 years.
Moderate	2	Unlikely	At least every 20 years.
Low	1	Rare	More than 20 years between occurrences.

2.6.2.4 How to Calculate Hazard Rating

1. For each of the hazards below, identify how often the hazard has occurred at the facility/asset in the past 20 years using local data sources. See Appendix B for a definition of each hazard.
    a. VIP Situation
    b. Infant Abduction
    c. Hostage Situation
    d. Civil Disturbance
    e. Labor Action
    f. Forensic Admission
    g. Bomb Threat
    h. Violent Patient
    i. Hazmat Theft
    j. Other
2. Using Table 37 above, determine a Hazard Rating based on the frequency of the hazard occurrence.

2.6.2.5 How the THAM Tool Calculates the Hazard Rating

The THAM tool uses the user selected rate of occurrence for each of the Human hazards, corresponding to a Hazard Rating in Table 37 above as the Hazard Rating.

2.6.3 Internal Hazardous Materials

2.6.3.1 Description of Hazard

Hazardous chemicals, radiological material, and biological agents held internally pose numerous hazards to human health and safety when not properly handled. Facilities/assets within the HPH sector that produce, use, or store such materials must consider the risks to workers and patients that could occur should the materials be spilled or otherwise released into the environment. The level of hazard presented by these materials is dependent on the amount of material maintained on the facility/asset premises, as well as other factors such as the level of training of employees and protocols for storage and access. Because these factors are highly facility/asset-specific, the best data from which to assess facility/asset-level hazards posed by hazardous materials is local historical data.

2.6.3.2 Rating Scale Determination

A hazard rating scale was determined that incorporates the historical frequency of occurrence of specific hazardous material spills or exposures. The frequency of occurrence is translated to a hazard category (Very High, High, Moderate, or Low) in accordance with the WHO's Vulnerability Analysis, a component of the WHO Health Care Facilities Toolkit.[107]

2.6.3.3 Hazard Rating Table

Table 38. Hazardous Material Hazard Ratings.

Rating Category	Hazard Rating	Hazard Occurrence Description	Hazard Occurrence Range
Very High	4	Frequent	At least once per year.
High	3	Occasional	At least every 5 years.
Moderate	2	Unlikely	At least every 20 years.
Low	1	Rare	More than 20 years between occurrences.

2.6.3.4 How to Calculate Hazard Rating

1. For each of the hazards below, identify how often the hazard has occurred at the facility/asset in the past 20 years using local data sources. See Appendix B for a definition of each hazard.
    a. Chemical HAZMAT Exposure, Internal
    b. Radiological Exposure, Internal
    c. Biological Exposure, Internal
    d. Other
2. Using Table 38 above, determine a Hazard Rating based on the frequency of the hazard occurrence.

2.6.3.5 How the THAM Tool Calculates the Hazard Rating

The THAM tool uses the user selected rate of occurrence for each of the Hazardous Material hazards, corresponding to a Hazard Rating in Table 38 above as the Hazard Rating.

[107] Ibid.

Appendix A: Acronyms and Abbreviations

CDC	Centers for Disease Control and Prevention
CIP	Critical Infrastructure Protection
CSV	Comma separated values
DHS	Department of Homeland Security
DHS I&A	Department of Homeland Security Office of Intelligence & Analysis
EMP	Electro Magnetic Pulse
FBI	Federal Bureau of Investigation
HAZMAT	Hazardous materials
HHS	Depart of Health and Human Services
HPH	Healthcare and Public Health
HSIN	Homeland Security Information Network
HVA	Hazard Vulnerability Assessment
HVAC	Heating, ventilating, and air conditioning
HVE	Homegrown violent extremists
IC	Intelligence Community
IEP	Ingestion Exposure Pathway
ILI	Influenza like illness
MSA	Metropolitan statistical areas
MS-ISAC	Multi-State Information Sharing & Analysis Center
NAICS	North American Industry Classification System
NIPP	National Infrastructure Protection Plan
NM	Nautical mile
NOAA	National Oceanic and Atmospheric Administration
NPMS	National Pipeline Mapping System
NRC	Nuclear Regulatory Commission
NTHMP	National Tsunami Hazard Mitigation Program
PEP	Plume Exposure Pathway
PHI	Personal Health Information
PHMSA	U.S. Pipeline and Hazardous Materials Safety Administration
PHRAT	Public Health Risk Assessment Tool
TAC	Terminal area charts
THAM	Threat/Hazard Assessment Methodology
UCR	FBI Uniform Crime Report
USCERT	U.S. Computer Emergency Response Team
USGS	United States Geological Survey
WHO	World Health Organization

