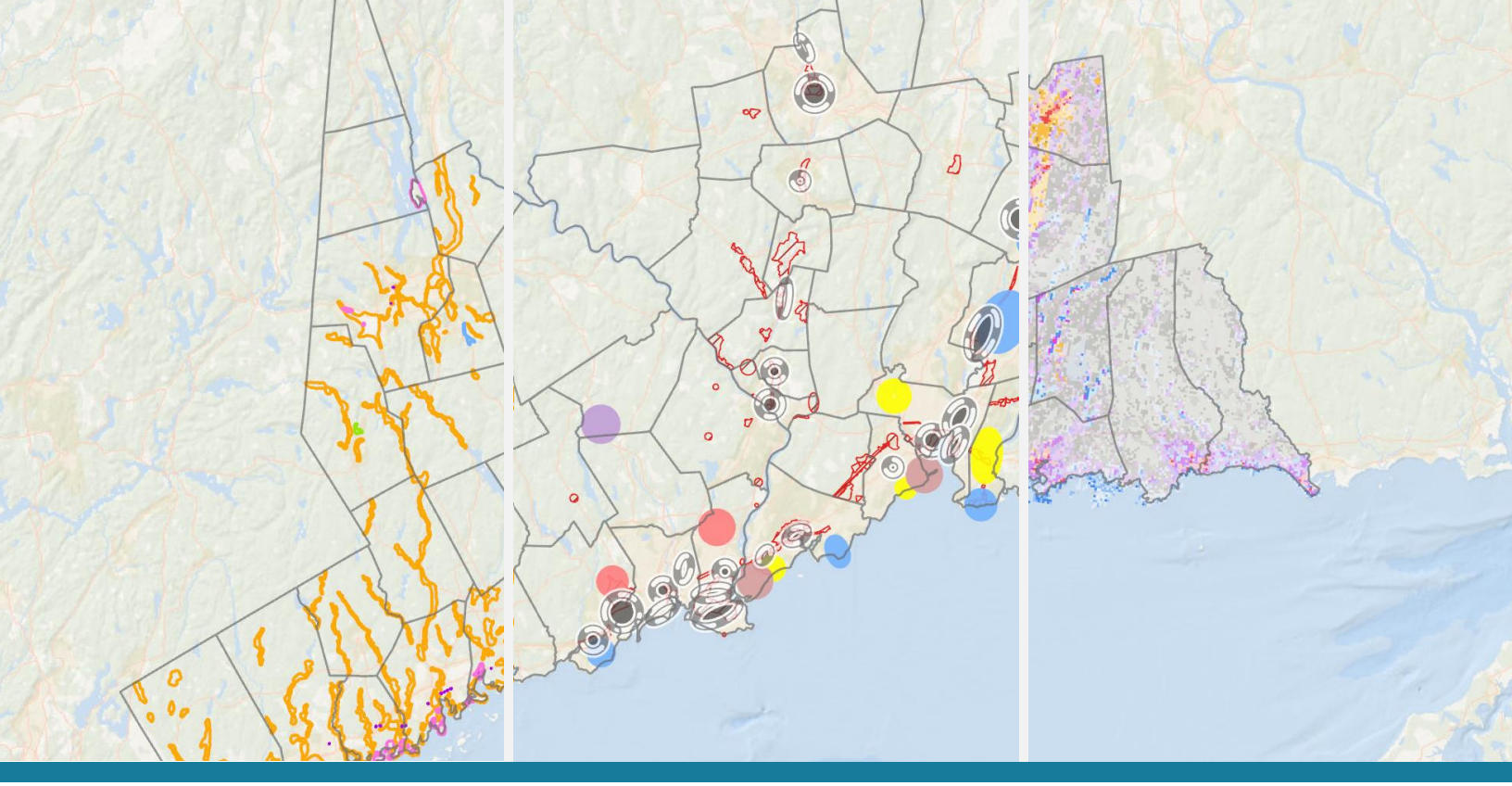


Resilient Connecticut

Phase II
From Regional Vulnerabilities to Resilience Opportunities

December 1, 2021

SLR Consulting
Formerly Milone & MacBroom, Inc.

CIRCA
Connecticut Institute for Resilience and Climate Adaptation

UCONN
UNIVERSITY OF CONNECTICUT

SLR
Dewberry

U.S. Department of Housing and Urban Development

CONNECTICUT
Department of Housing

This publication does not express the views of the Department of Housing or the State of Connecticut. The views and opinions expressed are those of the authors. Funding for this project was provided by the United States Department of Housing and Urban Development through the Community Development Block Grant National Disaster Recovery Program, as administered by the State of Connecticut, Department of Housing. More information can be found at:
https://resilientconnecticut.uconn.edu/

FUNDING FOR THIS PROJECT WAS PROVIDED BY THE UNITED STATES DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT THROUGH THE COMMUNITY DEVELOPMENT BLOCK GRANT NATIONAL DISASTER RECOVERY PROGRAM, AS ADMINISTERED BY THE STATE OF CONNECTICUT, DEPARTMENT OF HOUSING

PREPARED BY:

CIRCA
UNIVERSITY OF CONNECTICUT
AVERY POINT CAMPUS
1080 SHENNECOSSETT ROAD
GROTON, CT 06340

CIRCA@UCONN.EDU

SLR CONSULTING
99 REALTY DRIVE
CHESHIRE, CT 06410

MARKETINGUS@SLRCONSULTING.COM

DEWBERRY
59 ELM STREET, SUITE 200
NEW HAVEN, CT 06510

MEDIA@DEWBERRY.COM

The mission of the Connecticut Institute for Resilience and Climate Adaptation (CIRCA) is to increase the resilience and sustainability of communities vulnerable to the impacts of climate change on the natural, built, and human environments.

Table of Contents

List of Figures

List of Tables

Appendices

1 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 award to the State of Connecticut administered by the Department of Housing. Resilient Connecticut provides the state with a planning framework 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 resilience and adaptation planning through evaluations and engagement to inform municipal-to-regional scale resilience 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.

How to Use this Report

This report describes the vulnerability assessment conducted for the Resilient Connecticut planning process, along with some of the findings of the vulnerability assessment. The assessment tools described in this report can be used by communities and stakeholders as parts of their own resiliency planning frameworks. Throughout this report, look for assessment approaches and findings that can be used in your own adaptation and resilience planning and design tasks.

This report concludes with a presentation of 63 specific geographic areas where adaptation and resilience opportunities can be identified to address flood-related risks, extreme heat, or both. Review the opportunity areas in the communities where you live and work and think about ways that flood and heat risks may be addressed.

Resilient Connecticut recognizes that the impacts of climate change to infrastructure, public health, ecology, and other systems occur at a variety of scales beyond 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 concludes in late 2021. The central technical component of Phase II of Resilient Connecticut is a regional risk and vulnerability assessment for all 51 municipalities in New Haven and Fairfield Counties coupled with identification of "zones of shared risk" (ZSR) in the 33 municipalities of New Haven and Fairfield Counties that have potential for TOD (Figure 1). Phase II also included project administration,

stakeholder engagement, and data development and delivery through GIS and other platforms. The vulnerability assessment and the zone of shared risk analysis were then combined with, and informed by, stakeholder engagement and spatial data to identify potential resilience opportunity areas. This vulnerability assessment can be incorporated into both climate-specific and broader planning processes at the local, municipal, council of governments (COG), and state scale.

The results of Phase II of Resilient Connecticut are captured in several public-facing products such as map viewers, an ESRI Story Map, workshops, webinars, and reports.[1] This report summarizes the initial assessments of regional vulnerabilities and zones of shared risk.

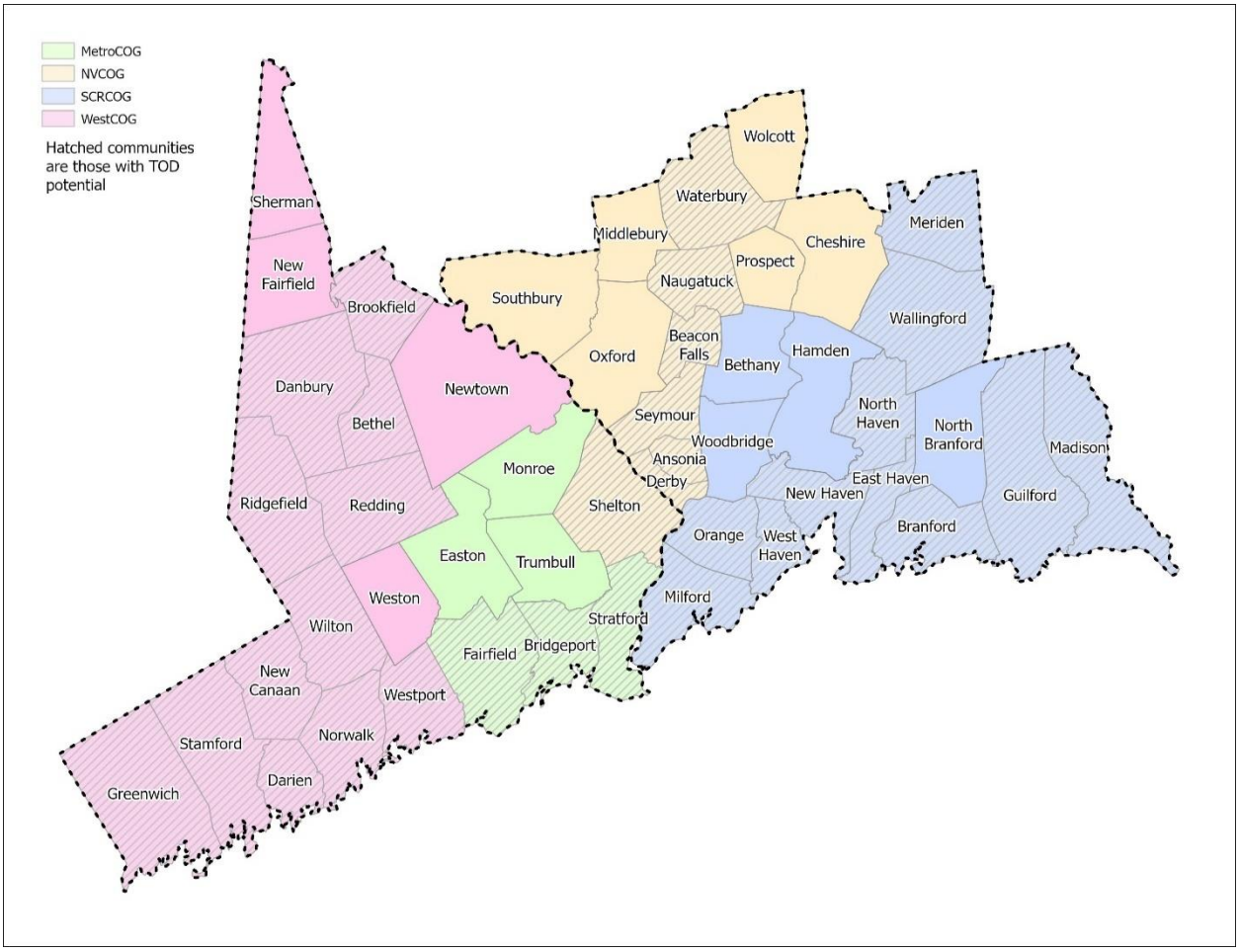


FIGURE 1: RESILIENT CONNECTICUT STUDY REGION

As Connecticut increases its climate change and extreme weather preparedness efforts, the products created during the Resilient Connecticut project could be enhanced to incorporate growing datasets, more precise measurements, and a wider geographic scope. The subsequent

[1] https://resilientconnecticut.uconn.edu/

vulnerability assessment and opportunity areas will be carried forward to Resilient Connecticut Phase III to advance adaptation scenarios throughout the region.

2 Vulnerability Assessment Tools

Numerous methods are available for evaluating vulnerability to climate change, natural hazards affected by climate change, or other types of climate-induced events. To assess the regional vulnerability of New Haven and Fairfield counties, a multipronged approach has been developed to identify those vulnerabilities present at a community systems level. This approach includes evaluating vulnerable assets and characteristics associated with the social, infrastructural, and ecological communities throughout the region using various tools and stakeholder engagement feedback.

Social vulnerability has been considered in two elements of the regional vulnerability assessment, developing social vulnerability (SV) mapping as a standalone tool and integrating demographics (and therefore, social vulnerabilities) into the Climate Change Vulnerability Index (CCVI) tools that characterize flood and heat vulnerabilities. The SV mapping, which has been developed based on established approaches, is the more comprehensive approach, in relation to the CCVI, to identifying social vulnerabilities throughout the region. The SV mapping is a tool that can be used for other research and planning projects, whereas the elements included in the CCVI are more specific to the climate-induced stressor being indexed. Both approaches are detailed in subsequent sections. Social vulnerability maps developed under Resilient Connecticut

How to Understand this Chapter

This chapter describes different ways of assessing and evaluating climate-related vulnerabilities and risks related to floods and extreme heat in the context of the Resilient Connecticut planning process. This report recognizes that the growing field of climate adaptation and resiliency relies on a variety of definitions of vulnerability and risk and does not change those definitions. A Climate Change Vulnerability Index (CCVI) tool has been developed for floods and extreme heat and is described in this chapter. The CCVI is an aggregate of sensitivity, exposure, and adaptive capacity. The CCVI does not attempt to quantify frequency of occurrence or consequence of an event. These additional terms are typically needed to quantify risk, but we understand that frequency of occurrence is changing, and consequences are difficult to calculate in a regional planning effort. Resilient Connecticut therefore focuses on characterizing vulnerability, with the general assumption that frequency of occurrence is changing as climate change unfolds. If we can find ways to reduce vulnerability, we will reduce risk.

Notwithstanding these limitations, Zones of Shared Risk have been delineated to identify areas that share a risk related to flooding and its indirect impacts. We can delineate the area where we anticipate the risks to be located without needing to understand the frequency of occurrence term in the risk equation. ZSRs imply that a shared solution may exist; in other words, the people living inside a ZSR may share a solution to direct flood damage, isolation from flooding, or some other impact of flooding. People inside another ZSR may share a different solution.

Phase II are suitable for both project as well as stakeholder uses as, these are not necessarily flood- or heat-specific.

The CCVI utilizes a quantitative approach to assigning vulnerability by indexing social, built, ecological, physical, and climate contributors that play a role in an area's vulnerability. This tool works to consider the community system as a whole, and calculates vulnerability based on the ranking of each contributor. This tool is an expansion of CIRCA's Coastal Vulnerability Index[2] which is a tool for coastal communities with direct shorefront on Long Island Sound. The CCVI has been expanded inland to include riverine communities and has been developed to express extreme heat vulnerability in addition to flooding. This tool provides localized insight to potential flood and heat vulnerabilities both on a small scale using approximately 10-acre grid cells, or on a regional scale looking at vulnerabilities that span municipal boundaries.

In addition to developing vulnerability tools, Resilient Connecticut delineated areas that can serve as effective adaptation and planning scale projects because they share a specific set of overlapping risks and/or opportunities related to the conditions of the built environment in relation to wetlands, riverine, and coastal conditions, as well as vulnerability to, severe precipitation, and combinations of flooding and sea level rise. Resilient Connecticut deployed the concept of "zones of shared risk"[3] as well as "opportunity zones" to examine locations for adaptation opportunities. A ZSR can be defined as "*regions that face common challenges either in existence already or caused by climate change, and therefore risks are shared among or between groups of people that may have different perspectives and priorities for resilience. A Zone of Shared Risk includes the houses, land, infrastructure, hydrological, ecological, social, and institutional elements that contribute to the functioning of a place*." The ZSR is a mixed methods approach that builds on analysis of the physical and spatial conditions of flood risk, as well as demographics and population data alongside more qualitative landscape architecture, urban design and planning strategies. ZSR are a planning approach for identifying shared flood-related challenges among stakeholders which can help to define scales for adaptation strategies with broader, community-wide impact.

"Resilient corridors" is a second urban design strategy that is deployed as a component of Resilient Connecticut. Resilient corridors connect low lying areas with upland areas where community resources exist and are outside of areas that flood. The concept of resilient corridors can work at different time scales. They can be used for evacuation immediately before flood events, during extreme heat events, or for movement of goods and services after extreme events. Resilient corridors provide a means for federal and state dollars to be invested in providing viable egress routes and in reinvesting in these routes while avoiding spending on coastal defenses in low-lying, high-risk areas. In addition, resilience corridors can connect to low lying existing critical infrastructure such as water pollution control facilities. These corridors, which can ultimately be

[2] https://arcg.is/0v5vbq

[3] Town of Guilford Community Coastal Resilience Plan

developed alongside and to support ZSRs, are a mechanism to adapt at risk areas while supporting infrastructure and economic development.

The delineation of ZSR and identification of resilient corridors are focused on the 33 municipalities in the region that have TOD potential i.e., at least one train station or plans for future station development.

In addition to the tools and maps developed, multiple planning resources have been reviewed to assess TOD and future development areas to both make existing TOD resilient through adaptation and encourage resilient future TOD to avoid costly adaptation in the future. To evaluate vulnerabilities and locate resilience projects in appropriate areas, 3/4-mile TOD zones and future areas for development identified in Plans of Conservation and Development have been mapped.

As noted by a participant in the Resilient Connecticut workshops, "critical infrastructure supports critical infrastructure." In other words, even infrastructure that may seem inconsequential may support infrastructure that is more obviously critical. Infrastructure is a necessary component of supporting TOD, resilient corridors, and resilient communities. Therefore, an inventory and analysis of various assets and infrastructure has been developed. This analysis identifies the degree of risk that a component is exposed to regarding flooding and extreme heat. The following features are included in this analysis:

- Affordable Housing
- Regional Employment Centers
- Economic Assets (including historic and cultural resources)
- Rail and Bus Service Infrastructure
- Sanitary Sewer Systems
- Public Water Systems[4]
- Areas supported by individual sewage disposal systems (septic systems)
- Critical Ecological Systems

The identification of these areas and the specific vulnerable assets will lay the foundation for further identification of resilience opportunity areas throughout the region.

2.1 Stakeholder Engagement

Stakeholder engagement has been a primary component of Resilient Connecticut since Phase I and has continued throughout the Phase II vulnerability assessment planning process. The four regional COGs with jurisdictions in Fairfield and New Haven Counties, were initially solicited for geographic Information system (GIS) data to ensure all tool development incorporated the most up to date data available. Each COG provided data that has been critical to the development of the subsequent assessment and ultimately resilience opportunity area identification. In addition, each COG provided a monthly platform for the Resilient Connecticut team to present on the

[4] The definition herein of a public water system is EPA's definition; this includes private-owned systems.

project's progress. COG committees were informed each month on tasks completed, milestones achieved, and most importantly how they could participate in the planning process. Some of these committees included:

- Transportation technical advisory
- Conservation technical advisory
- Regional planners
- Chief Executive Officers

Two stakeholder regional workshops were held with each of the four COGs, for a total of eight workshops. The first set of workshops, held in January and February 2021, was designed to allow participants to explore and comment on the vulnerability assessment tools being developed, review preliminary results, and to ground truth the CCVI and ZSR. The second round of workshops, held May 2021, aimed to review the resilience opportunity identification methodology, identify regional infrastructure or assets not captured in the methodology, and to recognize prioritization criteria. Both rounds of workshops resulted in extensive stakeholder feedback which helped shape the resulting tools, and guided resilience opportunity area identification. Workshop reports can be found in Appendix A.

A stakeholder and public webinar[5] was held on March 23 between the first and second set of workshops. This webinar focused specifically on the CCVI and how workshop edits had been addressed and incorporated into the tool. The CCVI was only discussed in terms of flooding during workshops; this webinar presented the tool and how it could potentially be developed for heat and wind events.

In addition to collaborative events, several resources have also been developed to provide a platform for information and project feedback. The Resilient Connecticut website acted as a hub and included technical tool pages with links to interactive viewers, a link to the Phase II ArcGIS Online Story Map, a feedback form, and fact sheets on the tools being developed. Those who wished to provide feedback were encouraged to do so through the website, Story Map, or via email.

Stakeholder feedback has been an integral component to the vulnerability assessment thus far and will continue to be as Phase II progresses and evolves into Phase III.

2.2 Data Gaps

The vulnerability assessment process identified several data gaps related to dated, non-existent, or inaccurate GIS data, or data that could be useful but likely not available on a public platform.

[5] https://resilientconnecticut.uconn.edu/2021/03/03/climate-change-vulnerability-index-webinar-progress-and-new-results-for-heat-and-wind/

TABLE 1: VULNERABILITY ASSESSMENT DATA GAPS AND RECOMMENDATIONS

Data Type	Comments	Recommendations for Future Endeavors
Evacuation routes	These exist; however, municipalities do not often post or share these to allow for route modification during different storm events. Not a true gap, but it's an analysis gap	Work with municipalities to identify main routes that typically do not change or identify those in specific resilience opportunity areas.
Cooling centers	These change often, and many are not formal, so it's not a true gap; it's a planning data gap	Update this GIS layer as designations change over time
Sewer system service area GIS	This GIS data is outdated and would benefit from updating.	Develop a more comprehensive, updated data layer.
Existing affordable housing	Not all COGs are mapped in GIS, so it's not a true gap; it's a planning and analysis gap	Work with COGs to identify and map local affordable housing assets
Potential affordable housing	This is a true gap; does not exist. Research needed.	Work with Desegregate CT to develop a methodology of identifying potential, low vulnerable, housing areas.
Historic resources	High quality point data in southern four counties, but lesser quality polygons in northern four counties. SHPO plans to work on this.	Update resources as identification and mapping evolves.
Bus stations that are not at RR stations or the 10 bus hubs	Only larger "hubs" were mapped under Resilient Connecticut. One state or region wide layer of major stops does not exist.	Coordinate with DOT or consultants to locate, or digitize, more comprehensive bus stop locations.
HMP actions that are not easily mapped –	but some cannot be mapped because they are town wide or programmatic or capacity-building	GIS staff or prior HMP consultant to complete
Wind CCVI contributing layers	True data gaps; these do not exist, and those that do, do not lend themselves to spatial analyses.	Explore and research how to spatially identify wind sensitivities, exposure, and vulnerabilities.
Some water system facilities, like tanks and pumping stations,	Not in one single GIS (whereas interconnections, water company land, sources, wells, etc. are all in a GIS).	Coordinate with the appropriate entities to develop comprehensive datasets.
Rep Loss Properties many flood losses occur. A new list should be obtained by CIRCA in early 2022, reflecting losses through September 2021.	These lists are challenging to obtain from FEMA starting in early 2020, therefore COGs and Towns are not asking.	

3 Social Vulnerability Mapping

One component of the vulnerability analysis independent of the demographics used in the CCVI is social vulnerability (SV) mapping. Mapping regional demographics such as socioeconomic status, health, and labor force factors highlights the communities that are potentially underserved by individual and community resources and therefore more vulnerable to climate change or extreme weather events that are influenced by climate change.

3.1 Resilient Connecticut SV Methodology

A multitude of resources and mapping tools are available by way of social vulnerability indices and environmental justice (EJ) mapping. Seven resources and tools were reviewed as part of this vulnerability assessment to identify a suitable methodology for representing social vulnerabilities in Fairfield and New Haven counties. Two were selected as the model for the Resilient Connecticut methodology. Appendix B provides a detailed review of these seven resources.

The final methodology for developing the Resilient Connecticut social vulnerability (SV) mapping utilizes two commonly cited sources: the CDC Social Vulnerability Index[6] (CDC SVI) and the University of South Carolina Social Vulnerability Index[7] (SoVI).

The SoVI is comprised of 30 socioeconomic variables, all of which were identified as pertinent to the Resilient Connecticut study region and ultimately adopted for this social vulnerability assessment mapping. Almost all 30 variables used for Resilient Connecticut (Table 2) exactly align with the SoVI variables identified, apart from nursing home residents per capita which was replaced with number of individuals with independent living difficulties. The percent employment in extractive industries variable was replaced with percent workers in blue collar industries. Blue collar industries encompass agriculture, forestry, fishing/hunting, mining, construction, manufacturing, transportation, warehousing, and utilities. These replacements were made due to the scale of mapping and data availability. The SV mapping is calculated and mapped at the census block group level, while the SoVI, which is a nationwide dataset, is calculated at the census tract level. In addition, almost all data was sourced from the U.S. Census American Community survey (ACS) 5-year estimates of 2015 – 2019. The only data sourced outside of the ACS were the hospitals per capita which is from the American Hospital Directory and is also mapped at the county level.

