Community Vulnerability Assessment Tool Methodology

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Abstract: Communities must identify exposure to hazard impacts to proactively address emergency response, disaster recovery, and hazard mitigation, and incorporate sustainable development practices into comprehensive planning. Hazard mitigation, an important part of sustainable development, eliminates or minimizes disaster-related damages and empowers communities to respond to and recover more quickly from disasters. The Community Vulnerability Assessment Tool (CVAT) is a risk and vulnerability assessment methodology designed by the National Oceanic and Atmospheric Administration's Coastal Services Center to assist emergency managers and planners in their efforts to reduce hazard vulnerabilities through hazard mitigation, comprehensive land-use, and development planning. CVAT analysis results provide a baseline to prioritize mitigation measures and to evaluate the effectiveness of those measures over time. This methodology is flexible, as results may be achieved using a geographic information system or static maps with overlays and handwritten data. This paper outlines how to engage stakeholders and explains the CVAT process. Several case studies also highlight some of the challenges/problems and best practices/opportunities associated with applying the CVAT methodology.

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Introduction

Bolstering the resiliency of communities to natural hazards, before they become disasters, must first begin with a comprehensive risk and vulnerability assessment (RVA). Regardless of whether the RVA is performed by the community or an outside firm, a steering committee (or community representatives) should be established to provide knowledge, insight, and feedback throughout the RVA process. Communities can use RVA results to reduce the impacts from hazards through the development or revision of emergency response, disaster recovery, and hazard mitigation strategies, and comprehensive land use plans that incorporate sustainable development practices.

Research, initiatives, and mandates encourage and require that RVAs be completed to objectively formulate hazard mitigation strategies. As promulgated by the Disaster Mitigation Act of 2000, the Federal Emergency Management Agency (FEMA) has mandated states to submit Standard State Mitigation Plans that include an RVA by November 2003. Unless FEMA approves the plan, states will not be eligible to receive disaster recovery funding for permanent infrastructure and property repairs or hazard mitigation funding following a presidentially declared disaster. If states develop Enhanced State Mitigation Plans that are approved by FEMA, they will be eligible to receive additional Hazard Mitigation Grant Program (HMGP) funds (Hazard 2002). To help states meet this requirement, FEMA predisaster mitigation funds are available for conducting risk and vulnerability assessments, among other measures.

Many researchers and practitioners ardently support the need to conduct a national RVA. Dennis Mileti, director of the Natural Hazards Center at the University of Colorado in Boulder, in his book *Disasters by Design: A Reassessment of Natural Hazards in the United States* (Mileti 1999), gives many valuable recommendations and findings and stresses the need for a nationwide hazard and risk assessment as a way to determine changes within the physical, social, and constructed systems. *A National Priority: Building Resilience to Natural Hazards* (National Hazards 2001), a report published by the American Meteorological Society and the University Corporation for Atmospheric Research, co-signed by the Natural Hazards Caucus Work Group in 2001, includes recommendations to the United States presidential administration to conduct a national assessment of community vulnerability and to develop incentives that will encourage communities and states to implement hazard mitigation measures. This is prudent for setting national priorities and policies; whereas, a community level vulnerability assessment will help set priorities and affect policy decisions at the local and grassroots level, as well as funnel data into a broader national assessment.

The Community Vulnerability Assessment Tool (CVAT) CD-ROM and web site (www.csc.noaa.gov/products/nchaz/startup.htm) demonstrate a community RVA methodology, based on the H. John Heinz III Center's Panel on Risk, Vulnerability, and the True Cost of Hazards (Heinz Panel) findings, as reported in the *Hidden Costs of Coastal Hazards* (H. John Heinz III 2000). Although many RVA methodologies exist, CVAT is one specific type that will be further explored in this paper. In 1996, the H. John Heinz III Center for Science, Economics and the Environment and the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (CSC) organized a panel of ex-

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perts to identify and create innovative strategies to reduce potential hazard-related costs associated with escalating coastal development activities. The Heinz Panel employed one working group that focused on overall risk and vulnerability assessment and a second working group that focused on the true costs of weather-related coastal hazards. Together, they developed a framework for a community-level RVA methodology that factored in economic, business, social, and environmental considerations. This approach was different from traditional RVAs, which were based on structural damage and did not include indirect costs to families, natural resources, or community support systems (H. John Heinz III 2000).

The CVAT methodology provides a comprehensive and systematic framework to identify and prioritize hazards and to assess vulnerabilities of critical facilities, the economy, societal elements, and the environment. CVAT includes a tutorial and a case study on a community-level assessment that was conducted in New Hanover County, North Carolina, to guide the user through a seven-step risk and vulnerability assessment process. Although CVAT was piloted in a coastal county, it can be applied to any type of hazard in any geographic location, both at macro and micro levels. CVAT is a highly flexible tool, from which results can be obtained in a geographic information system (GIS) or through the use of static maps and handwritten data overlays. However, GIS provides a richer environment for analysis and data modification. Results from CVAT analysis provide a baseline from which to prioritize the mitigation measures to employ and to evaluate the effectiveness of those measures over time. Mapping allows the community to spatially analyze hazards and vulnerabilities and make informed decisions about risk reduction.

Because CVAT has already proven to be a successful framework for performing RVAs at the local and state levels, states may wish to use this tool to help meet the requirements of upcoming FEMA regulations that will implement the Disaster Mitigation Act of 2000. This paper will outline how to engage stakeholders to conduct or provide input for the methodology, explain the methodology, and then illustrate how CVAT was used to conduct RVAs for communities in the United States.

Stakeholder Engagement

Stakeholder involvement is crucial to a community's ability to perform a viable RVA. Prior to embarking on the RVA, a chairperson should be designated to coordinate resources and activities required to conduct the RVA and lead a steering committee that will either do the assessment or receive the results from an outside party. Since the RVA process is time-consuming and involved, a chairperson who can dedicate full-time efforts to the project would best serve that role.

Potential steering committee members may be notified through correspondence and with assistance from the media (e.g., public service announcements and public notices). The steering committee should include representatives from throughout the community. (A thorough list of potential members would include the mayor/town administrator's staff, city/county/town council, planner, building/zoning official, fire/police, engineering, public works, public utilities, transportation officials, emergency management officials, hazard mitigation officer, public safety, GIS office, the entity that has the authority to implement the hazard mitigation strategy, environmental/coastal zone management, academia, military bases, health and human services, FEMA, U.S. Army Corps of Engineers (USACE), NOAA National Weather Service (NWS), U.S. Geological Survey (USGS), nongovernmental organizations such as the Red Cross, chamber of commerce, tourism development council, board of realtors, Small Business Administration, Economic Development Administration, land trusts/nature conservancies, developers, local business leaders, media, special interest groups, and the general public, etc.). Realistically, all of these groups or individuals would not be able to sit on the committee, but the leader should make efforts to include them throughout the process by inviting them to the steering committee working meetings.

After the group is organized, it is necessary to conduct an orientation during the first steering committee meeting on the hazards history of the community, the CVAT methodology, why the committee members need to be involved, how they can contribute to the process and benefit from the results of an RVA, and what hazard mitigation is and why it is important. It is also important to apprise this group of how this process is tied to local planning initiatives, which might include sustainable development or smart-growth practices, and to the Community Rating System and the National Flood Insurance Program. The group must be aware that disaster impacts worsen as more development occurs in high-risk zones. During successive meetings, other organizations and agencies can be included in the process to provide technical support and data for conducting the RVA. During the process, the media can help efforts by publicizing key RVA activities to educate the general public, as well as invite them to provide feedback on their perceived hazard risks and vulnerabilities.

