Note to File: The following additions to the report will be made by June 30. Appendix D: Hazard Mitigation Plans has been added as of May 25, 2022.

Add to Page 18

During the planning process for Resilient Connecticut, some of the municipalities engaged during the workshops (i.e., Monroe) explained that in lieu of the TOD opportunities and regional infrastructure located in their communities that would presumably lead to comprehensive climate adaptation and resilience projects, the process should honor and acknowledge the needs described in the annexes of their multi-jurisdiction hazard mitigation plans. Likewise, some of the municipalities with TOD opportunities and regional infrastructure (i.e., Brookfield) wished to acknowledge hazard mitigation actions that would not likely be linked to comprehensive climate adaptation and resilience projects, yet represent additional local challenges which may also be considered in the state's resilience project pipeline. CIRCA and its consultants concurred and recognized this need, ultimately determining that this report should incorporate all actions in the WestCOG, MetroCOG, NVCOG, and SCRCOG multi-jurisdiction hazard mitigation plans. However, two of these plan updates were underway from 2020 through 2021, and final lists of actions were not available until the end of 2021. This report hereby incorporates the actions in the WestCOG, MetroCOG, NVCOG, and SCRCOG multi-jurisdiction hazard mitigation plans for the municipalities of Fairfield County and New Haven County. These can be found in Appendix D.

Add to Page 87 at the end of Recommendation #5

In addition, the hazard mitigation plan actions in the WestCOG, MetroCOG, NVCOG, and SCRCOG multi-jurisdiction hazard mitigation plans (Appendix D) should be considered candidates for the resilience project pipeline.

PHASE II

ResilientConnecticut

February 2022

edited 5/25/22

CIRCA
Connecticut Institute for Resilience and Climate Adaptation

ResilientConnecticut

February 2022

Prepared by SLR International Corporation
Formerly Milone & MacBroom, Inc.

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More information can be found at https://resilientconnecticut.uconn.edu.

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List of Acronyms

BFE	Base Flood Elevation
BPFA	Balanced Priority Funding Area
CCVI	Climate Change Vulnerability Index
CDC	Centers for Disease Control
CIRCA	Connecticut Institute for Resilience and Climate Adaptation
COGs	Council of Governments
CRB	Community Resilience Building
CWS	Community Water System
CVI	Coastal Vulnerability Index
DEEP	Department of Energy & Environmental Protection
DOH	Connecticut Department of Housing
DOI	Department of the Interior
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GC3	Governor's Council on Climate Change
GIS	Geographic Information Systems
HDe	Hybrid Delta Ensemble
HMP	Hazard Mitigation Plan
HUD	Department of Housing and Urban Development
MetroCOG	Metropolitan Council of Governments
NDDB	Natural Diversity Data Base
NDRC	National Disaster Relief Competition
NFWF	National Fish and Wildlife Foundation
NVCOG	Naugatuck Valley Council of Governments
TOD	Transit-Oriented Development
RCC	Resilient Connecticut Collaborative
ROAR	Resilience Opportunity Area
SAFR	State Agencies Fostering Resilience
SCRCOG	South Central Regional Council of Government s
SFHA	Special Flood Hazard Area
SHPO	State Historic Preservation Office
SoVI	Social Vulnerability Index
SWRPA	Southwestern Regional Planning Agency
SVI	Social Vulnerability Index
TNC	The Nature Conservancy
UConn	University of Connecticut
WestCOG	Western Council of Governments
WPC	Water Planning Council
WPCF	Water Pollution Control Facility
WUCC	Water Utility Coordinating Committee
VCOG	Valley Council of Governments
ZSR	Zone of Shared Risk

1.0 Introduction

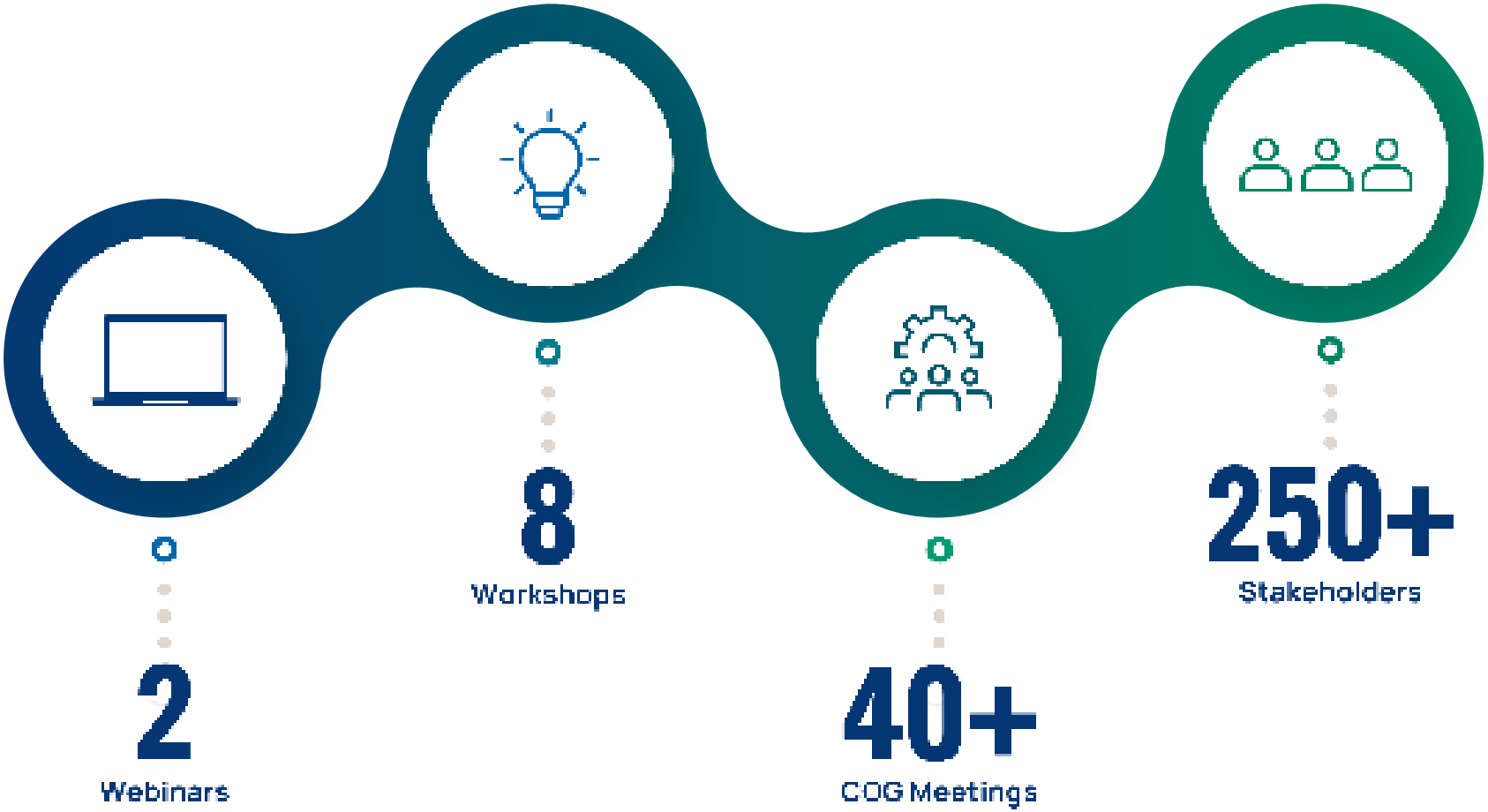
The Connecticut Institute for Resilience and Climate Adaptation (CIRCA) initiated Resilient Connecticut in 2019 as a component of the U.S. Department of Housing and Urban Development (HUD) National Disaster Resilience Competition (NDRC) award to the State of Connecticut, which is being administered by the Connecticut Department of Housing (DOH). Resilient Connecticut provides the state with a climate resilience planning framework and is being piloted in New Haven and Fairfield Counties, as these areas were most heavily impacted by Superstorm Sandy in 2012.

The Resilient Connecticut project focuses on regional climate resilience and adaptation planning through evaluations and engagement to inform municipal-to-regional scale initiatives and pilot projects. "Resilient Connecticut's guiding principle is to establish resilient communities through forward-looking planning that incorporates economic development framed around transit-oriented development (TOD), conservation strategies, and critical infrastructure improvements."

Resilient Connecticut recognizes that the impacts of climate change to infrastructure, public health, ecology, and other systems occur at a variety of scales beyond and across municipal boundaries. This work builds on the extensive previous planning in Connecticut to understand risks and identify vulnerabilities to regional infrastructure. Resilient Connecticut is focusing on regional scale risk assessments through a process of shared discussion and decision-making and crafting pilot projects at scales appropriate

to address shared and similar problems among stakeholders.

Phase II of Resilient Connecticut commenced in mid-2020 and will conclude in early 2022. This second phase of Resilient Connecticut is comprised of a regional risk and vulnerability assessment, the main technical component; a robust stakeholder outreach and engagement process; and the development of multiple public-facing resources regarding the project and climate change vulnerability, as well as numerous lessons learned that can be implemented throughout Phase III and future resilience planning efforts for Connecticut.



Phase II Planning Process 2.0

2.1 Methodology

With an overarching vision of developing a regional resilience plan for New Haven and Fairfield Counties (Figure 1), Resilient Connecticut has devised several goals and objectives. In general, it is to increase coordination, develop plans to guide adaptation, leverage CIRCA and University of Connecticut (UConn) technical support, and provide recommendations for a statewide resilience roadmap.

While Phase II of Resilient Connecticut sought to work toward achieving all of these objectives, this phase focused acutely on increasing regional coordination and communication, executing a regional vulnerability assessment, and identifying resilience opportunities to further develop in Phase III and future resilience endeavors.

The engagement component of this Phase included webinars, workshops, and monthly interactions with the four regional Councils of Government (COGs) within the two counties. The COGs host monthly committee meetings that are attended by municipal Chief Elected Officials, staff, state representatives, non-governmental organizations, and the public. The COGs worked closely with the Resilient Connecticut team to both provide data and information needed for the assessment and to help keep municipalities engaged during the process. In addition to monthly COG meetings, workshops and webinars were also

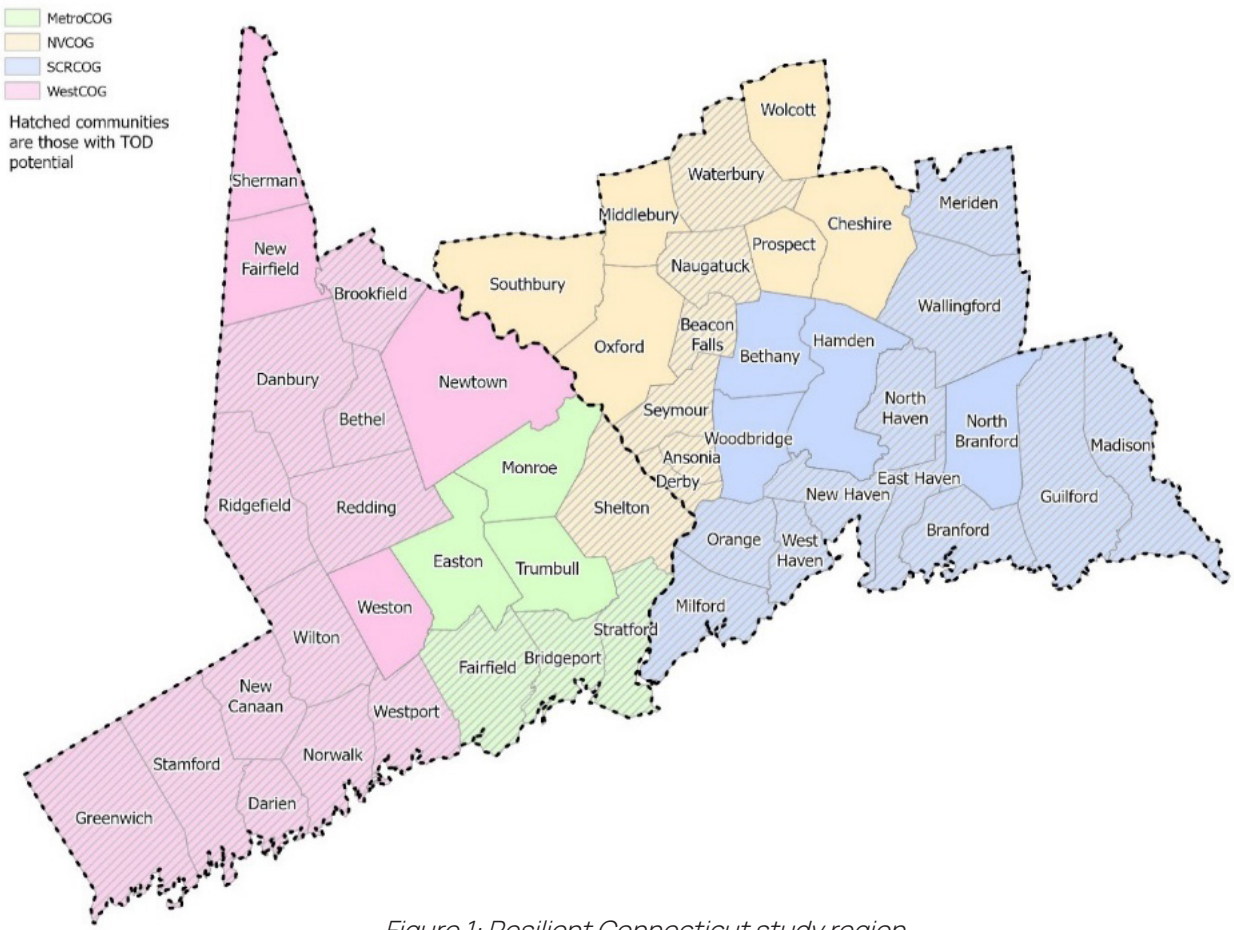


Figure 1: Resilient Connecticut study region

held throughout the planning process. All meetings and events aimed to communicate the project and the need for climate resilience planning in general to communities, stakeholders, and the public.

A regional vulnerability assessment, one of the primary components of Phase II, was carried out using robust stakeholder feedback and collaborative tool development. The assessment characterizes flood and heat vulnerabilities for communities as well as regional and local assets. The two primary tools developed include the Climate Change Vulnerability Index (CCVI) for flood and heat, and Zones of Shared Risk (ZSR) for flood.

CCVI includes two indices, one for flood and one for heat. The indices use 10-acre grid cells to capture social, built, and ecological sensitivities and adaptive capacities within an area along with current and future hazard exposure. As discussed in Chapter 4.0, CCVI has been used to evaluate regional, COG, and asset vulnerabilities. ZSR, which is a flood-specific tool, identifies locations that share a common flood-specific risk to aid in bringing stakeholders together to solve flood challenges.

Social vulnerability has also been assessed using a social vulnerability index (SVI) developed specifically for the region. The assessment, with a particular focus on technical tools, was developed with communities in mind. One major goal for the assessment was to develop tools that are useful for communities. The abundance of stakeholder feedback was a primary driver for tool development, data use, and the process in general. Tailoring this assessment to community needs is what will ultimately drive resilience and adaptation projects.

The regional vulnerability assessment identified assets and areas that are vulnerable to flooding and extreme heat, which was a primary component of identifying resilience opportunity areas (ROARs). These ROARs, presented in Chapter 5.0, have been identified by intersecting the highest flood and heat vulnerable areas with critical assets and other important planning data. Each ROAR was identified for its regional significance and high degree of vulnerability.

2.2 Engagement

CIRCA has remained committed to working closely with communities and stakeholders across the state to enhance community resilience; Phase II of Resilient Connecticut further emphasizes that approach. The Resilient Connecticut team worked during Phase II to successfully host two sets of stakeholder workshops and two webinars; attended numerous COG meetings; developed online feedback tools; and provided open lines of communication for stakeholders to help shape the Resilient Connecticut process. The Resilient Connecticut team also attended various stakeholder events throughout the project planning timeframe, including COG board committee meetings, State Agencies Fostering Resilience (SAFR) meetings, and Governor's Council on Climate Change (GC3) meetings. While a full engagement report can be found in Appendix A, a brief synopsis of the virtual events held, and their outcomes are presented below. In addition, to explore materials from the engagement activities discussed below and in the report, visit https://resilientconnecticut.uconn.edu/engagement/.

Two series of workshops were held during Phase II: the first in January and February 2021, and the second in May 2021. The first workshop series was designed to present the vulnerability assessment tools being developed (CCVI and ZSR) and utilized for the Phase II assessment, and to allow stakeholders an opportunity to review the tools and provide feedback. The second series presented the preliminary ROARs that had been identified as a result of the vulnerability assessment. This series again provided stakeholders with a platform to voice thoughts and feedback on the ROARs and methodology introduced. Feedback from both series of workshops was categorized as either short or long term and ultimately incorporated into the Phase II planning process and tools where appropriate, or, for long term, was documented for future resilience assessments and planning.

In addition to the workshops, two webinars were held. The first webinar was held in March 2021, which presented a detailed update on the CCVI development and how workshop feedback was incorporated into the latest version of the tool. Participants were also referred to the various options that were still available for providing tool feedback. In May 2021, a second webinar was developed both to present the high-level findings of the vulnerability assessment that was a result of the previous engagement efforts and tool development, and to review the format and information present in the Phase II vulnerability assessment.

In addition, CIRCA developed the Resilient Connecticut Collaborative (RCC). The grant originally identified the need for a "citizen advisory committee" to inform the project. The needs of the project led to other methods of localized engagement that will be intensified throughout Phase III. As an alternative representative group, RCC consists of representatives from statewide organizations that bring perspectives from housing, utilities, agriculture, food, conservation, and more. RCC operates as a facilitated community of practice where members can network and advance their understanding of climate change. Throughout Phase II, RCC members provided invaluable feedback on several important project deliverables while learning about climate activities peer organizations are undertaking. To learn more about the Resilient Connecticut Collaborative, visit the webpage https://resilientconnecticut.uconn.edu/resilient-connecticut-collaborative/.

Engagement with key municipal staff from departments such as planning, engineering, public works, and emergency management was important for ensuring that communities were comfortable with the ROARs delineated; and with the potential for a specific ROAR in their community to advance to additional consideration in Phase III. CIRCA initiated municipal

engagement in May 2021 and continued this engagement through December 2021. The target municipalities were those with ROARs that include moderate to high flood, heat, and social vulnerabilities. Meeting dates are listed below in . Direct email correspondence continued in some cases.

Municipalities with ROARs of relatively lower flood, heat, and social vulnerabilities were not included in this targeted engagement, but they were nevertheless provided with opportunities to review ROARs through the workshop series, COG board meetings, and COG committee meetings in spring, summer, and fall 2021.

In most cases, direct municipal engagement helped reality-check the vulnerabilities and risks anticipated in the ROARs, pointed CIRCA toward the unmet needs in the ROAR, and helped craft potential adaptation and resilience scenarios of potential value in the ROARs. For example, the engagement with Meriden was useful for understanding which part of the downtown ROAR was targeted for the next phase of the City's flood mitigation strategy; and highlighted the lingering need to address challenges associated with Clark Brook near the railroad station. Direct municipal engagement also brought to light situations where State or federal efforts were already addressing vulnerabilities throughout a ROAR, such as the Long Wharf flood

Municipality	Dates of Meetings
Ansonia	6/28/2021
Branford	7/14/2021
Danbury	8/5/2021
Darien	10/20/2021
Derby	10/14/2021
Fairfield	9/29/2021
Meriden	7/19/2021
Milford	11/12/2021
Naugatuck	6/21/2021
New Haven	5/13/2021 and 12/2/2021
Norwalk	6/16/2021
Stratford	6/22/2021
Waterbury	7/13/2021

Table 1: Dates of meetings held with key municipal staff

protection strategy under evaluation by the Army Corps of Engineers in New Haven.

In some cases, the discussions that occurred during direct municipal engagement were helpful for developing an alternative approach for evaluating factors that affect community resilience. The ROAR in Derby appropriately recognized high flood and heat vulnerabilities. Prior to meeting with the City, ideas for adaptation and resilience projects included considerations for new community facilities on the southeast side of downtown where future development is planned. While engaging with the City, CIRCA learned that a focus on existing affordable housing and potential uses of a City-owned building may be more aligned with addressing unmet needs in Derby.

Finally, in other cases, municipal engagement helped obtain an understanding that potential adaptation and resilience projects in a ROAR were not aligned with the short-term needs of the community. For example, the Town of Darien was focused on addressing reduction of flood damage to single-family homes near Stony Brook and in a few other areas, choosing to pursue hazard mitigation grants for acquisitions and elevations. Attention can be turned to the ROAR at a later date.

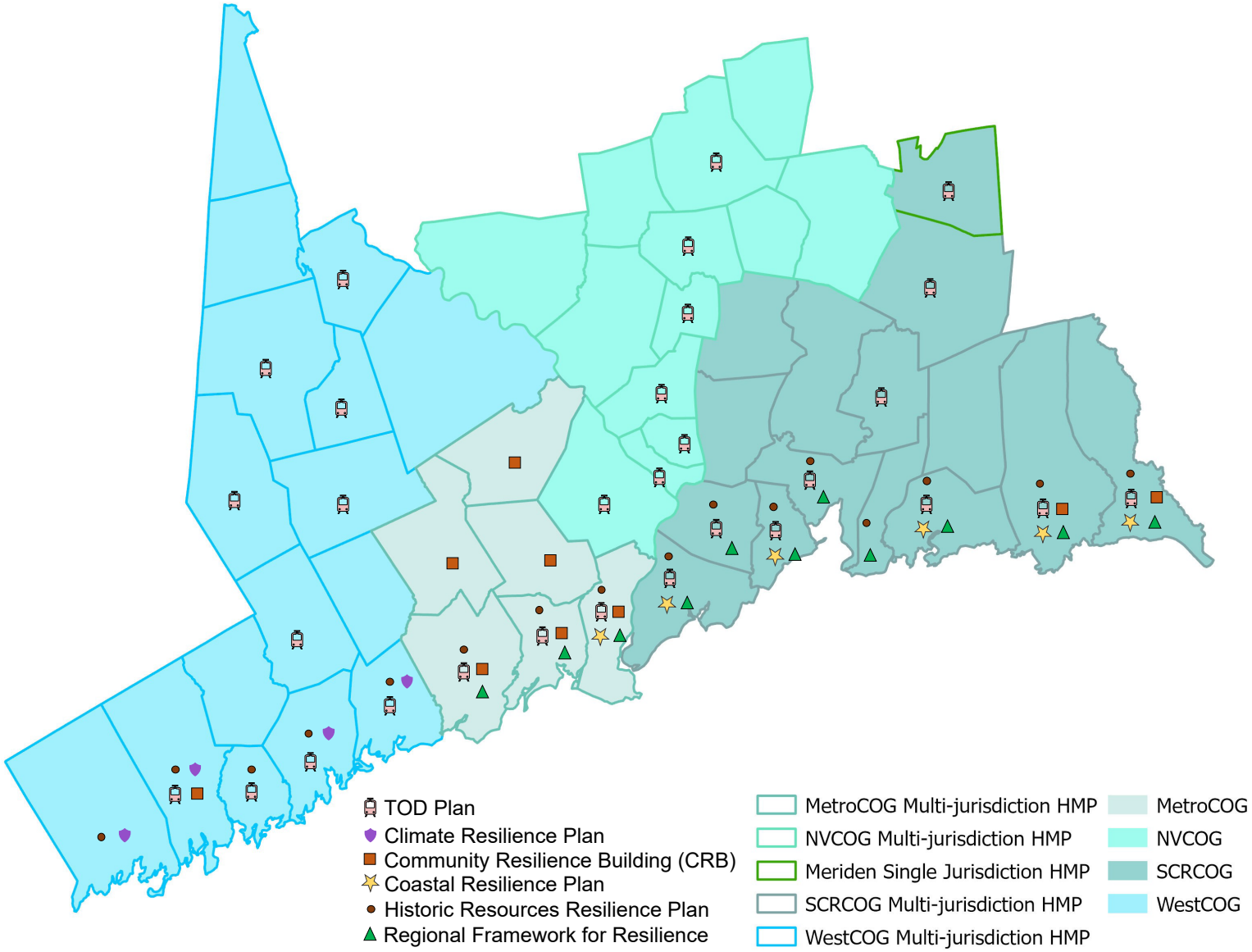
Overall, municipal engagement was a critical activity for runup to the PERSISTS scoring described in Section 5.5, and for the development of Phase III evaluations and concept designs.

Resilience Planning Status 3.0

Connecticut communities are continuously planning for development, conservation, and natural hazards; they are also increasingly planning to address climate change resilience. While many planning efforts do not directly contribute to climate resilience, themes can often be found interwoven with longstanding planning efforts. To evaluate the status of both longstanding traditional and more recent climate resilience planning efforts, many documents and processes that have occurred at the local, regional, and state levels were reviewed to identify climate-related activities; how they might inform the Resilient Connecticut project; and resilience gaps within each project. This discussion and the in-depth review in Appendix B are companion pieces to forthcoming research papers on the relatedness of climate efforts in local planning processes and policy gaps within local resilience planning. Figure 2 identifies the Resilient Connecticut communities and some of their relative planning efforts.

There are several plans that all communities throughout the region have adopted and maintained, including Plans of Conservation and Development (POCDs) and Hazard Mitigation Plans (HMPs). A POCD typically encompasses all aspects of community planning and development but does not always include a climate change or climate resilience component. On the other hand, HMPs are specifically geared toward natural hazard mitigation; however, they are often developed

Figure 2: Municipal community planning efforts



in response to historic events and not necessarily climate projections. While some communities have begun to include a climate component into these plans, most have not, or at least not to a large extent. Both of these planning efforts present opportunities to outline and plan for future climate resilience needs and to develop hazard mitigation strategies with changing climate in mind.

In addition to these plans, there are several other efforts that some communities throughout the region have participated in. Several coastal municipalities have developed coastal resilience plans. These plans focus specifically on coastal challenges like storm surge or sea level rise, projected future conditions, and identifying adaptation strategies. Other communities have participated in community resilience building (CRB) workshops. These workshops have been devel-oped by The Nature Conservancy (TNC) as a method of stakeholder-driven climate vulnerability planning. A CRB identifies a community's strengths, vulnerabilities, and potential solutions via robust engagement. Several other communities have embarked on other resilience planning efforts such as flood mitigation plans or critical facility assessments. The Southern Connecticut Framework for Resilience was focused on the Metropolitan Council of Governments' (MetroCOG) and the South Central Regional Council of Governments' (SCRCOG) coastal communities and identified potential coastal resilient strategies for the communities within these two regions.

Most communities with TOD potential have also devel-oped TOD plans to better develop around transit sys-tems. These plans do not always acknowledge climate challenges; however, municipalities are realizing the importance of developing resilient transit systems. Sector- or asset-specific plans have also been developed throughout the region for communities and utilities to utilize. The Historic Resources Resiliency Plan identifies the climate-related challenges posed to historic resources and identifies and characterizes some of the resources at risk. Sector-specific plans have also been developed that impact the region, in-cluding the Drinking Water Vulnerability and Resilience Plan (DWVARP), the State Water Plan (SWP), and the Water Utility Coordinating Committee (WUCC). These three efforts geared toward drinking water aim to increase drinking water infrastructure resilience by way of stakeholder coordination, vulnerability assess-ments, and planning for projected climates.

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4.0 Vulnerability Assessment

A major component of the Phase II planning process included an in-depth vulnerability assessment[1] to understand regional climate change vulnerabilities. Vulnerability for this assessment can be defined as the propensity or predisposition to be adversely affected, and areas with higher vulnerability are likely to be impacted worse by the effects of climate change. In all, three tools were used to characterize vulnerability and risk throughout the region. The Climate Change Vulnerability Index (CCVI) was used for flood and heat vulnerability; the identification of Zones of Shared Risk (ZSR) was used to identify flood risk areas; and social vulnerability index (SVI) mapping was used to characterize social challenges and vulnerabilities.