The CDC SVI methodology was utilized for the mathematical processing of the data to quantitatively represent vulnerability as a "score", based on a percentile rank. For the analysis a higher percentile was translated to "higher vulnerability" i.e., a higher percentile of those living in poverty equates to higher vulnerability. However, five variables were incorporated using the

[6] https://www.atsdr.cdc.gov/placeandhealth/svi/index.html
[7] http://artsandsciences.sc.edu/geog/hvri/sovi%C2%AE-0

opposite logic i.e., higher per capita income equates to lower vulnerability. Each variable was evaluated on how it impacts social vulnerability, either negatively or positively.

The Resilient Connecticut SV mapping focuses on New Haven and Fairfield counties at the census block group scale using statewide demographics. The use of statewide demographics was chosen in the event this SV mapping methodology is expanded beyond the current study region.

In addition to *overall* social vulnerability, which encompasses all 30 variables, five subgroup types were also developed based loosely on the groupings of the CDC SVI methodology. Calculating vulnerability indices for each of these five subgroups (Table 2) allowed for the highlighting of types of vulnerabilities that may not be as obvious in the mapping of overall social vulnerability. These subgroup scores are calculated based on only the variables within that subgroup, other subgroup variables are excluded from that calculation.

Ultimately, there are six different social vulnerability scores attributed to a community that are relative to overall social vulnerability and five different subgroups.

1. Overall Vulnerability (comprised of all factors found in Table 2)
2. Minority Status and Language
3. Household Composition & Disability
4. Labor Force
5. Socioeconomic Status
6. Housing Type and Transportation

To calculate overall social vulnerability the percentile rank for all 30 variables was first calculated. After all percentile ranks were identified, the sum of those ranks was calculated across each block group. The percentile rank was then determined using the sums, resulting in a vulnerability score on a scale of 0 to1.

This process was repeated for each of the five subgroups using only those variables relative to each group (Table 2). Final scores closer to 1 indicate increased vulnerability, while a lower score closer to 0 represents lower vulnerability.

TABLE 2: VARIABLES USED IN THE RESILIENT CONNECTICUT SV MAPPING AND THEIR RESPECTIVE SUBGROUP

Minority Status and Language	Percent Female Percent Black Percent Native American Percent Asian	Percent Hispanic (or Latino) Percent Speaking English as a Second Language with Limited English Proficiency
Household Composition & Disability	People per Unit Median Age Independent Living Difficulties Percent Children Living in 2-parent families*	Percent Female Headed Households Percent Households Receiving Social Security Benefits Percent Population under 5 years or 65 and over
Socioeconomic Status	Percent Poverty Per Capita Income* Percent Civilian Unemployment Percent with Less than 12th Grade Education	Percent Households Earning over $200,000 annually* Percent of population without health insurance Percent of all households spending more than 40% of their income on housing expenses
Labor Force	Percent Female Participation in Labor Force Percent Employment in Extractive Industries	Percent Employment in Service Industry
Housing Type and Transportation	Percent Unoccupied Housing Units Percent Renters Percent Mobile Homes Hospitals Per Capita *∞	Percent of Housing Units with No Car Median Gross Rent Median Housing Value*

* Indicates a variable where inverse percentile was used for calculations.

∞ Indicates county level data

3.2 Social Vulnerability Mapping Results

Using the Resilient Connecticut methodology resulted in the identification of several areas throughout the planning region that rank high based on all 30 variables included in the analysis (Figure 2). A majority of the more socially vulnerable areas are centered within the highly urbanized areas of New Haven and Fairfield counties. Bridgeport, New Haven, and Waterbury have some of the largest and most prominent concentrations of highly vulnerable populations. In addition, Danbury, Meriden, Norwalk, Stamford, and Ansonia/Derby also have areas of highly vulnerable populations.

Other areas of vulnerable populations include the southwest area of Greenwich, central Newtown, West Haven and East Haven; in the case of the two latter communities, SVI map patterns are continuous with the vulnerable core areas in New Haven.

3.2.1 Minority Status and Language

The subgroup "minority status and language" is comprised of variables representing race, ethnicity, and language barriers (Figure 3). In general, these vulnerable populations are concentrated in similar areas to those discussed regarding overall social vulnerability. However, it is noteworthy that, while there are a few large vulnerable areas (i.e., many block groups) in urbanized areas, several smaller areas (i.e., one or two block groups) exist in less urban areas throughout the region, including suburban or rural areas. For example, some moderately vulnerable minority status and language populations are in Weston, Greenwich, Ridgefield, Westport, the Southport section of Fairfield, and Naugatuck. Some of these municipalities have relatively affluent populations throughout their communities.

3.2.2 Household Composition and Disability

The subgroup "household composition and disability" vulnerability does not present a strong pattern of vulnerability throughout the region (Figure 4). This subgroup is comprised of variables representing age sensitive populations, certain economic or family care related challenges, and those with disabilities or mobility challenges. Many of these vulnerable populations are dispersed throughout the suburban and more rural areas of the region, with less prominent concentrations in the larger cities and urbanized areas that have increased overall social vulnerability. Some of the most vulnerable block groups in this category can be identified in suburban or rural areas such as in the towns of Wallingford and Woodbridge. High vulnerability in this category indicates where elderly or disabled populations and certain care facilities may be located, as well as higher concentrations of single parent households. These characteristics may help to inform adaption efforts by (1) locating residents that may need mobility assistance before or during storm events and (2) identifying families that may lack the financial means to recover from a storm event due to income constraints.

3.2.3 Socioeconomic Status

The "socioeconomic status" vulnerability pattern (Figure 5) is almost identical to the overall social vulnerability pattern and is also closely aligned with the distribution of vulnerable populations

based on the "minority status and language" subgroup variables. Many of the same areas, such as urbanized and larger cities, do have some of the highest concentrations of socioeconomically vulnerable populations. In addition, many areas that have "low to moderate" overall social vulnerability have "moderate to high" socioeconomic vulnerability.

3.2.4 Labor Force

"Labor force" vulnerability (Figure 6) conveys populations that work in industries that may be easily disrupted because of extreme weather, as well as higher densities of high female labor force. Females are more likely to remain home for family care in the wake of an event potentially reducing personal income and lowering workforce capacity.[8] The average labor force vulnerability score for the region is 0.48. Similar to "household composition and disability," this subgroup distribution does not have an obvious spatial pattern. The southwestern part of the region from Greenwich to Fairfield and north to Redding and Ridgefield appear to have the lowest labor force related social vulnerability. Other areas in the region with low "labor force" vulnerability are Guilford and Madison along the shoreline, and the town of Woodbridge.

The remainder of the region is scattered regarding highly vulnerable labor force populations. There are some notable high concentrations in the urbanized areas, however there are also vulnerable areas in suburban communtiies such as Southbury, Newtown, North Branford, and Wallingford.

3.2.5 Housing Type and Transportation

The fifth subgroup is "housing type and transportation" (Figure 7). These variables represent certain housing related financial challenges or constraints, high rent areas, and transportation limitations. Like overall social and socioeconomic vulnerability, the more vulnerable populations are concentrated around the urbanized areas. Bridgeport, New Haven, and Waterbury have the largest areas of high vulnerability in this subgroup, with Meriden, Danbury, Norwalk, Stamford, and Derby/Ansonia having smaller areas of vulnerable populations in this subgroup.

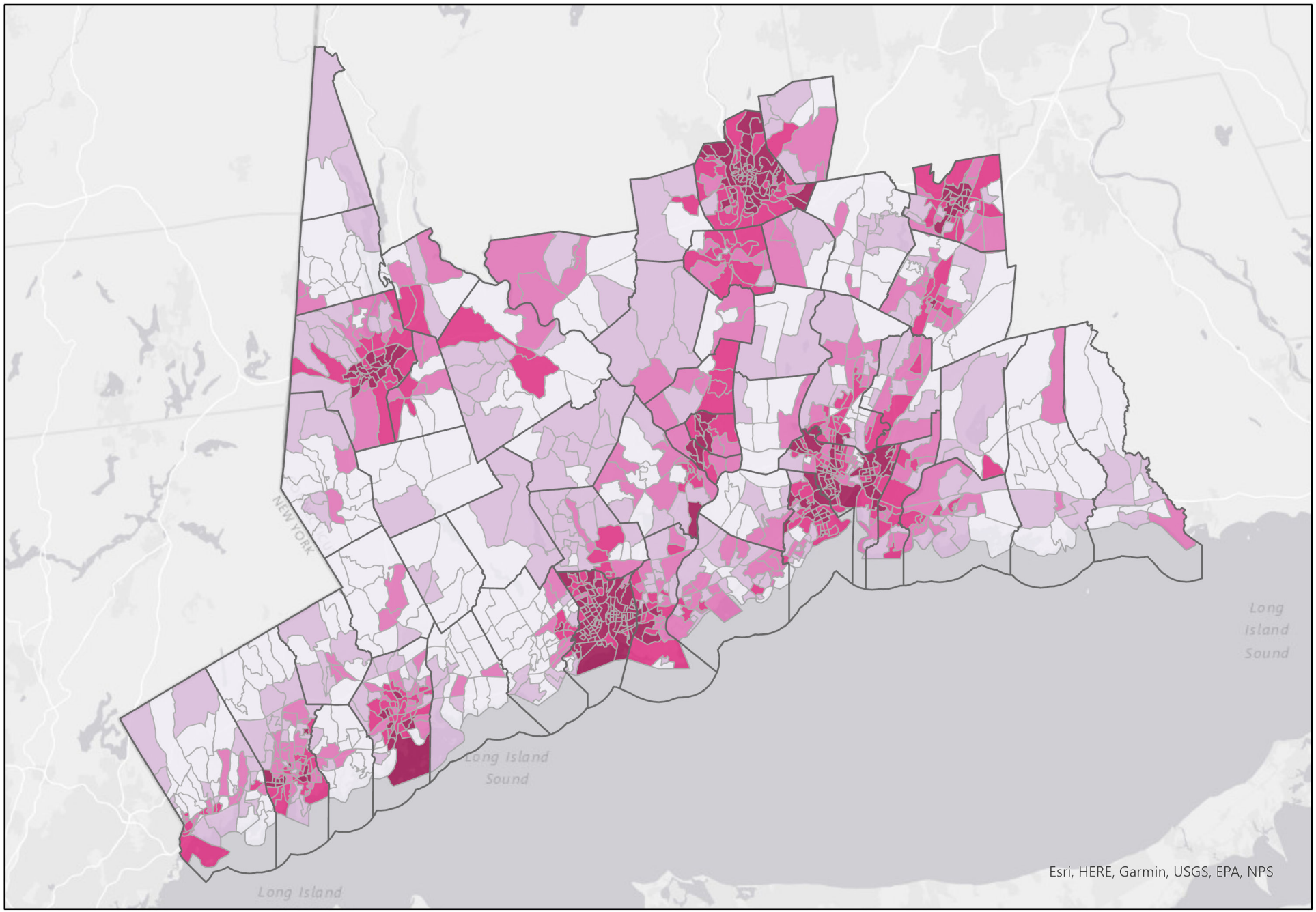
3.2.6 Conclusions

While it is challenging to draw conclusions at a large two-county scale, the patterns conveyed in the maps may identify some correlations between certain vulnerability types. For example, socioeconomic status and housing type and transportation subgroups have similar patterns with concentrations in urbanized areas. Also, populations vulnerable due to age or disability may be concentrated in areas that are more rural, and not often thought of as socially vulnerable areas.

While the methodology and factors used in the SV mapping are useful for understanding many of the social vulnerabilities in the region, there are several recommendations for future iterations. Future SV mapping could take various social capital factors into consideration to better understand the degree of community response and support during and after an event. In general,

[8] Cutter, S.L., B.J. Boruff, and W.L. Shirley, 2003. "Social Vulnerability to Environmental Hazards," ***Social Science Quarterly***, 84(1): 242-261.

these factors might include more refined cultural data, institutional or communitarian establishments, and community linkages. In addition to social capital, other social indices incorporate governance factors into tools. Those resources that have been reviewed in Appendix B provide numerous data types, sources, and reasoning for incorporation. As the SV mapping evolves, and objectives are established for the tool, the factor list can be expanded upon or refined to achieve specific goals.