To work more efficiently, the steering committee can create subcommittees to oversee subparts of the process, such as the RVA, hazard mitigation, finance (to identify funds or grants to pay for the RVA and mitigation measures), economic development, and outreach activities. Subcommittee members can come from the previously mentioned list of stakeholders and include any other representatives deemed pertinent by the steering committee.

Including stakeholders from the onset of the RVA process helps them, as well as others, understand what is vulnerable and why it is vulnerable, simply because they can contribute what they know about their community and can approach the issues from their area of expertise and discipline. Considering each representative's viewpoint and addressing his or her concerns throughout the process helps to establish buy-in from the community, ensures a more comprehensive perspective about which populations and resources are vulnerable, and provides a better forum to address how to implement hazard mitigation measures. Also, by engaging a wide variety of representatives in the process, the group can determine who has the authority and responsibility for accomplishing hazard mitigation.

Methodology

As depicted in Fig. 1, CVAT entails a seven-step process that may be followed in the prescribed sequence or modified to meet the needs of the user.

The CVAT Process

Step 1: Hazard Identification

In this step, the working group makes a general list of hazards (e.g., natural and technological) that have occurred or have the potential to occur within the community. The outcome of this step will result in a prioritized list of hazards, based on the concerns and perceptions of the community. Hazard prioritization is necessary to determine which hazards pose the greatest risk. In a per-

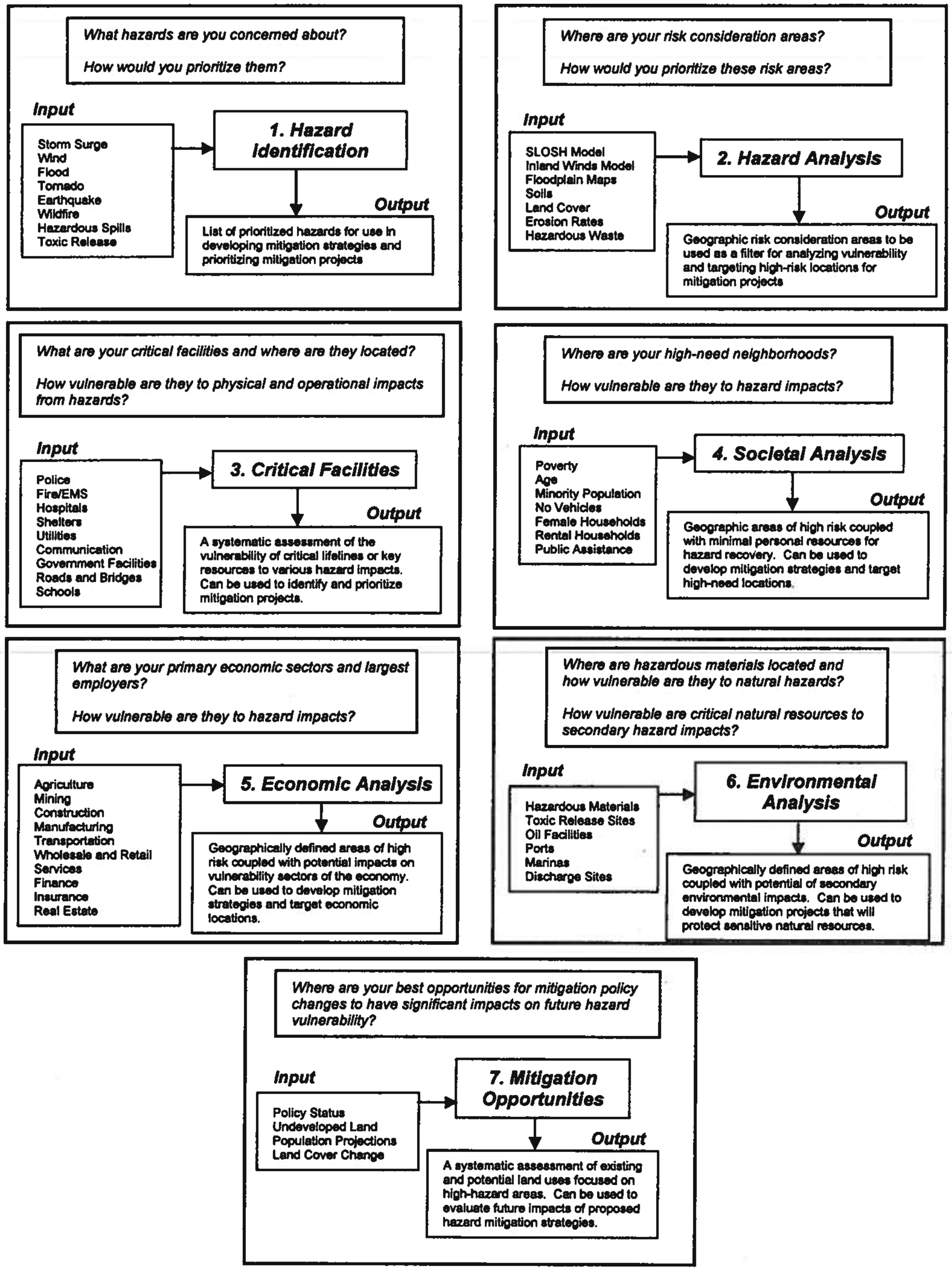

Fig. 1. Community Vulnerability Assessment Tool process overview

fect world, mitigation would be carried out for all hazards. In reality, hazard mitigation resources and funding are limited, and communities need to concentrate their efforts where it will do the most amount of good. Hazard identification is accomplished as follows:

- First, a list of the hazards is created based on historical records and probabilistic data. This can either be a comprehensive list of hazards posing some threat to the community or a more limited list of specific hazards for particular planning purposes (i.e., floods: floodplain management and mitigation).
- Then, the working group performs an analysis to prioritize which hazards pose the greatest level of risk according to each hazard's frequency, area impact, and potential damage magnitude. These three variables are calculated in the relative priority matrix used to compare the risks of each hazard by using a weighting formula as a general guide for addressing the different hazards. Though subjective in nature, the purpose of this step is to initiate thought and discussion among members of the community about the hazards and their potential impacts. The comparison of hazard scores, however, will provide relative rankings, which the working group can use as a basis for acquiring hazards data to map high-risk areas.
- Next, a scoring system is applied to determine which areas rank as high, medium, or low risk. The following scoring system was used for New Hanover County (Frequency+Area Impact)×Potential Damage Magnitude=Total Score (the fre-

quency, area impact, and potential damage magnitude values are defined by a scale of numbers ranging from 1 to 5, where 1 = low and 5 = high).

Step 2: Creating Hazard Analysis Map

This step guides the working group in creating maps of the risk areas (e.g., floods, high wind, erosion, wildfire, etc.) by using either GIS or transparencies over an opaque base map for the remaining analyses. Individual maps of risk areas are created for each hazard by geographically designating areas that are prone to high, medium, low, or no impacts. These maps are overlaid on one another to develop a multihazard map of risk areas. The individual maps will be used later to identify vulnerabilities and mitigation options for a specific hazard. The multihazard map will help to distinguish which areas are susceptible to multiple hazard impacts. These maps are useful in ascertaining which types of hazard mitigation measures should be pursued, and who has the authority or responsibility for implementing them.

It is necessary to differentiate between risk and vulnerability in this step. Although, people, property, and resources may be located within the risk areas, they may not necessarily be vulnerable to hazard impacts. For example, in one neighborhood of 50 homes there are 10 structures located within the floodplain (risk consideration area). These 10 structures would be considered potentially at risk for flooding and would be the targets for vulnerability assessment. Seven of the structures are elevated above the 100-year flood elevation and the remaining three structures are not elevated. The three nonelevated structures would be considered more vulnerable to flooding than those that were elevated. In this example, the risk area (floodplain) helps narrow the target of the detailed vulnerability assessment from 50 structures to 10 structures.

