



Research Report

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Valuing Army Installation Resilience Investments for Natural Hazards

Exploring the Use of Insurance Methods and
Historical Installation Storm Damage

This publication has completed RAND's quality-assurance process but was not edited.

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Executive Summary

U.S. Army installations experience significant damage and mission impacts from hurricanes, floods, and other natural hazard events. Many of these natural hazards are expected to increase in severity and frequency because of climate change. Given these facts, the U.S. Army plans to build more resilience into installations. Because of fiscal constraints, the Army needs to calculate the return on investment (ROI) for making installation buildings more resilient to natural hazards given their vulnerabilities and risk.

Insurance premium information may provide useful insights into these decisions. Some insurance companies provide property insurance for natural hazards and can provide discounts on insurance premiums for property owners who make selected building resilience investments (e.g., improve roof anchorage). Given this context, the ASA(IE&E) asked RAND to estimate the risks faced by installations from natural hazards disruptions, identify strategies to inform installation resilience ROI decisions, and recommend ways the Army can reduce associated costs by learning from insurance industry practices. We explored the possibility that by analyzing how some insurance companies and the National Flood Insurance Program (NFIP) value certain resilience investments and by examining Army resilience investment processes and storm damage data, we could provide recommendations to improve Army resilience.

We assessed patterns and trends of relevant natural hazards and examined past hazard-related data for installations to understand costs, exposure, vulnerabilities, and damage at buildings. The Army data on installation natural hazards damage have gaps, and quality and accessibility issues, but are useful to assess resilience. The Army should improve guidance, oversight, documentation, and access to installation storm damage data to make them more useful for conducting installation resilience data analytics and informing diverse Army decisions. We also found a broad range of installation natural hazard damages, costs, and resilience options beyond buildings. If the Army only focuses on building resilience investments and costs, they may miss other investment options that could potentially be more cost effective.

We were able to calculate values of resilience investments based on discounts to insurance premium and methods used for commercial property and NFIP insurance. But publicly available commercial property premium rate formulas were difficult to find and use, while NFIP information were available and useful. Given our results, to develop a working ROI model to inform resilience investment decisions, as specified in the “Army Installations Strategy Implementation Plan,” the Army should explore a partnership with the commercial property insurance industry, use the NFIP results as a starting point for flood resilience ROIs, and consider the full range of costs, damages, and resilience investment options. NFIP results about the value of different flood resilience investments should support installation resilience decisions, such as using them in enterprise-level facility investment decisionmaking tools.

About This Research Report

This report documents research and analysis conducted as part of a project entitled *Pricing Installation Resilience by Learning from Insurance Underwriting and Premium Risk Models*, sponsored by Office of the Assistant Secretary of the Army for Installations, Energy and Environment OASA(IE&E). The purpose of the project was to estimate the risks faced by Army installations from wind, flood, seismic, wildfire, and other natural hazards disruptions, identify potential risk mitigation strategies to inform installation resilience return on investment (ROI) decisions and recommend ways the Army can reduce associated costs. This research was conducted within RAND Arroyo Center's Forces and Logistics Program. RAND Arroyo Center, part of the RAND Corporation, is a federally funded research and development center (FFRDC) sponsored by the United States Army.

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Summary

Every year, the U.S. experiences significant damage from floods, hurricanes, tornados, and other natural hazards, including 20 different major natural hazards that each caused billions of dollars in damage in 2021. Many of these severe natural hazards have been increasing in much of the United States over the last few years and some are expected to increase in severity and frequency. Some natural hazards are also expected to shift in location in the future given global climate change. U.S. military installations have experienced significant impacts to mission capabilities (e.g., inability to deploy troops because of damaged infrastructure) and damage (e.g., to buildings and roads) from exposure to natural hazards. The financial costs to recover from a major natural hazard event can be significant. For example, after Hurricane Katrina in 2005, the U.S. Army National Guard received over \$0.5 billion in military construction (MILCON) funding to rebuild buildings that were destroyed in Louisiana and Mississippi. Repair costs can also be high; for example, it cost over \$43 million in sustainment funds to repair facilities and infrastructure from a flood at Fort Irwin in 2013.

Given the anticipated increase in such damages and costs, a goal of the U.S. Army is to build resilience against the impacts of climate change—including installation facilities and infrastructure—to preserve mission capabilities. Resilience is the “ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.”¹ In some cases, resilience investments in installation buildings (e.g., securing the roof to withstand stronger winds or elevating the foundation to avoid flood damage), can help reduce the consequences that may incur from future natural hazards. Making these types of resilience investments can potentially save long-term costs and minimize disruption to installation missions.

However, given the costs and expected benefits, it does not make sense to make resilience investments on every building. The challenge for the Army is deciding where to make these investments, taking into account installations’ and installation buildings’ vulnerabilities to natural hazards, building characteristics such as age, the importance of installations and specific buildings to the military mission, the costs of different actions, and limited budgets. Basically, the Army needs to understand the return on investment (ROI) for making installation buildings more resilient to natural hazards based on their different vulnerabilities and risk. In addition, the Army already faces financial challenges in maintaining, repairing, replacing, and modernizing its large portfolio of buildings across the United States. Given funding constraints and the increase

¹ Department of the Army, Office of the Assistant Secretary of the Army for Installations, Energy and Environment, “United States Army Climate Strategy,” February 2022.

in threats from natural hazards expected because of climate change, the Army needs quantifiable data to show which installation facility resilience investments make financial sense.

The insurance industry provides property insurance to cover losses from natural hazards (e.g., windstorm and flooding). Firms sometimes provide discounts on insurance premiums for property owners who make selected building resilience investments that could reduce the expected damage costs in the future. Essentially, through these incentives, insurance companies are valuing selected building resilience investments, and their valuations and methods could potentially provide lessons to help the Army make more efficient installation building resilience investments that reduce costs.²

Given the Army challenges and insurance industry experiences, the Assistant Secretary of the Army for Installations, Energy and Environment asked RAND Arroyo Center to estimate the exposure and vulnerabilities of Army installations and buildings to flood, hurricane, and other natural hazards disruptions; identify potential mitigation strategies to inform installation resilience ROI decisions; and recommend ways the Army can reduce associated costs by learning from insurance industry practices. The study's underlying premise was that analyzing how private insurance companies and the National Flood Insurance Program (NFIP) (a federal program) quantitatively value certain resilience—coupled with examination of Army installation resilience investment processes and historical installation natural hazards cost and other data—could inform decisions about installation resilience investments.

Approach and Methodology

This is an exploratory research study. The main hypothesis of this study is that there are commercial property or NFIP flood insurance premium rates that are reduced based on resilience investments and that these premium formula can provide insights that the Army can use to improve its building resilience investments. Another objective of this study is to provide insights into potential improvements to Army resilience-related processes and activities based on our analyses of information as part of this study (e.g., assessments of natural hazards information, Army installation storm damage patterns, and flood mapping data). The main focus of this study is on the repair and reconstruction of Army installation buildings.

We begin by assessing patterns and trends of different types of relevant natural hazards and examining past hazard-related impacts at installations to understand costs, exposure, and damage at buildings and their vulnerabilities to the natural hazards. Based on these natural hazards assessments, we developed illustrative building case studies for a set of Army real property building asset classes (e.g., maintenance buildings and barracks) that are important to Army

² Although the Army is self-insured in the sense that they budget for and pay for damage to their own buildings, these insurance-based valuations could provide useful proxy data, and the methods could potentially provide lessons for the Army's resilience investments. Also, as discussed in the main report, we view our estimates as lower bounds for the value of these investments.

missions and for different installation sites (e.g., Fort Stewart, GA, and Fort Carson, CO).³ For these case studies, we estimated a set of insurance premiums under the premise that premiums provide a quantitative expression of risk. We then assessed the discounts offered by private-sector insurance companies and NFIP for various resilience measures for the relevant natural hazards: these incentives provide a basis for valuing these investments. Based on these analyses, we provided insights and developed recommendations for Army installation resilience investment processes to improve the processes, improve resilience, and save long-term costs.

Our study has a number of caveats. First, we underestimate the costs of historical natural hazard damage to Army installations given the limited data available and our focus on building damages. Second, our premium discounts likely underestimate the value of resilience investments. Third, the resilience investment measures examined in this study based on the commercial property and NFIP insurance assessments were a limited set and other resilience options exist, including installation-wide measures, that should also be considered in installation resilience investment decisionmaking. Finally, given practical resource constraints, we focused on a limited set of natural hazards where the Army owns and operates a large number of buildings and where it has experienced costly storm damage in the past, and on the associated natural hazards and hazards that are most relevant for insurance coverage.

Assessment of Natural Hazards Patterns and Trends and Vulnerabilities of Army Installations

Since our study was focused on learning from insurance industry practices, we focused on identifying and understanding information about natural hazard types that insurance companies provide building coverage for and that they will give discounts for resilience investments in such buildings. We also focused on natural hazard events that can potentially cause significant amounts of facility damage that installations need to repair and recover from in the future based on historical damage and repair costs at Army installations and their exposure based on the natural hazard patterns and trends.

Damage and Costs to Army Installations from Historical Natural Hazards

We began our research by assessing U.S. natural hazards patterns and trends and examining damage from natural hazards at U.S. installations. Installations experience many different types of costs and damage from natural hazard events. During and immediately after a disaster, installations must contend with emergency response and actions to recover and maintain operations including dealing with loss of life and injuries and impacts to the mission, such as

³ Installation sites for the commercial property insurance case studies were chosen based on locations where we could find publicly available insurance rate formula for different natural hazards and where Army installations had natural hazard exposure and a history of damage from those natural hazards and expected continued exposure to such natural hazards in the future.

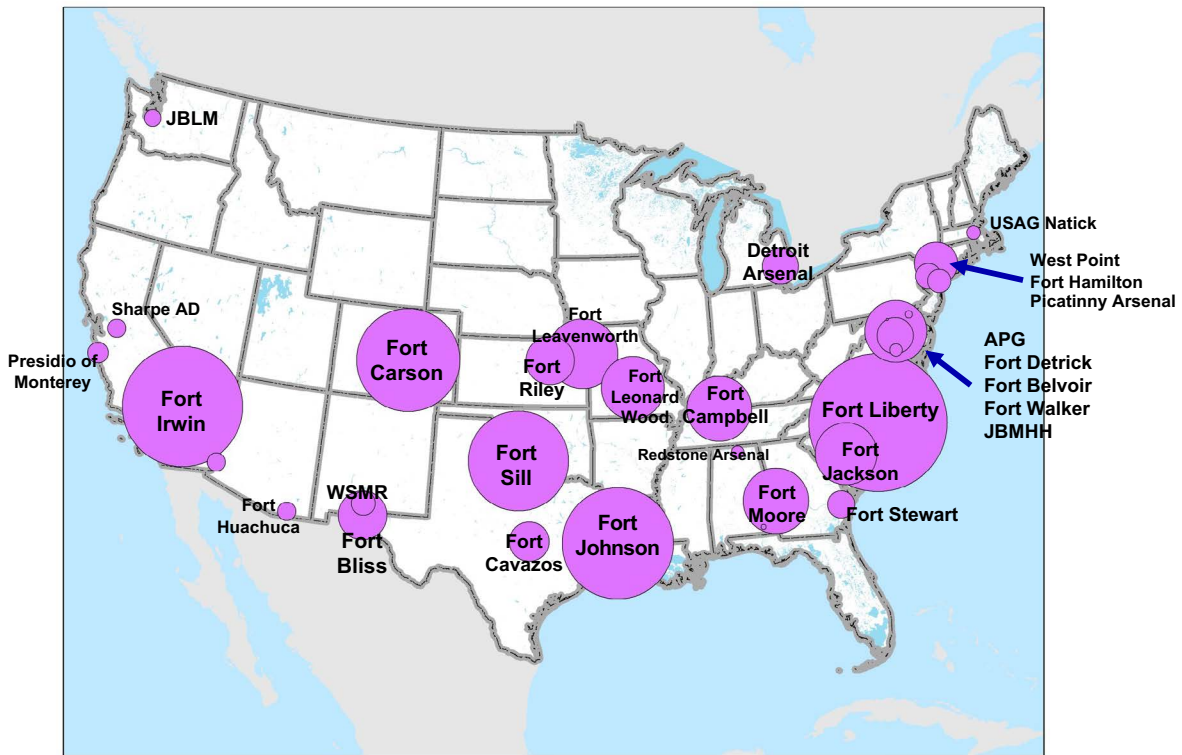
temporary degradation and loss of deployment and training capabilities. Over the longer term, installations need to restore the full function of facilities and operations, which includes Sustainment, Restoration, Modernization (SRM) and MILCON costs to repair and rebuild different installation facilities (e.g., buildings, roads, and power and water infrastructure). Both the response and recovery phases can include Base Operations Support (BOS) costs, e.g., clearing roads to access and/or rebuild facilities.

Because the commercial property and NFIP insurance primarily focus on damage to buildings, we focused on gathering SRM and MILCON cost data for Army installation buildings. There is no centralized Army data for natural hazards damage across the Army. Each Army organization that is responsible for Army-owned installations and facilities tracks these historical event costs to buildings through the SRM and MILCON projects. Army organizations that manage Army-owned real property and can have historical data include: Installation Management Command (IMCOM), Army Materiel Command (AMC), Army National Guard (ARNG), and the Army Reserve. We acquired and assessed SRM and MILCON funding data from the largest U.S. Army real property owners, IMCOM and the ARNG.

IMCOM headquarters reserves SRM funding each year to provide sustainment funding to installations that experience significant fire and natural hazard damages. Based on this IMCOM SRM Storm Damage data, there were 101 natural hazard events between FY 2011 through FY 2021, across 37 different installations that experienced significant cost damage from diverse natural hazards (see Figure S.1).⁴ These natural hazards events included: hurricane, flooding, storm, wind, freeze, tornado, rain, hail, and earthquake. Over the last ten years, at least 65 percent of these installations experienced such damage from two or more storms and at least 46 percent were repeatedly experiencing damage from the same type of storm. For example, Fort Leonard Wood had three floods, two freeze events, one tornado, and one strong wind event. In addition, often the damage types experienced at installation buildings are the same, e.g., recurring damage from wind and flooding. For many of the installations with such recurring storms and damage, we also examined natural hazard patterns and projections data and many of the recurring storm types showed a long history and had projections that they will continue to occur or get more frequent and/or more severe.

⁴ The historical storm damage data provided by IMCOM headquarters were missing data for FY 2012 and part of FY 2014.

Figure S.1. Total Validated SRM Storm Damage Costs at Each Installation Between FY 2011 and FY 2021



SOURCE: IMCOM Storm damage data for FY 2011 through FY 2021, excluding FY 2012 and including only some of the storms from FY 2014.

NOTE: The size of the dot indicates the validated SRM costs ranging from \$34,000 up to almost \$100 million in nominal dollars. Installations without validated costs for their events are not shown on this map. Installations must use 5 percent of their total sustainment funds before they can use IMCOM SRM storm damage data funds so these SRM building costs are a lower bound on IMCOM sustainment storm damage costs. Validated SRM costs includes costs for repairing buildings, structures, and utility systems. There was also 1 storm event for Fort Greely, AK, that is not shown on this map and its size would be much smaller than the circle for USAG Natick.

We assessed the available SRM and MILCON installation data related to building damage and costs from past natural hazards events for ARNG and IMCOM managed installations. We found that most Army installation storm damage to buildings comes from two fundamental forces of nature: water and wind. Water damage comes from flooding, hurricanes, storms, and rain. For example, within the 11-year period of IMCOM SRM storm damage data we found that the four storm types that involved water (i.e., hurricanes, floods, storms, and rain) accounted for over 69.3 percent of all storm types and 66 percent of the total validated SRM cost damage. Similarly, within the same 11-year period we found that the four storm types that involved wind (i.e., wind, tornados, hurricanes, and hail) accounted for 44.6 percent of all storm types and 48.7 percent of the total validated SRM cost damage. Most MILCON projects from natural hazards

also involved wind because all the building-related storm damage except for one building were from hurricanes and tornados.⁵

Broader Relevance and Challenges in Using Data About Historical Damage from Natural Hazards at Army Installations

In this study, we identified and examined other data in addition to the ARNG and IMCOM building SRM and MILCON project data, such as data about SRM cost damages to installation roads and utilities and the BOS costs from natural hazard events. We found potential for this broader set of natural hazards event damage data (i.e., building plus the other types of damage data) to help with diverse resilience investments and broader Army decisions impacted by climate change. For example, these data could potentially help inform future installation stationing decisions (e.g., helping identify which installations are more or less vulnerable to natural hazards), and help inform parts of both the *United States Army Climate Strategy* (ACS) and the Army Installations Strategy (AIS).

In addition, if the Army only focuses on building resilience investments and SRM and MILCON costs (as we did in this study), they may be missing other types of costs and resilience investments that could potentially be more cost effective. For example, regional storm water management approaches that increase the flood resilience for broader parts of the installation could potentially increase the resilience for a set of installation buildings, roads, utilities, and other structures at a lower cost than investing in flood resilience measures at individual buildings and other facilities.

Installation natural hazards data could be useful for many decisions, but we found three main challenges in working with these data sets. Specifically, they are incomplete, have quality problems, and are difficult to access. For example, the Army data systems are missing data so there is an incomplete picture of the costs from natural hazards at Army installations, and it is difficult to find, access, use, and combine data from the diverse systems with different data variables in them. Given these issues, it is difficult for the Army to assess the different types of individual costs along with the full costs to make appropriate ROI resilience investments. Also, our installation natural hazard cost data are lower bounds on the Army installation and building storm damage costs.

⁵ It is important to look at more than 11 years of data (as in the IMCOM SRM Storm Damage data) or even 20 years of data (as in the ARNG MILCON and SRM Act of Nature projects). We also looked at some historical and trend data, such as Missouri where Fort Leonard Wood is located. Looking at data back over 120 years to 1900, Missouri has a history of extreme precipitation events and the frequency and the intensity of extreme precipitation events has been and is projected to increase, along with the potential for an increase in the frequency and intensity of floods. R. Frankson, K.E. Kunkel, S.M. Champion, and B.C. Stewart, *Missouri State Climate Summary 2022*, NOAA/NESDIS, NOAA Technical Report NESDIS 150-MO, 2022.

Natural Hazards Most Relevant for Insurance Industry Discounts for Resilience Investments

Based on the insurance coverage types available (e.g., catastrophic windstorm coverage) and our assessments of the natural hazard information, four categories of effect from natural hazards —“causes of damage” or “perils” in insurance parlance—are most relevant for our purposes: flood, hail, hurricane, and wind/tornados.⁶ Different natural hazards can cause these same types of effects, for example, a thunderstorm could cause flooding, hail, and wind damage. Table S.1 provides a summary of the damage of these historical events at Army installations and the patterns for the natural hazards.

Table S.1. Summary of the Patterns and Historical Installation Damage of the Natural Hazards of Interest

Natural Hazard	Historical Events at Army Installations	Natural Hazard Patterns
Floods	- Nearly 25% of the events in the IMCOM SRM storm damage data - Single event had over \$43.3M SRM costs - Has resulted in the need for at least one MILCON project	- Heavy precipitation events, sea-level rise, and storm surge are projected to increase - Flood frequency influenced by weather and other factors (e.g., land use) but climatic conditions will be favorable for flooding^a
Hail storms	3% of the events in the IMCOM SRM storm damage data - One event had over \$20.4M SRM costs	- Causes significant damage in certain areas of the United States - Nebraska, Colorado, and Wyoming are areas with frequent hailstorms
Hurricanes	- About 25% of the events in the IMCOM SRM storm damage data - Highest SRM storm damage over \$51.7 million - Different hurricanes have resulted in multiple ARNG MILCON projects	- Intensity expected to increase in the future - Annual frequency will remain stable or decrease
Tornados and wind storms	- Over 15% of the events in the IMCOM SRM storm damage data - A tornado caused over \$30.1M in SRM costs - Tornados incurred MILCON costs for IMCOM and ARNG	- Usually, small special footprints with significant impacts - An unusually widespread tornado occurred across Arkansas, Missouri, Tennessee, and Kentucky in December 2021

SOURCE: IMCOM SRM storm damage data, Army MILCON data, and the literature.

^a Favorable for flooding means it could lead to more flooding in the absence of other factors.

⁶ These are the natural hazard effects that have or have the potential to cause significant cost damage to Army installation buildings and where the commercial insurance industry and NFIP provide hazard-specific coverage and offer reductions in premium for selected resilience investments.

Insurance Premium Calculations

To develop installation case studies for the insurance premium calculations, we identified a set of Army real property asset categories that have commercial comparisons and are important to the Army: vehicle maintenance buildings, barracks, and office buildings (e.g., a battalion or brigade headquarters building). We also assessed the IMCOM Army installation storm damage data to identify which of the Army building types have cost the Army a large amount to repair after previous storms, and then we identified actual buildings at selected installations as illustrative case studies based on the building, locational, and other factors needed for the commercial property and NFIP insurance calculations.

We found examples of commercial property and NFIP insurance rates that are reduced based on resilience investments. We were able to calculate illustrative premium values for different resilience investments for both commercial property and NFIP insurance using publicly available rate formula information and case study building characteristics. These values depend on how long the resilience investment remains in service: more years of services translate to more risk reduction benefits. We note that our method does not fully reflect the values of resilience investments: our calculations give lower bounds that may be useful for decisionmakers to understand the relative, rather than the absolute, value of different investment options.

Commercial Property Insurance Premium Calculations for Different Resilience Investments

Although commercial property insurance companies make public filings on their insurance premium calculations, complete formula are difficult to find. Insurance programs are typically updated in small pieces rather than all at once, although wholesale updates are occasionally made. We searched through over 5,000 insurance rate filing documents for 14 insurance companies in 13 states to find examples of sufficiently complete rate filing insurance information, and less than 2 percent had useful information.⁷ Ultimately, we found sufficient filings for comparative analysis for five companies in only seven states: California, Colorado, Georgia, Kansas, New Jersey, Oklahoma, and Virginia. These states limited which installations we could use as case studies for our commercial property premium calculations. Because we found more useful insurance rate filings in Georgia than in any other state and because being along the coast compared to inland made a difference on premium values, we chose Fort Stewart and Fort Moore (formerly Fort Benning), Georgia, as two case studies. We chose three other cases: Fort Belvoir, VA to include another state that experiences hurricanes, and two locations in the center of the country with likely higher incidents of hail, tornado, and windstorms: Fort Carson, CO, and Fort Sill, OK.

⁷ The documents we worked with typically ran over a hundred pages. Because none of the data are encoded in digital form, calculations generally required manual identification and input of values from over a dozen tables for each insurer and each case study.

In line with the risks that their policies cover, we found commercial property insurance companies primarily provide resilience investment discounts for windstorm/tornados, hail, and hurricanes. The five commercial property insurance companies valued resilience investments differently. Each of them provided discounts based on the basic building construction type, which affects its wind resistiveness. We found sufficient premium rate information for specific resilience investment measures for only one insurance company. Based on the formulas used for calculating this company's premium rates, we ran excursions with each of the illustrative resilience investments and calculated the impact on baseline premium. These resilience investment measures were:

- Roof anchorage
- Metal rolldown curtain doors
- Window protection: shutter protection provided for at least 50 percent of exterior glass
- Fitted storm shutters and hurricane straps for the shutters
- Condition of exterior caulking/sealing
- Insulation/freezing protection

Among these options, our results show that this insurer places the highest value on roof anchorage: premium declines by 14 percent as anchorage improves from below average to average condition, and it declines by a further 9 percent if upgraded to an above average condition for a total of 23 percent (see Table S.2.). For our case studies, these results are invariant to building type: the value of discounts scales with building value. We again stress that these results are intended to be interpreted on a relative rather than an absolute basis. Readers should conclude that, roof anchorage, for example, appears to be the most valuable of the resilience investments considered by this insurer: its total valuation necessarily includes more than we can measure here.

Table S.2. Annual Premium Savings for Specific Resilience Investment Measures for the Fort Stewart Maintenance Building Case Study

Construction Modifications	Below Avg -> Avg	Percent Savings over Baseline	Avg -> Above Avg	Additional Percent Savings
Roof anchorage	\$3,530	14%	\$2,353	9%
Insulation/freezing protection	\$1,647	6%	\$1,177	5%
Shutter protection provided for at least 50% of exterior glass	\$1,177	5%	\$941	4%
Metal rolldown curtain doors	\$ 0	0%	\$1,647	6%
Fitted storm shutters and hurricane straps for the shutters	\$ 0	0%	\$1,177	5%
Condition of exterior caulking / sealing	\$471	2%	\$471	2%

NOTE: This insurance company rates resilience investments in terms of “below average,” “average,” and “above average” condition. However, the public material that we obtained about this company’s premium calculations did not provide specific definitions for these terms.

NFIP Flood Insurance Premium Calculations for Different Resilience Investments

We were also able to calculate illustrative premium values for different resilience investments for FEMA’s NFIP flood insurance. NFIP information is generally available, consistent, and useful. We believe that the methodology could be usefully incorporated into Army models. We used the recently released NFIP Risk Rating 2.0 model to calculate estimated annual flood insurance premium values for illustrative real-world Army buildings. These calculations began with an illustrative maintenance building, barracks, and office building with diverse flood exposures from Fort Cavazos (formerly Fort Hood) as a base case.⁸ All buildings are located in the 100-year floodplain. We varied key factors related to resilience investments and calculated the impact on baseline premium. Then we ran excursions for a similar illustrative maintenance building, barracks, and office building at Fort Stewart, GA and Fort Carson, CO, and a maintenance building at Aberdeen Proving Ground, MD.⁹

We found that NFIP insurance rates are reduced based on specific resilience investments that help to reduce damage from floods. Some reductions are constant regardless of building characteristics or location while others vary based on these factors (see Table S.3). Generally, elevating buildings resulted in the greatest reduction in premiums.

⁸ We chose Fort Cavazos, TX, as our base case because of a wide range of barracks, maintenance, and office buildings with different types of flood exposure which provided three building examples with diverse and interesting flood exposure.

⁹ We chose buildings from Fort Stewart, GA; Fort Carson, CO; and Aberdeen Proving Ground, MD as case studies to represent flood exposures for different parts of the country and different types of flood exposure and risk.

Table S.3. Summary of NFIP Resilience Investment Measures That Have Constant and Variable Effects on Premium

Resilience Investments That Have Constant Effects on Premium	Resilience Investments That Have Variable Rates in Premium
• 5% reduction when machinery and equipment are above the 1st floor • 30% increase when there is a basement • 33% reduction when you convert a barracks to an office building • 33% or 58% reduction when you elevate the building by 2 or 5 feet in areas where flooding is possible	• Relative structure elevation to ground • Moving the building farther away from the water hazard source

SOURCE: Author analysis of Federal Emergency Management Agency (FEMA) NFIP data.

Recommendations

How the Army Can Use the Insurance Premium Assessment Results

Given commercial property insurance rate information, our analysis illustrates how to generate values for selected resilience investment decisionmaking for hurricanes, wind/tornados, and hailstorms. To use this kind of information on a wider basis, the Army would need to gather and analyze a more comprehensive, representative set of insurance rate data. The publicly available data we used was difficult to search and extracting the relevant information from each filing was time-consuming. There were also gaps in the data (e.g., rate data were not found for some states). *Therefore, to pursue commercial property insurance methods to help inform resilience investments, we recommend the Army explore partnering with the commercial property insurance industry.*¹⁰ We did not evaluate the full costs and benefits of such a partnership in this study, but we note that such a partnership is likely to be a more efficient approach than using publicly available data.

In addition, *to help develop a working ROI model to inform resilience investment decisions as specified in the Army Installations Strategy Implementation Plan, we recommend the Army explore a partnership with the commercial property insurance industry, use the NFIP results as a starting point for flood resilience ROIs, and consider the full range of costs, damages, and resilience investment options.*

Since NFIP insurance rates are reduced for some basic flood resilience investment measures, the Army should also use NFIP information to support Army installation investment decisions at different levels. At the installation level, *the Army should use this NFIP information in assessments to inform MILCON requests, in developing Installation Climate Resilience Plans and in master planning decisions.* At the enterprise level this information should be used to help compare investments across installations. For instance, *the NFIP methodology should be*

¹⁰ By the property insurance industry, we mean insurance carriers and the firms on which they rely to analyze property risks, often referred to as “Catastrophe Modelers.” See for example, Verisk, homepage, undated; Moody’s RMS, homepage, undated; or Marsh, “Catastrophe (CAT) Modeling,” webpage, undated.

incorporated into Army methods and models for helping to compare selected resilience investments strategies, e.g., in such enterprise-wide decisionmaking tools as the Facility Investment Analytics tool. However, when using our NFIP results, we also recommend, in comparisons of different resilience investment options, the Army be sure to assess and incorporate, as appropriate, other investment strategies that can also help increase installations' resilience to flood damage.

Improving the Use of Installation Natural Hazards Data for Army Decisionmaking

Since we found that some installations are repeatedly experiencing costly damage from the same storm types and incurring the same types of damage (e.g., recurring flood and wind damage), and since many of these storm types have a long history of occurrence and are projected to continue or get worse, the Army should be using this information for resilience investment decisions across installations to save long-term costs. Specifically, *Army headquarters organizations should prioritize selected resilience investments in their SRM and MILCON investment decisions at installations that repeatedly experience recurring storm damage because these investments would be expected to save money over the long term by avoiding damage from future storms and the repair costs of such damage.*¹¹

However, it is important to note that such investments should be made on high-value mission critical buildings and that before selecting which buildings and projects to invest in the Army should conduct building-specific cost benefit analyses that include assessing mission readiness benefits.¹² Similarly, for the same reasons, *IMCOM headquarters should consider setting aside a limited amount of funding for adding selected resilience features that have been shown to have value to installation buildings that have been damaged by storms and are being repaired for installations that repeatedly experience the same types of storms and recurring damage over time and where those natural hazards have a long history of occurrence and are projected to continue or get worse in the future.*

It would be useful to make installation data about past and on-going damage from natural hazards more accessible, complete, and accurate for installation resilience investment decisions, future data analytics especially because of climate change projections, and other types of

¹¹ For evidence about how natural hazards resilience investments can save money, see Keith Porter, Charles Scawthorn, Charles Huyck, Nicole Dash, Joost Santos, Kevin Mickey, Tarek Rashed, Adam Reeder, Michael Eguchi, Ron Eguchi, Sannidhye Ghosh, Zhenghui Hu, Moad Isteita, and Althea Cohen-Porter, *Natural Hazard Mitigation Saves: 2019 Report*, National Institute of Building Sciences, Multihazard Mitigation Council, December 2019.

¹² By mission readiness benefits we mean considering the benefits to the mission by having the mission-critical buildings with the resilience investments remaining functional after a natural hazard event because of the resilience investment compared to it being damaged without it. For example, there could be mission continuity benefits and cost savings by not having to temporarily stop the mission in a storm damaged building and not having to relocate the mission while the damaged building is being repaired. Similarly, energy and water resilience are also important to ensure mission readiness.

installation decisions related to the effects of natural hazards. To do this, *the Army should enhance guidance and oversight on installation natural hazards damage data to improve data quality, capture, tracking, storage, and management.* Specifically, Army headquarters organizations should ensure data gaps are being addressed in different Army databases including adding new fields to data systems as needed. The Army should also provide headquarters oversight to ensure that installations are properly entering and storing these data. To improve access and the usefulness of installation natural hazards cost damage data for installation and enterprise decisionmakers, Army headquarters should develop enterprise-level documentation about what data exists and where they are located within the Army; improve data capture in relevant Army data management systems; and improve access to current and historical data.

Last, *Army headquarters should conduct a study to identify where and how all Army storm damage data could help with different installation resilience decisionmaking (e.g., the ACS and the AIS) and how the data could be used to support future data analytics.* This study should also identify all the natural hazards damage data gaps, quality, and accessibility issues and how best to address them given current and potential future uses.

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Chapter 1. Introduction

Every year, the United States incurs significant damage from floods, hurricanes, tornados, and other natural hazards. In 2021, the United States experienced 20 different major natural hazards that each caused billions of dollars in damage, including extreme cold temperatures in Texas and other parts of the south, flooding in California and Louisiana, and an unusually widespread tornado in Arkansas, Missouri, Tennessee, and Kentucky in December 2021.¹³ Some of these severe natural hazards have been increasing in much of the United States over the last few years and most are expected to worsen given global climate change.¹⁴ Climate change effects and associated extreme weather events include heavy precipitation,¹⁵ flooding (coastal and inland), heat, and wildfires; and they are anticipated to increase in severity and frequency in the future.¹⁶ Infrastructure that is either poorly-maintained or built to codes and standards derived from historical weather patterns that may no longer hold true are especially vulnerable to damage.¹⁷

U.S. military installations have also experienced significant damage from exposure to natural hazards. Impacts to military installations can include effects on mission capabilities (e.g., inability to deploy troops because of damaged infrastructure), injuries and loss of life, and damage to installation buildings, other facilities, and infrastructure. The financial costs to recover from a major natural hazard event can be significant. For example, the ongoing cost to repair and rebuild Tyndall Air Force Base after over 480 buildings were damaged or destroyed from Hurricane Michael in 2018 is \$4.9 billion.¹⁸ The costs to repair facilities and infrastructure from

¹³ Adam B. Smith, “2021 U.S. Billion-dollar Weather and Climate Disasters in Historical Context,” NOAA, January 24, 2022.

¹⁴ USGCRP, *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, D.W. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, eds., U.S. Global Change Research Program, 2017; USGCRP, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart, eds., U.S. Global Change Research Program, 2018; and J.K. Summers, A. Lamper, C. McMillion, L.C. Harwell, “Observed Changes in the Frequency, Intensity, and Spatial Patterns of Nine Natural Hazards in the United States from 2000 to 2019,” *Sustainability*, Vol. 14, No. 7, 2022, p. 4158.

¹⁵ As defined in the Army Climate Strategy, climate change is “variations in average weather conditions that persist over multiple decades or longer that encompass increases and decreases in temperature, shifts in precipitation, and changing risk of certain types of severe weather events.” Department of the Army, Office of the Assistant Secretary of the Army for Installations, Energy and Environment, *United States Army Climate Strategy*, February 2022.

¹⁶ USGCRP, 2018.

¹⁷ USGCRP, 2018.

¹⁸ U.S. Department of Defense, “2021 Report on REPI Program Outcomes and Benefits to Military Mission Capabilities,” Office of the Assistant Secretary of Defense for Sustainment, 2021, pp. 6–7.

Hurricane Florence that hit Fort Liberty (formerly Fort Bragg) in 2018 was over \$51.7 million.¹⁹ The Army spent over \$43 million to repair facilities and infrastructure from a major flood at Fort Irwin in 2013.²⁰ Costs to repair or rebuild individual buildings can also be high. For example, it cost the Army \$25 million to build a new Army National Guard (ARNG) readiness center at Panama City, Florida, after it was severely damaged during Hurricane Michael in 2018.²¹ In that same year, a tornado devastated an ARNG readiness center in Pineville, Louisiana, which cost \$16.5 million to replace.²²

As stated in the *United States Army Climate Strategy*, a major goal of the U.S. Army is to build resilience against the impacts of climate change—including installation facilities and infrastructure—to ensure the Army is ready to accomplish its assigned missions. Resilience is the “ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.”²³ In some cases, resilience investments in installation buildings can help reduce the costs and other consequences that may incur from future natural hazards by reducing a building’s vulnerability through measures such as strengthening or hardening the structure (e.g., securing the roof to withstand stronger winds), modifying the design of the structure when being built (e.g., elevating the foundation to avoid flood damage), or moving its location (e.g., moving a structure to higher ground to reduce flood risk). These types of resilience investments can potentially save long-term costs and minimize disruption to installation missions. However, given the costs and expected benefits, it does not make sense to invest in resiliency for every building.

The challenge for the Army is deciding where to make these investments, taking into account installations’ and installation buildings’ vulnerabilities to natural hazards, building characteristics such as age, the importance of installations and specific buildings to the military mission, the costs of different actions, and limited budgets. The Army needs to be able to understand the value of making different installation investments which will vary by location and individual building characteristics because of the different risks. Basically, the Army needs to understand the return on investment (ROI) for making installation buildings more resilient to natural hazards given their vulnerabilities and risk and how that varies by location and other factors (e.g., number of stories of the building).

In addition, the Army already faces financial challenges in maintaining, repairing, replacing, and modernizing its large portfolio of buildings across the United States. Installations experience

¹⁹ Installation Management Command (IMCOM) storm damage data for FY 2011 through FY 2021, excluding FY 2012 and including only some of the storms from FY 2014.

²⁰ IMCOM storm damage data for FY 2013.

²¹ ARNG AoN data extraction from PRIDE, December 2021.

²² ARNG AoN data extraction from PRIDE, December 2021.

²³ Department of the Army, Office of the Assistant Secretary of the Army for Installations, Energy and Environment, *United States Army Climate Strategy*, February 2022.

difficulties in making sufficient investments in the maintenance and repairs necessary to keep facilities in good working order (called facility sustainment) because the Army has been underfunding facility sustainment costs in order to maintain warfighting readiness.²⁴ Similarly, budget considerations affect funding for facility restoration (i.e., repair and replacement work to fix facilities damaged by previous inadequate sustainment, excessive age, natural disasters, fires, and accidents) and facility modernization (i.e., updating facilities to implement new or advanced technologies or to accommodate new functions). Large reductions in the Army's military construction (MILCON) funding over the last dozen years or so makes it difficult to build new facilities and has led to installations having to rely on sustainment, restoration, and modernization (SRM) funding to address the Army's facility investment needs.²⁵ As a result, most Army installations have not been able to invest sufficient resources in basic SRM project needs, let alone invest in installation resilience—which can increase the cost of an already needed SRM project.

Given this funding situation and the increase in threats from natural hazards expected because of climate change, the Army needs quantifiable data to assess whether installation facility resilience investments make financial sense. Currently, the Army and the Department of Defense (DoD), as self-insured government entities, do not have a rigorous methodology to properly evaluate the monetary value of the natural hazard risks to their portfolio of real property and equipment assigned to those installations. The absence of appropriate methods and metrics for generating values for resilience significantly impedes Army and DoD's ability to select the right amount and types of investment to avoid future disruptions.

The insurance industry provides commercial property insurance to cover losses from natural hazards (e.g., windstorm, hail, and flooding). In some cases, their programs may offer discounts on insurance premiums for property owners who make certain types of building resilience investments (e.g., installing roof anchorage). These reductions in premium reflect the value insurance companies expect to save on future claims payments. Essentially, through these incentives, insurance companies are valuing selected building resilience investments, and their methods could potentially provide lessons to help the Army price installation building resilience investments.

Given the Army challenges and insurance industry experiences, the Assistant Secretary of the Army for Installations, Energy and Environment (ASA[IE&E]) asked RAND Arroyo Center to estimate the risks faced by Army installations from wind,²⁶ flood, hurricane, and other natural

²⁴ Ellen M. Pint, Beth E. Lachman, Katherine Anania, and Connor P. Jackson, *Improving the Allocation and Execution of Army Facility Sustainment Funding*, RAND Corporation, RR-3240-A, 2020.

²⁵ Pint, Lachman, Anania, and Jackson, 2020.

²⁶ For the purposes of this study, we are looking at contributors to risk, specifically the exposure and vulnerabilities of Army buildings to select natural hazards. Because we are interested in understanding how insurance pricing practices can be used to identify potential resilience investments, a full risk-assessment that assesses likelihood and consequences of natural hazards is beyond the scope of this study.

hazards disruptions, identify potential risk mitigation strategies to inform installation resilience ROI decisions, and recommend ways the Army can reduce associated costs by learning from insurance industry practices. By analyzing how private insurance companies and the federal National Flood Insurance Program (NFIP) quantitatively value certain resilience investments and by examining Army installation resilience investment processes, we can potentially develop both pricing and policy recommendations to improve Army installation resilience investments to save costs and improve installation resilience to natural hazards.

This is an exploratory research study. The main hypothesis of this study is that some commercial property or NFIP flood insurance rates are reduced based on resilience investments because of the reduction in expected claims that these investments may yield and that these analytical methods can provide insights that can be used by the Army to improve the valuation of its building resilience investments. Another objective of this study is to provide insights into potential improvements to Army resilience-related processes and activities based on our analyses and examination of these processes, Army installation storm damage data, and other data and information used in this study (e.g., assessments of natural hazards information, and flood mapping data). By examining private-sector commercial property insurance and NFIP premiums for commercial buildings, the Army could potentially develop better quantitative models to better assess and price resilience measures and better manage natural hazards risks at installations. Based on these objectives, the main research questions for this study were:

1. Can commercial property insurance and NFIP premiums and their values of resilience investment measures help inform Army installation building-related resilience investment decisions and if yes, how?
2. How can Army installation resilience-related processes and activities be improved based on our analyses of data and information conducted as part of this project?

Approach and Methodology

To investigate how insurance data may inform resilience investments at Army installations, we assessed natural hazards patterns and trends and installations' vulnerabilities to these hazards to understand where the highest costs and damages to installation buildings are likely to occur and where it might be appropriate to make such investments. Using this information, we developed a set of illustrative case studies based on specific Army installations and buildings. To increase the relevance of our findings, we focused on hazards that occur frequently at Army installations and are covered by typical insurance policies. These policies generally respond to damages to buildings: we discuss the impacts this has on our scope below.

We estimated the likely insurance premiums for a set of relevant natural hazards through our installation case studies for a set of real property building asset classes (e.g., barracks and maintenance buildings) and calculated and examined how premiums vary as a function of resilience investments. Based on these analyses, we provided insights and developed

recommendations for Army installation resilience investment processes to improve the processes, improve resilience, and save costs.

Scoping: Building Damage Compared to the Full Range of Installation Damages and Impacts from Natural Hazards

When examining the costs of natural hazards events at installations, it is important to understand the full range of potential impacts. Army installations experience many different types of costs and damages from natural hazard disasters beyond the costs of damage to buildings, as illustrated in Figure 1.1. During and immediately after a disaster, installations must contend with emergency response and immediate actions to recover and maintain operations. Costs immediately after a disaster include loss of life and injuries, emergency response personnel costs, initial installation operational recovery costs (e.g., emergency repair costs to facilities which are often captured in emergency work order data systems), and impacts to the mission and natural resources. Mission impacts can include operational and financial costs ranging from temporary degradation and loss of mission capability and function (e.g., deployment and training capabilities) and/or moving these missions to other locations to the costs of using backup systems and adapting to meet mission needs with damaged facilities. In the figure, mission impact is represented by a red X over one tank to show that the Army cannot deploy all its tanks because of the storm damage.

Over the longer term, installations pay for repairs to restore the full function of facilities, systems, and operations. Longer-term costs include the major costs for repairing, recovering, and rebuilding facilities, which include SRM and MILCON. Facilities include buildings; energy and water infrastructure (such as pipelines); road, railroads, and other transportation infrastructure; and communications infrastructure. Having reliable and resilient electrical power, potable water, operational communications, and wastewater systems are important to military readiness and ensuring mission capabilities.

Base operations support (BOS) costs, e.g., clearing roads to access facilities during the emergency response and removing debris from the installation during the recovery, can occur both immediately after a disaster and in the longer run. The BOS costs can be significant after hurricanes and other major disasters. Natural resources effects include degradation to installation landscaping, ecosystems, erosion control, and training range functionality.

Because commercial property insurance and the NFIP coverage mostly apply to damage to buildings, *we limited the scope of our research to examining resilience investment measures for Army installation buildings only*—that is, the costs for repairing and rebuilding installation buildings. Our scope and the methods used to conduct the study did not include emergency response and initial operational recovery costs; loss of life or injuries; the costs to missions; natural resources and environmental costs; BOS costs; or costs to repair utilities, roads, bridges, or other structures.

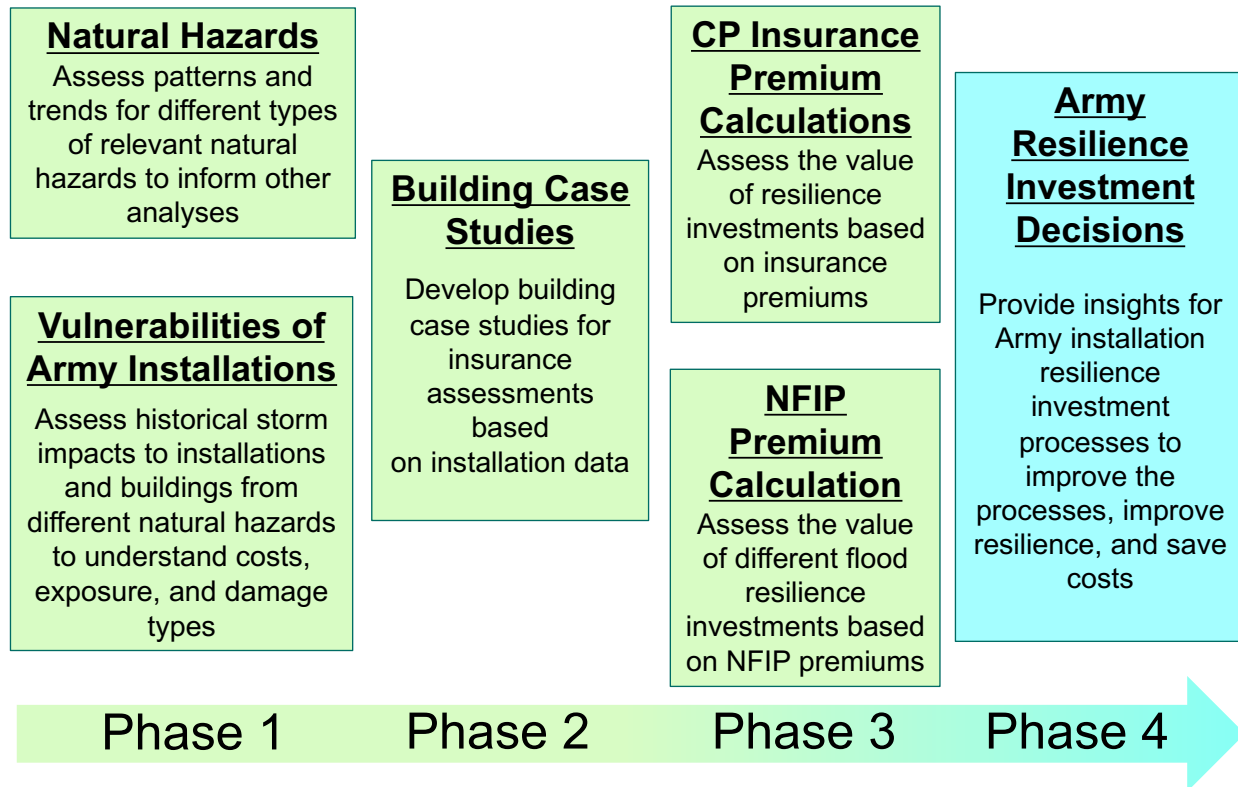
Figure 1.1. Installations Experience Diverse Damage and Costs from Natural Hazard Events



Project Methodology

We carried out this analysis in four phases, as shown in Figure 1.2. These phases were iterative, conducted simultaneously, and informed one another. Each element of the analytic process and the data used are discussed in detail in the following chapters of this report and the appendices; here we provide a brief overview. Phase 1 focused on understanding natural hazards patterns and trends and the vulnerabilities of Army installations to natural hazards. We then developed a set of building case studies in Phase 2, devising relevant examples informed by the Phase 1 research and where insurance premium calculations would be feasible and of interest. In Phase 3, we collected and analyzed insurance rate formulas, from commercial and NFIP insurers, to generate premium calculations and assess the value of resilience investments. In Phase 4 we examined Army installation resilience investment processes to understand how our research results could potentially improve them, enhance installation resilience, and save the Army costs. As part of Phase 4, we examined DoD and Army regulations, policy documents, and other relevant documents (e.g., DoD installation building codes, called Unified Facilities Criteria [UFC]) to understand different Army installation facility investment processes from installation to headquarters levels, including master planning and SRM and MILCON investment decisions.

Figure 1.2. Analytic Process Used for This Study



For multiple phases, we acquired and assessed damage data from different parts of the Army (i.e., Installation Management Command [IMCOM], ARNG, and the Deputy Chief of Staff for Installations, G-9) for both SRM and MILCON projects and for the ARNG and active-duty installations. MILCON data for the ARNG came from the Planning Resource for Infrastructure Development and Evaluation (PRIDE) system and active-duty installations the data came from the Army Construction Appropriation Programming Control and Execution System (CAPCES). We acquired all available SRM storm damage data for IMCOM-managed U.S. installations from the past ten years, a total of 101 storm events at 37 different installations. These data were assessed to understand the vulnerabilities and exposure of Army installations and buildings based on significant cost damage and by damage type (e.g., roof damage), building type, natural hazards, and location.

As part of our Phase 1 research, we discussed the Army data sources and data elements with Army subject matter experts from ASA(IE&E), G-9, Army Materiel Command (AMC) and IMCOM headquarters, ARNG, and U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) Construction Engineering Research Laboratory (CERL). For these analyses, as well as for developing the case studies (Phase 2) and for examining the resilience investment processes (Phase 4), we spoke with over 70 Army experts including construction engineers, master planners, researchers, modelers, and database managers. As part

of Phase 2, we also engaged in discussions with building experts from these Army organizations to understand the data and which buildings to focus on given the value to Army missions and to understand how the storm damage data could be more useful for Army installation resilience decisionmaking.

To select installations for NFIP case studies as part of Phase 2, we focused on installations with either a history of flood damage or relatively high exposure to flooding. To identify such installations, we analyzed different installation and building level flood related data in ArcGIS, including IMCOM historical storm damage data and Defense Climate Adaptation Tool (DCAT), and FEMA floodplain data. As part of this task, we examined over 20 candidate installations with a wide range of diverse buildings with different types of flood exposure along with the flood history information.

In parallel, we assessed what types of buildings at the case study installations would be most relevant in both insurance analyses given their importance to Army missions and costs to repair when damaged from natural hazards. As part of this assessment, we examined the IMCOM SRM installation storm-damage building-level data between 2011 and 2021 that were available. These data contained 35 unique installation storm events and 1,900 damaged buildings. We were also examining these data to understand how they could be useful in Army installation resilience-related processes and activities.