First, the CCVI is a spatial index that maps physical vulnerability to both flood and extreme heat hazards in terms of exposure, sensitivity, and adaptive capacity. The CCVI was adapted from CIRCA's Coastal Vulnerability Index (CVI). CCVI has been developed to depict both flood and extreme heat vulnerability either separately or combined. Wind was also explored; however, there were several factors that needed to be further considered to develop a more reliable wind index.

The second tool is the identification and delineation of ZSR to identify distinct flood risk areas. The ZSR

1 *Phase II: From Regional Vulnerabilities to Resilience Opportunities (2021)*

concept was developed as part of a community resilience planning effort and has evolved to include multiple typologies that define shared risks among communities, infrastructure, and ecological conditions to flooding (i.e., access related, proximity to flood risk, or underpass). As part of the vulnerability assessment, ZSR were delineated and mapped across New Haven and Fairfield Counties.

Both tools, CCVI and ZSR, underwent multiple iterations under Phase II as a result of peer and stakeholder review processes.

The tools provided a platform for evaluating flood and heat vulnerability across multiple spatial scales from regional to municipal to local. Results were assessed across a variety of scales, from the COG level down to site-specific level (i.e., affordable housing assets or major employer sites). Evaluation at multiple scales allows for a more flexible application of the assessment results, ranging from regional planning to localized project development. Ultimately, several scales were evaluated as part of this assessment, resulting in information that can be used by various stakeholders in support of planning efforts. While this assessment is certainly not the final step for understanding regional vulnerability, it provides a strong foundation for identifying resilience and adaptation needs both throughout the region and statewide.

The third tool is the SVI which examines community and demographic characteristics known to increase the likelihood of individuals or communities experiencing harm during and after a hazard event. The methodology used for Phase II acknowledges the heightened propensity of marginalized populations to suffer adverse disaster impacts and is a composite of two commonly cited sources: the Centers for Disease Control and Prevention (CDC) Social Vulnerability Index[2] (CDC SVI) and the University of South Carolina Social Vulnerability Index[3] (SoVI). The resulting SVI characterizes overall social vulnerability and five subgroup scores for Fairfield and New Haven Counties, normalized using statewide census data.

The vulnerability assessment yielded an extensive report that documents the results in greater detail. However, to highlight the importance of this assessment and to set the stage for Resilient Connecticut Phase III, high-level results from the vulnerability assessment are presented below. The findings discussed are at a very coarse scale; CCVI is a unique tool that provides insight into vulnerability that can also be explored at a hyper-local scale.

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2 https://www.atsdr.cdc.gov/placeandhealth/svi/index.html

3 http://artsandsciences.sc.edu/geog/hvri/sovi%C2%AE-0

4.1 FloodandHeatVulnerability

Flood and heat vulnerability can both be understood by assessing how factors contributing to exposure, sensitivity, and adaptive capacity, vary throughout the region. Exposure can be measured by looking at physical features or characteristics of the landscape that are likely to increase the impacts of a hazard event, as well as the climate change-related factors that increase the magnitude and frequency of hazard events. Both sensitivity (susceptibility to harm) and adaptive capacity (potential to adjust to climate change and cope with the consequences) can be broken down further by examining factors that relate to social, ecological, and built components of the environment.

The CCVI is a spatial index that measures vulnerability factors within geographically defined grid cells. The CCVI index for Fairfield and New Haven Counties contains a total of 84,605 cells, each with its own flood and heat vulnerability score. Numerous contributing factors have been ranked from 1 (low) to 5 (high) based on their contribution to sensitivity, exposure, or adaptive capacity, within a grid cell. A score of 0 indicates the absence of a contributing factor. These three component scores (sensitivity, exposure, and adaptive capacity) were then calculated based on the geometric mean of their relative factors. Once each component score was determined, the equation below (Figure 3) was used to determine overall vulnerability, for either flood or heat.

Factor, component, and vulnerability scores are relative, unitless values and therefore most useful for comparison across locations or characterizing smaller geographic areas. As shown in the charts below, which is a breakdown of the percent of cells within each COG by component and vulnerability scores(Figure 4 and Figure 5), most have low to moderate flood vulnerability and low to moderate heat vulnerability. Approximately 3 percent of the region has high flood vulnerability, and about 3 percent of the region has high heat vulnerability.

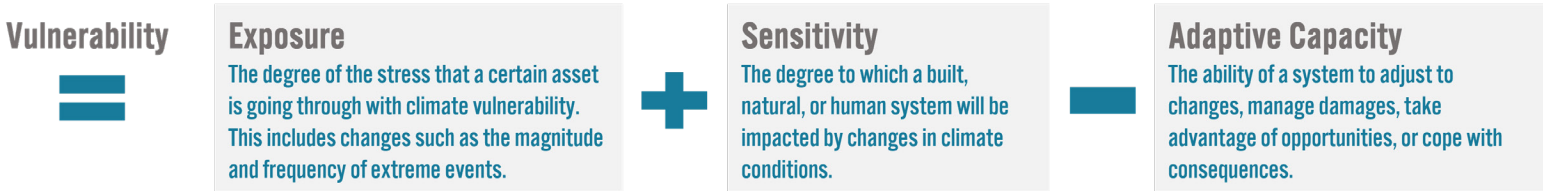

Figure 3: CCVI equation and component definitions

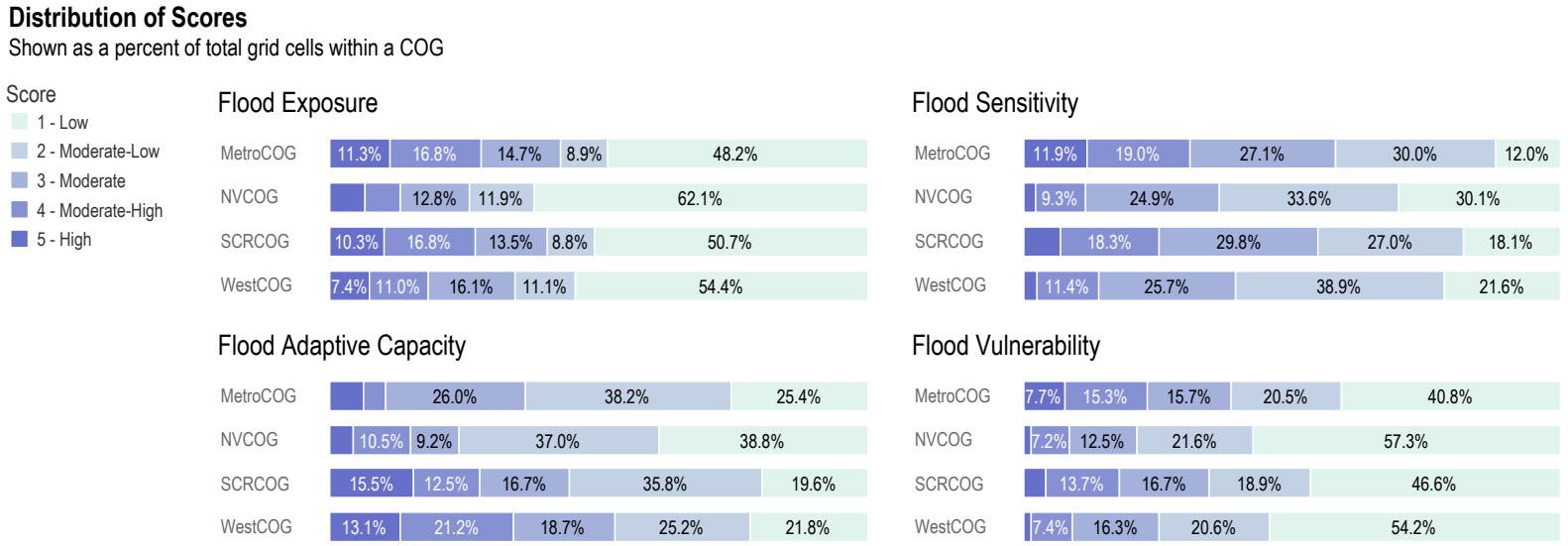

Figure 4: Distribution of flood component and total vulnerability scores by COG, shown as percent of total grid cells within the COG.

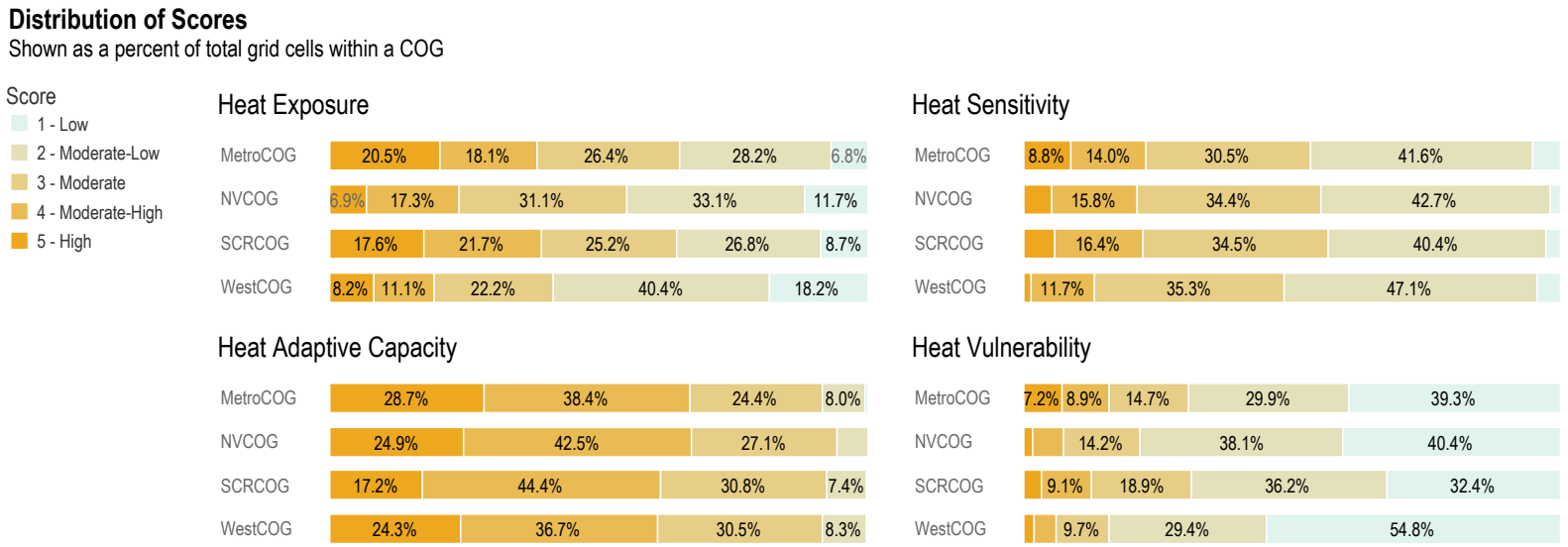

Figure 5: Distribution of heat component and total vulnerability scores by COG, shown as percent of total grid cells within the COG.

In addition to component and vulnerability distribution, the regional statistics are shown in Figure 6 and Figure 7. The regional vulnerability composition for flood and heat (Figure 6A and Figure 7A, respectively), are shown as percent of total grid cells throughout both Fairfield and New Haven counties. The average component scores for regional flood and heat are also represented (Figure 6B and Figure 7B, respectively). Regionally speaking, both counties appear to have larger areas vulnerable to heat than flood with 49 percent of the region scoring at least moderate-low flood vulnerability and 57 percent of the region scoring at least moderate-low heat vulnerability. These regional statistics may be useful for comparing smaller geographic areas, such as COGs or municipalities, to the larger scale regional average.

If a grid cell scores higher for adaptive capacity than exposure or sensitivity, this does not mean that vulnerability and risk does not exist. This ultimately

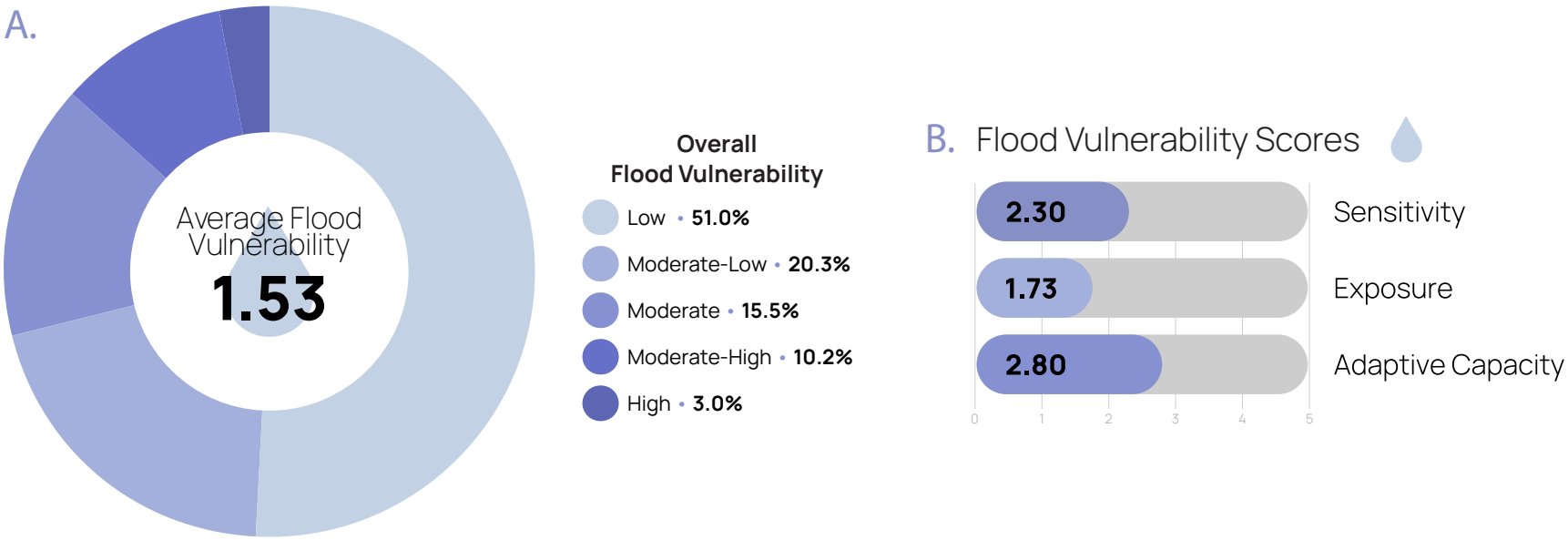

Figure 6: (A) Regional flood vulnerability shown as percent of total grid cells; (B) Average flood vulnerability component scores across the region on a scale of 0 to 5.

means that there are factors present that improve the area's ability to adjust and cope with the impacts of climate hazards, but those factors do not cancel out adaptation and resilience challenges that may persist. For flood, some of these challenges might include neighborhoods that are distant from shelters or highway access, a high number of rental properties, or little open space in the Special Flood Hazard Area (SFHA). For heat, challenges may include low numbers of residents with health insurance, reduced vegetation cover, or communities that are distant from cooling centers. Specific contributors, or challenges and strengths, can be evaluated using CCVI and evaluating the specific rankings for the various factors.

In addition to flood and heat individually, the two climate stressors were joined to assess the combined vulnerability for an area. The assessment highlighted locations throughout the area that have combined high vulnerability and a higher degree of climate

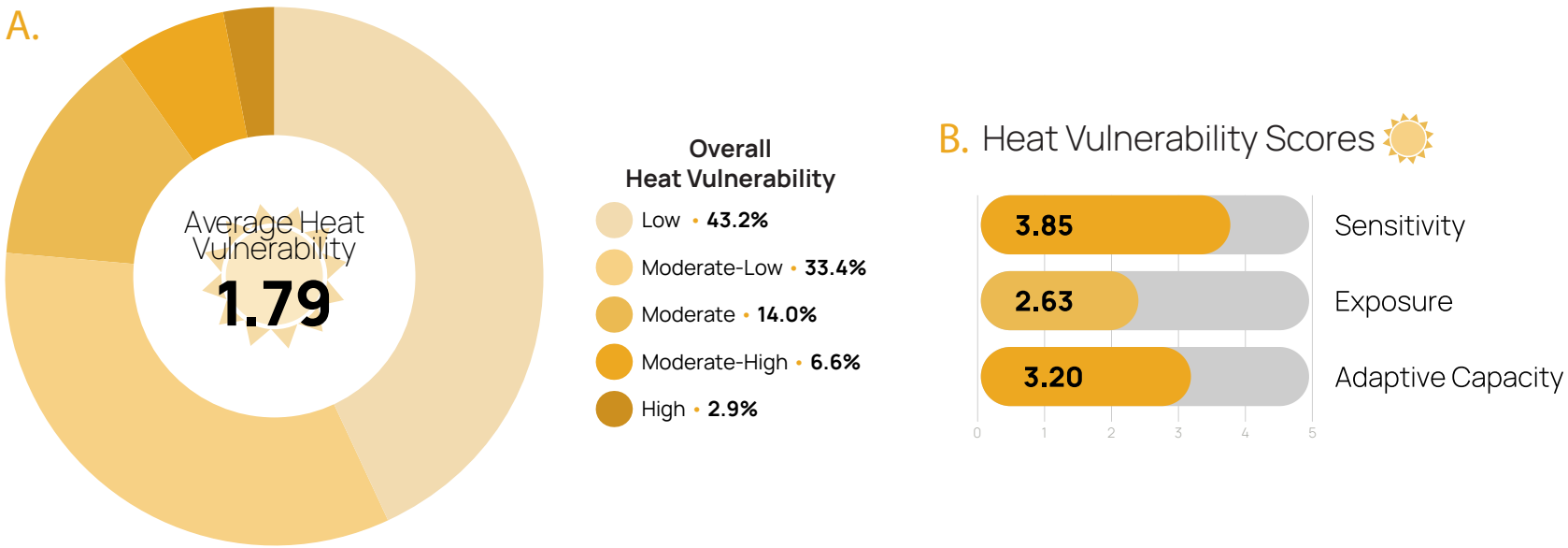

Figure 7: (A) Regional heat vulnerability shown as percent of total grid cells; (B) Average heat vulnerability component scores across the region on a scale of 0 to 5.

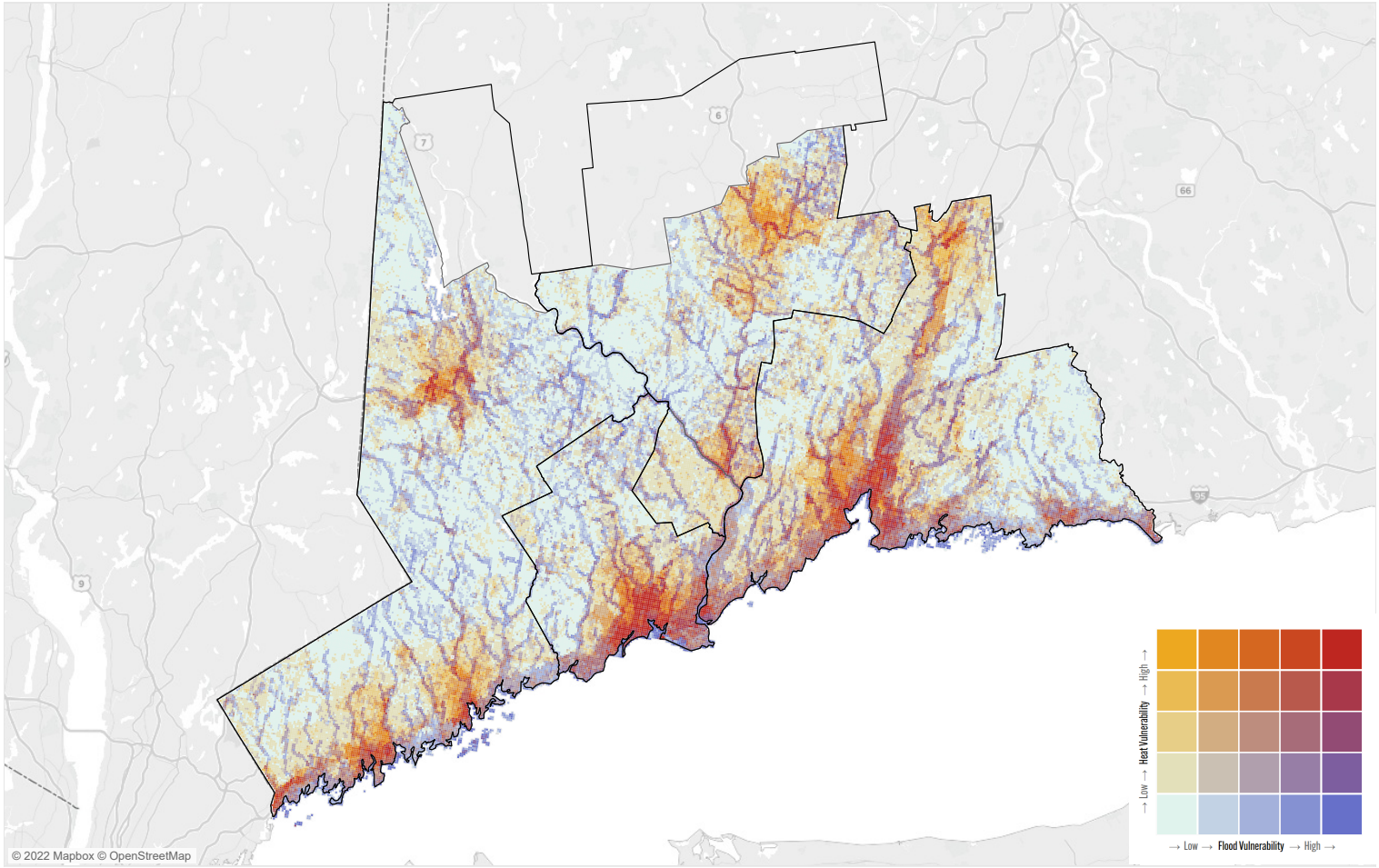

Figure 8: Combined flood and heat vulnerability map for the region

vulnerability than moderate to low combined vulnerable locations. The map found in Figure 8 depicts the combined vulnerability throughout Fairfield and New Haven Counties.

The following sections delve into these statistics for each of the four COGs to gain a deeper understanding of how vulnerability varies throughout the two counties but within each planning region.

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4.2 MetroCOG

The Metropolitan Council of Governments (MetroCOG) region is comprised of three coastal communities and three inland communities. The entire MetroCOG region has an average population density of 7,512 people per square mile, with an average of 8,661 in the three coastal municipalities and 1,195 in the three inland communities.

4.2.1 Flood

The Metropolitan Council of Governments (MetroCOG) is primarily low to moderately flood vulnerable, with approximately 8 percent of the region scoring high flood vulnerability (Figure 10 and Figure 11). Relative to the other COGS, MetroCOG generally scores higher on sensitivity and exposure, as well as overall flood vulnerability (Figure 9).

The highest flood vulnerabilities are found along the shoreline and major rivers of the MetroCOG region, although urbanized areas in the COG's three coastal communities also have vulnerabilities not associated with rivers and streams. These may be due to storm-water drainage concerns reflected in the aspects of CCVI that capture pooling and ponding. Higher social vulnerabilities in Bridgeport and Stratford also lead to relatively high flood vulnerabilities. Flood vulnerabilities in the three northern communities of Easton, Trumbull, and Monroe are primarily aligned with watercourses.

The most flood vulnerable TOD area in the MetroCOG region is the Bridgeport TOD. In addition, there are three shelters located in high flood vulnerable areas: Columbus School, Jettie Tisdale School, and Multicultural Magnet School.

ZSR were primarily delineated along the developed portions of the riverine corridors and shorelines.

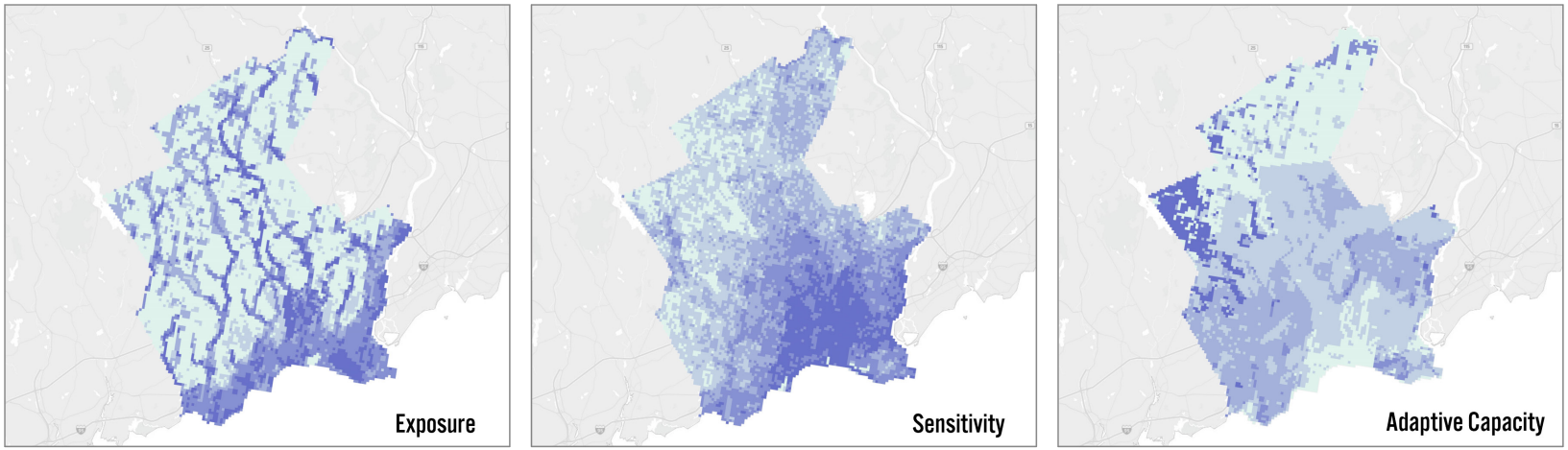
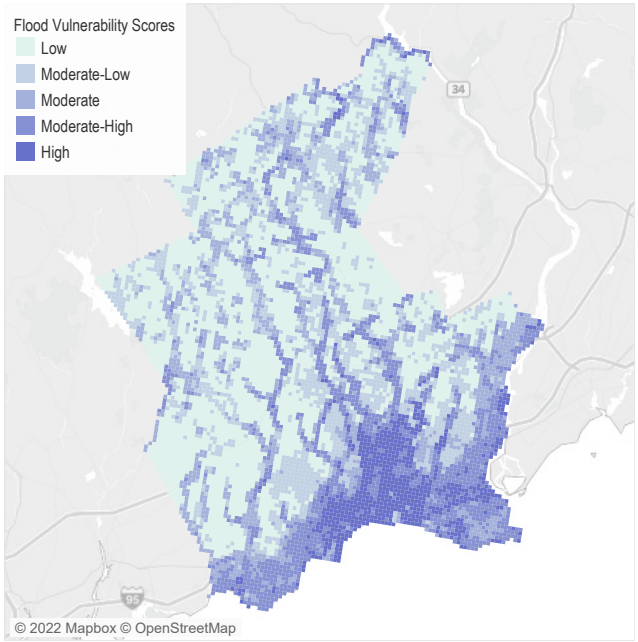


Figure 9: MetroCOG flood exposure, sensitivity, and adaptive capacity distribution

Numerous nested ZSR were delineated in coastal Fairfield and Stratford to represent areas that can be isolated or affected by multiple scales of isolation during an evolving flood event. Areas of potential isolation in northern Stratford were also identified. Downtown Fairfield was identified due to its frequent flooding caused by stormwater.