The best available information is used to identify risk areas for the hazards that were prioritized in the first step. Some hazards, such as tornadoes, do not have well-defined risk areas but are associated with broad areas of greater risk (i.e., tornado corridors). In other cases, such as floods or storm surge, one may have access to useful risk-area data (i.e., floodplain or storm surge models/maps). The more risk data that are available, the more opportunity there is to focus vulnerability assessment activities in the highest-risk areas. Yet it is possible to develop some priorities using limited publicly available data and improve upon those priorities over time using more accurate local data sources. Hazard analysis mapping is accomplished as follows.

- First, the risk area for each hazard is mapped on the most current base map of the area being assessed. Sources for data can be found in FEMA's *Multi-Hazard Identification and Risk Assessment* publication (FEMA 1997), by contacting the state and local GIS consortiums, or at ⟨www.csc.noaa.gov/products/nchaz/htm/dinfo_2.htm⟩. Some examples of hazards data include but are not limited to the Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model; inland winds model; floodplain maps (Q3 data); soils, land cover, erosion rate, and hazardous facilities; and others.
- Second, scores are assigned within risk areas using a ranking system, where possible, and these scores are noted on the individual hazard maps (e.g., flood map). CVAT uses a scoring system for a range of flood risks based on FEMA flood insurance rate maps, with designated flood V and VE (Velocity zones) having the highest score of "5" and areas outside of the 500-year floodplain without flood-prone soils having the lowest score of "1." Similar scoring systems are used for all of the hazards selected. Areas that are not subject to hazard impacts can be assigned a score of "0." Identifying locations that are subject to a single hazard helps the community coordinate with specific organizations that have the authority to implement changes (e.g., a county floodplain manager would only be concerned with flood-risk areas).
- Next, a hazard summary map is created to highlight areas that are vulnerable to impacts from multihazards to prioritize mitigation measures and allocate scarce funding.

Step 3: Critical Facilities Vulnerability Analysis

This analysis focuses on determining the vulnerabilities of key individual facilities, lifelines, or resources within the community. Critical facilities include emergency shelters, schools, hospitals, nursing homes, public buildings, and facilities for fire and rescue, police, utilities, communications, transportation, etc., or those identified as critical by the risk and vulnerability assessment working group. It is important to protect critical facilities (e.g., through relocation, elevation, or retrofit: backup of essential records; and backup of power supplies) to ensure that service interruption is reduced or eliminated, because these facilities play a central role in disaster response and recovery. Because it is not usually feasible to conduct a structural and operational analysis for every structure in a community, this step helps to prioritize which facilities are most vulnerable, so that individual assessments may be performed later. A structural analysis is used to examine the structural integrity of the building and its ability to withstand potential hazard damage; whereas, an operational analysis helps determine how daily activities will be affected if the building is damaged or if utility services are interrupted. The critical facilities vulnerability analysis has four components:

- First, critical facilities are identified by type and location to determine facilities that provide essential services to the community on a regular basis and are integral to disaster response and recovery operations.
- Second, a critical facilities inventory must be established by collecting general information on facility types and locations. The type and amount of information collected depends on the intended use of the database. Most local emergency management offices collect and maintain information on certain categories of critical facilities, which may provide a starting point for the critical facilities inventory. It is imperative to collect accurate information because these data will be essential for completing the individual facility assessments in the last step of this analysis.
- Third, critical facilities that are in and within close proximity to high-risk areas are identified by overlaying the critical facility locations over the map of hazard-risk areas.
- Next, critical facilities that will require further structural and operational assessments are identified by completing a critical facilities inventory, which should include but is not limited to construction type and quality, location, age, size, occupancy rates, monetary value, insurance coverage, auxiliary-power capability, backup capacity and process for electronic files, and protection and storage procedures for hard-copy documents. Assessment questions should be designed to meet the needs of the audience or investigators. Some questions may require professionally trained inspectors or engineers, while others may rely on subjective evaluations from managers or property owners.

Step 4: Societal Vulnerability Analysis

This analysis focuses on societal vulnerability by analyzing special consideration areas (preferably at the neighborhood level), where individual resources for loss prevention and disaster recovery tend to be minimal. Individuals that reside in special consideration areas are more likely to be uninsured or underinsured for hazard damages and have limited financial resources for pursuing individual hazard mitigation options. The population in these areas would be most dependent on public resources (e.g., disaster relief and recovery grants, unemployment assistance, subsidized health care and child care, social services, public transportation, etc.) after a disaster and therefore could indicate good investment areas for hazard mitigation activities. Special consideration areas can be identified by utilizing existing low-to-moderate income designations for community development grants or by analyzing key census data categories. Demographic characteristics can be selected to help identify special considerations such as mobility, literacy, or language, which can significantly hinder disaster recovery efforts. A societal vulnerability analysis is accomplished as follows:

- First, special consideration areas (e.g., areas with high concentrations of poverty, elderly, minorities, single-parent households, rental dwellings, no high school diplomas, public assistance recipients, non-English speaking populations, no vehicle available, etc.) are identified by type and location to determine which populations may require special care or may have more difficulty with disaster response and recovery.
- Second, special consideration areas that are in high-risk areas are identified by overlaying the special consideration neighborhoods onto the risk areas.
- Next, a general inventory is completed of special consideration areas that are located in high-risk areas. There are several ways to complete this type of inventory. A community might elect to conduct a windshield survey to determine the number and type of vulnerable facilities in high-risk areas, unless these data are readily available from the local tax assessor's office. New Hanover County used a parcel-based land use inventory in a GIS format to distinguish the number and type of residential structures located in each census block group that was identified as a special consideration area.

Step 5: Economic Vulnerability Analysis

This analysis focuses on economic vulnerabilities to hazard impacts by identifying major economic sectors and mapping primary centers of activities in those sectors. Economic centers are areas where hazard impacts could have adverse effects on the local economy and would therefore be ideal locations for targeting certain hazard mitigation strategies. Some of the most devastating disaster costs to a community include the loss of income associated with business interruptions and the loss of jobs associated with business closures. A progressive community will actively pursue business continuity plans and hazard mitigation options to prevent or minimize such losses. It is important to begin this step by conducting a general overview of the local economy to provide a basis for targeting business sector partners in community-wide hazard mitigation efforts. The identification process will rely on local expertise such as the chamber of commerce or economic development council. Economic information can also be derived from widely available data sources such as the county business patterns located on the U.S. Census Bureau Web site. Land use or zoning data can often help in mapping business and industrial centers. Steps to accomplish an economic vulnerability analysis are as follows:

- First, the primary economic sectors and their geographic locations must be identified (i.e., economic centers) to determine which businesses are most important to the community (e.g., products and services, employment, tax revenue, disaster response and recovery capabilities, etc.).
- Second, primary economic centers that are located in high-risk areas are identified by overlaying the economic center locations over the risk areas.
- Third, a general inventory of high-risk economic centers is conducted. A community may choose to conduct a windshield survey to determine the number and type of vulnerable facilities in high-risk areas if this information is not readily available. A table (e.g., GIS attribute table or spreadsheet) can be used to summarize the type of industries, the number of facilities within each industry, the number of employees, the percentage of employees per industry and/or facility, and the annual payroll to help narrow the focus for facilities to be targeted for hazard mitigation.
- Fourth, large employers that are located in high-risk areas are identified to help prioritize the facilities on which to perform further analyses. Economic census data can help identify employment levels by economic sector and determine the size threshold.
- Next, a structural and operational vulnerability analysis is conducted. While this step is largely up to the private sector, it is recommended that vulnerability assessments for large employers be addressed in a manner similar to critical facilities. FEMA endorses engaging with key private sector establishments in hazard mitigation partnerships and asking them to assess their structural and operational vulnerability to hazards (Hazard 2002).