Appendix B: Local/Internal Hazard Definitions

Technological Hazards

- **Failure (General Reference) - not operating or available at normal operation levels or as expected to operate.**
- **Communications Failure-** The loss of normal communication operations at a localized level, requiring the activation of redundant forms or methods of communication. Communication loss may be short-term or long-term. Example: A fiber optic line is cut in a construction zone on site, resulting in the loss of all Voice Over Internet Protocol (VOIP) communications in a hospital clinic. A back-up landline or "power fail" phone is used to contact patients.
- **Electrical Failure** – A facility-level power outage caused by a failed circuit breaker or similar technical failure or a localized loss of power to a facility due to an issue with the local electric distribution system. A loss of electrical power at this level is normally short term in nature.
- **Fire Alarm Failure -** When the normal process associated with the activation of a fire alarm system fails. Example: Fire Alarm cabling is cut to the fifth floor during unrelated repair work and requires the entire floor to go on Intermittent Life Safety Measures (ILSM) alarms as repairs are made.
- **Generator Failure** – When a generator does not start or run to expectations. Example: A generator misses several monthly routine maintenance inspections; local facility managers attempt to start it during a local power outage situation, but it fails to operate.
- **HVAC Failure** – A situation in which the facility heating, ventilation and air conditioning (HVAC) system fails to operate properly. Example: A hospital is experiencing record breaking heat, causing the HVAC system to run at full capacity for several days. Eventually one of the coolers goes down causing the temperature to rise 8 degrees above normal range. Lab equipment starts shutting down and patients must be moved out of the hospital until it is repaired.
- **Information Systems Failure** – A facility-level disruption or outage of critical information systems and services, typically caused by human error, technical failure, or malicious IT activity. Example: a computer virus accidentally introduced by an inattentive employee creates a disruption of facility IT servers.
- **Medical Gas Failure** – A situation in which medical gases are not readily available to support normal operations. Example: Due to a leak in the main oxygen line into a hospital facility, the hospital is required to use portable tanks.
- **Medical Vacuum Failure** – A situation in which the vacuum system no longer provides vacuum power at the level needed to support normal operations. Example: The pump on the medical vacuum fails to undergo monthly maintenance checks for several months and runs low on oil, causing the pump to seize and stop working.
- **Natural Gas Failure** – A situation in which the supply of natural gas to the facility is no longer at sufficient levels to meet normal operational needs. Example: A construction crew accidentally cuts the natural gas distribution line to a local hospital facility. The natural gas supply to the hospital is disrupted for 8 hours as repairs are made.
- **Sewer Failure** – A situation in which normal solid and/or wastewater removal systems are disrupted or are not operating normally. Example: A construction crew doing repair work on the facility premises accidentally breaks a sewer line, causing a temporary disruption in normal waste removal operations.
- **Steam Failure** – A situation in which the steam supply to the facility is no longer available to support normal levels of operation. Such a situation may be due to physical or mechanical causes and can be short-term or long term. Example: The facility boiler is accidentally struck by a delivery cart, knocking a pipe loose and requiring the boiler to be shut down with a resultant two

hour shutdown in steam availability. Or, due to the main water line breaking during a hard-extended freeze, steam is disrupted for four days.