Figure 11: MetroCOG overall flood vulnerability



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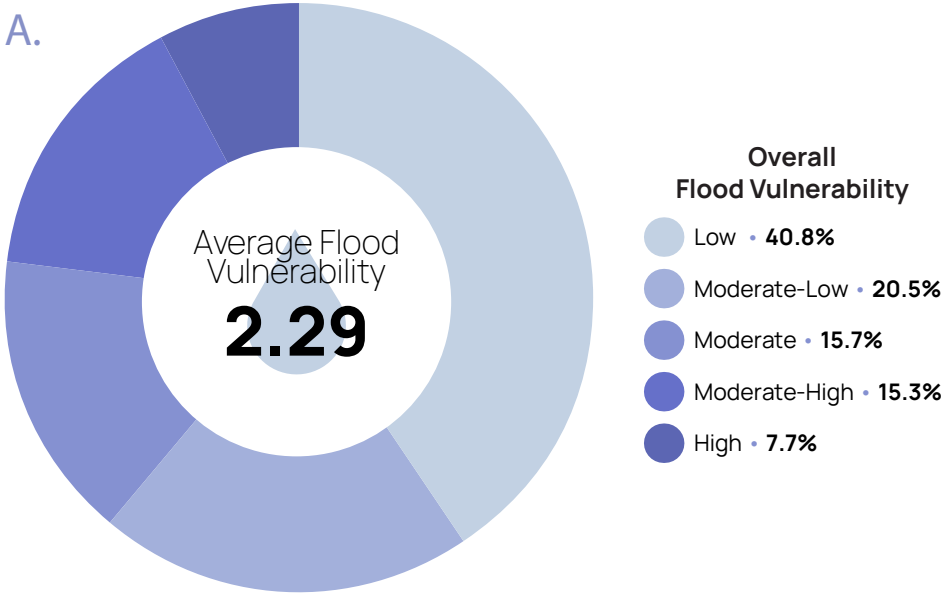


B. Flood Vulnerability Scores

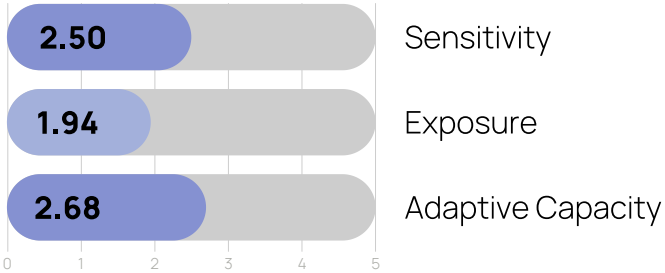


Figure 10: (A) MetroCOG flood vulnerability shown as percent of total grid cells; (B) Average flood vulnerability component scores across MetroCOG on a scale of 0 to 5.

4.2.2 Heat

Like flood vulnerability, a majority of MetroCOG is low to moderate heat vulnerability, with approximately 7 percent of the area scoring high (Figure 13 and Figure 14). In comparison to the entire region, MetroCOG scores are about average for heat sensitivity and adaptive capacity, with above average heat-related exposure (Figure 12).

Bridgeport is almost entirely heat vulnerable due to social factors. This includes a high density of heat-vulnerable populations and lower adaptive capacities. This is also true for much of Trumbull and Stratford, as both communities are predominantly vulnerable because of social factors; however, both have some locations that are driven by built factors. This indicates high impervious surface density, high emissivity, and lower built adaptive capacity. Easton and Fairfield are both predominantly heat vulnerable because of built contributors, with eastern Fairfield having high social concerns. Monroe shares both social and built concerns as the driving factors behind heat vulnerability. While certain areas, such as Bridgeport and southern Stratford, may also have high built-related vulnerability (high emissivity or impervious surface density), the social implications outweigh the built according to the CCVI method. There are likely ways to reduce

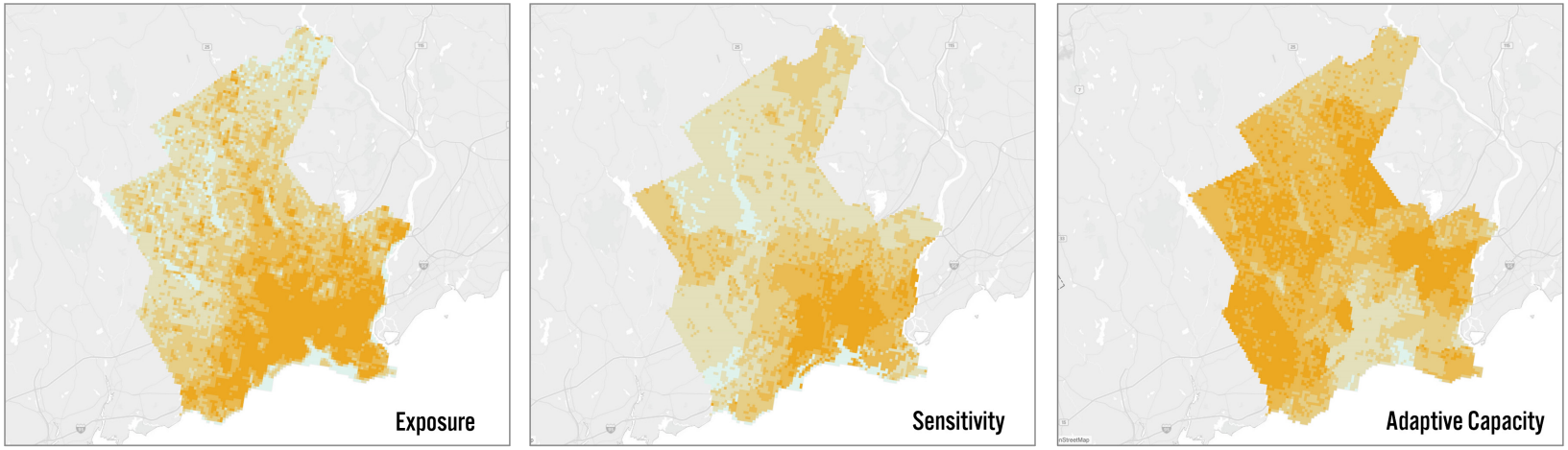
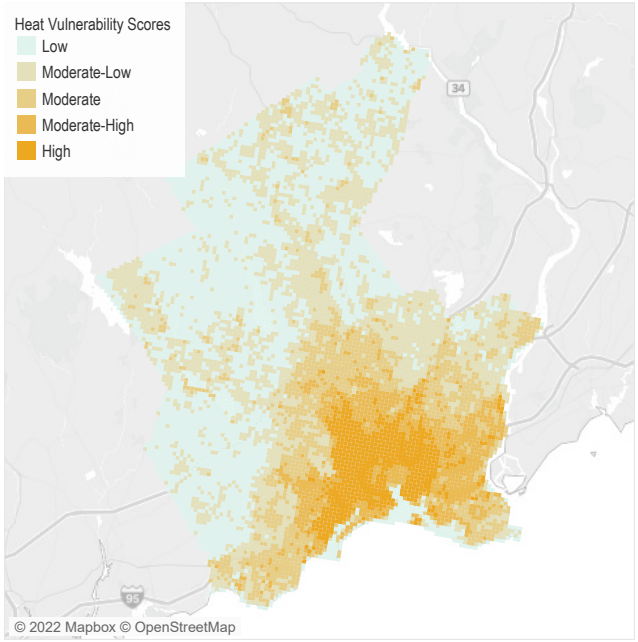


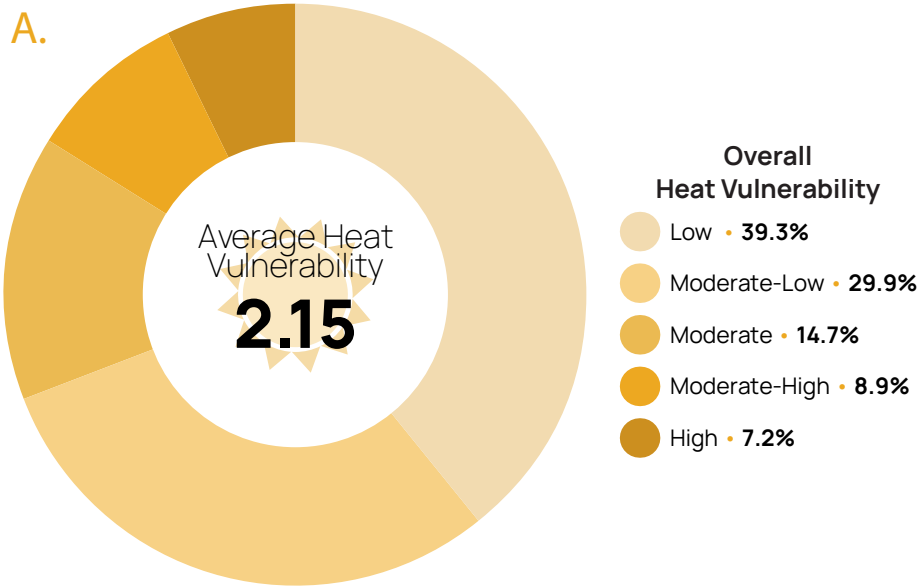
Figure 12: MetroCOG heat exposure, sensitivity, and adaptive capacity distribution

social sensitivities to heat by way of adapting the built environment.

The most heat vulnerable TOD in the MetroCOG region is the proposed Barnum Station. While this station has not yet been developed, it is important to consider heat vulnerability in the area during future development to not exacerbate vulnerability. Also of note, the Easton Senior Center and Black Rock Church are cooling centers greater than one mile from a bus route, which elevates heat risk due to potentially reduced access by vulnerable populations.

Figure 14: MetroCOG overall heat vulnerability





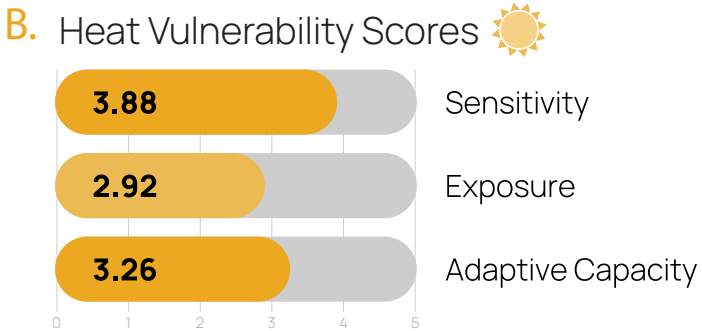


Figure 13: (A) MetroCOG heat vulnerability shown as percent of total grid cells; (B) Average heat vulnerability component scores across MetroCOG on a scale of 0 to 5.

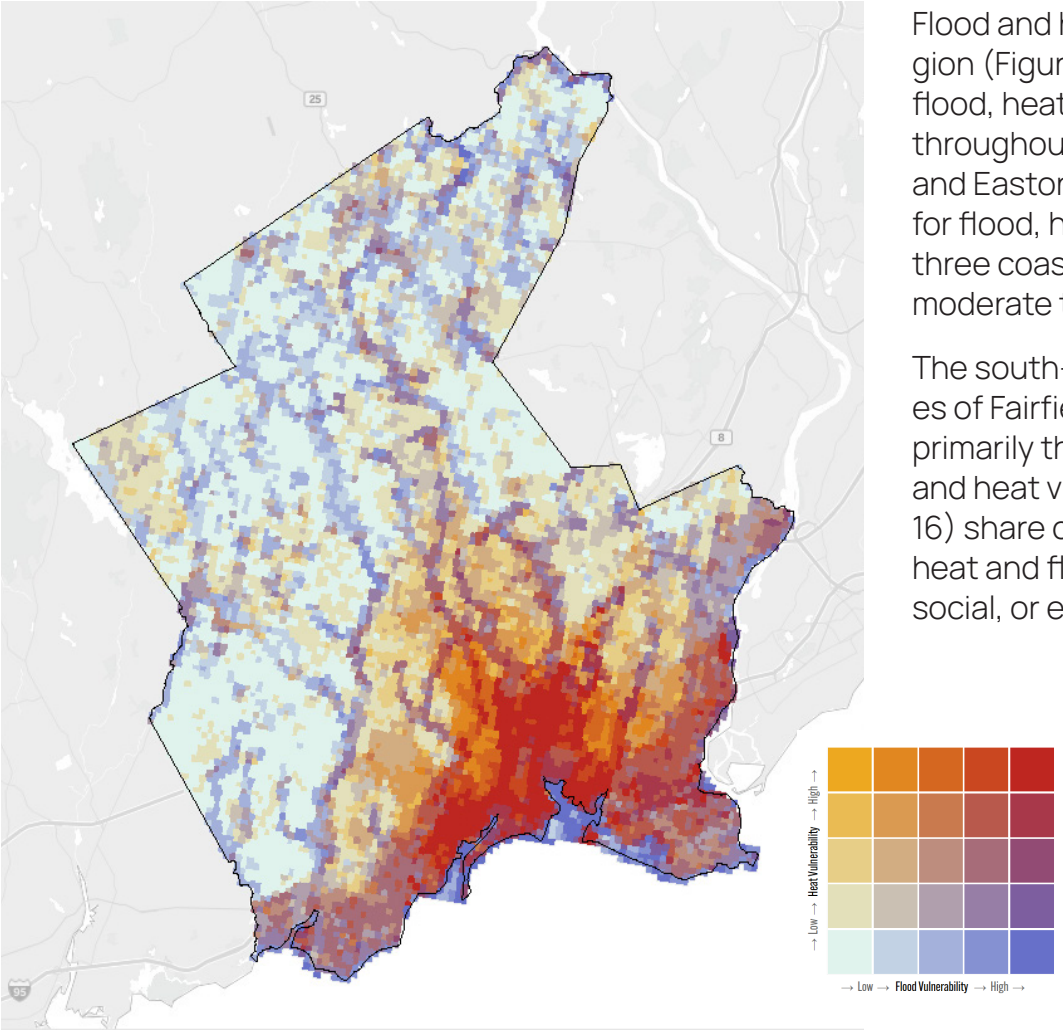


Figure 15: MetroCOG combined flood and heat vulnerability throughout the region

Flood and heat vulnerability varies throughout the region (Figure 15). The adjacent map depicts the varying flood, heat, and combined flood and heat vulnerability throughout the region. The towns of Trumbull, Monroe, and Easton are primarily low to moderate vulnerability for flood, heat, and combined vulnerability, while the three coastal communities generally have the more moderate to high vulnerability areas.

The south-central area of Bridgeport, eastern stretches of Fairfield, and southern reaches of Stratford are primarily the locations with the highest combined flood and heat vulnerability. These dark red locations (Figure 16) share characteristics that are indicative of both heat and flood vulnerability, some of which are built, social, or ecological.

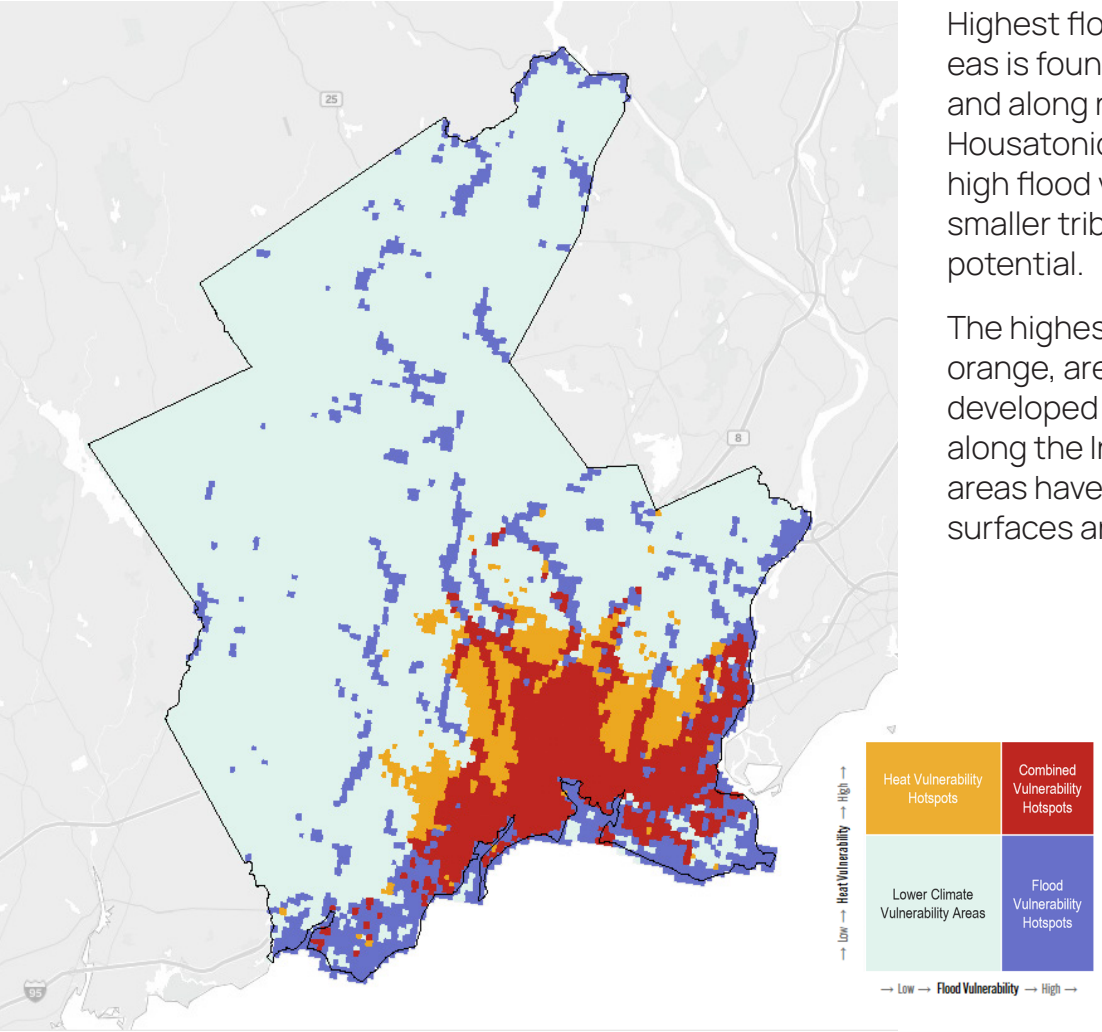


Figure 16: MetroCOG simplified combined high flood and high heat throughout the region highlighting the most vulnerable areas

Highest flood vulnerability outside of the combined areas is found along the shores of Fairfield and Stratford, and along rivers and streams such as the Pequonnock, Housatonic, or Rooster Rivers. Other areas that have high flood vulnerability include locations surrounding smaller tributaries or those with poor drainage potential.

The highest heat vulnerable locations, as shown in orange, are centered around some of the densest developed areas in Bridgeport, Stratford, and Fairfield along the Interstate 95 and Route 8 corridors. These areas have some of the largest amounts of impervious surfaces and highest social vulnerability.

4.3 NVCOG

The NVCOG region is comprised of 19 municipalities, however only 13 are located in the Resilient Connecticut study region and therefore only these are included in the vulnerability assessment. All communities in the region are inland with the Housatonic and Naugatuck Rivers traversing through many of these communities. Population density for the 13 communities in the region averages 3,268 people per square mile.

4.3.1 Flood

Proportional to its area, the Naugatuck Valley Council of Governments (NVCOG) region has the lowest flood exposure and vulnerability of the four COGs, with just over 1 percent of the COG's land area having high flood vulnerability (Figure 18 and Figure 19). The landlocked NVCOG region scores lower that all other COGs in the region on all components: sensitivity, exposure, and adaptive capacity (Figure 17).

Flood vulnerability in the NVCOG region is highest along the Naugatuck, Housatonic, Mad, Pomperaug, and Tenmile Rivers. Several tributaries throughout the region contribute to moderate to high flood vulnerability. All of the communities located along the Naugatuck River have some degree of high flood vulnerability, including those that enjoy flood protection from upstream dams and/or from local flood protection (levee) systems such as those located in Ansonia and Derby. The only NVCOG community that lacks extensive riverine flood vulnerability is Prospect, which is due to its headwaters position. Flood vulnerability drivers vary greatly throughout the region, but it is important to note that Derby, Ansonia, Beacon Falls, Naugatuck, Waterbury, and Wolcott have the highest density of

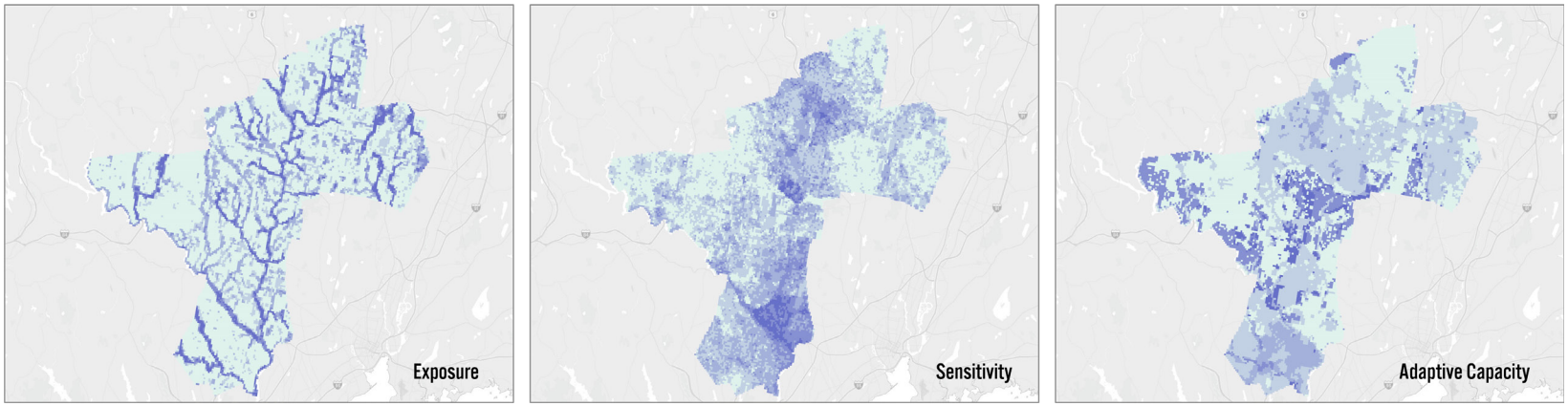


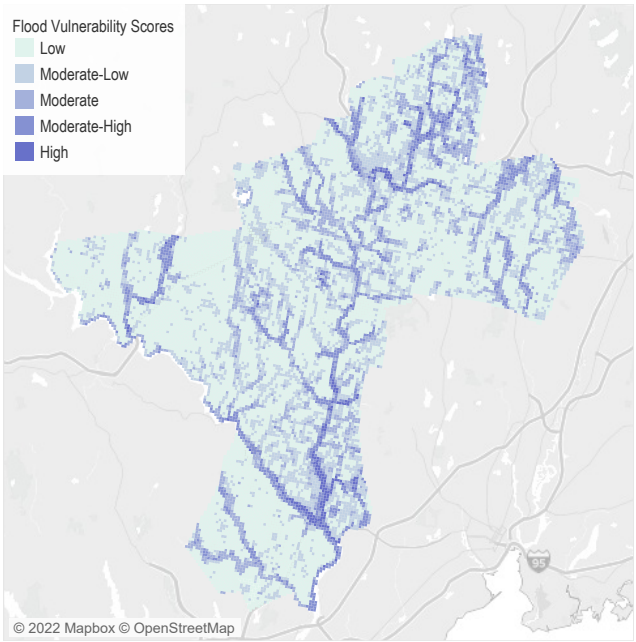
Figure 17: NVCOG flood exposure, sensitivity, and adaptive capacity distribution

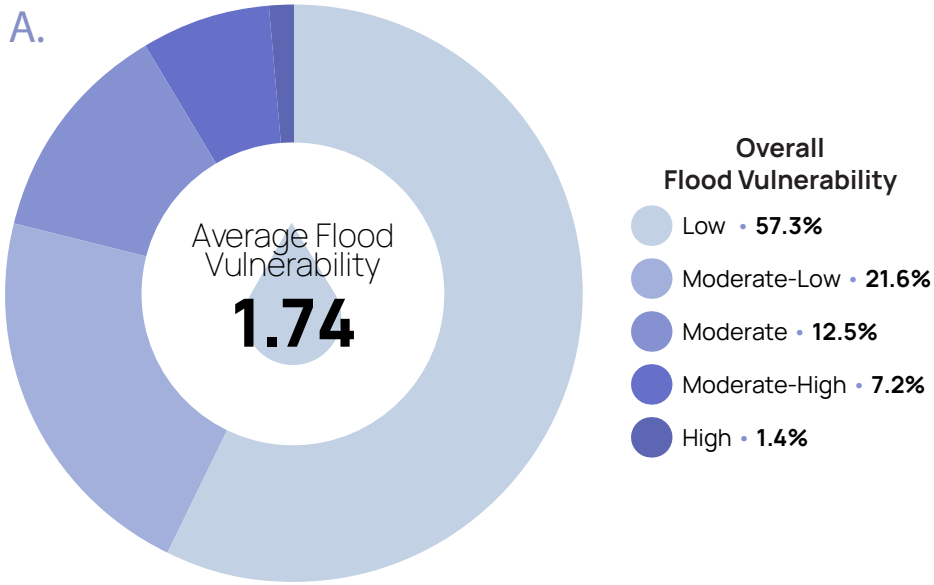
social sensitivity, which may be driving overall flood vulnerability.

The Derby/Shelton TOD area along the Naugatuck River has the highest flood vulnerability in the NVCOG region. In addition, the Beacon Falls Town Hall (shelter) is in a moderate-high flood vulnerable location.

ZSR were primarily delineated along the developed portions of the river corridors. Hazard mitigation plans were critical for locating ZSR that do not follow mapped floodplains, such as ZSR in Waterbury, Naugatuck, and Shelton. These ZSR identify shared risks that may not be directly interpreted from traditional flood mapping.

Figure 19: NVCOG overall flood vulnerability





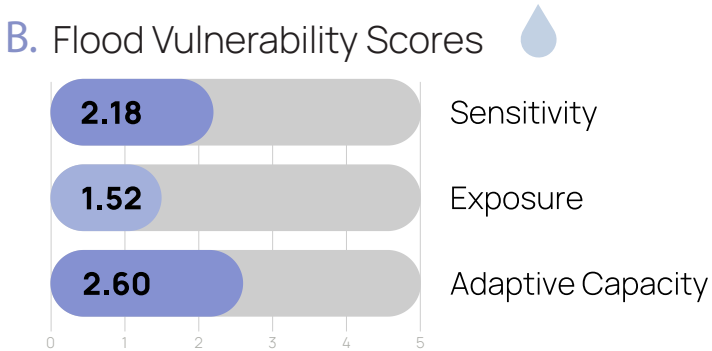


Figure 18: (A) NVCOG flood vulnerability shown as percent of total grid cells; (B) Average flood vulnerability component scores across NVCOG on a scale of 0 to 5.

4.3.2 Heat

Over 90 percent of the COG scores low to moderate for heat, and about 1.5% of grid cells score high (Figure 21 and Figure 22) for heat vulnerability. The factors driving high heat vulnerability in the NVCOG communities are primarily social, with component distribution seen in Figure 20. This is also true for most of the region. While many communities are low to moderate for heat vulnerability, their driving contributors are associated with socially sensitive populations. Relevant social indicators include heat-related health concerns, transportation challenges, living below poverty levels, or populations without health insurance. Built factors are driving vulnerability in Southbury, Middlebury, eastern Prospect, and much of Cheshire and Wolcott, with contributing factors such as high building or impervious surface density, potentially inefficient structures, and high emissivity.