Step 6: Environmental Vulnerability Analysis

This analysis focuses on identifying locations where secondary environmental impacts caused by natural hazards (primary impacts) may occur. Before embarking on this step, it is necessary to explain the terms "secondary impacts" and "secondary risk sites." Secondary impacts occur when natural hazards (e.g., flood) trigger additional hazards such as toxic releases or hazardous spills. Therefore, a solid-waste facility or a building that stored hazardous materials would be characterized as "secondary risk sites" if they are in close proximity to areas of environmental concern (e.g., wetland). Although CVAT uses the term "secondary risk sites," these are often called "hazardous facilities." Environmental impacts are important to consider, as they not only jeopardize habitats and species, but can also threaten public health (e.g., water quality), various economic sectors (e.g., tourism and fishing), and quality of life (e.g., access to natural landscapes and recreational activities). For example, flooding (a primary hazard) can result in contamination (a secondary hazard) whereby raw sewage, animal carcasses, chemicals, pesticides, hazardous materials, etc. are transported through sensitive habitats, neighborhoods, and businesses. These circumstances can result in major cleanup and remediation activities, as well as natural resource degradation. Data can be obtained from state and local emergency management offices, local planning commissions, and environmental and natural resource management agencies to locate natural resources and secondary risk sites. Steps to accomplish an environmental vulnerability analysis are as follows.

- First, secondary risk sites (e.g., hazardous materials, toxic release sites, solid-waste facilities, nuclear power plants, underground storage tanks, oil facilities, ports, marinas, discharge sites, etc.) and key natural resource sites (e.g., wetlands, sensitive/endangered species and habitats, fisheries, wildlife refuges, aquaculture sites, shellfish harvest areas, groundwater recharge areas, etc.) are identified.

- Next, secondary risk sites and environmentally sensitive areas are overlaid onto the risk areas to determine the types of hazardous materials and locations of potential releases into environmentally sensitive areas.

Step 7: Mitigation Opportunities Analysis

This analysis focuses on identifying mitigation opportunities to decrease or alleviate vulnerabilities noted in the previous analyses that are to be addressed during the community's hazard mitigation and comprehensive planning. Hazard mitigation is a concept that includes a range of actions that, when comprehensively implemented, increases a community's resiliency to disasters. Mitigation is best implemented throughout all phases of disaster planning, preparedness, response, and recovery, and through both structural and nonstructural techniques. By using a GIS format to compile and analyze risk and vulnerability data, a baseline is established to evaluate how well mitigation measures are working, and a GIS provides an easier means to add new data. (For more information about hazard mitigation please visit www.csc.noaa.gov/products/nchaz/htm/dinfo_3.htm). Some potential methods of assessing hazard mitigation opportunities include the following actions.

- Identify undeveloped land located in high-risk areas to enhance future zoning and land-use decisions. The preservation of undeveloped floodplains and wetlands allows these areas to serve as storm and erosion buffers and as temporary flood storage for floodwaters (H. John Heinz III 2000). After a disaster, a community could assess prior zoning decisions in high-risk areas by calculating damage and losses in those areas. In the absence of a disaster, the community could use zoning information in conjunction with population data to determine the effects of new development (i.e., increased population and vehicles) on a community's disaster resiliency. For example, population growth in high-risk areas will impact evacuation measures and abilities, emergency shelter levels, and other response and recovery activities.
- Assess flood insurance program participation to determine the number of uninsured structures and target these properties to increase the number of standard flood insurance policy holders. Aggregate data are available from FEMA's National Flood Insurance Program. Although flood insurance won't prevent damages, it shifts some of the fiscal responsibility for disaster-related repairs to those who reside in floodplains.
- Prioritize critical facilities in high-risk areas for structural or nonstructural retrofitting, elevation, or relocation. Water, sewer, electric, fuel, and communications systems may also be buried or elevated.
- Identify populations that need special care and services to target predisaster outreach and expedite postdisaster recovery programs.

CVAT Case Studies and Examples

New Hanover County, North Carolina

As a result of impacts from five tropical storms from 1996 through 1999, New Hanover County, located in southeastern North Carolina, needed a systematic process to identify and understand its hazard risks and vulnerabilities. A partnership between the NOAA CSC, FEMA, and the New Hanover County Department of Emergency Management was formed to accomplish this task. The CVAT methodology was applied to New Hanover County to address community vulnerability, with particular emphasis on hurricane hazards. This was the first full-scale application of the CVAT methodology. The methodology provided the framework for assessing community vulnerability on a regional (countywide) basis by building a foundation for identifying and prioritizing community-based hazard mitigation activities.

The CSC worked closely with New Hanover County to identify the data sets needed to conduct a community-wide RVA. The general data types used in the analysis included those on erosion, wildfire, earthquake, and tornado hazards; infrastructure; critical facilities; environmental resources; economic and socioeconomic elements. In addition to providing a framework for hazards assessment, the methodology illustrated how GIS could be used to conduct vulnerability assessment analyses and aid in visualizing results. The use of GIS complemented the CVAT methodology by providing a visual, map-based perspective that identifies spatial relationships between critical resources and hazards. While the use of GIS is not required to conduct a RVA, this case study demonstrated the value of GIS as an analytical tool in this process. Examples of how the data were used to show community vulnerability are shown in Figs. 2(b–d).

New Hanover County's Project Impact Risk Assessment and Hazard Identification Committee drove the CVAT process, with support from other project impact committees. These committees included the following: (1) Risk Assessment and Hazard Identification (National Weather Service–Wilmington Weather Forecast Office, U.S. Coast Guard–Wilmington District, local industries, Occidental Chemical Corporation, U.S. Army Corps of Engineers–Wilmington District, town representatives, airport staff, etc.); (2) Mitigation Planning (county planning, building inspection, and engineering departments; local emergency management staff; county board of education; town planning staff; utility providers; North Carolina Division of Emergency Management; U.S. Army Corps of Engineers–Wilmington District; Convention and Visitors Bureau; Realtors and Home Builders Association, North Carolina Sea Grant, etc.); (3) Financial and Economic Issues (county and town finance department staff, Economic Development Agency representatives, Community Development Block Grant Program representatives, Project Impact coordinator, etc.); and (4) Public Information and Human Services (county and town public information, senior citizen volunteers, American Red Cross, educational organizations, civic groups, etc.).

The first and second steps in the CVAT process, hazard identification and analysis, are illustrated in Fig. 2(a). The New Hanover County multidiscipline RVA working group chose to evaluate the following hazards: tropical storms, flooding, tornadoes, wildfires, and wind. Natural hazards data were aggregated to develop a multihazard risk map composed of the individual hazard risk-area maps, derived from the community's prioritized list of hazards. This map was used as the basis for assessing community vulnerabilities with regard to critical facilities and societal, economic, and environmental factors. Fig. 2(b) displays special residential consideration areas within hazard-risk zones created from 1990 U.S. Census demographic variables. Fig. 2(c) presents economic sectors located in hazard-risk zones.