Social Vulnerability

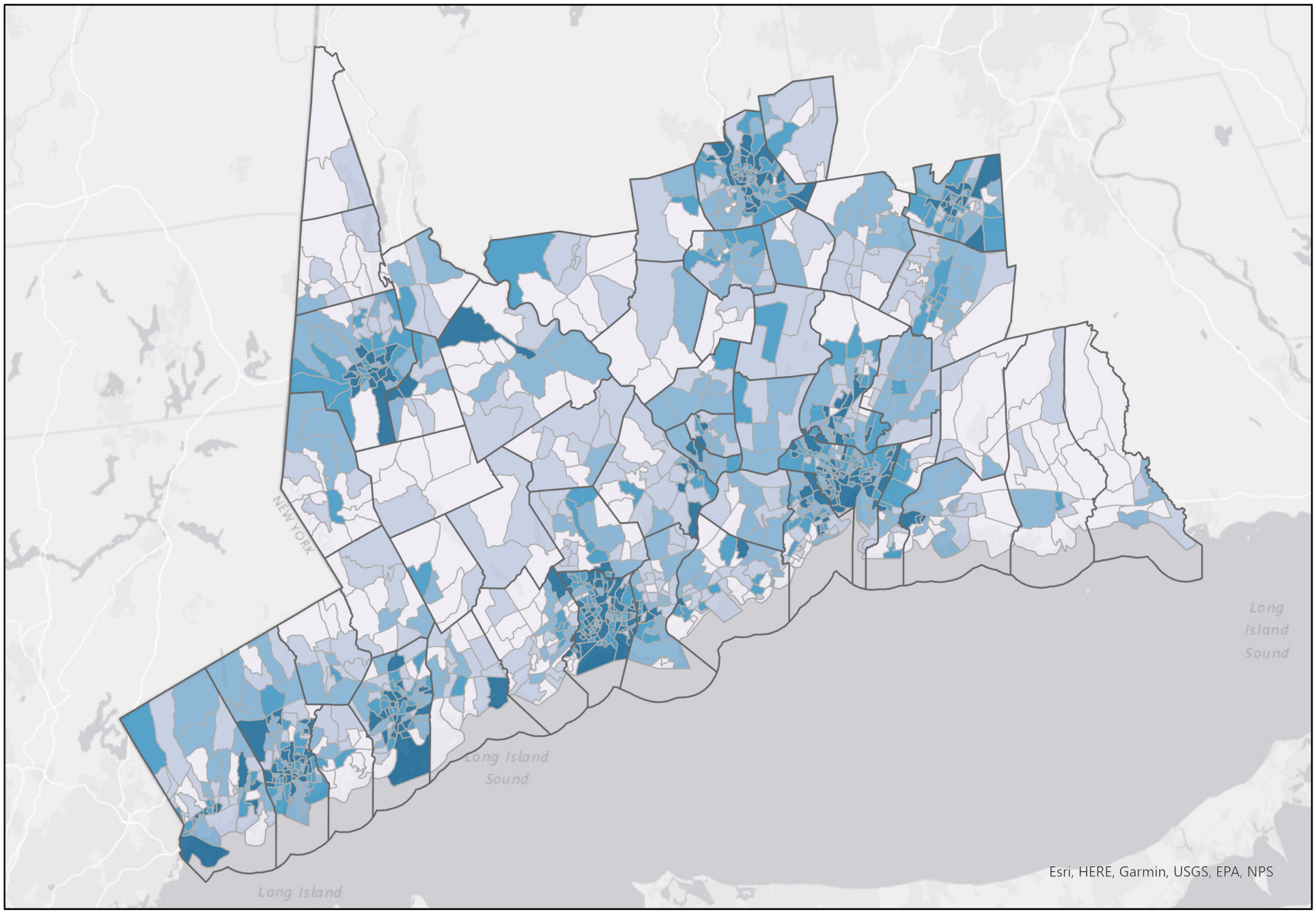
Overall Vulnerability

0 - 0.20
0.21 - 0.40
0.41 - 0.61
0.62 - 0.81
0.82 - 1.00

N

0 1.5 3 6 9 12

Miles



Social Vulnerability

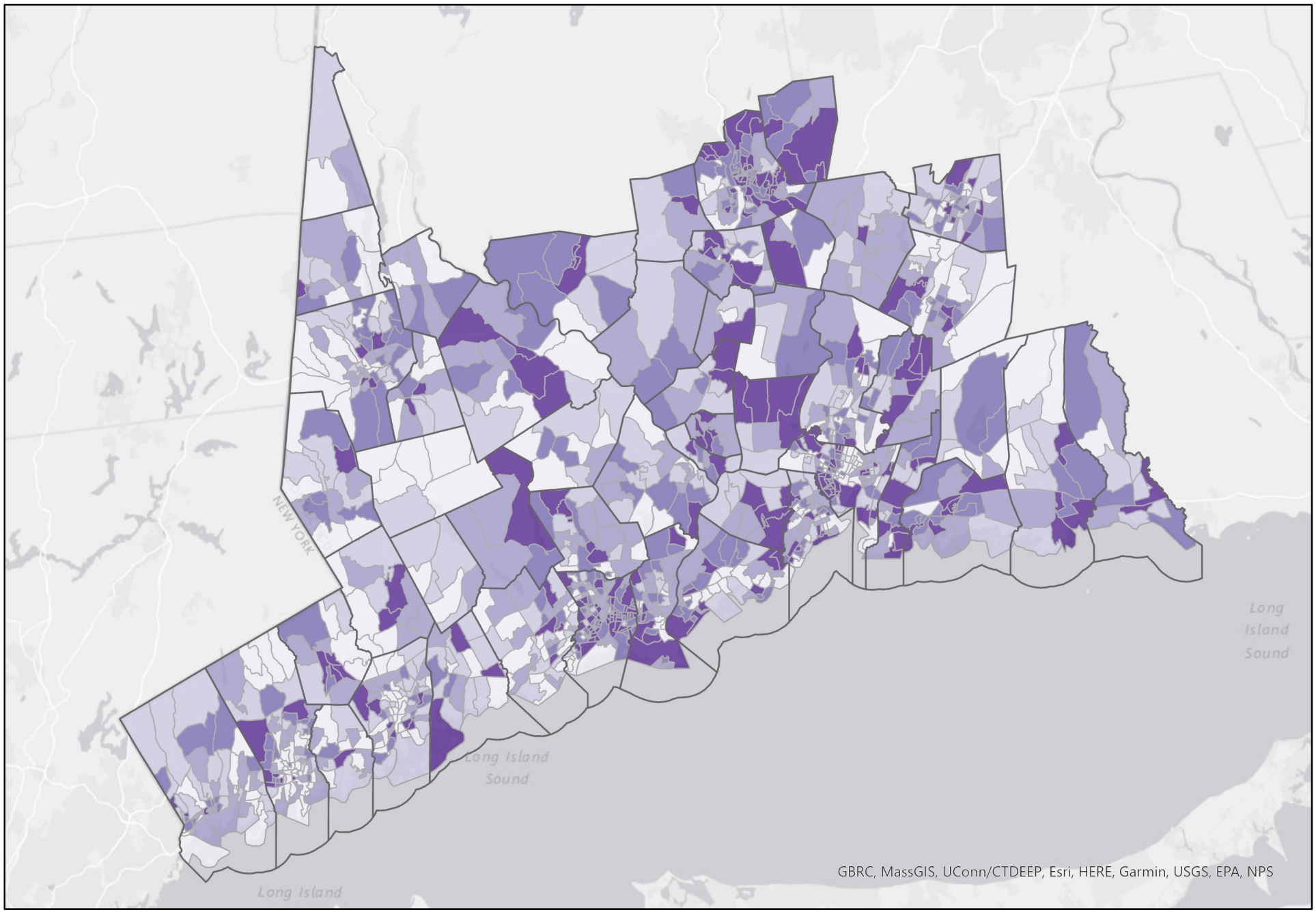
Minority Status and Language

0 - 0.18
0.19 - 0.37
0.38 - 0.57
0.58 - 0.77
0.78 - 1.00

N

0 1.5 3 6 9 12

Miles



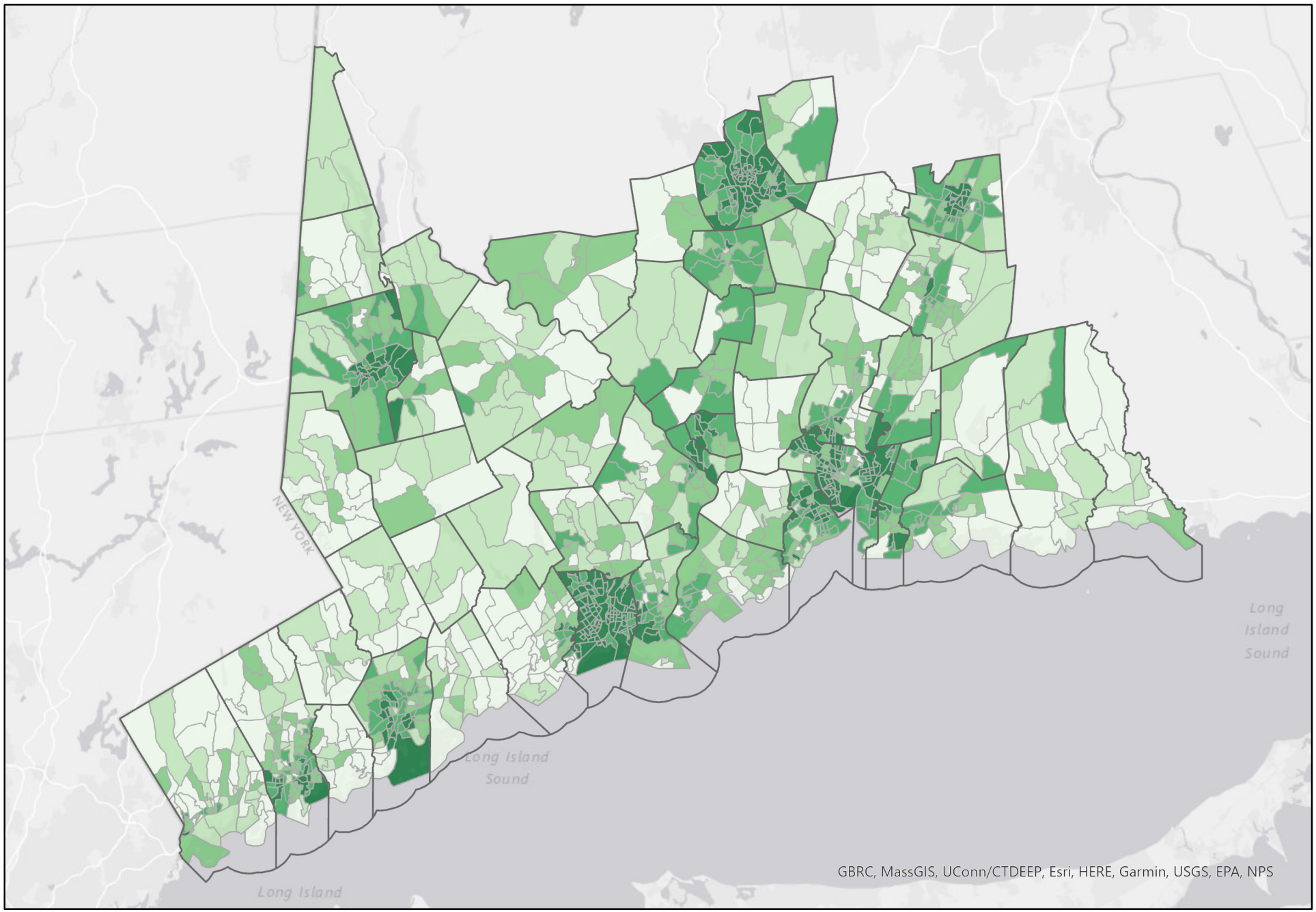
Social Vulnerability

Household Composition and Minority Status

0 - 0.21	0.42 - 0.61	0.82 - 1.00
0.22 - 0.41	0.62 - 0.81	

N

0 1.5 3 6 9 12 Miles



Social Vulnerability

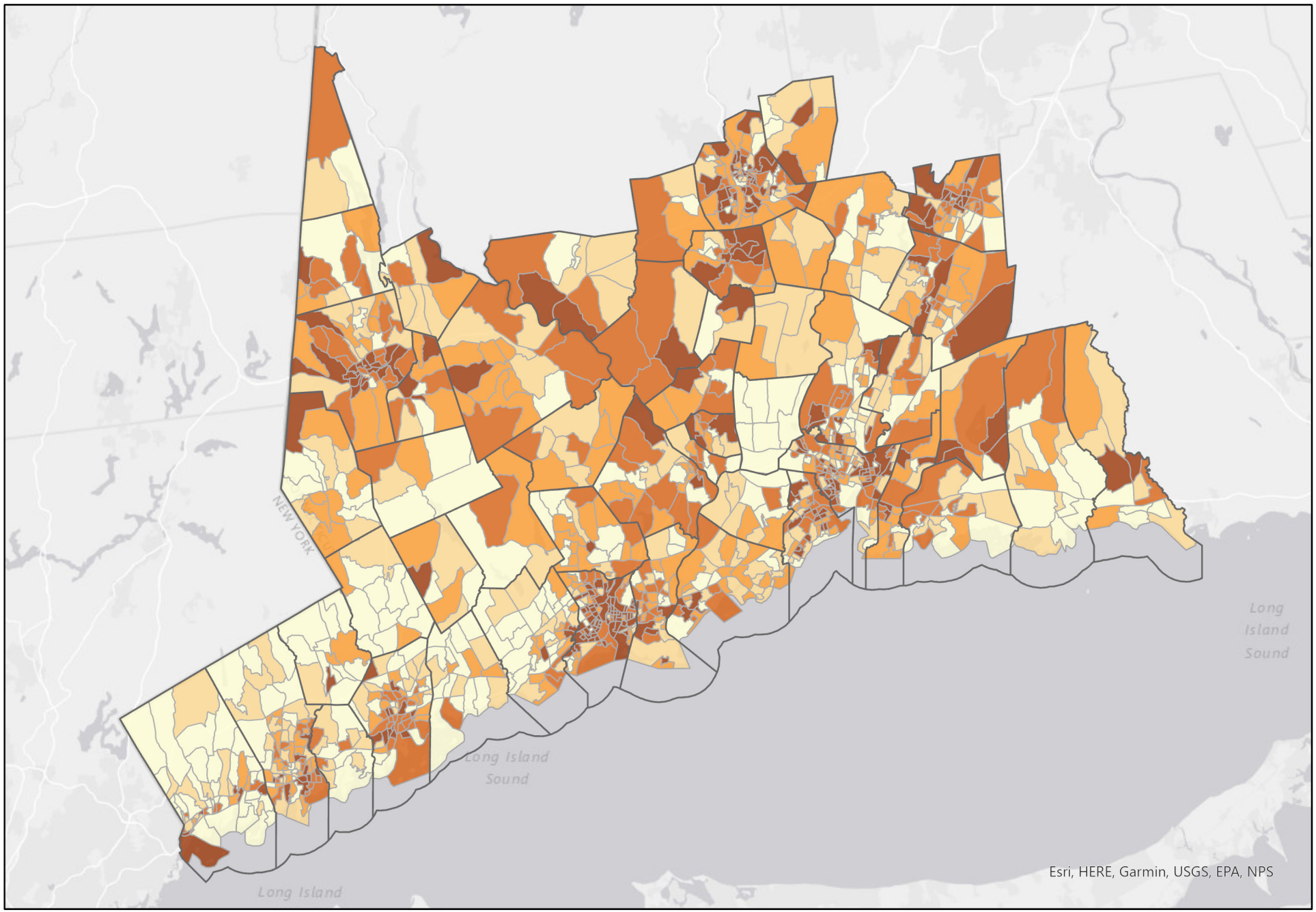
Socioeconomic Status

0 - 0.23
0.24 - 0.43
0.44 - 0.63
0.64 - 0.83
0.84 - 1.00

N

0 1.5 3 6 9 12

Miles



Social Vulnerability

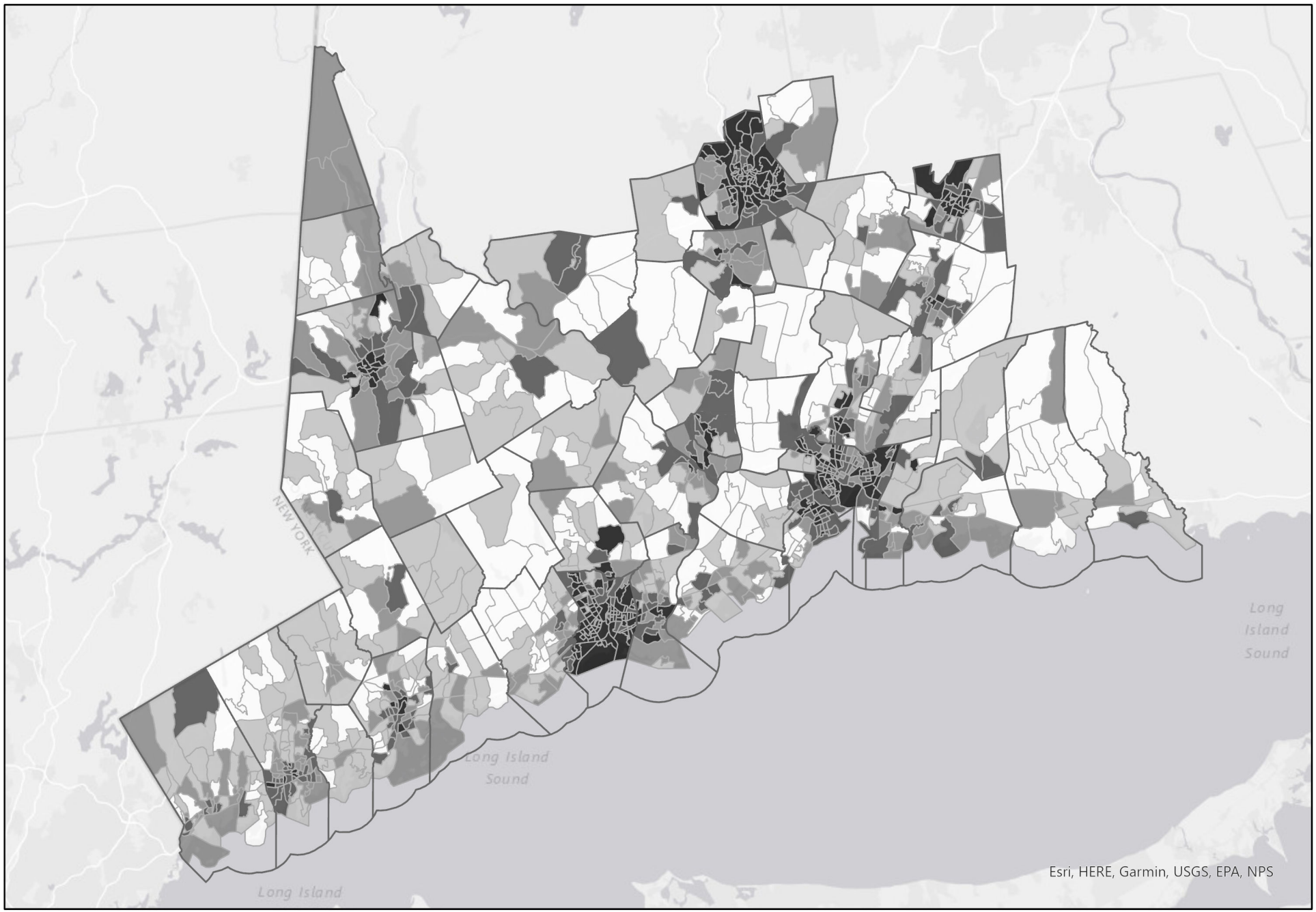
Labor Force

0 - 0.18
0.19 - 0.38
0.39 - 0.58
0.59 - 0.79
0.80 - 1.00

N

0 1.5 3 6 9 12

Miles



Social Vulnerability

Housing Type and Transportation

0 - 0.20
0.21 - 0.40
0.41 - 0.59
0.60 - 0.79
0.80 - 1.00

N

0 1.5 3 6 9 12

Miles

4 Climate Change Vulnerability Index

4.1 CCVI Methodology

The CCVI methodology has been expanded and adapted from the CIRCA Coastal Vulnerability Index (CVI) methodology.[9] The CCVI is a grid analysis index containing thousands of grid cells (specifically, the CCVI is comprised of over 94,000 10m x 10m cells). Each cells contains numerous data types and ranking that together are used to quantify the region's climate change vulnerability. In this case, flood and heat vulnerabilities are assessed through two separate indices. A grid analysis does not divide by political borders, and, as a result is able to highlight regional or transboundary vulnerabilities. Figure 9 is a good reference for the general flow of the subsequent methodology.

All of the gridded data points and their rankings result in a final vulnerability "score" comprised of three component scores: sensitivity, exposure, and adaptive capacity. The component scores are used to calculate vulnerability by multiplying sensitivity and exposure and dividing by adaptive capacity. Each of the three components are comprised of several indicators (Figure 8). Within each of these indicators are relevant contributing factors. A complete list of contributors can be found in Appendix C. All contributors used on the CCVI are ranked on a scale of 1 to 5. A rank of 5 indicates higher sensitivity or higher exposure, and in the case of adaptive capacity a rank of 5 indicates a greater degree of recovery or response capabilities. Therefore, a contributor with a rank of 1 may indicate lower sensitivity or lower exposure or reduced adaptive capacity. A zero (0) was assigned if the contributor was not considered in the calculation, or if data for that contributor was not present in a given geographic location.

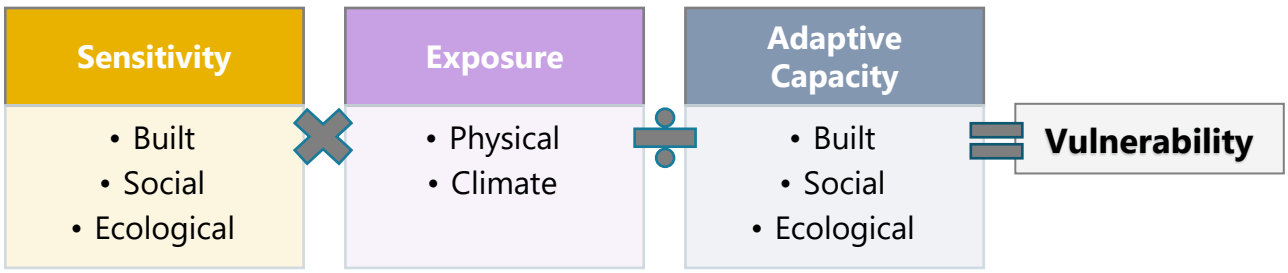


FIGURE 8: CCVI COMPONENTS AND RELATIVE INDICATORS

Most contributor layers are readily available for public use as geographic information system (GIS) files as either point, line, or polygon features. Other layers however have been developed specifically for the CCVI and formatted into the appropriate layer type. For example, pooling areas, distance to shelters or highways, and flood protection systems were either digitized for the CCVI or produced using other data and analyses. As previously discussed, the values associated with

[9] https://resilientconnecticut.uconn.edu/resources/

each contributor data layer were converted into rank scores on a scale of 1 to 5 and incorporated into each contributor source data layer. To translate these contributor layers and their rank into the index, each layer was spatially joined to the regional CCVI grid. The spatial join technique and merge rule varied depending on the layer type and information being conveyed. Specific join information for each contributor can be found in Appendix C. Once each contributor was joined to the grid, forming a new, contributor-specific grid layer, a union was performed to combine contributor grids into their respective indicator grids. For example, a union was conducted on multiple social-sensitivity-related contributor grids to generate a single social sensitivity indicator grid. The geometric mean of the contributors was then calculated to generate a "social sensitivity score". This process was repeated for each of the indicators for heat, flood, and wind.

Once all indicator scores have been calculated, the arithmetic mean is taken of the indicators to find the relative component score. Figure 9 presents the general mathematical process of determining each component score. This component score, being either exposure, sensitivity, or adaptive capacity, is then plugged into the vulnerability equation identified above, generating an overall vulnerability score.

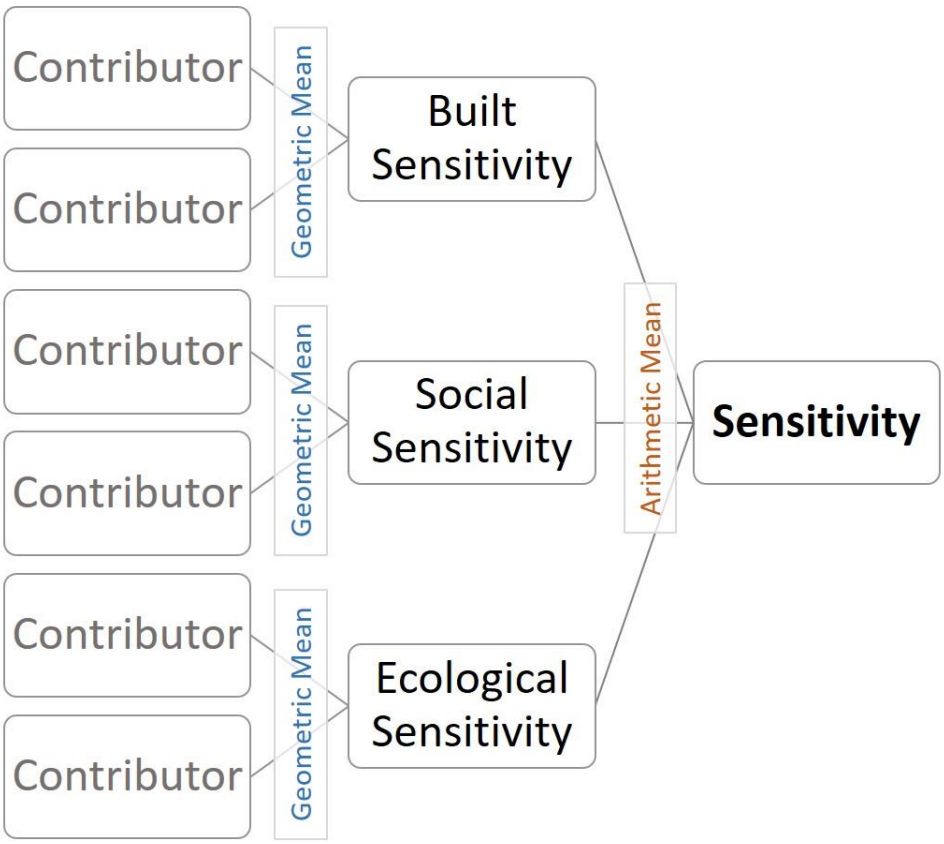


FIGURE 9: GENERAL MATHEMATICAL PROCESS OF CALCULATING A VULNERABILITY COMPONENT SCORE

To better convey the overall climate vulnerability, final *overall* vulnerability scores are normalized. The equation below equation is used to convert the raw scores to a range of 0 to 1. This

normalization was done at a regional level, so all cells in New Haven and Fairfield counties were included, however, this process could be replicated to normalize within a county or COG if necessary.

$$\frac{\text{(Vuln. Score – Vuln. Score minimum)}}{\text{(Vuln. Score maximum – Vuln. Score minimum)}}$$

Future iterations of the CCVI should address those relevant data gaps identified in Table 1.

4.2 Flood Vulnerability CCVI

The flood CCVI incorporates several contributors that elevate the vulnerability analysis to a systems level. These contributors include social, built, and ecological contributing factors, as well as the climate and physical factors that may exacerbate flooding.

This flood index has been developed to acknowledge the ongoing challenge of mitigating flood risks across the region and to aid in identifying the potential drivers of some of these challenges. Both coastal and inland municipalities face flood related challenges whether it be due to coastal storm events, heavy precipitation, seasonal flooding, or due to inadequate drainage systems. With the type and degree of flooding varying across the region, so do the factors that contribute to vulnerability. Communities across the region have varying ecosystems, demographics, and age and adequacy of infrastructure.

It is important to note that while the CCVI contains numerous data points this is not an exhaustive list of data that could be considered when evaluating vulnerability. The CCVI is meant to act as an informational planning tool to be used in conjunction with other resources such as the social vulnerability mapping, zones of shared risk, and other environmental data such as soil or geologic information.

4.3 Heat Vulnerability CCVI

As heat waves and extreme heat become a more frequent occurrence, communities and ecosystems are becoming more vulnerable to potential heat-related consequences. There are various populations that are more vulnerable to extreme heat due to age or health related issues, or some populations face challenges regarding financial limitations which hamper the ability to upgrade homes for cooling, and ecosystems may struggle to adapt to increased heat or have become impaired due to development ultimately limiting cooling ecosystem services. Therefore, an extreme heat CCVI has been developed to characterize a location's vulnerability increasing temperatures. This index is comprised of the same components as the flood index, sensitivity, exposure, and adaptive capacity, however the heat CCVI does not account for ecological sensitivity as the flood does. A suitable dataset to represent ecological sensitivity should be explored in future iterations as on was not clearly identified in the planning process.

While extreme heat data is not as readily available as flood data, several new datasets have been integrated, and existing data has been processed to help to interpret certain conditions . Examples include impervious surface density which can be used to imply the location of heat islands or land cover data which can be used to identify tree cover density. Unlike flooding, which represents a moving volume or changing elevation of water that can be modeled, heat and its impacts are felt differently by different receptors on the ground, depending on length of exposure, the heat index, and physical characteristics.

5 Flood and Heat Analysis

In addition to standalone flood and heat analyses, it was also important to evaluate which areas throughout the region were vulnerable to both flooding and extreme heat. The identification of combined vulnerabilities is important to adaptation and resilience project development. Many communities in the region, and across the state, are facing challenges related to several climate change stressors, therefore understanding the degree of these stressors is critical to developing strategies to address them. Adaptation projects and resilience opportunity areas for Resilient Connecticut will be designed to address combined climate change impacts.

5.1 Combined Vulnerability Methodology

The heat and flood vulnerability indexes were developed separately using a custom set of variables and inputs. High heat vulnerability scores appear in more developed urban areas while high flood vulnerability scores generally appear in waterbody-adjacent areas. While each provides insight into a particular aspect of climate change vulnerability, combining these analyses allows for their integrated use in holistic planning and project development.

To assess and visualize the two factors as a single combined variable, a two-dimensional gradient was deployed. As shown in Figure 10, this gradient was developed by creating a grid with simplified (low-high) flood CCVI scores along the x-axis and heat CCVI scores along the y-axis. As the vulnerability increases, the colors get more saturated, and as the vulnerabilities overlap, the colors converge towards red, indicating the highest combined vulnerability.

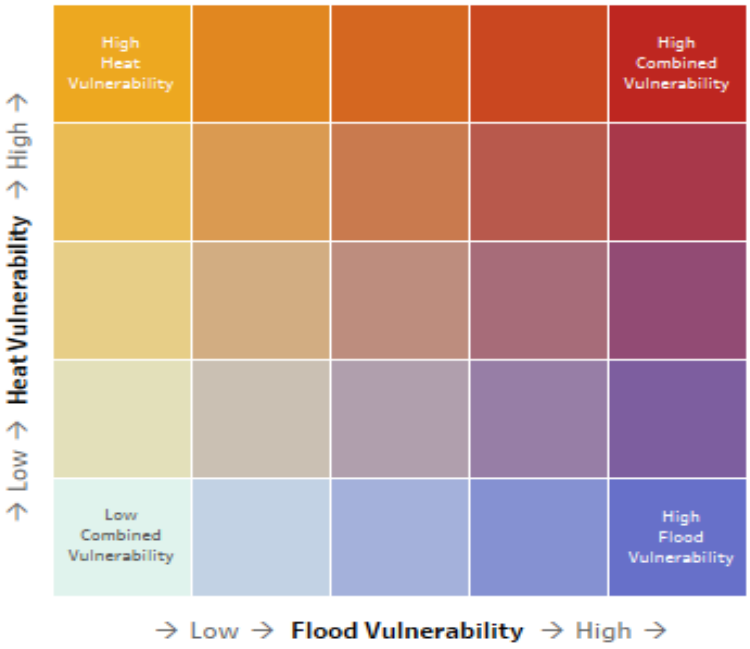


FIGURE 10: TWO-DIMENSIONAL SPECTRUM USED TO CHARACTERIZE COMBINED HEAT-FLOOD VULNERABILITY

Additional analyses and data visualizations, such as the one shown in Figure 11 can provide further information about the distribution of vulnerability within a particular area of interest. This is used to further characterize zones of shared risk and supports the identification of opportunity areas where interventions may serve both flood- and heat-related concerns.

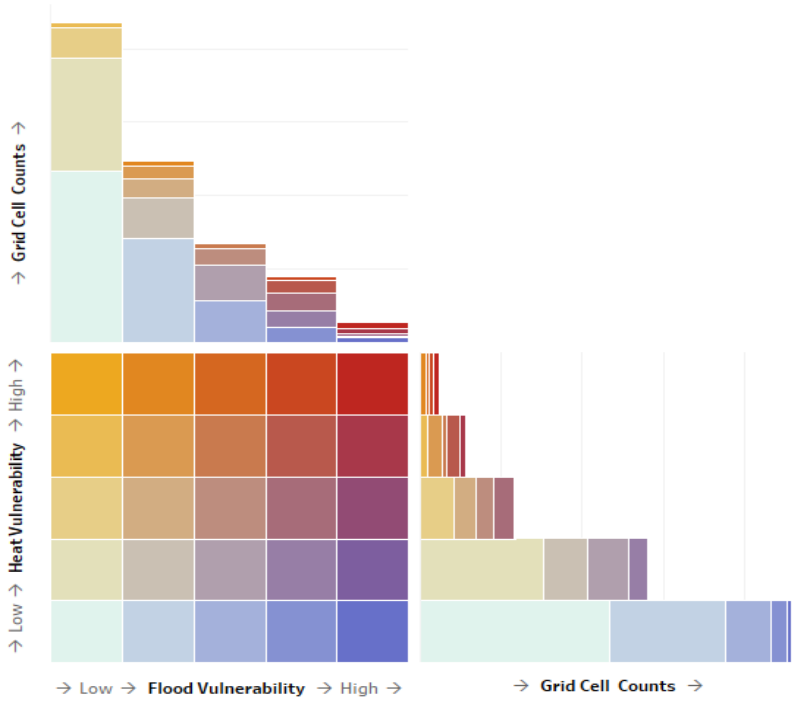


FIGURE 11: TWO-DIMENSIONAL SPECTRUM WITH BAR CHARTS SHOWING THE RELATIVE BREAKDOWN OF GRID CELLS FALLING INTO EACH CATEGORY

Figure 12 provides a regional depiction of combined flood and heat vulnerability using the same color schemes as in Figure 10 and Figure 11. This approach can provide swift insight into whether a particular area suffers from heat-driven climate vulnerability, flood-driven climate vulnerability, neither, nor a combination of both. Darker red areas indicate those with the highest combined flood and heat vulnerability. Areas that are orange are those that are higher heat with lower flood vulnerability, and those that are darker blue are higher flood vulnerability and lower heat. The lightest blue areas are those with the lowest flood and heat vulnerability.