The Waterbury TOD area has the highest heat vulnerability of all TODs in NVCOG. This indicates high social and built sensitivities within the 0.75mile radius surrounding the station. These factors should be considered during any TOD redevelopment. It is also important to note that of all cooling centers in the NVCOG region, the Oxford Town Hall and Southbury Senior Center are both located over 1 mile from a bus

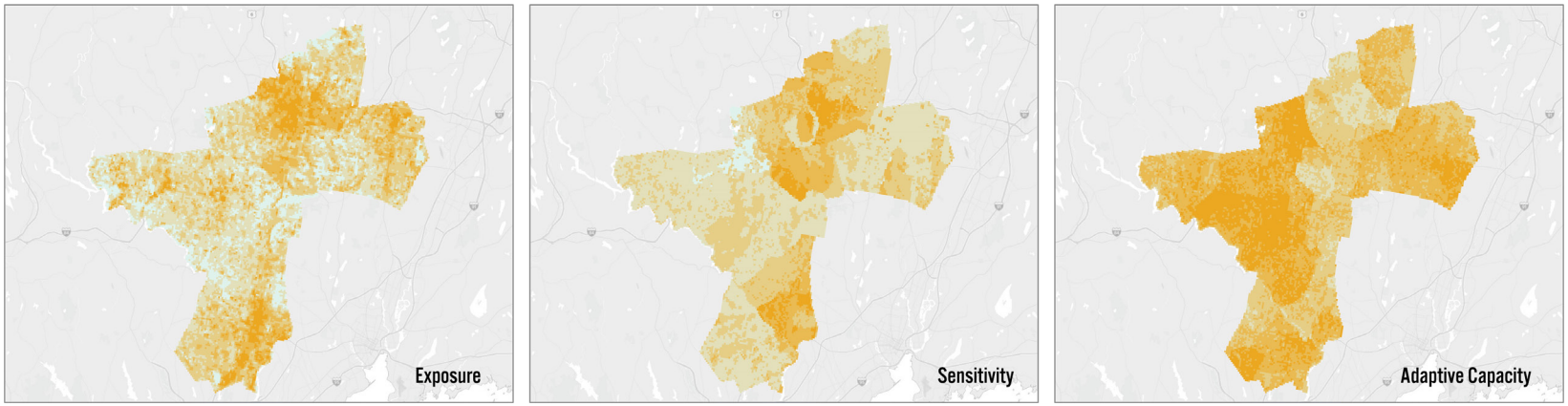
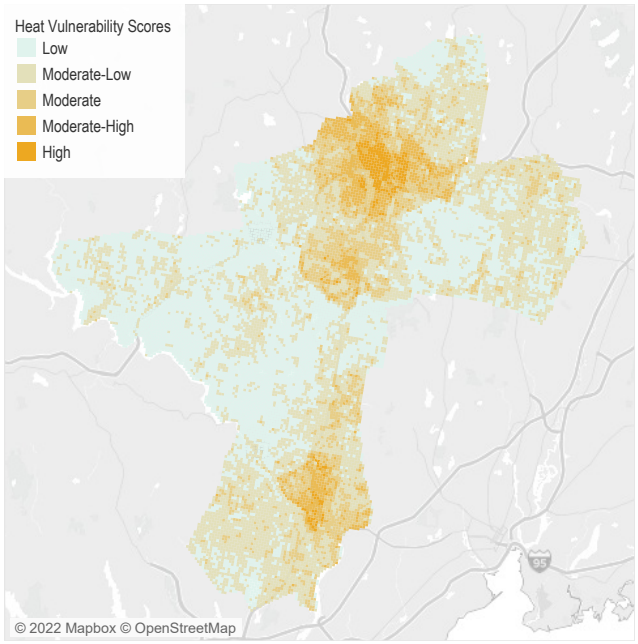


Figure 20: NVCOG heat exposure, sensitivity, and adaptive capacity distribution

route, potentially reducing accessibility to these sites for vulnerable populations.

Flood, heat, and combined flood vulnerability varies throughout the NVCOG region. Heat and flood vulnerability, as shown in Figure 23, appears to be higher throughout the Naugatuck River communities with lower to moderate combined vulnerability in Southbury, Oxford, and Middlebury.

Figure 22: NVCOG overall heat vulnerability



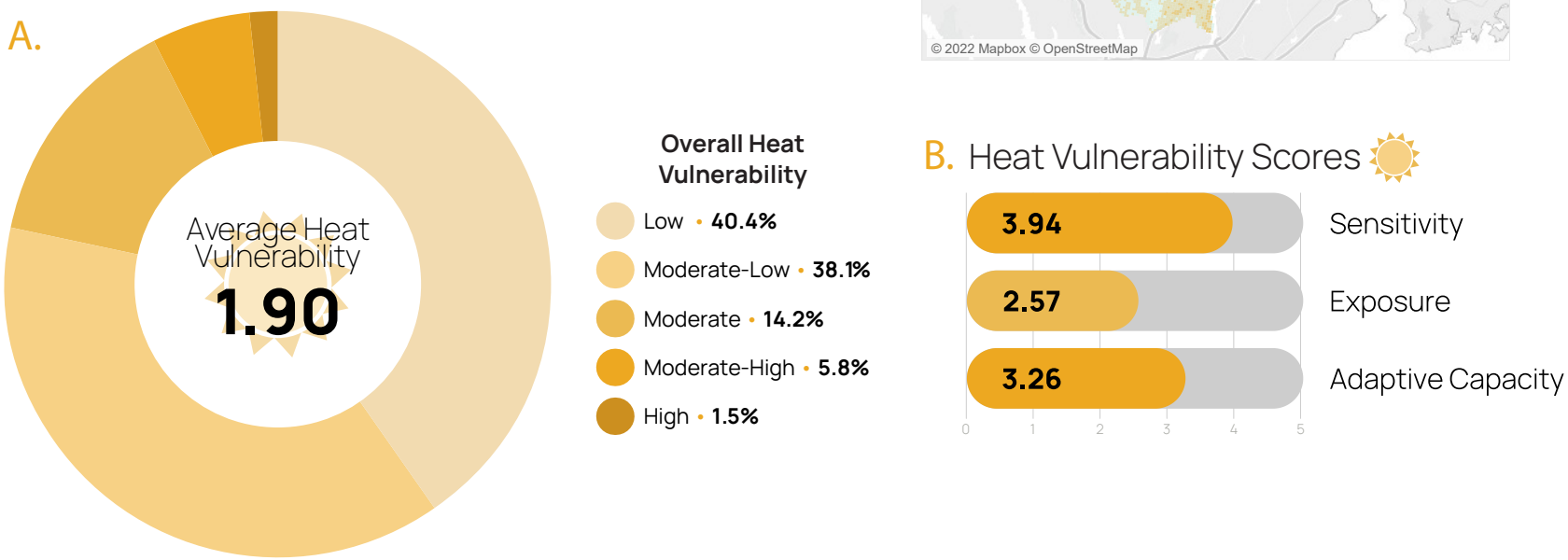


Figure 21: (A) NVCOG heat vulnerability shown as percent of total grid cells; (B) Average heat vulnerability component scores across NVCOG on a scale of 0 to 5.

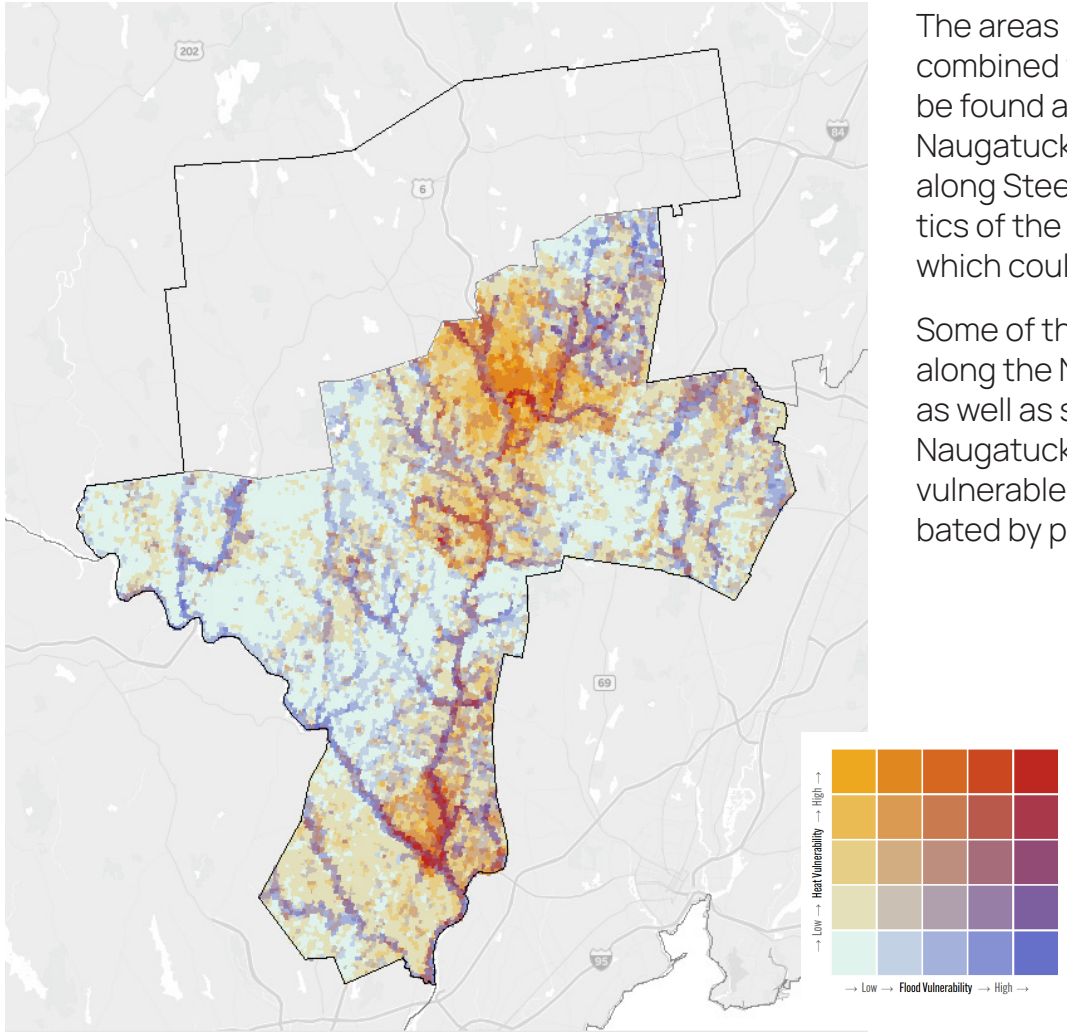


Figure 23: NVCOG combined flood and heat vulnerability throughout the region

The areas in the NVCOG region with the highest combined flood and heat vulnerability (Figure 24). can be found at the confluence of the Housatonic and Naugatuck Rivers, upstream along the Mad River, and along Steel Brook. These locations share characteristics of the most flood and heat vulnerable locations, which could be built, ecological, or social.

Some of the highest flood vulnerable locations are along the Naugatuck, Housatonic, and Mad Rivers, as well as smaller tributaries throughout area. The Naugatuck River corridor has the greatest number of vulnerable tributaries, some of which could be exacerbated by pooling.

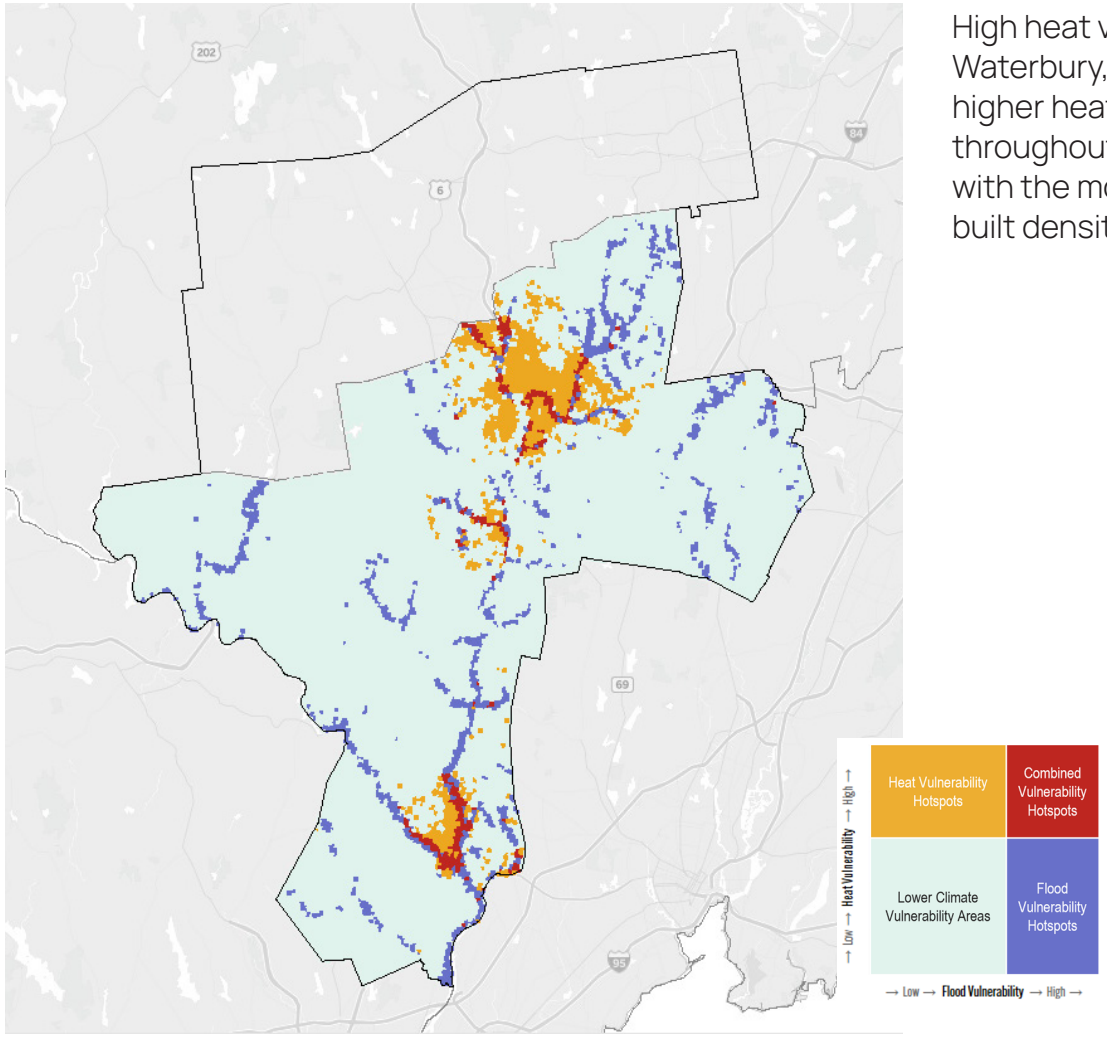


Figure 24: NVCOG simplified high flood and high heat throughout the region highlighting the most vulnerable areas

High heat vulnerability is concentrated throughout Waterbury, Naugatuck, and Derby. Three are also higher heat vulnerable smaller scatter locations throughout the region. These areas are likely those with the most vulnerable populations and the highest built density, which increases exposure.

4.4 SCRCOG

The SCRCOG region is comprised of 15 municipalities; seven of which are coastal. The average population density for the entire region is 4,243 per square mile, with an average of 5,122 for the coastal communities, and 3,002 for the non-coastal communities.

4.4.1 Flood

Flood vulnerability throughout the South Central Regional Council of Governments (SCRCOG) region is relatively high, with more total area scoring moderate-high (14 percent) and high (4 percent) flood vulnerability than any other COG in the region with approximately 1.5 percent of the area being moderate to high for flood vulnerability (Figure 26 and Figure 27). Vulnerability components, exposure, sensitivity, and adaptive capacity varies throughout the SCRCOG region (Figure 25).

Flood vulnerability is concentrated along the coastline, the Housatonic River, the West River in New Haven, and the Quinnipiac River extending from Meriden to New Haven. Flood vulnerability is primarily driven by social factors in New Haven, Wallingford, and Meriden, where sensitive populations reside. Union Station in New Haven has the highest collective vulnerability of the TODs throughout the SCRCOG region. Shelters, including Branford High, East Haven Senior Center, Hamden High, Muravnick Senior Center, Platt High, and

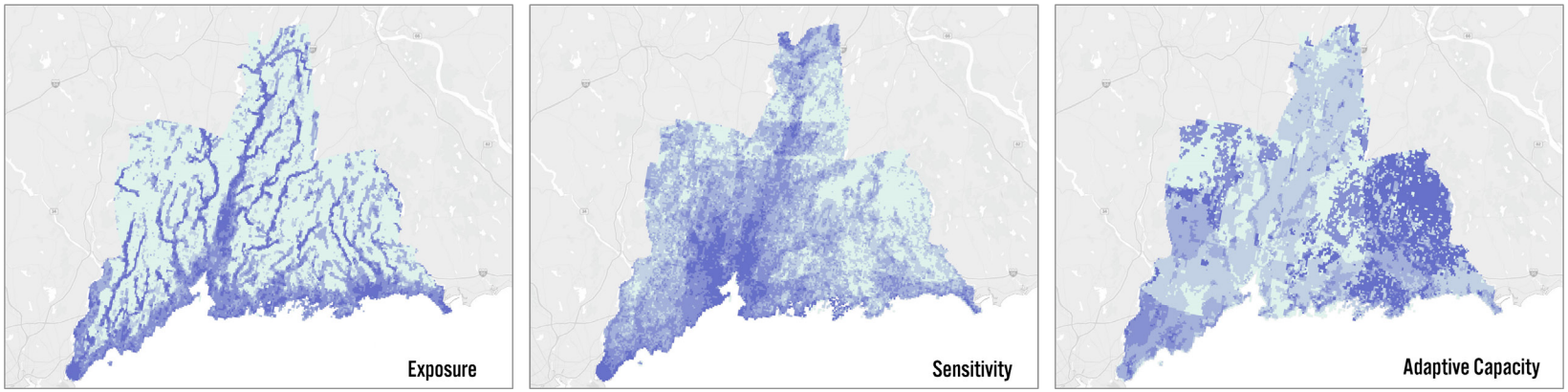
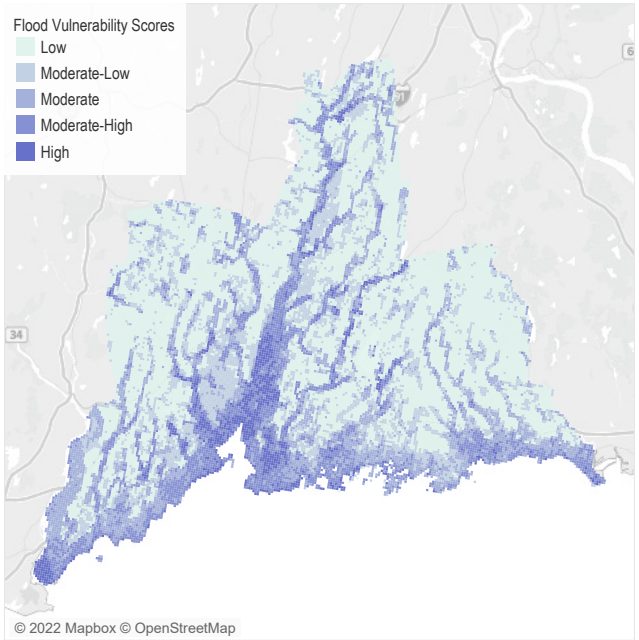


Figure 25: SCRCOG flood exposure, sensitivity, and adaptive capacity distribution

New Haven Fire Academy, are in moderate-high flood vulnerable areas.

ZSR were primarily delineated along the developed portions of the riverine corridors and shorelines in the SCRCOG region. Numerous nested ZSR were delineated in coastal Milford, East Haven, Branford, and Guilford to represent areas that can be isolated or affected by multiple scales of isolation during an evolving flood event. Hazard mitigation plans and coastal resilience plans were helpful for locating ZSR that do not necessarily follow mapped floodplains, such as some in Milford, West Haven, Branford, Guilford, and Madison. Stakeholder input also aided in ZSR delineation, such as the Post Mall area in Orange.

Figure 27: SCRCOG overall flood vulnerability



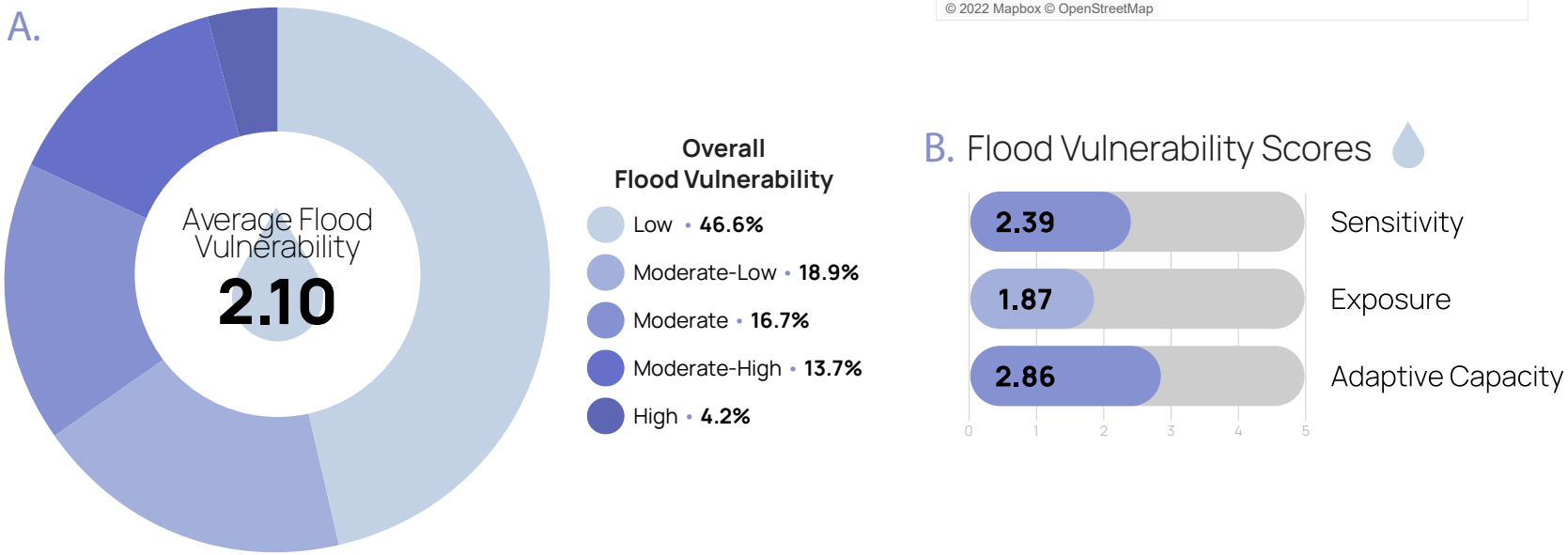


Figure 26: (A) SCRCOG flood vulnerability shown as percent of total grid cells; (B) Average flood vulnerability component scores across SCRCOG on a scale of 0 to 5.

4.4.2 Heat

Heat vulnerability is widespread throughout SCRCOG, but primarily exists at a moderate level (Figure 30). Only about 3 percent of the COG area scores high heat vulnerability (Figure 29), while only 32 percent scores low heat vulnerability (a lower percentage than any other COG). Heat exposure, sensitivity and adaptive capacity varies throughout the region (Figure 28).

The highest heat vulnerability is concentrated in New Haven in the Port Area and in the Hill area near the West River. High heat vulnerable areas are found in downtown Meriden and in West Haven. Moderately high heat areas radiate from the high heat areas throughout New Haven, in a majority of West Haven and Meriden, and along the Route 15 corridor in Wallingford. Smaller moderate heat areas are also along the Milford shoreline and in East Haven, southern Branford, and southeastern Guilford. A majority of the high and moderately high heat areas are primarily driven by social contributors. This includes heat vulnerable populations that may not have health insurance, have heat-related health concerns, have low income, or high population density. The low to moderate heat areas are primarily driven by built contributing factors. This includes high emissivity and impervious surface density, older structure age, or locations that are far from a shelter or cooling center. There are some areas, such as central Guilford, eastern Madison, and

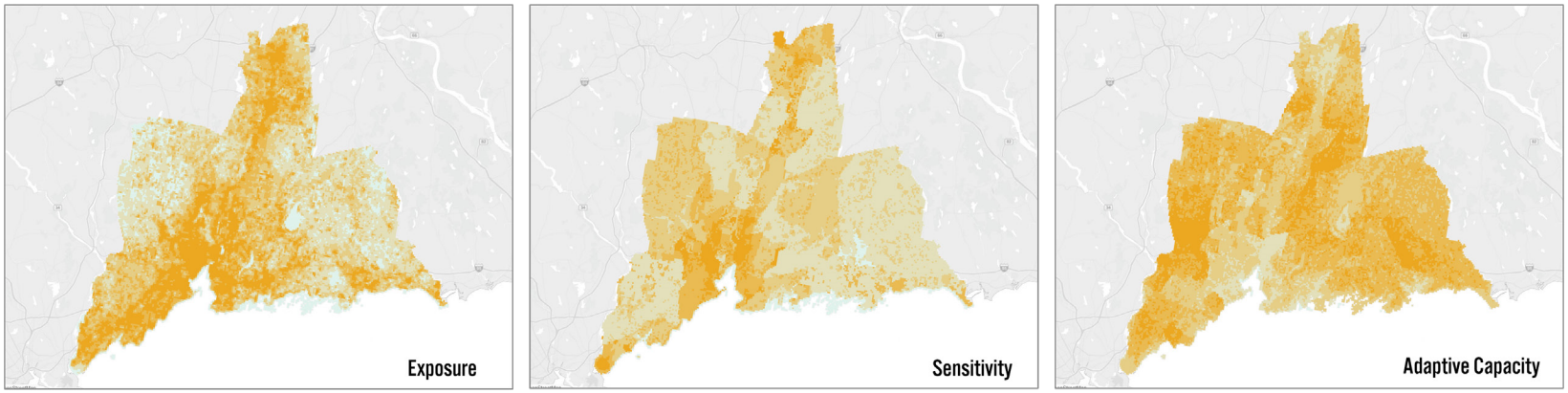
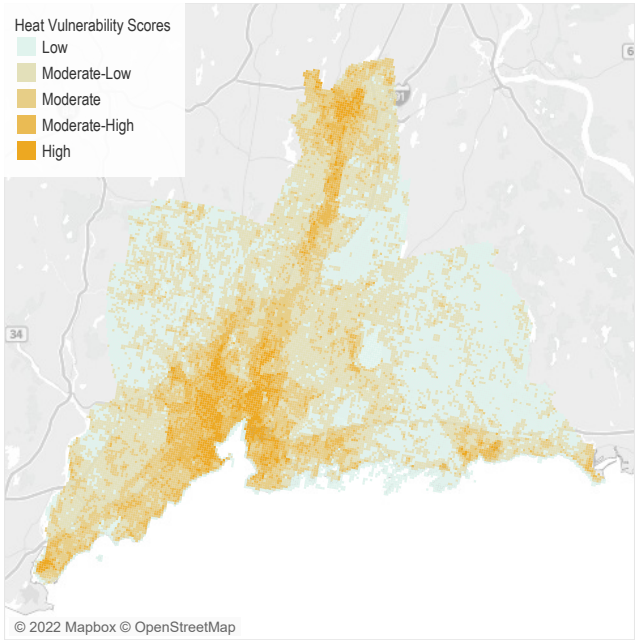


Figure 28: SCRCOG heat exposure, sensitivity, and adaptive capacity distribution

northwestern Hamden, where built and social factors equally contribute to heat vulnerability.