Once the first six steps of CVAT were accomplished, mitigation opportunities were explored. The purpose of this phase of the analysis was to identify structural and nonstructural hazard mitigation opportunities within and beyond the existing built environment. For example, Fig. 2(d) reveals tracts of undeveloped land in

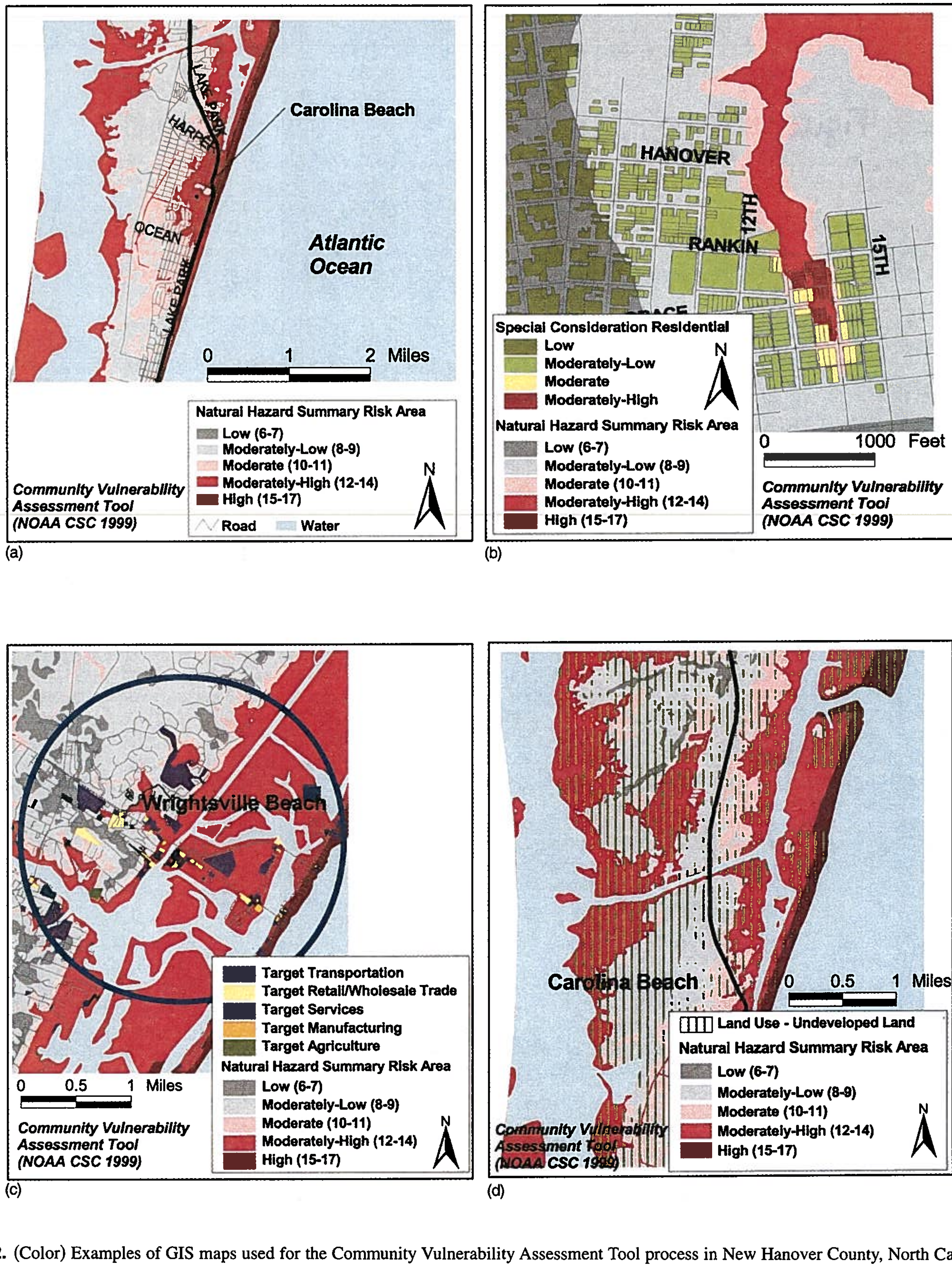

Fig. 2. (Color) Examples of GIS maps used for the Community Vulnerability Assessment Tool process in New Hanover County, North Carolina: (a) Natural hazard summary risk areas (Step 2—Hazard analysis); (b) Special consideration residential areas with high risk areas (Step 4—Societal vulnerability analysis); (c) Economic sectors in high-risk areas (Step 5—Economic vulnerability analysis); (d) Tracts of undeveloped land in high-risk areas (Step 7—Mitigation opportunities analysis)

hazard-risk areas. Recommendations in New Hanover County included evaluating existing development regulations to ensure that hazards are considered during zoning and subdivision application processes, and identifying hazards considerations for incorporation into comprehensive plans. The establishment of this baseline in a GIS format will enhance the use of existing data and creates a foundation for adding new data. This makes it easier to evaluate the efficacy of implemented mitigation measures and to project the possible cumulative impacts of future development and land use.

After completing this assessment, New Hanover County used its CVAT results in concert with its FEMA Project Impact endeavors to implement changes to make the community more disaster resilient. Prior to the completion of CVAT, the county enacted a liquid petroleum (LP) gas tank ordinance that requires tanks be strapped and secured in beach communities, thus removing the risk of the tanks floating away during flood events. The county used data collected from its CVAT critical facilities analysis to identify the locations of the LP tanks.

The county greatly improved its educational outreach programs to special needs populations. For example, a Spanish disaster hotline was created to provide vital information to the Spanish-speaking community before, during, and after a disaster. The county used special consideration data from its CVAT societal analysis to determine the breadth of the Hispanic population that resided in the county. In June 1999, the county held a Project Impact hurricane preparedness exposition to improve the level of disaster awareness and increase the knowledge of disaster mitigation techniques among all county citizens, during which a live demonstration of CVAT was provided to show its citizens where vulnerabilities existed (e.g., storm surge inundation zones). The county continues to host this event annually. The county is also currently using CVAT results for a new application—to jointly develop and administer a training course on terrorism with FEMA.

As illustrated in the New Hanover County case study, the CVAT methodology serves as a flexible model that can be adapted to most scales and regions; however, for CVAT to be successfully used as a hazard identification and planning tool, the data gathered to support the planning process should be dependent on the scale at which the analysis is being conducted. For example, in some cases FEMA Q3 flood data may be too coarse to use in a small area. It might be more suitable to use large-scale local flood data, if available.

Maui County, Hawaii

Maui County, Hawaii, became a FEMA Project Impact community in April 1999. As the first area in Hawaii attempting to comprehensively address hazard mitigation, Maui County sought help from other experienced agencies and organizations. Maui County's initial efforts included hosting a 2-day workshop on hazard mitigation in April 2000. The workshop was sponsored by the Pacific Disaster Center, FEMA Region IX, the National Aeronautics and Space Administration, Prescott College, and the NOAA CSC. The workshop, attended by 43 government, business, and nonprofit organizations from the islands of Maui, Oahu, and Hawaii, was designed to assist Maui County as it began its planning efforts to become a more disaster-resilient community. NOAA CSC staff provided training on the CVAT methodology.

The workshop motivated local interest in conducting a RVA. However, shortly after the completion of the workshop, it was evident that there was no local agency or representative with the ability to champion the RVA process to ensure that the training would be applied. The NOAA CSC helped the locals address this situation by funding an experienced state hazard mitigation officer from the state of Rhode Island to facilitate the effort.