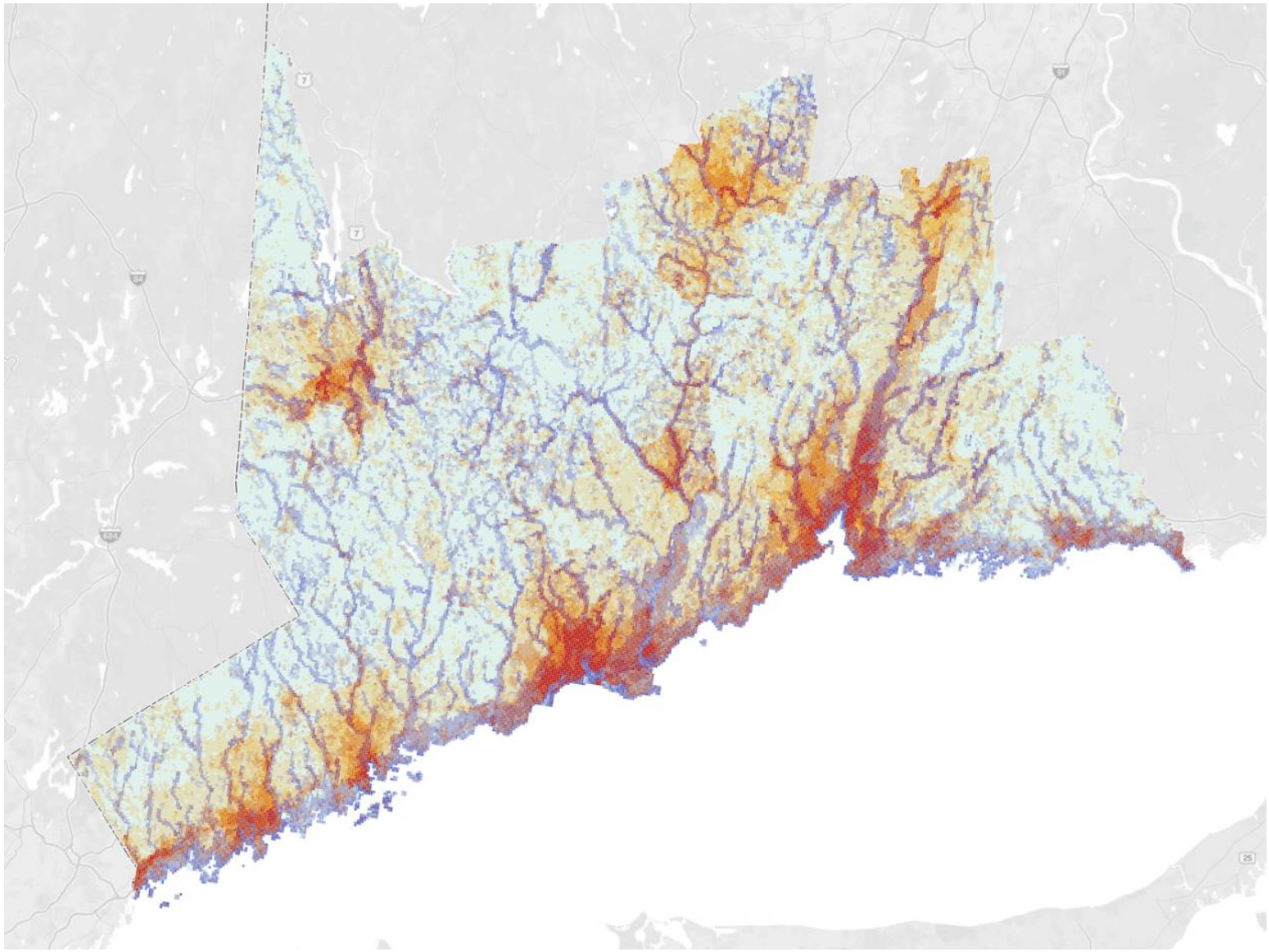


FIGURE 12: MAP OF STUDY AREA WITH COMBINED VULNERABILITY VISUALIZATION APPROACH

5.2 Typology Analysis (Environmental Vulnerability Drivers)

CCVI scores can be broken down further into their indicators to better characterize the vulnerabilities within a particular area and identify trends in the data. CCVI Scores were derived using variables related to the ecological environment, social environment, and built environment. High scores in any or all of these areas may contribute to high overall CCVI scores for the grid cell. In order to drive insight into why a particular grid cell is identified as high vulnerability, the approach assessed which environmental factor was the primary driver of vulnerability. This was done by comparing how the sensitivity and adaptive capacity scores associated with a particular environment type compared with those of the other two types. For example, the vulnerability of a grid cell was considered driven by social environmental factors if:

(Social Sensitivity / Social Adaptive Capacity) > (Ecological Sensitivity / Ecological Adaptive Capacity) and
(Social Sensitivity / Social Adaptive Capacity) > (Built Sensitivity /Built Adaptive Capacity)

Areas of moderate, moderate-high, and high flood vulnerability have been colored by their environmental driver (Figure 13). This map is showing which of the indicators is potentially driving vulnerability in a certain area. In addition to the flood hazard exposure present across all mapped areas, grid cells shown in purple are more vulnerable to flooding due to the presence of socially vulnerable populations, areas in orange are more vulnerable to flooding due to the presence of critical and sensitive built infrastructure, and areas shown in green are more vulnerable to flooding due to the presence of sensitive ecological areas. The dominance of one vulnerability driver above the rest is indicated by color saturation. An environmental driver is considered a "strong" influence if there is a substantial difference between that environmental type and the other two.

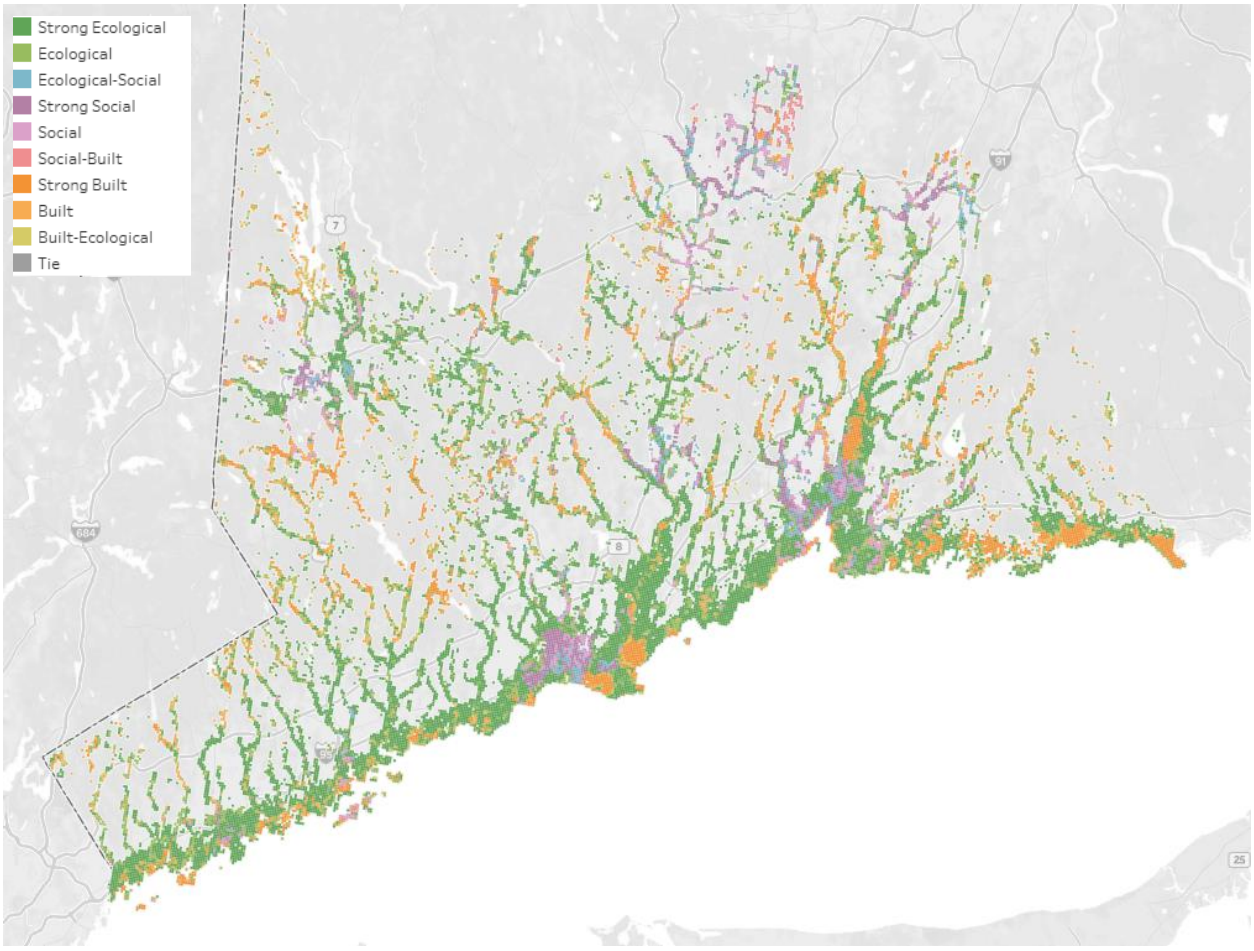


FIGURE 13: REGIONAL AREAS OF MODERATE, MODERATE-HIGH, AND HIGH FLOOD VULNERABILITY CHARACTERIZED BY ENVIRONMENTAL DRIVERS

6 Zones of Shared Risk

Zones of shared risk, an urban design strategy, can be defined as "regions that face common challenges either in existence already or caused by climate change, and therefore risks are shared among or between groups of people that may have different perspectives and priorities for coastal resilience. A Zone of Shared Risk includes the houses, land, infrastructure, hydrological, ecological, social, and institutional elements that contribute to the functioning of a place."[10] ZSR are manually delineated areas, and are qualitative planning tools that can be utilized in various scenarios:

- Used for municipal and community planning when looking to implement technical measures such as protective infrastructure or zoning overlays;
- Understanding the dynamic relationship between people and their surrounding environment which may be attractive to funding sources such as FEMA or state programs;
- Identify area specific stakeholders that should be involved in adaptation and mitigation planning efforts

Throughout the region, flood ZSR have been delineated in those municipalities with TOD potential. The resulting ZSR are often closely aligned with delineated FEMA flood zones, however, often these zones have also been delineated based on local knowledge of locations that experience flood related challenges.

To better understand the risks captured within ZSR, four types have been identified:

- An **"Access Zone of Shared Risk"** contains risks primarily derived from the ability (or lack thereof) to enter or exit an area due to flooding caused by increasing sea levels or surges associated with strong storms.
- A **"Location Zone of Shared Risk"** contains risks primarily derived from a prevalence of low-lying lands within an area. These lands are vulnerable to flooding caused by increasing sea levels or surges associated with strong storms due to their low elevation.
- A **"Proximity Zone of Shared Risk"** contains risks primarily derived from adjacency to low-lying, vulnerable lands. These lands are vulnerable by being close to areas that will experience more flooding caused by increasing sea levels or surges associated with strong storms and are likely to experience some flooding of their own.
- A **"Natural protection Zone of Shared Risk"** contains risks to lands that provide natural flooding protection. These lands can attenuate flooding and damage and flooding from storm surges, contribute to both improved water quantity and quality in non-storm events, and provide valuable habitat. This Zone of Shared Risk type often overlaps with the other three types.

In addition to the above four ZSR types, a more specific ZSR has also been identified for "underpasses". While the four types have been developed as a result of previous efforts, as

[10] https://resilientconnecticut.uconn.edu/zones-of-shared-risk-dataset/#brief-description

described in Appendix F, the underpass ZSR type evolved organically under Resilient Connecticut as these locations are a region wide challenge for many communities. These ZSR identify the railroad underpass locations that, during heavy precipitation events often flood and are a source of either disruption due to roadway closure or a frequent emergency response due to stranded vehicles.

All ZSR delineated have been classified by their primary and secondary type. These areas are dynamic and should evolve as shared risks change throughout the region. Appendices F1 through F5 present a more detailed methodology, as well as narrative for those ZSR throughout the region.

7 COG Level Flood and Heat Vulnerabilities

The CCVI has been used to present a high-level overview of the flood and heat vulnerabilities present throughout each of the COGs. The subsequent analysis first presents the trends within the region in relation to flood and heat sensitivity, exposure, and adaptive capacity, followed by the same statistics but normalized to each COG.

7.1 Flood statistics

Within the region, MetroCOG has the highest overall flood vulnerability of the four COGs, with WestCOG and NVCOG both having the lowest flood score (Figure 14). Adaptive capacity is the strongest component throughout the region with WestCOG communities having the highest adaptive capacity scores and NVCOG communities scoring the lowest. NVCOG also has the lowest flood sensitivity and exposure scores; this may correlate to NVCOG being the only non-coastal COG of the four. To understand what is driving these component scores throughout the region, reviewing indicator scores (Figure 15) can provide insight into how sensitivity, exposure, or adaptive capacity are evaluated

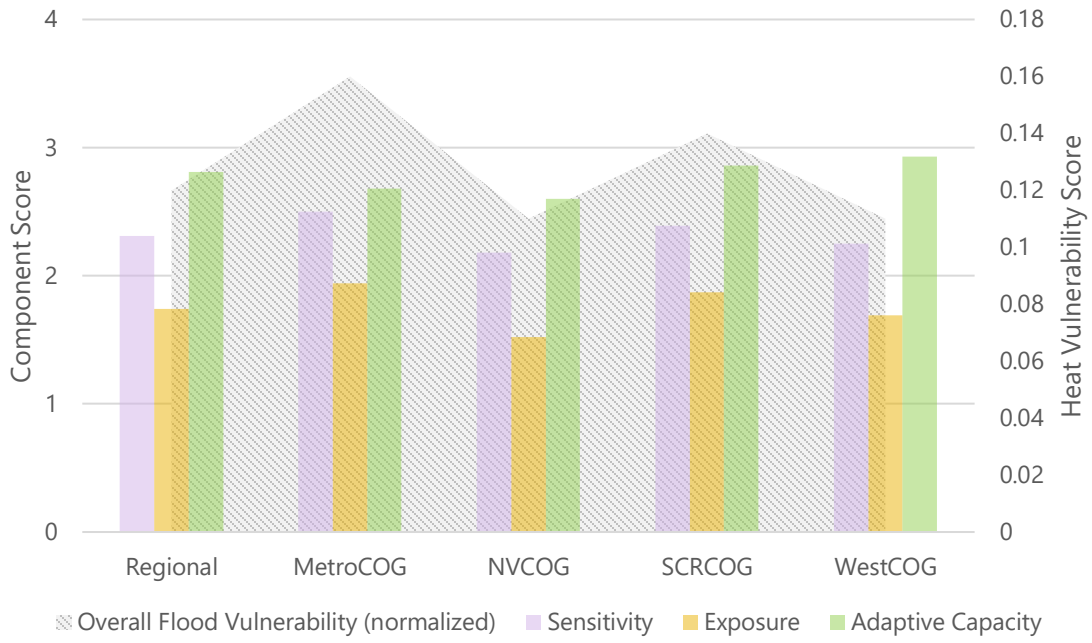


FIGURE 14: REGIONAL AND COG OVERALL FLOOD VULNERABILITY AND COMPONENT SCORES

Figure 15 provides a more in depth understanding of each component score by showing a breakdown of the percent contribution of each indicator within that component score. This graph compares COGs to each other, as well as regional scores.

Both at the regional level and COG level, ecological sensitivity scores are highest and built sensitivity scores are lowest. This trend signifies potential region wide challenges associated with resilient ecosystems, and infrastructure that is potentially in better condition to withstand flooding. This may also indicate the absence of other factors. A low built sensitivity score should not misrepresent the fact there is likely flood vulnerable infrastructure throughout the region; rather, that cumulatively, the built environment may not be as sensitive as other indicators. To better evaluate specific built environment sensitivities within an area, community, assessments should be done at a finer infrastructure-specific scale. Social sensitivity is relatively consistent throughout the region will all four COGs scoring similarly. This may be since each COG is comprised of both urban and suburban communities, with similar demographics, facing similar challenges. Social sensitivities, particularly regarding flood vulnerability, may be more obvious at a finer scale.

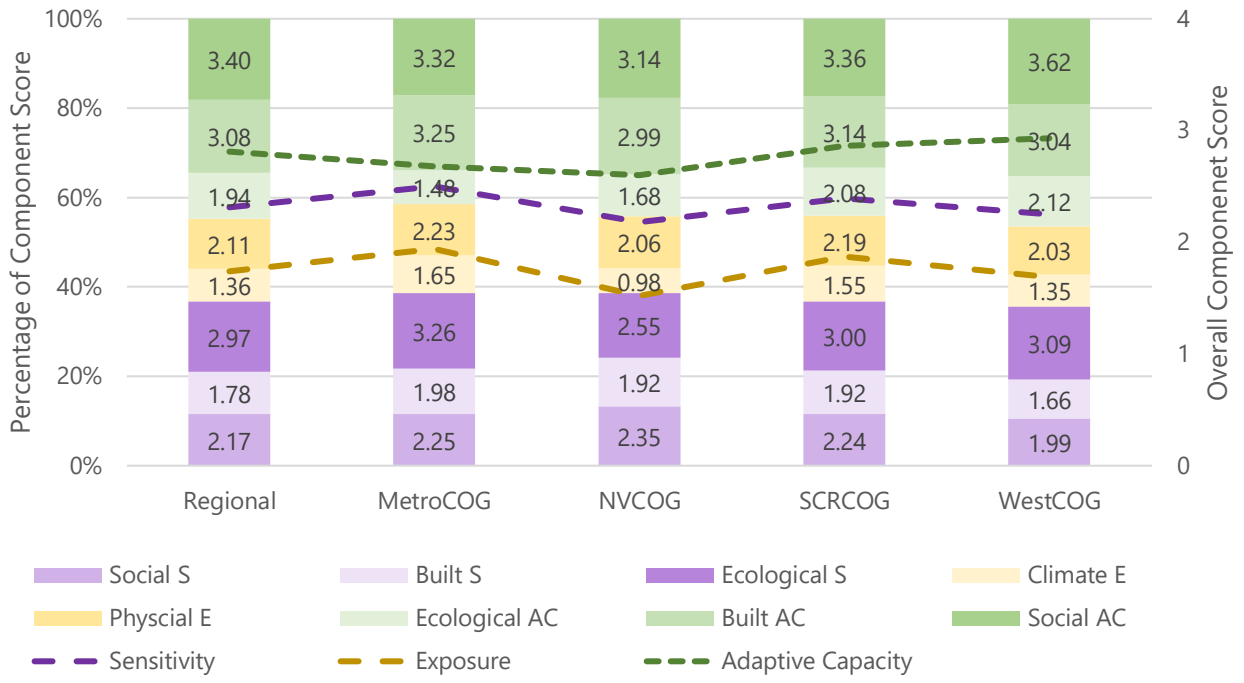
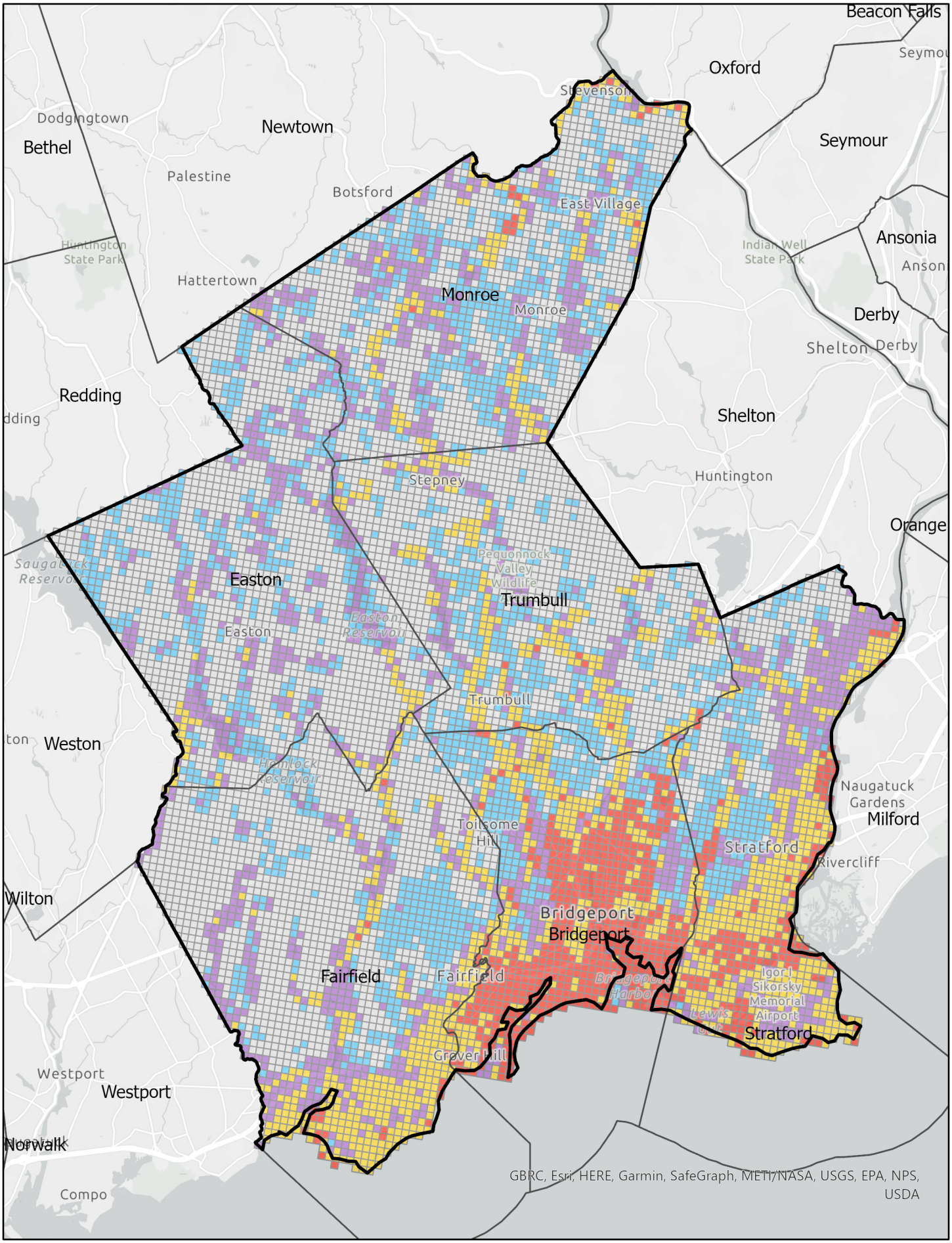


FIGURE 15: REGIONAL AND COG FLOOD OVERALL COMPONENT SCORES (DOTTED LINES) AND INDICATOR SCORES (BAR GRAPH), WITH A PERCENT CONTRIBUTION OF EACH INDICATOR WITHIN THE COMPONENTS

The CCVI incorporates more coastal climate exposure contributors than those found inland, including storm surge, tidal range, and sea level rise projections; therefore, the three coastal COGs have higher climate related flood exposure in comparison to the inland NVCOG. In addition, the NVCOG region has flood protection systems along the Naugatuck River, ultimately reducing exposure. However, regarding physical exposure WestCOG scores the lowest with MetroCOG scoring highest. Again, these scores are comparable across the board indicating similar levels of

physical exposure; factors including impervious surface density, soil drainage characteristics and elevation to identify pooling areas. These physical exposure contributors are less specific to coastal areas.

All regions score highest for social adaptive capacity and lowest for ecological. The low ecological capacity parallels the high ecological sensitivity throughout all four COGs. The high social adaptive capacity indicates a strong number of flood insurance policies, disposable income, and high owner-occupied housing. As with all indicators discussed previously, there are certainly disparities throughout the region regarding social adaptation and ultimately should be assessed at a finer community scale. The SV mapping developed for Resilient Connecticut explores this topic in greater depth.