Of all TODs in the region, the Meriden TOD has the highest heat vulnerability. However, the TOD areas in New Haven and West Haven also rank highly. Four cooling centers in the region are further than 1 mile from a bus route: Bethany Town Hall/Senior Center, Atwater Memorial Library, Edward Smith Library, and North Branford Recreation Department. This elevates heat risk in those communities, as residents who are dependent on public transit may not be able to reach cooling centers easily.

Figure 30: SCRCOG overall heat vulnerability



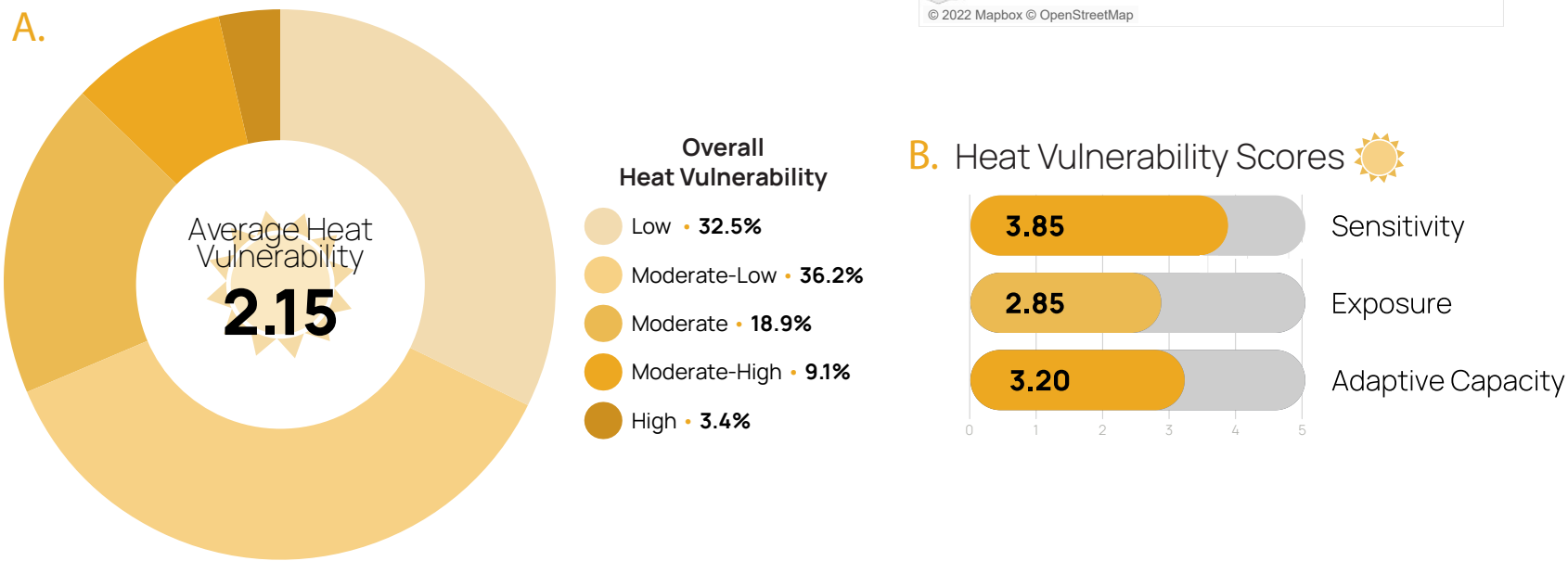


Figure 29: (A) SCRCOG heat vulnerability shown as percent of total grid cells; (B) Average heat vulnerability component scores across SCRCOG on a scale of 0 to 5.

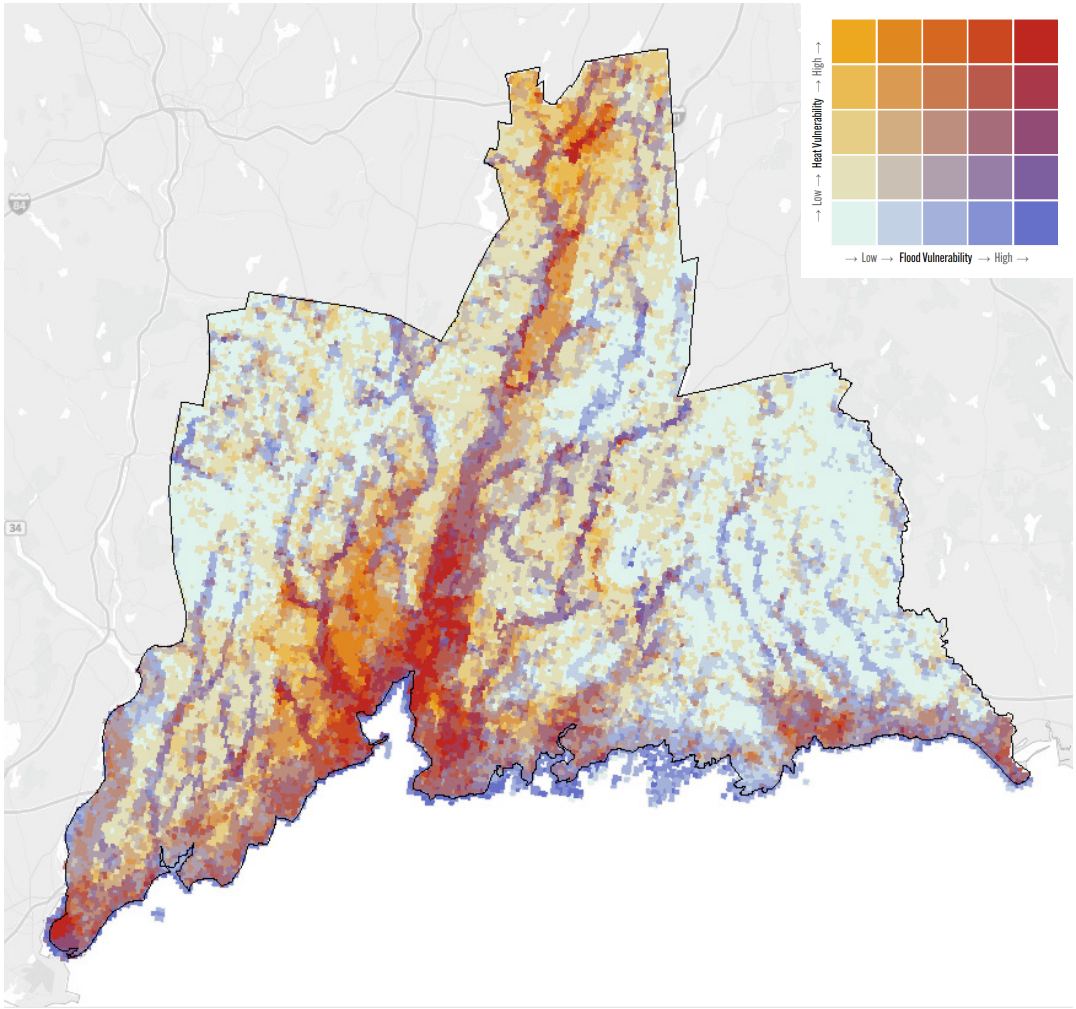


Figure 31: SCRCOG combined flood and heat vulnerability throughout the region

Flood and heat vulnerable areas (Figure 31) throughout SCRCOG are highest in the shoreline communities of New Haven, West Haven, and East Haven, with relatively high vulnerability areas along the Quinnipiac River and in Branford, Guilford, and Madison. The other SCRCOG communities have less pronounced vulnerable locations; however, there is flood, heat, and combined flood and heat vulnerability throughout the region.

The highest concentration of combined high flood and heat vulnerability can be found in New Haven along the shore and rivers, in smaller pockets in the other shoreline communities, and on stretches along the Quinnipiac River in Wallingford and Meriden. These areas share characteristics that are indicative of high flood **and** high heat vulnerability such as built, social, or ecological factors (Figure 32).

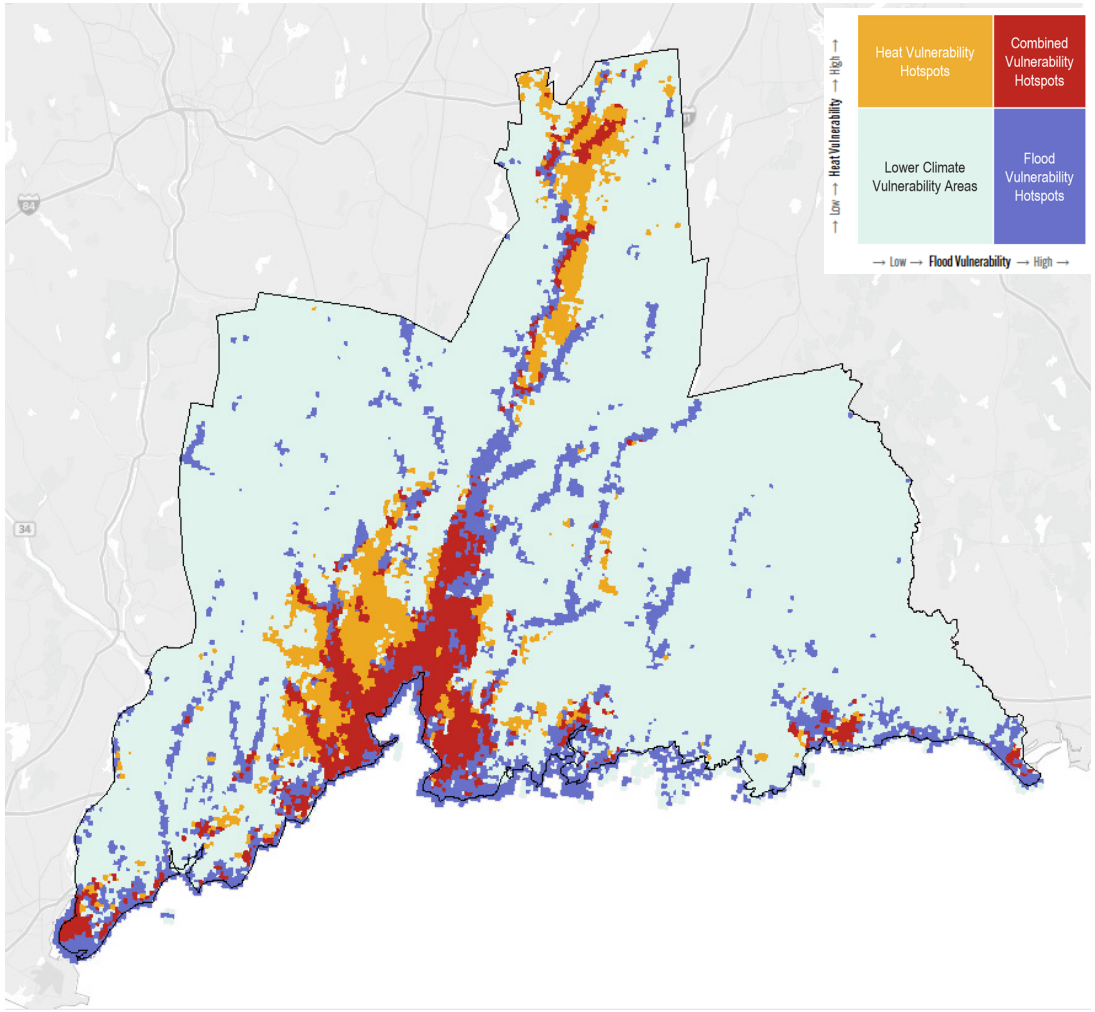


Figure 32: SCRCOG simplified high flood and high heat throughout the region highlighting the most vulnerable areas

Flood vulnerability is not limited to just one stream in the SCRCOG region but to many of the rivers and tributaries throughout the region. Some of the denser flood vulnerable locations surround the Quinnipiac, Wepawaug, and Farm Rivers. In addition, there are several locations along the shoreline that are high flood vulnerable.

High heat vulnerability can be observed in New Haven, West Haven, and along the Quinnipiac corridor in Wallingford and Meriden. In addition to these concentrated high heat areas, there are other locations throughout SCRCOG, such as in East Haven and Branford, that exhibit certain characteristics associated with high heat vulnerability.

4.5 WestCOG

There are 18 municipalities in the WestCOG region, however, two are located in Litchfield County and therefore not included in the analysis. Of the 16 in the Resilient Connecticut study region, five are coastal municipalities. The WestCOG region (Fairfield County) is roughly 492 square miles with an average population density of 3,685 people per square mile. The coastal communities have an average density of 4,994, with the inland communities at 1,811 people per square mile.

4.5.1 Flood

The Western Council of Governments (WestCOG) has the second-lowest average flood vulnerability (Figure 35) of the four COGs, with less than 2 percent of the area scoring high (Figure 34). WestCOG is below the regional average for flood sensitivity and exposure, while slightly above average for adaptive capacity (Figure 33).

The Stamford TOD has the highest flood vulnerability of TOD areas in the region. Six shelters are in moderately high flood areas: Mather Community Center,

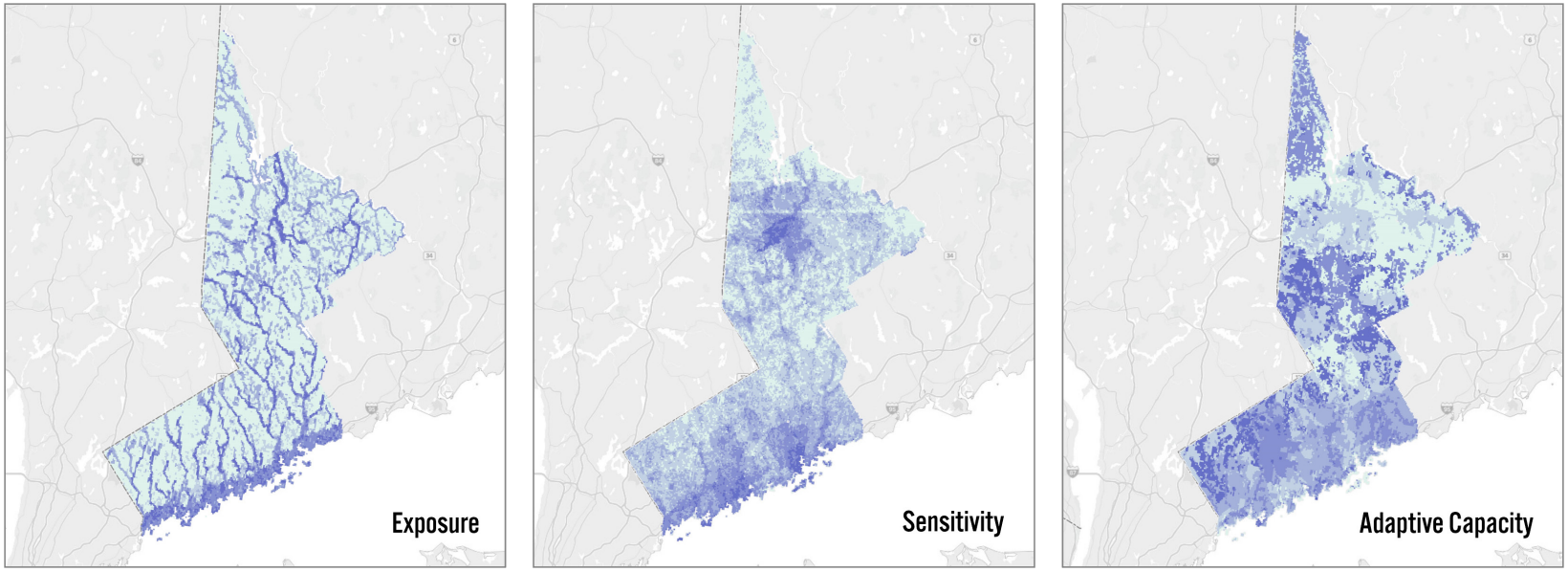
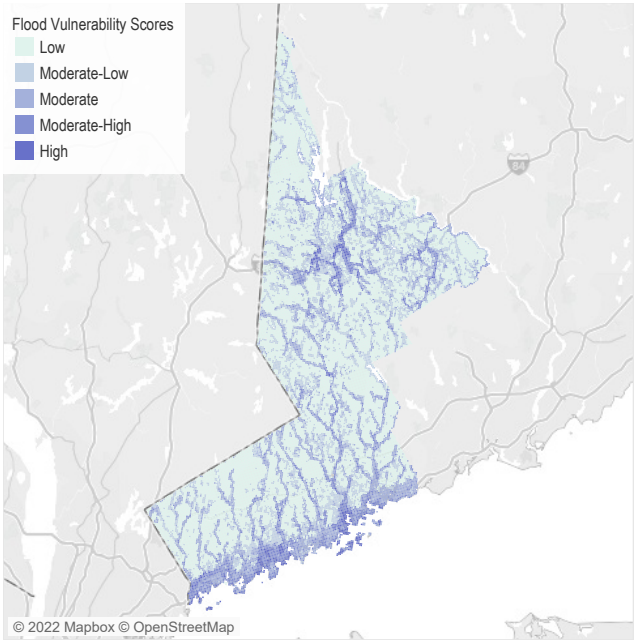


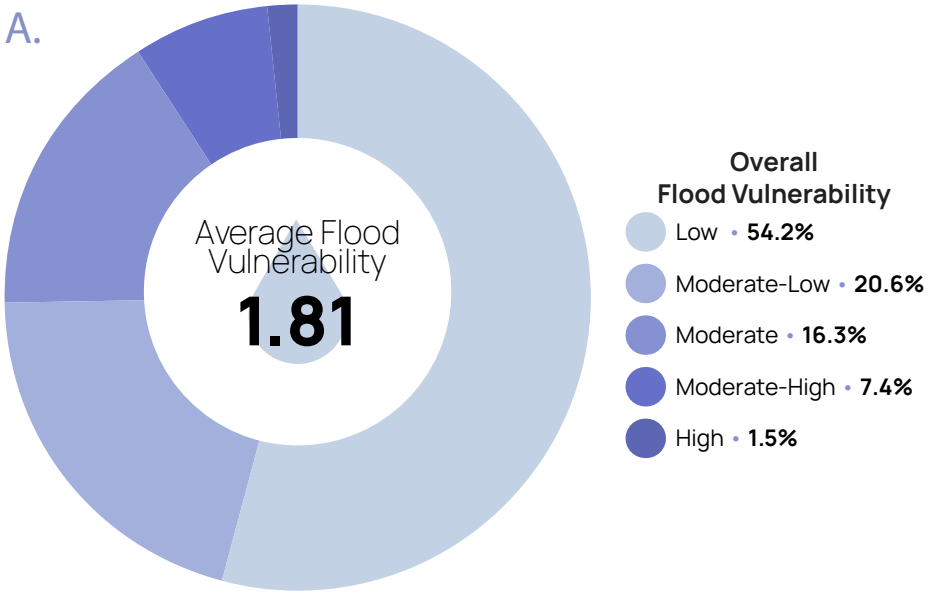
Figure 33: WestCOG flood exposure, sensitivity, and adaptive capacity distribution

Darien Town Hall, John Read Middle School, New Fairfield Senior Centers, Stamford Government Center, and Wilton YMCA.

ZSR were primarily delineated along the developed portions of the riverine corridors and shorelines. Numerous nested ZSR were delineated in coastal Greenwich, Darien, Norwalk, and Westport to represent areas that can be isolated or affected by multiple scales of isolation during an evolving flood event. Hazard mitigation plans were helpful for locating ZSR that do not necessarily follow mapped floodplains, such as some of the ZSR in Danbury, Bethel, Ridgefield, and Norwalk. Stakeholder input also aided in ZSR delineation, such as in Danbury.

Figure 35: WestCOG overall flood vulnerability





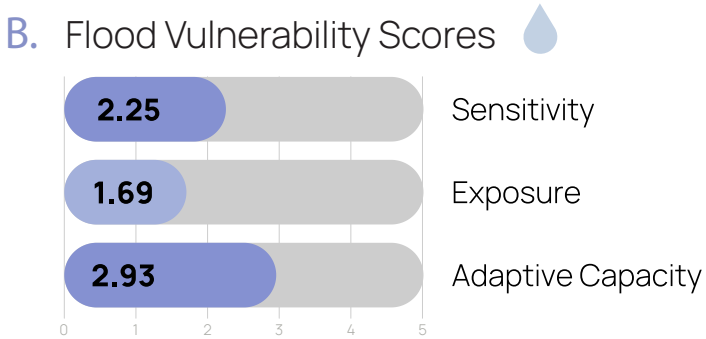


Figure 34: (A) WestCOG flood vulnerability shown as percent of total grid cells; (B) Average flood vulnerability component scores across WestCOG on a scale of 0 to 5.

4.5.2 Heat

Of the four COGs, WestCOG is lowest in overall heat vulnerability (Figure 38), with approximately 2 percent of the COG having high heat vulnerability, and nearly 55 percent having low heat vulnerability (Figure 37). Overall WestCOG has notably below average heat exposure and sensitivity (Figure 36), but approximately average adaptive capacity.

High heat vulnerability areas are in southern Stamford, southwestern Greenwich along Route 1, south Norwalk, and downtown Danbury. Radiating from these high heat areas in these communities are moderately to moderately high vulnerable areas. New Canaan center and the Route 1 corridor in Darien also have some heat vulnerability. Much of the region has low to moderate heat vulnerability. The high and moderately high heat areas are mostly driven by social factors. Contributing factors include high numbers of asthma-related emergency visits, low disposable income, and old or young populations. In addition to the high heat areas already listed, west Redding, northeast Wilton, and southern Ridgefield are driven by social factors. Many of the remaining areas are driven by built factors such as older structure age, longer distance to shelters or cooling centers, and high building density. Some smaller areas

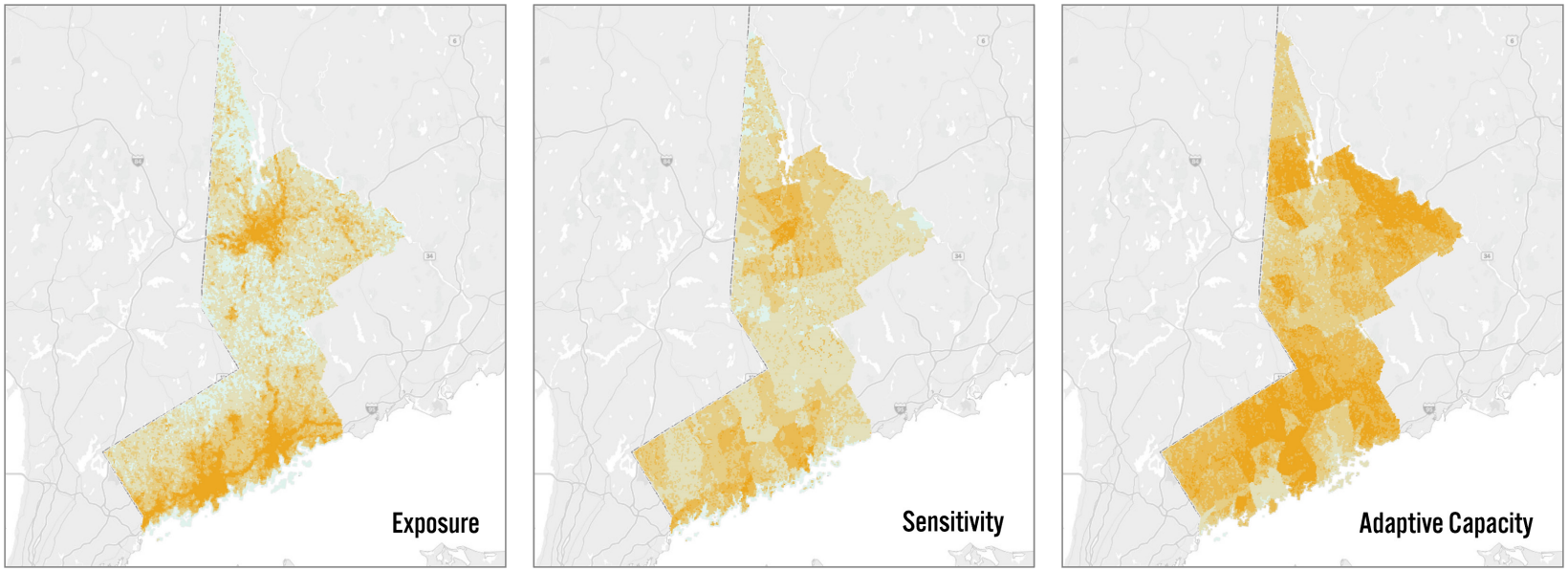
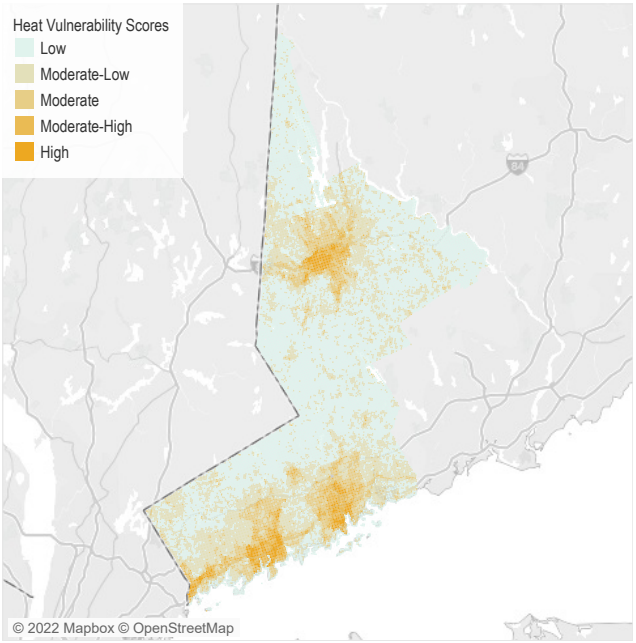


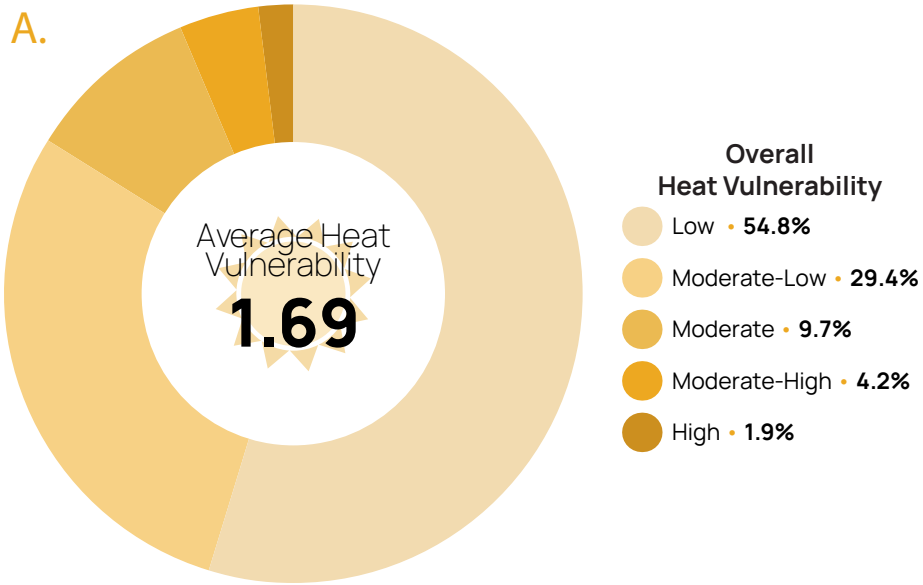
Figure 36: WestCOG heat exposure, sensitivity, and adaptive capacity distribution

are driven by ecological factors including reduced tree and vegetative coverage. There are also several areas throughout the region where vulnerability is equally driven by built and social contributing factors.