The application of CVAT in Maui County validated the ease of adaptability of the methodology to other geographic locations and for other hazard types. Like New Hanover County, North Carolina, Maui County is a coastal area susceptible to some similar coastal hazards, such as hurricanes, coastal flooding, and coastal erosion. Maui County is also vulnerable to similar noncoastal hazards, such as earthquakes, inland flooding, and wildfires. Because the island of Maui is located in the Pacific Ocean, it is also susceptible to tsunamis and Kona storms. "Kona" is a Hawaiian term for the stormy, rain-bearing winds that blow over the islands from the southwest or south-southwest (opposite direction of the normal trade winds). Kona storms can produce damaging wind gusts of over 161 k/h (100 mph) when reinforced by mountainous topography (Pacific Disaster Center 2001).

Prior to implementing the seven-step CVAT process, Maui County established a multiagency working group to oversee the RVA process. The establishment of the working group proved to be the most important factor for guaranteeing the success of the process. The working group consisted of representatives from Maui County Civil Defense, Hawaii Civil Defense, Hawaii Coastal Zone Management, Pacific Disaster Center, University of Hawaii Social Sciences Research Institute, State Hazard Mitigation Forum, Maui County Planning, and Maui County Project Impact. The various backgrounds of the working group members helped to ensure that all potential hazards and vulnerability issues of the community were addressed and helped facilitate data mining efforts. The inclusion of academia and agencies responsible for the development of many key hazard, demographic, and cadastral data sets helped populate the GIS databases with the most current and accurate information available. Based on feedback and historical hazards information provided by the community, the following hazards were addressed during the RVA in Maui County: hurricanes and Kona storms, inland and coastal flooding, coastal erosion, earthquakes, tsunamis, drought, wildfires, landslides, and dam failure.

Another key factor of the success of the project was garnering awareness, buy-in, and input from political representatives, government officials, business leaders, and citizens. During the 4-month CVAT process, a series of meetings with political officials and the public were held to educate the community about the process, explain why the RVA was being conducted, and reveal the stakeholders' and assessors' expectations for the end results. Some of the political officials and community representatives included in the meetings were the mayor and his cabinet, county council, the planning commission, the board of variances and appeals, the Maui Hotel and Resort Association, the Kihei Rotary, and the Maui County Emergency Technical Standards Committee. The feedback received during the meetings also helped steer the RVA toward actual community concerns. This community involvement, combined with the adaptability of the process, provided a sense of ownership of the process and its results. Community ownership is critical if the implementation phase of the hazard mitigation strategy is to be successful.

The CVAT process was utilized in New Hanover County to address the vulnerability of critical facilities, economic sectors, society, and the environment. Maui County chose to address these same issues, but isolated building stock and public infrastructure vulnerability as a separate category from critical facilities. The New Hanover County case study addressed some public infrastructure vulnerability within its critical facilities analysis, but the working group in Maui County felt that public infrastructure vulnerability would be best addressed as a separate issue. This methodology can easily adapt to these different needs.

Although CVAT is not a loss-estimation program, the ability to rapidly combine hazards risk data with the Maui County tax assessor's information provided the community with potential information about financial losses. This information helped the community realize approximately how much property, lives, and tourism-related infrastructure were potentially at risk and convinced county officials to enact hazard mitigation legislation. The working group felt that the potential financial loss information was necessary to convince county politicians to enact such legislation or to utilize county funds to finance structural hazard mitigation measures.

The application of the CVAT methodology in Maui County proved to be very successful in helping the community understand its risks and vulnerabilities, and the results of the assessment led to the creation of a new full-time county hazard mitigation planner, a county hazard mitigation committee, and a county multihazard mitigation strategy (Apana 2001). The scope of the multihazard mitigation strategy is vast, covering everything from structural measures (e.g., hardening county facilities against flooding and hurricanes) to nonstructural measures (e.g., drafting new legislation to give homeowners and hotels tax credits for the creation of "safe rooms" in preparation for natural disasters).

Rhode Island

Rhode Island is a densely populated state vulnerable to numerous natural hazards, especially high winds, rain, and flooding from hurricanes and nor'easters. Like most coastal areas, it is experiencing an increase in coastal development, which translates into a broadening of property and individuals at risk to natural hazards. The state of Rhode Island determined that a comprehensive RVA would be the essential basis for making wise land use and development decisions, selecting and implementing appropriate disaster protection measures, developing and implementing emergency response plans, creating postdisaster redevelopment plans, safeguarding economic investments, and attracting and retaining economic development (IBHS 2000).

On December 18, 1998, Governor Lincoln Almond signed Executive Order 98-13 designating Rhode Island as the first Showcase State for Natural Disaster Resistance and Resilience in the country (Almond 1998). The Showcase State program is an initiative of the Institute for Business and Home Safety (IBHS), a nonprofit association of the insurance and reinsurance industry whose mission is to reduce deaths, injuries, property damage, economic losses, and human suffering caused by natural disasters through communication, education, engineering, and research. The goal of the Showcase State program is to make natural hazard loss reduction an integral part of everyday planning and decision making in Rhode Island. The executive order designated the Rhode Island Emergency Management Agency (RIEMA) as the lead agency charged with directing state agencies to cooperate with public- and private-sector partners to reduce natural-hazard vulnerabilities. One of the directives in the executive order is to "complete a statewide hazard analysis and risk assessment, and provide assistance to municipalities to identify their natural hazard risks" (Executive Order 98-13).

Based on the executive order and the requirements of RIEMA, it was determined that at a minimum the statewide assessment must address the following:

- State resources and infrastructure owned or managed by state agencies (e.g., bridges, major roadways, dams, parks, etc.).
- Statewide lifelines (e.g., gas, water, electric power, telecommunications, etc.).
- Critical facilities (e.g., hospitals, emergency shelters, etc.) and protective measures that may affect the state's ability to recover from hazard events (e.g., Fox Point Hurricane Barrier).

It was also recommended that the assessment incorporate the following:

- Hidden costs of natural disasters, such as the disproportionate vulnerabilities of certain portions of society to the impact of hazard events.
- Potential environmental impacts.
- Potential business interruption.

CVAT was selected because it was a good tool for conducting a statewide assessment that would meet the needs of the state. The NOAA CSC decided to partner with Rhode Island, IBHS, and Odeh Engineers, Inc. (Odeh 2001) to modify and adapt the methodology to conduct the statewide assessment. The NOAA CSC was interested in this pilot effort as another means by which to demonstrate how CVAT could easily be applied to various geographic locations and at various scales (e.g., community level, county level, state level, etc.).

Under the leadership of the RIEMA, Odeh Engineers successfully modified and expanded the CVAT methodology to conduct the statewide assessment. As with other applications of CVAT, data that were readily available, easily accessible, and nonproprietary were utilized to address multiple hazards and vulnerabilities. The statewide application of CVAT focused on identifying the relative risks and vulnerabilities of the following hazards: extreme wind events, floods, nor'easters, earthquakes, tornadoes, snow/ice, temperature extremes, and environmental hazards. Besides addressing some additional hazards, the application of CVAT in Rhode Island also relied on a modified hazard scoring process to identify the level of risk in various regions throughout the state.

CVAT enabled the state to complete an RVA that met all of the requirements outlined in the executive order. Pamela Pogue, state floodplain manager and Rhode Island Project Impact coordinator emphasized, "The statewide risk and vulnerability assessment has provided the foundation for the state to develop and prioritize hazard mitigation strategies that will ensure that the average citizen will be less vulnerable to a disaster's impacts. The statewide assessment will also serve as a baseline to measure the effect hazard mitigation measures have on the overall vulnerability of the state over time." The assessment has also been utilized as a model for all Rhode Island communities to conduct more detailed community-level assessments. Pogue explained, "State officials presented the CVAT methodology to local officials and helped them establish a hazard mitigation committee to analyze their physical, social, economic, and environmental vulnerabilities to natural hazards. CVAT improves a community's capability to do the assessment because it's easy, hands-on, and understandable. Using CVAT, state agencies and community leaders have a much better understanding of how to complete the assessment and how hazard mitigation plays a role in what they oversee" (Pamela Pogue, personal communication, May 24, 2001).