Caveats

We emphasize multiple caveats about our research. First, we underestimate the costs of historical natural hazard damage to Army installations for multiple reasons. We did not have data for all Army installations; for example, we did not have data for Army Reserve installations. Since we focused only on building damage data, we did not include cost data for damage to the buildings' contents, damage to utilities, or other types of natural hazard damage (see Figure 1.1). In addition, we are missing data from both the SRM and MILCON data sets, and we faced challenges working with the data available (e.g., at some installations for a small number of buildings the building SRM costs included some minor BOS-related costs in them). Since IMCOM installations must use 5 percent of their total sustainment funds before they can use IMCOM SRM storm damage data funds, the SRM building costs are a lower bound on IMCOM sustainment storm damage costs.

In addition, for all these reasons we do not make any attempt to sum up the total cost of historical natural hazard damage to Army installations. Given such limitations of this project, we stress the need for the Army to consider the full range of potential costs, damages, natural hazards, and resilience investment options in assessing and making installation resilience investment decisions. This later point derives from our second caveat—the resilience measures examined in this study based on the commercial property and NFIP insurance assessments were a limited set. Other resilience options exist and should be considered and assessed as part of

installation resilience investments, including installation-wide measures, such as built and natural infrastructure stormwater management actions.

Third, our premium discounts likely underestimate the value of resilience investments. At best, they capture the expected reductions in annual claims. But because of policy deductibles and limits, not all damages result in claims on a policy: for residential policies for example, typical deductibles are 1 to 5 percent of a home's insured value.²⁷ Moreover, the economics of insurance markets tends to push premiums higher for at least two reasons: parties with relatively greater risk seek more insurance where parties with little to no risk may not insure at all ("adverse selection"), and parties with insurance have reduced incentives to manage their risk ("moral hazard").²⁸ We also note that our estimates are based on recent rating formula and factors whose values are likely to evolve over time, particularly as climate change unfolds.

Fourth, the values we generate exclude more general benefits of resilience investments that may be present, like improved energy efficiency or aesthetics. Most critically for the Army, our analysis does not account for mission impacts of resilience investments. We therefore suggest that values of the kind that we calculate be used to provide insight into the relative benefits of resilience investments mainly as features that mitigate damage from the covered natural hazards. Specifically, resilience investments with higher values than others should be understood as conferring a greater degree of protection to the building.

Fifth, there are limitations to our NFIP model calculations and results. To ensure a high likelihood of relevant characteristics and parameters that were relatively sensitive to change, all our case study building sites were chosen to be in, or very close to, the DCAT 100-year floodplain. Buildings outside of the floodplain may be exposed to flood risk but are likely to show less extreme results in the NFIP calculations. Our analysis also mostly focused on riverine flooding and did not consider other sources of flood risk. The NFIP does account for some of these sources (e.g., coastal flooding from storm surge and tsunamis), but not all (e.g., effects of local low point ponding from a downpour and basement backups from precipitation that exceeds stormwater conveyance capacity).

Sixth, the NFIP has relatively low policy limits, with maximum coverage of \$500,000 available for non-residential buildings.²⁹ The NFIP data that we used allow us to calculate premiums for coverage limits up to \$1.2 million, but the buildings in our case studies, in fact, ranged in value from \$6 million to \$18 million. Given the NFIP model limitations, we cannot appropriately adjust our results to scale to these buildings values.

²⁷ See e.g., Hanover Insurance Group, "Understanding Wind Deductibles," webpage, 2018.

²⁸ The NFIP somewhat avoids the adverse selection problem by requiring any property owner in a high-risk flood area with a federally-backed mortgage to obtain flood insurance. For more information, see FEMA, "What Does My Flood Zone Mean?" [floodsmart.gov](https://www.floodsmart.gov), webpage, undated.

²⁹ See FEMA, "Flood Insurance and the NFIP," webpage, June 14, 2021.

Finally, given practical time and budget constraints for this project, we could not examine every location where the Army has buildings nor every hazard type. Consequently, we focused on locations where the Army owns and operates a large number of buildings and where it has experienced costly storm damage in the past, and on the associated natural hazards and other hazards that are most relevant for insurance coverage.³⁰ We began by focusing on the continental United States (CONUS), Alaska, and Hawaii.

Other parts of the world were outside our project scope for a variety of reasons. Our study was focused on areas where the Army owns, manages, invests in, and maintains large numbers of buildings; these were the priorities and focus for our study. The Army's ownership, management, and investments in property and facilities is different when a foreign government owns the land (e.g., in Germany and South Korea), so those areas were not included. Also, the Army does not have any active component installations in U.S. territories (e.g., Puerto Rico and Guam), so they have few buildings in those locations. In addition, given that private sector insurance coverage is different outside CONUS, Alaska, and Hawaii and since we could not cover every location, they were not included. Lastly, given where most of the Army buildings were located and based on our installation vulnerability assessment, we did not include a number of states in the final insurance analysis calculations, such as Alaska, Idaho, Montana, Wyoming, and Hawaii. In future assessments, the Army should consider more locations and more natural hazard types.

Background Information on Army Installations

To inform the discussion in the chapters that follow, this section discusses background information on Army installations and buildings, costs, and damage to installations from natural hazards, and installation resilience investments, and provides an overview of the Army Installation Facility Investment process.

Installations and Buildings

To learn about whether insurance practices can inform resilience investments in buildings at Army installations, we need to understand the set of Army installations and buildings that are vulnerable to damage. The Army operates 135 installations comprising about 13.5 million acres. Across these installations are buildings consisting of about 992 million total square feet. The total plant replacement value of Army installation buildings is about \$593 billion.³¹ These statistics include active Army (e.g., IMCOM managed installations), U.S. Army Reserve, and ARNG acreage and building square feet, but not ARNG facilities that are shared with the states.

³⁰ For example, we do not focus on climate risks that arise from small-scale, slow-moving, or diffuse hazards such as drought, sea-levels rise, and subsidence. These hazards can have the comparable aggregate costs over time as do the finite abrupt events that we discuss but they are not as relevant for our project focus.

³¹ U.S. Army, *Army Installations Strategy Implementation Plan: Fiscal Years 2022-2024*, 2022, p. 5.

Namely, an ARNG installation includes federally owned ARNG sites and buildings designated as depots, arsenals, ammunition plants, hospitals, and other special mission activities.

Army installations in the United States are managed by different parts of the Army. Active component Army installations are managed mostly by IMCOM, a subordinate command under AMC. IMCOM manages 73 installations across the world. AMC also manages about two dozen smaller installations consisting of the Army's organic industrial base sites and associated buildings and infrastructure.³² The reserve component installations consist of ARNG and Army Reserve installations. ARNG installations are spread across the United States and because of their unique role in support of individual states and territories, they maintain highly dispersed, smaller installations in all states and territories. In contrast, IMCOM-managed installations are larger footprints that are spread across the United States with a few hundred to a few thousand buildings on each of them.

An Army installation consists of an aggregation of contiguous or near contiguous, common mission-supporting real property holdings under the jurisdiction of an Army organization. An installation can consist of one or more sites. A site is Army controlled land and the buildings and other facilities on it that are often within a common boundary utilized as a post or camp, with functions such as training, troop housing, and airfield operations.³³ For instance, Fort Stewart, Georgia consists of two primary sites: the main site consisting of the cantonment area and the training ranges and other land around it, and Hunter Army Airfield (HAAF) which is a non-contiguous site located about a 40 mile drive away in Savannah, Georgia. Some sites are large, but many are small with only a few buildings or other facilities on them. For example, the ARNG maintains over 2,500 Readiness Centers located in more than 2,100 communities across the United States. These centers usually consist of one large building which serves as a key hub to train critical unit mission capabilities and coordinate support to states and the Army.³⁴

An Army facility is a real property entity consisting of a building, a structure (e.g., a bridge, flagpole, fence, and carport), a utility system, or underlying land or a combination of these items. A building is a facility constructed on Army land, covered by a roof, enclosed by walls, and usually it has flooring.³⁵

³² The management of these installations are being transitioned to IMCOM, but for historical storm damage data it would need to come from AMC.

³³ Army Regulation 405-45, *Real Property Inventory Management*, Headquarters, Department of the Army, November 1, 2004.

³⁴ "The Readiness Centers serve as distribution points, command and control hubs, and staging bases for first responders. Integrated into the communities they serve, the facilities also provide shelter and vital services for displaced civilians during emergency events that overwhelm local resources." Army National Guard Installations Division, "A Readiness Center for the Future," *Foundations of Readiness*, 2016, p. 7.

³⁵ Army Regulation 405-45, 2004.

Costs and Damage to Installations from Natural Hazards and Installation Resilience Investments

To understand how Army installations and buildings can potentially become more resilient to damage from natural hazards, we need to explain vulnerability and resilience in this Army context. Military installation resilience is defined in U.S. Code as

the capability of a military installation to avoid, prepare for, minimize the effect of, adapt to, and recover from extreme weather events, or from anticipated or unanticipated changes in environmental conditions, that do, or have the potential to, adversely affect the military installation or essential transportation, logistical, or other necessary resources outside of the military installation that are necessary in order to maintain, improve, or rapidly reestablish installation mission assurance and mission-essential functions.³⁶

Enhancing an installation facility's resilience to natural hazards can involve different types of approaches and options. One common approach is to focus on enhancing the survivability or hardening of the facility to make it stronger and better able to survive a disaster. These actions can focus on the facility itself, e.g., installing storm shutters to prevent damage to windows from hurricanes. Another approach is a system-level perspective, which would involve actions that focus on the system as a whole and its ability to function or a property-level action that focuses on changes surrounding the facility. An example of a property-level action is improving drainage so that stormwater flows away from the facility or reducing vegetation surrounding a facility to reduce fuel content and wildfire risk.

Another facility survivability approach is to focus on the regional level by taking actions for a larger area to help the entire system, e.g., implementing regional stormwater runoff best management practices within a neighborhood or more broadly throughout a watershed to better manage storm water runoff and help prevent flooding. Installations can implement life safety measures that protect lives during a disaster or protect lives after an event because of system or functional failure. Also, installations take rapid recovery actions to restore system functions more quickly after an event. One of the more common examples of this is repairing downed powerlines and other damage to the electrical system to restore electrical power to buildings as soon as possible.

For installations, ensuring resilience focuses on a range of facilities and systems, including energy, water, transportation, and communications. For example, energy resilience focuses on ensuring energy availability and reliability sufficient to provide for installation mission assurance and readiness, which can include installing on-installation power systems (e.g., large-scale solar arrays and other renewable energy projects), back-up generators, microgrids and large-scale energy storage to minimize power disruptions to mission-critical operations. Similarly, resilient potable water and wastewater systems are needed for mission assurance and readiness.

³⁶ 10 U.S.C. 101(e)(8).

For Army buildings, resilience means being able to keep them accessible, functioning, and operating during a natural hazard event, or if they are impaired or damaged during that event, being able to repair and rebuild them cost-effectively and efficiently so they are functioning at normal capacity again. Depending on the location and different building characteristics (e.g., how they are built and the condition of the building), some buildings are more vulnerable to natural hazards and damage from those hazards than others. Overall an installation's or building's vulnerability to a hazard is comprised of three factors:

- *Exposure*, which is the number or value of buildings, population, or other assets that are potentially exposed to a natural hazard and is determined by the occurrence of a hazard at a given location.³⁷
- *Sensitivity*, which refers to the degree to which exposure to natural hazards degrades an installation, its buildings and infrastructure, and its natural and cultural resources or affects the performance or use of the installation, its buildings and infrastructure, and its resources.³⁸
- *Adaptive capacity* for a building (other facilities and other asset type), which refers to the options to modify, repurpose, or relocate to reduce the potential for damage from natural hazards.³⁹

Resilience investments seek to reduce an installation or building's vulnerability and can do this by reducing the impacts of the hazard, such as through strengthening or hardening a structure (decreasing sensitivity) or modification such as elevating a foundation to avoid damage (adapting).⁴⁰

IMCOM, ARNG, and other Army organizations make investments in buildings, other facilities, and infrastructure to fix damage caused by natural hazards based on two main funding appropriation types, SRM and MILCON. MILCON funding is for constructing a new building and this type of investment is usually only made for older buildings in poor condition. Since it is more difficult for the Army to acquire funding to construct a new building (e.g., it requires congressional approval and Army MILCON projects compete with other Service MILCON projects for funding), SRM decisions and funding are more directly relevant for our study. Namely, since SRM resilience projects, (e.g., improving roof anchorage to make a building more

³⁷ Exposure refers to the extent to which a system is subjected to natural hazards. Adapted from A. O. Pinson, K. D. White, S. A. Moore, S. D. Samuelson, B. A. Thames, P. S. O'Brien, C. A. Hiemstra, P. M. Loechl and E. E. Ritchie, "Army Climate Resilience Handbook," U.S. Army Corps of Engineers, 2020, p. 219.

³⁸ Adapted from Pinson et al., 2020, p. 223.

³⁹ Adapted from Pinson et al., 2020, p. 217.

⁴⁰ For more on these topics see 10 USC 101 (e)(8); A.O. Pinson, K.D. White, E.E. Ritchie, H.M. Connors, and J.R. Arnold, *DoD Installation Exposure to Climate Change at Home and Abroad*, U.S. Army Corps of Engineers, 2021, p. 65; or U.S. Department of Transportation, Federal Highway Administration, *Vulnerability Assessment and Adaptation Framework*, 3rd Edition, 2017, referenced in U.S. Government Accountability Office, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters*, GAO 20-100SP, October 2019.

resilient to strong wind threats) are more common decisions that the Army needs to make to improve the resilience of existing facilities, SRM investments are more relevant for our assessment. However, our assessments could potentially help inform when the Army may want to consider a MILCON investment. For example, a resilience investment option to move a building farther away from a flood hazard source would involve the need to construct a new building which is a MILCON investment.

When planning for resilience investments, it is important to consider and assess the different types of damages, costs, and resilience measures that can help prevent and mitigate future damage and costs, rather than just focusing on building and other facility issues. For some natural hazards, non-facility approaches may be better investments, such as using regional built and natural infrastructure to increase resilience. For example, to prevent future flooding to buildings, investing in better regional stormwater management through nature-based solutions (also known as green or natural infrastructure or engineering with nature) may be more cost-effective in the long run rather than taking actions at the individual building level because it can potentially help reduce flood damage to multiple buildings and other facilities (e.g., roads and water infrastructure, see Figure 1.1).

In fact, Office of the Secretary of Defense programs (e.g., Readiness and Environmental Protection Integration (REPI) sentinel landscapes), FEMA hazard mitigation assistance programs (e.g., Building Resilient Infrastructure and Communities (BRIC) and Flood Mitigation Assistance grants) and some parts of the Army (e.g., USACE engineering with nature) are emphasizing these more strategic regional and nature-based solutions to help installations and communities to better adapt to the risks from floods. Regional nature-based solutions consisting of wetlands, floodplains, forests, and other natural systems provide flood protection, erosion control, and water purification and often provide more long-term hazard mitigation benefits than traditional built infrastructure.⁴¹

Some Army installations are also taking a regional approach to increase resilience to flood risk. For example, Detroit Arsenal, which has experienced mission degradation and significant costs from three major flooding events in the last five years, is working with Macomb County, City of Warren, the state of Michigan, and other stakeholders to improve regional drainage and stormwater management within their shared watershed to “reduce regional flooding.”⁴²

⁴¹ FEMA, “Building Community Resilience with Nature-Based Solutions: A Guide for Local Communities,” June 2021; P. Glick, E. Powell, S. Schlesinger, J. Ritter, B.A. Stein, and A. Fuller, “The Protective Value of Nature: A Review of the Effectiveness of Natural Infrastructure for Hazard Risk Reduction,” National Wildlife Federation, 2020; and Brittney Parker, Jessie Ritter, “Building Resilience through Natural Infrastructure: Barriers and Opportunities within FEMA Hazard Mitigation and HUD Community Development Block Grant Programs,” July 2021.

⁴² Converge Strategies, LLC, “Detroit Arsenal Regional Defense Assessment of Resilience (DAR2): Process and Project Concepts,” February 2022, p. 19.

Obviously, local conditions will help determine what approach to take and different approaches can be combined. For most cost-effective resilience investments, the important thing is to assess all relevant options. However, since our study is focused only on buildings, use of much of the information from this project is most relevant to those decisions. However, it can potentially provide insight about options that could be incorporated into a broader analysis beyond buildings alone. Given that part of the objective of this study was to learn from our analyses (including from examining the Army's installation historic storm damage data) our study does provide some insights regarding how some of these data could potentially help inform other assessments.

Army Installation Facility Investment Processes

Different organizations within the Army have different processes for determining how to invest in installation buildings and other facilities, and how to acquire and allocate SRM and MILCON funds for these investments. By examining these processes, we can identify where in the Army's facility investment processes resilience investments are currently being made or where they could potentially be made. Since IMCOM manages the largest portfolio of Army buildings, we provide a brief overview of these processes for IMCOM. To better understand where the findings from this study could potentially fit into IMCOM and other Army installation facility investment and execution processes, we also examined the Army, other federal agency, and literature on practices and guidance on resilience investment planning, which is discussed in Appendix F.

Figure 1.2 provides a brief overview of the assessment and decisionmaking processes regarding Army installation SRM and MILCON facility investments for IMCOM managed installations. The Army has developed a long-term Facility Investment Plan (FIP) process of restoration and modernization (R&M) and MILCON facility investments that AMC and IMCOM headquarters implement for IMCOM managed installations.⁴³ The FIP process is intended to meet Army senior leader priorities and focuses on a maximum ROI and achieving tangible readiness outcomes. AMC develops for the active component, or regular Army, a ten-year FIP for R&M and MILCON facility investments which the Army reviews and approves.⁴⁴ This FIP is based on projects that are submitted by Army commands and identified and prioritized by IMCOM headquarters based on installations' analyses of their R&M and MILCON needs and priorities. IMCOM headquarters conducts yearly assessments to recommend to AMC leadership to update the FIP and this includes updates to R&M funding requests and MILCON projects.

The USACE ERDC CERL has been developing a Facility Investment Analytics (FIA) tool to help in the FIP process. As part of FIA, this research organization has also been developing an

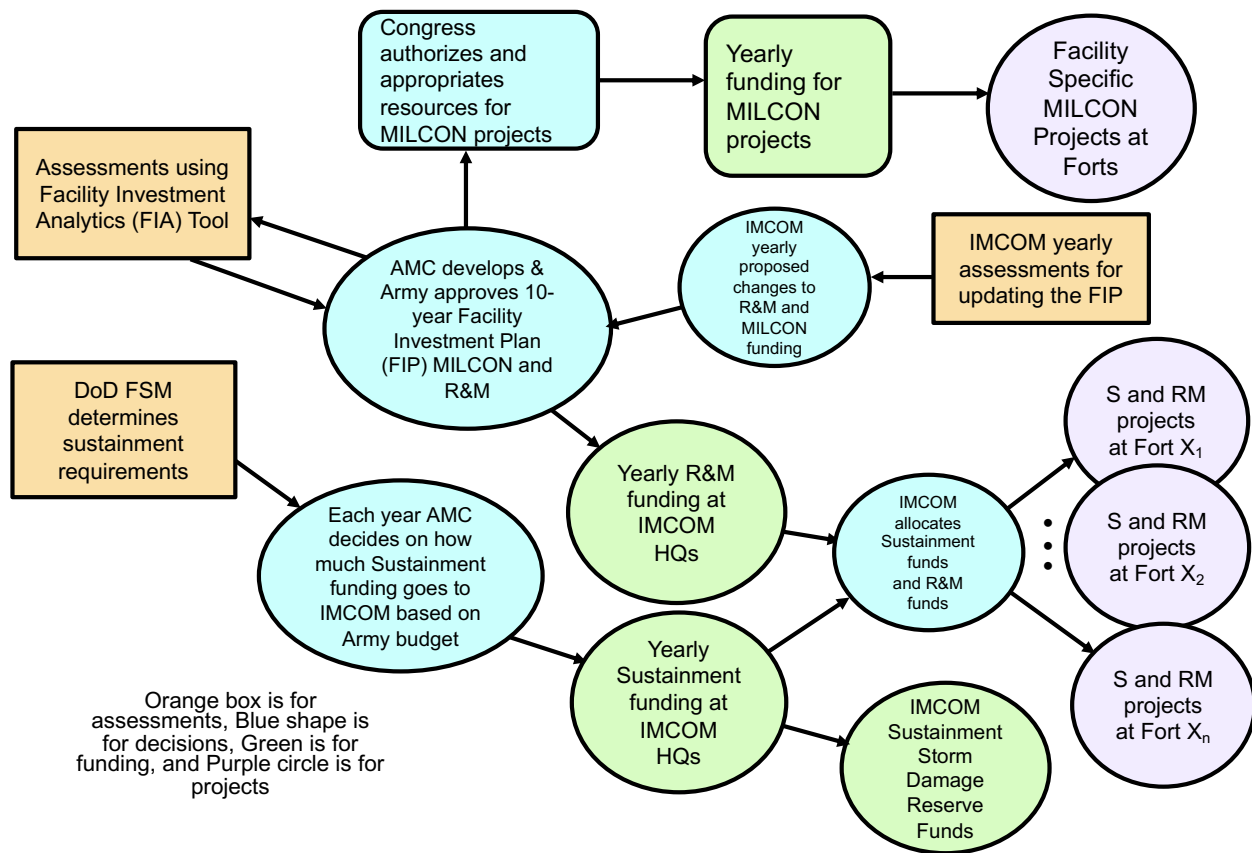
⁴³ HQDA Execution Order 273-20, *10 Year Facility Investment Planning*, November 2020.

⁴⁴ Office of the Chief of Army Reserve develops a FIP for the Army Reserve and the National Guard Bureau controls a FIP for the ARNG.

Operational Readiness Index (ORI) Construct to incorporate resilience to natural hazards and other threats to installation facilities into this process. The ORI Construct is a multicriteria decision analysis tool that evaluates risks to support resource and investment decisionmaking.⁴⁵ As part of this analysis, the ORI Construct seeks to evaluate the resiliency of installations by assessing its ability to respond to and recover from natural hazards. This work by ERDC CERL, is one example of how, recently, different parts of the Army have started focusing more on developing methods for assessing the value of natural hazard resilience investments and ways of incorporating them into decisionmaking, including enterprise decisions.

⁴⁵ David Savatgy, Jack Dempsey, Carrie Heishman, Jeffrey Freemyer, Marc Vandever, and Doug Hammer, “Facility Investment Analytics Roadmap” preliminary draft, April 13, 2022; U.S. Army, “Facility Investment Analytics (FIA) Framework Prototype Functional Design Document,” April 2022; and Jack Dempsey, Carrie Heishman, Jeff Freemyer, “Facility Investment Analytics (FIA) System Overview,” April 2022.

Figure 1.3. Army Facility Investment Execution Processes for Active-Duty IMCOM Installations



NOTE: The three dots refer to the fact that there are multiple installation from X_1 to X_n . Installations can in some cases also acquire some limited specialized funding from other sources to make resilience investments (e.g., energy and water projects from the competitive Office of the Secretary of Defense Energy Resilience and Conservation Investment Program [ERCIP]) and these are not shown on this diagram.

Based on the FIP analyses, the list of requested MILCON projects is submitted by the Army to Congress to review, authorize, and appropriate the funding. After Congress completes this process, the funding is allocated for specific MILCON facility projects that are implemented at the installation level. Similarly, after the Army and Congress have approved R&M funding, it is allocated to IMCOM HQs which then further allocates funding to the installations for R&M projects.

For sustainment funding, the DoD Facility Sustainment Model (FSM) is used to determine sustainment requirements for the facility inventory present at each installation. FSM estimates costs for maintenance activities necessary to keep a typical inventory of installation facilities in good working order over their expected service lives. Historically, the Facility Sustainment Model has not explicitly included costs related to natural hazards. Sustainment is not just for

facility repair projects; it includes preventative and demand maintenance.⁴⁶ Based on the total amount of sustainment funding requirement across all IMCOM installations and the Army budget, AMC decides on the total amount of sustainment funding for all IMCOM installations and passes this amount of sustainment funding to IMCOM each year.

IMCOM headquarters then decides how much sustainment money will be provided to each installation. In the last five years the funded portion of the sustainment requirement ranged from about 56 percent to a high of 83 percent.⁴⁷ IMCOM headquarters holds aside some of these funds at headquarters for special needs, including about 3 percent of the sustainment funding that is saved as a special storm damage and fire reserve source, called the IMCOM SRM Storm Damage funds, to pay for any unexpected large building and other facility repairs that are needed by installations each year to repair the buildings to the same condition. Installations must use 5 percent of their total SRM funding for such damage out of their existing unallocated SRM funding before they can request repair funding from this HQ IMCOM storm damage reserve to pay for the SRM costs.

Another important installation facility investment-related process that is not illustrated in this figure, is the installation master planning process which occurs at the installation level. IMCOM installations are each required to develop a Real Property Master Plans and update it every five years. Because of a FY 2020 NDAA requirement, installations are also required to start developing Installation Climate Resilience Plans (ICRPs) and incorporating them into installation master plans and resulting investment strategies. “The ICRP identifies and prioritizes infrastructure and real property actions required to sustain installation operations under emerging climate conditions.” An ICRP is to be developed by using installation mission impact analysis and climate planning tools to provide risk-based assessments and recommendations for installation mitigation projects that would be incorporated into the master plan. All Army components must update current installation master plans no later than fiscal year 2023 with available climate information as an initial step to incorporate climate threat and resilience considerations in current plans.⁴⁸

Besides Army funding processes, installations can also acquire some limited funding from other sources for installation resilience investments, which are not shown in this diagram. These are often in specialized installation facilities, such as energy and water systems. For instance, Office of the Secretary of Defense provides some limited funding that helps pay for some installation energy and water resilience projects including the ERCIP, the Strategic

⁴⁶ For IMCOM installations, demand maintenance refers to demand maintenance orders (DMO). A DMO is a request for an unscheduled maintenance to repair a component or system that is broken or has failed, e.g., a leaky roof, a broken window, or an air conditioning system that is not working.

⁴⁷ Verbal communication by Mr. Jeff Michels, IMCOM G-4, August 1, 2022.

⁴⁸ To facilitate this effort, installations must establish a working group chaired by the garrison or installation representative to make initial climate impacts assessments including the impacts to mission, training, logistics, real property, energy, utilities, environmental, and emergency management.

Environmental Research and Development Program (SERDP), and the Environmental Security Technology Certification Program (ESTCP).⁴⁹ For example, in FY 2023, Fort Cavazos, Riley, and Stewart all received ERCIP grants for power generation and microgrids.⁵⁰ In some cases, these projects can include resilience investments related to buildings. Funding to improve installation resilience can also come through partnerships with communities. An example related to ensuring adequate potable water occurred with a partnership supported by state and local agencies at Fort Leonard Wood. Fort Leonard Wood and the City of Saint Robert partnered in a joint emergency water supply line that enhances installation water resilience and a major part of the funding for this water line came from city funding and a HUD community development block grant which the State of Missouri acquired for the project.⁵¹

Background on Insurance Policies and Practices

For the Army to learn from property insurance practices for insuring against natural hazards, it is important to understand relevant terms and concepts connected to property insurance. Property insurance is a contractual agreement by which a person or company pays an insurance company, and the company provides a guarantee to pay for the value of property lost or damaged from potential disasters, accidents, and other risks, as specified in the contract.⁵² It is a contractual means for spreading specified risks among many individuals to mediate individual losses. Insurance companies, or “carriers,” sell policies that cover a set time-period (“term”) to buyers who are referred to as “policyholders” or “insureds.” In general, the carrier pays a policyholder when the policyholder suffers (“claims”) a loss from some cause identified in their contract during the policy term.⁵³ The cause of loss is also called a “peril,” which is an event (e.g., a windstorm, fire, or break-in) that may damage the insured building and/or its contents.

This study focuses on the analysis of commercial property and flood insurance premiums. A “premium” is the money paid for insurance coverage by the policyholder to the carrier. For an insurance company to stay in business, premiums collected from insureds must be sufficient to

⁴⁹ For more information about these and other funding sources for energy and water systems see RR-2773-1-A, *Alternatives for Reducing Army Installation Utility Bills While Enhancing Installation Readiness*, June 2020.

⁵⁰ Under Secretary of Defense (Comptroller), “FY 2023 Energy Resilience and Conservation Investment Program (ERCIP) Project List by State/Country,” undated.

⁵¹ For more information, see Beth Lachman, et al., *Comprehensive Army Installation and Community Partnership Reference Guide: Guidance and Best Practices for Effective Installation Partnerships*, unpublished RAND Corporation research, 2021.

⁵² Insurance is defined as, “a method by which interested members of a society can band together and collect funds to pay losses suffered later by members of the group,” Marshall Wilson Reavis III, *Insurance: Concepts & Coverage: Property, Liability, Life, Health and Risk Management*, Friesen Press: Victoria, BC, Canada, 2012.

⁵³ Typically speaking, property insurance operates on a “claims made” basis, which a claims-made policy provides coverage for claims that occur during the policy term and are reported within some time frame specified by the policy.

compensate for losses incurred by policyholders. Insurance carriers must therefore evaluate the risk of losses covered by the policy and charge premiums that consider the claims that the company expects to pay. The assessment of these risks is referred to as “underwriting,” and “underwriters” weigh the contribution of a variety of factors in their assessment based on previous losses and forward-looking considerations.

Standard commercial property insurance policies typically cover the following causes of loss: fire, lightning, windstorm, hail, riot or civil commotion, damage by aircraft or vehicles, smoke, explosion, vandalism, volcanic action, sinkhole collapse, and sprinkler leakage.⁵⁴ Special insurance coverage is available for certain natural hazards, called “named peril” policies, and the premiums charged often varies by location. In general, landslide, earthquake, and flood risks are excluded from standard property insurance and covered under separate named peril policies: because of the high correlation of losses from these causes by location and the strong potential for these losses to be large, providing insurance for these risks poses distinct challenges for carriers.⁵⁵ Catastrophic windstorm coverage can also be excluded from standard property insurance in some states, but it is typically available as an add-on (“endorsement”) to standard property insurance or as a separate policy. Commercial property insurance premiums can also vary based on the building characteristics that connect to resilience investments. For instance, if a building includes investment measures to help prevent damage from strong winds (e.g., hurricane straps and fitted storm shutters), the property owner could potentially be charged less for insurance regarding hurricanes and other strong windstorms because of reducing the expected damages from these types of events.

The NFIP is the most widely available flood insurance for residential and commercial properties throughout the United States. The NFIP was established by Congress in the National Flood Insurance Act of 1968. Administered by FEMA in partnership with property and casualty insurance providers, states and local governments, and lending institutions, the program is designed to mitigate the consequences of floods by working with local governments to adopt and enforce floodplain management regulations codes and standards and offering insurance to participating communities. The perils covered by NFIP include inland flood, storm surge, tsunami, Great Lakes flooding, and coastal erosion.⁵⁶ Like commercial property insurance, NFIP charge lower premiums (providing a discount) to property owners who invest in making their buildings more resilient to the natural hazard, in this case, reducing vulnerabilities to flood damage. Investment measures to make buildings more resilient to flood often focus on changes to the building characteristics or location to reduce the risk of damage from floods (e.g.,

⁵⁴ Reavis, 2012.

⁵⁵ For a discussion of landslide and mudflow coverage in particular, see Insurance Information Institute, “Insurance for Landslides and Mudflow,” webpage, undated.

⁵⁶ FEMA, “National Flood Insurance Program Risk Rating 2.0 Methodology and Data Sources,” January 18, 2022.

installing flood vents, elevating the building, or moving it farther from a river or creek that has a history of flooding).

Organization of this Report

The chapters in this report generally follow the four phases of our analytical process (see Figure 1.2.). Chapter Two describes our assessment of the natural hazard historical patterns and projections. Chapter Three explains our analyses of the vulnerabilities and exposure of Army installations and buildings to natural hazards based on past natural hazards events that have caused damage at those installations. This chapter also provides an overview of how we developed the illustrative installation and building case studies for the insurance assessments based on installation data.

The next two chapters describe the insurance premium calculations: Chapter Four covers commercial property insurance and Chapter Five the NFIP flood insurance. Chapter Six briefly summarizes the key findings to inform our recommendations for the Army resilience investment processes and presents actionable recommendations for Army headquarters and installation decisionmakers.

The report contains six appendixes. Appendix A provides supplemental information about our natural hazards assessment and Appendix B about the IMCOM SRM storm damage data and other installation data. The criteria and process used to select the installation building case studies is explained further in Appendix C. For background information on commercial property insurance and NFIP see Appendix D. Appendix E explains the data sources for the NFIP flood insurance premium calculations. Appendix F presents an overview of resilience investment planning based on the literature.

This report is primarily a technical document for Army installation leaders, managers, planners, engineers, and cost analysts. We realize that some readers may be interested in only select topics covered in the report. For example, some people may be interested in learning about the historical installation storm damage discussed in Chapter Three, while some others may be interested in learning about the value of resilience investment measures to help reduce flood risk, which is discussed in Chapter Five. Most of the chapters are self-explanatory, but when skipping chapters, a reader may need to refer back to earlier chapters or to the abbreviation list at the end of the report if he/she is not familiar with all the terminology. Because we try to keep the main chapters self-explanatory there is some minor repetition among them.

Chapter 2. Assessment of the Relevant Natural Hazards

Historical Patterns and Projections

The Army definition of hazard is “a condition with the potential to cause injury, illness, or death of personnel; damage to or loss of equipment or property; or mission degradation. Therefore, a hazard can have several possible consequences or losses (for example, injury, death, damage, mission failure, mission degradation, increased resource(s) expenditures, and adverse public relations).”⁵⁷ Natural hazards are those geophysical, hydrological, climatological, meteorological, celestial, or biophysical events that occur in the environment and have the potential to negatively affect people and their communities.⁵⁸ Extreme weather events such as storms, heavy precipitation, and hurricanes are examples of meteorological natural hazards. Climate change has the potential to affect the temporal and spatial distribution and the severity of some natural hazards in the future, particularly drought, extreme heat and cold, flooding, sea-level rise, tropical cyclones and hurricanes, severe storms, and wildfire.⁵⁹

This chapter discusses natural hazards and the approach we used to identify those natural hazards on which to focus. We selected natural hazards at the intersection of natural hazards that could potentially cause significant facility damage at Army installations in the future and hazards covered by the insurance industry in standard property policies. Our assessment of facility damage is based on historical damage and repair costs at Army installations and projected natural hazards exposures. Since another objective of this study is to provide insights into potential improvements to Army resilience-related processes, we also provide information on natural hazards data sources that Army planners and other decision makers can potentially use when making investment decisions.

⁵⁷ Department of the Army Pamphlet 385-30, *Risk Management*, Headquarters, Department of the Army, December 2, 2014, p. 3.

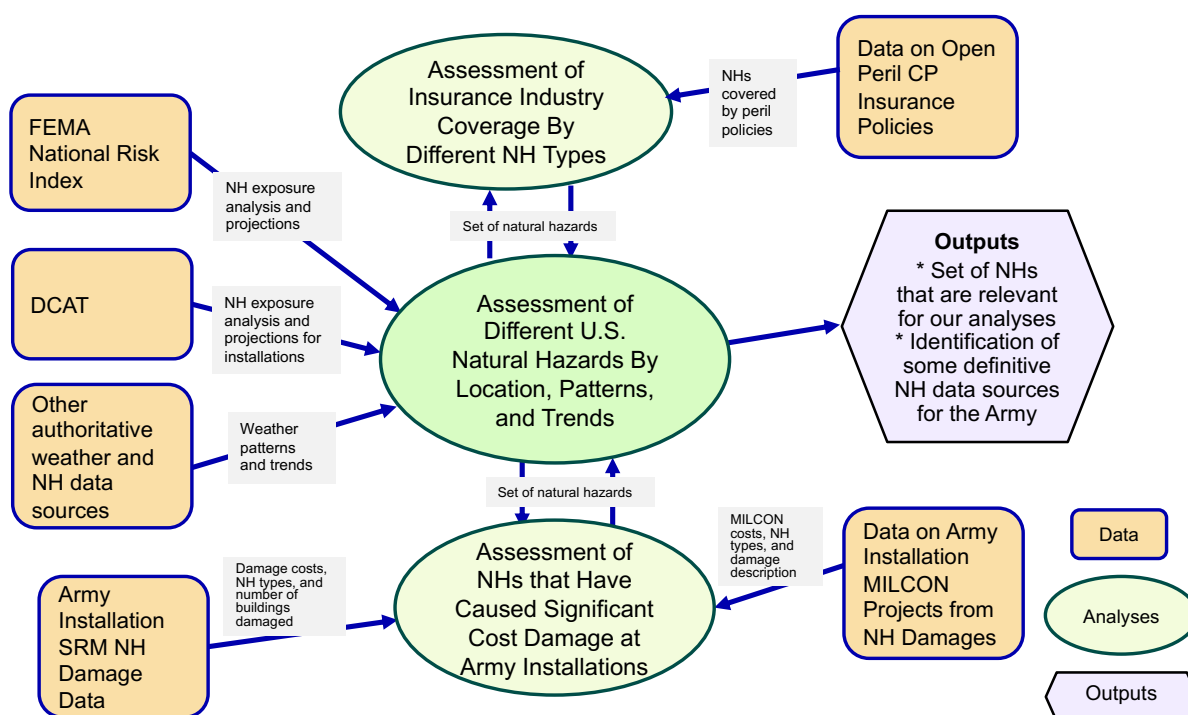
⁵⁸ Natural hazard classifications vary somewhat. For more on the subject see Peijun Shi “Hazards, Disasters, and Risks,” in *Disaster Risk Science*, June 5, 2019. Other sources include United Nations Office for Disaster Risk Reduction, *Sendai Framework for Disaster Risk Reduction 2015–2030*, 2015; United Nations Office for Disaster Risk Reduction, “Terminology,” webpage, undated; Keith Smith, *Environmental Hazards: Assessing Risk and Reducing Disaster*, Routledge, 2013; and I. Burton, Robert W. Kates, and Gilvert F. White, *The Environment as Hazard*, Oxford University Press, 1978.

⁵⁹ For a high-level summary of these effects see Michelle E. Miro, Andrew Lauland, Rahim Ali, Edward W. Chan, Richard H. Donohue, Liisa Ecola, Timothy R. Gulden, Liam Regan, Karen M. Sudkamp, Tobias Sytsma, Michael T. Wilson, and Chandler Sachs, *Assessing Risk to the National Critical Functions as a Result of Climate Change*, Homeland Security Operational Analysis Center operated by the RAND Corporation, 2022, pp. 13–19.

Approach to Natural Hazards Analysis

We employed a multi-phase, iterative approach for determining the key natural hazards on which to focus our analysis. We begin by considering the natural hazards of greatest concern to states and communities using historical patterns and projected exposures across the United States from authoritative federal sources on weather- and climate-related data. We then narrowed our aperture to the natural hazard patterns and trends in geographic areas where Army installations are located. This analysis is supplemented by the Army's historical experience with damage from various natural hazards over the last ten years. Finally, we examine how insurance industry practices treat specific natural hazards, focusing on broad, "open peril" policies that cover most typical forms of property damage.⁶⁰ Each of these assessments reveal potential data sources on natural hazard exposures that can be incorporated into long-term installation investment decisionmaking. We illustrate this approach in Figure 2.1.

Figure 2.1. Natural Hazards Analysis Process and Outputs



NOTE: CP = commercial property and NH = natural hazards.

We examined over 15 data sources for national, regional, and local information about U.S. natural hazards patterns and trends before focusing mostly on four authoritative national sources:

⁶⁰ Open perils policies (also referred to as "all perils") are defined by risks excluded rather than risks explicitly covered. This type of insurance is akin to standard homeowner's insurance and contrasts with named peril insurance, which covers damages due to explicitly identified risks (e.g., earthquake insurance).

FEMA’s National Risk Index (NRI), DCAT, the Department of the Air Force’s Severe Weather/Climate Hazard Screening and Risk Assessment Playbook, and NOAA’s NCEI. It is important to note that dozens of different data sources and web-based tools provide natural hazards patterns and trend data for the United States, regions, states, counties, and other local sites. These data sources range from primary federal agency data to academic studies of specific hazards to regional, state, and local sources (e.g., state and local hazard mitigation plans). Because this plethora of data sources can be overwhelming for installation (and community) managers planners we provide an overview of some useful natural hazard data sources for Army installations in Appendix A.

FEMA’s NRI provides communities with a tool to evaluate natural hazard risks and focuses on those that have relevance across the United States by assessing approved state hazard mitigation plans. DCAT was derived from the Army Climate Adaptation Tool (ACAT) and both have been developed by the U.S. Army Corps of Engineers. DCAT is a screening tool that installations can use to examine potential exposure to natural hazards, including the climate change effects on those hazards. It was designed to provide a nationally consistent tool for examining exposure analysis of climate hazards and extreme weather. These tools focus on those hazards that were strongly influenced by climate and that were determined to be relevant to installation and site operations and planning.⁶¹

We supplemented these sources with data from the NOAA’s NCEI data, including the NCEI Storm Events Database, which contains county-level or forecast zone-level historical information on 48 weather event types as reported by the National Weather Service. Another useful source from NCEI is the state climate summary reports from 2022, which summarize historical climate trend data for each state from 1900 through 2022 and future projections that account for climate change.⁶²

We also used other specialized data sources as needed, such as the Forest Service’s Research Data Archive; the Rocky Mountain Insurance Information Association; the research studies generated for the U.S. Global Change Research Program; and the Fourth National Climate Assessment to better understand the national temporal and spatial historical patterns and projected trends for these hazards.

To complete the analysis, we reviewed the historical natural hazard events at U.S. Army installations that caused damage to buildings and used NFIP and commercial property insurance data sources to explore the availability of coverage by different natural hazard types.⁶³

⁶¹ USACE, “Documentation of and Justification for Collapsing NOAA Storm Event Categories,” undated [but post-July 2021 because it cites a NOAA report from then].

⁶² See K. E., Kunkel, J. Runkle, S. M. Champion, L. E. Stevens, D. R. Easterling, B. C. Stewart, A. McCarrick and C. R. Lemery, eds., *State Climate Summaries for the United States 2022*, NOAA/NESDIS, NOAA Technical Report NESDIS 150, 2022.

⁶³ Additional information on natural hazard data sources is in Appendix A, on U.S. Army installation storm damage data are in Appendix B, and on commercial property and NFIP insurance data in Appendixes D and E.

Natural Hazards Patterns and Projections

Our analysis of natural hazards involved three components: (1) identifying the primary natural hazards that are of concern across the United States and their patterns and trends, (2) assessing the available information on previous natural hazard events at Army installations that caused damage, and (3) comparing these results to hazards for which incentives are offered by insurance providers for resilience investments. These analyses led to a set of natural hazards on which the remainder of our work would focus.

Identifying an Initial Set of U.S. Natural Hazards

We compared the natural hazard types from FEMA's National Risk Index, DCAT, and the DAF playbook (recall that the Army Climate Resilience Handbook references the DCAT hazards), as shown in Table 2.1, to develop an initial set of natural hazards for the United States.

Table 2.1. Natural Hazards Identified in Exposure- or Risk-Analysis Tools in the United States

National Risk Index (FEMA)	Defense Climate Adaptation Tool	Air Force Civil Engineer Center Severe Weather/Climate Hazard Screening and Risk Assessment Playbook
Avalanche		
Cold wave		Extreme Cold
Drought	Drought	Drought
Earthquake		Earthquakes
	Energy Demand	
	Extreme Weather	Extreme Precipitation
Coastal Flooding	Coastal Flooding	Coastal Flooding
Riverine Flooding	Riverine Flooding	Riverine Flooding
Hail		
	Historic weather extremes (tornado, hurricane level winds and maximum precipitation, ice storm or jams)	
Heat wave	Heat	Extreme Heat
Hurricane	X	Hurricane/cyclones
Ice Storm	X	
	Land Degradation	
Landslide		
Lightning		
Tornado	X	Tornado
Tsunami		Tsunami
Volcanic activity		Volcano
Wildfire	Wildfire	Wildfire
Strong wind		High winds
Winter weather		

SOURCE: FEMA, "National Risk Index Technical Documentation," November 2021; J.T. Gade, et al., "Department of Defense Climate Assessment Tool," U.S. Army Corps of Engineers, 2020; and U.S. Air Force "Severe Weather/Climate Hazard Screening and Risk Assessment Playbook, Air Force Civil Engineer, April 24, 2020.

NOTE: An "x" in the table cell indicates that this hazard is included in the historic weather extremes category.

We narrowed the focus of our analysis by considering where Army installations were located using basic information about natural hazards and the potential to cause costly damage to large numbers of buildings and then we assessed information for these natural hazards. For the most part U.S. Army installations and their buildings are not located in areas with avalanches, landslides, tsunamis, and volcanic activity,⁶⁴ so we eliminated these hazards from the set presented in Table 2.1. We also eliminated natural hazards such as cold or heat waves and drought from consideration because they do not directly relate to building resilience. Table 2.2

⁶⁴ We examined geospatially the locations of Army installations and buildings on those installations in relationship to such natural hazards.

presents some of the general hazard information that we collected and used to further refine our list of hazards. We assessed the available information considering geographic overlap with installation locations, potential of the hazard to cause damage, projections that indicate increasing severity in areas where Army installations are located, and general relevance to the Army enterprise-wide.

Table 2.2. Summary of Natural Hazards Trends Nationally

Natural Hazard	Patterns and Projections	Geographic Distribution	Observations
Coastal flooding	Coastal flooding has increased in recent years and will continue with sea-level rise.	Sea-level rise is projected to lead to greater inundation in the Atlantic and Gulf coasts than in the Pacific.	
Earthquakes	Expected occurrence ranges from 1 in 250 to less than 2 in 10,000 years. In addition, earthquakes are not affected by climate change.	Occurs in most areas within the U.S., but are most frequent in Alaska, California, Hawaii, Puerto Rico, and Washington.	Infrequent but potential for high damage to buildings
Hail events	Co-occurs with severe thunderstorms and heavy precipitation events. Data on hail events are limited to direct observation and therefore may undercount frequency. Predicting and projecting hail events is challenging, but some evidence suggests that in North America the hail will be larger and exposure may be moving eastward in the future.	Nebraska, Colorado, and Wyoming are areas with frequent hailstorms. Texas, South Dakota, Kansas, Oklahoma, and Nebraska experienced highest damage in 2020.	Hailstorm frequency experiences year-to-year fluctuations. Roofs are vulnerable to hail but damage may not immediately be observed.
Precipitation events	More precipitation is expected to occur the form of rain versus snow. Heavy precipitation events, those in the 99 th percentile in terms of rainfall, are expected to increase in frequency.	Precipitation in the form of snow is anticipated to decrease in the West, Central, and Northeastern U.S. Heavy rain events are increasing in particular in the Northeast and Midwest.	These changes can contribute to drought and flooding, but several other factors influence the impact.
Riverine flooding	Changes to frequency and magnitude are generally consistent with changes to heavy rainfall events.	The Northeast, Upper Midwest, and Pacific Northwest will see the greatest increases. The West and Southwest will see decreases.	Future flooding is affected by many factors including land-use patterns, soils composition, and topology.
Tornados	National Weather Service (NWS) data indicate that the median number of tornados in the United States was 1,219 per year for the 1990 to 2017 timeframe. The effects of climate change on future tornado activity is unclear.	Tornados predominately occur in the Midwest Southcentral U.S., and the Gulf coast.	The spatial footprint of an individual tornado is usually relatively small and extreme winds are the primary cause of damage to buildings.
Tropical cyclones	The Intensity of each event is projected to increase with climate change, but overall frequency will remain stable or decline slightly	Tropical cyclones occur in the Caribbean and along the Atlantic and Gulf coastlines.	
Wildfire	Wildfire hazard potential varies across the U.S. and depends on several factors, such as fuel availability, climate/weather conditions, and topography.	Wildfire hazard potential is highest in parts of the Western U.S., AK, and FL.	

Natural Hazard	Patterns and Projections	Geographic Distribution	Observations
Wind	High winds, 40 mph or higher, are associated with multiple hazards such as tornados or hurricanes.	High winds can occur anywhere in the U.S.	More damage has been reported from winds associated with thunderstorms than with tornados.

SOURCES: (by natural hazard types)

Coastal Flooding: Environmental Protection Agency, "Climate Change Indicators: Coastal Flooding," webpage, August 1, 2022.

Earthquakes: USGS, "2018 Long-term National Seismic Hazard Map," webpage, undated.

Hail: Rocky Mountain Insurance Information Association, "Hail Damage and Statistics," webpage, undated; Brian H. Tang, Vittorio A. Gensini, and Cameron R. Homeyer, "Trends in United States Large Hail Environments and Observations," *Npj Climate and Atmospheric Science*, Vol. 2, No. 45, 2019; Timothy H. Raupach, Olivia Martius, John T. Allen, Michael Kunz, Sonia Lasher-Trapp, Susanna Mohr, Kristen L. Rasmussen, Robert J Trapp, and Qinghong Zhag, "The Effects of Climate Change on Hailstorms," *Nature Reviews Earth & Environment*, Vol 2, 2021.

Precipitation: D. R. Easterling, J. R. Arnold, T. Knutson, K. E. Kunkel, A. N. LeGrande, L. R. Leung, R. S. Vose, D. E. Waliser, and M. F. Wehner, "Precipitation Change in the United States" in D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, eds., *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, U.S. Global Change Research Program, 2017; and Sarah Stanley, "Extreme Rainfall Statistics May Shift as U.S. Climate Warms," *Eos*, 102, April 12, 2021.

Riverine Flooding: M. F. Wehner, J.R. Arnold, T. Knutson, K.E. Kunkel, and A.N. LeGrande, "Droughts, Floods, and Wildfires, in D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, eds., *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, U.S. Global Change Research Program, 2017, pp. 231–256; Environmental Protection Agency, "Climate Change Indicators: River Flooding," webpage, August 1, 2022.

Tornado: Virginia Iglesias, Anna E. Braswell, Michael W. Rossi, Maxwell B. Joseph, Caitlin McShane, Megan Cattau, Michael J. Koontz, Joe McGlinchy, R. Chelsea Nagy, Stefan Leyk, William R. Travis, "Risky Development: Increasing Exposure to Natural Hazards in the United States," *Earth's Future*, Vol. 9, No. 2, 2021; and NOAA, "U.S. Annual Tornado Maps (1952-2011)," webpage, undated.

Tropical cyclones: U.S. Global Change Research Program, "Atlantic Tropical Cyclone Days," webpage, undated.