The Danbury TOD is the highest heat vulnerable TOD area. Relative to the other COGs, WestCOG has the most cooling centers that are greater than 1 mile from a bus route: Cyrenius Booth Library, Newtown Municipal Complex, Redding Community Center, Mark Twain Library, Ridgefield Parks & Recreation, Westport/ Weston YMCA, New Canaan Library, and New Canaan YMCA. This elevates heat risk in those communities.

Figure 38: WestCOG overall heat vulnerability





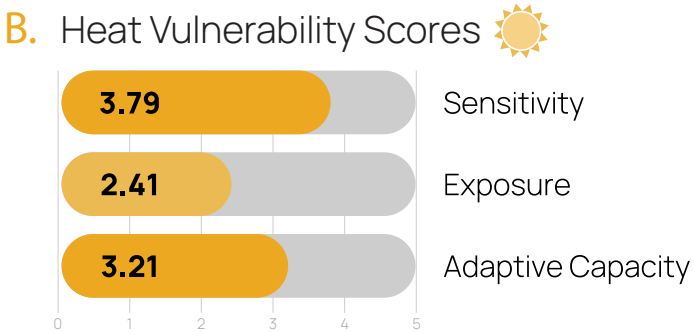


Figure 37: (A) WestCOG heat vulnerability shown as percent of total grid cells; (B) Average heat vulnerability component scores across WestCOG on a scale of 0 to 5.

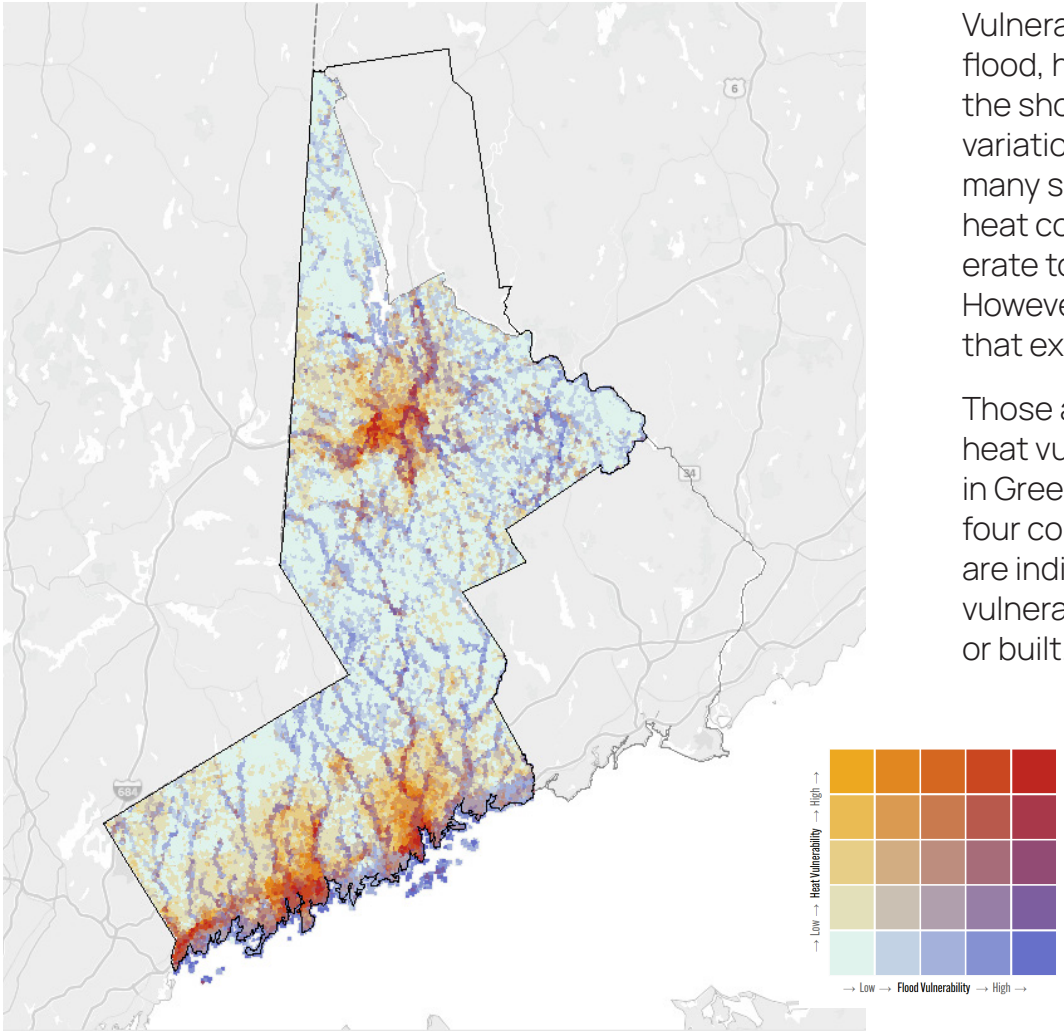


Figure 39: WestCOG combined flood and heat vulnerability throughout the region

Vulnerability throughout WestCOG (Figure 39) for flood, heat, and combined is generally highest along the shoreline and throughout Danbury. While there is variation throughout all of WestCOG, these areas have many shared characteristics of a high flood and high heat community. The remainder of the region is moderate to low for flood, heat, or combined vulnerability. However, there are smaller areas throughout WestCOG that exhibit high vulnerability.

Those areas with the highest combined flood and heat vulnerability (Figure 40) can primarily be found in Greenwich, Stamford, Norwalk, and Danbury. These four communities have certain characteristics that are indicative of high flood vulnerability and high heat vulnerability. These factors might be social, ecological, or built.

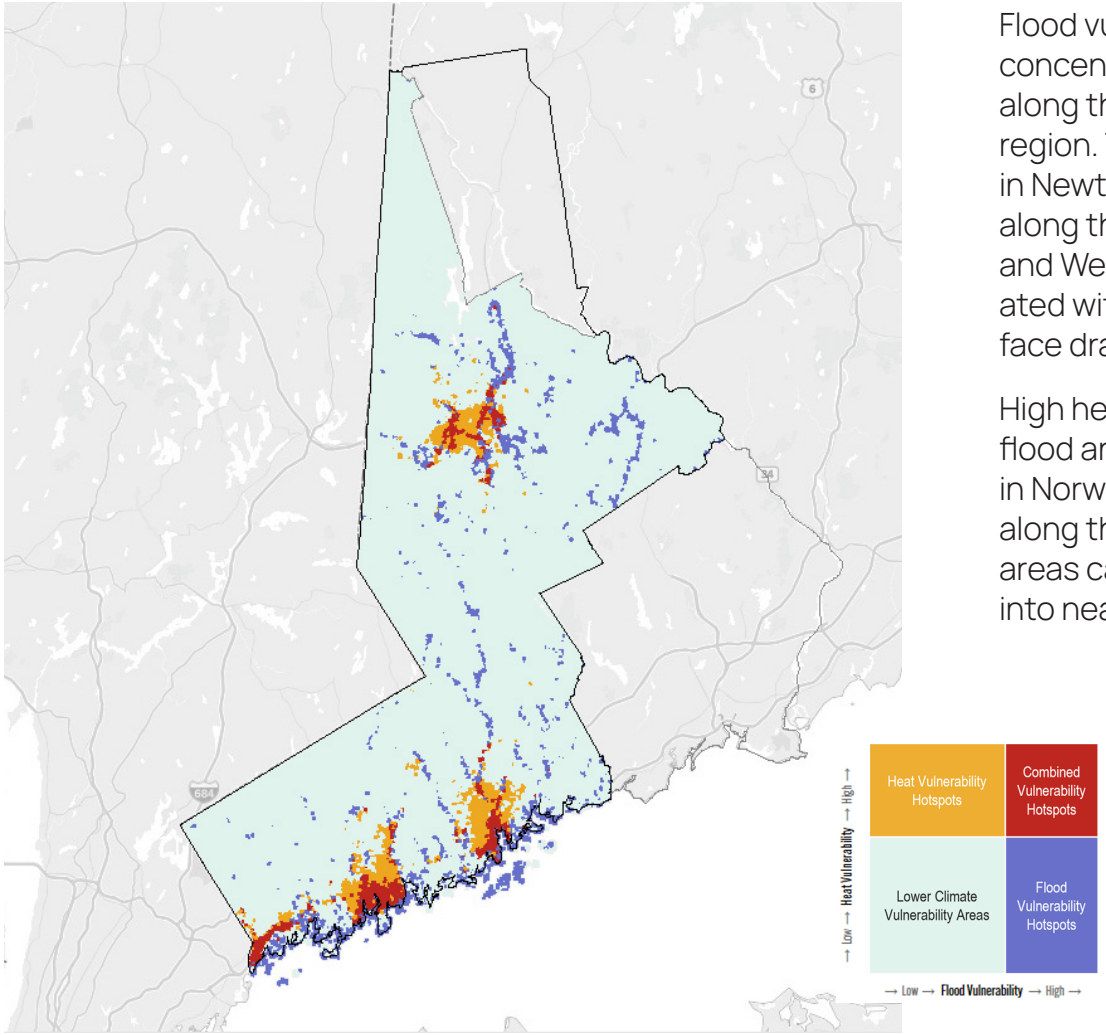


Figure 40: WestCOG simplified combined high flood and high heat throughout the region highlighting the most vulnerable areas

Flood vulnerability throughout WestCOG is not concentrated in one area or community, but rather along the coast, rivers, and tributaries throughout the region. There are high flood vulnerable areas inland in Newtown, Danbury, Wilton, and Ridgefield, but also along the shoreline in communities such as Greenwich and Westport. Flood vulnerability is likely most associated with the shoreline and rivers, but some areas may face drainage- or pooling-related challenges.

High heat areas are like those that have combined high flood and heat vulnerability. Areas are concentrated in Norwalk, Stamford, and Danbury, with several areas along the Interstate 95 corridor. Smaller high heat areas can be found radiating from these dense areas into nearby communities.

4.6 Social Vulnerability

Social vulnerability can be defined in several ways depending upon the scenario; under Resilient Connecticut, it is considered to be the societal conditions that make certain populations vulnerable, or prone to loss, from extreme weather and climate change. Characteristics of social vulnerability, such as age, race, home type, or income, may impact a population's degree of resilience and response, as oftentimes specific characteristics limit adaptive capacities or resource availability. Resilient populations

are an integral component to resilient communities; therefore, understanding social vulnerability trends is critical to increasing community and regional climate resilience.

To explore regional social vulnerability, an SVI has been developed to assess overall regional social vulnerability, comprised of 30 factors along with five subgroups that focus on more specific social vulnerabilities. The following sections present the overall social vulnerability and subgroup trends in the region.

4.6.1 Overall Social Vulnerability

Regional overall social vulnerability, which is comprised of all 30 social demographic factors, is 0.53 on a scale of 0 to 1, with 1 being greatest vulnerability. This regional overall vulnerability average can be used to gauge how each of the four COGs compare to the region (New Haven and Fairfield Counties) as a whole. Both WestCOG and SCRCOG are slightly below average, while MetroCOG and NVCOG are slightly above average (Figure 42). In addition, each subgroup vulnerability has been calculated at the regional scale and the COG scale to again compare COG averages to regional.

The overall social score can be broken down further into the five subgroups. By focusing in on these groups, specific vulnerabilities can be identified more acutely and adaptation and resilience measures can focus on these populations. Strategies may include tailored outreach materials, emergency response and transportation planning focused on specific vulnerable populations, and assistance programs to help communities secure resources for adaptation measures.

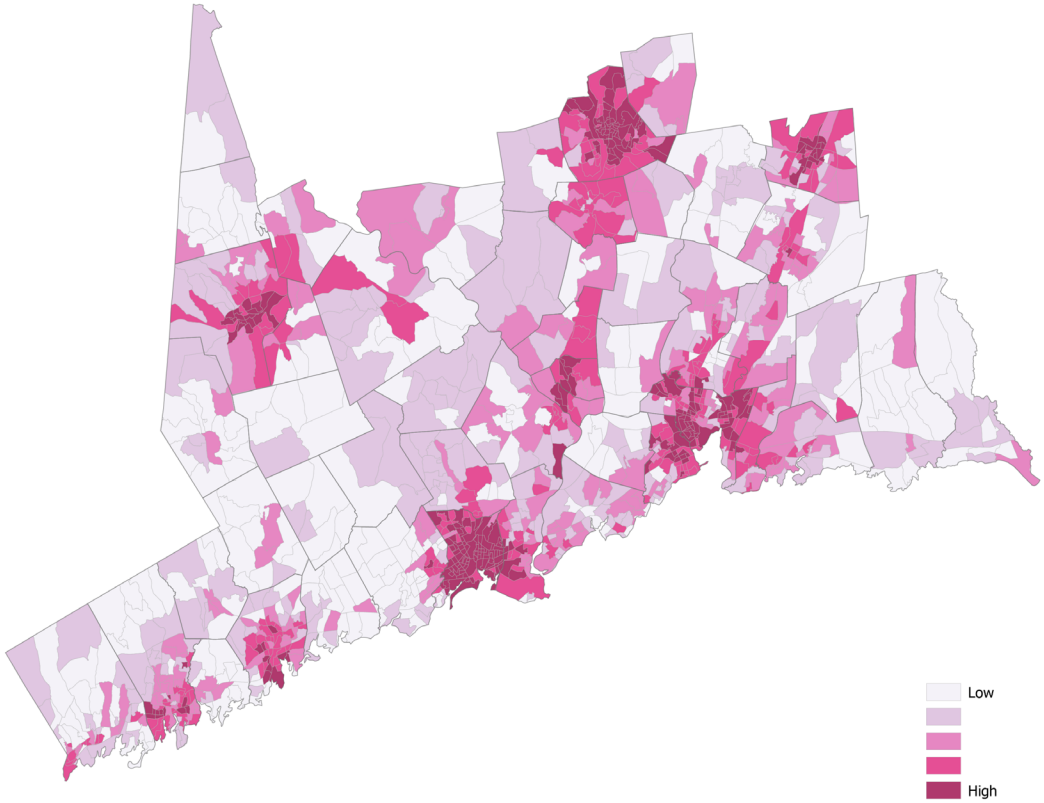


Figure 41: Overall social vulnerability in Fairfield and New Haven Counties

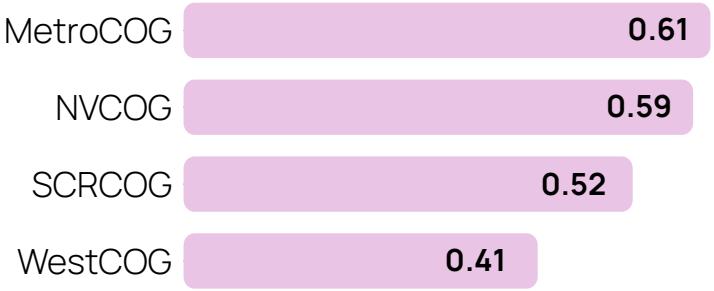


Figure 42: Average overall social vulnerability by COG

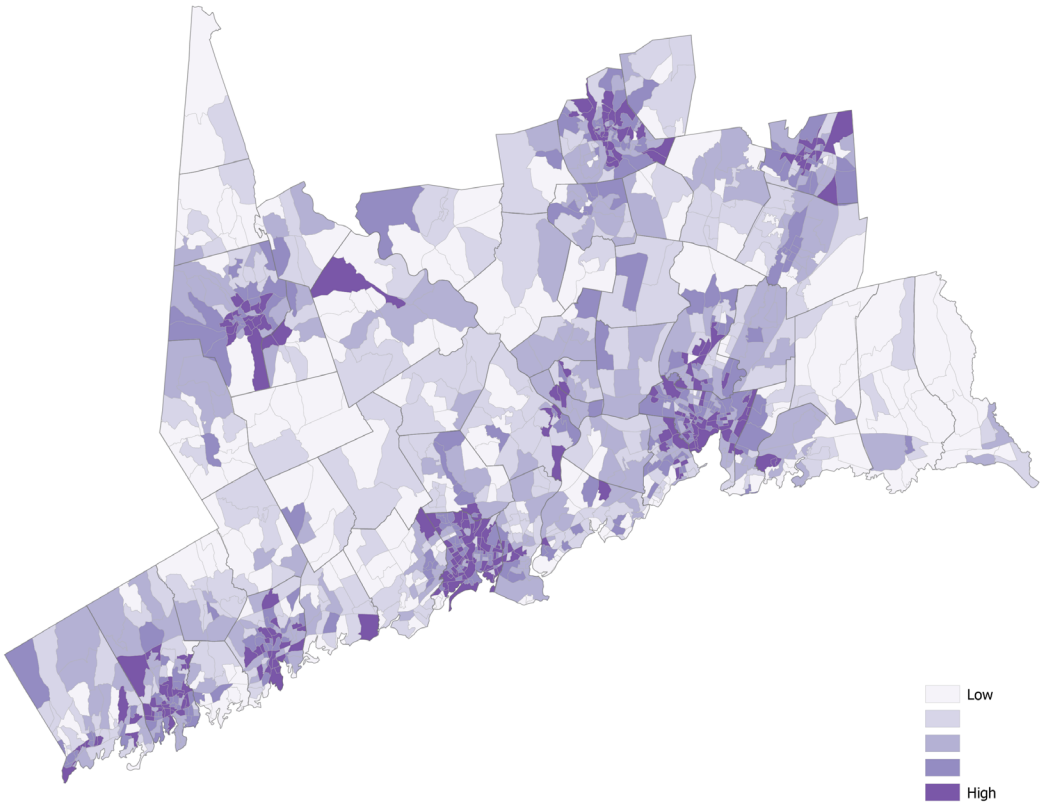


Figure 43: Minority status and language vulnerability in Fairfield and New Haven Counties

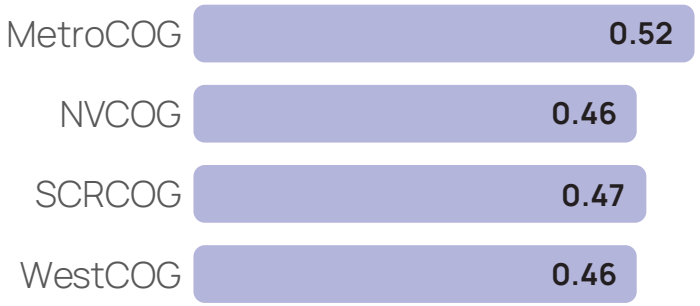


Figure 44: Average minority status and language scores by COG

4.6.2 Minority Status and Language

Minority status and language vulnerability varies throughout the region, with an average score of 0.48. This subgroup is comprised of six variables: percent female, black, Native American, Asian, Hispanic/Latino, and percent speaking English as a second language. MetroCOG has significantly higher minority status- and language-related vulnerability in comparison to the other three COGs (Figure 44). This score represents a diverse population within the COG and the region, and should be considered during resilience and adaptation planning.

Certain considerations might include the development of educational information in several languages, identifying community "champions" to assist in climate change resilience outreach, and ensuring that planning processes are inclusive.

4.6.3 Socioeconomic Status

The socioeconomic subgroup Socioeconomic Status, which includes seven variables, is highest in the MetroCOG region and lowest in the WestCOG region (Figure 46). The entire region has an average socioeconomic vulnerability of 0.58. The specific demographic variables that drive this vulnerability are poverty levels, median income, unemployment, education level, annual household earnings, populations without health insurance, and households spending more than 40% of income on housing expenses.

Socioeconomic factors play into climate vulnerability as those populations with lower socioeconomic status experience limited factors, such as education or access to resources, that determine the degree of climate change impacts. Oftentimes these populations do not have the means or capacity to adapt to climate change and therefore existing inequalities are exacerbated further by climate impacts. Communities with socioeconomic sensitive populations should provide additional resources throughout and to these communities to support residents and aid in adaptation and mitigation efforts.

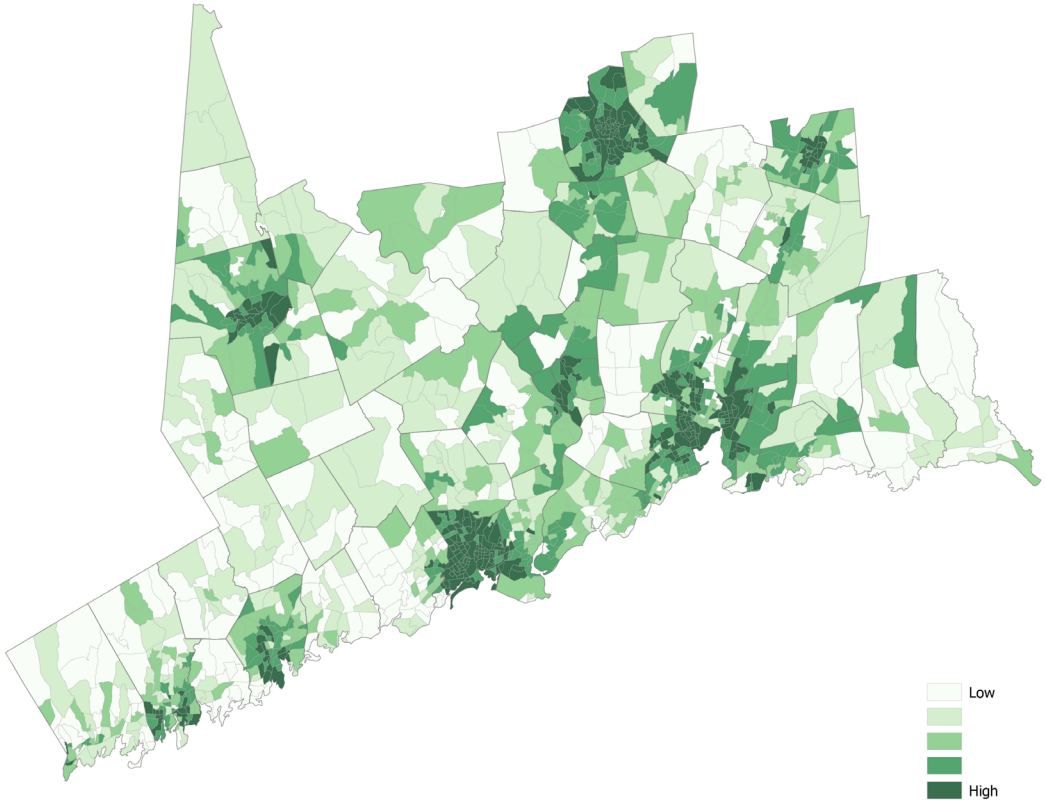


Figure 45: Socioeconomic vulnerability in Fairfield and New Haven Counties

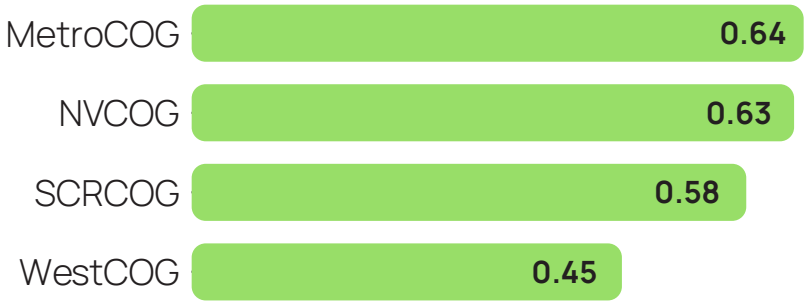


Figure 46: Average socioeconomic scores by COG

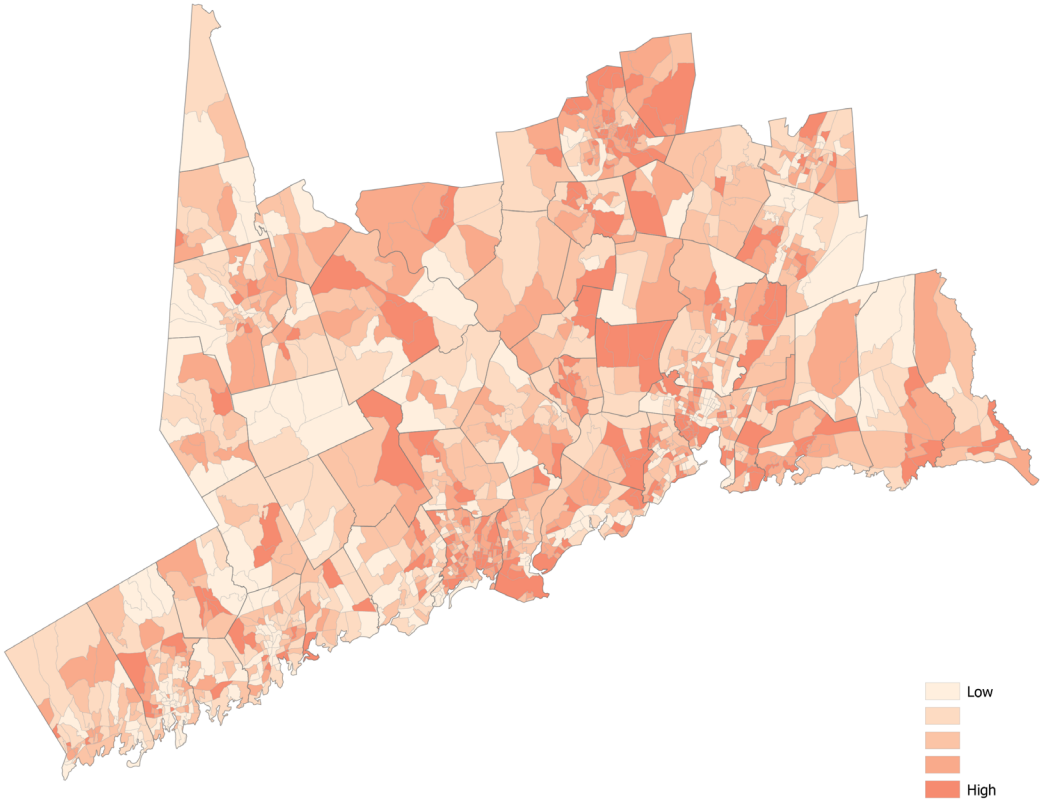


Figure 47: Household composition and disability vulnerability in Fairfield and New Haven Counties

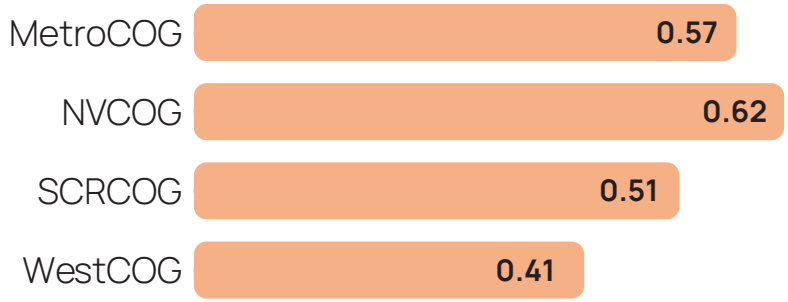


Figure 48: Average household composition and disability scores by COG

4.6.4 HouseholdCompositionandDisability

On average throughout Fairfield and New Haven Counties, household composition and disability vulnerability is 0.53. Household composition and disability throughout the region varies with the SCRCOG and WestCOG being below the regional average, and MetroCOG and NVCOG above (Figure 48). NVCOG has the greatest household composition and disability vulnerability. This subgroup identifies populations that are under 5 or older than 65 years old, those with independent living difficulties, median age, number of female-headed households, single-parent families, people per housing unit, and households receiving social security benefits.

Populations identified in this subgroup may face challenges with mobility or evacuation during extreme weather events. Resilience-related strategies could include developing tailored evacuation plans, programs to assist families that may need additional resources pre- or post-event, and backup or emergency power options for specific buildings or neighborhoods.

4.6.5 Labor Force

The average regional labor vulnerability is 0.49. Regional labor force vulnerability is only comprised of three variables: females in the labor force, employment in service industry, and employment in blue collar industries (i.e., extractive industries, construction, forestry, agriculture). In general, regional labor force vulnerability is moderate, with WestCOG scoring lowest, and MetroCOG scoring highest (Figure 50).