Case Study Lessons Learned

The following table, Table 1, displays a list of challenges, problems, opportunities, and best practices developed from all three case studies.

Table 1. CVAT Case Studies: Challenges, Problems, Opportunities, and Best Practices.

Step	Case study	Challenges/Problems	Best practices/Opportunities
Hazard Identification	New Hanover County	The county had recently been impacted by several hurricanes. Thus, initially it was hard to get the community to focus on other hazards, especially those that had not impacted the area recently (earthquakes, wildfire, etc.).	Utilizing existing databases that the community was initially unaware of, including the Storm Events database from the NOAA National Climatic Data Center, helped members realize that they were vulnerable to hazards other than hurricanes. It also helped them to determine the frequency and damage potential of each hazard.
	Maui County	Forming the multidisciplinary steering committee for identifying hazards was difficult. The lack of general knowledge of hazard risks and vulnerabilities and concept of hazard mitigation caused the emergency management agency, the group initially tasked with developing the RVA, to question why some of the other participants were necessary. It was apparent that the EM and Land Use Planning Departments had not worked together in the past. EM thought they were going through the process only to identify potential HMGP projects, not a more holistic view of hazard mitigation.	Utilized series of meetings/presentations to educate not only public officials and state and local agencies, but also the general public about the need for risk and vulnerability assessments and concept of hazard mitigation. Presentations were aired on the local television stations on several occasions.
	Rhode Island	Prior to conducting the RVA, RI had not had a major disaster since 1938. This made the process of identifying hazards more difficult.	In addition to sources used by the other case studies, RI also relied on insurance industry information to help determine what types of hazards had impacted the state in the past.
	All	Getting communities to address all hazards can be a challenge. Depending on an area's recent hazard experience, it may be hard to get them to focus on lower probability events that can cause significant damage.	Data on historical hazard impacts can be obtained from readily available sources such as FEMA, NOAA, USACE, and USGS.
Hazard Analysis	New Hanover County	Due to data limitations and the nature of some hazards, the risk consideration areas for some hazards (tornado and earthquake hazards) could not be broken down spatially beyond the extent of the entire county.	Recent hazard impacts in the area enabled the community to ground truth some of the risk consideration areas.
	Maui County	For some of the hazards identified there were not data available to map hazard risk consideration areas. For example, hurricane storm surge models had never been run for Maui, but this was a hazard that the committee was very concerned about. Therefore, they had to arbitrarily pick a potential storm surge elevation for each storm category based on model results for other Hawaiian islands.	In Maui County the mayor had just initiated a program to develop a county GIS system through their intranet. Since the county was already utilizing existing resources to collect, store, and integrate all of their GIS data sets in one central location, the mayor allowed his GIS staff to spend some of their time working on the project. The mayor saw this as an opportunity to use the new centralized system to address issue and concerns throughout the county.
	Rhode Island	When mapping hazard risk consideration areas for a statewide analysis it is necessary to validate the maps locally. This can be a time-consuming effort.	No new data had to be created for the analysis.
	All	Depending on the scale of the analysis, sometimes publicly available data may not be suitable for accurately displaying hazard risks.	Utilized publicly available, nonproprietary data for the analysis.

Table 1. *(Continued)*

Step	Case study	Challenges/Problems	Best practices/Opportunities
Critical Facilities Vulnerability Analysis	New Hanover County	New Hanover County identified over 400 critical facilities during its analysis. This presented a challenge when gathering and processing data about each individual facility.	The use of GIS enabled county officials to quickly identify which critical facilities were located in the highest (or multi-hazard) risk areas. This enabled them to prioritize a limited number of their critical facilities for detailed assessments.
	Maui County	—	The ability to visualize critical facility location in relation to hazard impact areas through the use of GIS enabled them to realize that several essential services such as fire and police services, would be unavailable due to access issues during flood events. Prior to the analysis, flooding wasn't considered a hazard to these services since they were located outside of the floodplain.
	Rhode Island	It was a challenge trying to address critical facilities throughout the entire state, especially when some critical facilities were clearly of more importance than others. Critical facilities included marinas, emergency shelters, school, hospitals, fire and rescue stations, police stations, water treatment or sewage processing plants, railroad stations and airports, and government facilities.	They developed an importance factor to account for the critical nature of some types of facilites. This approach was consistent with national building code standards, which assign a higher importance factor to critical facilities.
	All	The methodology does not give quantitative loss or damage estimates for critical facilities.	The ability to visualize critical facility locations in relation to hazard impact areas through the use of GIS enabled communities to prioritize facilities to conduct future structural and operational vulnerability assessments.
Societal Vulnerability Analysis	New Hanover County	Missing data for individual census tracts can skew results.	Utilized parcel level GIS data, combined with census data, to further refine their analysis.
	Maui County	In some cases, recent changes in development and the limited number of census tracts for the county made census data inadequate for the analysis.	Utilized local officials to verify existing data and to provide additional data.
	Rhode Island	Limitation on availability of current data; they had to utilize 1990 U.S. census data, which may not accurately reflect current conditions, even though the study was performed after the 2000 U.S. Census had been conducted.	The state recommended local verification of the results to ensure the accuracy of the analysis.
	All	The use of census tract data can be limiting, especially in areas that have a partial number of census divisions (tracts, blocks, block groups) for the area. The use of census data does not account for transient populations such as tourists, seasonal employees, and homeless populations.	It is important to seek assistance from local officials to enhance publicly available (census) data. For example, a county housing authority could identify the exact locations of low income housing, whereas census data could only identify areas of higher concentration of low-income housing.
Economic Vulnerability Analysis	New Hanover County	—	Utilized existing data from a national source, US Census Community Business Patterns, supplemented with data from the local Chamber of Commerce for the analysis.

Table 1. *(Continued)*

Step	Case study	Challenges/Problems	Best practices/Opportunities
	Maui County	—	The county was able to utilize the impacts of Hurricane Iniki on the Island of Kauai to demonstrate how disasters can devastate a community's economy. This information helped to secure private sector involvement in the process.
	Rhode Island	The best available economic data was at a low resolution, zip code level. Several assumptions had to be made to convert the data to the census tract level.	Utilized the 1997 Rhode Island Economic Census for the analysis.
	All	The methodology does not give loss or damage estimates, only estimated impact areas. Trying to get private businesses interested in hazard mitigation can be a challenge, but is more effective when using dollar loss estimates.	GIS data, such as land use data, was enhanced with national databases, such as the U.S. Census Community Business Patterns.
Environmental Vulnerability Analysis	New Hanover County	Although they had been impacted by several hurricanes prior to conducting the analysis, not much data was available on the impacts of these events on the environment.	—
	Maui County	—	Historically, Hawaiian culture has always placed significant value on the environment. The CVAT process served to institutionalize their desire to protect the environment.
	Rhode Island	—	Utilized existing GIS data from the Rhode Island Geographic Information System (RIGIS).
	All	It can be a challenge to raise the issue of environmental impacts to public officials that are more concerned with saving lives and property.	This step helped public officials and business leaders realize that hazard-induced environmental impacts jeopardize natural resource dependent industries such as tourism, recreation, and fishing; resulting in adverse economic impacts.
Mitigation Opportunities Analysis	New Hanover County	—	The CVAT process enabled the county to implement several hazard mitigation measures, such as changing land use plans, which would have been very difficult politically and publicly without the backup information from the process to justify the measures.
	Maui County	Initially it was difficult to get local politicians to see the true benefit of hazard mitigation. Many politicians might not consider issues beyond their own term of office and most hazard mitigation measures may not show a return on investment until after that timeframe.	The CVAT process helped to demonstrate the importance of hazard mitigation planning and resulted in the creation of a new position within the county, a hazard mitigation planner.
	Rhode Island	Following completion of the process, it was apparent that several additional studies or information, such as potential impacts on the tourism industry and information on nursing homes and daycare facilities, were necessary to fully address hazard risk and vulnerability.	The results of the RVA were presented to numerous planners, business people, and state officials in order to identify mitigation opportunities. This resulted in several macroscopic policy initiatives, such as adoption of the International Building Code (IBC) 2000 building code, and microscopic programs, such as accelerating development of community hazard mitigation plans in the high-risk areas identified by the assessment.