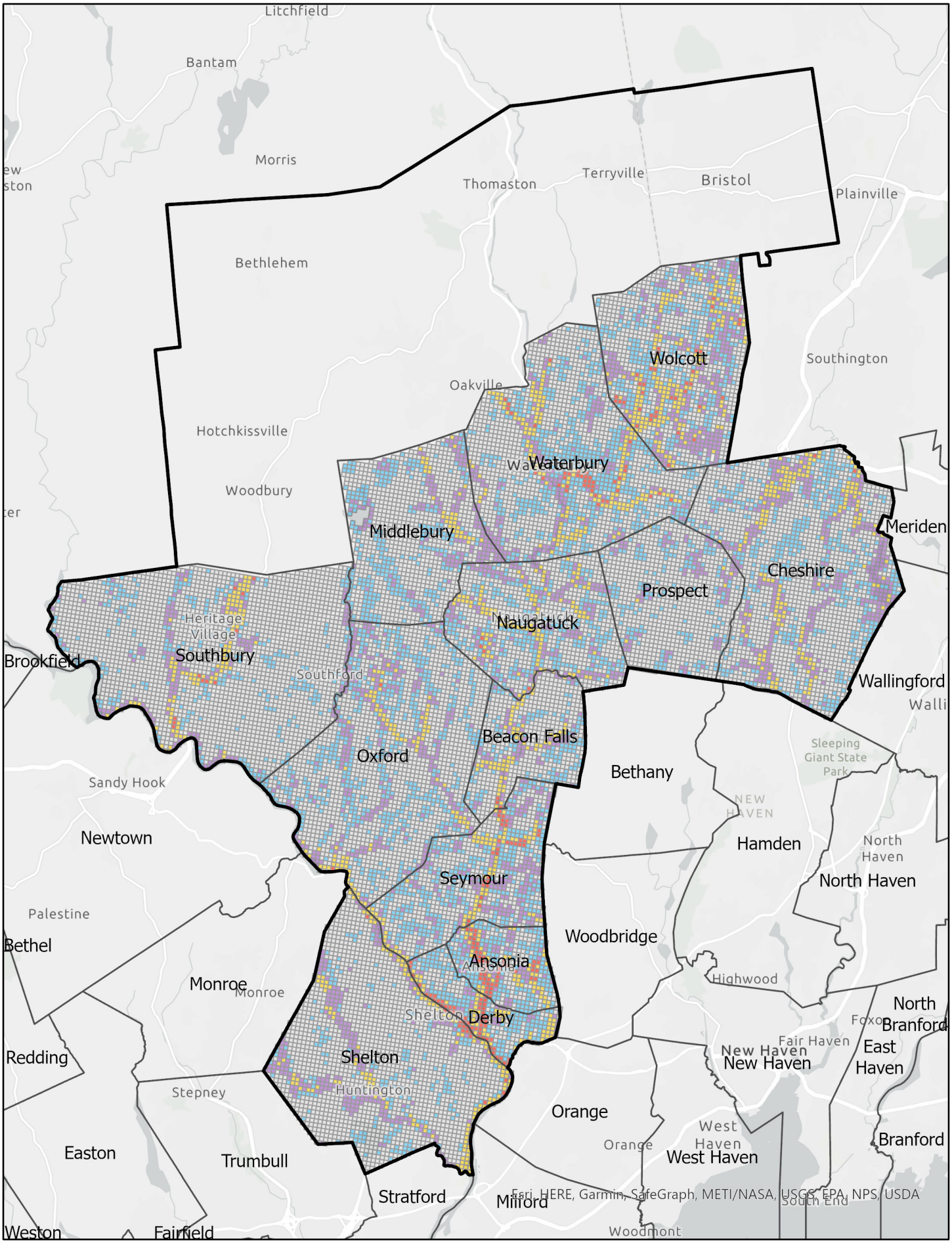


Flood Vulnerability
MetroCOG

High
Moderate-High
Moderate
Moderate-Low
Low

N

0 1 2
Miles



Flood Vulnerability

NVCOG

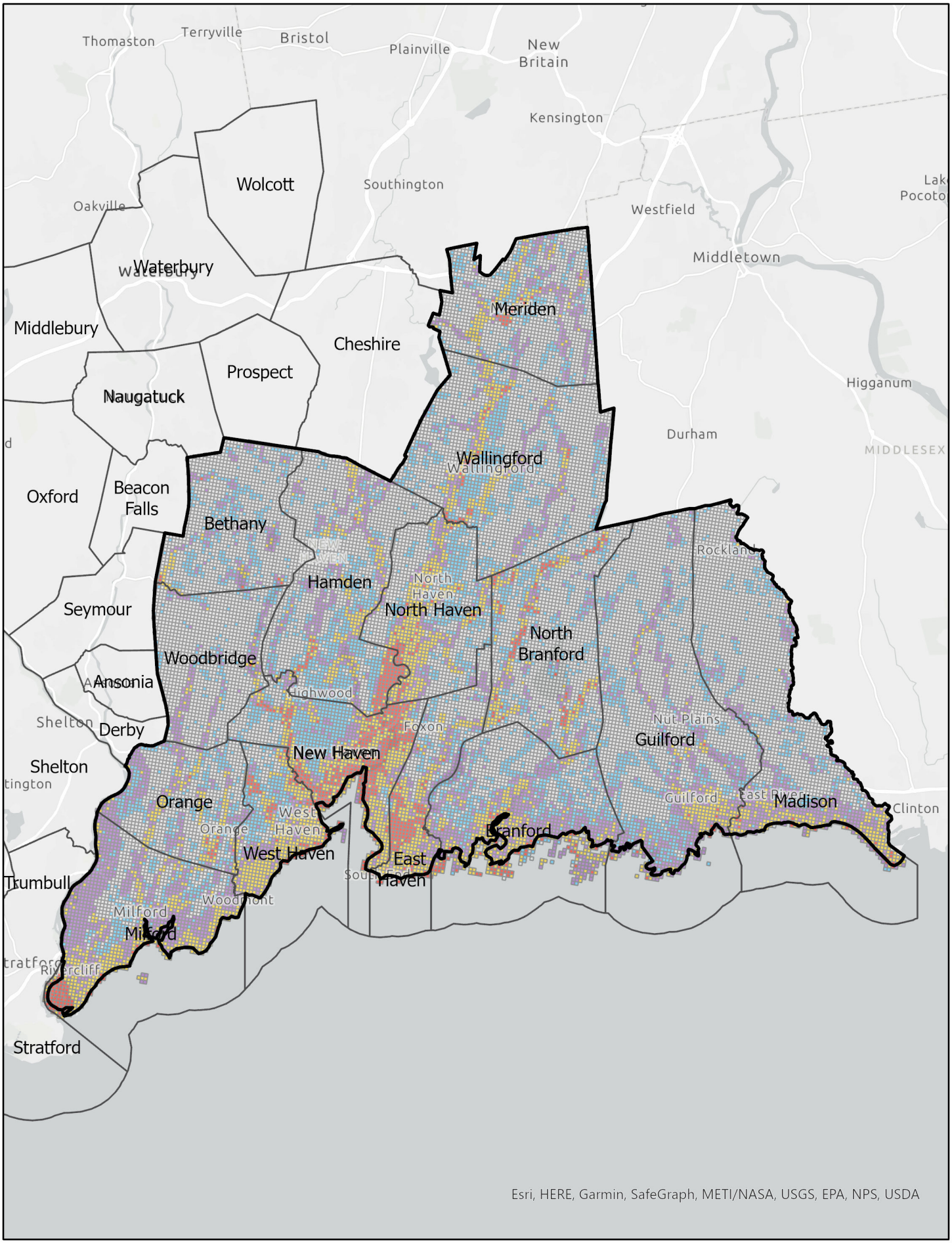
High | Moderate | Low

Moderate-High | Moderate-Low

N

0 1 2

Miles

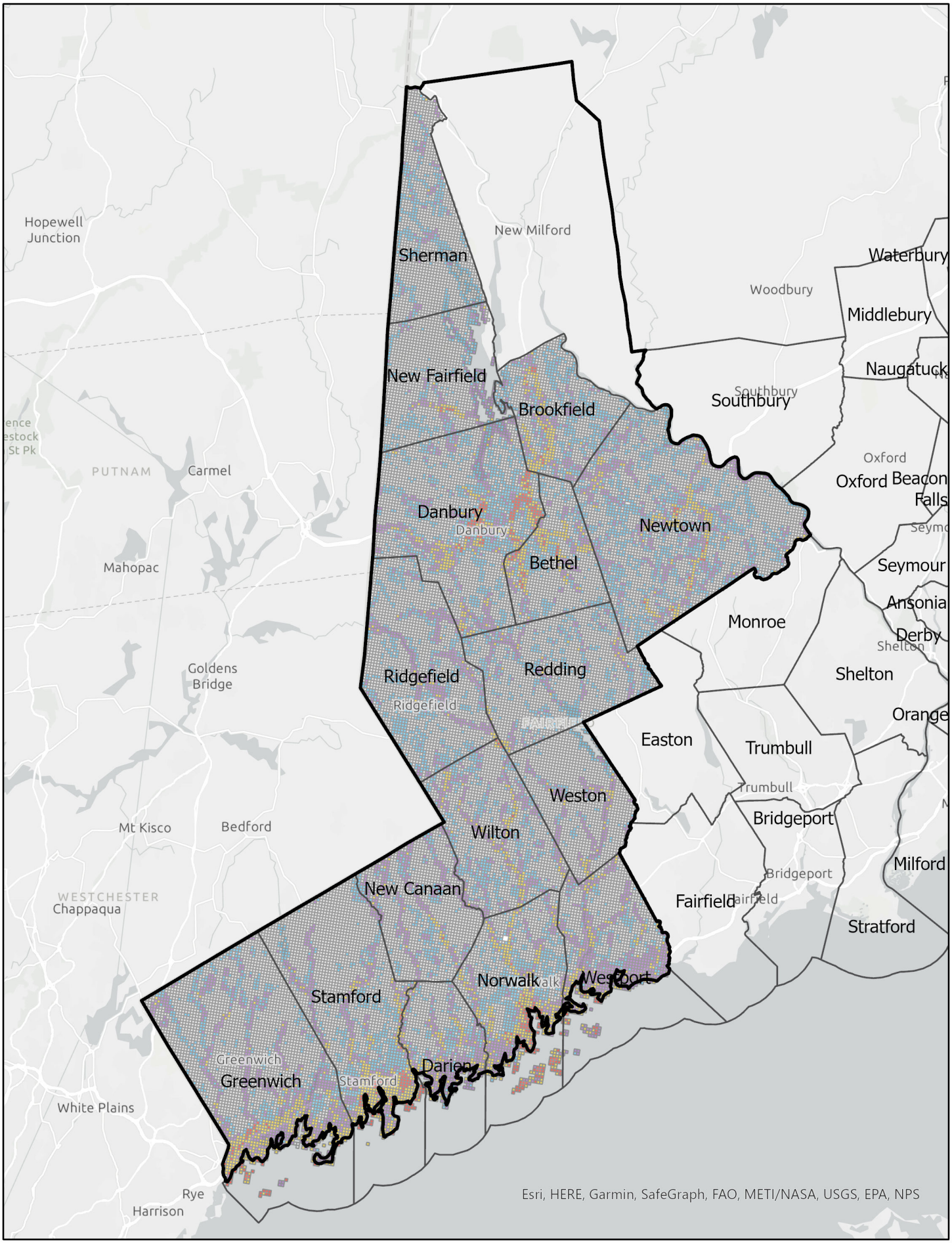


Flood Vulnerability
SCRCOG

High
Moderate
Low
Moderate-High
Moderate-Low

N

0 1 2
Miles



Flood Vulnerability

WestCOG

High | Moderate | Low

Moderate-High | Moderate-Low

N

0 1 2

Miles

7.2 Heat Vulnerability Statistics

Of the four COGs, MetroCOG communities have the highest overall heat vulnerability along with the highest heat exposure and sensitivity (Figure 20). However, scores do not drastically vary amongst the COGs for any one component or overall vulnerability. SCRCOG communities score the lowest for all three components and have the lowest overall score along with WestCOG. WestCOG and SCRCOG both have the lowest overall score, and although WestCOG has slightly higher exposure and sensitivity than the SCRCOG region. WestCOG has greater adaptive capacity.

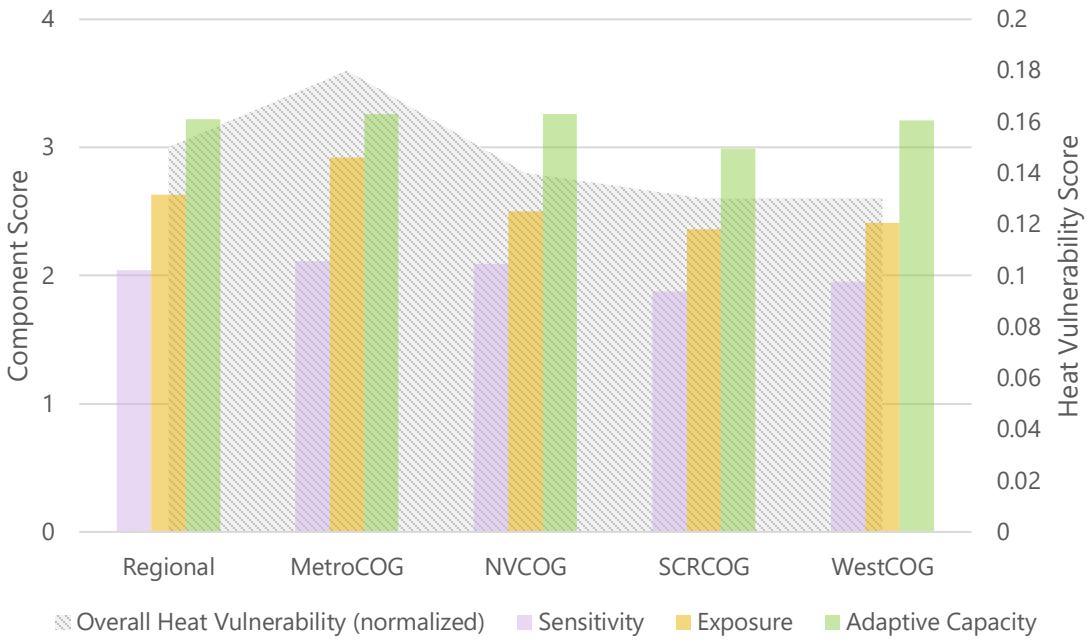


FIGURE 20: REGIONAL AND COG OVERALL HEAT VULNERABILITY AND COMPONENT SCORES

The NVCOG region has the highest social sensitivity and MetroCOG has the highest built sensitivity. A socially heat sensitive community likely has vulnerable age populations, health concerns, financial challenges, or populations living in older structures. Built sensitivity equates to higher building density, older structures, or possibly private well dependence (though private well dependence would not be the case in Bridgeport or Stratford). While neither of these COGs has a drastically higher sensitivity score than the others, there are likely similar concerns throughout the entire region.

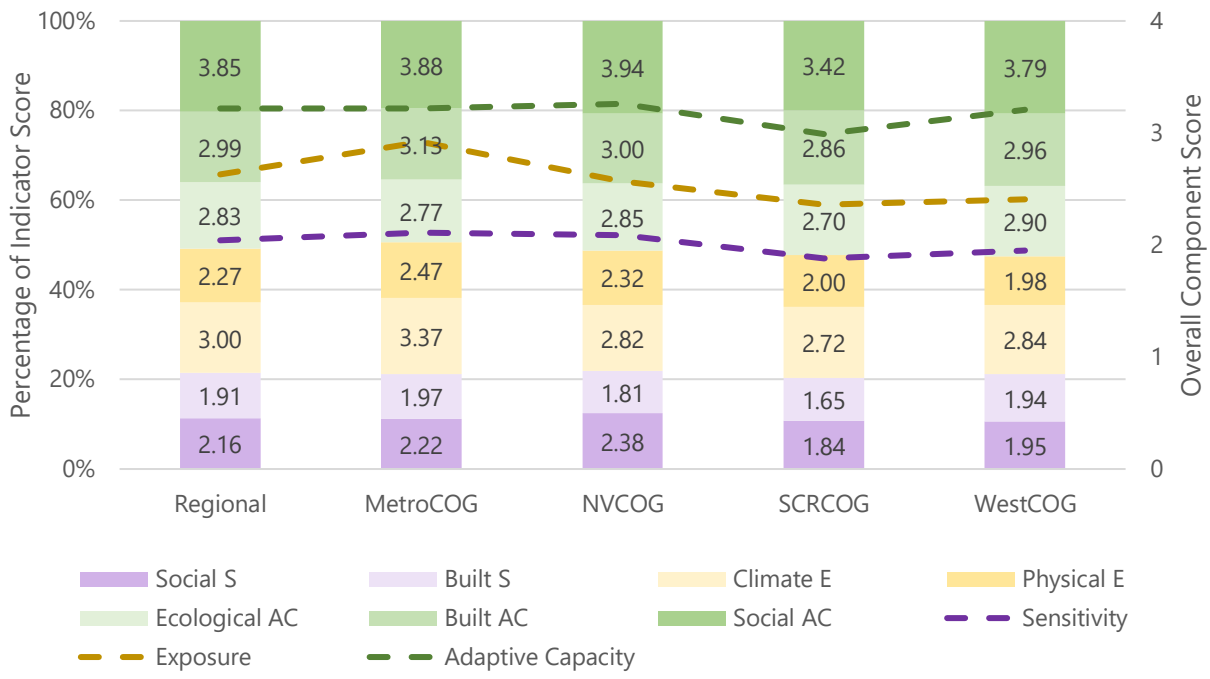
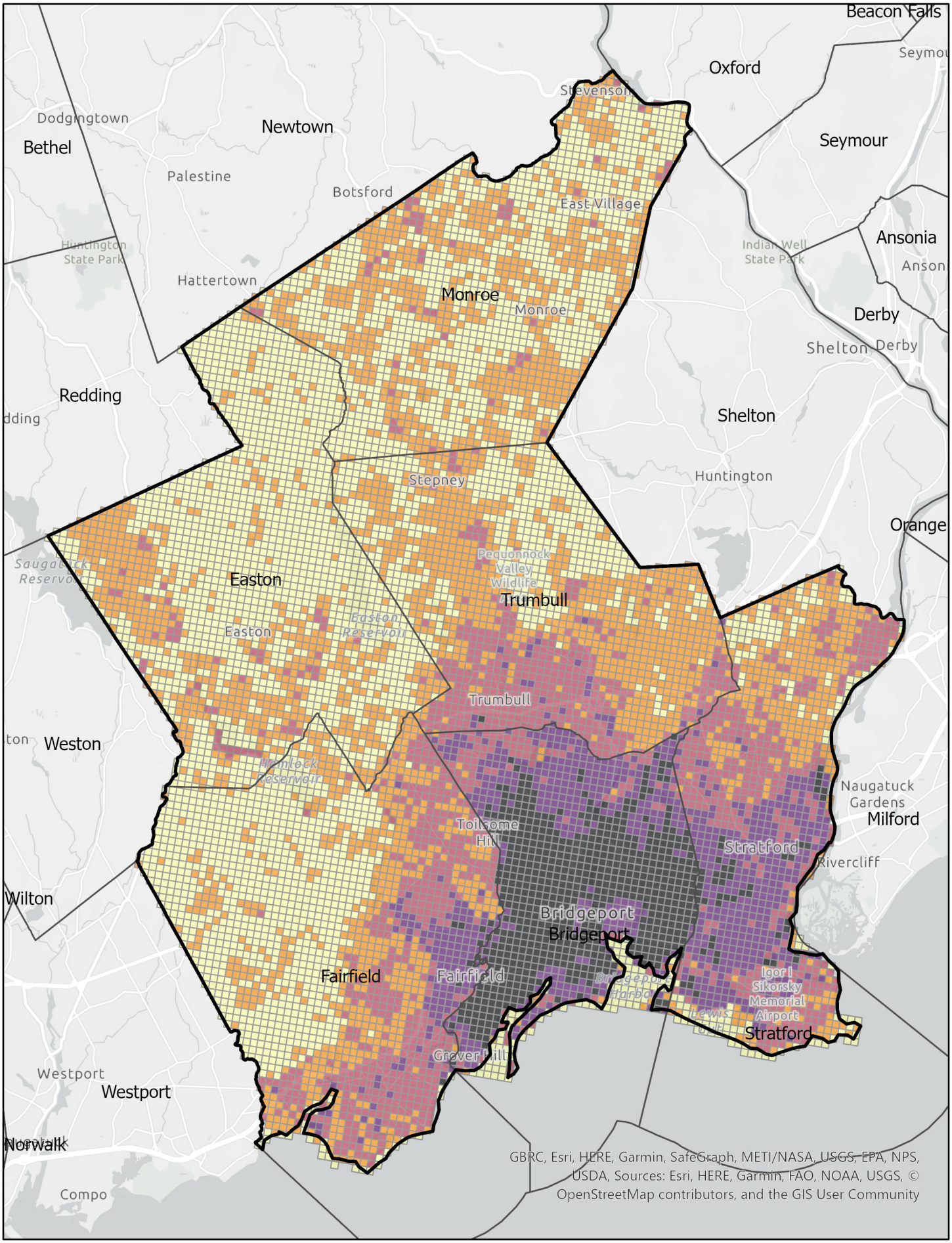


FIGURE 21: REGIONAL AND COG HEAT COMPONENT AND INDICATOR SCORES

All four COGs score highest for climate exposure versus physical, with MetroCOG having the greatest climate score. Climate exposure is based on maximum land surface temperatures (LST) and air quality. While air quality data is considered at a broad scale, LST is much finer. Physical exposure, which is also highest in MetroCOG, relates to emissivity. This high score, in conjunction with high climate exposure, indicates development that emits high level of heat ultimately resulting in hotter temperatures and conditions on the ground.

While sensitivities and exposure vary amongst the COGs, adaptive capacity is overall the highest scoring component, with all COGs scoring highest for social capacity, followed by built then ecological. Social heat adaptive capacity includes high owner-occupied housing or a higher population with health insurance. Built adaptive capacity contributors, similar to flood vulnerability, identify communities that have healthcare facilities, shelters, or cooling centers within close proximity. Lastly, a high ecological adaptive capacity, which is highest in the WestCOG region, indicates high percentage of tree cover and vegetation, along with land cover that aids in absorbing heat. While no one COG has a particularly low adaptive capacity indicator score, examining these drivers further, particularly the ecological capacity, can aid in development and redevelopment projects and identify where may need additional greening, cooling centers, or where populations may need assistance.