Wind: NOAA National Severe Storms Laboratory, "Severe Weather 101 – Damaging Winds," webpage undated.

Our analysis included projections because climate change is expected to affect the intensity, frequency, and geographic distribution of many natural hazards.⁶⁵ For example, changes in precipitation will affect the frequency and severity of riverine flooding. However, while climatic conditions in the future may exacerbate conditions required for hazards to form, models and available historical data are not always able to project with confidence how the frequency and severity of a given natural hazard may change, particularly at the regional or local level.

Both the Intergovernmental Panel on Climate Change (IPCC) and the U.S. Global Change Research Program (USGCRP) produce reports that present the scientific consensus on climate change. The IPCC produces three reports on a six-year cycle focused on climate science (Working Group I), climate effects, vulnerabilities, and adaptation (Working Group II), and climate change mitigation (Working Group III), as well as reports on methods and other special topics.⁶⁶ The most recent working group reports published in 2022 represent the Sixth Assessment. The USGCRP produces the National Climate Assessment every four years that synthesizes the best available science and projections for climate change in the United States.

⁶⁵ USGCRP, 2017; USGCRP, 2018; and J.K. Summers, et al., 2022.

⁶⁶ The IPCC reports can be found at: The Intergovernmental Panel on Climate Change, "Reports," webpage, undated.

The Fifth National Climate Assessment (NCA) is in draft.⁶⁷ The research summarized in these reports provides the foundation for natural hazard projections (for those affected by climate change). For example, the DCAT exposure analysis includes projection for coastal flooding, riverine flooding, drought, heat, wildfire, and land degradation and relies on historical data for hurricanes and tornados. The version used for this analysis was based on data generated for the National Climate Assessment 4, which is in the process of being updated to include more recent model outputs. For more information on the different natural hazards assessments see Appendix A.

Army Installation Historical Damage from Natural Hazards

We were also interested in assessing the types of natural hazards events that have caused damage to buildings on Army installations in the past. We began by examining IMCOM SRM historical storm damage data.⁶⁸ Staff from IMCOM provided us with summary cost and damage data for 101 natural hazard events that occurred at U.S. installations between fiscal years 2011 to 2021. We identified ten natural hazard types that caused damage at installations during this time period. On some occasions installations classified these storm events inconsistently, therefore some data cleaning was required.⁶⁹ For example, one installation listed “rain/wind,” as an event while another use “storm” for both rain and wind events. We changed this “rain/wind,” event to “storm” for consistency.

The IMCOM storm damage data are summarized in Figure 2.2, which presents the number of events that occurred during FY 2011 to FY 2021 and IMCOM–validated costs to repair the damage caused by storms of those type.⁷⁰ As shown in the figure, historically, nine natural hazards caused damage to Army installations over the last ten years. Hurricanes, flooding, storms, and rain account for 69.3 percent of all natural hazards occurring at Army installations and 66 percent of the total funds spent on storm damage repairs. Events that incurred higher than average cost across all these events, but did not occur as often are freeze, tornado, and hail.⁷¹

⁶⁷ For information on the USGCRP see U.S. Global Change Research Program, homepage, undated.

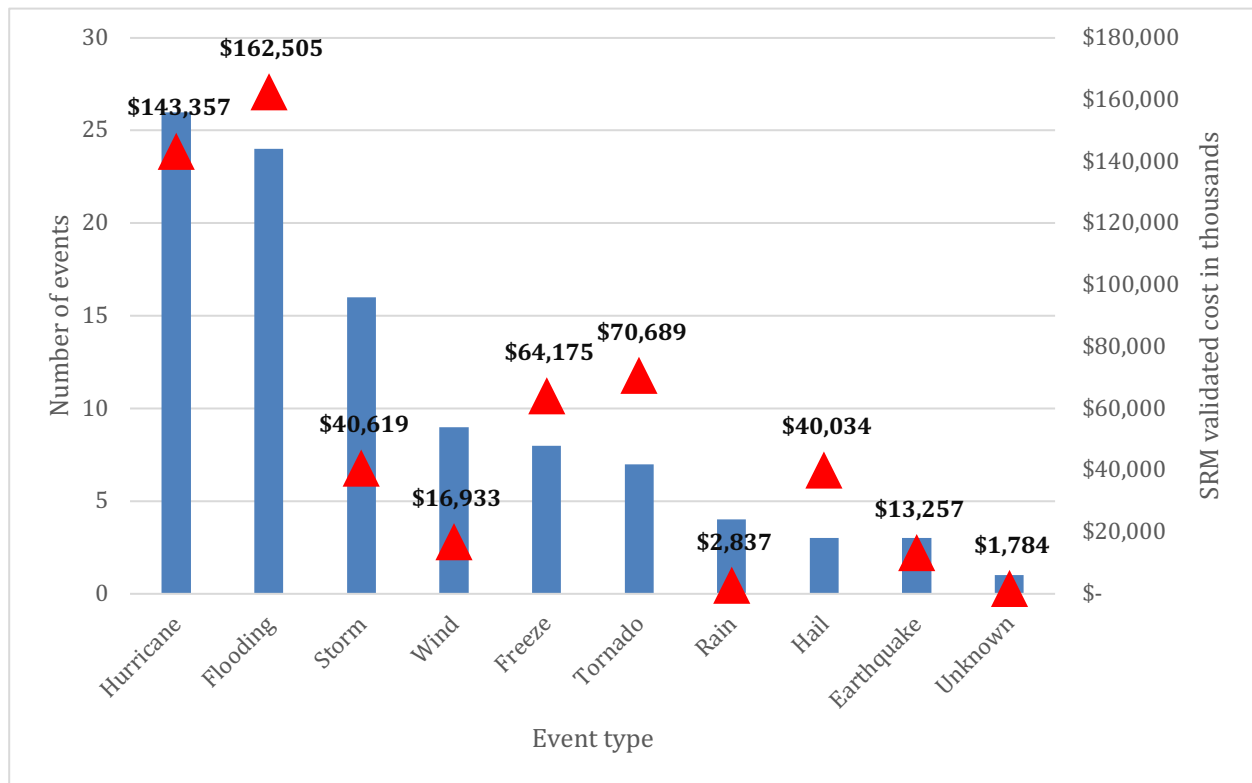
⁶⁸ For more information on these data see Appendix B.

⁶⁹ RAND researchers could verify the storm type and name through an internet search for articles about the storm or a review of NOAA NCEI storm database.

⁷⁰ According to the business rules for the fund, installations are responsible for five percent of the cost and these values do not include those amounts. This business rule is explained more in Chapter 3.

⁷¹ Since the storm category included events with rain or snow, it was important to include rain in this total, since it could have been grouped in with storms. This total also captures all the storm types that involved damage by water.

Figure 2.2. Total Number and Validated SRM Costs for Storm Damage Occurring at U.S. Installations Between FY 2011 and FY 2021 by Natural Hazard



SOURCE: IMCOM Storm damage data for FY 2011 through FY 2021, excluding FY 2012 and including only some of the storms from FY 2014. Validated SRM costs includes Army costs for repairing buildings, structures, and utility systems.

We also examined past natural hazards damage at Army installations that required MILCON funding to rebuild the facilities. Staff from the Army G-9 provided information on MILCON projects for active component installations from between fiscal years 2011 to 2021 that included damage from a thunderstorm, a flood, and a tornado. Army National Guard act of nature (AoN) MILCON projects include multiple projects from four hurricanes and three tornado projects. It is interesting to note that thunderstorm, hurricanes, tornados, and a flood were severe enough to cause enough damage to buildings to warrant new construction.

By reviewing and assessing the hazards in Tables 2.1 and 2.2 and Figure 2.2 we narrowed our focus. Historically, nine natural hazards—hurricane, flooding, storm, wind, freeze, tornado, rain, hail, earthquake—caused damage to Army installations over the last ten years.

We did not include earthquakes and wildfires in our analysis. Earthquakes were eliminated because they are infrequent events that historically have caused a nominal amount of damage and to which a majority of Army installations have low exposure. Furthermore, earthquakes are driven by geological and not climate conditions and as a result are not projected to increase in

severity. In addition, standard insurance policies do not typically cover earthquakes.⁷² In locations where there are named-peril policies for earthquake damage the policies vary in terms of coverage and market size.

We also eliminated wildfire based on historical experience at Army installations and the lack of available insurance information. While wildfire risk is increasing in the Western United States and Alaska,⁷³ Army installations traditionally have not had a history of damage to buildings from them.⁷⁴ This is due in part because at many Army installations most of the buildings are located away from fuel sources such as large, forested areas or other vegetation. Furthermore, the Army implements numerous preventative measures on training ranges and other parts of an installation, such as controlled burn to reduce the risk of fire. Because fire coverage is included in standard commercial policies, pricing for wildfire is not differentiated.

In addition, we did not include storm as a separate category because it is too vague a term, is inconsistently defined in the Army data, it is not included in the NRI and other natural hazards tracking and projection data sources, and it is not used by the insurance industry. In addition, storm is captured by other natural hazard categories and the impact of the natural hazard, e.g., it may cause flood damage. Similarly, rain was not included because it is not used by the insurance industry nor is it included in the NRI, but it can cause flood damage. So, before considering insurance coverage, we identified the following hazards for consideration: hurricanes floods, freeze, winds, tornados, and hail.

Commercial Property Insurance and National Flood Insurance Program Coverage

The final element of our analysis to identify national hazard focus areas was to assess how natural hazards are covered by the insurance industry. We were particularly interested in identifying those hazards that have differentiable premiums, such as named-peril policies, and those that have incentives for resilience investment.

Insurance policies can be one of two kinds, either open- or all-peril policies that cover all hazards unless specifically excluded and named-peril policies that cover specific hazards identified. Table 2.3 presents a summary of the five natural hazards that we narrowed our focus on, how they are covered by commercial property insurance, and the types of policies and limitations associated with them. As the table indicates, insurance policies vary in how they cover specific natural hazards, and they also differ across states. Therefore, analyses of insurance pricing and resilience incentive information must consider the specific hazard and location and it

⁷² See, e.g., Insurance Information Institute, “Are There Any Disasters My Property Insurance Won’t Cover,” webpage, undated.

⁷³ USGCRP, 2018.

⁷⁴ It is important to note that wildfire risk is important to training and other missions at Army installations. For example, in Northern Arizona, the risk of high-intensity wildfires threaten the Army National Guard’s training mission at Camp Navajo because of on-going drought problems and unhealthy forests. REPI, “2022 REPI Challenge Recipients,” U.S. Department of Defense, 2022.

may be challenging to develop generalizable conclusions that are applicable to the entire United States. Since cold or freeze hazards do not have named separate peril policies they were not included.

Table 2.3. Selected Natural Hazard Coverage across Commercial Insurance Policies

Hazard	Standard Commercial Property Insurance	Named Peril Policy	Locational Differences
Flood	Not covered	NFIP covers water flowing overland into a structure and commercial property companies provide for higher value buildings and niche markets	NFIP is available to over 22,500 ^a participating communities throughout the U.S. NFIP has Flood Insurance Rate Maps for floodplains for most of the U.S.
Freeze	Covers building contents damaged by power loss and by a pipe that burst from the freeze event, but it will not cover the pipe that was damaged nor building systems damage	Not generally available	
Hail	Usually covered in most states except for coastal and hurricane prone areas	Wind and hail policies available in some states for hail damage to structures	
Hurricane	Usually covers structure damage from wind and rain; but not the flooding damage	Named storm, windstorm, wind and hail, or hurricane perils Prone states often have separate coverage	Prone states: AL, CT, DE, DC, FL, GA, HI, LA, ME, MA, MS, NJ, NY, NC, PA, RI, SC, TX, and VA
Wind/Tornado	Building and contents covered for storms unless specifically excluded	Wind/windstorm and Hail policies if not included in standard policies	Wind/windstorm, hail deductibles have special triggers

NOTE: a FEMA, "Virtual Media Toolkit," February 2022.

Natural Hazards Focus Areas

This analysis was exploratory to determine what, if anything, can be learned from analyzing commercial insurance information. Because gathering insurance premium and resilience investment incentives information for the insurance industry is nontrivial, we focused the analysis on hazards that either have caused or have the potential to cause significant damage to Army installations and where the commercial insurance industry provides hazard-specific coverage or pricing.

Based on the intersection of these factors, we selected four categories of damage that are caused by natural hazards most relevant to the Army and that are likely to have insurance rate or pricing information. These categories of damage are:

- Flood

- Hail
- Hurricane
- Wind (straight-line)/Tornado

The Army's historical experience with and insurance treatment of these hazards is summarized in Table 2.4.

Table 2.4. Summary Natural Hazards Under Consideration

Natural Hazard	Historical Events at Army Installations	Insurance Policies	Natural Hazard Patterns
Flood	- Account for nearly 25% of the events in the IMCOM SRM storm damage data - Second highest total expenditures for repairs - Single event had high cost for repair (over \$43.3M SRM) and a MILCON event	- NFIP and commercial policies are available - Rate information available for NFIP program	- Heavy precipitation events, sea-level rise, and storm surge are projected to increase - Flood frequency influenced by weather and other factors such as land-use but climatic conditions will be favorable for flooding^a
Hail	Only 3% of the events in the IMCOM SRM storm damage data, but one had over \$20.4M SRM costs	Windstorm and hail named-peril policies available in some states	Causes significant damage in certain areas of the U.S., for example in CO, KS, OK, NE, SD, and TX and overall damage might be underestimated by claims data.
Hurricane	Account for about 25% of the events in the IMCOM SRM storm damage data with high-cost events, including the highest SRM storm damage over \$51.7 million	Storm, windstorm, wind, and hail, or hurricane named-peril policies available	Intensity expected to increase in the future but annual frequency will remain stable or decrease
Wind or Tornado	Moderately frequent, over 15% of all IMCOM events, that can have high cost per event. One tornado caused over \$30.1M in SRM cost	Named peril policies for windstorm or wind and hail may be available when windstorm excluded from standard policies	- Usually small footprints with significant impacts; damage caused by wind - However, an unusually widespread tornado occurred across Arkansas, Missouri, Tennessee and Kentucky in December 2021

SOURCES: Army data: IMCOM Storm damage data for FY11 through FY21, excluding FY12 and including only some of the storms from FY14 and ARNG and active-duty installation MILCON data from PRIDE and CAPCES databases respectively. Environmental Protection Agency, "Climate Change Indicators: Coastal Flooding," webpage, August 1, 2022; Rocky Mountain Insurance Information Association, "Hail Damage and Statistics," webpage, undated; Tang, et al., 2019; Raupach, et al., 2021; Easterling, et al., 2017; Stanley, 2021; Wehner, et al., 2017; Environmental Protection Agency, "Climate Change Indicators: River Flooding," webpage, updated August 1, 2022; Iglesias, et al., 2021; NOAA, "U.S. Annual Tornado Maps (1952-2011)," webpage, undated; U.S. Global Change Research Program, "Atlantic Tropical Cyclone Days," webpage, undated; NOAA National Severe Storms Laboratory, "Severe Weather 101 – Damaging Winds," webpage undated; and Arindam Samanta, *Understanding Evolving Hail Risk*, Verisk, 2022.

^a Favorable for flooding means it could lead to more flooding in the absence of other factors.

Although we aimed to focus on these four categories of damage and events, other events can cause the same kind of damage. Exploring a broader group of events was of interest because insurance policies are written to cover certain categories of damage that are caused by the perils (or natural hazards) covered by the policy. As described earlier, standard policies cover a common set of perils and named-peril policies cover only the peril that is identified. A peril, or natural hazard can cause different categories of damage to a building. For example, a hurricane can cause wind, flood, or hurricane damage. Also, multiple hazards can cause the same type of damage. For example, hurricanes and thunderstorms both can lead to wind damage. Table 2.5 provides a crosswalk of these damage categories that have relevant insurance discounts to the

natural hazards that could potentially generate them. For example, insurance coverage for wind damage could be caused by strong winds associates with seven natural hazard types (e.g., hurricanes, precipitation events, and snowstorms).

Table 2.5. Natural Hazards Crosswalk with Damage Categories

Natural Hazard	Hazard Effects that Have Resilience Discounts in Relevant Insurance Coverage			
	Flood	Hail	Hurricane	Wind
Cold wave/freeze	X			
Flood (riverine and coastal)	X			
Hail		X		
Hurricane	X		X	X
Precipitation events	X	X		X
Snowstorm	X			X
Storm	X	X		X
Thunderstorm	X	X		X
Tornado				X
Wind				X

We used our understanding of natural hazard prevalence where there are Army installations and the categories of damage that these hazards may cause to focus our search for state level insurance information. For instance, hurricanes tend to occur along the Atlantic and Gulf coasts. Tornadoes, which often cause wind-damage to buildings, have historically been concentrated in the Midwest, South-Central United States, and Gulf Coastal Plain.⁷⁵ The four-state supercell that developed across Arkansas in December 2021 yielded a nearly unprecedented series of long-track tornadoes that moved nearly 250 miles from Arkansas, through Tennessee, and into Kentucky affecting communities in eight states and causing widespread and severe damage from the 190 mph winds.⁷⁶

Implications for the Army from our Natural Hazards Assessment

Army installations are exposed to and experience damage from a variety of natural hazards some of which are anticipated to increase in severity in the future as a result of climate change.

There are many sources for natural hazard data that can be useful to Army installation planners and other decision makers but there is limited guidance on which to use. In fact, the Army is working on improving and developing such guidance now, such as the Installation

⁷⁵ Iglesias, et al., 2021.

⁷⁶ Jared Guyer, “The 2021 Tornado Season: December Devastation,” *Weatherwise*, Vol 75, No. 4, 2022.

Climate Resilience Plans (ICRPs). Analyses may vary in scope and focus (exposure, vulnerability, or full risk assessment) and therefore may require different information. Resiliency investment decisions require location- and building-specific information and therefore reliance on regional, state, or local data.

We identified **four authoritative sources that aggregate information across a range of potential hazards**, but for different purposes and **that can provide useful information for Army installation decisions related to resilience investments: FEMA’s NRI, NOAA’s NCEI Storm Events Database, FEMA flood maps, and the DCAT**. However, how each of these data sources can and should be used will vary based on the intent and scope of the specific Army decisions as well as the decisionmaking level (e.g., installation- or enterprise-level). It was not part of this study’s objectives to explain how to use these data sources for the full range of potential Army decisions, but we do provide an illustrative example for master planning decisions related to flooding since we examined floodplain data as part of our analyses (see Chapter Five).

Each of these data sources has strengths and weaknesses. The NRI is useful because it provides annualized frequencies for the 18 natural hazards included in the tool for a county or census tract. It uses historical data and is therefore not suitable for projecting exposure to natural hazards. The NCEI Storm Event Database also provides accessible, historical information on weather events at the county level, although, because it relies on reported data there may be gaps. FEMA Flood Insurance Rate Maps (FIRM) data provide 100-year floodplain information, but these data are not always generated for some installations and may not be up to date (discussed more in Chapter Five). DCAT is an authoritative DoD tool that generates standardized installation reports summarizing natural hazard exposures using historical data and providing projections that may help installation planners in the initial scoping stages to focus on those hazards for which there is a high level of exposure. However, DCAT includes a limited set of natural hazards—those that are related to the climatological, hydrological, or metrological hazards—and is best suited for comparing relative exposure at the national, not the local scale.⁷⁷

Natural hazards installation planners should also consider future trends when making long-term investments. **For those hazards affected by climate change, projecting frequency and severity is fundamentally different than assessing historical data. Projected hazard information is more challenging to access, interpret, and apply.** This is true for several reasons. First, global climate projection models are simplifications of the physical, chemical, and biological processes that generate climate and weather. They vary in terms of the purpose, geographic scale, methods, and analytics used. Furthermore, certain weather events must be

⁷⁷ We note that the DoD has been updating DCAT since we used it for this study to make it more applicable for local installation uses.

modeled at a regional or local scale to generate actionable projections.⁷⁸ Future climatic conditions are only one necessary input to understanding future natural hazards patterns and trends. Therefore, climate model outputs, such as sea-level, average and extreme temperatures, precipitation patterns, and storm frequencies, are often used in other models (e.g., hydrological and wildfire models) to determine the effects on natural hazard severity, such as wildfire, flood, or drought.⁷⁹

For these reasons there is no single model that can provide high-confidence projections of future weather for the nation, a region, or locality. Projections of any kind also involve uncertainties. Climate projections involve uncertainty in large part because of natural variability, model simplifications or availability of supporting data, and assumptions about human response.⁸⁰ **Before natural hazard projections can be incorporated into installation planning and investments there needs to be more guidance and support for accessing natural hazard projections applicable to local decisionmaking. Without guidance or support, installation planners may not have the resources or expertise to access the best available information, which could lead to ineffective or counterproductive investments.**

The IMCOM storm damage data provides very useful insights for identifying the hazards experienced by Army installations and understanding the consequences of those hazards. **Ensuring consistent reporting of storm type, by referring to the NCEI Storm Event Database, is a simple step that can improve the data for routine analytics.** For instance, having a common definition may benefit categorization of the damages, as illustrated with floods. Flooding as defined by the NFIP is

a general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties from:

- Overflow of inland or tidal waters;
- Unusual and rapid accumulation or runoff of surface waters from any source;
- Mudflow; or
- Collapse or subsidence of land along the shore of a lake or similar body of water as a result of erosion or undermining caused by waves

⁷⁸ Both global- and regional-climate models are being developed at finer scales, improving our understanding of the effects of topography, water bodies, land use, etc. on climate variability and change. (Gutowski, 2020 and Schär, 2020).

⁷⁹ Cremen, 2022; USGS, 2020; and Zscheischler, et al., 2018. The IPCC's latest assessment also provides an overview of the state of modeling approaches for natural hazards affected by climate change (see Seneviratne, 2021).

⁸⁰ An excellent, but slightly dated discussion of the use of climate data for decisionmaking is Rao Kotamarthi, Linda Mearns, Katherine Hayhoe, Christopher L. Castro, and Donald Wuebbles, *Use of Climate Information for Decision-Making and Impacts Research: State of Our Understanding*, Strategic Environmental Research and Development Program, March 2016.

or currents of water exceeding anticipated cyclical levels that result in a flood as defined above.⁸¹

Typically, these events will leave a high-water mark indicative of a flood in contrast to wind-driven rain that may enter through damaged windows, doors, roofs, or walls and is not considered flooding but rather wind-storm damage.⁸²

The natural hazards discussed for our insurance premium analyses are a smaller set than those that should be considered when making investments in Army buildings. This is for two reasons, first, as illustrated in the previous section, these are natural hazards that have the potential to cause damage at Army installations. Second, the insurance industry, through its offering of premium discounts for the categories of damage indicated in the Table 2.5, has signaled that investments in resilience measures are cost-effective for these types of natural hazards effects.

⁸¹ FEMA, “What You Need to Know about Flood Insurance,” July 2021.

⁸² Jason Metz, “How Does The National Flood Insurance Program Work,” *Forbes*, May 8, 2023.

Chapter 3. Assessment of the Vulnerabilities of Army Installations and Buildings Based on Past Storm Damage Data

Phase I of our analysis continues with an assessment of the vulnerabilities of Army installations and buildings to natural hazards, which is discussed in this chapter. Such vulnerabilities consist of three factors: exposure, sensitivity, and adaptive capacity to a given hazard. These factors help provide a framework for our analysis and this chapter. To understand exposure to a natural hazard we examined Army installation and building locations and past natural hazard events that have caused damage to them to help determine occurrence patterns of a hazard at different locations.

For sensitivity, we examined the costs of damages to different installations and buildings to help understand the degree to which exposure to natural hazards degrades an installation and its buildings and other facilities. Measuring sensitivity also involves examining a building's age, condition, construction type, roof type, and whether the building has any resilience features (e.g., hurricane straps).⁸³ For example, a building that has exterior walls constructed of wood is more sensitive to wind damage than one that has exterior walls constructed of masonry materials, such as concrete block. Buildings with additions from resilience elements shows investment in adaptive capacity measures.

Use of building codes is important to understand sensitivity and adaptive capacity. Assessments by the National Institute of Building Sciences and FEMA have shown how buildings that are in poor condition and constructed to older less resilient building codes are more sensitive to damage from natural hazards and that investing in building resilience measures to the latest building code or above it can be cost effective.⁸⁴ FEMA has also demonstrated the importance of roof design and appropriate roof anchorage for high wind resistance.⁸⁵ Many Army installations buildings are older and they were constructed based on older building codes

⁸³ Structures made of different materials (e.g., brick, wood, and metal siding) can sustain more or less damage from major weather events based on the construction materials, type of construction, and the design styles. For instance, different roof designs (e.g., flat or pitched) and roof materials (e.g., rubber, shingle, metal, slate) can make a difference in the sensitivity of a building to wind damage.

⁸⁴ For more information see K. Porter, et al., "Natural Hazard Mitigation Saves: 2019 Report," National Institute of Building Sciences, Multi-Hazard Mitigation Council, 2019; FEMA, "Design Guide for Improving Critical Facility Safety from Flooding and High Winds," FEMA 543, January 2007; and FEMA, "Successfully Retrofitting Buildings for Wind Resistance," Recovery Advisory 1, June 2019.

⁸⁵ For example, see FEMA, "Design Guide for Improving Critical Facility Safety from Flooding and High Winds," FEMA 543, January 2007; and FEMA, "Successfully Retrofitting Buildings for Wind Resistance," Recovery Advisory 1, June 2019; and FEMA, "Best Practices for Minimizing Wind and Water Infiltration Damage," Recovery Advisory 2, June 2019.

so they are not built to the latest more resilient Unified Facilities Criteria (UFC, the DoD installation building codes).

UFCs mostly follow the building codes maintained by the International Code Council as do most U.S. states and local governments.^{86,87} When new Army buildings are constructed or existing buildings have major restoration or upgrades made they are required to meet the latest UFCs. If local building codes include a higher standard for resilience investment measures than the DoD standards,⁸⁸ installations can use that standard or go beyond them as long as the Army cost benefit analysis shows it make financial sense. In the last few years DoD has upgraded its UFCs to include more resilience requirements. For instance, by 2021 DoD had updated “UFC 1-200-02: High Performance and Sustainable Building Requirements” to incorporate more resilience measures for climate change impacts.⁸⁹ However, most Army buildings were built or upgraded before these new requirements.

We examined some of these sensitivity factors (such as building age) to help determine the installation and building case study choices and to use as inputs for the insurance assessments. This assessment of the vulnerabilities helped inform the insurance case study analyses and provided insights for the Army resilience investment processes. The results also helped ensure that our insurance assessment is relevant to Army installations and resilience investments and focuses on areas that we would expect to have the highest potential cost savings and ROI for the Army.

This chapter begins with a brief overview of our approach and methodology (for more details see Appendix C). Then it explains our assessment of storm damage at the installation level and at the building level to help understand the exposure and sensitivity. The building-level discussion also explains some findings from this assessment related to water and wind. We also explain how we used this vulnerability information to help identify case study installation and building choices and some important data considerations.

⁸⁶ According to the UFCs, DoD installations should use the 2018 International Building Code when constructing new buildings and the 2018 International Existing Building Code for major alterations, repairs, and additions to most existing structures. DoD, “Unified Facilities Criteria (UFC) DOD Building Code,” October 1, 2020.

⁸⁷ See FEMA, “Seismic Building Codes,” webpage, May 23, 2023. In some cases, state or local codes may be stronger, such as in the state of Florida.

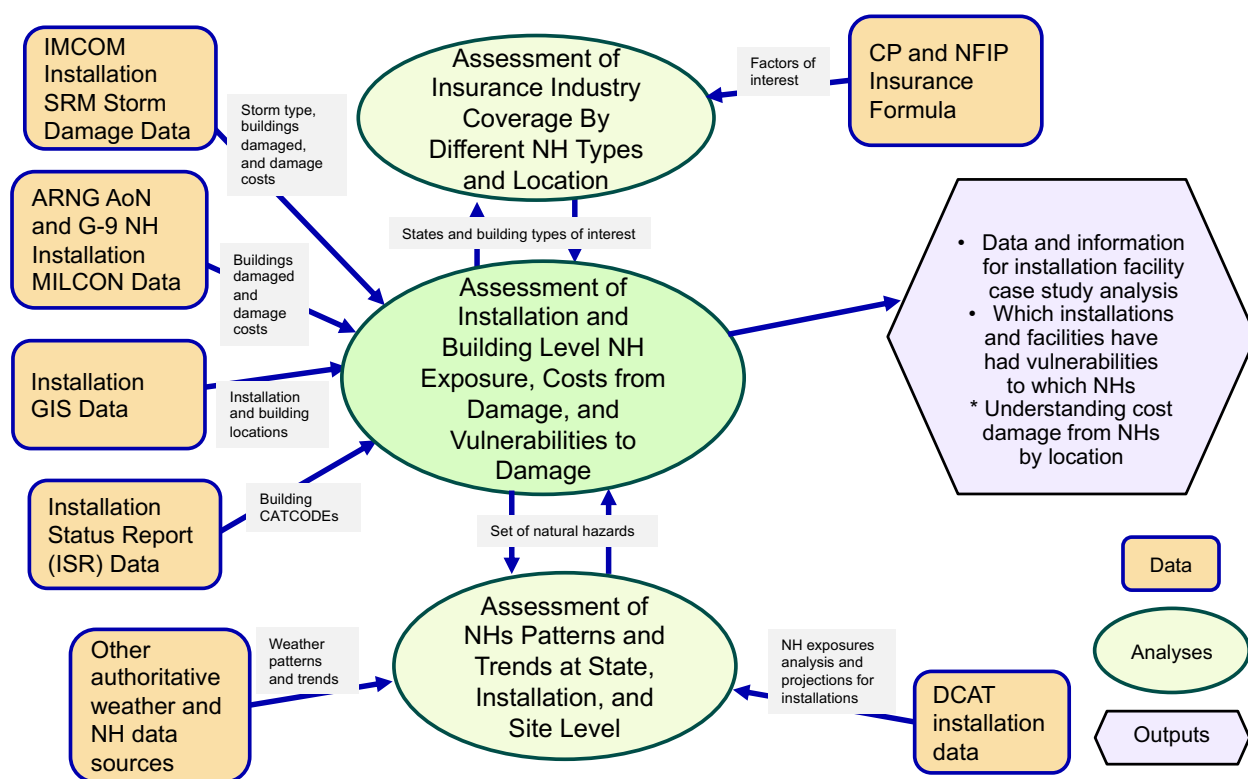
⁸⁸ For example, Florida has instituted stronger building codes for wind resilience, see William Rabb, “Florida Building Codes Made a Big Difference for Newer Homes in Ian, Reports Show,” *Insurance Journal*, October 17, 2022.

⁸⁹ U.S. Department of Defense, Office of the Under Secretary of Defense (Acquisition and Sustainment), *Department of Defense Draft Climate Adaptation Plan*, Report Submitted to National Climate Task Force and Federal Chief Sustainability Officer, September 1, 2021.

Approach to Army Installation and Building Storm Damage Data Analysis

We used installation damage data from different parts of the Army—IMCOM SRM storm damage data, ARNG AoN SRM data, and MILCON data from the G-9 and ARNG—⁹⁰ for both SRM and MILCON projects to understand the vulnerabilities of Army installations and buildings based on significant cost damage and by damage type (e.g., roof damage), building type, natural hazards, and location (shown in the center of Figure 3.1). For example, part of the IMCOM SRM Storm Damage data that we used is called the SRM Storm Damage Data Validation Report and for an installation's storm event it includes information about each facility damaged (by facility number), a brief description of the damage, the estimated SRM and BOS costs from the installation, and other data.⁹¹

Figure 3.1. Analysis Process of the Vulnerabilities of Army Installations and Buildings to Natural Hazards



⁹⁰ For more information about these data see Appendix B.

⁹¹ These SRM costs are not just for buildings; they also include costs for other facilities, namely, structures (e.g., bridges and carports) and utility systems. IMCOM staff validate this SRM funding request for each facility and create a final validation report spreadsheet with both the validated and unvalidated SRM and BOS costs in it. For more information see Appendix B.

Army IGI&S geospatial data were used to examine installation locations. This geographic information system (GIS) data are also used to examine building location data by different types of buildings (e.g., barracks, maintenance buildings, and administrative buildings). Throughout our assessment, the natural hazards patterns and trend data from the natural hazards assessment helped inform our understanding about natural hazards exposure. For example, we used DCAT information to examine installation-level exposure for different natural hazards. Similarly, the assessment of insurance industry information helped inform which natural hazards were of interest (based on coverage) and what data and information were needed for the insurance building case studies (e.g., an estimate of the facility's replacement value, called the engineering replacement value [ERV]).

We assessed Army historical storm damage data at two levels: for installations as a whole and for building types. Installation-level data were examined to understand historical exposures to natural hazards by state and locations within a state (e.g., close to the coast) and where most Army buildings of interest are located. Building-level data were used to understand which Army real property asset classes (i.e., building types) to focus on in our case studies based on the cost, the extent and patterns of damage by building category, type of damage, and importance to the Army mission (e.g., a maintenance facility to repair tanks is more important to the military mission than the golfing club house). We tried to understand the higher cost storm damages that could potentially be avoided by a resilience investment in a building that is important to the Army mission, such as investing in roof anchorage on a barracks to potentially prevent the roof from being blown off during a hurricane, tornado, or other high wind storm event and avoiding the high SRM costs to repair the building.

We classified and examined installation storm-damaged buildings by their real property category codes, which is fundamental to how the Army classifies and manages its buildings and was central in our analyses. Army real property facility types are grouped together with five-digit facility category codes that are based on a hierarchical grouping of similar facility types to classify, categorize, plan, budget, and manage real property.⁹² For instance, category code number 72111 is for enlisted unaccompanied personnel housing, namely, a permanent party barracks for housing active-duty single soldiers on an installation. The Army uses hundreds of category codes to manage its real property assets. Other barracks category codes are used to distinguish different types of barracks usage, such as for new trainee barracks, transient training barracks for advanced skills training, and barracks on training ranges.

⁹² “These code numbers are based on nine basic functional classes directed by the DOD. The Army generally uses a five-digit code to identify, plan, program, budget, design, construct, inventory, and maintain its facilities. Some commands add digits to refine the functional description.” Army Regulation 420–1, *Army Facilities Management*, Headquarters, Department of the Army, August 24, 2012. For more information see Department of the Army Pamphlet 415–28, *Guide to Army Real Property Category Codes*, Headquarters, Department of the Army, April 11, 2006.

The style, design, construction, and use of these barracks types are different which is why they have different category codes. For our analysis purposes, we assessed the data by category code and initially grouped different category codes together in similar building categories (such as maintenance facilities and barracks)⁹³ to examine the total amounts and costs of the storm damage for different types of facilities.⁹⁴ This analysis helped us understand which real property asset types had experienced the most costly damage in the past. The category codes were also used to help identify the building types that could potentially be compared with similar commercial insurance categories.

Army subject matter experts from ASA(IE&E), G-9, ARNG, IMCOM, and other parts of the Army helped us understand the various data and which aspects are important to the Army, such as which real property asset categories to focus on. In this case, we wanted to identify real property asset categories (i.e., building types) that are important to the Army and where it is worthwhile to make building resilience investments given the cost to construct and repair the buildings.

We will illustrate with Army maintenance buildings as an example. Many Army installations have motor pools to repair Army operational vehicles (e.g., Stryker and M1 Abrams) and garrison vehicles (e.g., cars, vans, and trucks used to conduct the management of the installation). There are multiple buildings in maintenance areas ranging from large buildings for repairing vehicles to smaller buildings for storing equipment and supplies and disposing of hazardous wastes. We are more interested in the actual buildings used to perform the vehicle maintenance at an Army operational motor pool and for those that repair the larger combat vehicles, such as tanks, because they are more important to the Army mission; they require larger, more costly, and more specialized buildings (e.g., with larger bays, bay doors, and overhead lift capability); and it would be more difficult to find an alternative for performing the repairs if these buildings were damaged by a storm event. At these motor pool complexes the buildings for repairing combat vehicles would be higher priority to the mission and for making resilience investments in to increase the probability of their functioning during a natural hazard event than those that are used for supplies or other functions.

⁹³ The category codes were not consistently contained within the storm damage data, so we merged our storm damage building level data file with each installation's building common installation picture (CIP) file by facility number so we could identify the category codes for each building and to examine the locations of different categories of buildings within the GIS.

⁹⁴ For example, we grouped all barracks types together since they can be compared with college dorms which have similar construction and usage types. Similarly, we grouped Army category codes related to different maintenance facilities (e.g., Vehicle Maintenance Facility, the CATCODE for warfighting vehicles and the General Purpose Maintenance Shop, the CATCODE for repairing garrison vehicles) together into a maintenance building category because of similarities with commercial maintenance shops. Different administrative buildings and headquarters buildings (e.g., battalion and brigade headquarters buildings) were grouped together as office buildings because of the analog with commercial office buildings. Army schoolhouse buildings and others with classrooms in them were grouped into educational buildings.

It is important to note that for this study, we focused on building damage for comparability to insurance data, but the costs to recover from a natural hazard event would be higher. For example, we do not include the costs of recovering power, water, and transportation infrastructure or the cost of loss vehicles. Systematic resilience investment decisions should consider the full cost of storm recovery and resilience, especially because some of these other costs can be significant (see Figure 1.1 for examples of the other costs). For instance, SRM building costs do not include the mission costs (e.g., costs of having to relocate mission functions while a building is repaired), the BOS expenses (e.g., cost of debris removal), or the costs to replace the building contents that are damaged or destroyed. In some cases, these BOS or other facility costs can be significant.

Storm Damage at Army Installations

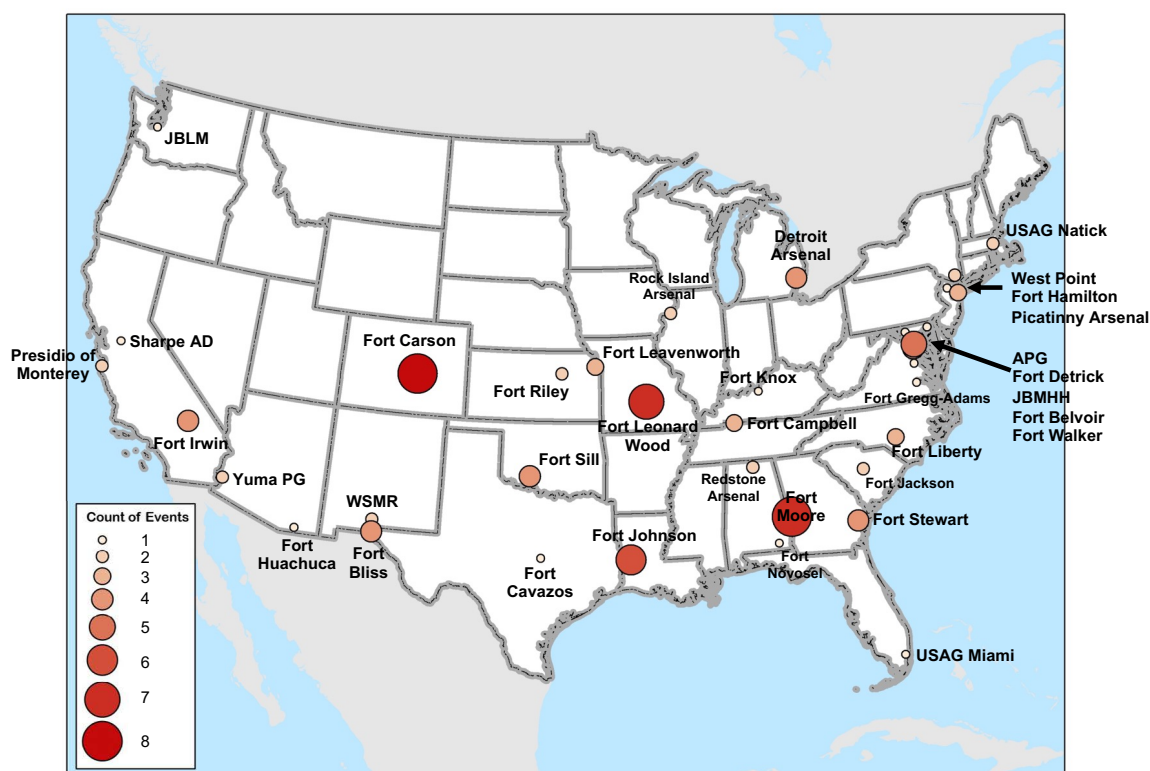
Given its large set of buildings, our analysis of Army historic storm damage data began with an assessment of the IMCOM SRM storm damage data across all installations. We were interested in where the Army has many buildings that have been exposed to potential storm damage and where the cost to the Army to recover from such damage has been significant. For instance, IMCOM manages several large installations in the southeastern United States, lower Midwest, and West but hardly any in the upper Midwest and New England (e.g., none in Idaho, Montana, Wyoming, North and South Dakota, and Nebraska). IMCOM manages two installations in Alaska and a few in Hawaii. We examined IMCOM SRM storm damage data both by number of storm events and total cost of storm events by location for CONUS, Alaska, and Hawaii.

The map in Figure 3.2 shows the total number of storm events for each installation that received IMCOM SRM storm damage funds between FY 2011 and FY 2021.⁹⁵ These data included 101 natural hazard events that occurred across 37 different installations.⁹⁶ Fort Carson and Fort Moore have both had the most storm events, eight, that required resources from this special sustainment fund. At Fort Carson, these hazardous weather events included three hailstorms, two windstorms, a rainstorm, a flood, and an arctic freeze event; Fort Moore experienced three hurricanes, two tornados, two storms, and one flood. In the last 10 years, 65 percent of the Army's installations experienced more than one major storm event. If we had the data on the expenses to repair storm damages with the 5 percent of sustainment funds that were spent before these installations requested IMCOM headquarters storm damage funds, percentages would likely be higher.

⁹⁵ The historical storm damage data provided by IMCOM headquarters were missing data for FY 2012 and part of FY 2014.

⁹⁶ Note this installation storm damage data included only one event for an installation in Alaska (i.e., a wind event at Fort Greely) which did not have major total cost damage and no events in Hawaii, so we do not include Alaska and Hawaii on the GIS maps in this report.

Figure 3.2. Total Number of Storm Events During FY 2011 and FY 2021 by Installation that Received IMCOM SRM Storm Damage Funds



SOURCE: IMCOM storm damage data for FY 2011 through FY 2201, excluding FY 2012 and including only some of the storms from FY 2014.

NOTE: Installations must use 5 % of their total sustainment funds before they can use IMCOM SRM storm damage data funds. These data are for 101 natural hazard events which includes 3 earthquakes. There was also one storm event for Fort Greely, AK. that is not shown on this map.

We also found that 46 percent of these installations repeatedly experienced the same storm type two or more times in the last 10 years, as was the case for both Fort Moore and Fort Carson. For many of the installations with such recurring storms, we also examined natural hazard patterns and projections data and many of these recurring storm types showed a long history and had projections that they will continue to occur or get more frequent and/or more severe in the future.⁹⁷ In addition, many of these installations with the same type of recurring storm events involved water and wind. Some of these installations are repeatedly experiencing the same type of building damages, such as flooding and wind damage. Given reoccurrence of the same type of large storms, installations are also likely to experience similar types of damage again. As these repairs from repeated storm damage are being made, it could be prudent to also invest in resilience measures and to prioritize selected resilience investments at installations that

⁹⁷ For examples, see K. E., Kunkel et al., eds., *State Climate Summaries for the United States 2022*, NOAA/NESDIS, NOAA Technical Report NESDIS 150, 2022.

repeatedly experience the same type of costly storm damage, especially if climate data show longer trends for such storms.

For instance, we examined some longer trends of selected natural hazard types for Army installations in NOAA/NESDIS state climate summaries to see historical occurrence and projected climate change implications for these storm types. Consider Fort Liberty, North Carolina, which has been damaged by the wind and rains from multiple hurricanes. North Carolina is vulnerable to hurricanes and tropical storms with a hurricane impacting the state about every three years over the last 100 years; in addition, tropical and other lesser storms can also have major impacts. Recent active hurricane periods have been the late 1990s through the early 2000s and the late 2010s through 2020.⁹⁸ Relevant climate change projections for this state include that the total annual precipitation is expected to increase and hurricane intensity and rainfall rates are expected to increase.⁹⁹ Given this information for buildings with roof damage, investing in better wind resilience measures for roofs, such as stronger roof anchorage,¹⁰⁰ when repairing selected buildings (e.g., mission critical buildings that were fairly recently built) likely makes sense.¹⁰¹ However, a full cost analysis would be needed before making such investments. In addition, it is important to also consider the implications of investing in some resilience measures for natural hazards that are low-probability, but high-consequence events, such as earthquakes.

We were also interested in the total cost of the damage across all storm events for each installation. The map in Figure 3.3 shows the total validated SRM costs for all the storm events at each installation that received IMCOM SRM storm damage funds between FY 2011 and FY 2021.¹⁰² In the figure, the size of the dot is proportional to the validated SRM costs and range from a few thousand to almost \$100 million. Some dots stand out, such as Fort Liberty (formerly Fort Bragg as shown on the map) which had the highest total damage costs of \$99,257,000 from three storms. This installation had significant damage from Hurricane Florence. Given that Detroit Arsenal is a very small installation with under 50 buildings compared to over 5,000 buildings at Fort Liberty, Detroit Arsenal actually stands out with about \$7 million in damage

⁹⁸ R. Frankson, et al., *North Carolina State Climate Summary 2022*, NOAA/NESDIS, NOAA Technical Report NESDIS 150-NC, 2022.

⁹⁹ R. Frankson, et al., *North Carolina State Climate Summary 2022*, NOAA/NESDIS, NOAA Technical Report NESDIS 150-NC, 2022.

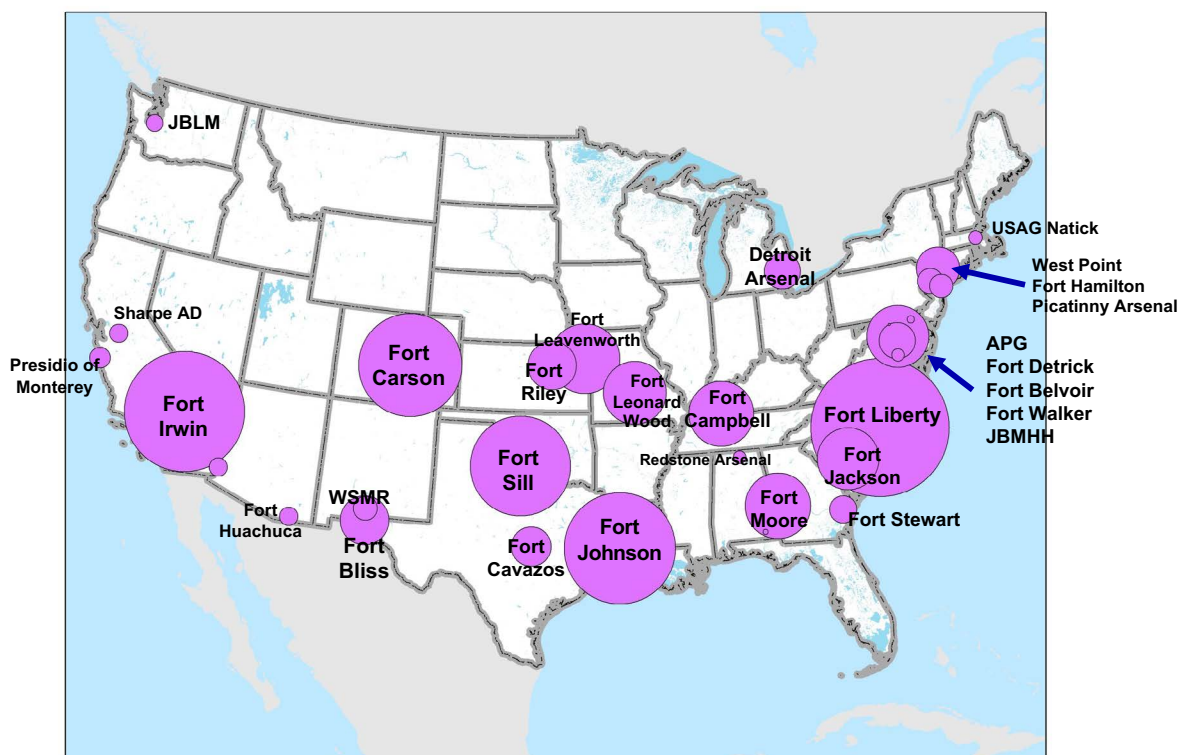
¹⁰⁰ It is important to note that amount and type of roof damage can also be based on the type of roof (flat versus pitched) as well as the material (shingle, metal, slate, rubber membrane), so resilience measures for roofs could also address these issues.

¹⁰¹ For more information about increasing resilience to wind from better roof anchoring and other investment measures see FEMA, “Design Guide for Improving Critical Facility Safety from Flooding and High Winds,” FEMA 543, January 2007; and FEMA, “Successfully Retrofitting Buildings for Wind Resistance,” Recovery Advisory 1, June 2019; and FEMA, “Best Practices for Minimizing Wind and Water Infiltration Damage,” Recovery Advisory 2, June 2019.

¹⁰² Data were missing for FY 2012 and some of FY 2014.

from three floods and one rainstorm. In fact, Detroit Arsenal “has withstood the consequences of critical infrastructure failure, resulting in mission degradation and significant financial impact, from three major flooding events in the last five years alone.”¹⁰³

Figure 3.3. Total Validated SRM Storm Damage Costs at Each Installation Between FY11 and FY21



SOURCE: IMCOM Storm damage data for FY 2011 through FY 2021, which were missing data from FY 2012 and included only some of the storms from FY 2014.

NOTE: The size of the dot indicates the validated SRM costs ranging from \$34,000 up to almost \$100 million. Installations without validated costs are not shown on this map. Data were missing for FY 2012 and incomplete for FY 2014 and installations must use 5 percent of their total sustainment funds before they can use IMCOM SRM storm damage data funds so these SRM building costs are a lower bound on IMCOM sustainment storm damage costs. Validated SRM costs includes costs for repairing buildings, structures, and utility systems. There was also one storm event for Fort Greely, AK, that is not shown on this map and its size would be much smaller than the circle for USAG Natick.