Table 1. *(Continued)*

Step	Case study	Challenges/Problems	Best practices/Opportunities
	All	The methodology is intended to be a planning process to help identify potential mitigation options. Once potential mitigation options are identified, further analysis, such as benefit cost analysis, is required to determine which options are economically feasible.	The networks established by involving multiple agencies in the process help in identifying potential resources for implementing the hazard mitigation measures.
Process as a Whole	New Hanover County	The county had been impacted by several hurricanes prior to conducting their assessment. Even though they had been impacted, it would have been difficult to get the commitment they needed to complete the process without the financial incentive provided by FEMA through their Project Impact Initiative.	By utilizing GIS to conduct their assessment, the county has been able to add additional layers to address new hazards, such as terrorism.
	Maui County	Data were collected from many different sources, most not in digital format. In some cases it was challenging to convert the data to GIS.	County staff and officials, in three short months, went from virtually no knowledge of hazard mitigation to advocating the need for county department-wide integration of the concepts of hazard mitigation and the importance of implementation through land-use decision-making. Politicians and officials began to see the long-term benefits of mitigation beyond their terms in office.
	Rhode Island	Statewide results indicated high levels of risk and vulnerability in individual census tracts. However, it is recommended that all data be locally validated to ensure accuracy.	The process resulted in a baseline of hazard risk and vulnerability that will be used to compare with future risk and vulnerability assessments to measure the state's progress towards becoming a disaster resistant state.
	All	The results are only as good as the data used to complete the analysis. Some communities may not have the resources or time to fully commit to conducting the process.	The process helped to foster and, in some cases, develop new working relationships between emergency managers, planners, natural resource managers, business leaders, and public officials. The networks created during the process are also used during hazard response and recovery activities.

Limitations

As beneficial as CVAT is, there are limitations with using the methodology. CVAT is a planning tool to evaluate relative risk only and should not be confused with loss estimation software, such as FEMA's Hazards United States (HAZUS) (FEMA 2001). CVAT requires input and ongoing collaboration from a range of community stakeholders, and it may be challenging to engage and maintain the proper individuals to sustain the momentum of the process. Communities might not have adequate expertise or resources to collect and integrate data, nor the finances to hire a contractor to do so. Although most data (e.g., hazards, census, facility locations, utilities, natural resources, hazardous material storage sites, etc.) are freely available, it is necessary to compile and ground-truth this information with local stakeholders. The RVA results are only as good as the data used, which might also be a limitation of the CVAT methodology. It is highly recommended by the Federal Geographic Data Committee that only data for which metadata records are available be used; metadata records contain data about data, and ensure that the user will understand the content, quality, and condition of a particular data set (Clinton 1994).

CVAT is designed for aggregate exposures, not to assess individual structures; however, it pinpoints people, property, and resources in high-risk locations to conduct further analyses. Also, the hazard identification process uses a formula that combines somewhat subjective hazard-specific variables to arrive at a total hazard risk score. The ideal method for assigning priorities to the various hazard threats would be a scientific, quantifiable probability assessment (with social values input). Unfortunately, probability data are not consistent among the different hazard types, nor are they always available or usable at the local level. Nonetheless, CVAT provides an example of how high-risk scores were derived for several hazards using the best available information (e.g., hurricane risk was based on the Saffir-Simpson hurricane scale categories).

Conclusion

The CVAT methodology provides both a straightforward process to conduct an RVA and results that can be used to develop and prioritize hazard mitigation strategies and identify sustainable development solutions for comprehensive planning. Through the use of advanced GIS technology or less technical static maps, the community is able to spatially analyze vulnerable populations, property, and resources. The methodology may be used for any hazard the user chooses, and is easily adaptable for any geographic location.

While CVAT recommends the process to conduct the RVA, the community is in the driver's seat. Stakeholder involvement is exigent to establish buy-in from the community, and to develop a comprehensive RVA that addresses multiple perspectives. Community members with a wide range of expertise and knowledge can work together to perform an RVA and develop effective strategies for reducing or eliminating disaster-related damages. This process can establish a network in the community for sharing information and working more efficiently when a disaster occurs. Mapping appears to facilitate community understanding and action, as people can see the spatial and consequential relationships between risk areas and vulnerable populations and locations. Understanding these relationships is essential for comprehensive planning and disaster preparedness, including proper hazard mitigation, response, and recovery. More information and a free copy of the CVAT CD-ROM can be obtained by visiting the CVAT Web site www.csc.noaa.gov/products/nchaz/startup.htm.

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References

Almond, L. (1998). "Rhode Island Executive Order 98-13" ⟨http://www.state.ri.us/riema/sstateexec.htm⟩ (November 30, 2001).

Apana, J., Jr. (2001). *Working together to make things better: State of the county address*, ⟨http://www.co.maui.hi.us/online/Address2001.txt⟩ (November 8, 2001).

Clinton, W. (1994). "Coordinating geographic data acquisition and access: The national spatial data infrastructure." '*Executive Order 12906 of April 11, 1994*, ⟨http://www.fgdc.gov/metadata/contstan.html⟩ (July 15, 2002).

Federal Emergency Management Agency (FEMA). (1997). *Multi hazard identification and risk assessment: A cornerstone of the national mitigation strategy*, Federal Emergency Management Agency, Washington, D.C. pp. 3, 13, 194.

Federal Emergency Management Agency (FEMA). (2001). "HAZUS 99 estimated annualized earthquake losses for the United States." Federal Emergency Management Agency, Washington, D.C.

Hazard Mitigation Planning and Hazard Mitigation Grant Program. (2002). *Federal Register*, Title 44 of the Code of Federal Regulations: Parts 201 and 206, Interim Final Rule. Vol. 67 (No. 38, Feb. 26), (8849–8850).

H. John Heinz III Center for Science, Economics and the Environment. (2000). *The hidden costs of coastal hazards: Implications for risk assessment and mitigation*, Island, Press, Washington, D.C., 16–19, 154.

Institute for Business and Home Safety (IBHS) (2000). *Rhode Island first year report: Showcase state for natural disaster resistance and resilience*, ⟨http://www.state.ri.us/riema/rhodeis.pdf⟩ (November 30, 2001).

Mileti, D. S. (1999). Disasters by design: A reassessment of natural hazards in the United States. Joseph Henry Press, Washington, D.C., p. 3.

National Hazards Caucus Work Group. (2001). *A national priority: Building resilience to natural hazards*, ⟨http://www.ucar.edu/communications/awareness/2001/hazards/⟩ (April 16, 2001).

Odeh Engineers, Inc. (2001). *Statewide hazard risk and vulnerability assessment for the state of Rhode Island.* North Providence, R.I.

Pacific Disaster Center. (2001). *Hawaii wind information*, ⟨http://pdc.org/pdc/pub/HighWinds/HighWindInfo.html⟩ (November 30, 2001).