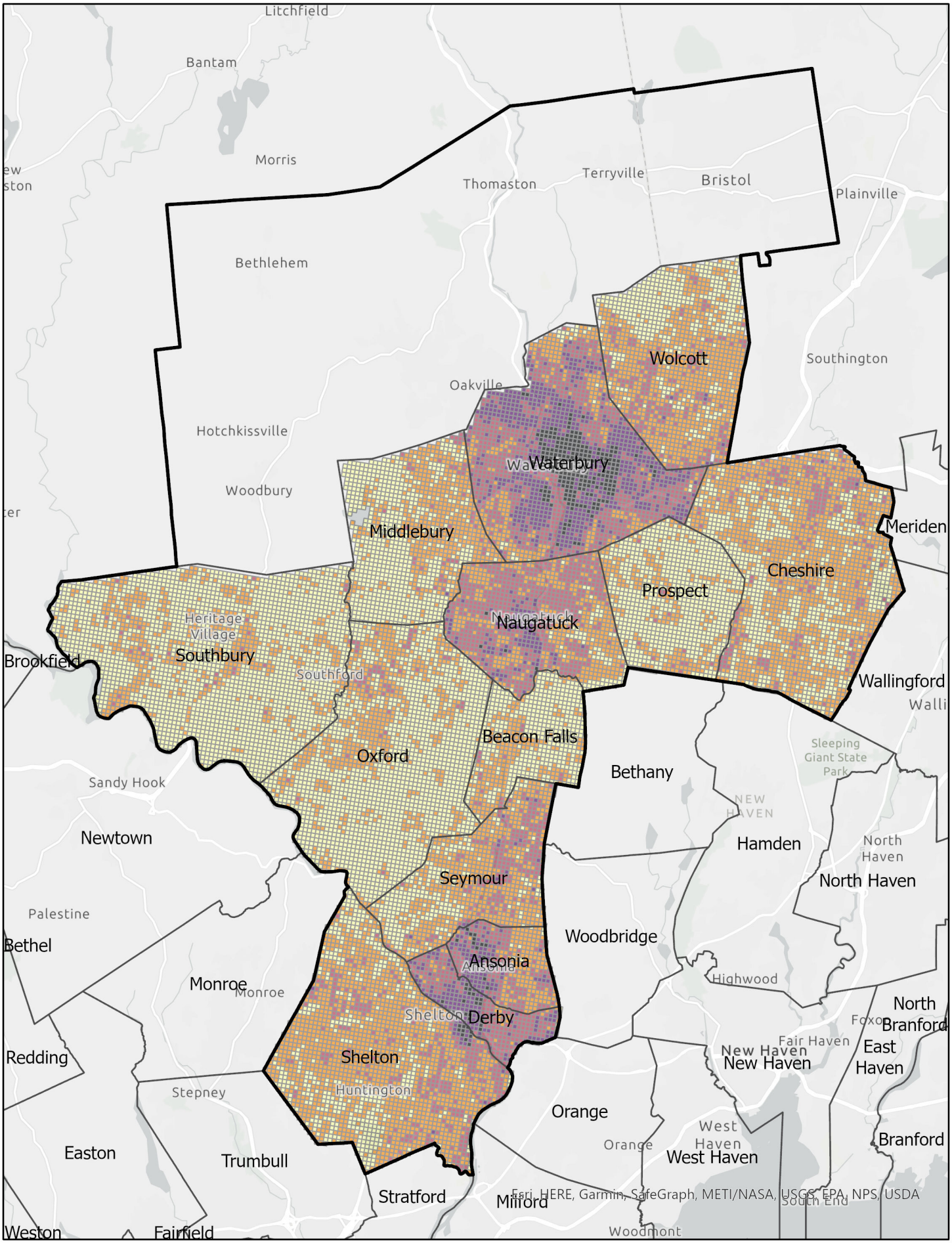


Heat Vulnerability
MetroCOG

High
Moderate
Low
Moderate-High
Moderate-Low

N

0 1 2
Miles



Heat Vulnerability

NVCOG

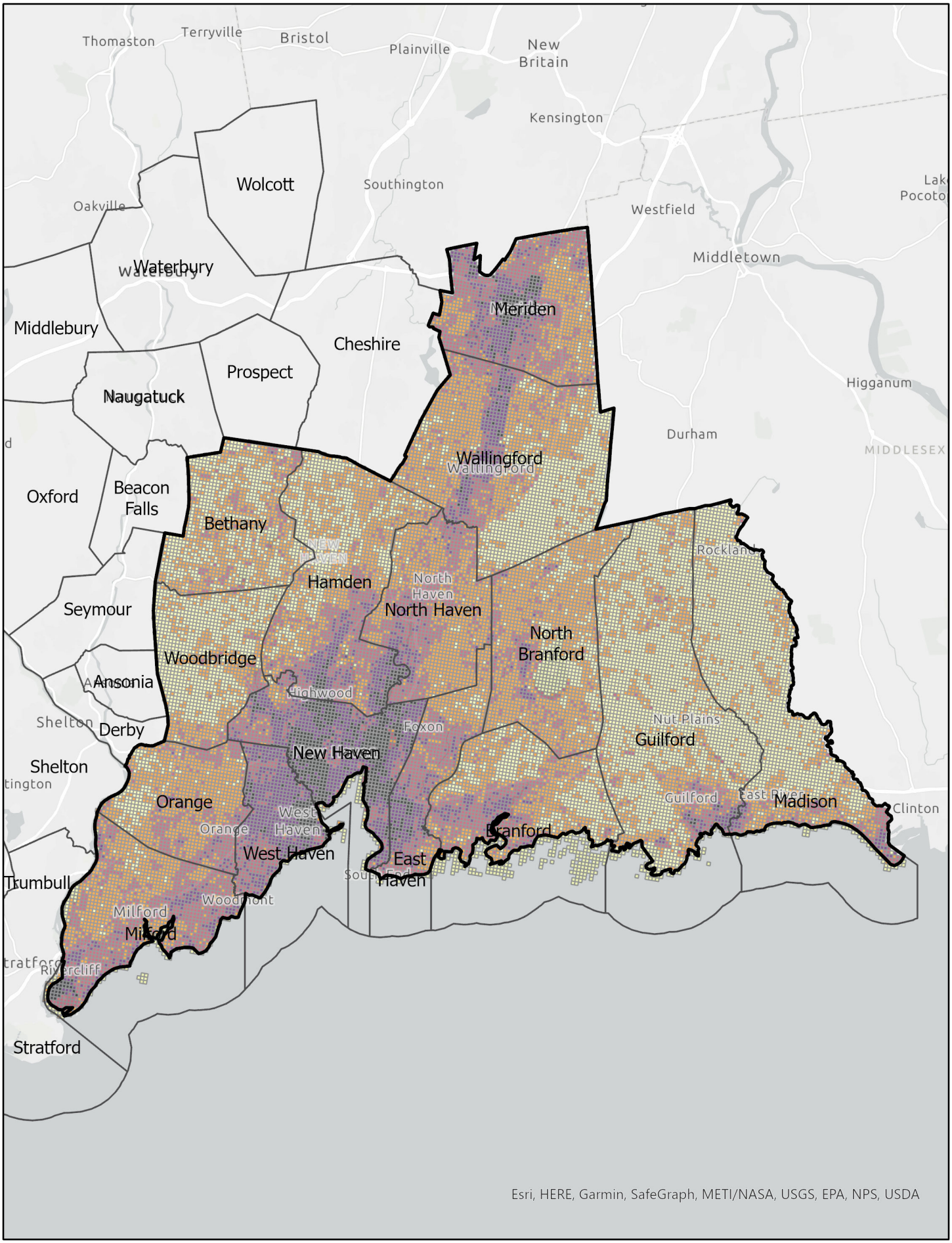
High | Moderate | Low

Moderate-High | Moderate-Low

N

0 1 2

Miles



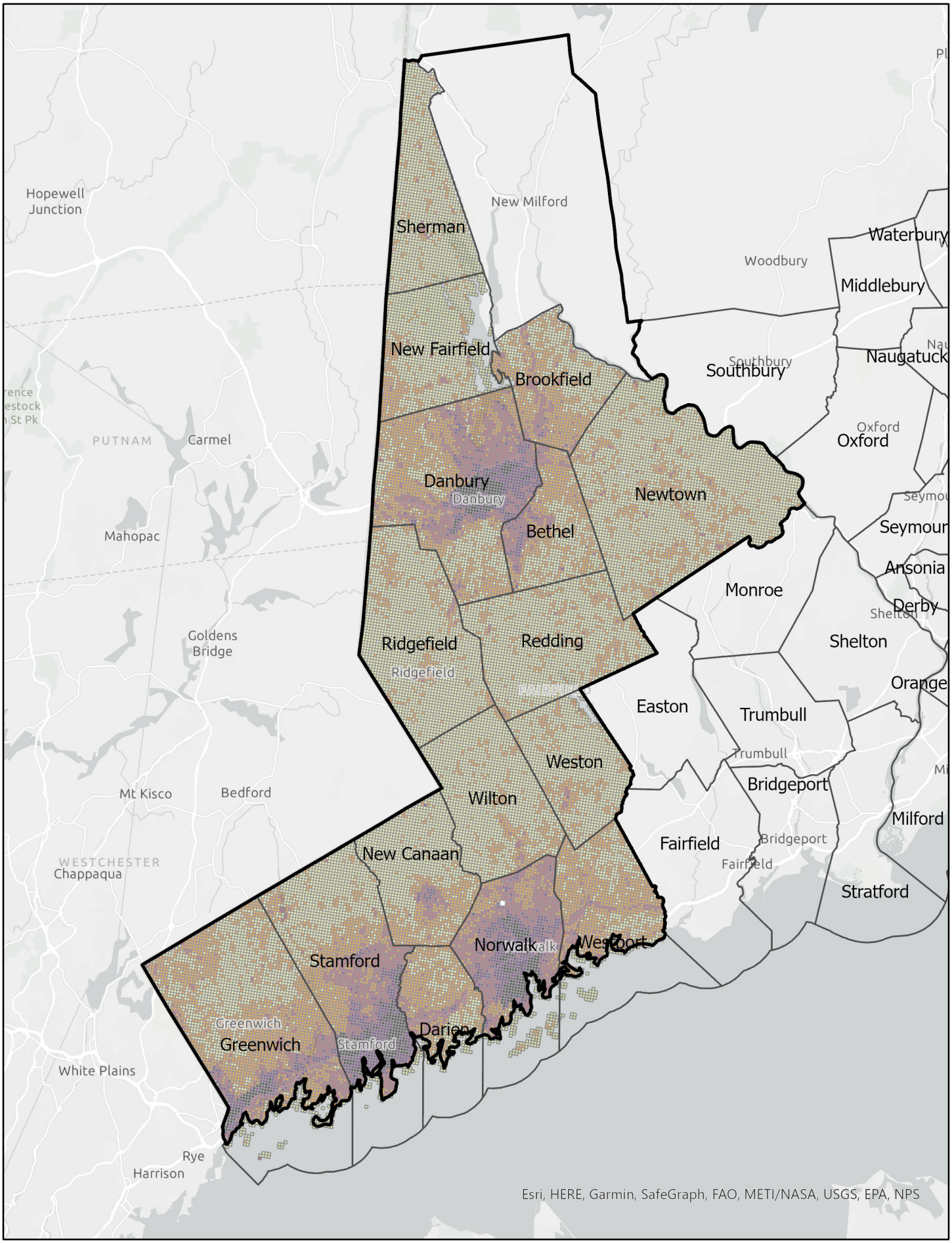
Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

Heat Vulnerability
SCRCOG

High
Moderate
Low
Moderate-High
Moderate-Low

N

0 1 2
Miles



Heat Vulnerability
WestCOG

High
Moderate-High
Moderate
Moderate-Low
Low

N

0 1 2
Miles

7.3 MetroCOG

The 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.

7.3.1 Flood

The high flood vulnerable areas are primarily coastal with much of the Bridgeport shoreline comprised of high flood vulnerability. Riverine and inland areas are also located along Ash Creek, Pequonnock River, and the Housatonic River. Of the 96,691 parcels in the region, 13,584 are in the high flood vulnerable areas with roughly 20% of them designated for single family residential, 19% for 2-family residential, 13% is designated for 3-family residential, 11% is commercial use, and 7% is industrial. The remaining land use types vary and include uses such as vacant land, municipal, tax-exempt, and state owned.

Moderate to high flood vulnerable areas are more prominent along Fairfield and Stratford coastlines, along with larger areas of the Housatonic River and Ash Creek, as well as along the Rooster River, Bruce Brook, and Horse Tavern Brook. With moderate to high flood vulnerability covering a larger area, a total of 25,845 parcels are located in, or adjacent to, these vulnerable locations. Of these an estimated 20% are single family, 11% are condominium, 6% are 2-family, 4% 3-family and 3% commercial.

There are several indicators that identify what is primarily driving vulnerability in a certain community or area.

7.3.2 Heat

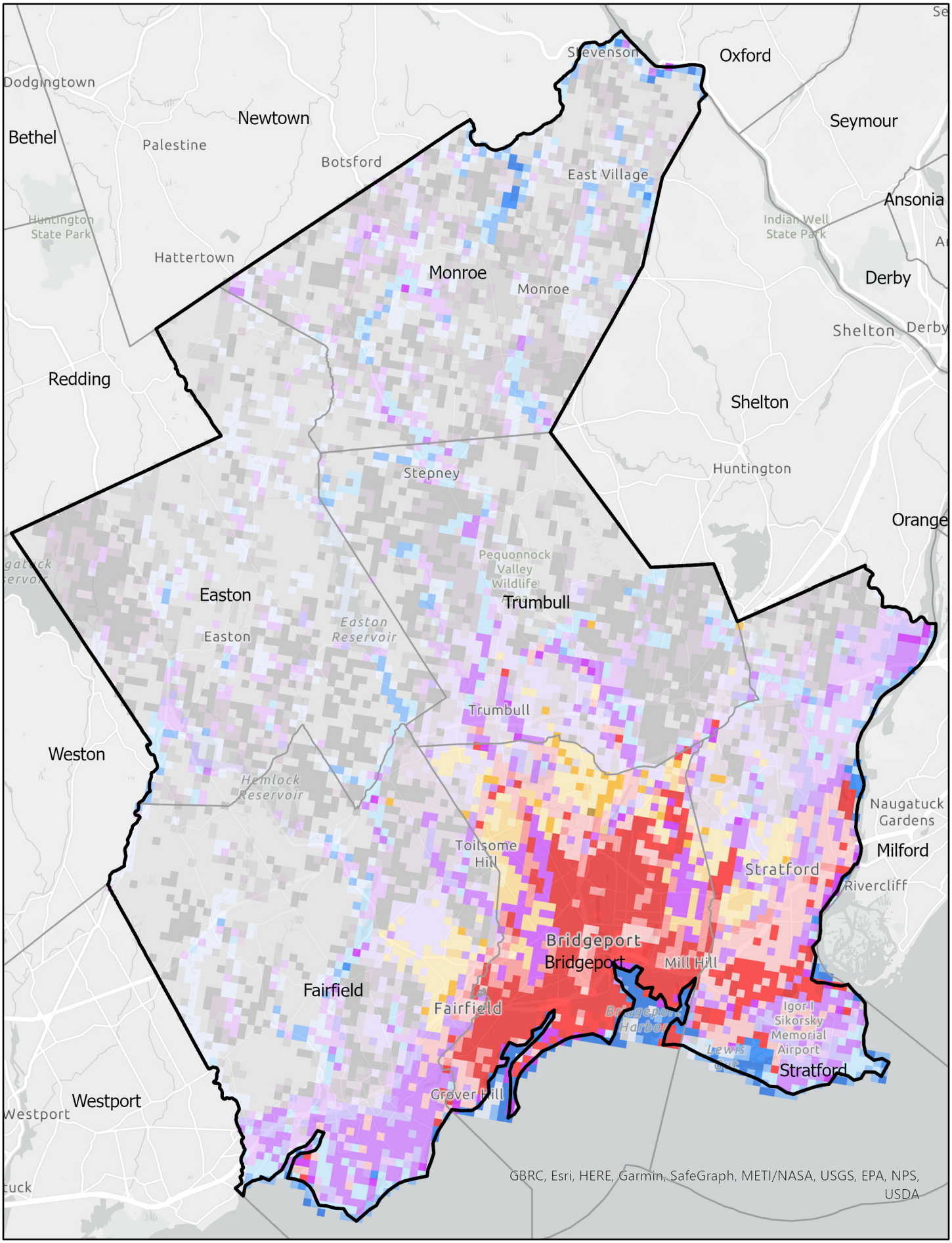
Most high and moderate to high heat vulnerable areas concentrated along the coastline, with the highest areas concentrated in southern Bridgeport stretching into bordering neighborhoods of Stratford and Fairfield. Trumbull, Easton, and Monroe are predominantly low to moderate high heat vulnerability.

The high heat vulnerable areas are comprised of 22,193 parcels; like most of the flood and heat vulnerable areas throughout the region the primary land us is residential with 37% for single family, 21% for two family, and 15% for three or four family housing. In addition to the residential, about 10% is designated for commercial, 5% for industrial, and 4% is identified as vacant land. Other uses include retail, public utility, and state-owned land.

Just over 20,000 parcels are within a moderate-high heat vulnerable area with about 35% designated for single family use, 11% being two-family of duplex, and 2 to 3% designated for three or four family use. Several others uses in these vulnerable areas include retail, apartment, and condo use. Commercial and industrial uses comprise about 3 to 4% of the area.

7.3.3 Combined

A majority of the combined vulnerability, which is conveyed with the red shaded areas in Figure 26, is centered around the City of Bridgeport, with some areas in southcentral Stratford. The remaining areas shown in this figure are either high flood/low heat (blue), high heat/low flood (orange), moderate flood and heat (purple), with grey areas representing low flood and heat vulnerability. In the moderate to high heat areas the majority land use if residential.



Combined Heat & Flood Vulnerability

MetroCOG

N

0 1 2

Miles

7.4 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 analysis. 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.

7.4.1 Flood

The high flood vulnerability areas are centered around the confluence of the Housatonic and Naugatuck Rivers, as well as upstream of the confluence along the Naugatuck River into Seymour. There are also several high flood vulnerable areas in Waterbury along the Mad River, small areas of the Naugatuck River, and in various locations in Wolcott along the Mad River and several tributaries. These highly vulnerable locations in Wolcott are not contiguous (in comparison to other areas in NVCOG) and are somewhat scattered throughout the town.

There are approximately 152,135 parcels in the thirteen communities, approximately 2,298 are located in a high flood vulnerable area. Of the vulnerable parcels roughly 58% are residential, 14% are undeveloped, 11% is for commercial use, and community features, industrial and recreational use are each about 4%. The remaining include other uses such as utilities, right-of way, vacant, or agricultural. In addition, there are two parcels that are identified as "resource extraction" in the high flood area. One is located in Seymour along route 8, the other in Southbury on Roxbury Road.

The moderate to high flood vulnerable areas span from Shelton to Waterbury along the Naugtuck River, upstream along the Housatonic into Oxford, and along several Naugatuck River tributaries such as Little River, Bladens River, Spruce Brook, and Hockanum Brook.

There are about 9,278 parcels within the moderate to high flood vulnerable areas of the NVCOG study region. Of these, 63% are residential, 17% is undeveloped, 7% is commercial, with 2% of each recreational, industrial and community facility land uses. Other types include agricultural, vacant and right-of-way.

7.4.2 Heat

Moderate to high heat vulnerable areas in the NVCOG region are centered in Derby, western Ansonia, Waterbury, Naugatuck, and northeastern Seymour. The City of Waterbury has the high density of heat vulnerable areas, with the downtown area being the highest in the region. There are 8,216 parcels in the high heat vulnerable areas of the region. Of these approximately 73% are residential, 14% are undeveloped, and 7% are commercial. The remaining uses include uses such as community features, industrial, and recreational.

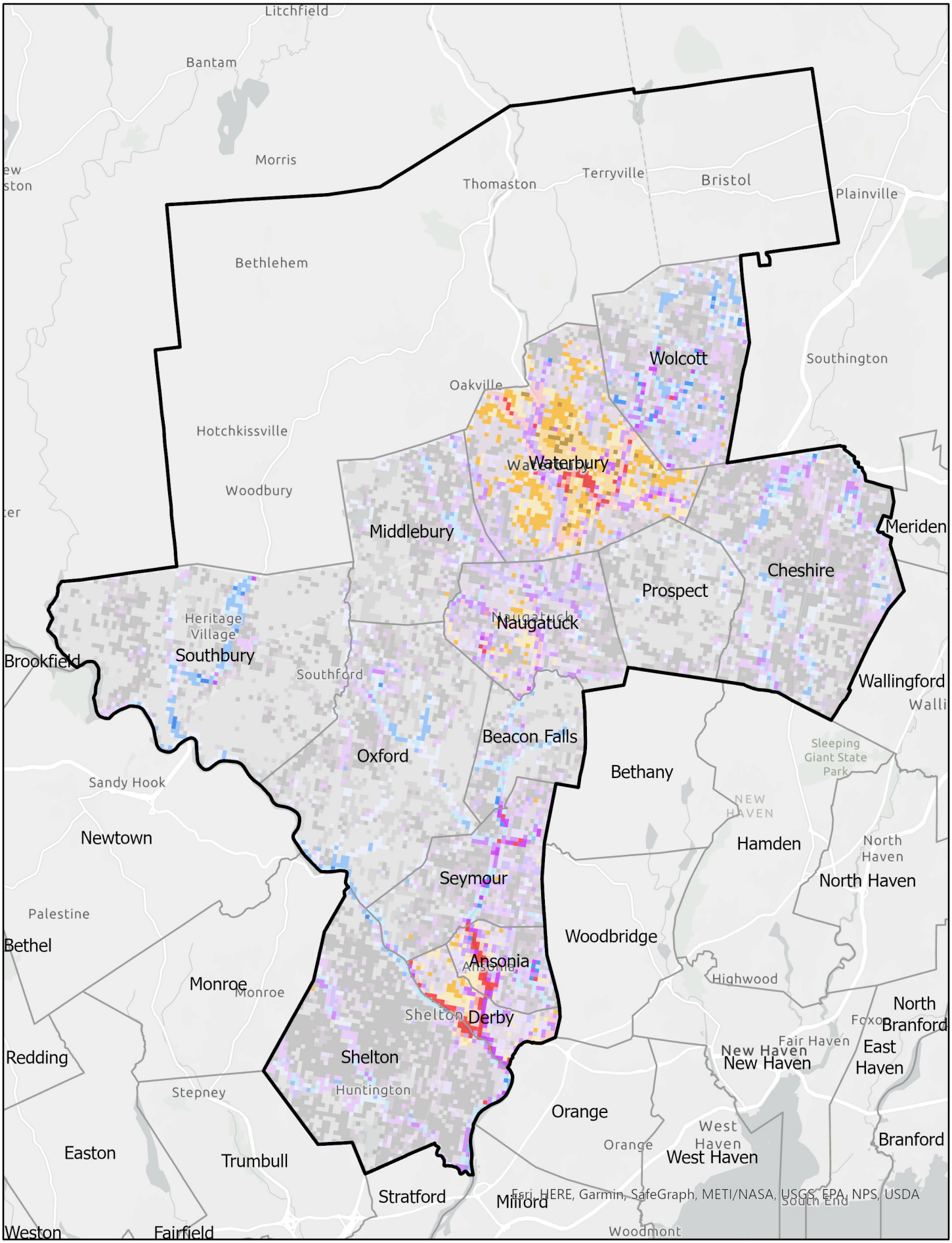
There are over 19,500 parcels within moderate to high heat vulnerable areas again with those being predominantly residential land use at 79%. The remaining land uses in this moderate to

high area include 11% undeveloped, 5% commercial, and about 1% each of community features, industrial, and recreational.

7.4.3 Combined

Most of the land in the NVCOG region can be classified as low flood and low heat vulnerability (Figure 27), but small pockets of high combined flood in heat are present. These areas are concentrated along the Naugatuck River from Ansonia into Derby, along the east bank of the Housatonic River in Derby, and in downtown Waterbury. Much of the City of Waterbury is highly heat vulnerable, with areas of both moderate heat/flood throughout.

Other notable highs include high flood/low heat along the Pomperaug River in Southbury, moderate flood/heat and high flood/low heat patches in Wolcott and Naugatuck, high flood along the Housatonic River, and some high flood areas in Oxford.



Combined Heat & Flood Vulnerability

NVCOG

N

0 1 2

Miles

7.5 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.

7.5.1 Flood

Much of the high flood vulnerable area in the region is concentrated along the coastline in West Haven, New Haven, East Haven, and Branford. The high flood vulnerable areas also extend upstream from the sound along the Quinnipiac, Mill, and West Rivers. In addition to these areas, there are smaller highly vulnerable areas in Guilford and Madison along the shoreline, as well as along smaller inland streams.

There are over 182,000 parcels throughout the SCRCOG region and about 10,826 are in a high flood vulnerable area. Roughly 70% of these parcels are designated as residential land use, 8% are condominiums, and commercial and industrial are each roughly 6%. Other land use types include open space, institutional, mixed-use or right-of-way.

Areas of moderate-high flood vulnerability can be found consistently along the coast of all shoreline municipalities in the SCRCOG region with these areas reaching father inland from the coastline in comparison to highly vulnerable areas. Moderate-high areas are also found more consistently along the Quinnipiac River corridor and along several other smaller inland streams. Overall, moderate-high flood vulnerability spans a greater area than the high areas.

There are approximately 44,501 parcels located in moderate-high flood vulnerable areas. Of these, roughly 80% are residential, 4% are condominiums, 4% are commercial, followed by small areas of land uses such as open space, institutional, and industrial.

7.5.2 Heat

Heat vulnerability is highest in the City of New Haven with several other high areas in downtown Meriden, along route 15 in Wallingford, West Haven, East Haven, southern North Haven and Hamden, and small pockets in Guilford.

Over 21,100 parcels are encompassed by high heat vulnerable areas with over 75% of these designated for residential use. In addition, 8% is designated specifically for condo use, about 6% is commercial and about 2% of industrial, and 2% for mixed-use.

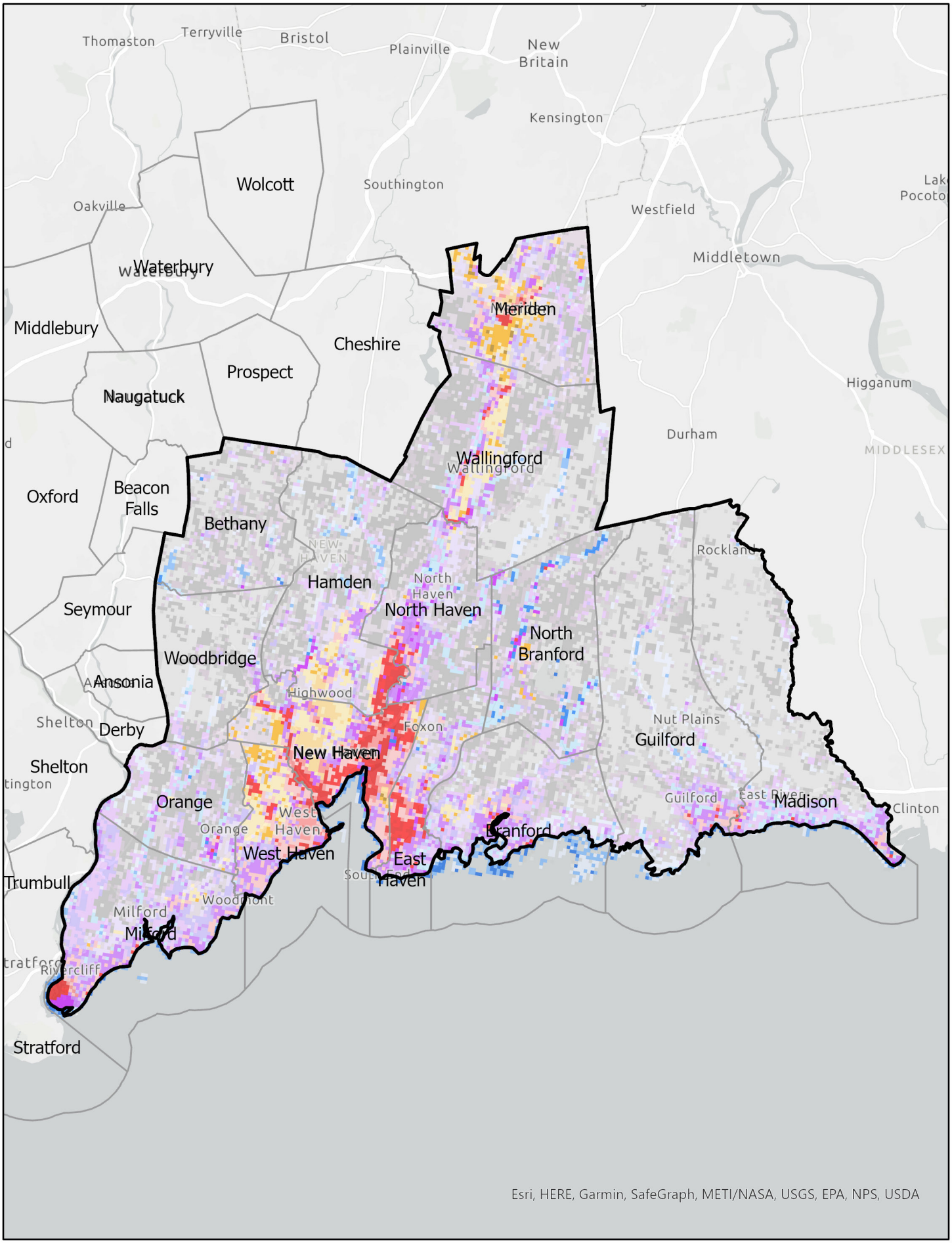
Almost twice as many parcels are within a moderate to high heat vulnerable area; 77% of these are designated for residential land use. About 6.5% are designated for condo use, 6% for commercial and 2.5% for industrial.