We also looked at which storm events caused the highest amount of SRM damage by installation. In Table 3.1, the values include damage for buildings, other facility types, and infrastructure. In cases, where we were able to acquire detailed damage information by facility type, we found that for some of these events the costs to repair roads, culverts, and other

¹⁰³ Converge Strategies, LLC, “Detroit Arsenal Regional Defense Assessment of Resilience (DAR2): Process and Project Concepts,” February 2022.

facilities were as high or even higher than the costs to repair the buildings. We also examined these data by incident storm type as discussed in the last chapter (see Figure 2.2).

Table 3.1. Most Costly SRM Storm Events for IMCOM Army Installation for Those with Total SRM Storm Damage Greater Than \$5 Million

Total Cost of SRM Damages for the Storm Event	Installation Name	State	Fiscal Year of the Storm	Type of Storm Event	Rank By Highest Cost
Over \$40 to \$52 million (Total of \$95,118,600 million)	Fort Liberty	NC	FY18	Hurricane	1
	Fort Irwin	CA	FY13	Flooding	2
Over \$30 to \$40 million (Total of \$107,070,600 million)	Fort Sill	OK	FY21	Freeze	3
	Fort Johnson	LA	FY21	Hurricane	4
	Fort Liberty	NC	FY11	Tornado	5
Over \$20 to \$30 million (Total of \$41,044,700 million)	Fort Campbell	KY	FY11	Tornado	6
	Fort Carson	CO	FY18	Hail	7
Over \$10 to \$20 million (Total of \$124,254,000 million)	Fort Leavenworth	KS	FY19	Flooding	8
	Fort Irwin	CA	FY16	Flooding	9
	Fort Liberty	NC	FY17	Hurricane	10
	Fort Moore	GA	FY16	Flooding	11
	Fort Leonard Wood	MO	FY11	Tornado	12
	Fort Jackson	SC	FY16	Flooding	13
	JBMHH	VA	FY19	Storm	14
	Fort Johnson	LA	FY17	Flooding	15
Over \$5 to \$10 million (Total of \$103,502,100 million)	Fort Carson	CO	FY18	Hail	16
	Fort Carson	CO	FY17	Wind	17
	Fort Carson	CO	FY19	Hail	18
	Fort Irwin	CA	FY20	Earthquake*	19
	Fort Cavazos	TX	FY21	Freeze	20
	Fort Riley	KS	FY21	Freeze	21
	Fort Johnson	LA	FY16	Storm	22
	Fort Sill	OK	FY15	Flooding	23
	Fort Bliss	TX	FY11	Freeze	24
	Fort Sill	OK	FY16	Flooding	25
	Fort Jackson	SC	FY17	Hurricane	26
	West Point	NY	FY11	Hurricane	27
	Fort Leavenworth	KS	FY15	Flooding	28
	Fort Irwin	CA	FY14	Storm	29

SOURCE: IMCOM Storm damage data for FY 2011 through FY 2021, excluded FY 2012 and included only some of the storms from FY 2014.

NOTE: Each installation must use 5 percent of their total sustainment funds on storm damage repairs before they can use IMCOM SRM storm damage data funds so these SRM building costs are a lower bound on IMCOM sustainment storm damage costs. *Earthquakes are not affected by climate change.

We supplemented the SRM data with the information about the MILCON storm damage costs and storm locations. In terms of IMCOM installations, Fort Liberty required \$ 21.2 million of MILCON funding to build a new warehouse and a new storage building, both of which had

been destroyed in a tornado in 2011, and Fort Leonard Wood received \$7 million of MILCON funding to build a new storage building, which had been destroyed in a thunderstorm in 2009.¹⁰⁴ The ARNG had more extensive damage from natural hazards between 2005 and 2021 (see Table 3.2), including receiving over \$530 million in MILCON funding to rebuild buildings that were destroyed in Louisiana and Mississippi by Hurricane Katrina in 2005.

Table 3.2. MILCON Projects for Act of Nature at ARNG Buildings Between 2005 and 2021

Year of AoN	Type of AoN	Location	State	Facility Description	Funding Amount
2005	Hurricane Katrina	Jackson Barracks	LA	6 buildings: Barracks, 2 Maintenance Shops, HQ Building, & 2 RCs	\$225,865,000
2005	Hurricane Katrina	7 Other Locations Across LA	LA	7 buildings: Aviation Support Fac, Maintenance Fac, & 5 RCs	\$209,881,000
2005	Hurricane Katrina	7 Locations Across MS	MS	7 buildings: 2 Maintenance Shops, & 5 RCs	\$94,641,000
2008	Tornado	Camp Shelby	MS	Billeting Space & Supply Building	\$11,503,000
2008	Tornado	Camp Atterbury	IN	DPW Facility	\$12,200,000
2012	Hurricane Sandy	Sea Girt	NJ	4 buildings: 2 Maintenance Shops, Health Clinic, and Instruction building	\$16,900,000
2018	H. Florence	Fort Fisher	NC	Admin Building	\$17,400,000
2018	H. Michael	Panama City	FL	Readiness Center (RC)	\$25,000,000
2018	Tornado	Pineville	LA	Readiness Center	\$16,500,000

SOURCE: RAND calculations based on ARNG AoN data extraction from PRIDE, December 2021.

These data show that in 37 states Army IMCOM installations experienced at least one storm causing damage that required IMCOM SRM Storm Damage reserve funds between FY 2011 through FY 2021. Five of the states had six or more storm events that required IMCOM SRM storm damage funding: Virginia (13), Georgia (11), Colorado (8), California (6), and Louisiana (6). The total SRM costs across all storms at an individual installation were highest in the following states: California, Colorado, Oklahoma, Louisiana, and North Carolina. For instance, Fort Liberty in North Carolina has had only three events (two hurricanes and one tornado) during this period, yet each of those storms resulted in SRM costs above \$17 million. Fort Liberty was also one of two Army installation which required MILCON funding for two buildings destroyed in the tornado in 2011.

Based on these results, we searched California, Colorado, Georgia, Louisiana, North Carolina, Oklahoma, Texas, and Virginia for insurance data. Given the risk of hurricanes and the fact that insurance companies can have named peril policies for hurricanes, we added three states along the east coast with hurricane risks to the search for insurance data: Florida, New Jersey,

¹⁰⁴ These data were acquired from the G-9 from CAPCES by searching for projects funded in FY 2011–FY 2021. These MILCON projects can include a time delay between the storm and the actual acquisition of the funding from Congress which is why these data include a 2009 storm. In researching these storms, we noticed additional buildings that had received MILCON funding to rebuild buildings damaged by a natural hazard event during the same time period.

and New York. We could not sample every state, but to capture any potential differences in the West, we added Washington to the list which is where Joint Base Lewis-McChord is located. Last, given the large tornado and hail risk in Kansas, which is the location of two Army installations that have had costly storm damage in the past (see Table 3.1), we added Kansas to the insurance state list search.

Building-Level Storm Damage

We examined Army installation building-level storm damage data to understand the range of vulnerabilities to different types of real property assets (e.g., an office building compared to a barracks) and for different types of hazards to understand the type of damage by storm type and where the highest cost SRM damage occurred. Building-level data were important to understand which building types to focus on in our case studies based on the cost, extent and patterns of damage, and importance to the Army (e.g., a barracks is more important to the Army mission than the installation bowling center). Examining the damage by different real asset classes and building types (e.g., fitness center, barracks, child development center, and educational classroom facility) helps us to identify the commercial analog for our commercial insurance assessments.

IMCOM SRM Storm Damage Data Validation Reports available between 2011 and 2021 indicated that 35 unique installation storm events had SRM building damage data.¹⁰⁵ We identified 1,900 buildings damaged across these 35 events and examined them by storm type and costs of damages.¹⁰⁶ Table 3.3 shows 1,620 of the buildings had lower amounts of cost damage (i.e., less than or equal to \$200,000) and 31 had very large amounts of damage (i.e., greater than or equal to \$1 million). Since our study is focused on how insurance industry values resilience investments for individual buildings, we are interested in those buildings with higher cost damage.

¹⁰⁵ We had reports for 40 different installation storm events, but five events did not have any SRM cost damages to buildings. These events only had SRM damage to other facility types and/or BOS related damages. For example, an event may have had damage to installation roads, bridges, and culverts and BOS costs to clear debris away.

¹⁰⁶ These reports contained SRM information on other structures and utility systems along with BOS costs that were not included in this count since we were focused on buildings only.

Table 3.3. Count of Buildings with SRM Cost Damage in Different Ranges by Storm Event Type

Type of Storm Event	Number of Event Reports	Total Number of Buildings for All Reports	Building Damage >= \$ 1 Million	Building Damage < \$1 M and > \$200 K	Building Damage <= \$ 200 K
Flood	11	178	4	30	144
Hail	1	37	3	23	11
Hurricane	7	1080	13	98	969
Rain	1	28	0	0	28
Storm	7	105	1	22	82
Tornado	1	105	1	3	101
Wind	2	42	1	11	30
Freeze	5*	325*	8*	62*	255*
Total	35	1900	31	249	1620

SOURCE: IMCOM SRM Storm Damage Data Validation Reports from between 2011 and 2021, excluding FY 2012 and including only some of the storms from FY 2014.

*Most of these events and buildings had only unvalidated costs.

As shown in Table 3.3, 31 buildings across all real property asset types had \$1 million or more in damage, which was not a large enough sample to distinguish between different building types. After assessing the data further, we determined that a damage threshold of \$200,000 or greater would yield a group of 280 buildings with sufficient diversity.

Next, we examined the category codes of the 280 buildings with \$200,000 or greater in storm damage and grouped them into similar building categories of interest. Groupings were based on similar facility design category, importance to the Army, and analogous to commercial property insurance building categories. We found there were many smaller unique building types that did not meet one or more of these criteria (e.g., bowling alley has a unique facility design and is not significant to the Army mission) or had only a few in the category (e.g., child development centers) or both (e.g., chapels have a unique facility design and there were not many damaged). Building categories that met the criteria and had more than five buildings damaged with costs greater than or equal to \$200,000 across all our storm events are shown in Table 3.4.

Among these categories, three had more incidents within this cost threshold: office buildings, barracks, and maintenance buildings. Since the Army tends to have a large number of each of these types of facilities at larger installations, this pattern is not surprising. It also provides a useful set of building case studies to use for insurance assessments since we wanted a small manageable set of general building types for our analyses. In addition, even though more office buildings were damaged than barracks and maintenance buildings, they have lower total SRM costs along with lower average, median, and maximum SRM costs. Given that Army installations can have many smaller office buildings, they would likely cost less to repair than larger and more costly brigade and battalion headquarters buildings (also with an office building category code) or barracks and maintenance buildings, like a three-story barracks.

Table 3.4. Installation Storm-Damaged Buildings by General Building Category

General Building Category	Number of Buildings in the Category	Total SRM Costs for Buildings in the Category	Average SRM Cost	Median SRM Cost	Maximum SRM Cost
Office Building	68	\$34,439,119	\$506,458	\$386,237	\$2,100,000
Barracks	30	\$28,320,935	\$944,031	\$498,500	\$5,000,000
Maintenance Building	36	\$26,728,868	\$742,469	\$450,000	\$4,000,000
Education Building	13	\$6,422,229	\$494,018	\$330,000	\$1,972,187
Warehouse	13	\$6,037,250	\$464,404	\$480,000	\$949,000
Fitness Center	9	\$4,648,674	\$516,519	\$250,000	\$1,524,000

SOURCE: RAND AC calculations using IMCOM SRM Storm Damage Data Validation Reports from between 2011 and 2021 excluding FY 2012 and including only some of the storms from FY 2014 and facility CATCODEs in the Army IGI&S GIS CIP.

We also observed when reviewing the damage descriptions that a large number of buildings mentioned roof damage and repairs. To better understand how significant these roof issues were from both a storm type and cost perspective and since part of the insurance industry cares about resilience investment measures related to roofs (see Chapter Four), we calculated the percentage of buildings for each event type that had roof issues (see Table 3.5).¹⁰⁷ In some of these cases, there also was other damage that needed to be repaired, including repairing other external features (e.g., gutters, lightning protection, and drain spouts) and internal damage from penetration by water that was likely caused because of the roof damage (e.g., replacing ceiling tiles, a collapsed ceiling and/or light fixtures, and repairing the drywall and wall finishes).

Table 3.5. Percentage of Buildings with Roof Damage/Issues by Different SRM Cost Ranges

Type of Event	No. of Damaged Buildings with Roof Issues	% of Damaged Buildings with Roof Issues	% of Buildings with Damage >= \$ 1 Million and Roof Issues	% of Buildings with Damage < \$1 M and > \$200 K and Roof Issues	% of Buildings with Damage <= \$ 200 K and Roof Issues
Flood	81	46 %	50 %	60 %	42 %
Hail	36	97 %	100%	100 %	91 %
Hurricane	199	18 %	62 %	36 %	16%
Rain	13	46 %	N/A	N/A	46%
Storm	85	81 %	100 %	82 %	80 %
Tornado	34	32 %	100 %	67 %	31 %
Wind	34	81 %	100%	91%	77 %
Freeze	*16	*5 %	*13 %	*15 %	*2 %
Across All Events	498	26 %	55 %	46 %	23 %

SOURCE: IMCOM SRM Storm Damage Data Validation Reports from between 2011 and 2021, excluding FY 2012 and including only some of the storms from FY 2014.

¹⁰⁷ To calculate these variables, we created a computer program to flag any building that mentioned roof or roofs. Since the search was based on the occurrence of the word roof, some of the buildings might not have had roof damage. However, in a random sample of these entries almost every one of them involved roof damage. In addition, at some installations the descriptions implied likely roof damage (e.g., replacing water damaged ceiling tiles), but the brief description did not mention the word roof.

NOTE: *Most of these events and buildings had only unvalidated costs.

In a discussion with ARNG subject matter experts, we learned that some ARNG buildings that were damaged from acts of nature involved the roof being blown away. The resulting rain water penetrated the building causing additional damage that was so significant that a new building had to be constructed with MILCON funds. We also learned that some installations are experiencing costly damage from multiple wind-related storm types (i.e., wind, tornados, hurricanes, and hail) and incurring the same types of wind damage to their buildings each time, such as roof damage from multiple hailstorms at Fort Carson. We found similar findings for installations experiencing building flooding damage, such as at Fort Leonard Wood.

By examining the installation and building level data in combination with the natural hazards assessments discussed in the last chapter, we were able to get a better understanding of Army installations' vulnerabilities to different natural hazards. Based on these analyses of the vulnerabilities of Army installation and buildings from historical storm damage and the assessment of natural hazards patterns and trends, we identified three things to help with the insurance assessment. First, this analysis helped us understand which states to focus on in the search for commercial property insurance information. Second, we identified which building types to focus on in the insurance case studies: office, barracks, and maintenance buildings. From these analyses, we also identified some challenges in accessing and using the Army installation data on historical natural hazards damage, which are discussed at the end of the chapter because these issues have important implications for Army managers and other staff who may want to use these data to inform their decisionmaking processes. Third, it helped inform the selection of case studies which is explained in the next section. However, first we summarize some key findings about the role of water and wind in an installation's building damage from our assessment of the building-level storm damage.

Most of the Installation Historical Building Damage is from Water and Wind

We found that most Army installation storm damage to buildings comes from two fundamental forces of nature: water and wind. As stated in one Army installation building damage description from a hurricane: "Loss of roof caused interior damage from wind and water."¹⁰⁸ Water damage comes from flooding, hurricanes, storms, and wind driven rain. Given the way the Army installation storm types are recorded, it is difficult to separate out the exact cost of these types of damages. However, these general findings about water and wind are demonstrated by the data. Within the 11-year period of IMCOM SRM storm damage data, the four storm types that involved water (i.e., hurricanes, floods, storms, and rain)¹⁰⁹ accounted for

¹⁰⁸ From IMCOM Storm Damage data.

¹⁰⁹ In some cases, hailstorms can include water damage. However, we did not include hailstorms in water damage because the building damage descriptions showed that these storms could damage the roofs without much water

69.3 percent of all storms types and 66 percent of the total validated SRM cost damage (see Figure 2.2). Flood events were nearly 25 percent of all events (see Table 2.4) and the damage descriptions indicated that the other events related to water also had flooding or water damage. MILCON projects also involved water because the majority of the installation damage that required MILCON projects was from hurricanes (e.g., see Table 3.2). Similarly, within the 11-year period of IMCOM SRM storm damage data examined, we found that the four storm types that involved wind (i.e., wind, tornados, hurricanes, and hail)¹¹⁰ accounted for 44.6 percent of all storms types and 48.7 percent of the total validated SRM cost damage (see Figure 2.2).

For the 35 storms that building-level data were available, 26 percent of the buildings damaged involved roof issues and 55 percent of the buildings with \$1 million or more in damages involved roof issues (see Table 3.5) which according to the damage descriptions can be from wind damage.¹¹¹ Similarly, MILCON projects also involved wind because all the building-related storm damage except for one building was from hurricanes and tornados (e.g., see Table 3.2). These costs were significant. For example, after Hurricane Michael in 2018, the U.S. Army National Guard received \$25 million dollars in MILCON funding to rebuild one readiness center that was severely damaged in Panama City, Florida. Understanding Army installations' buildings exposure and vulnerabilities to water and wind is important to facility investment decisions more generally and in the context of this study in the insurance analyses as is discussed in Chapters Four and Five.

Army Installation and Building Vulnerabilities Used to Determine the Case Studies

Our assessment of the installation and building vulnerabilities was combined with other information to determine our specific case studies (see Appendix C for details). Our choice of installations for the commercial property insurance case studies was driven by states for which we found sufficient commercial property insurance data, significance to the Army mission, where the Army has more buildings that are vulnerable, and coverage of relevant natural hazard risks in different parts of the United States. Our choice of NFIP case studies was based on an assessment of installations with either a history of flood damage or relatively high exposure to flooding for the building types of interest and to capture both the riverine and storm surge flood

penetration and because the insurance industry treats these as wind events. More analyses of these data are needed to understand what role water damage plays in them.

¹¹⁰ In some cases, storms can include wind damage. However, we did not include storms in wind damage because these events did not always involve winds. More analyses of these data are needed to understand what role wind damage plays in them.

¹¹¹ More analyses of these data are needed to understand the exact significance of wind.

risk.¹¹² Table 3.6 show the installations selected for our case studies. Fort Stewart was selected as the base case for the commercial property insurance assessment and Fort Cavazos was selected as the base case for the NFIP assessment.¹¹³

Table 3.6. Installations Selected for the Insurance Case Studies

	Commercial Property Insurance	NFIP Flood Insurance
Installations Selected (in alphabetical order)	Fort Belvoir, VA Fort Carson, CO Fort Moore, GA Fort Sill, OK Fort Stewart, GA	Aberdeen Proving Ground (APG), MD Fort Carson, CO Fort Cavazos, TX Fort Stewart, GA

Once we chose which buildings were of interest within each type based on the CATCODEs, we also needed to know which characteristics of individuals buildings and their location were relevant for the insurance industry case studies and which factors were needed for the insurance premium calculation. For instance, building construction type is an important indicator of the sensitivity of a building to certain hazards (such as strong winds) and was needed for the commercial property insurance premium calculations. We also considered factors of importance for Army purposes, such as the size and purpose of the building (e.g., CATCODEs). As a general rule, the Army would prefer to prioritize resilience investments for buildings that cost more to repair and replace and that are more important to the mission. Table 3.7 shows the main factors for each category: general information about each building case study (orange rows), the building characteristics (yellow rows), the general location factors (green rows), and the site level geographic factors (blue rows).

¹¹² Since the Army does not have many large installations along the coasts, few Army buildings are located in the coastal storm surge flood plain. We chose APG. This fact is also why our NFIP analyses tend to focus on riverine flooding. For more details see Appendix C.

¹¹³ For the explanation of how and why we chose the different installations as case studies see Appendix C.

Table 3.7. Summary of the Main Building Case Study Factors Needed for the Insurance Premium Calculations

Factor Category	Sample Factors	Selected Value of the Factor Needed for Army Comparison	Factor Needed for NFIP Calculation	Factor Needed for Commercial Property Insurance Calculation
General Case Study Information	Building category (i.e., barracks, office, or maintenance)	Yes	Yes	Yes
	CATCODE	Yes	No	No
Building Characteristics	ERV	Yes, e.g., high valued building	Yes	Yes
	Year Built	Yes	No	Yes
	Number of Stories	Yes	Yes	Yes
	Area (SF)	Yes, e.g., maintenance building $\geq 10,000$ SF	No	No
	Construction Type	Yes	No	Yes
	Foundation Type	N/A	Yes	No
	Machinery & equipment above 1 st floor	N/A	Yes	No
General Location Factors	State	N/A	Yes	Yes
	County	N/A	Yes	Yes
	Zip Code	N/A	No	Yes
Site Level Geographic Factors	First floor elevation to ground	N/A	Yes	No
	Drainage area/ watershed	N/A	Yes	No
	Distance to Water Hazard Source	N/A	Yes	No
	Relative Ground Elevation to Hazard Source	N/A	Yes	No

NOTE: The different colors are used to show the factors in each category: orange rows are for the general case study information, yellow rows are for the building characteristics, green rows are for the general location factors, and the blue rows are for the site level geographic factors. The details about these factors for the commercial property and NFIP insurance premium calculations are discussed in Chapter 4 and 5 respectively.

Once we identified the installation and building-level case studies, we gathered the data needed for each case. Since Fort Stewart was the base case for the commercial property insurance premium calculations and used as a case study for the NFIP insurance premium calculations, we gathered or calculated the data shown in Table 3.8. Where these data came from and how they are used are discussed in Chapters Four and Five for the commercial property insurance and the NFIP insurance assessments, respectively.

Table 3.8. Summary of the Main Factors for the Selected Fort Stewart Building Case Studies

Factors	Barracks	Office Building	Maintenance Building
Building Description	Enlisted Barracks	Battalion HQs Building	Field Artillery Maintenance
CATCODE	72111	14183	21410
ERV	\$16,279,000	\$5,861,000	\$18,528,000
Year Built	2007 (15 years old)	1986 (36 years old)	1983 (39 years old)
Number of Stories	3	2 with a 1 story addition	2
Area (SF)	16,872	11,283	50,290
Construction Type	ISO 3 or 4	ISO 3 or 4	ISO 3 or 4
Foundation Type	Slab/ no basement	Slab/ no basement	Slab/ no basement
Site	Hunter AAF	Fort Stewart, GA	Fort Stewart, GA
Zip Code	31409	31314	31314
County	Effingham	Liberty	Liberty
First Floor Elevation Relative to Ground	0 ft	0 ft	0 ft
Drainage area/ watershed	37.33 sq km	153.34 sq km	153.34 sq km
Distance to Water Hazard Source	400 meters	18 meters	50 meters
Relative Ground Elevation to Hazard Source	14 feet	4 feet	5 feet

NOTE: The different colors are used to show the factors in each category: orange rows are for the general case study information, yellow rows are for the building characteristics, green rows are for the general location factors, and the blue rows are for the site level geographic factors. The colors are consistent with the usage in Table 4.3.

Data Considerations

We experienced a number of challenges in accessing and using both SRM and MILCON installation storm damage data which is discussed in this section.

Challenges in Accessing the Data

Data about costs and damages from natural hazards are tracked by different Army organizations and Army data systems. Any Army organization that owns and/or manage buildings and other real property assets can have current and historic data about damage and costs from natural hazards. Owners and managers of Army sites and installations include: IMCOM, AMC, ARNG, and Army Reserve. Most of the active Army installations are managed by IMCOM headquarters. However, AMC also manages about two dozen smaller installations

consisting of the Army's organic industrial base sites.¹¹⁴ For instance, AMC manages and operates the Military Ocean Terminals that ship munitions overseas for U.S. military operations.

Different systems that include data about Army installation natural hazards include: General Fund Enterprise Business System (GFEBS), PRIDE, CAPCES, and IMCOM storm damage data systems. PRIDE and GFEBS are enterprise-wide and centralized data systems. Data about MILCON projects for active Army installations came from the G-9 and were extracted from the Army Construction Appropriation Programming Control and Execution System (CAPCES) database. The IMCOM storm damage data are not in a centralized data system, but rather a collection of different spreadsheets stored at IMCOM headquarters.

These data could potentially be useful for many diverse decisions, but it is difficult to access data from so many different sources, not to mention figuring out where the data are located, how to access them, and then actually extracting them from the data systems or having an Army subject matter expert extract them. For example, Military Ocean Terminal Sunny Point (MOTSU), North Carolina, was severely damaged by Hurricane Florence in 2018,¹¹⁵ but its facility damage was not included in any of the data that we received from IMCOM or G-9. This gap is likely because this installation was transitioned to IMCOM in the last year or two, and its historical storm damage data would likely need to come from AMC. In addition, some data are in various centralized data systems while others are not, which creates different challenges. For example, extracting data from the centralized data systems involves different Army organizations, definitions, formats, and computer software systems.

Challenges in Using the Data

The Army natural hazards damage data were difficult to use for multiple reasons, including missing data and inconsistency in how terms were used and recorded. In addition, the aggregation and integration of data made it difficult to figure out the cost of damages to individual buildings. We provide examples of some of these challenges.

Because of missing data, it was difficult to identify storm types associated with Army storm damage data. MILCON data related to natural hazards for both the ARNG and active Army installations did not include storm types; we had to find these in public records that contained information on special appropriations funding from Congress.

Both ARNG and IMCOM SRM natural hazards data had inconsistencies with capturing and recording the natural hazards type. The ARNG PRIDE data system does include the exact date of the storm but does not appear to include a field for tracking the actual storm types because the storm type was missing for most of the buildings damaged. The ARNG SRM projects mostly

¹¹⁴ The management of these installations is being transitioned to IMCOM, but historical storm damage data would need to come from AMC.

¹¹⁵ For more information see Russell Wicke, "Engineer Task Force Revolutionizes Disaster Response with MOTSU Recovery," U.S. Army Corps of Engineers, September 26, 2018.

stated things like: “storm damage repair” or “act of nature” as part of the project name and a description that includes a statement like “a tree fell on the building” but no mention what type of storm caused the tree to fall and damage the building. There were inconsistencies in how storm type was reported in the IMCOM SRM storm damage data (e.g., the file name states one type of storm while the information in the SRM Storm Damage Data Validation Report states a different storm type) and inconsistency in how different installations classified storms, e.g., where one categorized the nature hazard as “storm” while another stated “rain/wind” for a similar natural hazard event.

The historical building-level natural hazards cost and damage data we acquired from different Army sources were missing some of the buildings that were damaged by past natural hazards and/or corresponding costs. In examining public records about special appropriations funding from Congress regarding MILCON funds spent at Army installations, we were able to identify additional buildings that were being replaced because of storm damage that was not in the Army data we acquired. In IMCOM storm damage data, some of the historical SRM Storm Damage Data Validation Reports had not been saved for past storms so building details for these storms were missing. For some of these past storm events, the reports were missing the validated costs and only included the original unvalidated costs. These missing data tended to be from several years to 11 years ago and IMCOM has since improved the tracking and oversight of these data in the last few years.

In addition, some of the IMCOM SRM storm damage data are missing some installation storm damage costs because of the business rules for using this funding. Specifically, installations must use 5 percent of their initial, total unallocated sustainment funding for repairing storm or fire damage before they can request repair funding from the HQ IMCOM storm damage reserve to pay for the SRM costs. The cost data for this 5 percent of damages should be stored in GFEBs since once a repair project is executed installations are required to record the costs in GFEBs as management decision package (MDEP) VHUR (used for storm damage).¹¹⁶ However, the reliability is unknown since these records are not routinely verified by IMCOM headquarters staff.¹¹⁷ Lastly, some Army installation emergency work order and other minor repairs (e.g., replacing a few roof shingles after they were blown away in a strong wind storm) likely are not captured in any of the data we examined. For instance, for IMCOM installations these repairs would need to be extracted from GFEBs data. Extracting these types of detailed data from GFEBs can be challenging for installation and for enterprise analyses.¹¹⁸

¹¹⁶ Technically VHUR is the MDEP code for humanitarian and disaster relief expenses. It is used to track costs incurred in support of domestic and international humanitarian assistance and disaster relief operations, including hurricanes, floods, earthquakes, wildfires, and other emerging contingencies.

¹¹⁷ Discussion with IMCOM personnel, August 1, 2022.

¹¹⁸ For more information on the challenges of extracting these types of data from GFEBs see Pint et al., 2020.

Building-level details were also inconsistent, often because of how different data types (e.g., SRM and BOS costs or building and infrastructure types) were merged or aggregated when the damages were recorded. Mixing BOS costs in with SRM costs was a common and understandable problem given that an installation storm recovery project and contract may involve both types of activities. For example, at one installation the building project description stated how the SRM costs were for roof repair and removing debris that were impeding traffic near the facility and the comment stated it was work done through BASOPS Contract. In other installation cases, a building number was provided in the SRM Storm Damage Data Validation Report, but each description about what was damaged stated how the project was for road and/or culvert repairs, not for any building repairs. In an example of data aggregation, an SRM Storm Damage Data Validation Report stated that the building number was ‘multiple’ and the description said to repair minor roof damage for 74 roofs. In addition, in the SRM Storm Damage Data Validation Reports installations did not identify buildings by the Real Property Unique Identifier, the official Army code to uniquely identify a real property asset. Instead, these reports used the building number which is not always unique and cannot easily be linked to other Army installation real property data (e.g., such as data in ISR or the Headquarters Installation Information System [HQIIS]).

Implications for the Army

It could potentially make financial sense for the Army to prioritize selected resilience investments related to water and wind at installations that repeatedly experience the same type of costly storm damage. These investments could potentially save money over the long term by preventing damage from future storms and saving the repair costs of such damage. Research by the National Institute of Building Sciences has demonstrated that investments in flood and wind building retrofits can, for some buildings and parts of the country, save money, which is also why resilience measures have been incorporated into some local building codes and standards, such as in hurricane-prone areas.¹¹⁹ Similarly, FEMA's disaster assessment reports regarding hurricanes, floods, and other relevant disasters, stress the importance of sealing the building envelope, stronger roofs, and other wind, water infiltration, and flood mitigation measures.¹²⁰ However, the Army would need to conduct a cost benefit analysis for specific installation

¹¹⁹ For example, an NIBS study found that selected wind retrofits of single-family residential buildings is cost beneficial in hurricane-prone areas. It also discusses the benefits of changes in the Florida building codes. Keith Porter, Charles Scawthorn, Charles Huyck, Nicole Dash, Joost Santos, Kevin Mickey, Tarek Rashed, Adam Reeder, Michael Eguchi, Ron Eguchi, Sannidhye Ghosh, Zhenghui Hu, Moad Isteita, and Althea Cohen-Porter, *Natural Hazard Mitigation Saves: 2019 Report*, National Institute of Building Sciences, Multihazard Mitigation Council, December 2019.

¹²⁰ For examples see FEMA, “Flood Protection for Critical and Essential Facilities,” RA3, April 2017; FEMA, “Successfully Retrofitting Buildings for Wind Resistance,” Recovery Advisory 1, June 2019; and FEMA, “Best Practices for Minimizing Wind and Water Infiltration Damage,” Recovery Advisory 2, June 2019.

buildings and resilience investments to ensure the benefits would exist for those locations and buildings.

Our analysis focused on only a subset of the installation storm damage data, namely, damage to buildings. A wider range of analyses could be conducted with the data used in this study to understand the full costs to the Army from natural hazards events which could be used to inform planning and resilience investment decisions. For example, the roof damage data could be further assessed to better understand how and where roof damage occurs and to help figure out when and where to prioritize resilience investments for roofs. We see potential for the full set of data to help with not only resilience investments but also other Army decisions affected by natural hazards and climate change.

It would be useful to make installation data about past and on-going damage from natural hazards more accessible for future data analytics. Many natural hazards are projected to worsen due to climate change and being able to understand and assess the implications of these natural hazard projections could potentially help in a range of decisionmaking.¹²¹ For example, the Army could conduct analyses of ROI of installation resilience investment decisions for buildings and other facilities (e.g., energy and water infrastructure), which can inform BOS decisions; inform installation master planning decisions and the development of ICRPs; and inform decisions needed for achieving the goals in the *United States Army Climate Strategy* (ACS) and the Army Installations Strategy” (AIS). The ACS directs the Army to “Enhance resilience and sustainability by adapting infrastructure and natural environments to climate change risks...”¹²² The AIS envisions a future with installations employing a Common Operating Picture to guide decisionmaking and resource allocation.¹²³ Understanding local natural hazard threats and the most impactful resilience projects will provide key insights to this capability. Finally, these data could help provide information about which installations are less and more vulnerable to different types of natural hazard disaster to inform future stationing and design decisions.

However, it is difficult to use the installation natural hazards cost and damage data because of data gaps, quality concerns, and accessibility. Because of missing data there is an incomplete picture of the costs from natural hazards at Army installations. As a result, our SRM building costs are a lower bound on IMCOM sustainment storm damage costs and our MILCON costs are a lower bound on the MILCON costs from past natural hazards at Army installations. Thus, it is difficult for the Army to assess the information needed to make appropriate ROI resilience investments. In the last chapter, we provide some recommendations for how the Army can address these issues to improve the data systems and make these data more accessible and useful for installation resilience decisionmaking for the Total Army.

¹²¹ For more details see Chapter 2 and Appendix A.

¹²² Line of Effort 1: Installations Strategic Outcome. Department of the Army, Office of the Assistant Secretary of the Army for Installations, Energy and Environment, *United States Army Climate Strategy*, February 2022, p. 6.

¹²³ U.S. Army, *Army Installations Strategy*, December 2020, p. 2.

The Army may want to consider developing tools using some of our analysis and data processing methods to make future data more accessible for installation analytics. For instance, we developed some informal computer codes and other methods to check data quality and combine multiple IMCOM Storm Damage Reports into a central storm damage dataset. Our results could also potentially be incorporated into existing analytical tools, like Facility Investment Analytics (FIA). FIA was created by the USACE ERDC CERL to help decisionmakers understand infrastructure related risk through identification, analysis, and prioritization.¹²⁴ It is an analytical tool to support AMC's development of the Facility Investment Plan (FIP) for R&M and MILCON funding allocations.

¹²⁴ For more information on FIA see David Savatgy, Jack Dempsey, Carrie Heishman, Jeffrey Freemyer, Marc Vandever, and Doug Hammer, "Facility Investment Analytics Roadmap," preliminary draft, April 13, 2022; U.S. Army, "Facility Investment Analytics (FIA) Framework Prototype Functional Design Document," April 2022; and Jack Dempsey, Carrie Heishman, Jeff Freemyer, "Facility Investment Analytics (FIA) System Overview," April 2022.

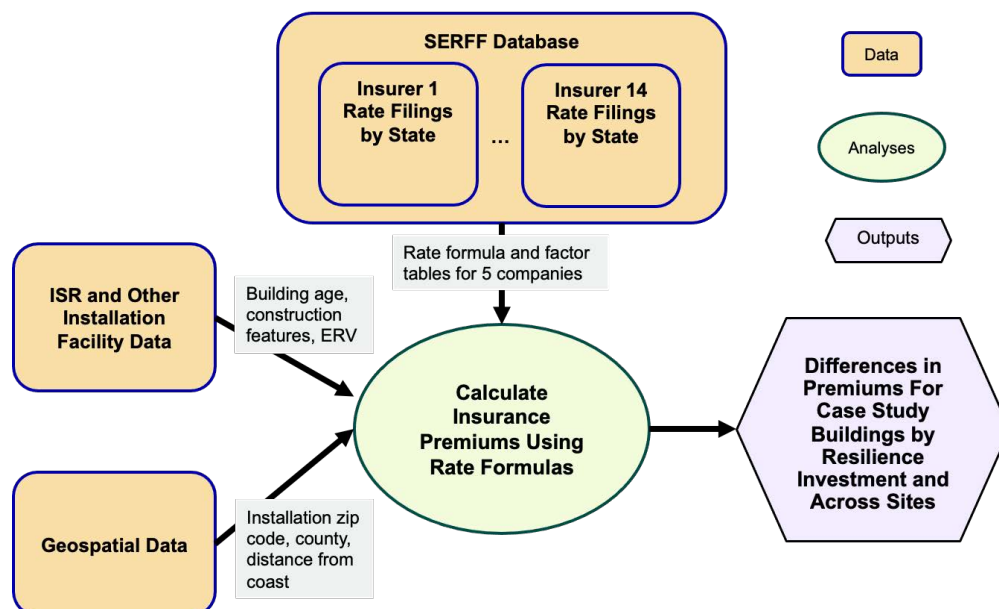
Chapter 4. Commercial Property Insurance Valuations of Resilience Investments

In this chapter, we analyze commercial property insurance premiums to provide information on the value of resilience investments to mitigate windstorm/tornado, hail, and hurricane risks. Although the Army does not purchase commercial property insurance for military installations, we examine differences in these premiums as proxy measures for the value of resilience investments. We begin with an overview of our approach, including a brief introduction to commercial property insurance, the calculation of insurance premiums based on insurance rate formulas, the translation of differences in premiums to valuations, and the interpretation and limitations of these values. We then discuss our primary data source for commercial property insurance rates. Our analysis follows, beginning with a report of the commercial property insurance information we obtain and then describing our case study facilities in terms of the inputs to rate formulas. We then present our results for each case study, showing how premiums vary across buildings and sites and by characteristics of interest. We close this chapter with a concise summary of key findings and a set of implications for the Army.

Approach

Figure 4.1 summarizes our overall approach to analyzing calculated commercial property insurance premiums at the case study sites to generate resilience investment valuations. Proceeding from left to right, we parameterize the characteristics of the sites and buildings identified in our case study analysis for insurance rate calculations by using geospatial data and installation and facility data from ISR and other sources. We obtain insurance rate formulas and factor values for select insurers from the NAIC's SERFF database. We apply these formulas to our case study facilities across the installations and calculate their baseline insurance premiums, drawing from the characteristics summarized in Table 3.8. We then calculate differences in premiums for these buildings as a function of resilience investments and consider implications for the Army resilience investment process.

Figure 4.1. Summary of Commercial Property Insurance Premium Analysis



Insurance Rate Formulas and Premium Calculations

For this study, we are interested in the value of resilience investments as reflected in changes in premiums for commercial property insurance (including windstorm cover) and flood insurance. Although this chapter focuses on commercial property insurance, premiums for both property insurance and flood insurance are calculated in a similar fashion. In brief, premiums are determined by insurance “rates,” which specify the price to be paid for the policy as a multiple of the total insured value (TIV) of the property: they are typically expressed in dollars per \$100.¹²⁵ In turn, insurance rates are determined by rate formulas, which themselves are a function of “rating factors.” A rating factor is an individual characteristic of the insured property connected to its risk of loss per unit of value. Generally, when a given characteristic of a property is associated with relatively lower expected claims as compared to some baseline, it maps to relatively lower factor values, which in turn imply lower premiums.

Mathematically, insurance rate formulas may take any form allowed by state regulators and useful to insurance companies. In practice, these formulas tend to be multiplicative in rating factors within a given category of risk and additive across categories when a policy covers multiple risk categories. To develop the rate within a category, insurance companies typically begin with a rate for the region and multiply it with factors related to the building’s characteristics that are viewed as driving the risk of loss. The exact characteristics and rate values used vary from company to company and state to state.

¹²⁵ See International Risk Management Institute (IRMI), “Glossary: Insurance Risk Management Terms,” 2022.

As a simple example, consider a rate determined by three factors: A “location factor” (f_1) that captures the component of risk of losses based on its zip code, a “base rate” factor (f_2) that reflects the risk associated with the building’s occupancy or industry type, and a “construction factor” (f_3) that tracks the contribution of the building’s construction to its risk of losses. Under a typical formulation, the property insurance rate for this building would be: $f_1 \cdot f_2 \cdot f_3$. Different rates are developed for distinct categories of risk, which typically group together related causes of damage. To obtain the premium for a policy, the rates are usually added across these categories and then multiplied by the TIV.

Commercial property insurance often breaks the risk of loss into two broad categories: Group I and Group II risk,¹²⁶ as shown in Table 4.1.

Table 4.1. Typical Risk Categories for Commercial Property Insurance

Group I	Group II
Fire	Windstorm or Hail, including Tropical Storms and Hurricanes unless excluded
Lightning	Smoke
Explosion	Aircraft or Vehicles
Vandalism	Riot and Civil Commotion
Sprinkler Leakage	Sinkhole Collapse
	Volcanic Action

A typical property insurance rate formula therefore develops a rate for Group I risks and a rate for Group II risks, adds these together to get a total base premium rate, and then adds any legally permissible adjustments for costs, profit margin, or taxes to get a final rate.¹²⁷ A similar procedure applies when the windstorm or hurricane coverage from other Group II risk is offered as an add-on to the policy: a separate rate is calculated for this coverage and then added to the rates for the other risks covered by the policy. In all cases, the final total rate is multiplied by TIV to obtain the policy premium.

Valuing Resilience Investments Via Insurance Premiums: Methods and Limitations

The main hypothesis of this study is that there exist commercial property insurance rates or flood insurance rates that incorporate building-specific factors related to resilience investments to account for the reduction in expected claims that these investments are believed to yield. To

¹²⁶ See, e.g., Terry Krueger, “The Basics on the Basic Causes of Loss,” Washington Survey and Rating Bureau, January 16, 2018.

¹²⁷ To the greatest extent possible, our analysis focuses only on rates for risk categories relevant to windstorm damage, and we remove or equalize any components of rates that adjust for costs (e.g., deductible factors), profit margin, or taxes.

examine this hypothesis for commercial property insurance, we gathered data on commercial property insurance rates for analysis. In accordance with state laws governing insurance carriers, changes to commercial property insurance rate formulas (including catastrophic windstorm covers) are filed for review and approval by state insurance commissioners. We identified recent program changes by major commercial property insurers in these filings that provide full rate formula information and illustrate how they can be used to inform resilience investment value. Because of the more peculiar and customized nature of private flood insurance, similar filings on commercial flood insurance are not available: we turn to flood insurance in the next chapter.

In our analysis, the values we generated for comparisons are simple premium differences calculated for a building with and without a given resilience investment. Described mathematically, for a given set of risks, we have:

$$(1) P = TIV * \prod_c f_c,$$

where P is the premium, TIV is the total insured value, and $\prod_c f_c$ is the product of multiplicative rate factors f_c indexed over characteristics c . On an annual basis, the savings from a given resilience investment is the change in premium arising from the fact that one factor, f_i , is reduced from a baseline value b to a resilience value r . Expressed in variables, the premium savings is then:

$$\Delta P = TIV * *.$$

If a resilience investment were in place for only a single year, this difference would reflect its value in terms of premium savings. For resilience investments that have a longer service life, premium savings accrue each year. Assuming the insurance formula and factor tables remain constant, we can calculate the present value of these differences over time to show how they depend on the remaining life of the investment where they are incorporated.¹²⁸ Because some insurance rate formulas incorporate factors for building age, this procedure involves an additional step relative to traditional discounting. Let $f_a = a_t$ represent the buildings age factor at any age t . The savings S associated with the resilience investment can then be written as:

$$(3) S = TIV * \prod_{c \neq i, a} f_c * (b - r) * \sum_{t=0}^T \frac{a_t}{(1+r)^t},$$

where T is the expected service life of the resilience investment in years. When age factors are not applied, this formula simplifies to a discounted sum of the premium differences: if $a_t = 1$ for all t , then

¹²⁸ For the purposes of creating illustrative calculations, we select a discount rate of 3 percent per year.

$$(4) S = \sum_{t=0}^T \frac{\Delta P}{(1+r)^t}.$$

The values that this approach produces should be interpreted with care: they should be viewed as lower bounds that do not represent the full benefits of a resilience investment. To the extent that underwriting is “actuarially fair,” meaning that insurance rates precisely reflect risk, the values represent an insurer’s expected reduction in annual claims when the resilience investment is present.¹²⁹ The presence of economic “frictions” in the insurance market (e.g., market power, asymmetric information, and moral hazard) would tend to increase premiums and dampen their responsiveness to risk reductions. Further, the values we generate do not reflect the reduction of risks not covered by the policy, reduction of damages that are less than the policy deductible, or the reduction of damages in excess of the insured value. The values also exclude more general benefits of such investments that may be present, like improved energy efficiency or aesthetics. Finally, our estimates are based on recent rating formula and factors whose values are likely to evolve over time, particularly as climate change unfolds.¹³⁰ We therefore suggest that values of the kind that we calculate be used to provide insight into the relative benefits of resilience investments as features that mitigate damage from the covered natural hazards. Specifically, resilience investments with higher values than others should be understood as conferring a greater degree of protection to the building.

SERFF Database Search Methodology

Our primary data source for information on commercial property insurance rates is the NAIC’s System for Electronic Rate and Form Filing (SERFF).¹³¹ SERFF is a web-based tool used by 47 states that enables insurers to publish policy forms and rate filings in a standardized setting.¹³² A large subset of insurance companies, representing 90.9 percent of premiums written, are required to submit such filings to state regulators.¹³³ We provide further details on these data set in Appendix D. Filing requirements for companies vary by state, but in general rate filings modify existing programs and do not provide full information on insurance programs.¹³⁴ Nonetheless, insurers sometimes do update their programs on a broad basis to incorporate new

¹²⁹ In general, the price of an “actuarially fair” annuity is the present value of the payments the annuity purchaser expects to receive over time. With respect to insurance, actuarially fair premiums imply zero excess profits for the insurer.

¹³⁰ See e.g., Steve Evans, “Property Cat Rates Must Rise 50% to Offset Rising Claims Costs, Restore Profitability: EY,” Artemis, December 15, 2022.

¹³¹ National Association of Insurance Commissioners, “SERFF Filing Access,” webpage, 2022.

¹³² Florida, Massachusetts, and Washington maintain their own systems.

¹³³ NAIC, “Surplus Lines,” webpage, May 11, 2022.

¹³⁴ NAIC, “Product Filing Review Handbook,” August 2016.

experience or respond to changes in law or regulation.¹³⁵ For this study, we are interested in these more sporadic, less common filings that provide relatively complete descriptions of insurance rate formulas and rating factor values.

Searches in SERFF take the following input: state, insurance type, company name, and date limits. To focus on relatively current information, we confined our searches to commercial property insurance filings from 2010 forward. Because the case studies for this project require commercial property insurance rate information, we searched for insurance rate filings across states based on locations of interest identified in our analyses in Chapters Two and Three. To provide a minimally reasonable set of comparisons in our case studies, we sought at least three rate formula descriptions per state. Our search began narrowly and expanded: over the course of this process, we searched for filings in 13 states. Ultimately, we found sufficient filings for comparative analysis of premiums for our case study buildings in seven states: California, Colorado, Georgia, Kansas, New Jersey, Oklahoma, and Virginia. Other states searched included: Florida, Louisiana, New York, North Carolina, Texas, and Washington.¹³⁶

To select appropriate insurers to include in our studies, we began by identifying five carriers who appear to have a large share of the commercial property insurance market.¹³⁷ When initial searches returned relatively few filings for analysis, we expanded our search set by examining online reviews of commercial property insurers and via consultation with subject matter experts internal and external to RAND. We required carriers to have rate filings available for at least two states in our study to ensure that we could compare their approach across sites. Over the course of our iterative process, we began with a small set of three insurers and expanded in states where relevant filings are available. Table 4.2 reports the company names of all 14 insurance carriers searched throughout the course of our process, whether we found rate filings for them or not. We anonymize content with respect to carriers for the remainder of this report.

¹³⁵ NAIC, 2016.

¹³⁶ For filings in the state of Florida, see Office of Insurance Regulation, “IRFS Forms & Rates Filing Search,” webpage, undated; for filings in the state of Washington, see Washington State Office of the Insurance Commissioner, “Rates and Forms Filing Search,” webpage, undated.

¹³⁷ While the NAIC does not provides information on total premium written for most major lines of insurance, the relevant statistics for commercial property insurance are not separately available. We instead rely on combined measures of commercial property and casualty premium underwritten: see for example NAIC, “NAIC Releases 2021 Market Share Data,” webpage, March 1, 2022.

Table 4.2. Insurance Carriers Included in SERFF Rate Filing Searches

The Allstate Corporation	Hiscox Ltd.
American International Group	Liberty Mutual Group
Berkshire Hathaway	Nationwide Mutual Insurance Company
Chubb Limited	State Farm Insurance
CNA Financial Corporation	Tokio Marine Holdings, Inc.
Farmers Insurance Group	The Travelers Companies, Inc
The Hartford Financial Services Group	Zurich

SOURCE: RAND generated based on expert judgements including discussions with two insurance industry experts.

Calculating Commercial Property Insurance Premiums

We begin this section by reporting on the insurance data we found and used to calculate premiums for the case study buildings. We report on the carriers whose policies we searched, the specific types of coverage analyzed, and the factors and formulas used.

Sparseness of Data and Processing Required

From the list of companies in Table 4.2, we found five insurance carriers with sufficient information (i.e., commercial property insurance formula and factor tables) for our analysis in multiple states of interest. The documents processed range in size, with most of them numbering in the hundreds of pages. We sifted through over 5,000 filings to find examples of sufficiently complete rate filing, and less than 2 percent had useful information. As such, we stress that the insurance policies we identified and analyzed are not intended to be in any way comprehensive or statistically representative: they provide examples for insurance premium calculations that we use to illustrate how resilience investment values may be generated.

Availability and Coverages for the Five Case Study Commercial Property Insurers

Table 4.3 reports the insurance carriers we found with sufficient rate filings available by case study states. We connect these with our case study installations for completeness. Per our search methodology, we required each site to have at least two different insurance carriers with complete rate filings available. For each site in our study, we have at least three rate filings for comparison. Insurance carriers A, B, and E had filings available for all sites while C and D each only had data available for two states included in this analysis.

Table 4.3. Insurance Companies with Complete Rate Filings Available by Case Study Installation

Installation/Insurance Carrier	A	B	C	D	E
Colorado: Fort Carson	X	X	X		X
Georgia: Fort Moore, Fort Stewart	X	X	X	X	X
Oklahoma: Fort Sill	X	X			X
Virginia: Fort Belvoir	X	X		X	X

The insurance rates and premiums we develop based on the available filings vary to some extent in the risks covered by the policies they represent and are therefore not wholly comparable. Specifically, for the insurance rate formulas we analyze, separating Group II risk from Group I risk is not always feasible. As we report in Table 4.4, rates for insurance carriers A and B can be developed strictly in terms of Group II and catastrophic wind coverage. Rates for insurance carriers C and E both contain Group I risks, and we did not find catastrophic wind rate information for insurance carrier E. The rate analyzed for carrier D corresponds roughly to the rates offered by A and B, but the cover excludes some of the less common Group II causes of damage, namely: smoke, aircraft or vehicles, riot and civil commotion, or sinkhole collapse.