- **Water Failure** – A situation in which the supply of water to the facility is insufficient to meet normal operational needs. Example: An on-site construction crew accidentally cuts through the main water line to the facility, causing loss of water to the facility.
- **Fuel Shortage** – A situation in which facility fuel requirements are not met by the supply on hand or are not readily available. Example: Local fuel distribution is disrupted due to a local transportation workers' strike.
- **Supply Shortage** – Any disruption in the flow of goods or services required to support normal operation at the facility. Example: Due to the shortage of Succinyl Choline, Rapid Sequence Intubation Kits have to be filled with Etomidate instead.
- **Fire, Internal-** A fire event initiated at the facility level as a result of human error, technical failure, or a local weather event, typically indicated by smoke, flames, or an alarm. Example: anesthesia gases are sparked in the hospital operating room causing a flash fire burning several staff and the patient.
- **Flood, Internal** – When unexpected or undesired loss of control over facility water systems occurs, resulting in water spillage and cleanup beyond normal operations. Example: The sprinkler head in a lab is hit by a duct mop causing it to break. High flow water floods the lab floor requiring remediation for mold.
- **Gas/Emissions Leak** – A situation in which there is a probable or verified release of gas or gas emissions. Example: A construction crew working on site inadvertently cuts through a gas distribution pipe.
- **Heliport Accident** – A situation in which a helicopter is damaged during takeoff from or in an attempt to land at the facility helipad. Example: A helicopter was attempting to land on Helipad 1 when a strong wind forced it to collide with an adjacent light pole.
- **Dam Inundation** – A situation in which the area downstream from a dam becomes flooded and covered with water if the dam ruptures or fails. Example: Fears that the Oroville Dam might fail in February 2017 led to the evacuation of several towns in the Dam Inundation Zone.
- **Water Contamination** – A situation in which the facility's water supply is found to affected by a known or suspected contaminant. Example: The local water supply to the facility is found to be contaminated by Xylene and Toluene.

Human Hazards

- **Bomb Threat** – A threat, usually verbal or written, to detonate an explosive or incendiary device to cause property damage, death, or injuries, whether or not such a device actually exists. Example: A hospital staff member receives a telephone call indicating that there is a bomb in a hospital facility.
- **Civil Disturbance** – An act of violence and/or disorder that violates the law and disrupts normal work activities and/or access to the workplace. Example: A protest closes the main roads into the hospital, delaying staff in getting to work.
- **Forensic Admission** - A patient admitted or being treated in a medical facility who is under the custody of a law enforcement agency or Department of Corrections. Example: A prisoner from a state prison or county jail is transported to a medical facility for admission.
- **HAZMAT Theft** - Illegally taking possession of a chemical or substance that is a hazardous material. Example: A person steals a chemotherapy drug vial from a hospital pharmacy, or appropriates red waste containers with formalin from the hazmat storage area.
- **Hostage Situation** - An incident in which a person or group of people are being held illegally against their will either by the threat of violence or the use of restraints. Example: A behavioral health patient threatens to harm anyone who tries to leave a group room on a psychiatric unit. Or,

a parent who does not have custody of a child takes the child into a locked room inside the facility and refuses to give the child up.

- **Infant/Child Abduction-** An incident in which an infant, child, or person under the age of 18 is taken from a facility without the knowledge or consent of the legal parent or guardian.
- **Labor Action** - A legally allowable action or actions organized by multiple employees that disrupts operations to change a policy or practice or negotiate terms of employment. Example: A union strike or picketing.
- **Suspicious Package/Substance** - An object whose origin and/or contents are unknown and are to be treated as if it MAY pose a risk to life or property until it is investigated and declared safe. Example: An unattended backpack in a common area.
- **Violent Patient** - An admitted patient who, due to their medical, mental or emotional state, is legitimately threatening to or actively physically assaulting (hitting, spitting, kicking, biting, etc.) another person or persons including other patients, visitors, or staff.
- **VIP Situation** - The admission or visit (scheduled or unscheduled) of an individual whose presence in the hospital can attract an audience, prompt media attention, or create a heightened security risk. In some cases, these situations require pre-planning and coordination with outside agencies. Example: Government officials protected by the Secret Service, celebrities, community leaders, etc.

Hazardous Material Hazards

- **Biological Exposure (Internal)** - An exposure to biohazardous materials (including biohazardous waste) that may pose a risk to human life and/or the environment. Example: A hospital staff member accidentally drops a medical waste storage container, spilling its contents.
- **Chemical HAZMAT Exposure (Internal)** - An exposure (by contact, inhalation or ingestion) to any chemical substance that poses a risk to the safety of facility staff, patients and/or visitors, the facility itself, or the environment. Example: An environmental services worker is exposed to harmful disinfectant while diluting a solution without wearing gloves.
- **Radiological Exposure (Internal)** - An exposure to a radiant energy or particles in the air, typically due to the accidental release of radioactive material. Example: An accidental of spill of radioactive seeds during a radiation implant procedure.