7.5.3 Combined

Most of the high and moderately vulnerable areas in the SCRCOG region are concentrated along the shoreline, or along the I-91 corridor. New Haven (along the West River and up the Mill and Quinnipiac Rivers) and similar riverine areas of Hamden and North Haven have some of the

highest concentrations of combined vulnerability. A concentrated area of combined vulnerability on the New Haven/East Haven border encompasses Tweed Airport and marsh areas. Wallingford and Meriden have small pockets of combined vulnerability, but these areas are less prominent than those found to the south. The southwest Milford border just at the mouth of the Housatonic River also has some high combined vulnerability (consistent with tidal marshes having high heat scores) as well as moderate flood/heat.

Figure 28 shows high heat/low flood in most of the remaining parts of New Haven as well as northern West Haven, along I-91 in Wallingford north into the center of Meriden. This trend coincides with the level of development in these municipalities and along major routes. Many of the streams and rivers found throughout the region are moderately flood/heat vulnerable, with some areas of high flood/low heat in North Branford, North Haven, and Hamden.



Combined Heat & Flood Vulnerability

SCRCOG

N

0 1 2

Miles

7.6 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,

7.6.1 Flood

The high flood vulnerable areas are found along the southwest shoreline of Greenwich, Stamford coastline, the Noroton River, Norwalk coastline, and the Still River and Kohanza Brook in Danbury.

Moderate-high flood vulnerable areas are located along most of the shoreline in Greenwich, Stamford, and Norwalk, as well as the Holly Pond and eastern Tokeneke areas in Darien. In addition, moderate-high areas are found along many of the larger and smaller streams in the region including the Norwalk River, Fivemile River, Still River, Sympaug Brook, and Limekiln Brook.

7.6.2 Heat

High heat vulnerability is centered around the more urbanized areas. Some of these neighborhoods include:

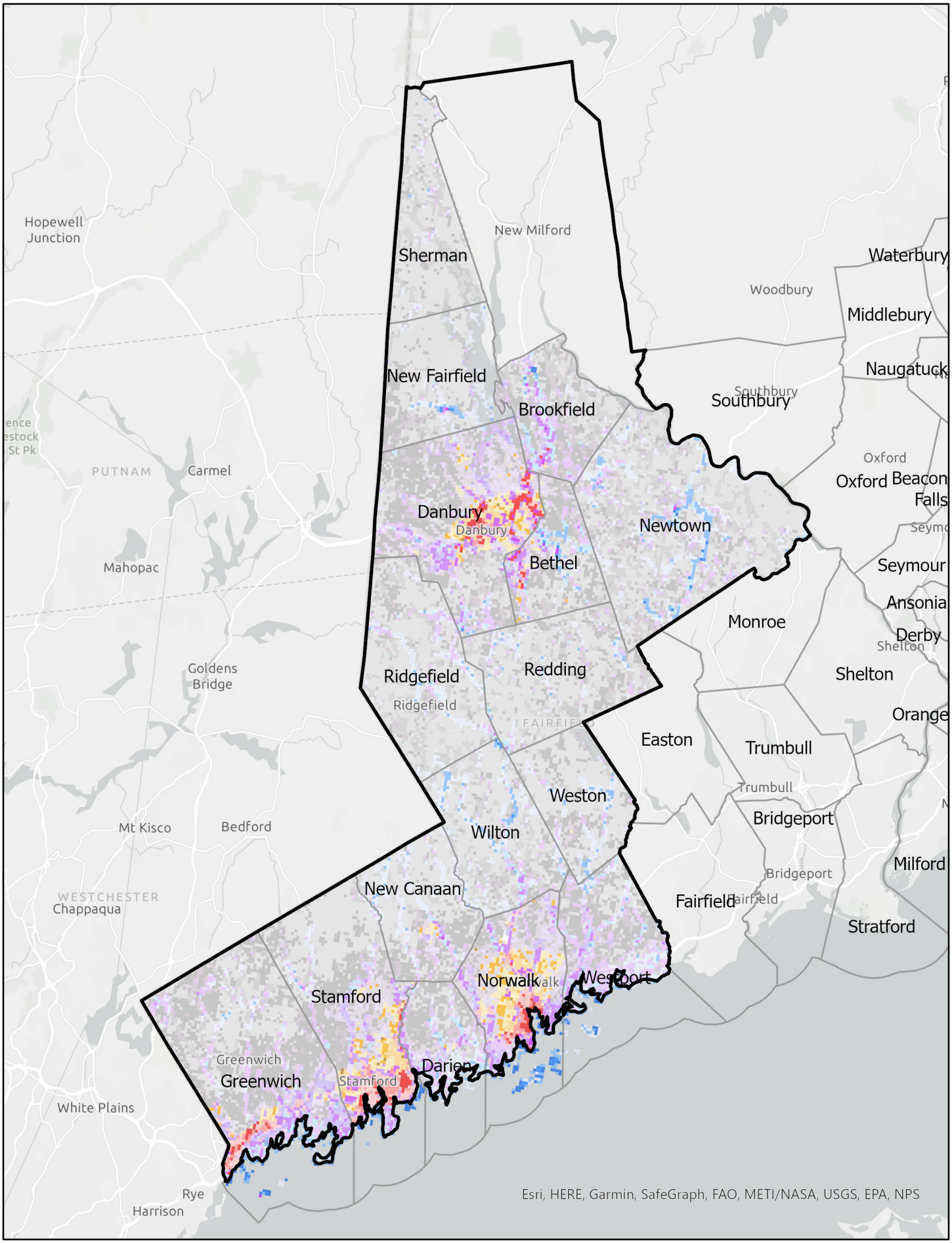
- Danbury in
    - City Center,
    - Western Connecticut State University, and the
    - Rose Hill Avenue neighborhoods; South and East Norwalk, ,
- Norwalk
    - South Norwalk
    - Liberty Square
    - Main St./Cross St.
- Stamford
    - Downtown
    - East Side
    - West Side
    - Cove
    - Portions of Glenbrook and Springdale
- Greenwich
    - Byram
    - Downtown West

Moderate heat vulnerable locations radiate into the adjacent neighborhoods in these communities, in addition to a New Canaan center which is found to have moderate to high heat vulnerability.

7.6.3 Combined

As shown in Figure 29, much of the combined vulnerability is concentrated in downtown Danbury east of I-84, along Norwalk Harbor, the shoreline of Stamford, and southwestern Greenwich along I-95. These combined vulnerable areas are primarily encompassed by either moderate flood/heat areas or high heat/low flood. Particularly Stamford, Norwalk, and Danbury have pronounced high heat areas to the surrounding combined high areas.

Similar to SCRCOG, moderate flood/heat vulnerability and high flood/low heat can be found concentrated along rivers and streams throughout the region. Pronounced high flood/low heat can be found in Wilton along Comstock Brook and Norwalk River, and in Newtown along the Pootatuck River. Brookfield, Westport, and Darien all have significant areas of moderate flood/heat vulnerability.



Combined Heat & Flood Vulnerability

WestCOG

N

0 1 2

Miles

8 TOD and Future Development Areas analysis

Transit Oriented Development (TOD) as defined by the Connecticut General Statutes, Section 13b-79o is *the development of residential, commercial, and employment centers within one-half mile of walking distance of public transportation facilities, including rail and bus rapid transit and services, that meet transit supportive standards for land uses, built environment densities, and walkable environments, in order to facilitate and encourage the use of those services.*[11]

Areas throughout the region with TOD potential, i.e., a functioning, planned, or potential passenger railroad station, serve as potential resilience opportunity areas that support greenhouse gas reduction strategies, encouragement of transit supportive land uses, increased used public transportation systems, and enhanced regional economies.

While only a select number of municipalities have developed TOD plans, all throughout the region have developed a Plan of Conservation and Development (POCD) in accordance with Connecticut State Statute. A POCD oftentimes describes areas within a community that are targeted for a certain type of development or redevelopment project. To identify potential project linkages between municipal plans and resilience efforts, these planned development areas have been identified, reviewed, and spatially mapped.

Appendix D provides a detailed review of the current state of TOD and future development planning efforts.

8.1 TOD Area Vulnerability Analysis

Climate change considerations are being incorporated into TOD plans throughout the region. Various efforts are being made to better understand TOD climate vulnerabilities and risks; this includes the UConn study which addresses TOD challenges and opportunities.[12]

To understand the present vulnerability surrounding established and planned TOD areas, the CCVI and ZSRs have been used to evaluate the various vulnerabilities, the type of risk (if any) present, and the stakeholders within the TOD area that should be involved in project development.

8.1.1 CCVI Analysis for TOD Areas

With the State defining a TOD area as 0.5 miles surrounding a public transportation facility, Resilient Connecticut has opted to analyze the vulnerability within a 0.75-mile buffer to account for potentially expanded TOD development in any of the areas. The use of this buffer allows for CCVI statistics to be summarized to evaluate to vulnerability throughout the TOD area.

In addition to overall vulnerability, each TOD area has been evaluated for its score of sensitivity, exposure, and adaptive capacity. The inclusion of these statistics aid in identifying what is

[11] https://portal.ct.gov/DOT/Transit-Oriented-Development/Transit-Oriented-Development-Home-Page
[12] https://resilientconnecticut.uconn.edu/tod/

potentially driving a vulnerability in the area. Of course, each of the three components can be broken down further into indicators which narrow down the vulnerability driver into specific categories.

The following analysis has been done on all TOD areas in each of the four COGs, including potential and planned for TODs. Summary statistics for overall heat and flood vulnerability, heat and flood components, and their relative indicators have been developed. The breakdown of each component into indicator scores provides a more detailed understanding of what is driving a potential increase in exposure or sensitivity, or perhaps where adaptation may be needed. To further understand an indicator, the specific mean score for each contributing factor in a specific TOD can be found in Appendix E.

8.1.1.1 MetroCOG

There are six TOD areas in the MetroCOG area, one of which, the P.T Barnum Station, is a potential site with the other five already established and operating. In general, the Bridgeport TOD has the highest composite CCVI flood vulnerability, and the potential Barnum site currently has the highest heat vulnerability. However, given that the Barnum TOD has not yet been developed, there is an opportunity to address some of the current heat and flood related challenges in the area.

The Southport station has the *lowest* overall heat vulnerability while the Fairfield area has the lowest flood vulnerability (Figure 30). Although these two TODs have the lowest vulnerabilities in the MetroCOG area, that does not indicate a lack of flood or heat risk; it simply implies either stronger adaptive capacities or less sensitivity and exposure. There is likely a challenge each TOD can address to reduce either heat or flood vulnerability. The subsequent figures and narrative outline some of the strengths and weaknesses of the TODs in the MetroCOG region in relation to the CCVI results.

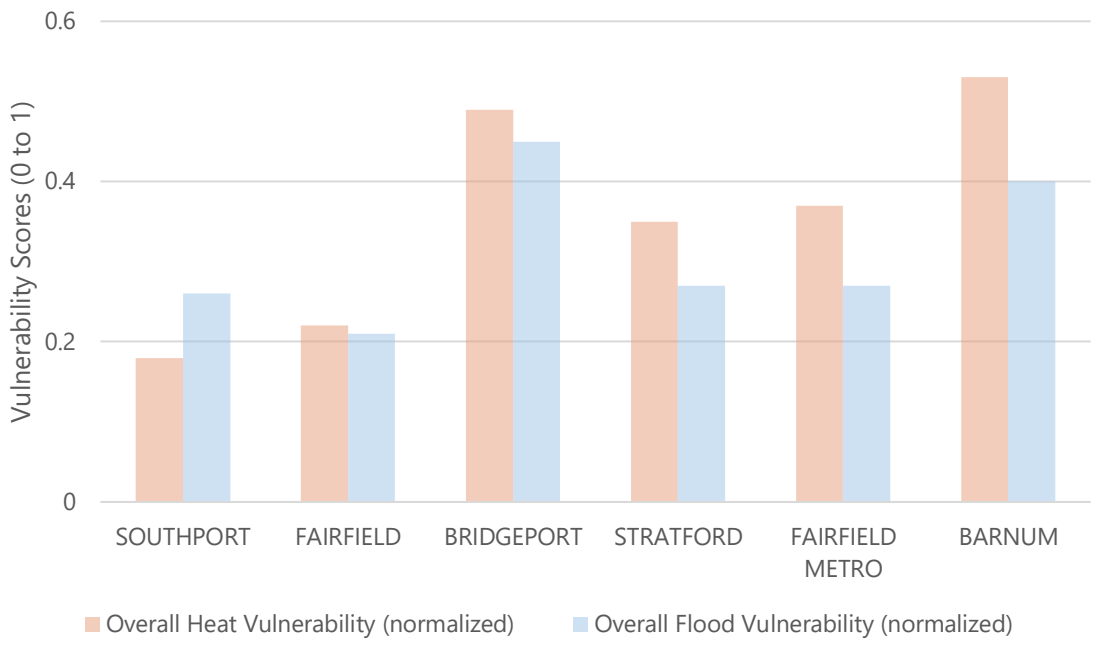


FIGURE 30: METROCOG TODS OVERALL HEAT AND FLOOD VULNERABILITY SCORES

Flooding is a concern among most MetroCOG TOD areas as many are situated within proximity to a river or the coastline. As see in Figure 31 the Bridgeport TOD is the most vulnerable to flooding (0.45), while the Fairfield Downtown TOD has the lowest flood vulnerability (0.21) of the six TODs in the MetroCOG area. Although, flooding *does* occur in the downtown Fairfield[13] area due to a lack of sufficient drainage conveyance infrastructure combined with high imperviousness. Across all six TODs most have moderate to high overall flood vulnerability, with the greatest variation among the sensitivity scores. The P.T. Barnum station scores high for vulnerability with the second highest overall flood score and the highest sensitivity score. This presents an opportunity to address the flood related vulnerabilities in conjunction with any heat vulnerabilities.

While only Fairfield has adaptive capacity as their highest scoring component, Southport, Stratford, and Fairfield Metro all have strong adaptive capacity in relation to their exposure and sensitivity; the two Bridgeport TODs have lower adaptive scores. By identifying the driving indicators of these low adaptive scores, development or redevelopment plans can incorporate certain strategies to increase adaptation.

[13] Refer to the Downtown Fairfield Green Infrastructure Plan, 2018

FIGURE 31: METROCOG TODS OVERALL FLOOD VULNERABILITY AND COMPONENT SCORES

Specific indicator scores, seen in Figure 32, shows the Bridgeport TOD area having relatively high sensitivities, in addition to the second highest climate exposure. This ultimately equates to this 0.75-mile area having vulnerable populations, infrastructure in flood prone areas, ecosystems that are vulnerable to flood impacts, with an increased risk of flooding. In addition, the area has lower ecological and social adaptive capacity, but has a higher built adaptive capacity; this indicates close proximity to shelters, medical facilities, or access to major roadways for evacuation purposes.

Across all TOD areas, all six have higher ecological sensitivity and *low* ecological adaptive capacity. This indicates potential for natural mitigation strategies that can leverage what little resilient ecosystems are present throughout the areas. One positive indicator shows all areas having relatively high built adaptive capacity, enabling businesses and residents' closer access to medical care, shelters, or main roadway access.

While physical and climate exposure are not the highest scores in the region, by identifying the specific contributors that are driving the exposure, these too can be addressed in development plans to mitigate flood impact and reduce TOD vulnerability.

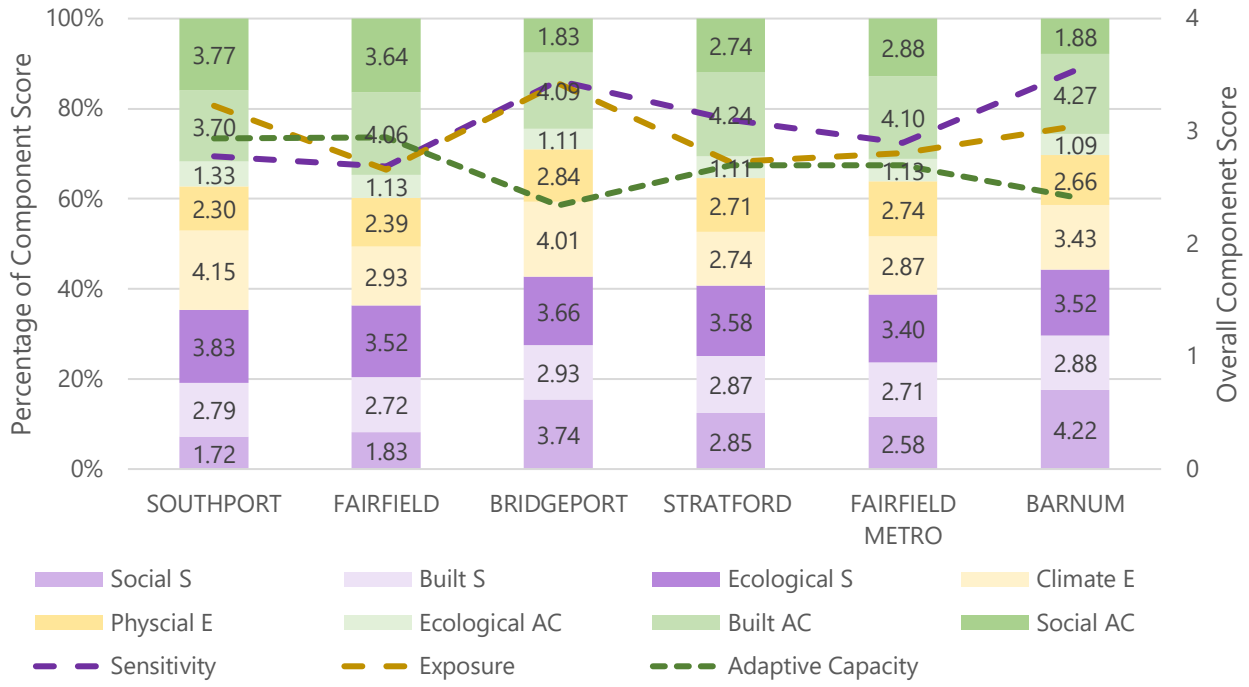


FIGURE 32: METROCOG TODS FLOOD COMPONENT AND INDICATOR SCORES

Of the five TODs that are *developed*, the Bridgeport TOD has the highest overall heat vulnerability (0.49) with Southport having the lowest (0.18); these scores can be explored in Figure 33. The Bridgeport area also scores the highest for exposure and sensitivity among the five already in existence; however, the P.T. Barnum Station site *currently* has the highest overall heat vulnerability as well as sensitivity and exposure, according to the CCVI, however, this will likely change after construction. It is important to note that overall, all six of the MetroCOG TODs have relatively high exposure scores, likely due to the urbanized nature of the locations. The Southport TOD scores the *lowest* for both exposure and sensitivity and is a marginal runner up for highest adaptive capacity.

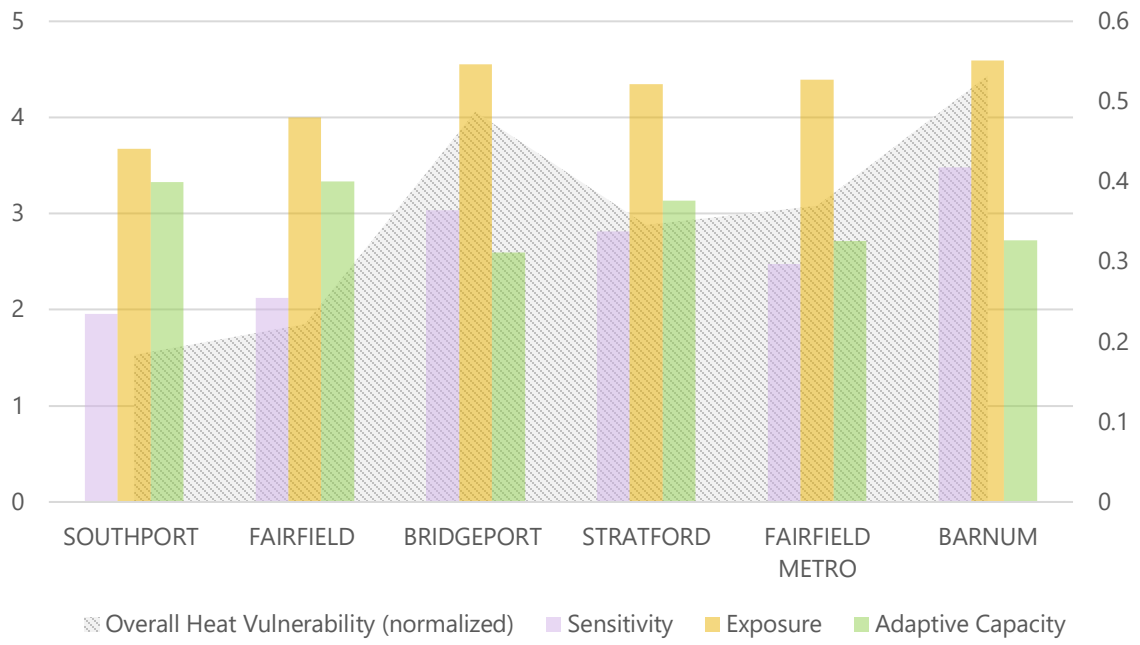


FIGURE 33: METROCOG TODS OVERALL HEAT VULNERABILITY AND COMPONENT SCORES

Figure 34 shows the indicator scores for each area. Bridgeport TOD, the most vulnerable area currently developed, scores the highest for physical exposure and social sensitivity. This indicates a high level of developed area with structures emitting increased levels of heat, as well as populations that are more vulnerable to impacts of extreme heat events. In addition, adaptive capacity is low with the lowest level of ecological or social adaptive capacity across the five developed stations.

This analysis presents a unique opportunity to identify how to develop the P.T. Barnum station with certain vulnerabilities in mind. With this station area currently scoring highest for overall heat vulnerability, exposure, and social sensitivity, development and redevelopment plans should take into consideration the contributing factors driving this vulnerability and address them to mitigate increased heat impacts to the surrounding area. Plans can focus on design elements to reduce exposure and increase adaptive capacity.