Table 4.4. Coverage Type Analyzed by Insurance Company

Insurance Company	Group II Risk Only, with Catastrophic Wind Included	Group I and Group II Risk, Catastrophic Wind Included	Group I and Group II Risk, Catastrophic Wind Excluded	Weather*
A	X			
B	X			
C		X**		
D				X
E			X	

NOTES: *Insurance carrier D offers “Weather” coverage, which responds to property damage from windstorm, hail, freezing, tornado, hurricane, and volcanic action. This element of their coverage excludes other risks, including flood, tsunamis, or earthquakes.

**The premium component for windstorm cover for carrier C responds specifically to named storms (i.e., tropical storms or hurricanes).

Insurance Rate Factors Used by the Five Insurance Companies

Each insurance rate formula we analyzed depends on a set of factors that varies across companies. To facilitate comparison of factors across carriers, we developed generic descriptive labels for the factors we observed and applied them to the specific terms used by carriers in their filings. Although this process required some judgment, the available definitions of factors in the rate filings made this analysis relatively straightforward. We report factors that reflect the impact of location characteristics and building characteristics on premiums: rate formulas also

incorporate factors specific to policy terms or carrier business characteristics, but these idiosyncratic considerations do not inform our analysis.¹³⁸

Location characteristics reflected in insurance rate factors are reported in Table 4.5. For the most part, the rate formulas we review rely on a single factor to represent location-based risk, typically specified at the county or zip code level. Some of the insurance carriers use other factors to modify premiums for the presence of adjacent exposures (buildings or structures) and their attachments, locational hurricane risk, and fire response rating time. Of the formulas reviewed, only insurer D incorporates more than three locational factors into their rates, although Insurer C does include more such factors in their hurricane and tropical storm rate, discussed further below.

Table 4.5. Rate Factors Reflecting Location Characteristics by Insurance Company

Factor	A	B	C	D	E
Adjacent exposures				X	
Attachment on adjacent exposures				X	
Distance from intracoastal waterway				X	
Distance inland				X	
Locational base risk	X	X	X	X	X
Locational hurricane modifier	X		X		
Locational quality (rating of fire department response time)			X		

NOTE: In the rate formulas analyzed, the structure of the formulas did not vary within insurer across states. However, factor values can and often do vary from state to state.

Table 4.6 reports the rate factors connected to building characteristics in the filings we analyze. The most consistent characteristic accounted for in commercial property insurance rate factors is building construction. Other factors considered include building age, height, and use/risk class—a factor that attempts to account for the typical occupancy and characteristics of buildings used for different purposes. Two of the rate formulas analyzed include factors for total insured value: while all premiums are determined as product of TIV and the premium rate, these factors adjust the premium rate itself for the level of value insured.

¹³⁸ Policy terms factors can include policy deductible level, policyholder loss history, or level of wind sublimit. Insurance carrier business factors can include commission rate, state taxes, commission, expense load, engineering expenses, general expenses, regional reinsurance load, regional risk load, or underwriting profit.

Table 4.6. Building Characteristics Rate Factors for Group II Risks by Insurance Carrier

Factor	A	B	C	D	E
Building age	X*	X		X**	
Building construction: ISO class or wind resistiveness rating	X*	X	X	X	X
Building elevation characteristics				X	
Building height			X		
Building use/risk class	X*	X	X		
Construction-specific modifiers of weather risk (multiple)			X	X	
Total insured value	X	X			

NOTES: *Insurer A uses base factors for buildings that are a joint function of building age, building construction, and building use.

**Insurer D allows underwriters to account for building age on a discretionary basis as part of a Construction Exposure Modification Factor: it is not required in rate development.

For reference, Table 4.7 provides a short description of the ISO construction type definitions. In our case studies, we focus on ISO Class 3 and Class 4 buildings. These building classes were identified by Army subject matter experts as most typical of construction on Army installations.

Table 4.7. Insurance Standards Office Building Construction Types

ISO Class	Class Name	Short Description
1	Frame	Exterior walls are wood or other combustible materials including construction where combustible materials are combined with other materials such as brick veneer, stone veneer, wood iron-clad, stucco on wood
2	Joisted Masonry	Exterior walls are constructed of masonry materials such as adobe, brick, concrete, gypsum block, hollow concrete block, stone, tile or similar materials and where the floors and roof are combustible
3	Non-Combustible	Exterior walls and the floors and roof are constructed of, and supported by metal, asbestos, gypsum or other noncombustible materials
4	Masonry Non-Combustible	Exterior walls are constructed of masonry materials, such as concrete block or other fire-resistive materials with at least one-hour rating, with floors and a roof of metal construction or other non-combustible materials
5	Modified or Semi Fire Resistive	Exterior walls and the floors and roof are constructed of masonry or fire resistive material with a fire resistance rating of one hour or more but less than two hours
6	Fire Resistive	Exterior walls and the floors and roof are constructed of masonry or fire resistive materials having a fire resistance rating of not less than two hours.

Examining Factors Related to Resilience Investments

Insurance companies C and D further incorporate a set of building factors reported related to weather risk. We identified some of these characteristics as “potential resilience investment measures.” For commercial property insurance, we view potential resilience investments as

features that are relatively easier to change after the completion of a building's construction. Other building characteristics might also be changeable, but they are typically determined at the time of construction and are relatively more difficult or expensive to change over time than those we term potential resilience investments. Most of the construction-specific factors that insurers C and D recognize mitigate the impact of windstorms/tornados or hurricanes. With respect to resilience investment measures, these factors reduce premiums for better roof maintenance, roof anchorage, window and door protection measures, and the like. Similarly, the other building characteristic factors generally reward construction that is more wind-resistive and less likely to have various pieces of the surroundings or architecture become a damaging projectile in a high wind event. While flood cover is excluded, some attention is nonetheless given to flood vulnerabilities by insurer C. Finally, we note that, consistent with the coverage their policy provides, insurer D offers rate reductions for improved insulation and freezing protection.¹³⁹

Factor values and rate formula information connected to potential resilience investment are only available for insurer D. Our analysis focuses on a subset of these factors to illustrate how they can be valued. In particular, we examined factors for shutter protection, condition of exterior caulking/sealing, fitted storm shutters and hurricane strap for the shutters, metal roll down curtain doors, insulation/freezing protection, and roof anchorage.

Rate Formulas Used by the Five Insurance Companies

In Table 4.8, we provide concise descriptions of the formulas we analyzed by carrier. In line with the discussion of premium calculations at the beginning of this chapter, each of the formulas are additive in risks and multiplicative in factors except for the rate for insurer D. In the formula for their weather rate, the base rate incorporates all the location characteristics multiplicatively in their “Weather Zone” component, and the construction factors—including factors for resilience investments—entered as a second component additively. This feature of insurer D’s formula implies that, for a given location and construction base factor, c^{Base} , the value of resilience investments scales with the insured value of the property.¹⁴⁰

Before moving to our analysis of the case studies, we note that Table 4.8 mathematically emphasizes that the rates we analyzed map to slightly different risks. The premiums are therefore not intercomparable across insurers. For this reason, in the analysis that follows, we generally compare premiums within an insurer, holding the coverage constant as we vary building and location characteristics. Our analysis gives a sense of the directionality of different factors and coverage-grounded frame of reference for understanding the magnitude of impacts.

¹³⁹ Sudden and accidental water damage is not typically covered as a basic (i.e., Group I or Group II) risk, but it can be covered under more extensive policies written on the broad or special form. For more information see, e.g., BreAnn Stephenson, “Is it Covered? Burst Pipes,” National Real Estate Insurance, January 2, 2018.

¹⁴⁰ In this formula, the factor c^{Base} depends on the building’s wind-resistiveness, which in turn depends on its ISO construction type: see Table 4.7 for details on ISO types.

Table 4.8. Rate Formulas Analyzed for Case Studies
Annual Premium = TIV * Rate

Insurance Carrier	Rate Calculated	Formula
A	Group II Rate + Hurricane Rate	$\prod f_i^{Group II} + \prod f_j^{Hurricane}$
B	Group II Rate (Windstorm/Hurricane Included)	$\prod f_i^{Group II}$
C	(Group I and Group II Rate) + Hurricane Rate	$\prod f_i^{Group I and II} + \prod f_j^{Hurricane}$
D	Weather Rate*	$\prod f_i^{Weather Zone} * (c^{Base} + \sum f_j^{Constr.})$
E	Group I and Group II Rate	$\prod f_i^{Group I and II}$

NOTE: *The contribution of construction-specific factors to this rate is bounded such that $-0.25 \leq \sum f_j^{Constr.} \leq 0.25$.

Case Study Analysis

We now turn to our premium calculations and analysis of resilience investment measure values. Because we found more useful rate filings in Georgia than in any other state, we present full results for Fort Stewart (the base case) first and offer a cross-site comparison with Fort Moore, which is further inland. One insurance rate formula that we analyzed had a structure that incorporates more detailed factors connected to resilience investments. We investigated these rates in detail for Fort Stewart, showing the premium based valuations of different investments and comparing between them. We close with a cross-site comparison of premiums, examining the impact of location for otherwise identical buildings.

Analysis of the Base Case: Fort Stewart Premiums and Savings Calculations

Table 4.9 reports the annual baseline premiums for our case study buildings at Fort Stewart, using the ISO 3 construction type. We compare these to the annual premiums for ISO 4 buildings, holding all other factors constant and report the relative percentage premium reduction offered for the ISO 4 construction type. For the formula analyzed, annual premiums are on the order of \$10,000s for most ISO 3 buildings and insurers. The coverage from insurer A appears to be the most expensive for the Barracks and Office Building, and it changes precipitously between ISO 3 and ISO 4 building types. Excluding insurer A as an outlier, ISO 4 premiums are between 13–24 percent lower in comparison to ISO 3 buildings. Moreover, the pattern of reduction in premium across each of the building types is identical for insurers B–E. Upon inspection, the building characteristics selected for the case studies do not drive premium differences between the base cases for the rates analyzed. The differences are determined by location characteristics, ISO type, and engineering replacement value (ERV) only. For the remainder of this analysis, we therefore focus on the maintenance building without loss of generality.

Table 4.9. Baseline Insurance Annual Premiums for Case Study Buildings at Fort Stewart by Construction Type

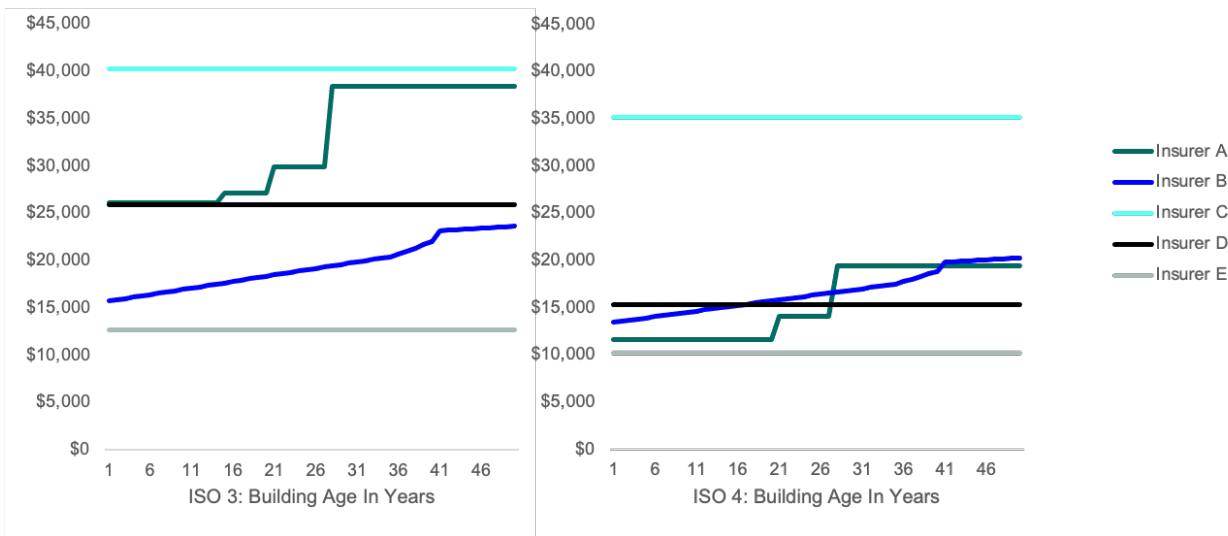
	Insurer	ISO 3	ISO 4	% Reduction
Barracks	A	\$40,127	\$14,539	64%
	B	\$17,333	\$14,857	14%
	C	\$37,064	\$32,392	13%
	D	\$25,843	\$19,641	24%
	E	\$11,076	\$8,937	19%
Office Building	A	\$15,462	\$5,906	62%
	B	\$7,379	\$6,325	14%
	C	\$13,111	\$11,434	13%
	D	\$9,304	\$7,071	24%
	E	\$3,988	\$3,218	19%
Maintenance Building	A	\$38,353	\$18,690	51%
	B	\$21,961	\$18,824	14%
	C	\$40,220	\$34,945	13%
	D	\$29,413	\$22,354	24%
	E	\$12,607	\$10,172	19%

NOTE: For the Barracks, Office, and Maintenance buildings, ERV's are \$16.28 million, \$5.86 million, and \$18.53 million, respectively.

Figure 4.2 illustrates the impact of building age on the maintenance building insurance premiums for ISO 3 and ISO 4. Two insurers, A and B, increase their rates as the insured building ages. We note this factor because it has an impact on the value of investments in a building over time as shown in equation (3). While discounting reduces future savings on premiums over time, higher factors for age lead to higher premiums in later years, increasing values associated with investments.

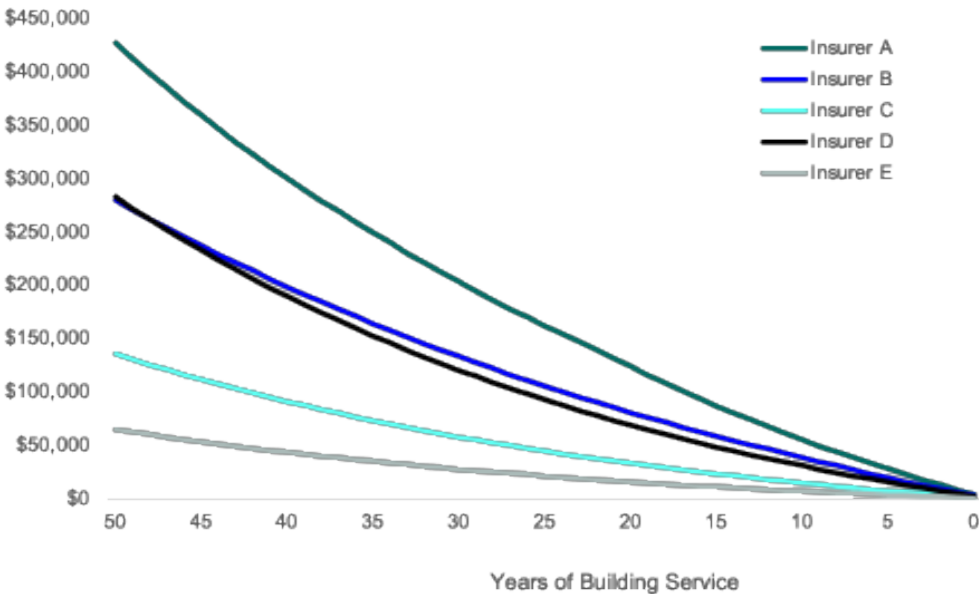
To illustrate the value of a resilience investment decision, we calculated the premium savings of ISO 4 construction relative to ISO 3 construction for the Fort Stewart maintenance building. The total savings depends on how many years the building remains in service: all else equal, buildings that stay in service longer have more years to accrue savings. In Figure 4.3, we plotted the present value of total savings as a function of the number of years that the building is in service assuming a discount rate of 3 percent. Based on the rate formulas we analyzed, the present value of premium savings ranges between \$65,000 and \$427,000 for a building expected to last 50 years. Scaling for the maintenance building value, these results are equivalent to \$3,000 to \$23,000 per \$1 million total insured value (TIV).

Figure 4.2. Fort Stewart Maintenance Building Annual Premiums as a Function of Building Age



NOTE: This figure traces out the effects of building age for the maintenance building case by ISO construction type. For reference, this building is taken to be 39 years old in later calculations.

Figure 4.3. Present Value of Premium Savings for ISO 4 vs. ISO 3 Construction by Years of Service, Fort Stewart Maintenance Building



Premium Differences by Location

We next examined how location can affect premiums with the idea that an analysis at this level might inform construction choices or prioritization of resilience investments across locations. We begin with a comparison of Fort Stewart to Fort Moore in Table 4.10. These two

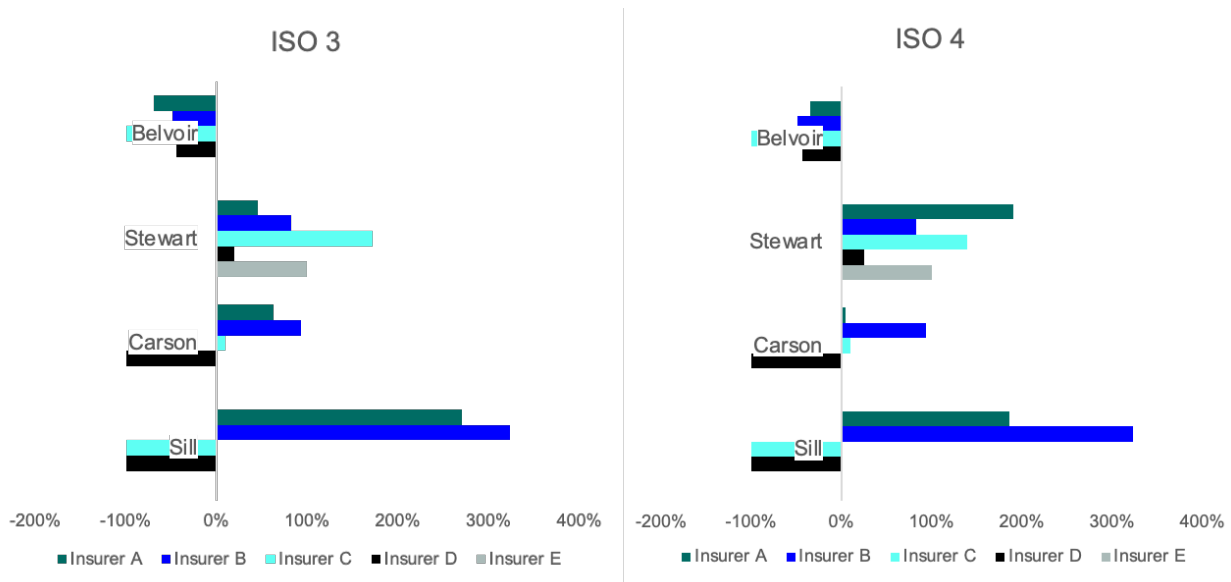
installations are both in Georgia, with Fort Stewart nearer to the coast in Savannah and Fort Moore further inland, near Columbus. Among other differences between the sites, Fort Moore faces less risk of damage from hurricanes because it is further inland. Premiums are consistently lower at Fort Moore, with differences between the two locations ranging between 16–63 percent for an ISO 3 building and 20–66 percent for an ISO 4 building.

Table 4.10. Maintenance Building Annual Premiums at Fort Stewart and Fort Moore

	Insurer	Fort Stewart	Fort Moore	Percent Difference
ISO 3	A	\$38,353	\$26,350	31%
	B	\$21,961	\$12,043	45%
	C	\$40,220	\$14,812	63%
	D	\$29,413	\$24,661	16%
	E	\$12,607	\$6,303	50%
ISO 4	A	\$18,690	\$6,448	66%
	B	\$18,824	\$10,323	45%
	C	\$34,945	\$14,619	58%
	D	\$22,354	\$17,935	20%
	E	\$10,172	\$5,086	50%

In Figure 4.4, we broaden our comparison to include all case study sites. For each insurer and site, we used the premium values for the maintenance building at Fort Moore as a basis of comparison. We report the percentage difference from Fort Moore annual premium values. In this graph, 0 percent indicates no difference, while 100 percent would indicate a doubling of premium: we therefore note in the title that “Fort Moore = 0.” The results reveal some directional agreement: relative to Fort Moore, the rates analyzed are consistently lower for Fort Belvoir and consistently higher for Fort Stewart. Premiums may be higher or lower at Fort Carson and Fort Sill, depending on the insurer.

Figure 4.4. Relative Percentage Difference in Maintenance Building Annual Premium Across Case Study Installations (Fort Moore = 0)



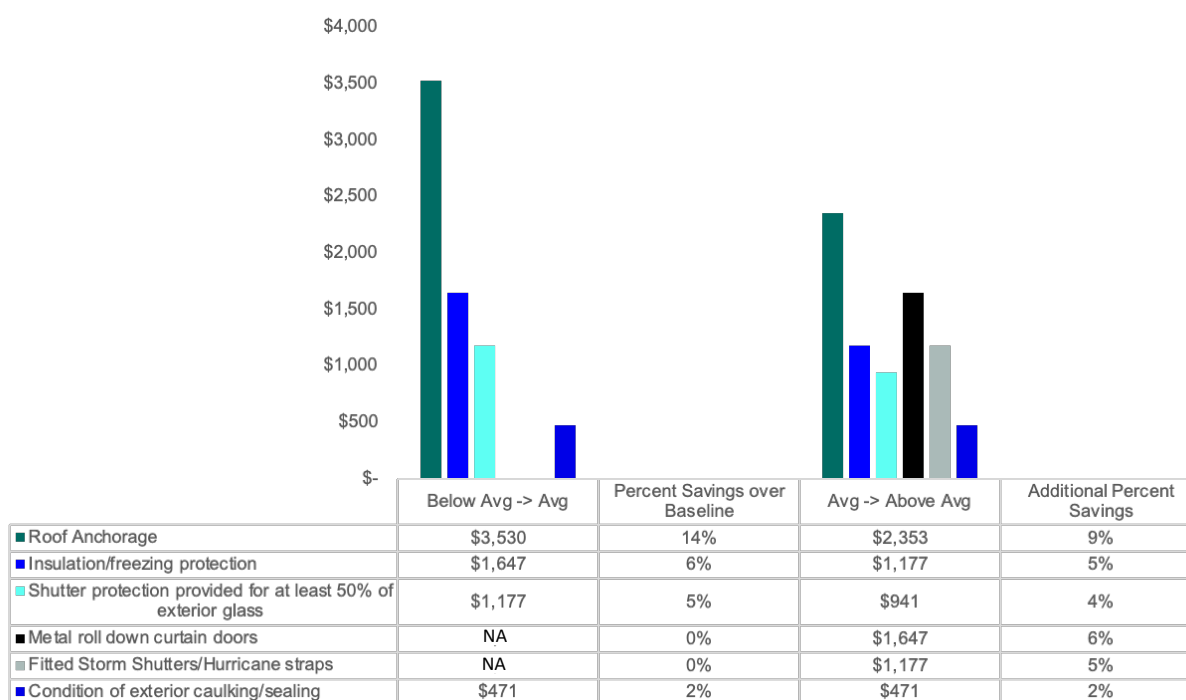
Note: percentage change for insurer E is 0 at Fort Belvoir, Fort Carson and Fort Sill

Premium Differences for Specific Resilience Investments

The data we gathered allow premium calculations as a function of resilience investments for Insurer D. To make these calculations, we vary one specific resilience investment factor at a time from the base case (ISO 3) maintenance building. Insurer D rates resilience investments in terms of “below average,” “average,” and “above average” condition, although the material we obtained about this company’s rates did not provide a specific definitions for these terms. In Figure 4.5, we report the impacts of resilience investments by looking at how the premium changes as their condition improves from below average to average, and from average to above average.

For the illustrative resilience investment measure examined for company D, these results show that this insurer places the highest value on roof anchorage: premium declines by 14 percent as anchorage improves from below average to average condition, and it declines by a further 9 percent if upgraded to an above average condition for a total of 23 percent. This amount is comparable to the premium reduction this insurer offers for ISO 4 over ISO 3 construction for this building (24 percent). More generally, at least some of the factors that this insurer uses are consistent with diminishing marginal returns to resilience investments: where possible to compare, savings are greater for moving from a below average condition to an average condition than they are for moving from an average to above average condition. Last, we note that the rate formula limits the total impact that a combination of resilience investments can have on annual premiums to 25 percent of the value, or \$7,353 in this example.

Figure 4.5. Annual Premium Savings for Specific Resilience Investment Measures for the Fort Stewart Maintenance Building Case Study (ISO 3)



NOTE: In fitted storm shutters/hurricane straps, the hurricane straps are for the shutters.

In Table 4.11, we report the present value of premium savings for these investments as a function of their years of service, assuming a discount rate of 3 percent.¹⁴¹ We total the value associated with each investment, representing the savings available for moving from a below average to an above average condition. To provide a set of scaled values, we divide these totals by the maintenance building's value (\$18.53 million). The results show that roof anchorage lasting 50 years would be valued at \$151,350 per \$1million of TIV by this method. As noted previously, resilience investments have greater value as their service life increases with diminishing returns due to discount.

¹⁴¹ Insurer D does not use factors for age: these are discounted value sums as shown in equation (4).

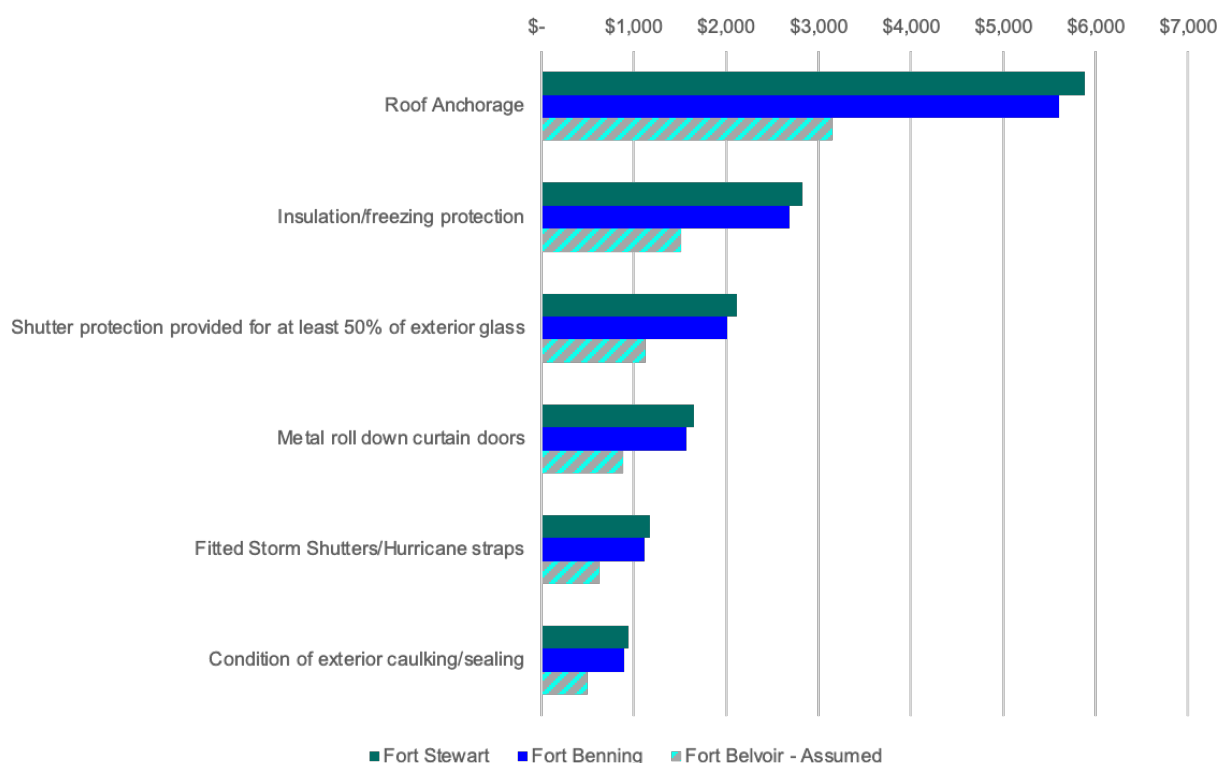
Table 4.11. Present Value of Premium Savings for Specific Resilience Investments by Years of Service, Fort Stewart Maintenance Building

	Years	Below Avg -> Avg	Avg -> Above Avg	Total	Value/(\$1M TIV)
Roof Anchorage	50	\$90,816	\$60,544	\$151,360	\$8,169
	40	\$81,586	\$54,391	\$135,977	\$7,339
	30	\$69,182	\$46,121	\$115,303	\$6,223
	20	\$52,512	\$35,008	\$87,520	\$4,724
	10	\$30,108	\$20,072	\$50,181	\$2,708
	1	\$3,427	\$2,285	\$5,711	\$308
Insulation/freezing protection	50	\$42,381	\$30,272	\$72,653	\$3,921
	40	\$38,074	\$27,195	\$65,269	\$3,523
	30	\$32,285	\$23,061	\$55,346	\$2,987
	20	\$24,506	\$17,504	\$42,009	\$2,267
	10	\$14,051	\$10,036	\$24,087	\$1,300
	1	\$1,599	\$1,142	\$2,741	\$148
Shutter protection provided for at least 50% of exterior glass	50	\$30,272	\$24,218	\$54,490	\$2,941
	40	\$27,195	\$21,756	\$48,952	\$2,642
	30	\$23,061	\$18,449	\$41,509	\$2,240
	20	\$17,504	\$14,003	\$31,507	\$1,700
	10	\$10,036	\$8,029	\$18,065	\$975
	1	\$1,142	\$914	\$2,056	\$111
Metal roll down curtain doors	50	\$0	\$42,381	\$42,381	\$2,287
	40	\$0	\$38,074	\$38,074	\$2,055
	30	\$0	\$32,285	\$32,285	\$1,742
	20	\$0	\$24,506	\$24,506	\$1,323
	10	\$0	\$14,051	\$14,051	\$758
	1	\$0	\$1,599	\$1,599	\$86
Fitted Storm Shutters/Hurricane straps	50	\$0	\$30,272	\$30,272	\$1,634
	40	\$0	\$27,195	\$27,195	\$1,468
	30	\$0	\$23,061	\$23,061	\$1,245
	20	\$0	\$17,504	\$17,504	\$945
	10	\$0	\$10,036	\$10,036	\$542
	1	\$0	\$1,142	\$1,142	\$62
Condition of exterior caulking/sealing	50	\$12,109	\$12,109	\$24,218	\$1,307
	40	\$10,878	\$10,878	\$21,756	\$1,174
	30	\$9,224	\$9,224	\$18,449	\$996
	20	\$7,002	\$7,002	\$14,003	\$756
	10	\$4,014	\$4,014	\$8,029	\$433
	1	\$457	\$457	\$914	\$49

NOTES: In fitted storm shutters/hurricane straps, the hurricane straps are for the shutters. The condition of the Maintenance Building with respect to these factors is unknown, and the criteria for Below Average, Average, and Above Average condition are not well-described by the rate formula document.

Finally, we compare the value of the illustrative resilience investments across sites in Figure 4.6, totaling the rate differences as the condition of the investment moves from below average to above average. We obtained rate formula filings for insurer D in Georgia and Virginia, but the tables for specific resilience investment factors were not available for Virginia. We therefore report results for Fort Stewart and Fort Moore and include calculations for Fort Belvoir under the assumption that the factors remain the same across the sites. The results show that the value of the investments scale across sites: the bars differ by constant percentages. Analysis of insurer D's rate formula in Table 5.8 shows that these percentages are based on the differences in premiums across the sites. Drawing from the results displayed in Figure 5.4, each investment is valued 19 percent more at Fort Stewart and 44 percent less at Fort Belvoir relative to Fort Moore.

Figure 4.6. Annual Premium Savings for Resilience Investments by Installation, Maintenance Building (ISO 3)



NOTE: In fitted storm shutters/hurricane straps, the hurricane straps are for the shutters. This figure was created before Fort Benning was renamed Fort Moore.

Key Insights

Over the course of this exploratory analysis, we found that commercial property insurance rate filings are copious, with relatively few documents relevant to this effort and significant processing required to ingest and analyze premium rates. Our analysis is meant to be illustrative

rather than comprehensive or representative: out of 14 insurers and thousands of documents, we found complete data for five companies. The documents we drew from were voluminous, exceeding hundreds of pages in some cases.

The values our method produced have inherent limitations and should be interpreted as lower bounds that can provide insight into the relative benefits of resilience investments. In short, our method assumes that all the savings generated by adopting a resilience investment are passed on to the policyholder: this assumption probably does not hold since insurance companies strive to make a profit. The values do not reflect any effects of resilience investments on risks outside of the coverage analyzed or other benefits they may have (e.g., aesthetics, energy savings).

In the small illustrative set of insurance rates we analyzed, the formulas most consistently reflect fundamental construction and location-driven elements of risk. Premiums are always a product of total insured value and rate, which implies that resilience investments generate greater savings for higher-valued buildings, all else equal. Based on our method, the value of a resilience investment depends on its service life as it confers premium savings over time. Although some insurers increase premiums as buildings age, older buildings that will soon be taken out of service generally benefit less from resilience investments because they will accrue premium savings for relatively fewer years compared with a newer building.

We found some examples of rate formulas that consider specific resilience investments, but not all carriers give them weight. The factors that we analyze are consistent with diminishing returns for some resilience investments, although we only observe these factors at three levels at most (Below Average, Average, and Above Average). To an extent, diminishing returns are also implied by our approach: as resilience increases and premiums fall, there is less premium to be saved by further investment. While the values we generate are not authoritative, they are indicative of the order of magnitude of premium-based values for resilience investments. For the specific illustrative resilience investment measures that we analyzed in our case studies, roof anchorage was the highest value investment. The presence of roof anchorage reduces premiums by approximately \$6,000 per year, or roughly \$150,000 in present discounted value over a service life of 50 years. This value depends directly on the TIV of the case study building (\$18 million) and scales to approximately \$8,000 per million dollars of building value.

Implications for the Army

Given a commercial property insurance rate formula and factors, our analysis illustrates how to generate values for the benefits of resilience investment for a set of natural hazards (i.e., windstorm or hail, including tropical storms and hurricanes). To use this approach on a wider basis to support Army installation resilience investment decisionmaking across the Army, the Army would need to gather and analyze a more comprehensive set of insurance rate data. The main difficulty we encountered was that assembling the necessary inputs from public sources is time-consuming and requires specialized knowledge and expertise. To create a representative

sample of insurance formulas would multiply this work. Because of the challenges involved in this process, we do not recommend it. If the Army wants to pursue commercial property insurance premium rate data, it may be more efficient to partner with the insurance industry—including carriers or the analytic firms on which they rely—to access the appropriate data rather than to use publicly available filings. This kind of collaborative effort may afford the Army the opportunity to obtain more tailored metrics based on their actual loss history data. In turn, partners in the insurance industry may find the Army’s detailed loss history data attractive for model development.

In addition, by using the findings from our insurance assessments (including the NFIP results discussed in the next chapter) and partnering with the insurance industry, the Army could use this information to start developing a ROI model to inform resilience investment decisions, a task required as part of the “Army Installations Strategy Implementation Plan.” Specifically, “Strategic Objective 2C - Adopt Resilient Systems,” Item 12, Task 2.9 aims to:

Develop a ROI model by the end of FY23 that benchmarks insurance industry examples to enable the Army installation enterprise to price the value of resilience investments, including investments that address climate risks.¹⁴²

It is important to note that our analyses focused on a method to value benefits for resilience investments. We showed how insurance rate and premiums can be used to that purpose with caveats. Specific resilience investment implementation costs were not considered: a full analysis would incorporate the direct, financial costs of these investments and their expected payback period along with an evaluation of whatever other benefits they may provide. These costs will vary by location and other factors. This type of detailed cost assessment was not in the scope of this study. However, the Army should include full life cycle cost and benefit analyses of all relevant resilience investment options and alternatives when using our study results.

¹⁴² U.S. Army, *Army Installations Strategy Implementation Plan: Fiscal Years 2022-2024*, 2022, p. 10.

Chapter 5. Assessing the Value of Flood Resilience Investments for Buildings Using NFIP Premium Calculations

Standard commercial property insurance does not cover flood damage, but commercial property owners have options for obtaining separate flood insurance policies.¹⁴³ While NFIP provides coverage throughout the United States, communities must agree to establish land-use planning and management policies and building codes to control or limit development in floodplains before insurance is available to residents and businesses.¹⁴⁴ In this chapter, we explain our analysis of NFIP-based premiums to provide information on the value of resilience investments to mitigate flood risk. The chapter begins with an explanation of our approach for the NFIP calculations and then explains our analysis process and its results. The chapter ends with a discussion of the implications of this analysis for the Army.

Approach for NFIP Premium Calculations

Historically, NFIP premium calculations included whether a building was located in a 100-year floodplain as a rating criterion. FEMA works with communities to produce Flood Insurance Rate Maps (FIRMs) that identify a community's flood zone, floodplain boundaries, and base flood elevation.¹⁴⁵ Among other purposes, these maps are the basis for determining whether property owners in an area are required to purchase flood insurance in order to obtain a mortgage or other lines of credit secured by buildings. These maps are not updated consistently or within a specific time-period however updates may be triggered by new building construction in or near a flood zone, changes to flood-protection infrastructure, and other developments in the community.

As of October 2021, however, FEMA has implemented a new methodology, referred to as Risk Rating 2.0, to determine flood insurance rates that does not have mapped threshold factors with the goal of using more variables to more closely reflect a specific property's flood risk.¹⁴⁶

¹⁴³ Many alternatives to the NFIP are specific to select markets including those that may not be participating in the NFIP program either because they are very high-risk, or the communities have not committed to floodplain management practices required by the program. Other private insurers may provide umbrella policies that cover items the NFIP does not cover or provide a higher-level of coverage. Information on rates for these insurers is not readily accessible. According to FEMA, over 22,500 communities are participating in NFIP. See FEMA, "Community Status Book Report," webpage, March 17, 2022.

¹⁴⁴ For more information about the goals and coverage provided by NFIP see Appendix D.

¹⁴⁵ Base Flood Elevation is defined as, "The elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year." See FEMA, "Base Flood Elevation (BFE)," webpage, March 5, 2020.

¹⁴⁶ Additional detail on the methodology and data sources are available see FEMA, "National Flood Insurance Program Risk Rating 2.0 Methodology and Data Sources," January 18, 2022.

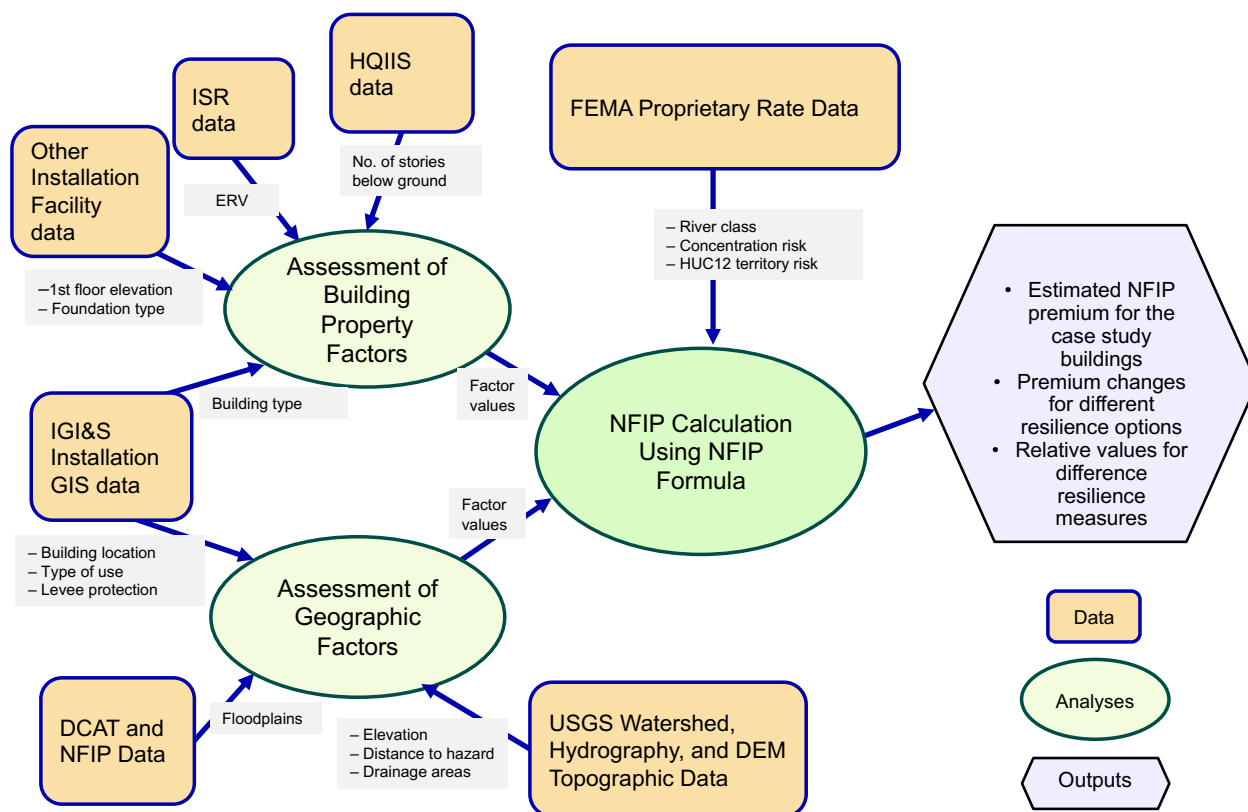
For example, Risk Rating 2.0 uses both geographic factors about the buildings height (i.e., first floor elevation related to ground) and distance relationship to the potential water hazard source and building property factors such as foundation type and replacement cost to determine the insurance premium rate. Based on publicly available Excel workbook-based models of the flood insurance rate formulas and value lookup tables, we used the Risk Rating 2.0 methodology to calculate estimated annual flood insurance premium values for illustrative real-world Army buildings.¹⁴⁷

Figure 5.1 provides an overview of our analysis. As this figure shows, the NFIP premium calculations require detailed information about the building's site level geographic factors and building characteristics and property factors. Table 3.7 summarized some of these factors. To calculate these factors, we acquired data for each building case study from multiple sources as shown in Figure 5.1. In our assessment of the geographic factors, we used information about whether the building was in the floodplain, which drainage area, and relationship to water hazard source to calculate the factors needed for the NFIP formula calculation (e.g., distance to creek and relative ground elevation to hazard source). The assessment of geographic factors included using installation IGI&S Common Installation Picture (CIP) datasets to examine building locations relative to floodplains and various hydrological features which were acquired via DCAT, NFIP, and USGS data. The assessment of building factors used installation datasets to identify the number of stories below ground, foundation types, and other needed factors. For example, the installation CIP GIS files provided the CATCODES and other information about the building types, ISR provided ERV, and HQIIS can be used to determine if the building has a basement.¹⁴⁸

¹⁴⁷ Premium calculation worksheet examples are available from FEMA (see FEMA, "Risk Rating PCW Rating Examples," excel spreadsheet, undated), as are the rating factors (see FEMA, "Appendix D Rating Factor Tables_1-22," excel spreadsheet, undated).

¹⁴⁸ Since we wanted to compare across all building case studies equally regarding basements, we assumed all case study buildings did not have basements rather than acquiring these data directly from HQIIS. Similarly, HQIIS could have been used to acquire plant replacement value instead of ERV but we used ERV in our calculations instead of plant replacement value. Based on the structure of NFIP premium calculations and factors published, this assumption is relatively innocuous: relative to the "slab/no basement" foundation-type, the presence of a basement increases the premium rate by 30 percent with no non-linear impacts.

Figure 5.1. Summary of the NFIP Flood Insurance Premium Analysis



NOTE: Number of stories below and above ground, FEMA proprietary data, and some other limited data were estimated for each case study building based on publicly available information in Google Earth Pro and/or First Street Flood Foundation's Flood Factor.

Analysis of Resilience Investments for Floods Using NFIP Formula

To conduct the NFIP insurance premium calculations using the NFIP formula we needed site-scale information to understand a building's characteristics and relative geographic factors. This flood risk also helps determine NFIP's potential premium reductions for different resilience investments. In Appendix C we described how we chose the NFIP installation and building-level case studies based on different installation and building level flood-related data in ArcGIS, and IMCOM historical storm damage data about flooding. The installations chosen were: Fort Cavazos, Fort Stewart, Fort Carson, and APG.

Fort Cavazos Building Case Studies

We chose Fort Cavazos as the initial case study because it had a variety of local site characteristics that could be used to explore different aspects of the NFIP insurance premium calculations, and because these situations were comparable to those of other buildings at the other installations. We examined Fort Cavazos' building locations relative to a diverse set of

drainage features embedded in the surrounding topography. Table 5.1 provides these different site level geographic factors, along with building characteristics and other general information about the barracks, office, and maintenance building cases for Fort Cavazos.

Table 5.1. Summary of Selected Factors for the NFIP Fort Cavazos Building Case Studies

Factors	Barracks	Office Building	Maintenance Building
Building Description	Enlisted Barracks	Battalion HQs Building	Vehicle Maintenance Shop
CATCODE	72111	14182	21410
ERV	\$5,123,000	\$3,891,000	\$11,278,000
Number of Stories	3	1	2
Area (SF)	10,825	11,733	28,961
Foundation Type	Slab/no basement	Slab/no basement	Slab/no basement
First Floor Elevation to Ground	0 feet	0 feet	0 feet
Drainage area/ watershed	117.01 sq km	63.02 sq km	117.01 sq km
Distance to Water Hazard Source	40 meters	15 meters	150 meters
Relative Ground Elevation to Hazard Source	11 feet	9 feet	6 feet

SOURCE: Author analysis of IGI&S, ISR, USGS, and Google Earth Pro data.

NOTE: The different colors are used to show the factors in each category: orange rows are for the general case study information, yellow rows are for the building characteristics, and the blue rows are for the site level geographic factors. The colors are consistent with Tables 4.3 and 4.4.

We used a variety of data sources to understand building characteristics relative to flood risk rating. One of the most important tools we used, as a substitute for a site survey or documentation equivalent that contained a FEMA elevation certificate, was Google Earth Pro, which combined visual and terrain data, often with three-dimensional projection (e.g., for the barracks and office building, but not the maintenance building).¹⁴⁹ Both the enlisted barracks and battalion HQs office building were relatively close to their hazard source—40 and 15 meters, respectively—though reasonably well elevated at 11 and 9 feet, respectively. Though the foundation design and footprint are largely the same, and one might expect the hazard exposure based on building characteristics to be relatively similar, the geographic characteristics of the hazard source are substantially different. The barracks is located next to an engineered, channelized creek (Figure 5.2). In contrast, the office building is adjacent to a vegetated creek that has a similar bank height, but it has both large brush and trees (Figure 5.3).

¹⁴⁹ For a sample elevation certificate, see FEMA, National Flood Insurance Program, *Instructions and Elevation Certificate*, 2019 Edition, OMB No. 1660-0008, 2019. Google Earth Pro is free, publicly available software. See Google “Google Earth,” webpage, undated. Additional information on the attribution and fair use of imagery is available at Google, “Google Maps & Google Earth,” webpage, undated.

Figure 5.2. Enlisted Barracks at Fort Cavazos



SOURCE: Google Earth Pro, Image: Landsat / Copernicus; Data: SIO, NOAA, U.S. Navy, NGA, GEBCO, as of October 2022.

Figure 5.3. Battalion HQs at Fort Cavazos



SOURCE: Google Earth Pro, Image: Landsat / Copernicus; Data: SIO, NOAA, U.S. Navy, NGA, GEBCO, as of October 2022.

The maintenance building is situated relatively far (150 meters) from the intermittent creek that traverses a scrubby basin (see Figure 5.4). While these geographic factors might imply less flood risk, the building characteristics might point in the other direction: the vehicle shop has over twice the footprint and is located only six feet above the hazard source. To understand the relative importance of these factors, we looked up the rate tables and calculated the flood insurance premia for each of these buildings.

Figure 5.4. Vehicle Maintenance Shop at Fort Cavazos



SOURCE: Google Earth Pro, Image: Landsat / Copernicus; Data: SIO, NOAA, U.S. Navy, NGA, GEBCO, as of October 2022.

Overview of an NFIP Inland Flood Calculation Example

The NFIP premium calculation requires parameter-dependent factors looked up from rate tables for both geographic and building/contract characteristics. The geographic rate by peril and coverage is calculated as the product of the factor line items (in turn dependent on certain variables) that are shown in Table 5.2.¹⁵⁰ Similarly, the building rate by peril and coverage is the product of the factor line items shown in Table 5.3.

¹⁵⁰ The NFIP contemplates flooding from a variety of different sources as distinct perils. These perils are: Inland Flood, Storm Surge, Tsunami, the Great Lakes, and Coastal Erosion. We focus on Inland Flood in our analysis.

Table 5.2. Geographic Factors for NFIP Premium Calculation

Geographic Factor Line Items	Parameter Dependent Factors
Base Rate (per \$1,000 of Coverage Value)	Levee Presence
	State
	Single Family Home Indicator
Distance to Water Hazard Source	Levee Presence
	Region (from State)
	Distance to River (meters)
Relative Ground Elevation to Hazard Source	Levee Presence
	River Class
	Elevation Relative to River (feet)
	Region (from State)
Drainage Area/Watershed	Levee Presence
	Drainage Area (km ²)
	Region (from State)
First Floor Elevation to Ground	Levee Presence
	Structural Relative Elevation (feet)
	Region (from State)
Territory Proprietary Term (HUC12 & Barrier Island Indicator)	Barrier Island Indicator
	Levee Presence
	HUC12

SOURCE: Author analysis of FEMA data.

Table 5.3. Building and Contract Factors for NFIP Premium Calculation

Property Factor Line Items	Parameter Dependent Factors
Type of Use	Type of Use
Number of Stories	Single Family Home Indicator
	Condo Unit Owner Indicator
	Floors of Interest
Foundation Type	Foundation Type
First Floor Elevation to Ground	First Floor Height
	Foundation Design
	Flood Vents
M&E above First Floor	Machinery and Equipment (M&E) above First Floor
Concentration Risk Proprietary Term	Metropolitan Statistical Area (MSA)
Building Value ('000s)	Engineered Replacement Value

SOURCE: Author analysis of FEMA data.