Appendix C: Calculating Threat/Hazard Ratings

The ability to compare Threat/Hazard Ratings across threats and hazards requires that all ratings be expressed in terms of a common rate denominator (e.g., number of events per year). Therefore, each non-local threat/hazard rating (i.e., those determined using national data sources) calculated in the THAM is adjusted by a relative modifier that scales the preliminary rating according to the common rate definition.

The relative modifier for each threat/hazard was calculated by determining the national incidence of the event type in number of events per year. Because the range of estimated incidence rates spanned several orders of magnitude (from less than 10 to greater than 100,000 events per year), each event rate was log-transformed. The log-transformed rates were then normalized so that the greatest rate received a modifier of 1.0 (i.e., unchanged). The most frequently occurring event type (lightning: 109,000 events per year), defined the maximum relative modifier value. The remaining log-transformed event rates were then scaled proportionally, with a minimum value (floor) of 0.1. This mathematical relationship is presented by the following equation:

$$\boldsymbol{RM = \frac{log(E)}{log\ (E_{max})}}$$

Where:

RM = Relative Modifier

E = Number of events per year of the event type of interest

E_{max} = Number of events per year of the most frequent event type

Given:

$0.1 \leq RM \leq 1.0$

Any RM values calculated to be less than 0.1 were set at 0.1. Similarly, events occurring too frequently to enumerate (i.e., cyber-attacks) were assigned a relative modifier of 1.0. The data used to calculate relative modifiers and the resulting modifier values are presented in Table B1 below.

Table B1. Relative Modifier Determination.

Threat/Hazard	Number of Events	Years	Event Rate ($year^{-1}$)	Log-transformed Event Rate	Relative Modifier
Information Theft	308	18	17	1.23	0.24
Terrorism	555	20	28	1.44	0.29
Active Shooter	214	16	13	1.13	0.22
Cyber	Infinite	N/A	N/A	N/A	1.00
Violent Crime	92,490	1	92,490	4.97	0.99
Property Crime	107,755	1	107,755	5.03	1.00
Earthquake	974	20	49	1.69	0.33
Tsunami	3	20	0.15	-0.823	0.10
Landslide	2,281	20	114	2.06	0.41
Subsidence	12,024	20	601	2.78	0.55
Volcano	70	20	4	0.54	0.11
Damaging Wind	111,756	20	5,588	3.75	0.74
Drought	4,162	5	832	2.92	0.58
Flash Flood	31,284	20	1,564	3.19	0.63
Flood	17,784	20	889	2.95	0.59

Threat/Hazard	Number of Events	Years	Event Rate ($year^{-1}$)	Log-transformed Event Rate	Relative Modifier
Hail	86,289	20	4,314	3.63	0.72
Ice Storm	1,568	20	78	1.89	0.38
Snow	15,746	20	787	2.90	0.57
Storm Surge	383	20	19	1.28	0.25
Tornado	14,238	20	712	2.85	0.57
Wildfire	4,514	20	226	2.35	0.47
Extreme Heat	3,239	9.4	345	2.54	0.50
Extreme Cold	2,079	9.4	221	2.34	0.47
Hurricane	82	20	4	0.61	0.12
Space Weather	99,663	20	4,983	3.70	0.73
Thunderstorm	109,196	1	109,196	5.04	1.00
Influenza	1,148	9	128	2.11	0.42
Aircraft Crash	10	20	1	-0.30	0.10
HAZMAT Facility	51	18	3	0.45	0.09
HAZMAT Highway	45,758	20	2,288	3.36	0.67
HAZMAT Maritime	640	20	32	1.51	0.30
HAZMAT Railway	15,306	20	765	2.88	0.57
HAZMAT Pipeline	2,684	20	134	2.13	0.42
External Radiological Event	0	20	0	0	0.10