Individuals employed in certain industries may be more impacted than others due to the nature of the work i.e., those working outdoors are more vulnerable to extreme heat or flood related site impacts. In addition, certain service industries may be more sensitive to disruptions in access to transportation routes or longer-term economic impacts associated with climate change. The inclusion of females in the labor force can often identify populations that find recovery more challenging due to factors such as reduced wages, employment type, and family care responsibilities[4]. Communities and employers should work to educate on certain job-related vulnerabilities, evaluate the need for employee support systems, and focus on equal-opportunity employment.

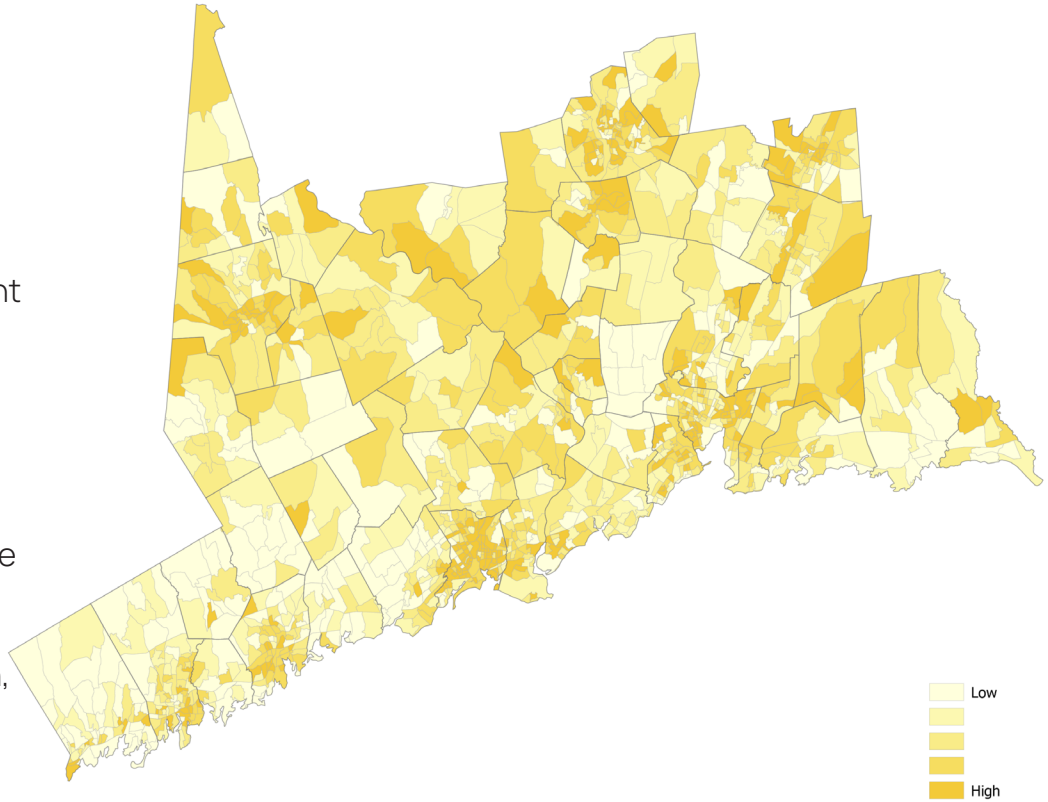


Figure 49: Labor force vulnerability in Fairfield and New Haven Counties

Figure 50: Average labor force scores by COG

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Figure 51: Housing type and transportation vulnerability in Fairfield and New Haven Counties

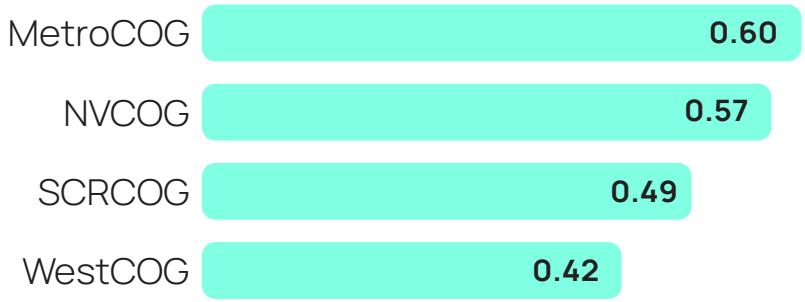


Figure 52: Average housing type and transportation scores by COG

4.6.6 HousingTypeandTransportation

This subgroup is comprised of seven variables that help to identify residential- and transportation-related vulnerabilities. The variables include unoccupied housing units, percent renters, mobile homes, housing units without a car, median gross rent, housing values, and hospitals per capita (county level). The mean vulnerability score throughout the region is 0.49 with WestCOG having the lowest housing type and transportation vulnerability and MetroCOG having the highest (Figure 52).

High vulnerability in this subgroup highlights populations that face transportation barriers, low homeownership, or high density of vulnerable mobile home housing. To assist these populations communities, can work with landlords to fill units with incentivization programs or strategic community development and educate them on climate change adaptation strategies; often renters may be limited on what home upgrades they can perform. In addition, populations without vehicles should be located and available public transit options ensured for both emergency evacuation and accessing public facilities during heat or flood events.

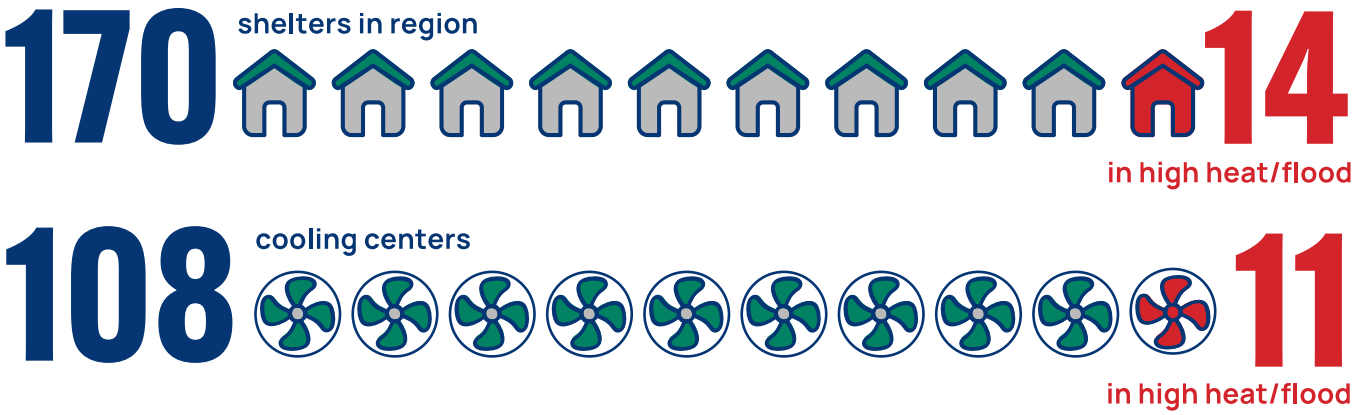
4.7 Regional Asset Vulnerability

In addition to COG and TOD area assessments, various asset types throughout the region were evaluated. These include the following:

- Critical facilities
- Regional employment centers
- Historic and cultural resources
- Rail assets
- Bus assets
- Affordable housing
- Drinking water infrastructure
- Wastewater infrastructure
- Critical habitats

4.7.1 Critical facilities

A critical facility as defined by the Federal Emergency Management Agency (FEMA) is a facility (or infrastructure) that is critical to the health and welfare of the population and that is especially important following hazard events. The regional facilities assessed include locations such as emergency response, community facilities, shelters, medical facilities, and assisted living. While many of these facilities provide municipal-level support, many facilities and their associated services



can provide regional-level support during or after an event. In addition, maintaining municipal safety and operations is often vital to sustaining regional operations, as individuals do not always work or recreate solely in their community.

Often during a flood or heat event, sheltering and/or cooling are of critical importance. To better understand the capacity – or vulnerability – of some of these locations, CCVI was used to locate those facilities used as shelters that are most vulnerable to flooding or are located within high heat vulnerable neighborhoods.

In total, there are 1,596 critical facility parcels throughout New Haven and Fairfield Counties encompassing 1,782 facilities. Of these parcels, 422 are in a high flood, high heat vulnerable location, 418 are in a high flood, low heat location, and 601 are in a low flood, high heat location. In addition, there are 170 identified shelters throughout the region; 14 are in a high heat, high flood vulnerable location. There are 108 cooling centers identified in both counties and of these, 11 are in a high heat and high flood location. Overall, while there are many facilities located in high flood, high heat, or combined vulnerable areas, actual site and facility risk will vary dependent upon the structure's adaptation measures, access and egress capabilities to the location, and specific location adaptive capacities.

4.7.2 Regional Employment Centers

With approximately 270 major employers in the region, many of which also provide critical services such as police, fire, and hospitals, it is imperative to understand the vulnerabilities surrounding these locations. If a large regional employer were to be impacted, this could reduce service capability, which could be critical, but also impact the economic stability of the community and the region.

Of the 270 major employer locations used in this analysis, 59 are in a high flood, high heat location. There are also 33 employers in a high flood, low heat location, and 88 in a low flood, high heat location. The facilities in this analysis include sites where employees physically work, or sites that serve as headquarters

or offices. Sites where employees work rely on access and continuity of operations to maintain business levels and to provide stable employment. In addition, some sites may face challenges regarding power disruption. For example, grocery stores need power to maintain refrigeration; medical facilities require safe site access for emergency intake. Those sites that are offices or headquarters also rely on access; however, if there were disruptions to that location, field or satellite operations may be available but potentially limited with headquarters disruptions. Understanding site or operational vulnerabilities is key to maintaining operational continuity and economic stability. By evaluating each facility and employer on a case-by-case basis, vulnerabilities can be mitigated to minimize operational disruptions, ultimately reducing regional economic impacts and critical services.

4.7.3 Historic and Cultural Resources

Many communities throughout the region have historic buildings and homes, often located in historic districts, that are in high flood or high heat areas. These resources are often limited by the level of retrofit possible to address these hazards. Many of these resources provide cultural and economic benefits to communities and the region as they are often part of tourist attractions or community events.

By identifying those that are vulnerable, planning can begin on how to mitigate impacts to sites and districts without having to face the hurdle of building retrofit. Examples might include improved drainage adjacent to sites, street greening to promote walking access, or flood barriers at nearby underpasses or flood points.

4.7.4 Rail Assets

Although rail is the primary focus of the TOD analysis, rail lines themselves were not included in that analysis. A two-dimensional desktop analysis was conducted to identify those stretches of rail that are in a SFHA and to compare estimated rail elevation, using Light Detection and Ranging (LIDAR), to base flood elevation (BFE).

Throughout the region, 1,395 points were associated with rail line segments within the SFHA. Of those, 363 points were assigned an elevation to be compared to relative BFE. Depending on whether a point is located on a rail bed or bridge crossing impacted the accuracy of the rail elevation. In summary, there are roughly 57 miles of rail within the SFHA, and 275 of the 363 that are below BFE. These stretches may present challenges during a flood event given that they are in a SFHA and at low elevation. In addition, those that are estimated to be above BFE may still have some degree of rail bed at BFE, still presenting stability challenges.

4.7.5 Bus Assets

With hundreds of bus stops throughout Fairfield and New Haven Counties and no single dataset to represent them all, "bus hubs" were included as part of the assessment. Oftentimes a bus hub is synonymous with a train station; whenever that was the case, these locations have already been assessed. There are, however, other hubs located throughout the region that represent important bus stops. These hubs are typically located in urbanized areas and are where multiple bus routes intersect.

12 hubs were mapped as part of the assessment, with ten in a high flood and high heat vulnerable area. The CTFastrack stops in the region were also assessed. Of the six stops identified, all have moderate to low flood vulnerability, while four of the six have moderate to high heat vulnerability.

4.7.6 Affordable Housing

Using HUD- and COG-provided data, housing location vulnerability was evaluated as part of the assessment. Many of these housing assets are in urbanized areas and are home to vulnerable populations. However, there are some assets that are vulnerable and located in suburban communities.

Of the 443 housing assets mapped, almost 100 complexes have been located in a high flood and high heat vulnerable area. Affordable housing assets were used as a main criterion for identifying ROARs.

4.7.7 Drinking Water Infrastructure

Utility reliability is a critical component of a resilient system; drinking water is no exception. While some statewide planning efforts have focused solely on drinking water infrastructure resilience, Resilient Connecticut aimed to identify compounded vulnerabilities because of utility vulnerabilities.

Drinking water in the state can be classified as community water systems, non-community systems, and non-transient non-community systems, with the latter two primarily served by private drinking water supply wells. To determine vulnerability to the systems in the region, drinking water supply well locations were assessed using CCVI. There are 924 In total, with 13 wells in flood vulnerable areas, 3 of which belong to a community system. While understanding vulnerability based on location (i.e., physically in or out of a flood zone, or location within CCVI), certain infrastructural components should also be used to identify resilience opportunity areas to further assess vulnerabilities.

4.7.8 Wastewater Infrastructure

In addition to drinking water, wastewater utilities have also been evaluated. Sanitary sewer system components, such as wastewater treatment plants and pumping stations, often serve multiple communities and are typically located in proximity to water sources, increasing vulnerability.

While the wastewater dataset may not be complete, of the data available five pumping stations and five water pollution control facilities (WPCF) were found to be located in a high flood vulnerable area and a ZSR. In addition, two other WPCFs are in an access ZSR in a moderate-high flood vulnerable area.

While infrastructure present can be a risk, the absence of this infrastructure can also pose a climate change related risk. Certain areas throughout the region lack sewer systems, with two communities of particular concern. The Guilford-Madison area, which faces sea level rise challenges, has historically lacked a traditional wastewater system. These septic system areas throughout the region, especially those in high flood vulnerable areas, may be at risk of damage or washout. Although most systems can withstand flooding due to the system being located below ground, damage could include debris or silt clogging systems, erosion due to moving floodwaters or elevated tides or surge, or contamination within a residence or into groundwater due to an over inundated system. Coastal areas in particular that are experiencing rising seas and water table levels, may be more prone to standing water flooding and potentially damaged septic systems.

4.7.9 Critical Habitats

According to the Natural Diversity Data Base (NDDB) and critical habitat data developed by the Connecticut Department of Energy & Environmental Protection (CTDEEP), there are locations throughout the region that both encompass critical habitats and endangered species populations and are vulnerable to flooding. A total of 34 sites have been identified as an NDDB or critical habitat and in a flood vulnerable area.

Many of these sites provide important ecosystem services or act as economic stimulators for the region as they serve as public access or tourist attractions. Conservation and restoration of these habitats may increase community and regional resilience in numerous ways.

4.8 Vulnerability Assessment Lessons Learned

The development and application of CCVI and the vulnerability assessment resulted in several overarching lessons learned.

- While stakeholder engagement was a major component of the assessment, it also led to the understanding of the diversity of uses for the tools and analysis. Many different stakeholders are interested in using the vulnerability assessment and related tools for different purposes. More work can be done to develop and refine the public-facing tools that will better serve a variety of audiences. Tools that are more accessible and inclusive would present CIRCA with the opportunity to maximize the benefits of the CCVI tool and associated approach to a broader audience of external stakeholders.
- A major accomplishment of the CCVI process is the collection and aggregation of data assets. However, data availability and accessibility were both a challenge for tool development; this was highlighted in feedback from participating stakeholders. Making the datasets used throughout the analysis more accessible and usable to stakeholders would be a welcomed service.
- The development of CCVI would have been improved by clearer direction on and communication of the intended audience and primary use case of the CCVI data, web viewer, and story map. This could have led to more targeted and streamlined stakeholder engagement processes.

4.9 Vulnerability Assessment Recommendations

Future iterations of CCVI and statewide resilience planning efforts might take the discussed lessons learned and incorporate appropriate changes. Specifically, numerous recommendations have been developed to assist future tools for assessing vulnerability as well as specific climate adaptation and resilience strategies. These recommendations are presented below.

4.9.1 Future Tool and Vulnerability Assessments

- Weighting of various contributing factors could be explored in more detail, or even facilitated in an interactive dashboard. The CCVI team began developing a Tableau dashboard that could be used to adjust the weighting of individual factors and

visualize the impacts on the final index, but it was not fully developed nor implemented.

- Additional effort could go into characterizing vulnerable areas to better understand what is driving areas of high climate change risk. This may be particularly helpful for characterizing zones of shared risk and identifying the most appropriate adaptation projects. It can also be enlightening for external stakeholders, particularly focused on resilience in certain facets of the physical environment.

  The CCVI team began exploring these opportunities through the typology analysis, which identified which environmental factors (built, ecological, social) drive vulnerability for a given area. The initial typology analysis was informative but not fully completed nor integrated into the overall approach. Among other things, the analysis found that over half of the grid cells identified as moderate, moderate-high, or high flood vulnerability have ecological factors contributing substantially more than built or social factors to the overall valuation of risk. Further research could uncover whether these findings are concerning and should be cause for adjusting the factor weighting schema, or due to the lack of or too few contributing factors in certain cells.

  Similarly, additional effort could go into better understanding how much of an area's total vulnerability index value is driven by the presence of hazard exposure, asset or social sensitivity, or adaptive capacity. Again, this type of information could be utilized to inform the most appropriate intervention for a given high-vulnerability area.

  The ZSR concept could also be expanded and refined to capture other types of flood-related risk and be characterized beyond those identified in Phase II. Delineation of ZSR should also be explored for identifying extreme heat risk areas.
  Measuring change over time and incorporating this into the assessment, particularly by way of CCVI, could provide an understanding of how vulnerability or risk is projected to change over time. This would include establishing a baseline vulnerability score based on current flood and heat hazard information, and then additional scores based on projected changes using the appropriate time horizons.
  If possible, it may also be worth exploring the available data in spatial variations of temperature changes. Incorporating various scenarios would allow for an understanding of not just which areas

are currently at risk, but which are likely to see the biggest increase in risk.

- Regional and statewide affordable housing datasets should be developed to ensure a more comprehensive understanding of vulnerability to these assets. A degree of collaboration is required for this effort and stakeholders might include state agencies and COGs. The development of these datasets would ensure consistent housing data and ensure that affordable housing is included in assessments through reasonable methods.

4.9.2 Climate Adaptation and Resilience Recommendations

Recommendations were identified for specific asset types that could support targeted next steps to further climate adaptation and community resilience. These include the following:

- **Critical facilities:** Communities should evaluate specific vulnerabilities to the shelters and cooling centers identified. Aspects may include evaluating the condition of backup power or pursuing backup power sources if none currently exist; conducting a site vulnerability assessment to evaluate specific flood risks; locating entry points for flooding or vulnerable utilities; and using CCVI to assess other facility vulnerability levels such as the populations being served, drainage-related challenges, or nearby critical habitat vulnerability. CCVI has an abundant amount of data built in that would provide a holistic view of the vulnerability within the critical facility area. Communities should also explore the use of CIRCA's Southeastern Connecticut Critical Facility Assessment to develop a framework.

  In addition, to bolster future assessments COGs and state agencies should collaborate to develop a comprehensive spatial database of these facilities, taking into account contributions from communities during hazard mitigation plan updates.

- **Regional employment centers:** Ensure that climate adaptation and resilience is considered as sites are developed and redeveloped; include strategies in business continuity plans; and work with municipalities to ensure that emergency response teams are aware of specific needs or challenges during an event.

  State agencies and COGs should also collaborate to develop a comprehensive spatial database of major employers and employment centers, taking into account contributions from municipalities; and

ensuring that vulnerabilities to climate change are incorporated into applicable planning processes such as POCD updates.

- **Historic and cultural resources:** Use CCVI to identify the vulnerability to a site or district and evaluate options available for mitigation. Review the State Historic Preservation Office (SHPO) resilience guidelines to identify appropriate strategies for at-risk sites. In addition, a process should be developed to include historic and cultural resources more directly in future vulnerability assessments such as CCVI, in future delineation of ZSR, and in future identification of ROARs.

  The Department of Economic and Community Development (DECD) SHPO should follow the process utilized in the southern four counties to develop a detailed Geographic Information Systems (GIS) database of historic and cultural resources in the northern four counties. Developing this dataset would contribute to future resilience planning efforts throughout the remainder of the state.

- **Rail and Bus:** Rail and bus transit companies should continue to work to identify their vulnerable assets throughout the region and state; particularly those that service communities with vulnerable and underserved populations. Coordination between these entities and the municipalities they traverse can multiply resilience effort ultimately increasing system resilience and reliability during and event. In addition, bus lines should add service locations (bus hubs and bus stops) in locations of high heat vulnerability to increase accessibility to public transit for those seeking transportation to cooling facilities.

- **Affordable Housing:** Communities should continue to identify those affordable housing locations that are most vulnerable to flooding or exposed to extreme heat and develop strategies to increase resilience. Efforts might include increased education on flood preparation and emergency information, distribution of cooling center information before anticipated heat waves, and providing education and guidance to property owners seeking advice on resilience measures or pursuing resilience related upgrades such as flood-proofing through elevation or heating and cooling efficiencies.

- **Drinking Water:** Several resilience related efforts have been undertaken to address drinking water

vulnerability and resilience. Communities should work to become aware of those drinking water related vulnerabilities that may impact their community, and work DPH and drinking water systems to address these vulnerabilities and develop solutions. In addition, municipal and local department of health staff should work to educate residents on potential private well challenges associated with floods and drought, and work with those seeking advice on resilience strategies. Appendix B provides additional information on the Drinking Water Vulnerability and Resilience Plan (DWVARP) and Water Utility Coordinating Committee (WUCC) recommendations.

- **Wastewater:** Sanitary sewer system operators should evaluate system infrastructure vulnerability on a finer scale using predicted flood and sea levels. Evaluating future inundation and flood scenarios more acutely can help better prepare systems for increased flooding. In addition, those that have been identified in a high flood vulnerable location can also assess their infrastructure more closely including identifying the low-lying components of the system, and developing resilience strategies to protect those components.

5.0 Resilience Opportunities

After assessing the regional climate vulnerability through the CCVI and ZSR methods, the CIRCA team developed a methodology to identify resilience opportunity areas in Fairfield and New Haven Counties. The regional scale of the project required a systematic approach to achieve the deliverables of the grant within the specified timeframe. These ROARs advance the objectives identified in the Resilient Connecticut Planning Framework, incorporate feedback from multiple engagement methods, including advisory groups and regional workshops, and reflect local and regional priority planning areas. Succinctly, the ROARs seek to address one or more climate-related hazards, advance planning objectives, protect human health, and enhance quality of life.

This pilot methodology uses spatial data to identify converging areas of high flood and/or heat climate vulnerability with community-identified planning objectives or related planning efforts that are not otherwise captured in CCVI or ZSR. The combinations follow select themes to create "recipes" of GIS layers. ROARs are target areas with soft boundaries that illustrate high impact convergence areas without a prescribed solution. After identification, local engagement and individualized technical support can guide the design of solutions. The recipes were developed from themes inspired by the long-term vision of resilient communities within the Resilient Connecticut Planning Framework.

- Focusing community development around transit (resilient TOD);
- Creating corridors resilient to climate change (Resilient Corridors);
- Creating opportunities for affordable housing, and preserving and enhancing the quality of life of existing affordable communities;
- Developing energy, economic, and social resilience;
- Increasing transit connectivity;
- Adapting structures and critical infrastructure in the flood zone to withstand occasional flooding; and
- Protecting communities through healthy buffering ecosystems where critical services, infrastructure, and transport hubs are located on safer, higher ground, and where strong connections exist between the them.

The methodology described here does not imply that other adaptation project areas or resilience opportunities identified in other planning processes (e.g., coastal resilience plans, natural hazard mitigation plans, plans of conservation and development, etc.) are not worthwhile or achieve similar objectives. Local planning priorities were included as spatial layers where possible, such as conservation and development areas, repetitive challenge areas for hazard mitigation, and affordable housing. Opportunities for other "recipes" for ROAR identification and ways to improve the methodology are highlighted below and discussed in detail in a forthcoming paper.

5.1 Methodology

This section describes the general process to identify ROARs. A more detailed and technical description is in development for a forthcoming paper. Generally, the process is a two-fold deduction from compounding vulnerabilities and appropriate planning opportunities. In all, 63 ROARs have been identified with a focus on TOD, affordable housing, wastewater, and drinking water infrastructure. The identification of each ROAR incorporates different data sets into the steps. Figure 53 presents the data used in the process; the steps for identification are also outlined below. The primary steps to ROAR identification included the following:

(1) Identification of a resilience theme: The themes influence the set of GIS layers that are used within each "recipe." The resilience themes discussed reflect key themes from Connecticut's grant application to the National Disaster Resilience Competition (NDRC), known planning priorities within Connecticut, and

	TOD	Affordable Housing (Flood & Heat)	Affordable Housing (Flood)	Affordable Housing (Heat)	Wastewater Infrastructure	Shelters & Wells	Non-community Wells	Drinking Water Watersheds & Hazardous Sites
ROAR Identification Layers	High flood & heat vulnerability	High flood & heat vulnerability	High flood vulnerability	High heat vulnerability	High flood vulnerability	Community shelters & cooling centers with private wells	Flood & heat vulnerability	Hazardous sites in high flood vulnerable areas • Brownfields • Toxic release sites • Hazardous storage sites
	Regional ZSR		HUD & COG Affordable Housing Assets	HUD & COG Affordable Housing Assets	Wastewater system infrastructure			
	TOD Service Area	HUD & COG Affordable Housing Assets			ZSR	High flood vulnerability	Non-community drinking water wells (density)	• Public drinking water supply watershed
	Future Planned Development Areas		ZSR	Bus Route and/or cooling center accessibility (500 meters)	Balanced Priority Funding Areas (BPFAs)			
Layers for Further ROAR Consideration		Distressed Municipality	Distressed Municipality	Distressed Municipality	Distressed Municipality	Distressed Municipality	Distressed Municipality	
		Federal Opportunity Zone	Federal Opportunity Zone	Federal Opportunity Zone	Federal Opportunity Zone	Federal Opportunity Zone	Federal Opportunity Zone	

Figure 53: ROAR identification methodology and relative data sets

concerns that emerged through engagement during the Phase II process. The team considered the following themes:

- TOD*
- Affordable housing*
- Wastewater*
- Drinking water infrastructure* (supply well and watershed protection)
- Ecological communities
- Infrastructure
- Resilient corridors

For Phase II of Resilient Connecticut, the team focused on the layers denoted with an asterisk (*) above. Data limitations, time constraints, and need for additional stakeholder engagement are needed to explore the remaining themes. The remaining themes were not explored due to data limitations, time constraints, and the need for additional stakeholder engagement.

(2) Apply climate-related vulnerability layers: Climate-related vulnerability includes both the climate stressor (high flood and/or high heat using CCVI and ZSR) and the vulnerability amplifier. Heat or flooding were emphasized based on the theme. Secondary and/or tertiary layers for vulnerability included layers such as distance from shelters, wastewater treatment plants, and hazardous materials storage.

(3) Apply planning-related layers that either reduce vulnerability or advance local and regional planning objectives: This included the primary theme layer, such as affordable housing assets, then secondary and/or tertiary layers, such as access to parks, Opportunity Zones, and transportation routes. Given that TOD ROARs were the first identified, proximity to a TOD service area was excluded from subsequent analyses.

(4) Manually review the resulting map: As this is the first pilot of the process, the identification of the areas based on the themes emerged from manual review. Each theme required different scales and had different abilities to focus the area, i.e., some themes had set radii based on established practice (0.75 miles from a train station in the TOD theme) and others had wide established boundaries (watersheds in the watershed protection).