Using the January 2022 Risk Rating 2.0 Factor Tables, we use a coverage value of \$1.2 million to calculate deductible and limit as well as the deductible to coverage value ratios: this is

the maximum value available in the tables, which is the program cap.¹⁵¹ Other programs available from private insurance companies would certainly have a different cap and rate structure for this relatively minor factor line item. The difference of these two ratios results in the initial deductible and insurance to value rate, which is capped to find a final deductible and insurance to value rate.

The building rate by peril and coverage is multiplied by this final deductible and insurance to value rate, weighted by peril, focusing on their impact to the Inland Flood component of premium, and then bounded by minimum and maximum rates per \$1,000 of building value. We assumed no prior claims, resulting in the monthly premium excluding fees and a program expense constant.

NFIP Resilience Investment Measures

In examining the NFIP formulae and lookup tables, we found that NFIP offers lower flood insurance rates for several different types of characteristics that could be achieved through resilience investments that help reduce flood exposure. For discussion purposes, we have grouped them in three different categories: how the building is being used, changes to the building design, and changes to the building site and location.

Building use: The NFIP provides lower insurance rates for two resilience investment options that relate to how the building is used. First, the rate is higher if any machinery or equipment (e.g., HVAC, transformers, water pumps, microgrids, and generators) is located on the first floor or in the basement. Insurers receive a lower NFIP premium rate, in contrast, if machinery and equipment is elevated above the first floor. Second, insurers could change the building use from residential to office building to get a rate reduction of 33 percent on their premiums, since NFIP considers risk to residents higher than office buildings. This option is equivalent to the Army changing a barracks to an office building. Since this reduction does not vary by location or any other factor and is not as relevant to the Army, we do not show any model results for it.

Building design: The NFIP has two resilience investment options related to building foundations. First, the rate is higher for buildings with a basement. Some buildings may require specialized structure or contents (e.g., sensitive SCIF or heavy electrical equipment) in the basement that is not accounted for in our calculations. Some of this increased risk premium might be mitigated by having windows or flood vents to release hydrostatic and hydrodynamic pressure, but this would be atypical for the construction type of most installation buildings. However, moving sensitive or heavy equipment out of the basement may be feasible in some locations, so the basement does not need to be used in some circumstances. Thereby, we

¹⁵¹ The NFIP maximum coverage value for residential, multifamily, and non-residential is currently lower than the \$1.2 million available in the factor tables. Specifically, the NFIP offers a maximum of \$500,000 in building coverage for businesses and residential structures of five or more units. See FEMA, “Flood Insurance and the NFIP,” webpage, June 14, 2021.

included essentially changing to no basement option as a possible premium change in our calculations. Second, an alternative foundation type with piers instead of a closed wall slab, where there could be parking under the building, may have a lower rate. However, raising the building via piers, is one the Army does not usually use in its building designs in the United States, so we assumed it was not a viable option and did not use it in our calculations.

Building site and location: The NFIP provides lower insurance rates for three key building siting decisions related to the surrounding grade and the location relative to water hazard source. First, if the first floor is elevated relative to the foundation or the surrounding grade, the rate is decreased. This concept is one that Army and other military installations have used when a building is in an area with high flood risk. For example, at Joint Base Langley–Eustis the USAF has added fill at MILCON project sites to raise the buildings that were in flood-prone areas.¹⁵² Second, the building could be located at a site that is farther away from a water hazard source (e.g., out of the floodplain) but at the same elevation for a reduced rate. Third, if the building is located at a site the same distance from the hazard, but on higher ground, there is a rate reduction (which is distinct from the first-floor elevation). The last two options are only viable for the Army if it is planning to construct a new building and it is trying to locate it away from flooding risks. This type of option involves master planning and MILCON decisions.

Calculating and Comparing the NFIP Insurance Premiums for Different Resilience Investment Options for the Fort Cavazos Base Case

Given these rating options associated with potential flood resilience investments, we calculated illustrative NFIP premiums for the Fort Cavazos base case buildings to see how the estimated annual premium values might vary by building use, building design, and location. We started with calculations for each building type to give us a baseline estimated annual premium. For these base premium cases, we assumed the buildings did not have basements and that machinery and equipment were located on the first floor. Then we conducted excursions for these buildings with the two use and design options: raising the machinery and equipment above the first floor and if the building added a basement.¹⁵³

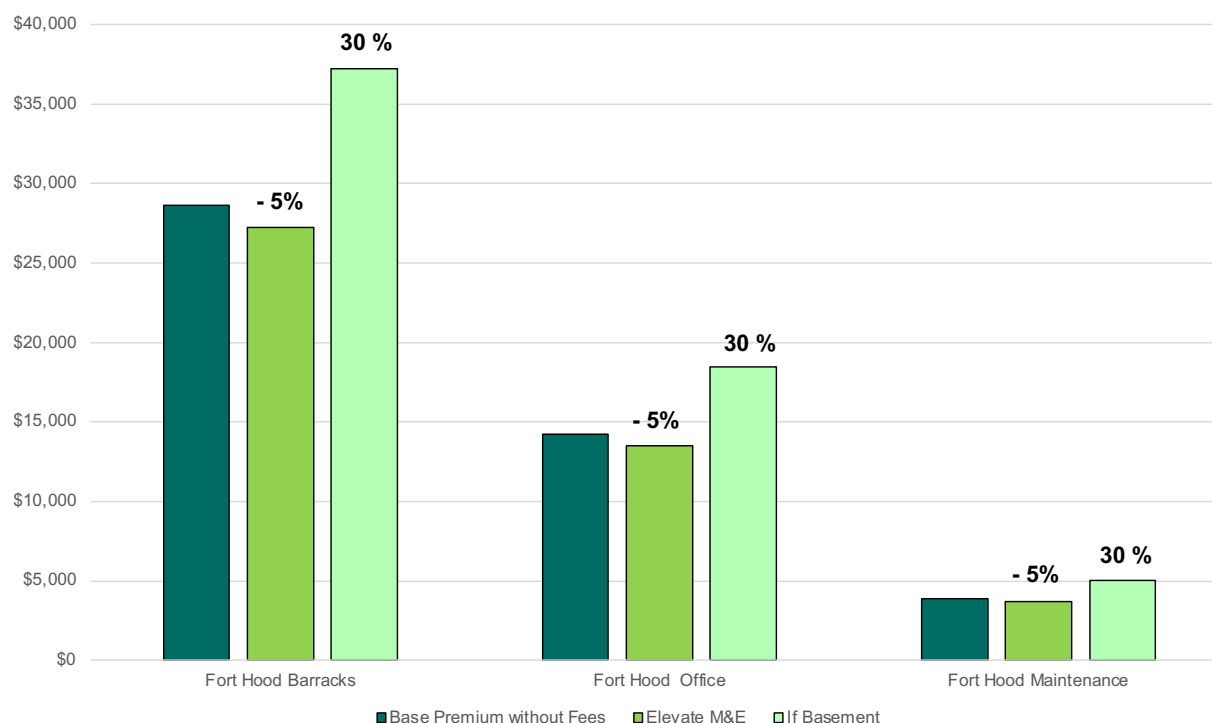
Figure 5.5 shows the estimated annual premium amount for each option and the percentage difference for the two options' premiums compared to the base premium rate. The premium reduction for elevating the machinery and equipment above the first floor was 5 percent regardless of building type. That 5 percent reduction was the same for all the installation case studies. Namely, the 5 percent is the constant premium rate that does not vary by location,

¹⁵² Beth E. Lachman, Mary Kate Adgie, Rachel Liang, Grace Gahlon, and Thomas Trail, *Comprehensive Army Installation and Community Partnership Reference Guide: Guidance and Best Practices for Effective Installation Partnerships*, unpublished RAND Corporation research, 2021.

¹⁵³ Even though our focus is mostly on a building's structural features, this action to move equipment is one that NFIP reduces premiums for and a useful one, so it was included in our assessment.

building type, or any other building characteristic. Also indicated in the figure is a constant 30 percent premium increase for having a basement in a building regardless of building type; this rate increase is consistent across all the installation case studies. Although the percentage changes are constant, the base premium might substantially affect whether a particular resilience investment is attractive.

Figure 5.5. Fort Cavazos Building NFIP Estimated Annual Premium Rate Changes for Elevating the Machinery and Equipment above the First Floor or if the Building Added a Basement



SOURCE: Author analysis of FEMA data.

NOTE: This figure was created before Fort Hood was renamed Fort Cavazos.

Next, we conducted excursions to assess the rate changes to premiums for each of the Fort Cavazos buildings if they were to be elevated or relocated hypothetically. Specifically, we looked at two excursions for each of the three options:

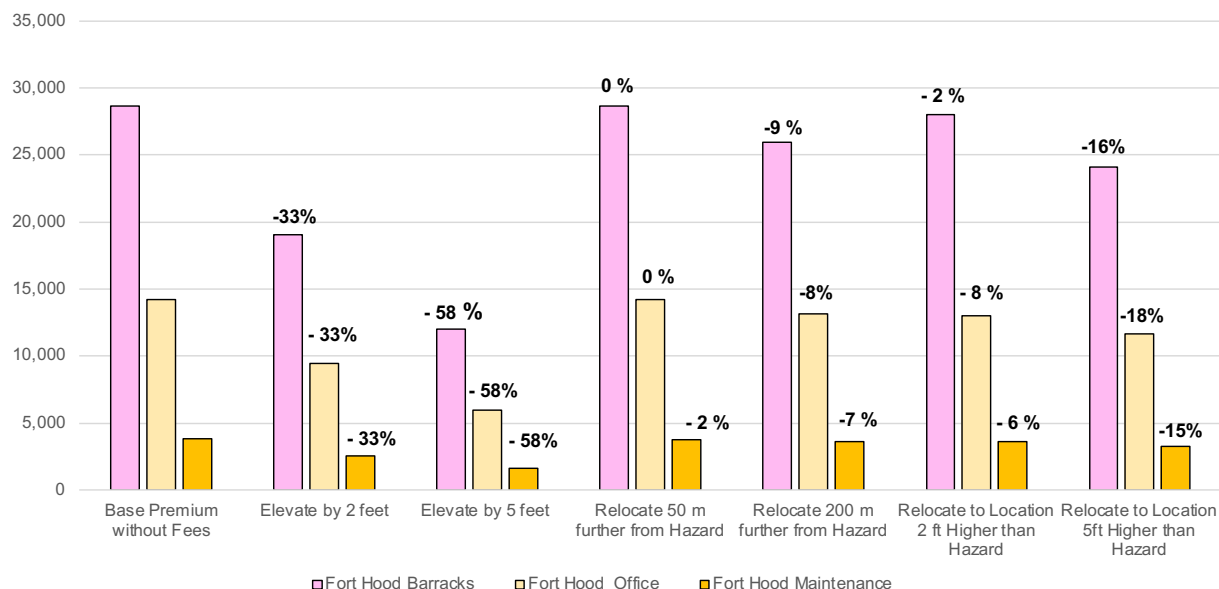
1. Elevate the building's first floor elevation by two feet or by five feet
2. Relocate the building 50 or 200 meters further from the water hazard source (at the same elevation)
3. Move the building to another location that is two or five feet higher than before (but the same distance away from the water source)

Note the rate formula is multiplicative in its factors for first story elevation, distance to water hazard, and elevation: the joint effects can be explored by multiplying them together.

Figure 5.6 shows the estimated annual premium amounts and percentage differences compared to the base premium rate results for these six excursions. These estimates show that for one of the options, elevating the building at the same location, NFIP provides the same decrease in premium rate of 33 percent for two feet and 58 percent for five feet for all three building cases. This percentage was the same across all case studies regardless of location and the other factors (unless the building was already elevated, in which case the change was diminished). In addition, NFIP gives a lower premium reduction for moving the building to another location on higher ground of the same height and same distance from the water hazard source, and the amount of this premium reduction varies based on other building factors.

For example, the Fort Cavazos maintenance building had a reduction of only 6 percent for being two feet higher at another location while at the same site it had a reduction of 33 percent. The results are similar for the other buildings and heights. The NFIP provides higher flood insurance premium reductions for the property owner elevating the building's foundation at the same site compared to moving it to another site at the same height. Speculatively, it may be that the NFIP is primarily a residential program where homeowners may not have another property which to relocate their building, or it may be that the program's equity goals and the physics of floods mean that rates should be less sensitive to landscape-scale rather than property-scale changes. We cannot conclusively determine whether these or other factors explain these findings.

Figure 5.6. Fort Cavazos Building NFIP Premium Rate Changes for Elevating the First Floor as well as Relocating Further Away or Higher Above the Hazard



SOURCE: Author analysis of FEMA data.

NOTE: The Y axis shows the estimated annual NFIP flood insurance premiums in dollars. This figure was created before Fort Hood was renamed Fort Cavazos.

Calculating and Comparing the NFIP Insurance Premiums for Different Resilience Investment Options Across the Different Installation Case Studies

Next, we conducted excursions to see what the premium reductions would be for different installation case studies across the United States. Specifically, for the options that were not constant for all the installation case studies: relocating the building farther away from the hazard source but at the same elevation and relocating the building to a location that is higher (but the same distance away). We explored these excursions:

- Relocate the building 50 or 200 meter from the water hazard source but at the same elevation
- Move the building to a location that is two or five feet higher than before (but same distance away)

Before discussing these excursion results, it helps to understand how some key geographic factors differ between the case studies because these factors influence the value of the resilience investments (see Table 5.4). For example, the Fort Carson barracks, Fort Stewart office building, and Fort Stewart maintenance building are all similarly close to their hazard source as the Fort Cavazos office building and barracks. In contrast, the Fort Carson maintenance building, Fort

Stewart barracks, and Aberdeen Proving Grounds maintenance building are over twice as far from the hazard source as the Fort Cavazos maintenance building.

Table 5.4. Comparing Selected Site Level Geographic Factors Across NFIP Case Studies

Installation	Factor	Barracks	Office	Maintenance
Fort Cavazos	Distance to hazard source	40 m	15 m	150 m
	Relative ground elevation to hazard source	11 feet	9 feet	6 feet
Fort Carson	Distance to hazard source	50 m	340 m	500 m
	Relative ground elevation to hazard source	17 feet	14 feet	32 feet
Fort Stewart	Distance to hazard source	400 m	18 m	50 m
	Relative ground elevation to hazard source	14 feet	4 feet	5 feet
Aberdeen Proving Grounds	Distance to hazard source	N/A	N/A	315 m to creek; 470 m to coast; close to coastal storm surge
	Relative ground elevation to hazard source	N/A	N/A	10 feet

SOURCE: Author analysis of USGS and Google Earth Pro data.

NOTE: We included the distance to coast for APG as well since it is close to the DCAT-delimited 1% Annual Exceedance Probability (AEP) coastal flooding zone.

To see the difference for one of these excursions, we consider moving the building 200 meters further from the nearest water hazard for all installations and case studies. Table 5.5 shows the percent changes in annual premium values for all the cases. In general, the further the building was originally from the hazard source, the less the reduction in premium, but there is some variation based on the river's class (a proprietary term) and the installation's state (a proxy for region of the country and typical flooding conditions there).

Table 5.5. Percent Changes in Annual Premium When the Building is Relocated 200 Meters from the Nearest Water Hazard for All NFIP Installation Case Studies

Installation	Barracks	Office	Maintenance
Fort Cavazos	-9%	-8%	-7%
Fort Carson	-7%	-1%	-2%
Fort Stewart	-3%	-9%	-9%
APG	N/A	N/A	-3%

SOURCE: Author analysis of FEMA and USGS data.

Table 5.6 shows the base case estimated annual premium values for each installation and the comparison across all installations for the four excursions.

Table 5.6. Comparing Estimated Annual Premium Values for Selected Building Elevation and Location Changes Across the NFIP Case Studies

Installation Name	Excursion	Estimated Annual Premium Difference from Baseline / Percent Difference		
		Barracks	Office	Maintenance
Fort Cavazos	Estimated annual baseline premium without fees	\$28,657	\$14,208	\$3,869
	Relocate 50 m. from hazard	\$28,657 \$0 / 0 %	\$14,208 \$0 / 0 %	\$3,774 -\$94 / -2%
	Relocate 200 m. from hazard	\$25,982 -\$2,675 / -9%	\$13,131 -\$1,077 / -8%	\$3,597 -\$272 / -7%
	Move to location 2 feet higher than the hazard	\$27,999 -\$658 / -2%	\$13,041 -\$1,167 / -8%	\$3,621 -\$248 / -6%
	Move to location 5 feet higher than the hazard	\$24,072 -\$4,584 / -16%	\$11,649 -\$2,559 / -18%	\$3,302 -\$567 / -15%
Fort Carson	Estimated annual baseline premium without fees	\$37,670	\$21,340	\$7,737
	Relocate 50 m. from hazard	\$37,670 \$0 / 0 %	\$21,297 -\$43 / 0%	\$7,737 \$0 / 0%
	Relocate 200 m. from hazard	\$35,099 -\$2,571 / -7%	\$21,059 -\$281 / -1%	\$7,620 -\$117 / -2%
	Move to location 2 feet higher than the hazard	\$37,670 \$0 / 0%	\$20,214 -\$1,126 / -5%	\$7,193 -\$544 / -7%
	Move to location 5 feet higher than the hazard	\$35,189 -\$2,481 / -7%	\$18,730 -\$2,610 / -12%	\$7,193 -\$544 / -7%
Fort Stewart	Estimated annual baseline premium without fees	\$1,332	\$9,888	\$3,647
	Relocate 50 m. from hazard	\$1,319 -\$13 / -1%	\$9,888 \$0 / 0%	\$3,647 \$0 / 0%
	Relocate 200 m. from hazard	\$1,288 -\$44 / -3%	\$8,965 -\$923 / -9%	\$3,306 -\$340 / -9%
	Move to location 2 feet higher than the hazard	\$1,332 \$0 / 0%	\$8,921 -\$967 / -10%	\$3,310 -\$337 / -9%
	Move to location 5 feet higher than the hazard	\$1,332 \$0 / 0%	\$7,816 -\$2,072 / -21%	\$2,942 -\$705 / -19%
APG	Estimated annual baseline premium without fees	N/A	N/A	\$3,272
	Relocate 50 m. from hazard	N/A	N/A	\$3,272 \$0 / 0%
	Relocate 200 m. from hazard	N/A	N/A	\$3,181 -\$91 / -3%
	Move to location 2 feet higher than the hazard	N/A	N/A	\$3,056 -\$216 / -7%
	Move to location 5 feet higher than the hazard	N/A	N/A	\$2,775 -\$497 / -15%

SOURCE: Author analysis of FEMA, USGS, and Google Earth Pro data.

NOTE: In this table the orange rows all correspond to the estimated annual base premium without fees, the light yellow is for relocating the building 50 meters from the water hazard, and the darker yellow is for relocating the building 200 meters from the water hazard. These matching yellows are so the reader can more easily compare across the different installation case studies. Similarly, the move to a location 2 feet higher than the hazard excursion is light blue for all installation cases and the darker blue color is for the move to location 5 feet higher than the hazard to facilitate easier comparison across installations. In each table cell, we provide the premium, the dollar-value change in premium, and the percentage change in premium (indicating “+” for premium increases and “-” for decreases).

In Table 5.7, we report the present value of the premium savings associated with these excursions over time, again assuming a discount rate of 3 percent. We focus on the two changes associated with the greatest reductions in total premium:

- Relocation 200 meters from the hazard
- Move to location 5 feet higher than the hazard

We again note that investments have greater value as their service life increases with diminishing returns over time due to discounting. Moreover, the results show that the value of these investments can range widely depending on the building’s exact characteristics and location. Over 50 years of service, increasing elevation by five feet is associated with a value of \$117,945 for the barracks at Fort Cavazos but only \$63,836 for the barracks at Fort Carson. Maintenance buildings generally derive the least benefit, with relocation of 200 meters from the hazard valued at only \$3,010 over 50 years at Fort Carson.

Table 5.7. Present Value of Premium Savings for Selected Building Elevation and Location Changes Across by Years of Service

		Fort Cavazos			Fort Carson		
Investment	Years	Barracks	Office	Maintenance	Barracks	Office	Maintenance
Relocate 200 m. from hazard	50	\$68,827	\$27,711	\$6,998	\$66,151	\$7,230	\$3,010
	40	\$61,832	\$24,895	\$6,287	\$59,428	\$6,495	\$2,704
	30	\$52,431	\$21,110	\$5,331	\$50,393	\$5,508	\$2,293
	20	\$39,797	\$16,023	\$4,047	\$38,250	\$4,181	\$1,741
	10	\$22,818	\$9,187	\$2,320	\$21,931	\$2,397	\$998
	1	\$2,597	\$1,046	\$264	\$2,496	\$273	\$114
Move to location 5 feet higher than the hazard	50	\$117,945	\$65,842	\$14,589	\$63,836	\$67,155	\$13,997
	40	\$105,958	\$59,151	\$13,106	\$57,348	\$60,330	\$12,574
	30	\$89,848	\$50,158	\$11,113	\$48,629	\$51,157	\$10,663
	20	\$68,198	\$38,071	\$8,436	\$36,911	\$38,830	\$8,093
	10	\$39,102	\$21,829	\$4,837	\$21,163	\$22,264	\$4,640
	1	\$4,450	\$2,484	\$550	\$2,409	\$2,534	\$528

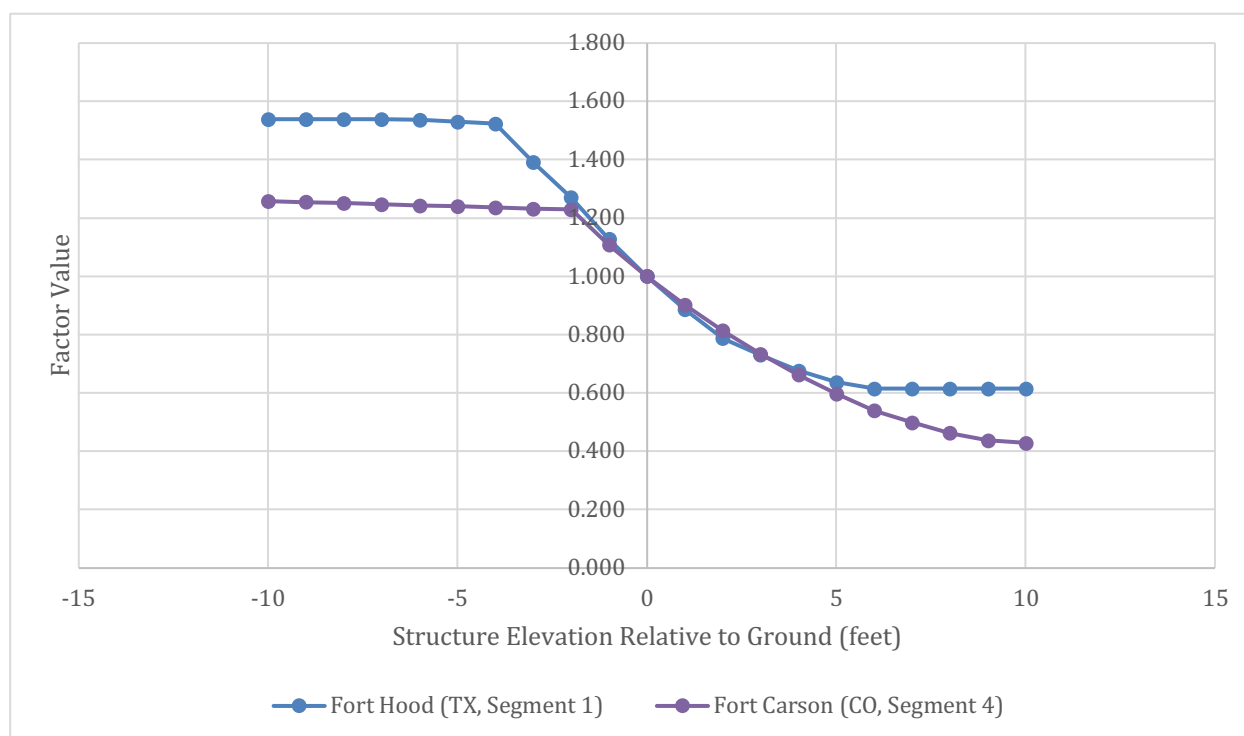
Examining the Influence of Different NFIP Flood Insurance Premiums Factors

We also examined more closely the elevation relative to ground and elevation relative to hazard source factors in detail as an illustrative example of their potential impact on calculations. We look at how these factors vary by state and therefore region (which are referred to as “segments” in the NFIP Risk Rating 2.0 model). Specifically, we compare Fort Cavazos (Texas, Segment 1), to Fort Carson (Colorado, Segment 4).

Figure 5.7 shows the flood premium changes for elevation relative to ground. If the structure is more than five feet below the surrounding grade, the rate is unchanged. Similarly, if the

structure is more than about five feet above the surrounding grade, the rate's rate of change diminishes to a constant. Overall, for reasons that are proprietary to the NFIP, Texas in Segment 1 experiences higher rates. Between these two thresholds, the rate changes relatively linearly, and so the overall premium is quite sensitive to small changes. For example, the approximately six steps up (nominally three feet) for the office building at Fort Carson in Figure 5.8. might result in a quarter decrease in this portion of the premium calculation.

Figure 5.7. Structure Elevation Relative to Ground Rate Changes for Two Different Installations



SOURCE: Author analysis of FEMA data.

NOTE: At Fort Carson, the case study office building is elevated three feet above surrounding grade on a mound, reducing its factor value. The other case study buildings at these installations have no additional structure elevation relative to ground (zero feet). This figure was created before Fort Hood was renamed Fort Cavazos.

Figure 5.8. Fort Carson Office Building with Structure Elevation Relative to Ground



SOURCE: Google Earth Pro, Image: Landsat / Copernicus; Data: SIO, NOAA, U.S. Navy, NGA, GEBCO, as of October 2022.

Figure 5.9 illustrates the impact of hydrogeomorphology on the rate for Fort Cavazos only. In the model, the impact of hydrogeomorphology varies by the elevation of the building relative to the hazard (i.e., the stream/river) and the river's class.¹⁵⁴ The calculations behind determining the class of a river are proprietary to a third-party contracted by FEMA, but definitions are available. The classes range from A through I, with the impact of precipitation on the intensity, or “flashiness,” of flooding increasing over the range. To sketch the range, note that:

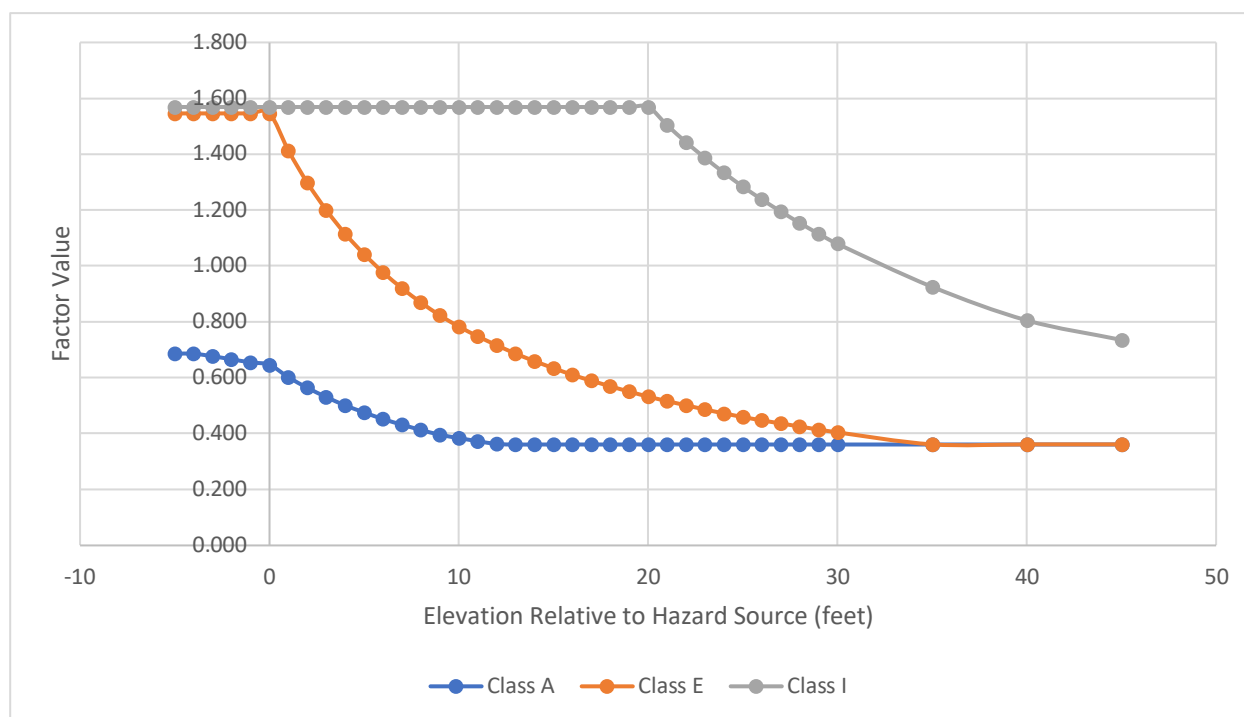
- Class A rivers have their 1 percent AEP flood elevation one foot above that of the 10 percent AEP flood elevation.
- Class E rivers have their 1 percent AEP flood elevation five feet above the 10 percent AEP flood elevation.
- Class I rivers have their 1 percent AEP flood elevation ten feet above the 10 percent AEP flood elevation.

Over these classes and at varying relative building elevations, we see features similar to those shown in Figure 5.8: the rate is fixed for portions of the distribution, and there are portions where

¹⁵⁴ River in this chapter refers to water flowing on the Earth's surface and can include streams, creeks, and brooks.

changes in elevation relative to the hazard source make substantial changes in the rate. Where these portions occur, however, are at different elevations depending on the river's class.

Figure 5.9. Elevation Relative to Hazard Source (by Class of River) Changes for Fort Cavazos

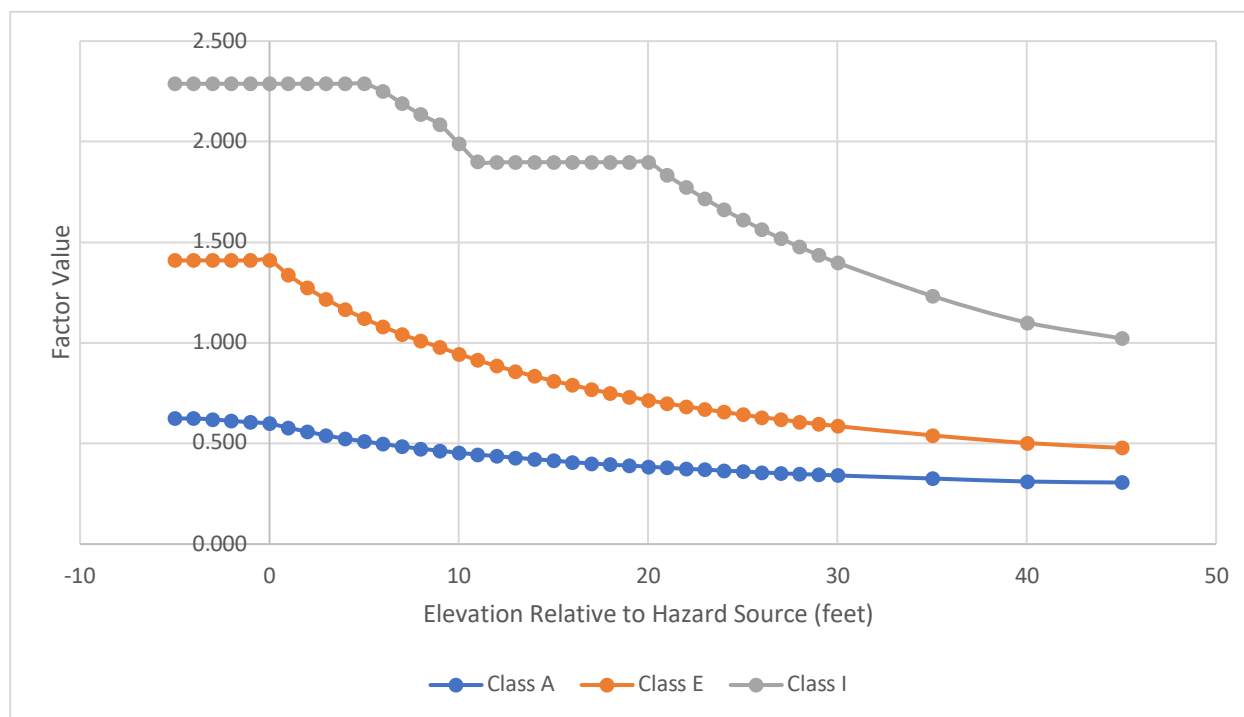


SOURCE: Author analysis of FEMA data.

NOTE: Buildings at Fort Cavazos are situated near different rivers, each of which has a different class: the barracks are located along a Class H river, elevated 11 feet above the hazard source; the office is along a Class D, elevated 9 feet, and the maintenance building along a Class B elevated 10 feet.

The magnitude of this factor varies by region, so we plot the same graph for Fort Carson (CO, Segment 4) in Figure 5.10. Though Class A rivers appear relatively similar, there is a substantial difference in the rate structure for Class I. While there are likely many reasons for this, it is important given the location of Fort Carson near the foothills of the Rocky Mountains, and that some of the drainage features on the installation may have this level of flashy response to precipitation events (for example, see Figure 5.11) and thereby require additional check dams, armoring, and other features to mitigate potential flood damage.

Figure 5.10. Elevation Relative to Hazard Source (by Class of River) Changes for Fort Carson



SOURCE: Author analysis of FEMA data.

Figure 5.11. Fort Carson Barracks with an Estimate Class I Flood Hazard Source



SOURCE: Google Earth Pro, Image: Landsat / Copernicus; Data: SIO, NOAA, U.S. Navy, NGA, GEBCO, as of October 2022.

Summary of Results of the NFIP Premium Calculations

We were able to calculate estimates for NFIP premium rates for illustrative installation buildings. Using the NFIP Risk Rating 2.0 methodology only, we found that NFIP insurance rates are reduced based on resilience investments that help to reduce damage from floods.¹⁵⁵ Some of these percentage premium reductions do not vary by building characteristic, whereas others vary based on location and building characteristics (see Table 5.8).

¹⁵⁵ We should note that this was comparing changes using only the NFIP Risk Rating 2.0 methodology. Since the previous NFIP method is so different from Risk Rating 2.0, it would not make sense to compare the premium changes with the previous rate from the older NFIP method.

Table 5.8. Summary of NFIP Resilience Investment Measures That Have Constant and Variable Effects on Premium

Resilience Investments That Have Constant Rates in Premium	Resilience Investments That Have Variable Rates in Premium
• 5% reduction when machinery and equipment are above the 1st floor • 30% increase when there is a basement • 33% reduction when you convert a barracks to an office building • 33% or 58% reduction when you elevate the building by 2 or 5 feet, respectively, at the same location in areas where flooding is possible	• Relative structure elevation to ground • Moving the building farther away from the water hazard source but at the same elevation

SOURCE: Author analysis of FEMA NFIP data.

All case study building sites were chosen to be in (or in the case of APG within 100 meters of) the DCAT 100-year floodplain. We made this choice to ensure a high likelihood of relevant characteristics and parameters that were relatively sensitive to change. There are two caveats. First, other buildings outside of the floodplain are likely to show less extreme results. Second, there may be buildings outside of the mapped floodplain, for methodological reasons beyond our control, that are at substantial flood risk from hazards other than mapped riverine flood (e.g., effects of local low point ponding from a downpour or basement backups from precipitation that exceeds stormwater conveyance capacity).

Implications for the Army from the NFIP Premium Calculations

Since NFIP insurance rates are reduced for some basic flood resilience investment measures, our results could potentially help with Army investment decisions at different levels, including headquarters processes (e.g., AIS implementation and headquarters FIA assessments) and installation level assessments to inform MILCON requests, restoration and modernization decisions, master planning decisions, and the development of Installation Climate Resilience Plans. The AIS calls for the development of a model to inform resilience investment decisions that draws from insurance industry benchmarks. The methods we deploy here could help in that development process.

The NFIP methods could also inform resilience investment models at the enterprise level for comparing across installations, such as FIA. Specifically, the NFIP methodology could potentially be incorporated into Army models to compare selected resilience investments strategies. However, it is important in comparisons of different resilience investment options related to flooding to consider not only individual building but also other investment strategies that can also help increase installations' resilience to flood damage, such as regional stormwater management approaches. For example, Detroit Arsenal, which has experienced mission degradation and significant costs from three major flooding events in the last five years, is collaborating with Macomb County, City of Warren, the state of Michigan, and other

stakeholders to improve regional stormwater management throughout the watershed to reduce flooding both on the installation and in the surrounding region.¹⁵⁶

Our findings about floodplain data could potentially be incorporated into Army headquarters master planning guidance for installations, including the ICRP guidance. For instance, our calculation of estimated NFIP premia for illustrative installation buildings were based on site level data about each building's characteristics and relationships to water hazards. A key finding was that the hydrogeomorphological characteristics of hazard sources (e.g., floodplain dimensions or flashiness of the watershed) were some of the most important variables in this calculation. However, even though DCAT 100-year floodplain maps were consistently available, they may not necessarily be the best available floodplain data for an individual installation.¹⁵⁷ For instance, in some cases, FEMA FIRMs can provide additional features and/or installations can have their own models and maps from past engineered infrastructure projects.

Specifically, we found that for installation floodplain data for each installation, given the variability in the availability and quality of local level data, installations need to examine relevant local NFIP, DCAT, and Hydrologic Unit Code (HUC) and USGS geospatial data and integrate these data with installation GIS and other relevant local data sources to find the best available floodplain and flooding information for each installation. In addition, we found that Army installation foundational GIS data would benefit from the inclusion of consistent HUC12 USGS geospatial data. Namely, Army installation GIS data should include the relevant layers from HUC12 USGS geospatial data (e.g., water bodies and watershed elements).

The findings about the value of different resilience investment measures could also potentially help inform updates to relevant DoD facility design standards, i.e., Unified Facilities Criteria (UFC). Multiple UFCs discuss issues related to flooding and they are routinely reevaluated and updated. For example, UFC 1-200-01 DoD Building Code was published in 2002 and defers to the first edition of the International Building Code (IBC) in 2000 that applied the concept of a "design flood," typically the 100-year floodplain or storm of historic record. More recently, the 2018 update to UFC 3-201-01 Civil Engineering and the 2020 update to UFC 2-100-01 Installation Master Planning referenced the 500-year flood as a *potential alternative* definition of the design flood, especially for critical buildings and infrastructure.

Based on our study results, DoD may want to assume more extreme flooding conditions for selected installations with recurring flooding problems and projections of future flooding risks, such as requiring the use of a 500-year design flood instead of a 100-year flood as the siting and design criteria in the UFCs for certain facilities or the Army could include it in its policies if the official DoD UFCs are not updated. This stronger standard would result in more resilient

¹⁵⁶ Converge Strategies, LLC, "Detroit Arsenal Regional Defense Assessment of Resilience (DAR2): Process and Project Concepts," February 2022.

¹⁵⁷ We note that the DoD has been updating DCAT since we used it for this study and may have improved its' installation floodplain data.

buildings and other facilities, important capabilities that installations rely on for mission accomplishment. Similarly, for Army installations with a history of flooding problems, ICRPs may want to use the 500-year flood as the definition of the design flood. However, more analyses are needed to identify the specific details of what type of flood history, what level of flood projections and which facility types (e.g., mission critical) are required for such a definition, and whether the costs and benefits of such changes yield a sufficient expected ROI to change the design criteria.

Chapter 6. Recommendations for Army Resilience Investment Processes

This chapter presents the recommendations for the Army. It starts with a summary of the main findings that are relevant for Army installation resilience investment decisionmaking. We briefly revisit the Army installation facility investment decision processes discussed in Chapter 1 to illustrate where the information learned from this study could be used to improve these processes and to enhance installation resilience and help save long-term costs. The chapter concludes with detailed recommendations for the Army.

Summary of Key Findings that Inform the Recommendations

We summarize the main finding from our research results to help set the context for the recommendations. For more details on these findings the reader can refer back to the relevant chapters as noted in footnotes.

Army Installations Planners Need More Guidance and Support to Use Natural Hazards Trend and Projections Data

Army installations are exposed to and experience damage from multiple natural hazards and because of climate change some are anticipated to increase in severity in the future. Many different sources of natural hazard data provide past experiences and future projections that can potentially be useful to Army installation planners.¹⁵⁸ But, projecting frequency and severity for those hazards affected by climate change is inherently different than assessing historical data, and much more challenging.

We identified four authoritative sources that aggregate information across a range of potential hazards, but for different purposes, that can potentially provide useful information for Army installation planners: FEMA's NRI, NOAA's NCEI Storm Events Database, FEMA flood maps, and the DCAT. However, based on the strengths and weaknesses of these data sources and complexities in using them, it can be difficult for installation decisionmakers to use them and to know which other sources to combine with them in their assessments. Installation planners likely do not have the resources or expertise to identify, assess, and access the best available information from these and other sources and this could lead to ineffective or counterproductive investments. There is also limited DoD guidance on which data to use for what purposes. Installations need more guidance and support on what natural hazards data to use and how to use it for decisionmaking.

¹⁵⁸ For more information see Chapter 2 and Appendix A.

Installation Damages from Historical Natural Hazards Events Data and Natural Hazards Trend Data Can Inform Army Investment Decisions

Installations experience many different types of costs and damage from natural hazard events from costs to mission, repairing roads and utilities, BOS costs to clear away storm debris and SRM and MILCON costs to repair and rebuild installation buildings. This study focused only on building related resilience investments for a limited number of investments, costs, and natural hazards. However, the Army needs to focus resilience investments more broadly to ensure the most cost-effective investments—such as regional storm water management approaches rather than investments only in installation buildings and other facilities.

In examining installation historical natural hazard data about damage and costs from past events, we found that most Army installation storm damage to buildings comes from two fundamental forces of nature: water and wind.¹⁵⁹ Water damage comes from flooding, hurricanes, storms, and rain. Similarly, wind damage comes from tornados, hurricanes, hail, and other storm types that involve strong winds. The costs from such events can be significant. Given tight Army SRM budgets, focusing building resilience investments in these areas first could be prudent at many locations.

We also found that over the last 10 years many IMCOM Army installations are repeatedly experiencing significant repair costs for the same types of damage from the same types of major storms—a trend that for some installations is likely to continue or even grow. Consequently, it could save costs over the long term to invest in resilience measures for such damages when making repairs to these buildings and to prioritize selected resilience investments where damage occurs most frequently and natural hazard risks are projected to continue. Of course, a full assessment of cost and benefits should be conducted before making such investments at an individual installation.

The different historical damages and costs are tracked by different Army organizations and Army data systems. We examined part of these data for building resilience investments and see potential for the building data and the broader set of historical storm data to help inform diverse resilience investments and broader Army decisions impacted by climate change. For instance, these data could potentially help inform future installation stationing decisions (e.g., helping identify which installations are more or less vulnerable to natural hazards), help installations in developing their ICRPs, and help inform parts of the AIS and ACS. For example, ICRPs aid installations in identifying and prioritizing projects to increase resilience in the face of natural hazards. These data could be utilized to help identify and prioritize projects that increase resilience of installation locations that have had historical storm damage in the past and are likely to have similar damage in the future. In addition, the AIS calls for the Army to develop installations that generate, preserve, and deploy the multi-domain operations capable force. Risk-

¹⁵⁹ Water damage includes all types of flooding and water infiltration damage from wind driven rain and other storm types involving water. For more information about the storm damage at Army installations see Chapter 3.

based assessments and hazard identification will ensure that installations are capable of understanding risks to ensure installations provide its critical support to ready forces. Finally, the ACS identifies Army installations as a major nexus to preserve the Army's ability to prepare and deploy as an integral part of the Joint Force. The data could potentially aid leaders in achieving the ACS stated goal to enhance resilience and sustainability by adapting infrastructure and natural environments to climate change risks.

Quality and Access Issues in Army Installation Natural Hazards Damage Data Limit the Ability to Use These Data in Army Decisionmaking

Installation natural hazards data could be useful for many types of decisions. However, we found three main challenges in using such installation data in Army decisionmaking: problems with missing data, data quality issues, and data accessibility.¹⁶⁰ First, the Army data systems are missing data so there is an incomplete picture of the costs from natural hazards at Army installations. Data tended to be missing more often for older time periods, but some recent natural hazard data were also missing information. Second, some data quality problems exist where data are being entered inconsistently or incorrectly which makes it difficult to use the data because data cleaning and validation is needed to ensure the accuracy of the data. Third, it is difficult to find, access, use, and combine data from the diverse systems with different data variables in them. Given these issues, it is difficult for the Army to understand and account for the full costs of past damage and to make appropriate ROI resilience investments.¹⁶¹

Implications of the Insurance Analysis Premium Calculations

Both commercial property insurance and NFIP insurance rates are reduced based on resilience investments for selected natural hazards.¹⁶² We were able to calculate illustrative premium values for different resilience investments for both commercial property and NFIP insurance. The premium reductions are mainly for two types of natural hazards damage, flood and wind.

However, commercial property insurance company premium rate formula were relatively difficult to find and use and the companies value resilience investments differently. We searched about 5,000 documents from the SERFF database on commercial property insurance rate filings and found less than 2 percent had useful information. From a total of 14 insurance companies searched across 13 states, we found useful information for only five companies in seven states. In addition, we found sufficient formula information for specific resilience investment measures

¹⁶⁰ For more information see Chapter 3.

¹⁶¹ As a consequence of these data problems, our installation natural hazard cost data are lower bounds on the Army installation and building storm damage costs.

¹⁶² For more information see Chapters 4 and 5 respectively.

for only one commercial property insurance company's methodology, though it could potentially be used to help value some limited Army installation investments in limited states.

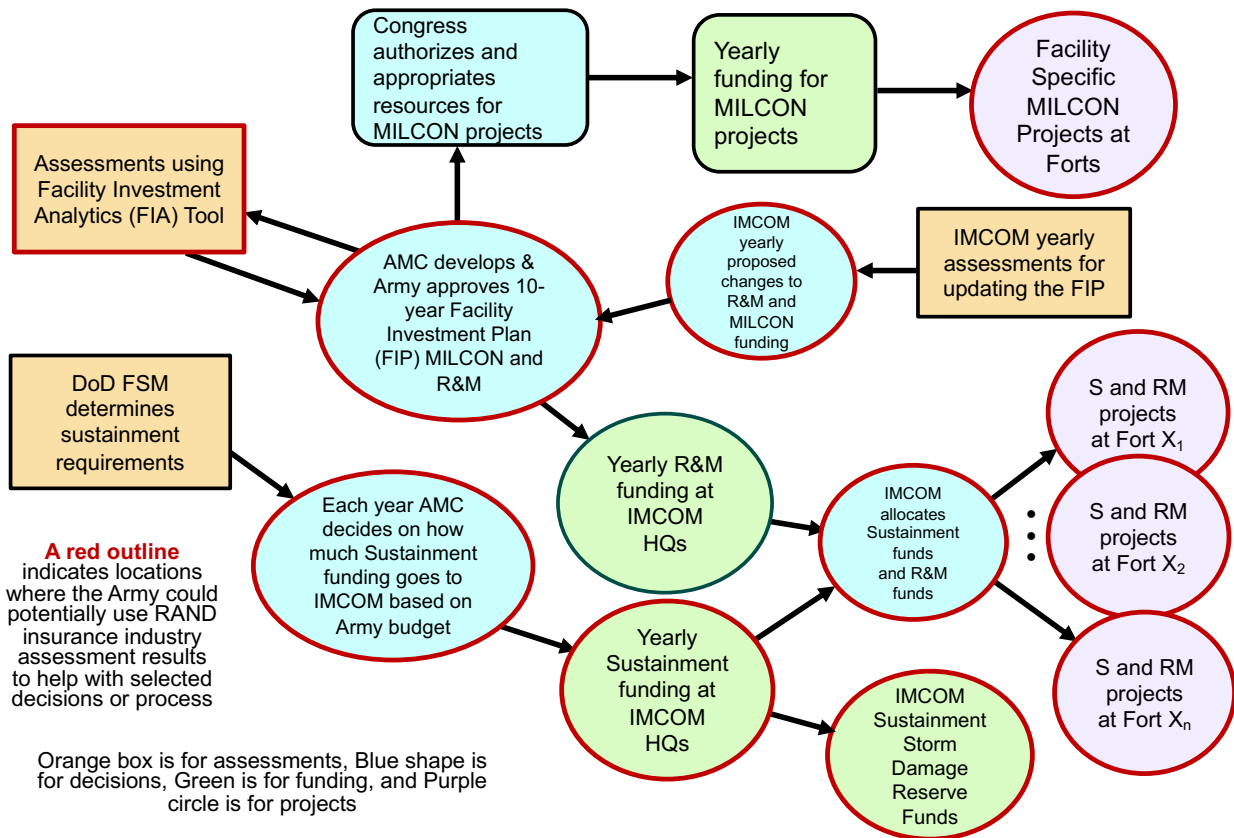
NFIP information is generally available, consistent, and useful and the methodology could potentially be incorporated into Army models and methods. We were able to calculate estimated NFIP premium for illustrative installation buildings based on site level data about each building's characteristics and relationships to water hazards. The hydrogeomorphology and other key water features were important in these NFIP calculations. Comparing different sources for the 100-year floodplain GIS data were needed for our use of this methodology. Depending on the data availability and its quality at the installation level different 100-year flood plain data were the best available data. These findings about floodplain data could be incorporated into Army headquarters master planning guidance for installations, including the ICRP guidance.

Since NFIP insurance rates are reduced for some basic flood resilience investment measures, our results could potentially help with Army investment decisions at different levels, including installation-level assessments to inform MILCON requests, master planning decisions, and the development of ICRPs. The NFIP methodology could also help inform Army resilience investment models at the enterprise level (e.g., FIA) for comparing selected resilience investments strategies across installations.

How Our Results Inform the Army Installation Facility Investment Processes

Figure 6.1 depicts the assessment and decisionmaking processes regarding Army installation SRM and MILCON facility investments for IMCOM managed installations. We have added thick red lines around the areas where the results of this study could potentially provide useful information. We briefly illustrate several potential opportunities where the study results can inform these processes and elaborate on them in the detailed recommendations in the following section.

Figure 6.1. Army Facility Investment Execution Processes for Active-Duty IMCOM Installations



NOTE: The three dots refer to the fact that there are multiple installation from X₁ to X_n.

As explained in Chapter 1, the USACE ERDC CERL has been developing an FIA tool to help in the active component FIP process that includes an Operational Readiness Index (ORI) construct to incorporate resilience to natural hazards and other threats to installation facilities into this process. What our study learned about the value of resilience investments could potentially be integrated in the FIA tool and the ORI analysis. For example, the NFIP methodology could potentially be incorporated into the FIA models calculations. Incorporating resiliency and other natural hazard considerations, MILCON and SRM decisions can be based more on risk mitigation and resilience, especially in light of increasingly frequent and severe natural hazards. Similarly, our NFIP results about the value of elevating buildings could help with assessments (e.g., design charrettes) related to facility specific MILCON projects at installations.

This diagram shows how IMCOM HQ sets aside some limited sustainment storm damage reserve funds for installations' unexpected large building and other facility repairs that are needed each year to repair the buildings to the same condition. Since we found that some installations have repeatedly experienced multiple storms where they have had to use the IMCOM storm damage funds during the last 11 years, it makes sense to potentially set aside

some funding for resilience investments at those installations when they are repaired. If a mission critical building at that installation is facing a major storm damage repair (e.g., replacing a roof that was blown off), for example, then it would be a good time to potentially invest in a resilience investment measure (e.g., hurricane straps) at the same time it is repaired to potentially prevent that damage from future storms and save the Army costs over the long run.

Another area where the information from this study can potentially help the Army in its resilience investment processes (not shown in the figure) is in developing policy guidance for installations' development and implementation of ICRPs and updates to their masterplans. In 2022, the Army and the other Services are each required to conduct two installation pilots at Fort Carson, CO, and Anniston Army Depot, AL to develop an ICRP. In March 2022, the Army G-9 provided interim guidance to installations for developing ICRPs. During spring 2022 in collaboration with different parts of the Army, Fort Carson developed its pilot ICRP based on this initial guidance. During summer 2022, the G-9 was developing ICRP guidance for installations to help them develop ICRPs using the lessons learned from this experience. This guidance will include information about which GIS data sources to use to help with installation resilience assessments related master planning, such as, which 100-year floodplain dataset to use.

Recommendations

Our specific recommendations for the Army fall into five categories that focus on how storm damage data and insurance assessment results can be used by the Army to inform installation resilience investments.

Provide More Guidance and Support to Army Installation Planners on Which Natural Hazards Data Sources to Use

1. The **Army should provide installation planners with more guidance on which natural hazard data sources to use for which decisions**, (as the G-9 is currently doing for ICRPs), because of the many sources, the complexities in accessing and using them, and limited DoD guidance on which to use. Installation planners should consider both historical patterns of natural hazards and future trend projections when making long-term investments.
2. Before projections of climate change driven natural hazards can be incorporated into installation plans and investments, the **Army should provide more guidance and support for accessing natural hazard projections that are applicable to local decisionmaking**. This guidance and support can help installation planners access and appropriately use the best available information for their installation resilience investment decisions.

Improving the Quality of and Access to Installation Storm Damage Data

3. The Army should make installation data about past and on-going damage from **natural hazards more accessible, complete, accurate, and uniform so it can be more effectively used to inform installation resilience investment decisions, and to help with future data analytics and other types of installation decisions impacted by natural hazards** issues. The use of such data analytics is especially important because of climate change projections. We have several general recommendations about how the Army should do this and also provide some specific examples of actions that could be taken to improve the quality and accessibility of the IMCOM storm damage data. Where relevant, similar actions should be applied to other Army storm damage data, e.g., ARNG Act of Nature data.
 - a. The Army should enhance guidance and oversight on installation natural hazards damage data to improve data quality, capture, tracking, storage, and management. Army headquarters should develop, issue, and enforce appropriate guidance that includes identifying and assigning oversight responsibilities to ensure implementation.
 - b. Army headquarters should ensure data gaps are being addressed in different Army organizational databases including adding additional fields to data systems as needed. G-9, AMC, IMCOM, ARNG, and other Army headquarters organizations that manage, provide policy and guidance, or other oversight of relevant Army data systems for tracking installation natural hazard damage and cost data should provide oversight to ensure that installations are properly entering and storing these data and provide guidance on consistent reporting of storm type.
 - c. To improve access and the usefulness of installation natural hazards cost damage data for installation and enterprise decisionmakers, Army headquarters organizations should develop enterprise-level documentation about what data exists and where they are located within the Army, improve data capture in different Army real property data management systems, and improve access to current and historical data.
4. To improve the content of the IMCOM storm damage data, IMCOM headquarters should update guidance, capture additional data, and ensure data access and quality. We have three recommendations that IMCOM headquarters should be able to implement with minimal resources.
 - a. Army (IMCOM headquarters) should update installation guidance to include consistent use of terms and definitions, e.g., use natural hazard event names in the NCEI Storm Event Database and use Army/DoD Real Property terminology consistently (e.g., the Real Property Unique Identification (RPUID)

number for the facility number). During the validation of the SRM costs, IMCOM headquarters should also ensure these and other data (e.g., the storm and facility types) are entered properly.

- b. **New attributes should be added to the installation reporting spreadsheet for IMCOM storm damage data to help with future data analytics,**¹⁶³ e. g., roof damage with type of damage and damage to selected building components such as “Building Exterior – Walls” and “Building Exterior – Windows,” which are evaluated and rated for quality within the installation ISR data or similar types of data within BUILDER.
 - c. IMCOM headquarters should address challenges with capturing data about the 5 percent SRM costs that are spent before an installation requests storm damage funds. Specifically, **IMCOM headquarters should review and assess MDEP VHUR (Storm Damage)**¹⁶⁴ **data annually to make sure these data are being entered correctly so the details are captured and make sure the 5 percent costs are clearly tracked and recorded within storm data systems** to make these data more accessible for data analytics, which we believe was done since we conducted this study.
5. Instead of using spreadsheets, **longer term the Army needs to be capturing and saving the IMCOM storm damage data into a centralized database as part of the Army’s Enterprise Business Systems – Convergence (EBS-C) process.**¹⁶⁵ This modernization and transformation will help to simplify, streamline, standardize, and make more accessible such data for future data analytics and help support the modernization goals in the AIS.
 6. **Similar guidance about the consistent use of terms and definitions, should be made for ARNG AoN SRM data and for other parts of the Army** along with similar improvements for the MILCON data systems.

Other Recommendations Based on Our Assessment of Installation Storm Damage Data

7. To facilitate the wide use of all the different installation storm damage data in appropriate Army decisionmaking processes, **Army headquarters should conduct a study to identity where and how these data could help with different installation resilience decisionmaking,** especially to help meet the goals of the ACS and the data analytics

¹⁶³ The SRM Storm Damage Data Validation Report.

¹⁶⁴ VHUR is the MDEP code used for natural disaster expenses. Technically VHUR is the MDEP code for humanitarian and disaster relief expenses. It is used to track costs incurred in support of domestic and international humanitarian assistance and disaster relief operations, including hurricanes, floods, earthquakes, wildfires, and other emerging contingencies.

¹⁶⁵ U.S. Army, “Enterprise Business Systems – Convergence,” webpage, undated.

and modernizations needs identified in the AIS. This proposed study should also identify how the data could be used to support future data analytics and should identify all the natural hazards damage data gaps, quality, and accessibility issues and how best to address them given current and potential future uses.

8. Since we found that some installations are repeatedly experiencing recurring costly damage from the same storm types and incurring the same types of damage (e.g., flooding and wind damage), the Army should be using this information about repeated storm damage when making resilience investments across installations to save long-term costs. Specifically, **Army headquarters organizations should prioritize selected resilience investments at installations that have experienced the same type of costly storm damage in their historical natural-hazards-related SRM and MILCON costs and when these natural hazards have a long history of occurrence and are projected to continue in the future.**¹⁶⁶
9. In addition, **IMCOM headquarters should consider setting aside a small amount of funding for adding selected resilience features that have been shown to have value to buildings that have been damaged by storms and are being repaired for installations that repeatedly experience the same types of storms and damage over time.** For example, Fort Liberty has experienced multiple hurricanes and incurs repeated damage from roofs being blown off during these storms. North Carolina has a long history of such storms and projections show that they will likely continue.¹⁶⁷ Since FEMA after-disaster assessments and other analyses along with our commercial property insurance results show value in roof anchorage and other roof resilience measures,¹⁶⁸ it could make financial sense to increase the roof resilience when repairing or upgrading roofs at more mission critical and other high-cost essential buildings at Fort Liberty (e.g., barracks and child development centers (CDCs)). This decision would depend on other factors as well, such as the expected remaining life for each building, so building level life cycle cost assessments are needed. If a building is older and will be replaced soon, then likely it would not make sense to invest in improved roof resilience. A full assessment of the costs and benefits for each actual building investment option (including comparing alternative options) should be made before making such investments.

¹⁶⁶ For a useful source to examine state-wide summaries of long-term natural hazard historical patterns and projections for the future because of climate change see K. E., Kunkel, R. Frankson, J. Runkle, S. M. Champion, L. E. Stevens, D. R. Easterling, B. C. Stewart, A. McCarrick, and C. R. Lemery, eds., *State Climate Summaries for the United States 2022*, NOAA/NESDIS, NOAA Technical Report NESDIS 150, 2022.

¹⁶⁷ R. Frankson, et al., *North Carolina State Climate Summary 2022*, NOAA/NESDIS, NOAA Technical Report NESDIS 150-NC, 2022.

¹⁶⁸ For example, see FEMA, “Design Guide for Improving Critical Facility Safety from Flooding and High Winds,” FEMA 543, January 2007; and FEMA, “Successfully Retrofitting Buildings for Wind Resistance,” Recovery Advisory 1, June 2019; and FEMA, “Best Practices for Minimizing Wind and Water Infiltration Damage,” Recovery Advisory 2, June 2019.

10. Based on our historical installation natural hazards damage assessment and commercial property insurance findings regarding wind, **DoD or the Army should consider incorporating stronger design criteria in the UFCs or their implementation for wind damage at mission critical facilities for installations with a long history of and projections of future wind damage.**¹⁶⁹ These changes would result in more resilient buildings and other facilities, especially critical capabilities that installations rely on for mission accomplishment. Key tenets of the ‘Army Installations Strategy’ include creating modern, resilient, and sustainable installations that enhance strategic readiness. However, more analyses are needed to identify the specific details of what type of wind history, what level of wind projections and which critical facilities are required for such a definition, and whether the costs and benefits of such UFC changes for wind damage yield a sufficient expected ROI to change the design criteria.

Recommendations for the Army’s Working ROI Model to Inform Resilience Investment Decisions

11. If the Army wants to pursue commercial property insurance premium rate data, it would likely be more efficient to partner with the insurance industry—carriers or the analytic firms that they rely upon—to access the appropriate data rather than to use publicly available filings because of the challenges with such data.¹⁷⁰ This kind of collaborative effort may afford the Army the opportunity to obtain more tailored metrics based on their actual loss history data, which may also be attractive to the industry for their model development. **To develop a working ROI model to inform resilience investment decision as specified in the AIS implementation plan, we recommend the Army:**
- a. **explore creating a partnership with the commercial property insurance industry and;**
 - b. **use the NFIP results as a starting point for flood resilience ROIs.**¹⁷¹
12. **However, the Army should consider the full range of costs, damages, and resilience investment options when developing its ROI model** because of the risk of sub-optimizing its investments by focusing only on building SRM and MILCON costs and damages (e.g., not considering mission, utility, BOS, and the ecological costs) and by not considering other resilience options (e.g., stormwater management built and natural infrastructure) that could potentially be more cost effective to help with installation

¹⁶⁹ We note that DoD may have updated their UFCs related to wind since we reviewed the latest relevant UFCs for this study.

¹⁷⁰ See Chapter 4 for an explanation of all the challenges.

¹⁷¹ For more information see U.S. Army, *Army Installations Strategy Implementation Plan: Fiscal Years 2022-2024*, 2022.

resilience for multiple buildings and other facility types (e.g., water and road infrastructure).

Use the NFIP Flood Insurance Assessment Results to Inform Installation-Level and Enterprise-Level Decisions

Since NFIP insurance rates are reduced for some basic flood resilience investment measures, these results should help with Army investment decisions at different levels. In these recommendations, our results need to be integrated into other installation assessments (e.g., cost benefit analyses and life cycle cost assessments).

13. At the enterprise level for comparison across installations, the **NFIP methodology should be incorporated into Army methods and enterprise-wide decisionmaking tools, where feasible, to help compare selected resilience investments strategies.**
 - a. Specifically, the USACE should consider incorporating the NFIP calculations into part of FIA.
 - b. However, we also recommend **in comparisons of different resilience investment options the Army be sure to assess and incorporate, as appropriate, other investment strategies that can also help increase installations' resilience to flood damage**, such as regional stormwater management approaches.
14. **DoD and Army planners should consider the implications of the NFIP resilience measures and our results for helping to update the DoD facility design standards, i.e., UFCs.**
 - a. For instance, the 2018 update to UFC 3-201-01 Civil Engineering and the 2020 update to UFC 2-100-01 Installation Master Planning referenced the 500-year flood as a potential alternative definition of the design flood, especially for critical buildings and infrastructure, but not required. Based on our study results, **for installations with a long history of flooding and projections of future flooding, the DoD may want to assume more extreme flooding conditions (e.g., 500-year design flood) and create stronger siting and design criteria in the UFCs.**¹⁷² However, more analyses are needed to identify the specific details of what type of flood history, what level of flood projections, and which critical facilities are required for such a definition, and whether the costs and benefits of such UFC changes for flood damage yield a sufficient expected ROI to change the design criteria.
 - b. Similarly, wherever feasible and **given the flooding history at an installation and projections for future flooding, the Army may want to require and**

¹⁷² We note that DoD may have updated their UFCs related to flooding since we reviewed the latest relevant UFCs for this study.

provide guidance to design its mission critical buildings and other associated facilities to higher flood standards (e.g., 500-year design flood) under certain conditions. Again, further assessment is needed to determine if such UFC changes for flood damage yield a sufficient expected ROI to change the design criteria. In addition, these conditions would include an assessment of the installation's flooding history and projections, along with a cost benefit analysis. This higher standard will ensure that installation critical facilities will be able to withstand and more rapidly recover from flooding associated with anticipated climate challenges.

15. **At the installation level NFIP insurance results should be used to help with assessments to inform selected MILCON and restoration and modernization requests.** Our NFIP assessment approach when integrated with installation assessments (e.g., design charrettes or a building-level condition assessment indicating a potential need for a MILCON project) could help installations better assess the risk and costs of flooding for some buildings and the need to be built at a new location which would require MILCON funds or to help with construction site preparation (e.g., raising the foundation of the building 2 or 5 feet).
16. At the installation level NFIP insurance results should be used to help with assessments to inform ICRPs and master planning decisions. **For installations with a history of flooding problems and projections for future flooding, installation planners may want to use the 500-year flood as the definition of the design flood in ICRPs and master plans.** However, local installation-level analyses are needed to assess the local flood history and vulnerabilities, flood projections, and which are the critical facilities, and whether the cost benefit analysis for such changes yield a sufficient expected ROI to change the design criteria.
17. Based on our examination of diverse 100-year flood plain data, we have some recommendations for **what installations should use and what the G-9 should incorporate into the master planning and ICRP guidance regarding installation's choice for 100-year flood plain GIS data for planning.**¹⁷³
 - a. **Installations should use the best available floodplain data source for each local installation,** which is not always going to be DCAT or NFIP data.¹⁷⁴
 - b. **The choice of data source should be made after examining relevant local NFIP FIRM, DCAT, and HUC/USGS geospatial data in combination with installation GIS and other local relevant data sources.** (We should note that we met with the G-9 staff who were developing the updated guidance for ICRPs

¹⁷³ We should note that the G-9 was working on such ICRP guidance while we were writing this document.

¹⁷⁴ We note that DoD has been updating DCAT since we used it for this study to make it more applicable for local installation uses.

during August 2022 and provided input to these standards regarding our lessons about floodplain data.)

- c. In addition, we recommend that **Army installation foundational GIS data should include the relevant layers from HUC12 USGS geospatial data** (e.g., water bodies and watershed elements).

Conclusion

This exploratory study examined and used commercial property and NFIP insurance data in new ways to potentially value building resilience investments for natural hazards. It also examined and used cost and damage data from Army natural hazards events in new ways by bringing together trend data from different parts of the Army and using both SRM and MILCON funding histories to examine historical storm damage and costs across U.S. Army installations. By implementing the recommendations from this study, the Army can begin to use the results to help improve installation resilience and save long-term costs. However, this study was only a starting point to explore how these data could be used to inform Army decisionmaking; more research needs to be done to make the data and methods more useful in diverse Army decisions.

This report also calls attention to the need for the Army to consider a broader range of costs and damages beyond buildings in their installation resilience assessments and investments along with a broader range of resilience investment options, such as regional built and natural infrastructure projects, especially in the face of climate change. In addition, by improving the quality and access to Army storm damage data as this study recommends, these data could help support future Army data analytics and the investments needed to modernize and prepare Army installations for the future by improving installation resilience. Given climate change projections, such assessments and investments will become more important to meet the goals of the AIS and ACS and to ensure the readiness capability of Army installations and the Army's fighting force.

Appendix A. Natural Hazards Definitions, Patterns, and Trends

When considering resilience investments Army decision makers, such as installation master planners, must determine an installation's and/or its buildings' exposure to local natural hazards. This appendix provides examples of some of the natural hazards patterns trends experienced across the United States, namely, some indication of frequency and severity, and overall future trends using annual precipitation rates, heavy precipitation events, flooding, and wind as examples. We also provide additional detail on selected resources that curate weather and climate data—those that we used in our analysis and others that could be of use to installation planners.

Illustration of Natural Hazards Patterns and Trends

We illustrate with precipitation, riverine flooding, and wind.

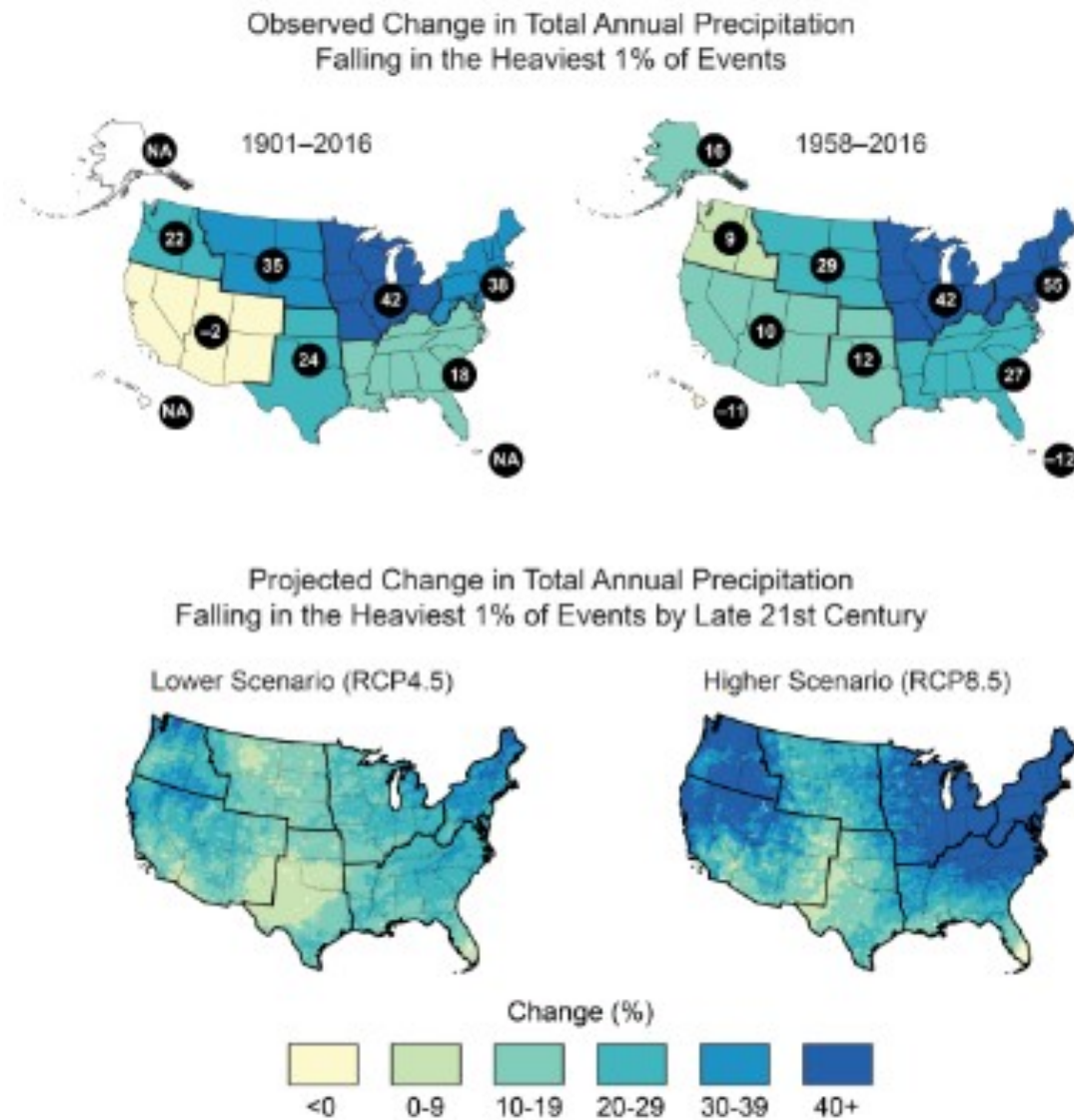
Precipitation

Changing precipitation patterns characterized by annual rates, form, seasonal shifts, and extreme or heavy events affect infrastructure, buildings, and natural systems. According to the Fourth National Climate Assessment annual precipitation is trending differently across the country. For example, annual precipitation is decreasing in the West, Southwest, and Southeast while it is increasing in the Northeast, Great Plains, and Midwest.

In addition to annual precipitation rates, the form and intensity of precipitation events are changing. For example, more precipitation is falling in heavy rain or snow events that are above normal for a given area (note that “above normal” varies with location and season). Figure A.1 shows that precipitation released in heavy rain or snow events has increased over most of the United States between 1901 and 2016 and the greatest change has occurred in the Northeast. According to NOAA nine of the highest ten years for extreme precipitation events have occurred since 1996 and “the percentage of land area experiencing greater than normal yearly precipitation totals increased between 1895 and 2020.”¹⁷⁵

¹⁷⁵ NOAA, “Standardized Precipitation Index data files,” as referenced in EPA, “Climate Change Indicators: Heavy Precipitation,” August 1, 2022.

Figure A.1. Change in Total Annual Precipitation Occuring in Extreme Events (1901 to 2016)

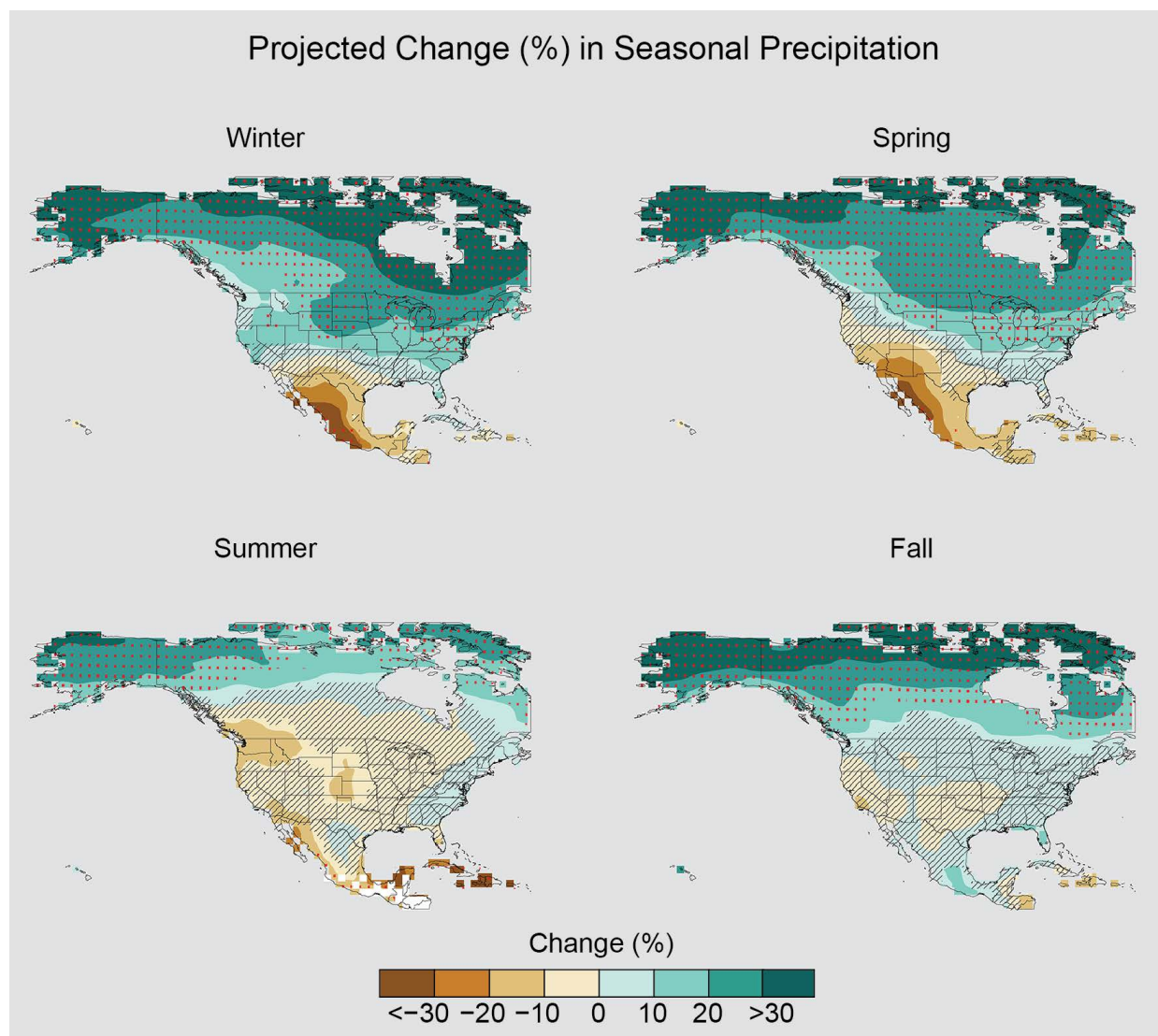


SOURCE: Easterling, et al., 2017.

Projecting changes in precipitation patterns, particularly at the regional scale, is challenging because precipitation exhibits natural variability and is influenced by many factors. As a result, there is more uncertainty over the projections of seasonal averages than in extreme or heavy events, which are more confidently projected to increase as atmospheric water vapor increases with higher temperatures. Figure A.2 shows that projections of future average annual precipitation for the high emissions scenario (RCP 8.5) is mixed across the United States by

2100. The higher, or more northern latitudes are projected to experience higher annual precipitation on average while the lower latitudes may experience less.¹⁷⁶

Figure A.2. Projections of Average Seasonal Precipitation in the United States in 2070–2099 for RCP 8.5 (high emissions scenario)



SOURCE: World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project from NOAA NCEI. NOTE: "Projected change (%) in total seasonal precipitation from CMIP5 simulations for 2070–2099. The values are weighted multimodel means and expressed as the percent change relative to the 1976–2005 average. These are results for the higher scenario (RCP8.5). Stippling indicates that changes are assessed to be large compared to natural variations. Hatching indicates that changes are assessed to be small compared to natural variations. Blank regions (if any) are where projections are assessed to be inconclusive."

¹⁷⁶ Easterling, et al., 2017.

Furthermore, in many parts of the United States precipitation is expected to occur in the form of rain, not snow by 2100 affecting stormwater runoff and water availability in late summer in the west. These and future events can lead to flooding and damage because infrastructure is typically designed using historical data and may not be sized for these extreme events or changing forms of precipitation.

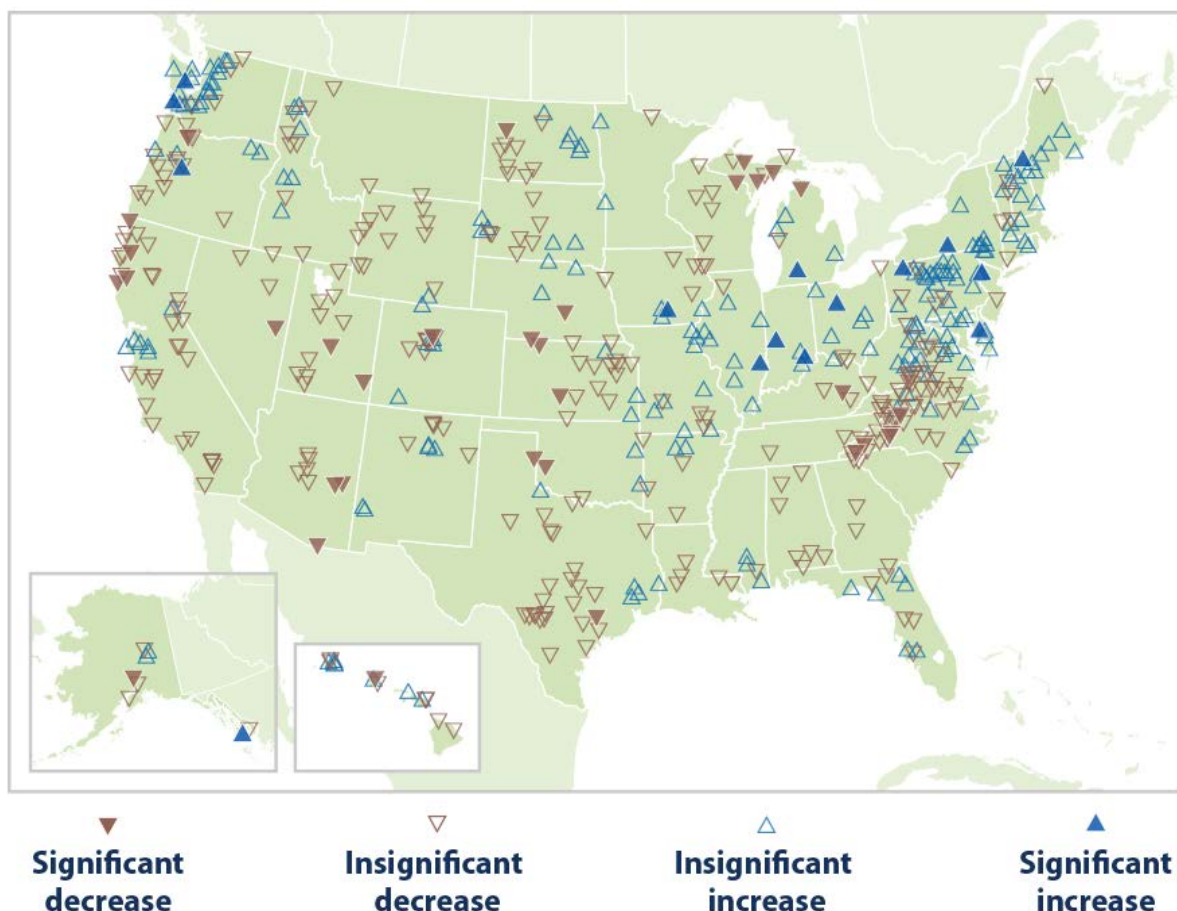
Riverine Flooding

The frequency and magnitude of riverine flooding generally follows the frequency of heavy precipitation events, although other factors such as infrastructure development and land-use changes are also important determinants. Figure A.3 shows where riverine flooding has increased and decreased over the 1965 to 2015 timeframe. As the figure illustrates the observed changes to flooding varies across regions and is increasing in magnitude across the Northeast and Midwest and decreasing in the West and northern Michigan. In terms of large flood frequency, the Northeast, Pacific Northwest, and Northern Great Plains have experienced increases while in other areas such as the Southwest and the Rockies decreases have been observed.

Linking future flooding to climate change has been inconclusive, although there is reasonable confidence that historical trends will continue and with heavier rain events flooding will increase in some areas.¹⁷⁷

¹⁷⁷ Wehner, et al., 2017.

Figure A.3. Change in Riverine Flooding Magnitude across the United States (1965 to 2015)



Data source: Slater, L., and G. Villarini. 2016 update and expansion to data originally published in: Mallakpour, I., G. Villarini. 2015. The changing nature of flooding across the central United States. *Nature Climate Change* 5:250–254.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

SOURCE: Slater, L., and G. Villarini, 2016 update and expansion to data originally published in: I. Mallakpour and G. Villarini, "The Changing Nature of Flooding Across the Central United States," *Nature Climate Change*, Vol. 5, 2015.

Wind

As discussed in Chapter 2, wind is also a potential source of damage to Army installations and may change in character because of climate change. According to NOAA analysis, it is unusual for large tornadoes to develop in late autumn.¹⁷⁸ While the effects of climate change on tornadoes are unclear, in part because of their usually small footprint and limited observational data, it is possible that the timing of these events or the regions in which they typically occur

¹⁷⁸ It was a 12 to 15 percent likelihood as opposed to 90 percent in June. NOAA, "The December 2021 Tornado Outbreak, Explained," webpage, December 20, 2021.

could shift.¹⁷⁹ High winds are associated with multiple hazards such as tornados or hurricanes. High wind warnings occur when wind speeds are over 40 mph. Damaging winds are those exceeding 50 to 60 mph. Wind events that see wind speeds around 70 to 80 mph may cause damage to buildings. Damage from severe thunderstorm winds is more common than damage from tornados. While climate change is expected to alter wind patterns, long-term trends are not well characterized.¹⁸⁰

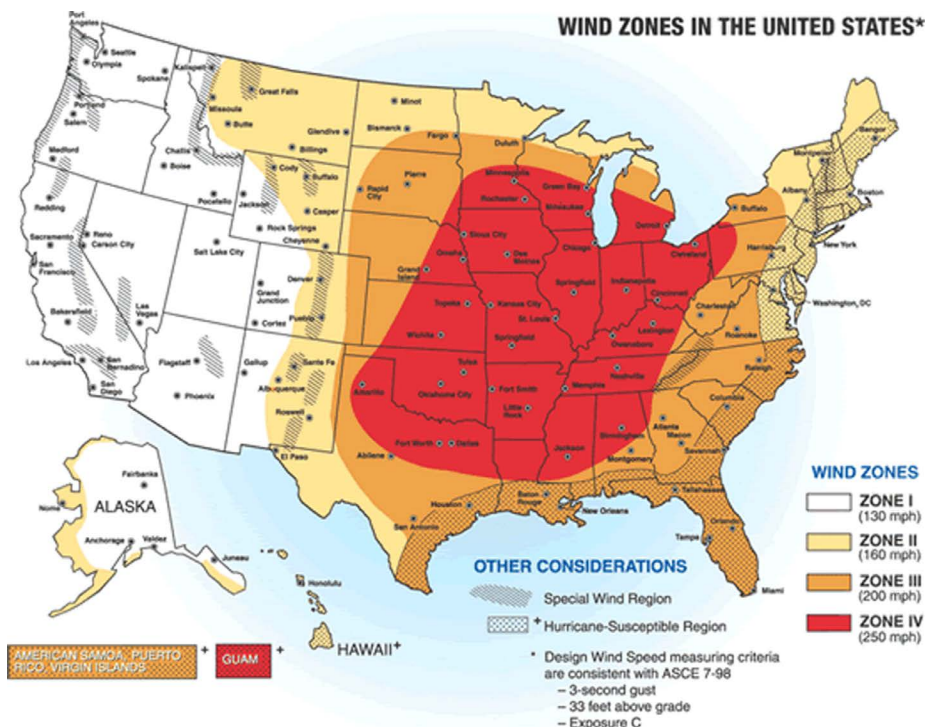
Shown in Figure A.4, FEMA published a wind zone map for use in developing standards for shelter. Both riverine and coastal flooding are expected to increase in the future as the frequency of heavy rain events increases and sea-level rise occurs. However, the distribution and magnitude of this change across the United States varies because of land-use patterns and other factors. The Northeast, Midwest, and Pacific Northwest are expected to experience more flooding, while the West and Southwestern United States are expected to see less. Both the Gulf and Atlantic coasts will see increase inundation from sea-level rise and the Pacific Northwest less so.¹⁸¹ The historical patterns and damages of such natural hazard events at Army installations are discussed more in the next chapter.

¹⁷⁹ Center for Climate and Energy Solutions, “Tornadoes and Climate Change,” webpage, undated.

¹⁸⁰ NOAA National Severe Storms Laboratory, “Severe Weather 101 – Damaging Winds at Severe Weather 101: Damaging Winds FAQ,” webpage, undated.

¹⁸¹ Wehner, et al., 2017; Environmental Protection Agency, “Climate Change Indicators: River Flooding,” webpage, August 1, 2022; and Environmental Protection Agency, “Climate Change Indicators: Coastal Flooding,” webpage, August 1, 2022.

Figure A.4. Wind Zones in the United States



SOURCE: FEMA, Reference Number 11EL015, September 13, 2011.

Data Sources on U.S. Natural Hazards, Patterns and Trends

Dozens of different data sources and web-based tools provide natural hazards patterns and trend data for the United States, regions, states, and localities. These data sources range from primary federal agency data to academic studies of specific hazards. Several federal agencies are responsible for gathering the primary data used in these sources, such as weather conditions and storm events, drought, stream-flow measurements, or agricultural and other economic activity. For example, NOAA's NWS collects information on storm events, the USDA's Forest Service provides historical data on wildfires, and the USGS monitors and collects information on stream-flows and floods. NASA's Earth Observing System collects data on the Earth's atmosphere, land, ocean, and cryosphere (the earth's surface over frozen water) that is used by climate modelers and other research scientists.

Other agencies and organizations combine or assess this primary data to provide information and tools that support their mission. For example, FEMA's National Risk Index draws from the storm data gathered by the NWS and published by the NCEI, U.S. Census data, Department of Agriculture, among other sources and synthesizes the information to help communities assess risk. The Spatial Hazard Events and Losses Database (SHELDUS)TM provides county-level information on hazards and losses drawing from many of the same data sources as FEMA's

National Risk Index. Many of these sources are designed to help communities plan for, prepare for, respond to, and recover from natural hazards disasters.

Furthermore, many of these sources include information about resilience and climate change. For example, U.S. Environmental Protection Agency provides access to over 25 tools to help communities and water utility managers and planners understand, plan for, and adapt to climate change.¹⁸² Many of these rely on the same primary data from other federal sources, such as Climate Resilience Evaluation and Awareness Tool (CREAT), a risk assessment tool to help water utilities adapt to climate change by providing information on current and projected weather conditions, which relies on output from climate projection models and climate and weather data collected by various federal agencies.¹⁸³

There are also state and local sources of data. For instance, each state has a hazard mitigation plan as well as many metropolitan areas or local municipalities, since FEMA requires the development of these plans for a community to receive certain types of non-emergency hazard mitigation grants.¹⁸⁴ Hazard mitigation plans have detailed information about state and local natural hazard trends for community planning that can be relevant for installation planners.¹⁸⁵ It can be overwhelming for installation managers and planners to know which natural hazard sources to use given the diversity of these tools and data sources. However, many of these sources rely on the same fundamental primary data sources for natural hazards data and transform it for their specific purpose.

As mentioned earlier, some natural hazards will be affected by climate change. To project local-effects for many natural hazards additional modeling at a finer scale such as a regional-level, and higher-resolution is required. Because of data and modeling limitations, suites of

¹⁸² U.S. Environmental Protection Agency, “Tools for Water Related Climate Change Adaptation,” December 23, 2021.

¹⁸³ For example, historical data includes temperatures, high-heat days, precipitation, stream-flow, and coastal subsidence and flooding. Spatial temperature and precipitation data are taken from the Parameter-elevation Regressions on Independent Slopes Model (PRISM), which ingests information from NWS Cooperative Observer Program and USDA Forest Service and Bureau of Land Management Remote Automatic Weather Stations data and several other primary sources. High heat days and extreme precipitation events are derived from a time series analysis of NOAA National Climate Data Center datasets and streamflow data are taken from USGS stream gauges. Projections are developed from Global Climate Models (GCMs) outputs provided through the Coupled Model Intercomparison Project, Phase 5 (CMIP5) using different methods for each climate factor of interest and combined to create a scenario for planning (these scenarios are intended to inform planning, and each climate factor is considered separately). Note that the newest CMIP models are phase 6 models. For more on additional primary data sources and methods used by CREAT see EPA, “Climate Resilience Evaluation and Awareness Tool: Version 3.1 Methodology Guide,” Office of Water, EPA 817-B-21-001, March 21, 2021. For more information see EPA, “Climate Resilience Evaluation and Awareness Tool (CREAT) Risk Assessment Application for Water Utilities,” November 29, 2021.

¹⁸⁴ Examples of such grants include: FEMA’s Hazard Mitigation Assistance (HMA) program and Fire Management Assistance Grants. FEMA, “Hazard Mitigation Planning for States,” Fact Sheet, March 2021.

¹⁸⁵ For an example for the Colorado Springs, CO, area see Pikes Peak Regional Office of Emergency Management, “Pikes Peak Multi-Hazard Mitigation Plan Update 2020,” 2021.

models are often used for analysis. These projections are inherently uncertain due to a variety of factors such as the modeling techniques used, availability and quality of historical data, natural variability, and others. Some tools are in development to assist communities with climate projections, for example through NOAA's Regional Integrated Sciences and Assessments Program (RISA).¹⁸⁶ A recently released tool, Climate Mapping for Resilience and Adaptation, provides natural hazard projection information for a limited number of hazards to assist individuals and communities in considering exposure to climate-related natural hazards. Hazards included are coastal inundation, drought, extreme heat, flooding, and wildfire. The tool also includes information on curated data sources.¹⁸⁷ Since the quality of the modeling, data, and information can vary based on location, it is difficult to identify any one national source for local needs.

After reviewing these and other data sources, we used information on natural hazards patterns and trends from four main primary data sources that were combined with local data from more specialized data sources. Each of the four main sources is discussed in greater detail below.

Data Sources Used for the Natural Hazards Analysis in this Report

We examined over 15 data sources for national, regional, and local information about U.S. natural hazards patterns and trends before focusing mostly on four authoritative national sources: FEMA's National Risk Index, Defense Climate Adaptation Tool (DCAT), the Department of the Air Force's Severe Weather/Climate Hazard Screening and Risk Assessment Playbook, and National Oceanic and Atmospheric Administration's (NOAA's) National Center for Environmental Information (NCEI). We also used other specialized data sources as needed, such as the Forest Service's Research Data Archive; the Rocky Mountain Insurance Information Association; the research studies generated for the U.S. Global Change Research Program; and the Fourth National Climate Assessment to better understand the national temporal and spatial historical patterns and projected trends for these hazards.

The National Risk Index

FEMA's National Risk Index is designed to help communities, homeowners or renters, and the insurance and mortgage industries understand risks from natural hazards.¹⁸⁸ Not only is understanding community exposure important for interpreting and applying insurance information, it also provides the broader context for determining installation resilience, since communities' affect installation resilience through land-use patterns, shared infrastructure, and

¹⁸⁶ NOAA Climate Program Office, "About the Regional Integrated Sciences and Assessments Program," webpage, undated.

¹⁸⁷ CMRA, "Climate Mapping for Resilience and Adaptation," climate.gov, webpage, undated.

¹⁸⁸ The risk index is a composite value, provided by census tract or county, is derived from information on the expected annual loss from natural hazards, a social vulnerability factor, and a community resilience factor.

services. Included in the index are 18 natural hazards of concern that occur across the United States, such as riverine flooding, hail, heat wave, hurricanes, and tornados. These 18 hazards were selected because they are included in at least half of the FEMA-approved state hazard mitigation plans.¹⁸⁹ These hazards can either be measured as distinct events (e.g., number of hail events) or as the duration of a condition (e.g., number of days of extreme heat) that affects a geographic area. Underlying exposure data are sourced from national-level records maintained by FEMA, NOAA, NWS, USACE, University of South Carolina’s Hazards and Vulnerability Research Institute, USGS, and the Spatial Hazards Events and Losses Database for the United States (SHELDUS), a fee-based service.¹⁹⁰

FEMA provides a mapper tool that allows users to review the risk index by county or census tract and view the underlying information for each component of the index, including historical rates of natural hazard occurrence.

The Defense Climate Adaptation Tool

DCAT was derived from the ACAT which was developed by the U.S. Army Corps of Engineers.¹⁹¹ DCAT is a screening tool that installations can use to assess potential exposure to natural hazards, including the climate change effects on those hazards. The DCAT was developed to ensure the Department of Defense and the Services evaluate vulnerability to natural hazards consistently. The hazards included in the DCAT include coastal flooding, riverine flooding, drought, energy demand, heat, historical weather extremes (e.g., tornado, hurricane level wind, precipitation, ice storm or jam), land degradation, and wildfire. Those hazards that are projected to be affected by climate change are assessed for two 30-year epochs that are consistent with the periods projected by climate models.¹⁹² DCAT allows analysts to review the exposure of installations across the Army or an individual installation may also use the screening tool to examine its projected hazard exposures for different time periods either in aggregate or for a given hazard of concern.

Underlying data and projections are derived largely from the same information used for the Fourth National Climate Assessment.¹⁹³ Exposure to the eight hazards listed is assessed and scored based on historical and projected data (where applicable) for a weighted set of normalized

¹⁸⁹ FEMA, “National Risk Index Technical Documentation,” November 2021, pp. 2-2 to 2-3.

¹⁹⁰ FEMA, “National Risk Index Technical Documentation,” November 2021, pp. 2-2 to 2-3.

¹⁹¹ In FY 2019 the Department of Defense expanded the ACAT, which assessed exposure to six hazards for 110 Army installations to include eight hazards and other Services’ installations, resulting in over 1,400 installations worldwide. The six hazards covered in ACAT are coastal flooding, riverine flooding, desertification, wildfire, thawing permafrost, and drought. See Pinson, et al., 2021.

¹⁹² Pinson, et al., 2020.

¹⁹³ Donald J. Wuebbles, David W. Fahey, and Kathy A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, eds., *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, U.S. Global Change Research Program, 2017.

indicators that measure contributors to the hazard. For example, riverine flooding risk indicators are flood extent, number of extreme precipitation days, flood magnification factor for the future, maximum one-day precipitation, and maximum five-day precipitation. The historical weather extremes hazard is projected using indicators of hurricane frequency, hurricane maximum average precipitation, tornado frequency, hurricane wind greater than 50 knots, wildland urban interface, ice storm occurrence, ice jam occurrence, and historical drought frequency.¹⁹⁴ The underlying indicator data comes from many federal agencies' primary sources including the U.S. Department of Agriculture, FEMA, USGS, U.S. Global Change Research Program, National Aeronautics and Space Administration, NOAA, and National Science Foundation's National Center for Atmospheric Research. For example, continuing the riverine flooding hazard example, the flood extent indicator is taken from FEMA's National Flood Hazard Layer one percent annual exceedance probability inundation maps, and future flood levels were approximated using GIS analysis approaches. DCAT includes 175 Army installations and 992 sites for all Army components.¹⁹⁵ Enhancements to DCAT to include sensitivity and adaptive capacity are underway.

The tool has built-in installation reports that draw from National Weather Service data to indicate which extreme weather events have occurred in the county of the installation, the number of events, an estimate of the damage that was incurred, and the top 15 most damaging events to property. These reports also provide some information on the relative importance of natural hazards in the future to that installation for two epochs, 2050 and 2080 and information on heat exposure, flood inundation, and permafrost including information on the number of buildings potentially affected using Defense Installations Spatial Data Infrastructure (DISDI) data.

Air Force Civil Engineer Center's Severe Weather/Climate Hazard Screening and Risk Assessment Playbook

The Air Force Civil Engineer Center's Severe Weather/Climate Hazard Screening and Risk Assessment Playbook is a resource to help installation master planners and other installation professionals assess potential risks from severe weather and climate hazards using a consistent, structured approach for a variety of planning activities such as building projects or emergency management plans. The playbook includes a list of severe weather and climate hazards (listed in Table 2.1) that installation professionals must include in their installation exposure, vulnerability,

¹⁹⁴ The DCAT (and the ACAT) weights the hazard's indicators to come up with composite value of relative exposure. The first weight accounts for the contribution of each indicator to the hazard. A second weight is applied to represent the risk tolerance of the planner. For more on the tool and the weighting scheme see Pinson, et al., 2020 or USACE, Hazard and Indicator Overview Fact Sheets, undated.

¹⁹⁵ Analysis of DCAT site data as of July 18, 2022.

or risk analyses.¹⁹⁶ The Army has created a similar resource, *The Army Climate Resilience Handbook*,¹⁹⁷ which discusses nuisance hazards and extreme weather events and references the list of hazards included in ACAT/DCAT.

In sum, these exposure and risk analysis tools were designed to serve different purposes and therefore the hazards covered will vary. FEMA's NRI provides communities with a tool to evaluate natural hazard risks and focuses on those that have relevance across the United States by assessing approved state hazard mitigation plans. In contrast, the DCAT/ACAT tools were designed to provide a nationally consistent, screening level exposure analysis of climate hazards and extreme weather in response to requirements in national defense authorization acts. Therefore, these tools focus on those hazards that were strongly influenced by climate and that were determined to be relevant to installation and site operations and planning.¹⁹⁸

NOAA's National Center for Environmental Information

The NOAA's NCEI Storm Events Database contains county-level or forecast zone-level historical information on 48 weather event types as reported by the National Weather Service. Records for some event types date to January 1950. Data for these events includes event type, date, locational information, damage information (deaths/injuries, property/crop lost estimates), and severity (if appropriate). Users can search and download information in the database. Event-types are consistently defined, and these definitions are provided in Appendix A of the NWS Instruction 10-1605.¹⁹⁹ Note, the database relies on others to report so there may be some gaps and inconsistencies (for example not all hail events may be observed).

Natural Hazards Resources for Installation Planners

In addition to the DCAT information, other authoritative natural hazards data sources and tools that we identified earlier can be helpful to installation planners who need natural hazards information for specific sites at their local installations. We identified four primary data sources and tools that are available throughout most of the United States that installation planners should find of interest in combination with specialized sources, such as regional, state, and local ones.