(5) Collect place-specific context: This step overlaps with the selection process described below; however, engagement with towns, COGs, and state agencies provided key information such as planned projects, regional priorities, compounding environmental health hazards, or highlighting potential unintended consequences.

5.1.1 Transit-Oriented Development

The TOD areas were identified by looking at the intersection of ZSR that contained the greatest number of regional assets, high flood and heat vulnerable areas, planned development areas, and TOD service areas (0.75 miles). Regional assets were considered those that are located in one community but provided services to several communities, those that traverse multiple communities, or those that act as large-scale economic stimulators. The overlap and intersection of these elements highlighted those TODs that are vulnerable, have regional significance, and where there is likely opportunity for redevelopment. Using this methodology, 40 TOD ROARs have been identified.

5.1.2 Affordable Housing

There are three affordable housing ROAR types: high heat and high flood (combined), high flood, and high heat.

Combined High Heat and High Flood: The combined high heat and high flood ROARs used HUD and COG housing assets that are collectively located outside of a TOD service area, are within a ZSR, and located in a high heat and flood vulnerable area. In addition, the federal opportunity zones, distressed municipality data, and planned development areas have been included not to further delineate the ROAR but to aid in future prioritization. In total, four combined vulnerability affordable housing ROARs have been identified.

High Flood: The high-flood-only affordable housing ROAR is a similar methodology to combined. However, instead of looking at high flood and high heat, only high flood vulnerable areas are used. The resulting ROARs include affordable housing assets outside of TOD areas, within a ZSR, and located in a high flood (moderate to low heat) vulnerable area. These maps also include the aiding data of federal opportunity zones, distressed municipalities, and planned development areas. Five high flood affordable housing ROARs have been identified using this methodology.

High Heat: Given that the data used represents spatial vulnerability, high heat vulnerable affordable housing ROARs have been identified in the context of accessibility to cooling capabilities. Affordable housing locations in high heat areas were located, and then those that were greater than 500 meters from a bus line or identified cooling center were identified. These high heat, distant housing assets identify a potential challenge or residents that may need to access public transit or a cooling center. Two ROARs have been identified based on the density of housing assets that are distant from a center or transit line.

5.1.3 Wastewater Infrastructure

Wastewater treatment plants not in proximity to a TOD service area were identified, then cross-referenced with their relative flood vulnerability and proximity to a balanced priority funding area (BPFA) identified in the State Plan of Conservation & Development. The BPFA data was used to highlight the eligibility and priority funding needs for the area. Four wastewater infrastructure ROARs have been identified.

5.1.4 Drinking Water Protection

Three types of drinking water infrastructure ROARs were identified, including shelters with vulnerable wells; high-density non-community well areas; and drinking water watersheds with potentially hazardous sites.

Shelters: Community shelters that also act as their own water system were first located, and then cross-referenced with the high flood vulnerable areas. Though multiple shelters have their own water system, only one is in a high flood area, resulting in one shelter and vulnerable well ROAR.

High Density of Non-Community Wells: A one-half mile radius was used to locate the denser non-community well areas. Three areas were identified in the region that have dense wells and therefore no community water system. While high heat and high flood were not used for this ROAR identification, identifying these areas is important for locating future long-term challenges regarding water supply. Long-term concerns might include drought, heat, and reduced water supply, or, for those in moderate flood areas, increased flood frequency resulting in physical well damage.

Watershed Protection: The last of the ROARs is the watershed and hazardous material scenario. First the CTDEEP brownfields, hazardous storage sites, and the Environmental Protection Agency (EPA) registered toxic release sites were overlaid on the drinking water watersheds. Those sites that were encompassed in a watershed were then cross-referenced to identify their flood vulnerability. This resulted in identifying four watersheds that encompass a potentially hazardous site within a high flood vulnerable area.

5.2 Results

The resulting 63 ROARs represent different regionally significant assets and locations. Vulnerabilities present in these locations and potential impacts from flooding or heat may result in disruptions beyond municipal boundaries. Therefore, these ROARs have been identified as not just a municipal opportunity, but a regional one. While each ROAR aside from the watersheds can be associated with a specific community, it is likely that residents in neighboring communities rely on these various assets presently, or may in the future.

5.3 Future ROARs

As noted above, a variety of themes for the ROARs were identified. Data limitations, time constraints, and/or the need for additional stakeholder engagement resulted in a deeper focus on the themes listed above. The remaining themes were still workshopped by the team to identify what is needed to advance the concept and identify areas.

5.3.1 Ecological

Ecological ROARs were explored given that healthy buffering ecosystems are a critical component of a resilient system. Though significant data exists, such as critical habitats, NDDB, and marsh migration areas, there were challenges in identifying what an opportunity might look like in these areas. This does not mean there is no opportunity, it means that opportunities relative to ecosystems vary greatly and thus a streamlined process was not accessible within the time constraints of the process. Scenarios explored included the following:

- Locating the need for open space by identifying the most heat vulnerable locations and their proximity to dedicated open space parcels
- Identifying the intersection of CTDEEP-designated critical habitats and high flood and high heat locations
- Exploring regional ZSR that encompass critical habitats
- Identifying optimal marsh migration areas and their proximity to critical facilities and assets

The four ROAR scenarios considered were omitted when delineating the final areas due to a need for additional information, data, or exploration. Some datasets are incomplete or outdated and would need a coordinating agency to update and review the contents (e.g., open space layers). Some data might not reflect conditions or adequately reflect the desired indication. For example, the mere presence or absence of a certain ecological system does not spatially delineate or quantify the extent of the ecosystem service as it relates to mitigating the climate stressor. Some datasets would require more in-depth analysis of the quantification and spatial analysis techniques (e.g., other multi-criteria decision support tools) to reduce redundancies or data conflicts with data from CCVI or across the other tools. Ecological components were, however, included as additional data for consideration in other ROARs. There are numerous future ecological- or conservation-focused ROARs that could be explored with additional time and data creation/analysis. Two examples are high flood/heat, important soils, and food access or high heat, over-committed water basins, and density of livestock/cropping activities.

5.3.2 Infrastructural

Most of the ROARs identified as part of Phase II take some form of infrastructure into account during identification. However, one noteworthy consideration that arose and was not addressed was ZSR that contain only a small number of assets, but those assets serve an extremely critical regional purpose. The TOD ROARs incorporate only those ZSR with the greatest number of assets, and the drinking water and wastewater ROARs incorporate only those relative system components, which indicates the potential for regional assets at risk that may not emerge from the other identification recipes.

These ROARs should be explored in the future and would likely require focused stakeholder engagement. Participants were asked throughout the planning process which assets they felt were most critical to their community and the region, and while some responded, oftentimes engagement had several objectives, and this specific question may not have been the primary focus. Future engagement could focus on identifying these specific assets, and further assessing their vulnerability, risk, and ultimately whether a ROAR should be delineated in relation to that asset. Additional data could also inform the analysis such as spatial delineation of service areas (e.g., substations), repetitive impacts in particular locations (e.g., wind exposure), or additional infrastructure functions (e.g., broadband accessibility, piers/wharves/deep-water ports).

5.3.3 Resilient Corridor

Resilient Connecticut aims to identify resilience or adaptation opportunity areas as well as resilient corridors. Resilient corridors connect low-lying areas to upland, low-flood-risk areas, where community resources are located. The concept of automating resilient corridor identification was explored during ROAR identification. The challenge with automating or streamlining the identification of these corridors is that coastal communities are often very different from one another. This includes neighborhood design, proximity to resources, road elevation options, and infrastructural components.

Future evaluations for resilient corridor implementation can potentially start with an automated foundation, such as mapping to identify low lying roads, neighborhoods at risk of isolation, and flood risk areas, but may need to be case-by-case beyond those elements. To some extent, GIS analysis can automate the process with intersections of high elevations, the road network, and ZSR. However, it would need individual reviews and additional regional data (e.g., spatially represented regional transportation improvement goals) before final selection.

5.4 ROAR Lessons Learned

Opportunities are abundant throughout the region and can be revised when the priority objectives are modified. This is reflected in the exploration of the ecological ROAR process. To identify and delineate ROARs with a replicable methodology, the questions that guided the Resilient Connecticut identification process were consistent for all ROARs: "Where is critical and where is vulnerable?"

The 63 ROARS were primarily identified via an overlay method of several important datasets. While this spatial analysis "narrowed the field," a degree of human assessment was needed with some degree of subjectivity. The influence of subjectivity was mitigated by the following: the use of priority concepts from engagement and the goals of the project; use of the CCVI and ZSR; incorporation of planning priorities; and criteria for prioritization (described below). As noted above, data limitations and the timeline for completion limited exploration of other themes. Potential alleviation of these limitations could include GIS coordination with planning agencies and sector-specific service providers to produce datasets; comparison of automation approaches; additional time to review and assess decision support tools in targeted sectors; research into spatial representation of ecosystem services; and piloting the methodology in additional geographies.

5.5 ROARPreliminaryPrioritization

Each of the 63 ROARs identified during Phase II of Resilient Connecticut highlights the intersection of unique challenges and opportunities to address climate impacts and develop adaptation strategies for communities, the two-county region, and the state of Connecticut. The inventory, maps, and data associated with these areas are building blocks that can be integrated within parallel planning efforts to develop a detailed resilience project pipeline that can help prioritize projects and coordinate key investments going forward.

As the Resilient Connecticut project transitions from Phase II to Phase III, a first round of ROARs will be selected for further concept development and site planning in 2022. This section describes the prioritization and selection process used by the project team to choose 6 to 8 ROARs from the portfolio of 63 areas. The CIRCA team used a stepwise approach for the selection: creation of and feedback on the PERSISTS framework in Phase I; development of draft criteria for each criterion within PERSISTS with the regional councils of governments, Resilient Connecticut Collaborative, and the SAFR council; revised decision support criteria from the PERSISTS criteria; and broad municipal engagement with interested municipalities. The goal of this evaluation was to assess the

near-term potential for carrying forward locations in Phase III.

Section 4.c. of the Resilient Connecticut Planning Framework[5] calls for incorporation of the "PERSISTS decision support criteria to assess near, mid, and long term strategies." PERSISTS is a multi-criteria framework that was developed in collaboration with stakeholders at the Phase I workshop[6] in May 2019. Similar to the FEMA STAPLEE method (which is used in the Connecticut State Hazard Mitigation Plan[7]), PERSISTS was envisioned as a way to evaluate climate adaptation actions for their potential to balance multiple goals and priorities among stakeholders. PERSISTS is made up of 8 categories: Permittable, Equitable, Realistic, Safe, Innovative, Scientific, Transferable, and Sustainable. The framework provides the following guidance for each category:

- **Permittable:** Can be authorized through necessary federal, state, and local permits
- **Equitable:** And ensures that benefits are equitable among populations
- **Realistic:** Can be realistically engineered and is plausibly fundable
- **Safe:** Reduces risks to people and infrastructure
- **Innovative:** Process has considered innovative options
- **Scientific:** Apply and improve on the best available science
- **Transferrable:** Can serve as a model for other communities
- **Sustainable:** Socially, economically, and ecologically sustainable and supported by the public and leadership

In April 2021, the Resilient Connecticut Collaborative (RCC)[8] workshopped ideas for specific metrics across each category of PERSISTS that could then be used to both evaluate locations for selection in Phase III as well as specific adaptation strategies that could be proposed in those locations (Figure 54).

A variety of questions and metrics were proposed by workshop participants that can be used in the

5 https://resilientconnecticut.uconn.edu/wp-content/uploads/sites/2761/2020/04/Resilient-Connecticut-Planning-Framework-Final-1-30-20.pdf

6 https://resilientconnecticut.uconn.edu/wp-content/uploads/sites/2761/2019/05/Workshop-summary-final_May-22-2019.pdf

7 https://portal.ct.gov/-/media/DEMHS/_docs/Plans-and-Publications/EHSP0023-NaturalHazardMitPlan.pdf

8 https://resilientconnecticut.uconn.edu/resilient-connecticut-collaborative/

development of Phase III concepts and site plans. A subset of questions from the workshop was selected and refined to assist the team in evaluating each of the 63 ROARs for potential inclusion in Phase III. Using these questions, the CIRCA team developed a scoring rubric which assigned points across the 8 categories of PERSISTS for a total of 30 possible points. See Figure 55 on the next page.

In addition to the PERSISTS criteria, each ROAR was also assigned one or more typological categories to enable a cross section of different land use, infrastructure, and socioeconomic conditions to be included in the Phase III

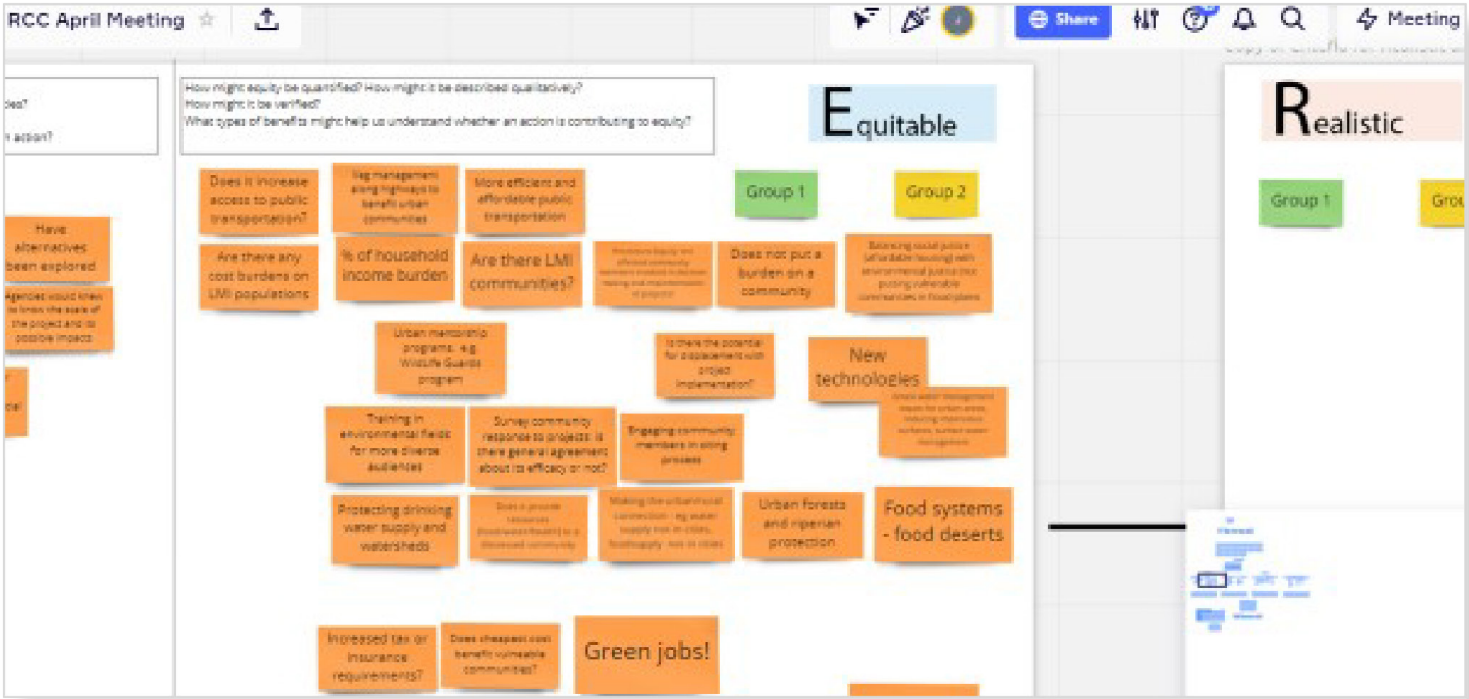


Figure 54: Screenshot from the RCC workshop April 2021

PERSISTS Decision Support Criteria		
Permittable	1. Are there historic or ecological sensitivities to consider?	Yes = 0, no = 1
Equitable	1. Does the opportunity area contain elements of high social vulnerability?	High = 3, moderate = 2, no = 0
Realistic	1. Are there potential adaptation options proportionate to the identical problem? (indicates realistic pathway for funding)	Yes = 1, unsure = 0, no = remove
Safe	1. Does the opportunity area have elements that would address public safety? (# of critical lifelines in ROAR)	Yes (3 or more) = 3, some (1-2) = 2, no = 0
Innovative	1. There is an opportunity for a multidisciplinary approach for climate solutions that incorporates greenhouse gas (GHG) mitigation and adaptation.	Yes = 2, maybe = 1, no = 0
	2. There is interest among multiple communities or jurisdictions to participate in the planning process.	Yes = 2, no = 0
	3. There is an opportunity to apply a new approach to planning, design, engagement, or financing that has been successful in other states that could be applied here.	Yes = 2, maybe = 1, no = 0
Scientific	1. There is an opportunity to develop new data sets that will contribute to the scientific literature on adaptation.	Yes = 1, no = 0
Transferable	1. Represents a common resilience typology in Connecticut: land use, infrastructure, or social, and could serve to demonstrate an approach or best practices.	Yes = 2, maybe = 1, no = 0
Sustainable	1. There is strong support from political leadership, municipal staff, and local community to engage in planning process in the opportunity area.	Yes = 3, unsure = 1, no = remove
	2. Are there strong community partners who could be directly involved in planning?	Yes = 2, maybe = 1, no = 0
	3. Is there a local commitment to resilience, as demonstrated by active involvement in resilience planning?	Yes = 2, somewhat = 1, no = 0
	4. Is there potential significant state support for a project (state agency involvement, state or regional priority, etc.?)	Yes = 2, maybe = 1, no = 0

Figure 55: PERSISTS decision support criteria for prioritization

project areas. The typologies used for this evaluation were the following:

a. **Coastal flood risk transportation infrastructure typology:** Represents the overlap of coastal flood risks with important transit and transportation infrastructure that is critical to efforts to enable more resilient, transit-oriented development along the Metro North, Amtrak, and Interstate 95 corridors.

b. **Riverine or inland stormwater flood risk transportation infrastructure typology:** Similar to typology (a.), this represents riverine and stormwater flood risks that impact major TOD corridors along the Naugatuck River Valley, Danbury transit line, and Interstate 91/Hartford line.

c. **Climate vulnerable community assets** (flood-prone locations, heat-vulnerable populations in affordable housing areas): This typology captures issues of flood and heat risks to affordable housing and infrastructure that impact socially vulnerable and/or environmental justice communities.

d. **Evacuation and isolation flood risk typology:** This typology represents zones of shared risk and communities that are potentially isolated during flooding and in need of the development of resilient corridors that can allow for egress to higher ground both in the near and longer term.

e. **Multijurisdictional or large-scale critical infrastructure typology** (wastewater, drinking water, power, critical infrastructure that affects multiple communities, neighborhoods, or jurisdictions): This typology represents flood and heat risks to critical assets and infrastructure whose impacts are felt across political and jurisdictional boundaries.

The evaluation of the 63 ROARs also included discussion of relevant previous planning efforts, feasibility considerations, and the potential support and commitment of local partners in participating in Phase III. Follow up discussions with the COGs were conducted in December 2021 to narrow the list of potential Phase III project areas to 5 in each COG jurisdiction for a total of 20 across the two counties that will be the basis for selection in Phase III. Additional meetings were held with individual state agencies to understand overlap with parallel planning efforts and inform prioritization. The State Agencies Fostering Resilience Council met in December 2021 to review the project areas. Additional follow-up discussions with individual municipalities were also held to confirm interest in possible participation in Phase III.

A draft list of 20 ROARs that represent a cross section of locations, communities, and challenges in Fairfield and New Haven Counties was assembled for review by stakeholders and recommendation for a final list that will be selected for Phase III. These 20 ROARS are included in the map portfolio section that follows.

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Phase II Recommendations

Phase II has been comprised of several components, such as technical tool development, robust stakeholder engagement, and climate vulnerability tool development. Given the depth of analysis and effort associated with Resilient Connecticut Phase II, recommendations for future endeavors have been identified. These recommendations have been categorized (Figure 56), and have different time horizons. Some of these recommendations are long term and should be considered for future resilience and community planning, while others should be incorporated into Phase III.

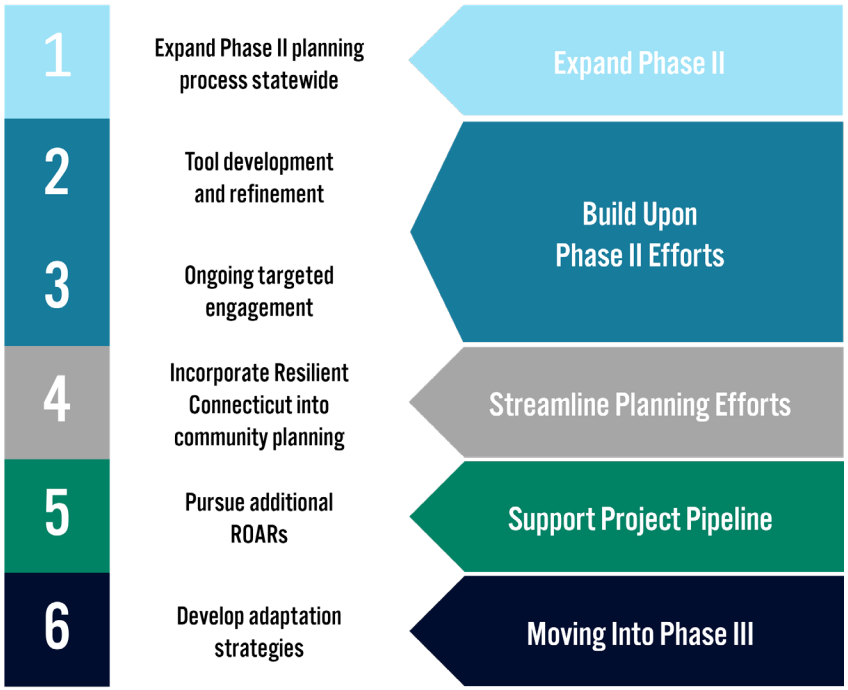

Figure 56: Phase II categorized recommendations

1 As a pilot study, Phase II of Resilient Connecticut was going to be both a standalone effort for Fairfield and New Haven Counties, complete with findings and recommendations, but also a step forward in the broader statewide effort to enhance climate resilience across all counties. Expanding this planning process and vulnerability assessment statewide could have several benefits and should be pursued so that all counties can benefit from the in-depth engagement on assessing vulnerabilities and identifying ROARs. In addition to expanding the process, new sources of funding should be explored for implementation . Given that Resilient Connecticut is a result of NDRC, future endeavors should aim to unlock funding that will allow for vulnerability assessments, ROAR identification, and project development.

2 With the development of CCVI, ZSR, and SVI mapping, communities have been equipped with additional tools to aid in climate change vulnerability evaluation. While these tools have room for expansion and refinement, these applications have been recognized as useful for community planning, grant fund support, and general vulnerability understanding. Each of these tools should be evaluated for usefulness and relevance going forward and refined based on the specific tool recommendations, continued stakeholder feedback, and as new data is developed and available. Specifically, for the CCVI, an update cycle of five years is reasonable. This schedule would allow for periodic incorporation of new information and data without causing a burden for practitioners charged with the update. As tools develop, and updates are made, iterations should also align with other climate vulnerability and resilience efforts to ensure the consistent and repeatable use of data. In particular, this might include coordinating with the development of a statewide environmental justice mapping product that is anticipated for 2022 to 2023. Coordinating with efforts like these maximize consistency among the climate resilience tools available to communities.

3 Engagement executed over the Phase II planning timeframe was primarily targeted at community and regional stakeholders in the broad sense. To emulate this planning process, engagement efforts should continue to interact with communities by way of COGs and work to focus on targeted engagement with specific interest groups, state entities, and the general public. Though workshops included many of these diverse groups, focusing on specific interests may yield a deeper understanding of resilience-related challenges and needs in the state, ultimately leading to a more advanced vulnerability assessment or stronger tools. Engagement events should be developed to directly interface specifically with resilience committees for various sectors included in the Phase II planning

process, such as drinking water, sanitary wastewater, transportation, emergency managers, medical facilities, etc. Interacting with these committees and stakeholders will continue to strengthen resilience partnerships and bring stakeholders together to discuss regional challenges and devise implementation plans.

4 Hazard mitigation plans and POCDs are typically the plans all communities have in common; therefore, they are the easiest to compare across municipalities. After evaluating both the state of these plans and the absence of more targeted climate adaptation plans, it is realized that many communities often plan and assess vulnerabilities in the context of historic events and climatic conditions rather than projected conditions. Climate change is being incorporated into planning more than in years past, but it is not always considered in great depth. These HMPs should be considering longer-term impacts to their communities and ultimately identify actions that address these long-term needs. Typically, HMP actions or strategies address short-term goals and are geared to be achieved in a 5-year timeframe; communities should seek to push this planning process to incorporate both the short-term and long-term needs of their communities. Efforts like Resilient Connecticut can aid in educating these communities on the importance and need for longer-term planning and incorporating the technical tools and assessment results into HMP and other community planning efforts.

While many communities in the region have completed additional planning efforts such as coastal resilience plans or participated in CRBs, there is again still opportunity for communities to incorporate the outcomes of Resilient Connecticut into future plan updates and projects that have been identified in these efforts. Ultimately, linking community planning with larger scale, long-term climate vulnerability assessments and data is critical to developing and redeveloping more resilient communities.

5 As tools and engagement continue to evolve both by way of Phase III and future resilience planning, the identification of ROARs based on current and future methodologies should be pursued. The identification of these opportunity areas presents communities and stakeholders with an understanding of a common vulnerability or risk, and the means to work toward resilience and adaptation. Identification of future ROARs and the development of adaption and mitigation strategies for areas can be pursued by state agencies, non-profit organizations, or municipalities. However, it is critical to continue coordination with stakeholders within a ROAR and those that are associated with present infrastructure (e.g., drinking water or transit assets). The continued identification of ROARs and the development of resilience strategies will continue

to support the advancement of a resilience project pipeline.

6

In addition to those long-term recommendations for resilience planning, moving into Phase III may include certain short-term strategies to support those communities that have been identified as vulnerable or where ROARs have been identified. Developing a suite of suitable strategies for various typologies would provide planners and decisionmakers with the means to pursue resilience applications outside of Resilient Connecticut. In addition, continuing engagement would help to keep stakeholders engaged and informed on resilience planning, and working to consciously include stakeholders in different parts of the state might be informative for a non-local perspective.

6.1 Looking Ahead to Phase III

As the Phase II planning effort confirmed, numerous challenges are faced by communities across Fairfield and New Haven Counties to address the impacts of climate change. These challenges can be viewed as opportunities when coordinated planning and action can lead toward a more resilient and sustainable vision of the future. As the Resilient Connecticut Project transitions from Phase II to Phase III, CIRCA will be partnering with municipalities, COGs, and state agencies to develop adaptation actions and implementation plans at the neighborhood and site scale for a subset of the ROAR locations.

Phase III will focus on localized engagement and the development of scientifically-informed adaptation strategies and project concepts at the site and community scale. While not all of the 63 ROARs that were identified during Phase II will be selected for further planning in Phase III of this project, these locations and associated maps and data are being assembled as a resource and project pipeline for future opportunities as they arise. CIRCA views this as a long-term process that will require sustained effort to move specific locations along the continuum from identifying problem areas and vulnerabilities, considering adaptation options, developing and scoping project concepts, implementing projects, to monitoring and maintenance. As additional funding opportunities emerge, CIRCA will be working with partners and stakeholders from Phase II to move additional ROARs along the project pipeline.

Although funded under a different grant, a similar process will be applied in the next year with expanded vulnerability tools for the rest of the state and ROAR identification with three additional COGs.

At the end of Phase III for Fairfield and New Haven Counties, CIRCA will produce a synthesis report of the process, including a Statewide Resilience Roadmap with policy recommendations to improve resilience efforts in Connecticut.