- FEMA National Risk Index tool
- Climate Mapping for Resilience and Adaptation website

¹⁹⁶ In addition to the natural hazards listed in Table 2.1, the playbook includes other climate hazards such as desertification, ecosystem shifts, permafrost changes, subsidence/sinkholes, and projections for flooding, precipitation, and temperature. U.S. Air Force "Severe Weather/Climate Hazard Screening and Risk Assessment Playbook," Air Force Civil Engineer, April 24, 2020.

¹⁹⁷ Pinson et al., 2020.

¹⁹⁸ USACE, "Documentation of and Justification for Collapsing NOAA Storm Event Categories," undated [but post-July 2021 because it cites a NOAA report from then].

¹⁹⁹ NOAA, Storm Events Database, webpage, undated; and National Weather Service, "National Weather Service Instruction: Storm Data Preparation," NWSI 10-1605, July 26, 2021.

- NOAA National Centers for Environmental Information, historical Storm Events Database
- U.S. Global Change website

FEMA National Risk Index

The FEMA National Risk Index tool and database, which we used in our analysis, may be helpful to installation planners.²⁰⁰ As explained earlier, the FEMA’s National Risk Index, is designed to help communities, homeowners or renters, and the insurance and mortgage industries understand risks from 18 natural hazards of concern across the United States and is intended to inform community hazard mitigation planning and risk communication.²⁰¹ However, it does not incorporate projections of natural hazard severity due to climate change.

The risk index is a composite value, provided by census tract or county, is derived from information on the expected annual loss from natural hazards, a social vulnerability factor, and a community resilience factor. As mentioned, FEMA provides a mapper tool that allows users to review the risk index by county or census tract and view the underlying information for each component of the index—expected annual loss, social vulnerability, and community resilience—for analysis.

An example of some of the detailed hazard and loss information provided for Bryan County, Georgia (census tract 13029920306), one of the counties within which Fort Stewart is located, is presented in Figure A.5. As seen in the figure, the hazards listed can either be measured as distinct events (number of hail events) or as the duration of a condition (number of days of extreme heat) that affects a geographic area and information on these hazards is provided as an annualized rate and the total for all historical occurrences over the period of record.

The site hosts an interactive map that allows users to review the details for specific counties or census tract and allows the user to generate risk profile reports. The NRI pulls from primary data sources across the federal government including NOAA, USACE, USGS, USDA, NWS, and FEMA. For example, NOAA NCEI data on lightning, riverine flooding; NOAA NWS data on cold waves, heat waves, and winter weather; and NOAA Storm Prediction Center data on hail, strong wind, and tornados were accessed for the NRI.

²⁰⁰ FEMA, “National Risk Index for Natural Hazards,” webpage, undated.

²⁰¹ These hazards were selected because they are included in at least half of the FEMA-approved state hazard mitigation plans. FEMA, “National Risk Index Technical Documentation,” November 2021, pp. 2-2 to 2-3.

Figure A.5. Detailed Information from the FEMA Risk Index Mapper Tool for Bryan County, GA for the Expected Annual Loss Calculation

Annualized Frequency Values

Hazard Type	Annualized Frequency	Events on Record	Period of Record
Avalanche	--	--	--
Coastal Flooding	2.7 events per year	n/a	Various (see documentation)
Cold Wave	0 events per year	0	2005-2017 (12 years)
Drought	22.2 events per year	399	2000-2017 (18 years)
Earthquake	0.113% chance per year	n/a	2017 dataset
Hail	1.8 events per year	58	1986-2017 (32 years)
Heat Wave	0.2 events per year	45	2005-2017 (12 years)
Hurricane	0.3 events per year	44	East 1851-2017 (167 years) / West 1949-2017 (69 years)
Ice Storm	0.5 events per year	34	1946-2014 (67 years)
Landslide	0 events per year	0	2010-2019 (10 years)
Lightning	97.7 events per year	2,151	1991-2012 (22 years)
Riverine Flooding	0.3 events per year	8	1996-2019 (24 years)
Strong Wind	1.1 events per year	35	1986-2017 (32 years)
Tornado	0 events per year	1	1986-2019 (34 years)
Tsunami	--	--	--
Volcanic Activity	--	--	--
Wildfire	0.445% chance per year	n/a	2016 dataset
Winter Weather	0.3 events per year	16	2005-2017 (12 years)

Historic Loss Ratios

Hazard Type	Overall Rating	Building Value	Population	Agriculture Value
Avalanche	--	--	--	--
Coastal Flooding	Very Low	\$2.09 per \$10M	6.59 per 10M	n/a
Cold Wave	No Rating	\$5.25 per \$10M	1.24 per 1M	\$7.01 per \$1K
Drought	No Rating	n/a	n/a	\$2.04 per \$10K
Earthquake	Very Low	\$1.68 per \$100	1.40 per 10K	n/a
Hail	Very Low	\$4.74 per \$1M	2.32 per 10B	\$5.11 per \$1M
Heat Wave	Very Low	\$2.77 per \$10B	5.96 per 10M	\$6.01 per \$1M
Hurricane	Very Low	\$3.63 per \$100K	3.78 per 10M	\$3.98 per \$1K
Ice Storm	Very Low	\$3.15 per \$1M	7.74 per 100M	n/a
Landslide	Very Low	\$9.15 per \$100K	3.31 per 100K	n/a
Lightning	Very Low	\$4.52 per \$100M	1.49 per 1B	n/a
Riverine Flooding	Very Low	\$7.05 per \$1M	1.17 per 100K	\$7.66 per \$1K
Strong Wind	Very Low	\$1.40 per \$1M	1.92 per 10M	\$3.33 per \$100K
Tornado	Very Low	\$1.67 per \$1K	4.91 per 100K	\$4.28 per \$10K
Tsunami	--	--	--	--
Volcanic Activity	--	--	--	--
Wildfire	Very Low	\$4.00 per \$10	2.53 per 100K	\$1.36 per \$100
Winter Weather	Very Low	\$1.24 per \$100K	5.34 per 100M	\$2.51 per \$1M

Climate Mapping for Resilience and Adaptation

The Climate Mapping for Resilience and Adaptation (CMRA) is a new tool that was developed to help communities that may not have a lot of resources or expertise understand their exposure to natural hazards specifically affected by climate change. As such it is a useful place to begin to screen potential exposure to climate-related hazards. The tool links to curated information on these hazards. It includes real-time, historical, and projection information for hazards such as coastal inundation, drought, extreme heat, flooding, and wildfire by linking to sources from across the federal government. For example, the tool links to the Climate Explorer that was developed for use with the U.S. Climate Resilience Toolkit to incorporate projections at the county-level for various statistics on temperature and precipitation, for two commonly used climate scenarios, a sample of which is shown in Figure A.6. In effect the Climate Mapping for Resilience and Adaptation is a one-stop shop for navigating and accessing federal data on climate-related hazards.²⁰²

²⁰² CMRA, “Climate Mapping for Resilience and Adaptation,” climate.gov, webpage, undated.

Figure A.6. Example of County-level Information in the Climate Explorer



NOAA Sites

NOAA National Centers for Environmental Information, Storm Events Database contains data gathered by the National Weather Service of storms spanning the period January 1950 to February 2022 (data for specific storm types may have different periods of record).²⁰³ Early data are limited to tornados, thunderstorm wind and hail, but 48 event types are tracked for the period 1996 to the present. Storm data fields include the location, county or zone, date, time, storm type, and reported deaths, injuries, property damage estimate and crop damage estimate. The database is searchable and downloadable. The database is useful for identifying storms and getting a rough understanding of their frequencies but because there are gaps in the information other sources may be more appropriate for modeling purposes.

NOAA also provides useful State Climate Summaries that provide state-level summary information on historical climate conditions such as temperature and sea-level rise, and

²⁰³ NOAA, “Storm Events Database,” [ncdc.noaa.gov](https://www.ncdc.noaa.gov/stormevents/), webpage, undated.

projections of long-term trends and extreme weather events for different greenhouse gas emissions scenarios.²⁰⁴ The state summaries from 2022 includes graphs showing many of the state relevant historical conditions since 1900 (e.g., observed annual precipitation and observed number of hot days).

U.S. Global Change

The U.S. Global Change website (GlobalChange.gov) is the central location for accessing federal information on climate change and therefore includes information on climate change science more broadly than the effects on natural hazard patterns and trends. However, the Fourth National Climate Assessment, state summaries of projected climate effects on natural hazards, and a climate resilience tool can be accessed through this site.

²⁰⁴ The state summaries can be accessed at NOAA, North Carolina Institute for Climate Studies, “State Climate Summaries,” statesummaries.ncics.org, webpage, undated.

Appendix B. Background on Army Installation Data

To understand installations' vulnerabilities to natural hazards and past cost damage from natural hazards we needed to identify which installation data sources in the Army captured this information. There is no centralized Army data for natural hazards damage across the Army. Each Army organization that is responsible for Army-owned real property (including installations, sites, and facilities) tracks these historical event costs to buildings (and other real property assets) through SRM and MILCON projects. Army organizations that manage Army-owned real property and have historical data include: IMCOM, AMC, ARNG, and the Army Reserve. We reached out to acquire data from all these organizations, but focused on acquiring and acquired data from the largest real property owners, namely, IMCOM and the ARNG.

In this appendix, we provide information about the main Army installation data sources used in this study, which includes sources for the natural hazards damage data and other relevant data. We provide source information about Army managed installation and buildings that have been damaged by natural hazards. The sources for data from different Army installation and facility owners include the Active Component (AC) installations managed by IMCOM, AC installations historically managed by AMC, ARNG installations, and Army Reserve installations. We obtained data for IMCOM and ARNG installations. The Army Residential Communities Initiative (RCI), which is the privatized housing, insurance covers a group of buildings, so it was not relevant for our building-level methodology. This appendix provides information about natural hazards damage data about the IMCOM SRM Storm Damage Data for SRM repairs, the ARNG Act of Nature SRM Data, and the MILCON Data from the G-9 and ARNG. In addition, this appendix provides information about geospatial data used in this study, which include Army Installation Geospatial Information & Services (IGI&S) and other geospatial data sources. Lastly, we provide a brief overview of the Installation Status Report data.

IMCOM Storm Damage Data for SRM Repairs

Headquarters Installation Management Command (HQ IMCOM), reserves sustainment funding to help pay for "natural disaster and fire damages" at IMCOM Directorate Garrisons, called the HQ IMCOM natural disaster and fire damage reimbursement funds, or SRM 'storm damage' funding. Based on a five-year running average of storm damage expenses IMCOM funds this account at roughly 3 percent of the annual sustainment account.

IMCOM has developed business rules and a process for distributing these funds.²⁰⁵ Installations are required to reserve 5 percent of their initial, unallocated sustainment funding

²⁰⁵ IMCOM Public Works, "Natural Disaster and Fire Damage Business Rules," U.S. Army, October 1, 2021.

(Management Decision Package (MDEP) QRPA (Real Property Maintenance (Sustainment))) for repairing storm or fire damage. Namely, installations must use 5 percent of their total SRM funding for such damage out of their existing unallocated SRM funding before they can request repair funding from this HQ IMCOM storm damage reserve to pay for the SRM costs. For example, if an installation receives a total of \$100 million for SRM funding then it must spend \$5 million of these funds on repairing facilities damaged by natural hazards events before requesting funds from IMCOM HQs. For storm or fire damage that exceeds five percent of an installation's SRM, installations can request funding from IMCOM's storm damage reserve to pay for the repair costs that are in excess.

According to these rules the funds' uses are limited to Sustainment, Restoration, Modernization (SAG 132), Army Family Housing Operations (SAG 1920), and Base Operations Support (SAG 131) and can only be used for getting "the affected facilities ... back into operation in a timely manner" by making repairs to return the buildings, other facilities, and infrastructure to the condition they were in before the storm occurred. "It does not provide funding for major repairs nor does it provide for "get well" solutions, the upgrade of original materials, fix design errors, or reduce maintenance responsibilities." If "major repairs or replacements are needed," the installation must request restoration or MILCON funding.²⁰⁶ In summary, these funds are only for getting the building, other facilities, and infrastructure operational in a timely manner by making repairs to return them to the condition they were in before the storm occurred.

Base Operating Support (BOS) costs are those for services to keep installations operating, e.g., grounds and infrastructure maintenance contracts. Storm-related BOS costs usually include the cost of removing trees and other debris after a storm, fixing equipment, and personnel overtime. SRM costs include costs to repair buildings, other facilities, and infrastructure. Non-building SRM costs can include repairs to roads, powerlines, fiber optic cables, fences, bridges, signs, railroad tracks, and culverts and other stormwater facilities.

There are three steps in the funding process. First, installations have 72 hours to notify IMCOM if damage occurred. Second, they submit a detailed report describing the damage and estimated repair costs within 30 days, which includes a completed draft of a spreadsheet validation report, digital photos, and DPW engineering estimates for repair projects. The submission must be signed by the garrison commander. Third, IMCOM staff validate the funding request and create the final validation report, usually through a site visit to the installation. This validation report spreadsheet is called the SRM Storm Damage Data Validation Report and it includes information about each facility damaged. Each row includes: a facility number, a short description of the damage, the requested SRM and BOS funds needed to repair the damage (called unvalidated costs), comments, and other information. These SRM costs are not just for

²⁰⁶ IMCOM Public Works, "Natural Disaster and Fire Damage Business Rules," U.S. Army, October 1, 2021, and U.S. Army IMCOM, "IMCOM FY21 Narrative Funding Guidance," Version 2, February 1, 2021.

buildings; they also include costs for other facilities, namely, structures (e.g., bridges and carports) and utility systems.

IMCOM also creates a fiscal year summary of the funding provided within each year. This FY storm damage funding spreadsheet contains installation-level information on each storm and fire event type, total unvalidated and validated SRM and BOS costs for the storm event, comments, and project tracking information.

We acquired these fiscal year storm damage funding spreadsheets for most years between FY 2011–FY 2021, except for FY 2012 and part of FY 2014 where data were not available. However, IMCOM did supply us with some individual SRM Storm Damage Data Validation Reports for FY 2014. Total we acquired installation level information for 104 storm and fire events between FY 2011–FY 2021.²⁰⁷ We also acquired all the available SRM Storm Damage Data Validation Reports for the 40 installation-storm events during this same time period of which 35 had building information. For the five events without any building damage data, they only had SRM damage to other facility types and/or BOS related damages. For example, one event may have had damage to installation roads, bridges, and culverts and BOS costs to clear debris away. In examining the building-level data, we found some inconsistencies in how data were entered and recorded.

The IMCOM storm damage fund is intended to cover repairs needed to maintain building operations after unforeseen events and does not cover all types of damage to installation buildings. Specifically, major repairs are not covered by the fund. If major repairs are required installations must submit those projects to a separate fund, the IMCOM Restoration Program (MDEP ERVT (Recapitalization deficit)). Furthermore, the buildings managed by RCI Housing and facilities on installations managed by AMC (e.g., Army Working Capital Fund (AWCF) installations) are not eligible for this natural hazard and fire damage funding.

While the fund cannot be used for general building upgrades and improvements, repairs must meet current building standards and codes applicable to the original design. Therefore, these repairs could potentially improve building resilience if either building codes or standards have changed since the building was constructed or last renovated.²⁰⁸ The fund is distributed in the first three quarters of a fiscal year, in part because of the time it takes to assess damage and establish contracts. In the fourth quarter IMCOM commanders accept some risk that a natural hazard or fire event may occur that cause damage affecting installations' ability to support mission operations and the funds are realigned into the FIP account.

²⁰⁷ Three of these events were structural fires which we removed from our dataset for analytical purposes, so our set became 101 storm events. These data included three earthquakes which we also removed, so our final number of storm events of interest were 98.

²⁰⁸ Discussion with IMCOM personnel, August 1, 2022.

Once a repair project is executed installations are required to record the costs in GFEBs as MDEP VHUR (Storm Damage), although the reliability is unknown since these records are not routinely verified by headquarters staff.²⁰⁹

ARNG Act of Nature SRM Data

ARNG calls damage from a natural hazard an AoN. We acquired SRM projects for the AoN damage for ARNG buildings between 2011 and 2021 which consisted of 118 building projects.²¹⁰ These data came from the ARNG PRIDE data system. These data included installation name, location, description of the building (e.g., Field Maintenance Shop or Readiness Center), the MDEP code, and the cost of the MILCON project. For example, VHUR (the MDEP code for natural disaster expenses)²¹¹ was listed as the MDEP for Jackson Barracks building projects that were damaged by Hurricane Katrina in 2005.

MILCON Data from the G-9 and ARNG

We acquired MILCON data from two primary sources: the G-9 and ARNG. Staff from the Army G-9 provided us with the active-duty installation MILCON projects required because of storm damage, which consisted of buildings and other facility damage for only four installations between FY 2011 and FY 2021.²¹² These data came from the CAPCES. We acquired MILCON projects for the AoN damage for 29 ARNG buildings between 2005 and 2021. These data came from the ARNG PRIDE data system. We should note that in examining documents about MILCON funds spent at Army installations we observed some additional buildings that were being replaced because of storm damage, and not in the data we acquired from the PRIDE and CAPCES enterprise databases. Thereby, the data in this report about costs from natural hazards damage to Army buildings that required MILCON funding should be considered a lower bound and additional analysis would be needed to understand the actual building and other costs for the Army from these past storm events.

MILCON costs are usually for buildings that were demolished and replaced with the construction of an entire new building, so it is difficult to assess the value of resilience investments on such buildings. Where MILCON data are useful is to help understand exposure from past storms and to understand the types of damage that may have been prevented by a

²⁰⁹ Discussion with IMCOM personnel, August 1, 2022.

²¹⁰ Since these data were missing key attributes, including natural hazard event type, we were not able to use them directly in our analyses as with the IMCOM storm damage data.

²¹¹ Technically VHUR is the MDEP code for humanitarian and disaster relief expenses. It is used to track costs incurred in support of domestic and international humanitarian assistance and disaster relief operations, including hurricanes, floods, earthquakes, wildfires, and other emerging contingencies.

²¹² Only two of the installations had MILCON building construction projects. The other installations had other types of MILCON projects, e.g., constructing a dam that had broken during a flood.

resilience investment. For example, if a building required MILCON funding because a hurricane blew the roof off and then rain from the storm damaged the interior so much that the building was a total loss, and hurricane straps might have been able to prevent such extensive damage that is useful to understand. However, if the building was destroyed by so strong a hurricane or tornado that such resilience investments would not have prevented the building from being destroyed that tells a different story.

Army Installation Geospatial Information & Services (IGI&S) and Other Geospatial Data

Army IGI&S data were acquired to assess installations and facilities geospatially. These data included the Army common installation picture (CIP) GIS layers for installation boundaries, buildings, roads, parking lots, water features, and other relevant data layers. IGI&S installation CIP data provided information about where the installation case study buildings are located and some of their basic characteristics, such as CATCODEs. We also used GIS data from Esri on basic U.S. state, county, zip code, transportation, and water to provide local and regional orientation and context and to help with the NFIP flooding analyses. USGS geospatial data about watersheds was also acquired and used for selected installations to help with the floodplain assessments (see Appendix E for more details).

Installation Status Report

The ISR is designed to provide information on the functionality and quality of each installation's permanent and semipermanent real property, environmental programs, and service activities. It is used to support funding decisions for installations, including to help inform decisions about MILCON and SRM funding. Part of the ISR, called the Installation Status Report-Infrastructure (ISR-I), is the main centralized reporting system for facility quality ratings and cost data for the Army. Facility managers conduct periodic standardized inspections of facility conditions, and the results are then recorded in the ISR-I. For each building and other facility types, ISR contains information about the building characteristics (e.g., year built, category code, and site location) quality ratings and cost data, including an estimate of the facility's replacement value, called the Engineered Replacement Value (ERV). ISR-I also includes some Component Quality Ratings for general components of the building such as the foundation, exterior roof, exterior walls, exterior windows and doors, interior corridors and stairways, and antiterrorism and fire protection features.

Appendix C. Selection Process and Criteria Used for the Installation Building Case Studies

In this appendix, we explain the selection process and criteria used to select the installations and individual buildings for our insurance case studies. The purpose of the case studies included providing the specific illustrative installation buildings that we are applying to the insurance assessments and to help us develop the methods for using insurance information to help value resilience investment measures. They also demonstrated the ability to value resilience investment measures using insurance data. In addition, the case studies also helped inform our recommendations for the Army.

Since the selection of the case studies was based on the needs for both the commercial property insurance and the NFIP premium calculations we explain this analysis first. Since this is an exploratory study we wanted to identify a manageable number of relevant case studies that were most useful to the Army and would reflect different building vulnerabilities, exposure, costs, and missions types. We also wanted to select case studies where it would be most feasible to calculate insurance premiums given the challenges between comparing Army building types to the insurance building types and the nature of the insurance premium calculations.

To select case studies, we needed information about the building types that are relevant to both insurance coverage and Army installations. Different Army real property asset types are more relevant to the Army than others because of the significant damage incurred to them from previous natural hazards. Case studies were selected in locations that have insurance coverage with incentives for natural hazards resilience investments, Army installations and facilities, and relevant natural hazards exposure. The selection of the case studies relied on the same data sources and methods described in Appendix B and Chapter 3. For example, we used Army geospatial data, CATCODEs from the ISR, and DCAT and NFIP floodplain data to help choose the case studies. We do not summarize the data sources nor the approach here. Instead, we explain the analyses used to choose the installations and individual buildings for the case studies.

For the case studies, we developed an illustrative set of buildings to represent different Army installation buildings by location and type, but we needed to balance it with the computational requirements for the insurance analyses. We choose five installations as case studies for commercial property insurance and four for NFIP insurance assessments with three building types—barracks, office, and maintenance buildings—for most installations.

Choosing Installations for the Case Studies

The selection process for installation case studies for the commercial property insurance was slightly different from the NFIP cases based on how the insurance coverage and premium

calculations work for each category of insurance, so we discuss the selection process for each insurance type separately. Table C.1 shows the results of these selection processes:

Table C.1. Installations Selected for the Insurance Case Studies

	Commercial Property Insurance	NFIP Flood Insurance
Installations Selected (in alphabetical order)	Fort Belvoir, VA Fort Moore, GA Fort Carson, CO Fort Sill, OK Fort Stewart, GA	Aberdeen Proving Ground, MD Fort Carson, CO Fort Cavazos, TX Fort Stewart, GA

Choosing Commercial Property Insurance Case Study Installations

To select installations for the commercial property insurance we needed to know which states had sufficient insurance rate formula data and how it varied in different states. We found sufficient data for seven states: California, Colorado, Georgia, Kansas, New Jersey, Oklahoma, and Virginia. We found that one insurance company had rate calculations for hurricane coverage only in GA and it varied by how close the building was to the coast given the hurricane risks. Because of this company, we decided to pick an installation in GA along the coast. Only one active-duty Army installation met these criteria: Fort Stewart–Hunter Army Air Field. It became the base case for the commercial property insurance.

To compare the difference between coastal and inland for this insurance company we decided to add another installation case study in Georgia. Fort Moore was the obvious choice since it was a large installation in Georgia and had had eight storm damage events that required IMCOM SRM storm damage funds, including two tornados and three hurricanes.²¹³ To keep the calculations manageable and to represent insurance calculation differences based on the locations of natural hazards exposure and where the Army has more buildings in potential harm's way, we selected three other locations as shown in Table 4.1: Fort Belvoir, Virginia; Fort Carson, Colorado; and Fort Sill, Oklahoma.

Because of the coastal hurricane risk, we wanted to select an installation in another Eastern or Gulf coastal state, like Fort Liberty, North Carolina, or Fort Johnson (formerly Fort Polk), Louisiana. However, we did not find sufficient insurance rate formula data for these states. The only two Eastern coastal and Gulf Coast states with sufficient data were New York and Virginia. Virginia was chosen over New York state because it had four installations with a total of 11 storm installation storm damage events including five hurricanes; in comparison, NY had only two installations with a total of five storm installation storm damage events. Fort Belvoir was chosen because it has coastal storm surge risk and it has had four storm events requiring IMCOM storm damage funds, including two hurricanes.

²¹³ Fort Gordon is another important IMCOM managed installation in GA, but it has fewer buildings and it had not been in any of the IMCOM storm damage data.

To capture storm risks in different parts of the country, especially related to tornados, hail and other types of strong wind events, we wanted to choose cases in the Midwest. Fort Carson, Colorado, was an obvious choice, because it has had eight storm damage events, including two windstorm and three hail events. The Colorado Springs region where Fort Carson is located is well-known for having frequent hailstorms. To make sure we had captured the tornado risk sufficiently we wanted to choose an installation in the middle of the United States with a history of tornados, for which we could also get sufficient insurance data, which meant selecting an installation in Kansas or Oklahoma. Since it had more storm damage events and has a large soldier population, we chose Fort Sill, Oklahoma instead of Fort Leavenworth or Fort Riley, Kansas.

Choosing NFIP Insurance Case Study Installations

NFIP coverage for flood varies by specific location and is available in every state so we did not have the same geographic limitations as with commercial property insurance. However, NFIP premium calculations depend on a variety of conditions at the specific site where the building is located and other factors (discussed more in Chapter 5). For instance, exposure at a building's location depends on the distance from water bodies and ground elevation relative to the typical water surface elevation of the hazard source, among other attributes.

For our potential case studies, we wanted to select installations with either a history of flood damage or relatively high exposure to flooding to ensure representative buildings (i.e., barracks, office, and maintenance building with desired CATCODEs) were likely to be affected. A key part to understanding flood exposure was examining installations with past flood damage within the IMCOM storm damage data and with a high percentage of area in the DCAT 1 percent AEP floodplain,²¹⁴ more commonly called the 100-year floodplain. Since Fort Stewart was chosen as the base case for the commercial property insurance assessment, had coastal property at Hunter Army Airfield, and had buildings of interest in the 100-year floodplain, it was chosen as a case study. We chose Fort Carson as a second case study because of its flooding history and because DCAT data showed a wide range of buildings of interest in the 100-year floodplain.

We wanted to select two additional installations with a history of flood damage and/or high DCAT flood exposure for the buildings of interest. First, we examined the percent of each installation within the DCAT 100-year flood plain and that had past flood events in the IMCOM storm damage data. We started by looking at installations with the highest percentages of area in

²¹⁴ This statistical threshold is equivalent to the delineated Special Flood Hazard Area on FEMA's FIRMs, commonly referred to as the 100-year floodplain. While a buildings presence either in or out of this zone is no longer used for rating purposes, it suggests for planning purposes that it is exposed to flooding at a frequency where flood insurance could be reasonably considered (and indeed required if a homeowner carries a federally backed mortgage, for example). We note, however, that FEMA has found that properties outside of high-risk areas are not impervious to flooding. FEMA analysis indicates that these properties are responsible for "more than 25 percent of NFIP claims and receive one-third of disaster assistance for flooding." (See FEMA, "Fact Sheet: Myths and Facts About Flood Insurance," DR-4421-1A FS 016, June 11, 2019, last updated March 18, 2021.)

the floodplain using DCAT, NFIP, and other data sources and the most past flood events. We examined these installations in ArcGIS to see where and how many buildings of interest were in the 100-year floodplain.

We examined over 20 different installations including Detroit Arsenal, Fort Belvoir, Fort Liberty, Fort Greely, Fort Irwin, Fort Leonard Wood, Fort Leavenworth, Fort Johnson, Fort Sill, and Redstone Arsenal. For example, we looked at Detroit Arsenal because it had had three floods in the last 10 years that were significant enough to need IMCOM storm damage funds. However, it is a small installation and had very few building types of interest and few within the 100-year floodplain. Some installations appeared to have a large percentage of buildings in the floodplain based on DCAT values but required additional analysis to examine the relationship to the cantonment areas and buildings of interest to floodplains. Upon additional study utilizing ArcGIS, some installations (e.g., Fort Johnson, Louisiana) had not built many buildings in the actual floodplain. In addition, we found that DCAT's 100-year floodplain data were not always sufficient to understand flood risk because, in some cases, it was not the most accurate dataset for the installation. We compared DCAT maps to FEMA FIRMs where available, as well as third-party resources such as Risk Factor maps generated by the First Street Foundation. We also used USGS hydrological data, including river and creek locations to help understand flood hazards.

We chose Fort Cavazos for the third NFIP case study because it had a high number of buildings of interest in the 100-year flood plain (over 80) and it had useful site characteristics to explore different aspects of the NFIP insurance premium calculations. Specifically, we examined building locations at Fort Cavazos relative to streams and other water bodies along with the type of stream and topography to identify diverse situations for calculating NFIP premiums. In fact, we decided to use Fort Cavazos as a base case for the NFIP premium calculations because of the diversity of its building site characteristics related to flood exposure.

Last, we also wanted to include an installation that had buildings within or near the coastal storm surge floodplain to demonstrate additional NFIP-based calculations, so we selected APG, MD, as a fourth installation. However, since APG does not have many Soldiers assigned to it because of its primary focus on research and development and equipment testing and evaluation, we did not use it to explore all building types, which is discussed more in the next section.

Choosing Individual Buildings for the Case Studies

At the same time as we were identifying which installations to include in the case studies, we were also trying to understand which buildings to select within each building type (i.e., barracks, office, and maintenance buildings) as representative case studies for the Army in our insurance analyses. We examined the installation storm-damage buildings by CATCODE in each of our building types and which CATCODEs were most important to the Army given the costs of those buildings and their missions.

First, we assessed IMCOM Army installation storm damage data to identify which of the Army buildings in each CATCODE have cost the Army a large amount to repair after previous storms. This helps us understand which buildings are likely more vulnerable to natural damage because of past damages. Table C.2 shows the number of buildings by primary CATCODEs of interest with storm damage costing more than \$200,000 from the IMCOM storm damage data. (We examined the data initially for a longer list of CATCODEs in each building type but narrowed it to the ones most applicable for our purposes.) Then we supplemented these data with Army documents about the various CATCODEs and building types and information gleaned from discussions with building experts from the G-9, ASA(IE&E) and other staff. Using this information, we identified which of the CATCODEs were most appropriate for our purposes as shown in Table C.2.

Table C.2. CATCODEs of Priority Interest for Barracks, Office Buildings and Maintenance Buildings

General Building Category	CATCODE	Army-wide No. of Buildings within the CATCODE	Number of Buildings with Cost Damage >= \$200K	CATCODE Title
Barracks	72111	1948	19	Enlisted Unaccompanied Personnel Housing (UPH)
Barracks	72181	148	4	Trainee Barracks
Office Building	14182	353	3	Brigade HQs Building
Office Building	14183	871	11	Battalion HQs Building
Office Building	14185	1946	21	Company HQs Building (COF)
Office Building	61050	5163	27	Administrative General Purpose
Maintenance Facility	21410	1328	15	Vehicle Maintenance Facility
Maintenance Facility	21885	417	9	General Purpose Maintenance Shop

NOTE: Yellow is for barracks; purple is for office buildings, and red is for maintenance facilities. Lighter colors within each building category are lower priority.

For barracks, we were primarily interested in permanent party enlisted UPH, rather than the training and transient barracks since the permanent party enlisted UPH are usually built to a higher standard because they are primary residences rather than temporary ones.

For office buildings, we identified CATCODEs for command headquarters buildings (e.g., brigade and battalion headquarters) because of their importance to the Army and administrative general-purpose buildings for other installation office buildings. However, in examining the administrative general-purpose buildings, we realized they can include a wide range of building types, including some smaller, less-costly buildings that are cheaper and easier to replace if damaged in a storm event and thereby a lower priority for a resilience investment. Company headquarters tend to have specialized building configurations which would not compare directly to a commercial office building. Given this information and because of their importance to the mission, their cost to replace, and their ability to be compared with commercial office buildings, our first choice for office buildings was a brigade or battalion headquarters. As Table 4.2 also shows the Army does not have as many of these building types, but if we could find ones that met our case study needs, they were our priority choices.

For maintenance buildings, our focus was on the actual facilities used to repair the vehicles and not other buildings located in a motor pool compound. We also focused on facilities that repair the larger combat vehicles (e.g., the Abrams tanks and Bradley fighting vehicles), rather than ones that repair non-tactical vehicles, such as vans and other fleet vehicles. CATCODE 21410 was our priority for the maintenance building case studies since it is used to identify buildings that primarily repair combat vehicles. However, since many different types of ground vehicles are used in warfighting operations, we needed some way to distinguish among these buildings. One way to do this is to choose larger size maintenance buildings since more bay space and larger cranes are needed to repair a tank compared with a wheeled tactical vehicle. Based on discussions with Army subject matter experts we chose maintenance buildings with 10,000 or more square feet.

Appendix D. Background on Commercial Property and NFIP Insurance

In this appendix we provide background information about commercial property and NFIP insurance.

Commercial Property Insurance Industry: Admitted and Non-Admitted Carriers

In the United States, the insurance industry is regulated by the states in the public interest under the McCarran–Ferguson Act and overseen by the National Association of Insurance Commissioners.²¹⁵ A large subset of insurance companies, referred to as “admitted carriers,” must comply with the regulations set by state departments of insurance or state insurance commissioners. Admitted carriers comply with state insurance laws in part by filing information on their insurance offerings and rate calculations. In return, states verify that an admitted carrier’s programs adhere to state law and offer them a financial backstop for claims payment if they face insolvency.

While not the interest of this study, we digress briefly to address “non-admitted carriers” for context. Non-admitted carriers sell excess and surplus lines of insurance to address larger or more complex risks: their policies do not necessarily conform to state laws and are therefore not subject to the same filing requirements.²¹⁶ However, we note that non-admitted carriers writing excess property insurance will make use of the information gathered by the primary (typically admitted) carrier of insurance. Most premiums in property and casualty insurance are written by admitted carriers. As of 2020, “surplus lines direct premiums written totaled \$66 billion, representing 9.1 percent of the \$726 billion in direct premiums written within the U.S. property & casualty market.”²¹⁷

For the purposes of this study, the distinction between admitted and non-admitted carriers implies that the insurance rate filings we obtain and analyze include standard commercial property risks and exclude more customized coverage and underwriting. This limitation may impinge on the generalizability of our examples for catastrophic windstorm cover in Gulf States. In an analysis of the commercial windstorm insurance market following Hurricane Katrina, one study found that,

²¹⁵ 15 U.S.C. §§ 1011-1015.

²¹⁶ See Insureon, “Business Insurance Glossary: Admitted vs. Non-admitted Insurance Carriers,” webpage, undated.

²¹⁷ NAIC, “Surplus Lines,” webpage, May 11, 2022.

The tightly regulated, admitted commercial insurers have dramatically reduced their exposure in coastal areas, causing a shift of hurricane risk to state residual market entities and the largely unregulated, surplus lines carriers.²¹⁸

If these conditions have persisted, existing rate filings on catastrophic windstorm cover in these states may represent a relatively narrow segment of the market.

Public Commercial Property Insurance Data

Commercial property insurance policy information can be accessed through the rate filings contained in the National Association of Insurance Commissioners (NAIC) SERFF, which is an electronic platform that allows insurance companies to submit forms such as rate filings to state regulatory agencies, among other purposes. Discussed in more detail in Chapter Four, states issue their own requirements for rate filings and this information is available through the SERFF system. The required information varies by state and there is some variability in the level of detail provided by insurers. For the purposes of this appendix, we are interested in using this information to understand the types of perils that are identified in these filings and the perils that have rate adjustments for resilience investments.

Overview of the NFIP

The NFIP was established to provide broadly accessible, government-subsidized and -managed flood insurance for residential and commercial properties, especially in high-risk areas referred to as Special Flood Hazard Areas (SFHAs), which are in a 100-year flood plain.²¹⁹ NFIP mapping, rating, and administering programs are administered by FEMA in partnership with property and casualty insurance providers, states and local governments, and lending institutions. NFIP has broader goals than a private insurer in that it is designed to mitigate the consequences of floods to individuals and communities by working with local governments to adopt and enforce floodplain management regulations and offering insurance to residents of participating communities.

Flood insurance is a type of property insurance that covers a building and optionally its contents for water damage caused by flooding that occurs after a weather event. Weather events that can lead to flooding are severe rain, snow melt, coastal storm surges, stormwater management system failure (such as clogged stormwater drainage systems), or flood protection infrastructure failure (such as a levee break). Policies typically cover the structure and some

²¹⁸ Lloyd Dixon, James W. Macdonald, and Julie Zissimopoulos, *Commercial Wind Insurance in the Gulf States: Developments Since Hurricane Katrina and Challenges Moving Forward*, RAND Corporation, OP-190-ICJ, 2007.

²¹⁹ More rigorously stated, Special Flood Hazard Areas have a likelihood of 1 percent or greater for an AEP flood event.

mechanical systems, or the contents, or both.²²⁰ NFIP offers policies that cover buildings-only, contents-only, or both buildings and contents and differentiates coverage for items in basements versus above-ground spaces. It does not cover items outside the built structure such as fences or patios. The insurance premium is affected by the building type (residential or nonresidential), the type and amount of coverage requested (building-only, contents-only, or both), and the selected deductible.

Discussed in Chapter Five, the NFIP Risk Rating 2.0 methodology is used to determine premium rates, which are driven by a building's proximity to the floodplain, among other factors. To support program objectives, FEMA works with communities to develop FIRMs that characterize flood exposure and risk.²²¹ The National Flood Hazard Layer (NFHL) viewer provides a seamless GIS resource for FIRMs, which includes additional attribute data such as the type of Special Flood Hazard Area and Base Flood Elevation if available.²²² While maps are updated periodically, it is worth noting that flood risk is dynamic and changes over time as land-use, surface erosion, implementation of flood control measures change evolve and that many FIRMs are not up to date because of such changes.

²²⁰ Property outside of an insured building (landscaping, wells, septic systems, decks and patios, fences, seawalls, hot tubs, and swimming pools) is generally not covered.

²²¹ FEMA produces several flood map products that serve different purposes. We refer specifically to the flood maps used for regulatory purposes by the NFIP.

²²² For more information on the specific map products that FEMA generates see FEMA, "FEMA Flood Map Service Center: Products and Tools Overview," webpage, undated.

Appendix E. Data Sources for National Flood Insurance Program Premium Calculations

This appendix describes the data sources used to calculate NFIP premium calculations.

Installation Data Sources

IGI&S installation CIP data were used to provide information about where the installation case study buildings are located and some of their basic characteristics, such as CATCODE. Other Army installation databases were used to acquire information about key building characteristics needed for the NFIP premium calculations. ISR was used to acquire the ERV since we had easy access to ISR data. HQIIS is the official source for Army installation real property data, and it can provide detailed real property asset information, such as the number of stories above and below ground for Army buildings.²²³

Floodplain Data Sources

We used multiple sources to examine floodplain data and flooding risk including: DCAT, NFIP FIRM, and Risk Factor maps generated by the First Street Foundation. While floodplains are not required for rating, we used the DCAT 100-year floodplain to help identify building case studies for two reasons. First, geographic risk rating factors are intended to be most sensitive to changes with a certain proximity of the hazard. Second, as mapped floodplains are often used to apply design standards such as height above Base Flood Elevation, for example, we might expect buildings to have certain mitigations, or benefit more greatly from adaptation and have that reflected in the premium calculation.

While DCAT riverine floodplain data were available for all installations in our screening process, the validity may be variable without more detailed analysis. For example, a relatively flat area that experiences large amounts of precipitation associated with a 100-year flood event and with drainage features below the limit of digital elevation resolution used to run the hydraulic model may overstate the potential exposure area. NFIP FIRM 100-year flood maps may be more accurate, if available, as they may have included additional drainage features, modeled phenomenon in a different way, or undergone correction through the peer review process with the community.

²²³ We used Google Earth Pro to estimate number of stories since we did not have direct access to HQIIS data.

Watershed and Other Data Sources

Additional geographic rating factors are required by the NFIP-based model including elevations, distance to hazard source, and generalized watershed characteristics. The USGS was our source for much of these data. For example, elevations for both the building footprint, adjacent landscape, and water surface can be estimated from digital elevation models provided on their National Map Viewer platform at a variety of resolutions.²²⁴ The USGS also maintains an authoritative data layer of drainage features at a variety of Hydrologic Unit Code (HUC) levels. The NFIP-based model uses data on the ~100,000 HUC-12 sub-watersheds nationwide that includes sixth order creeks, streams, rivers, and the like.²²⁵

FEMA Proprietary Rate Data

We used the NFIP publicly available Excel workbook-based models of the flood insurance rate formulas and value lookup tables for the Risk Rating 2.0 methodology to calculate estimated annual flood insurance premium values for our case study buildings. Risk Rating 2.0 is dependent on several proprietary calculations so we did not have insight into their relationship (in other words, a black box, which are essential to the actuarial soundness and competitiveness of the program).²²⁶ For example, Metropolitan Statistical Areas (MSAs) were used to determine a “concentration risk” that may have less relevance in an Army context. Similarly, each HUC-12 was assigned a separate “territory risk” that was independent of its size characteristics.

The one factor that we fully estimated was “river class.” A third-party firm calculated rates for the NFIP on each HUC-12 sub-watershed feature to determine water surface elevation height in both the 10 percent and 1 percent AEP event. A 10 percent AEP flood event is the 10-year floodplain map. The difference between these two numbers in feet is the river class as a measure of flash flooding (for example, three feet yields a Class C river). These data are not publicly available. As we did not have 10 percent AEP event modeling available via DCAT or FIRMs, nor absolute 1 percent AEP Base Flood Elevations, as such we had to make inferences based on data formerly available in the First Street Foundation’s Risk Factor flood mapping as well as intuited characteristics of the drainage feature (e.g., bank height). Unfortunately, this is a relatively important factor within the overall risk rating, and would likely require additional exploration, if possible, given it is doubly proprietary.

²²⁴ More information on The National Map and its data layers is available from U.S. Geological Survey, “USGS The National Map,” mapping tool, undated.

²²⁵ More information on the HUC system can be found from U.S. Geological Survey, “Hydrologic Unit Codes (HUCs) Explained,” website, undated.

²²⁶ FEMA proprietary data refers to data that FEMA has purchased from a commercial company for use in its calculations and these data cannot be made public.

Appendix F. Four Phases of Resilience Investment Planning

Four simplified phases for planning resilience investments were developed from a review of Army, other federal agencies, and the literature on guides for resilience investment planning.²²⁷ This generalized process provides background information about how to potentially use information presented in this report in planning. At its basic level resilience planning requires scoping, assessing, identifying options, and prioritizing and acting.

Scoping

Determining the assets and natural hazards that are going to be evaluated for risk and potential investment. The first phase of analysis requires installation planners and other personnel to determine the purpose and scope of the investment analysis. Often, time and resources are constrained, and it is not practicable to analyze every site or facility for every natural hazard. Questions such as: Are there particular plans or investment opportunities that the analysis will inform? Are particular assets of concern because of mission criticality, prevalence, or stage in life-cycle? Another scoping question is what is the geographic focus? Understanding key natural hazards (from historical experience, design standards and guidelines, and other installation analyses) can be helpful to focus the analysis. Clarifying scope helps to identify what information is needed for the analysis and focuses data gathering and decision criteria development. Ultimately this stage is about determining the purpose and coverage of the analysis, the time period of interest, and should generate a description of the problem and the objective of the analysis.

²²⁷ Pinson, et al., 2020; U.S. Climate Resilience Toolkit, homepage, January 13, 2023; Navy Facilities Engineering Command, “Climate Change Planning Handbook: Installation Resilience and Adaptation,” January 2017; U.S. Department of Transportation, Federal Highway Administration, “Vulnerability Assessment and Adaptation Framework,” 3rd Edition, 2017; David G. Groves, Edmundo Molina-Perez, Evan Bloom, and Jordan R. Fischbach, “Robust Decision Making (RDM): Application to Water Planning and Climate Policy,” in Vincent AWJ Marchau, Warren E. Walker, Pieter JTM Bloemen, and Steven W. Popper, eds., *Decision Making under Deep Uncertainty: From Theory to Practice*, Springer, 2019; Robert J. Lempert, “Embedding (some) Benefit-Cost Concepts into Decision Support Processes with Deep Uncertainty,” *Journal of Benefit-Cost Analysis*, Vol. 5, No. 3, 2014, pp. 487–514; Robert Lempert, James Syme, George Mazur, Debra Knopman, Garrett Ballard-Rosa, Kacey Lizon, and Ifeanyi Edochie, “Meeting Climate, Mobility, and Equity Goals in Transportation Planning Under Wide-Ranging Scenarios: A Demonstration of Robust Decision Making,” *Journal of the American Planning Association*, Vol. 86, No. 3, 2020, pp. 311–323; Vincent AWJ Marchau, Warren E. Walker, Pieter JTM Bloemen, and Steven W. Popper, eds., *Decision Making Under Deep Uncertainty: From Theory to Practice*, Springer, 2019.

Assessing

Obtaining asset and hazard data and evaluating the vulnerabilities and risks of the selected assets to the selected natural hazards. This phase involves obtaining asset and hazard information to evaluate the specific vulnerabilities and risks faced. This may require coordination with internal and external stakeholders to gather all the necessary data. Generally, information about asset location, condition, function, and design standards will be needed. Weather and climate information may be gathered from the Air Force weather squadron, NOAA's National Center for Environmental Information, and USGS. Although DCAT/ACAT contains some projected information for natural hazards, it is not granular enough for investment decisionmaking. Installation planners will likely need assistance to identify the appropriate projections of climate change effects on local natural weather patterns, but the U.S. Climate Resilience Toolkit offers some starting points. Once the required information is acquired the next step is to assess vulnerability to natural hazards using a system-level, engineering-based, or another approach. Vulnerability includes the potential exposure to the hazard, an assessment of how sensitive the asset is to the hazard, and what adaptations exist to mitigate the effects of the hazard.²²⁸

Identifying Options

Finding alternative feasible options for reducing these risks and assessing their benefits and costs. The third phase of the analysis process is focused on identifying options for mitigating the risk posed by the vulnerabilities identified in the second phase. Investment decisions should consider co-benefits; assess both short- and longer-term risks; and recognize that the severity of these natural hazards is increasing in most places, but that the precise changes and effects are uncertain. A preliminary portfolio of risk mitigation options can be assessed for the benefits (both monetized and nonmonetized), feasibility, and costs for the specific application. Depending on the scope and objective determined in phase one the analysis could focus on high-risk assets, those that share a common vulnerability (such in a low elevation area), or those identified for modification, replacement, or where investments are feasible.

Given the level of uncertainty around the magnitude, frequency, timing, and location of those natural hazards that are projected to be affected by climate change, investment decisions to mitigate these hazards should ideally use a form of iterative risk management, which uses an assessment, monitoring, learning, and adjustment cycle to manage risk. Some options may be classified as “no regrets,” which refers to the likelihood that the investment would be beneficial regardless of the future severity of these natural hazards (An example of this might be avoiding construction in existing flood-prone areas). When there is substantial uncertainty, investment

²²⁸ Note, the IPCC treats exposure separately and considers vulnerability to be a function of sensitivity and adaptive capacity.

decisions that employ strategies that are flexible or adaptable to changing conditions are generally preferable.

Prioritizing and Acting

Develop a portfolio of options, prioritize actions, and incorporate results into decisionmaking. Invest and monitor outcomes. The final phase is to incorporate resilience investment alternatives into existing planning and project development processes and develop priorities for investment. Determining these resilience investments for natural hazards is an iterative process. The process requires monitoring and evaluation to assess the realized benefits of these investments, and to reassess vulnerabilities as local conditions and hazard projections change. Monitoring investment outcomes may reveal the need to revisit the assumptions, underlying data, or approaches used in the original vulnerability assessment. Periodic updates to vulnerability assessments will help to ensure future resilience investments are addressing priority vulnerabilities over time.

Implications of Our Study for the Resilience Planning Phases

Given these phases of resilience planning, we illustrate where the information from this study might be useful for the Army. For example, the information provided in this report on natural hazards patterns and trends may help installations determine which natural hazards to assess. Information from the insurance premium discounts might help identify some options to include in the assessments. The synthesis of Army storm damage data provided by IMCOM provides information on the scale and types of damage experienced at installations in the past which can help inform the assessment process and the development and prioritization of options. In addition, more Army-specific guidance related to such phases can be found in the *Army Climate Resilience Handbook* (2021), produced by the U.S. Army Corps of Engineers.²²⁹

²²⁹ Pinson, et al., 2020. Navy installations use the Naval Facilities Engineering Command, “Climate Change Planning Handbook: Installation Resilience and Adaptation,” January 2017. The Air Force relies on U.S. Air Force, “Severe Weather/Climate Hazard Screening and Risk Assessment Playbook,” Air Force Civil Engineer, April 24, 2020.

Abbreviations

ACS	Army Climate Strategy
AEP	Annual Exceedance Probability
AIS	Army Installations Strategy
AMC	Army Materiel Command
AoN	Act of Nature
APG	Aberdeen Proving Ground
ARNG	Army National Guard
ASA(IE&E)	Assistant Secretary of the Army for Installations, Energy and Environment
BOS	Base Operations Support
CAPCES	Construction Appropriation Programming and Control Execution System
CATCODE	category codes
CERL	Construction Engineering Research Laboratory
CIP	Common Installation Picture
CONUS	continental United States
DCAT	Defense Climate Adaptation Tool
DoD	Department of Defense
ERCIP	Energy Resilience and Conservation Investment Program
ERDC	Engineering Research and Development Center
FEMA	Federal Emergency Management Agency
FFRDC	federally funded research and development center
FIA	Facility Investment Analytics
FIP	Facility Investment Plan
FIRM	Flood Insurance Rate Maps
FY	fiscal year
GFEBs	General Fund Enterprise Business System
GIS	geographic information system
HQIIS	Headquarters Installation Information System
ICRP	Installation Climate Resilience Plan
IGI&S	Installation Geospatial Information and Services
IMCOM	Installation Management Command
IPCC	Intergovernmental Panel on Climate Change
ISR	Installation Status Report
ISR-1	Installation Status Report-Infrastructure

MDEP	management decision package
MILCON	military construction
NCEI	National Center for Environmental Information
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NRI	National Risk Index
NWS	National Weather Service
ORI	Operational Readiness Index
PRIDE	Planning Resource for Infrastructure Development and Evaluation
R&M	restoration and modernization
REPI	Readiness and Environmental Protection Integration
ROI	return on investment
SERFF	System for Electronic Rates and Form Filing
SRM	sustainment, restoration, and modernization
TIV	total insured value
UFC	United Facilities Criteria
USACE	U.S. Army Corps of Engineers
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey

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