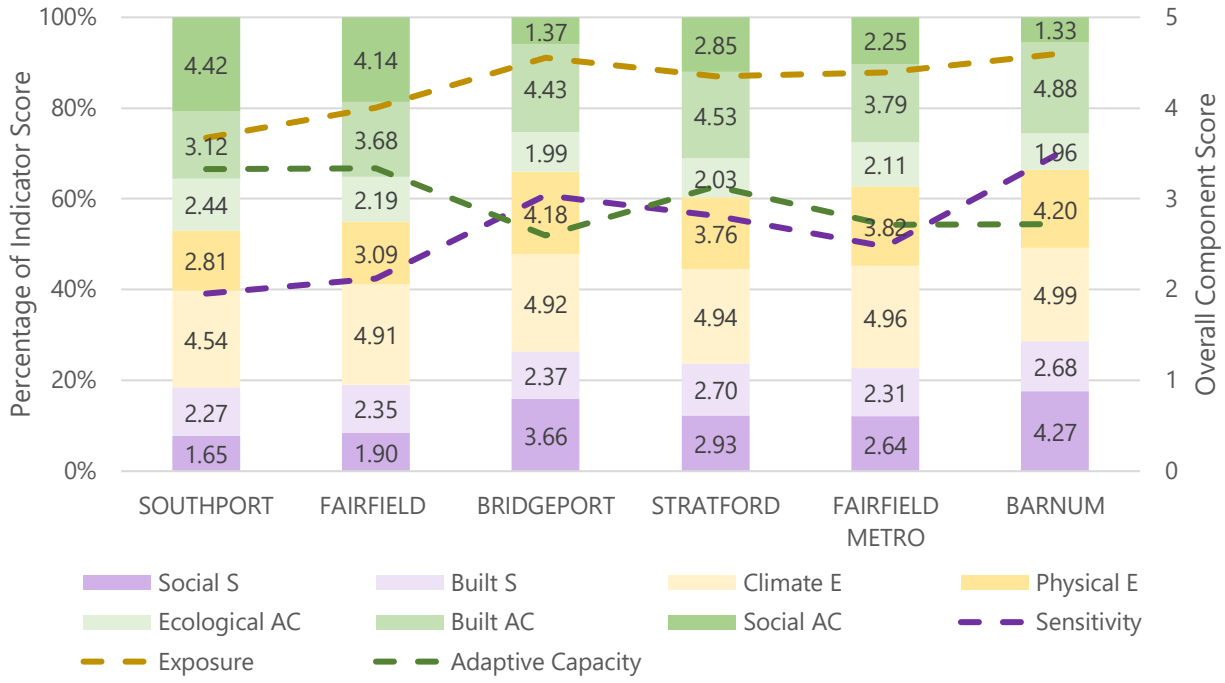


FIGURE 34: METROCOG TODS HEAT COMPONENT AND INDICATOR SCORES

8.1.1.2 NVCOG

The landlocked NVCOG region has a total of six TOD areas[14], all of which are developed in proximity to the Naugatuck River. It is important to note that the Naugatuck River has a flood control system that has been taken into account during the CCVI development. While this system reduces flood risk in some areas, there may be other areas that are not as protected or vulnerable to other types of flooding such as pooling from poor drainage. Furthermore, residual risk is always present on the protected side of a flood protection system.

As seen in Figure 35, the Derby/Shelton TOD area has the highest composite flood vulnerability (0.32), and the Waterbury TOD area has the highest heat (0.41); the Derby/Shelton area has the second highest heat vulnerability (0.35) as well. Beacon Falls TOD area has both the lowest flood and heat vulnerability with scores of 0.15 and 0.13 respectively, with flood slightly outweighing heat vulnerability. Seymour is the only other TOD area throughout the region where flood vulnerability outweighs heat vulnerability. Despite proximity to the Naugatuck River, the Naugatuck TOD area has the second lowest flood score (0.16).

[14] Community planners have discussed a potential relocation of the Seymour rail station, but for the purpose of this document, the potential new location is not considered a potential TOD.

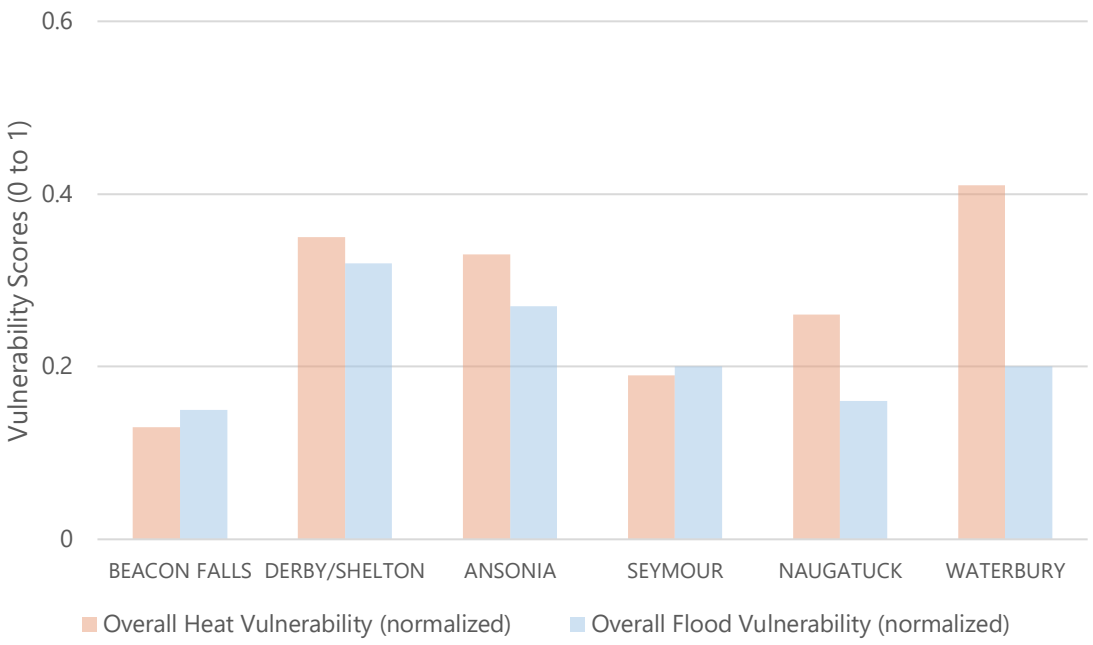


FIGURE 35: NVCOG TODS OVERALL FLOOD VERSUS HEAT VULNERABILITY SCORES

Flood sensitivity outweighs flood exposure throughout the TODs in the NVCOG region (Figure 36). The Derby/Shelton area has both the highest sensitivity and exposure score, and is the second least adaptive, with Ansonia being the first. Both of these TODs have the significant differences between sensitivity and exposure scores; the other four TODs have relatively similar sensitivity scores. Exposure and adaptive scores are relatively consistent across all six TODs with Naugatuck TOD being the most flood adaptive.

In general, all TODs in NVCOG have a higher sensitivity than exposure relative to flooding. It is important to note that while the Naugatuck River flood control system has been taken into account when calculating the CCVI, there are other contributing factors playing into flood exposure. While the risk of flooding may be reduced because of this system, there may be other sources of flood, such as poor drainage, or locations along the river that may not be as protected as others.

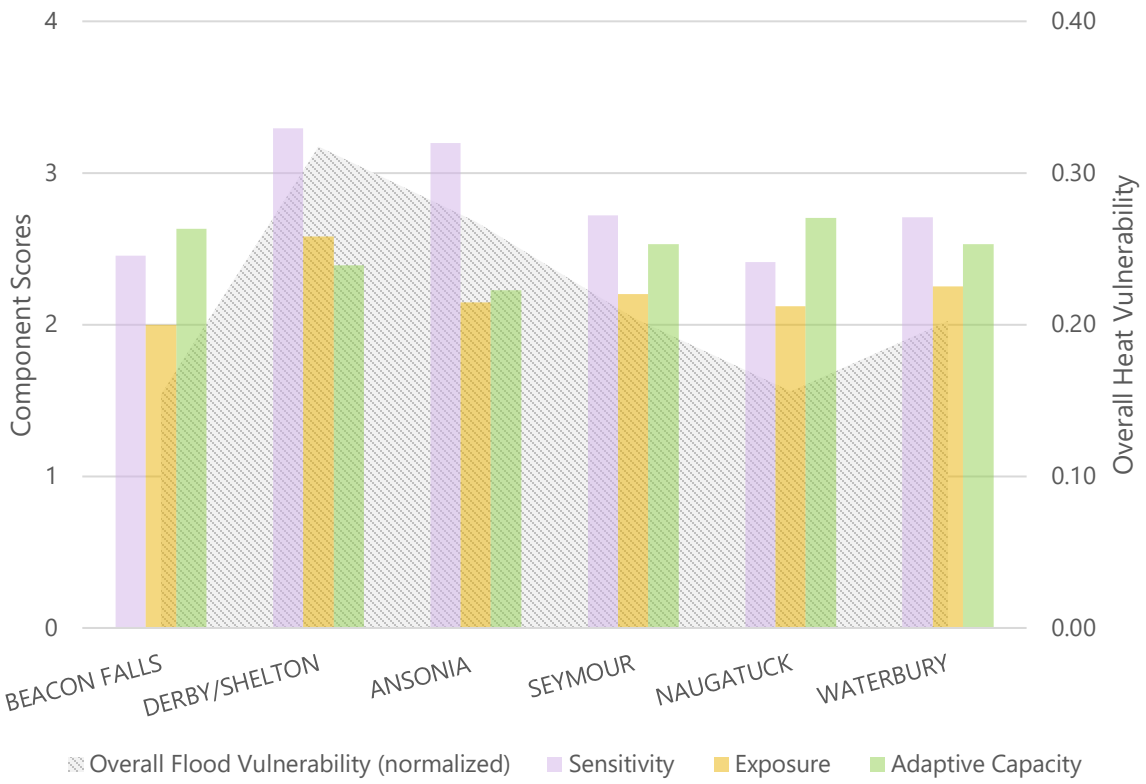


FIGURE 36: NVCOG TODS OVERALL FLOOD VULNERABILITY AND COMPONENT SCORES

The specific sensitivities in the NVCOG region vary depending upon the TOD (Figure 37)

. Naugatuck and Waterbury, according to the CCVI have similar sensitivities with both scoring highest for social and built, with low ecological sensitivities. This implies there are socially vulnerable populations in an area with infrastructure that is also vulnerable to flooding. On the other hand, the other four TOD areas score relatively high for ecological sensitivity as well as social and built. These scores add the ecological sensitivities indicating that while people and infrastructure are sensitive to flooding, ecosystems in the area may also be impacted.

Adaptive capacities vary slightly amongst the TODs with all having high built adaptive capacity and low ecological, with only two areas having low social as well; these are Ansonia and Derby/Shelton. The low adaptive score in these TODs indicates potential low numbers of flood insured properties, residents with little disposable income, or low owner-occupied housing. These factors play into a resident's ability to recover after a flood event.

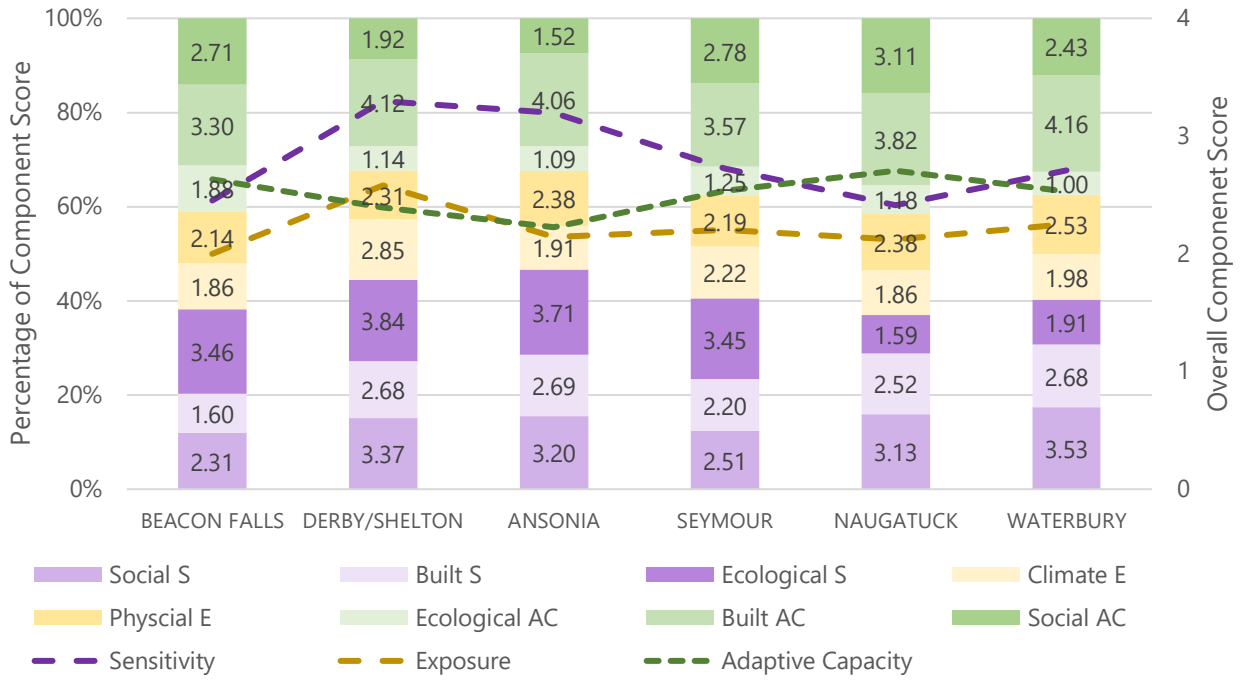


FIGURE 37: NVCOG TODS FLOOD COMPONENT AND INDICATOR SCORES

Of the six TOD areas in the NVCOG region (Figure 38Figure 35), the Waterbury area has the highest overall heat vulnerability (0.41), while the Beacon Falls TOD area has the lowest (0.13). The Waterbury station also has the highest average sensitivity and exposure score of those in the NVCOG region, with adaptive capacity being the lowest. The Beacon Falls area adaptive capacity significantly outweighs the exposure and sensitivity, with Seymour being the only other area to have a marginal, yet high adaptive capacity. While these scores do not fully express the dynamics of each TOD system, the subsequent figures and narratives provide a summary of what sensitivities are present, the type of exposure each TOD may be facing, along with some of the adaptive capacities each TOD and community has.

All six TOD areas have higher exposure than sensitivity indicating that within all areas, development is high, and temperatures have been extreme in these areas. With sensitivity scores being significantly lower than exposure, certain mitigation efforts to address the excessive heat emittance may result in less vulnerable communities surrounding these areas.

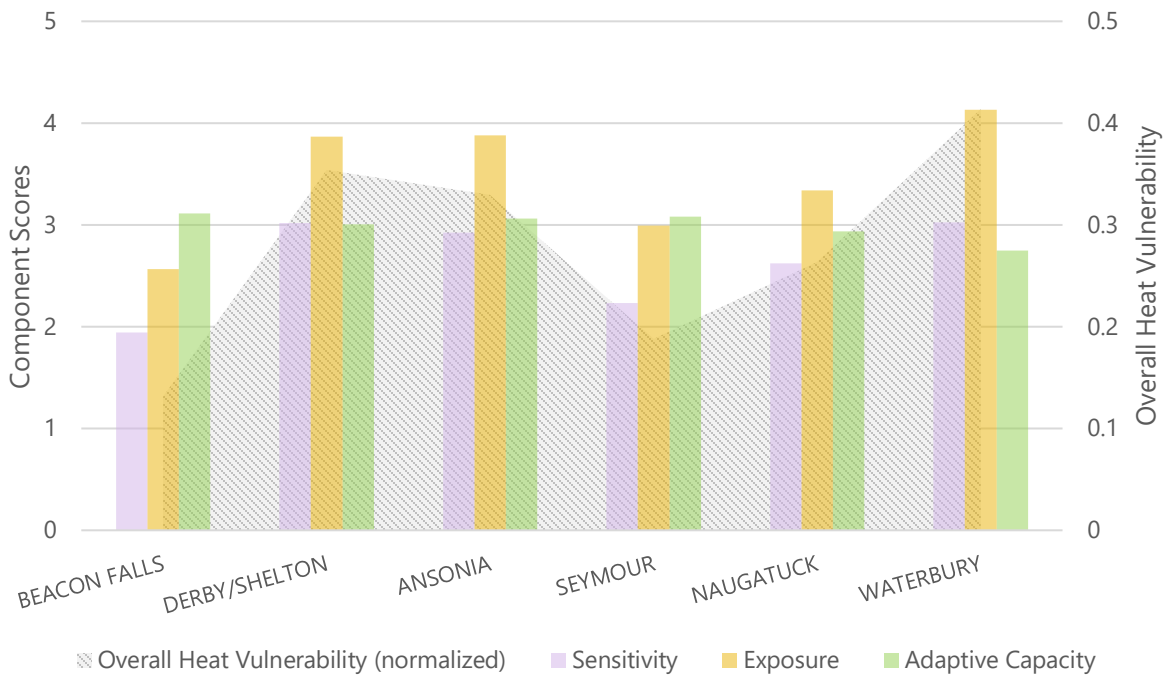


FIGURE 38: NVCOG TODS OVERALL HEAT VULNERABILITY AND COMPONENT SCORES

In particular, Derby/Shelton, Waterbury, and Ansonia have the three highest scores for climate exposure (Figure 39), equating to high maximum land surface temperatures and poor air quality. In addition to climate exposure, physical exposure is also high across these three TODs, with the addition of Naugatuck being the third highest. A high physical exposure indicates high emissivity, indicating infrastructure and buildings emitting increased levels of heat in comparison to areas with low emissivity. Therefore, a high exposure indicates higher temperatures, and a developed environment that potentially exacerbates the issue. Mitigation efforts, or redevelopment strategies, can potentially address the increased temperatures and heat emittance in the areas.

It is however important to note that while some areas have high exposure, all TOD areas in NVCOG do have higher built adaptive capacity, indicating a cooling center or medical facility within close proximity. Of the six, Beacon Falls and Seymour have moderate ecological adaptive capacity with the others scoring relatively low. A lower ecological adaptive capacity indicates a lower percent tree cover, vegetative cover, or land use type that does not necessarily aid in heat absorption. While Beacon Falls and Seymour have the two highest scores, there is likely room for all TOD areas to mitigate extreme heat impacts.

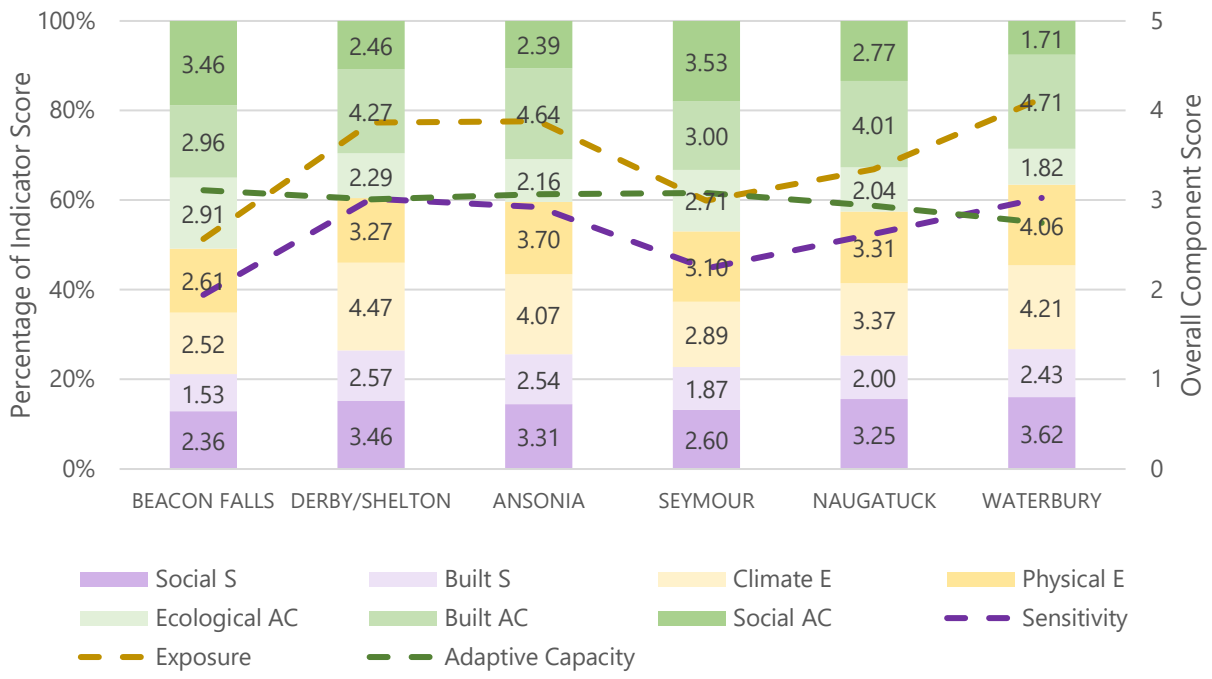


FIGURE 39: NVCOG TODS HEAT COMPONENT AND INDICATOR SCORES

8.1.1.3 SCRCOG

Eleven TOD areas are in the SCRCOG region. Two (Orange and North Haven) are planned and not yet developed. The characteristics of these TODs vary with some highly urbanized such as Union Station in New Haven, and others located in more suburban settings like Madison or Guilford.

Of the SCRCOG TODs, the Meriden area has the highest overall heat vulnerability and Union Station has the highest flood vulnerability (Figure 40). The Madison TOD has both the lowest heat and flood vulnerability. North Haven and Orange, in comparison to the existing developed TODs, both have moderate heat and flood related vulnerabilities. Incorporating some of the identified challenges into planning and development may reduce vulnerability in these areas. The subsequent figures provide more insight into some of the vulnerability drivers, with Appendix E providing scores on specific contributing factors.

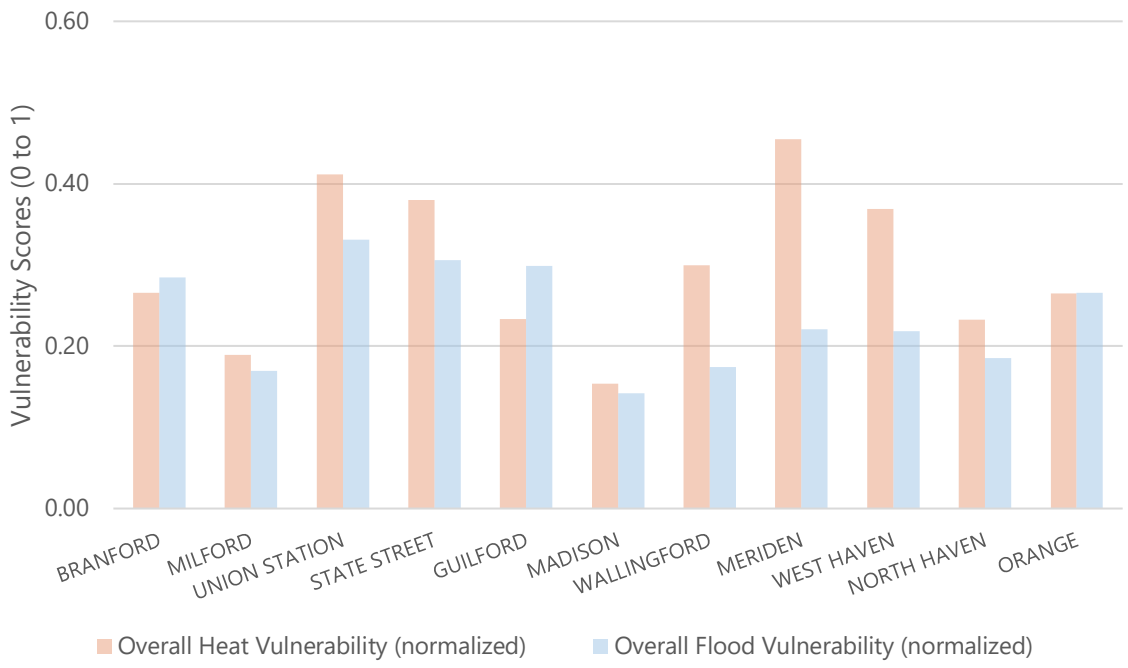


FIGURE 40: SCRCOG TODS OVERALL FLOOD VERSUS HEAT VULNERABILITY

As far as flood vulnerability is concerned, and as shown in Figure 41 Union Station in New Haven has the highest flood vulnerability (0.33) with Madison having the lowest (0.14). However, of the eleven TODs Guilford has the highest exposure, ultimately indicating an increased flood risk. The Union Station has high vulnerability due to sensitivity factors. This high score reveals vulnerable populations, infrastructure, or ecosystems. The high exposure score for Guilford indicates proximity to areas of flood risk or other physical attributes that may exacerbate flooding.

Milford, North Haven, and Madison all score highest for adaptive capacity, with West Haven, Wallingford, and Meriden having adaptive scores that outweigh their exposure. Meriden however does have the lowest adaptive score of all the SCRCOG TODs.

The potential North Haven and Orange TOD plans can leverage the CCVI data and results to address the higher sensitivity and exposure scores. Figure 42 breaks down the sensitivity and exposure scores in further detail.

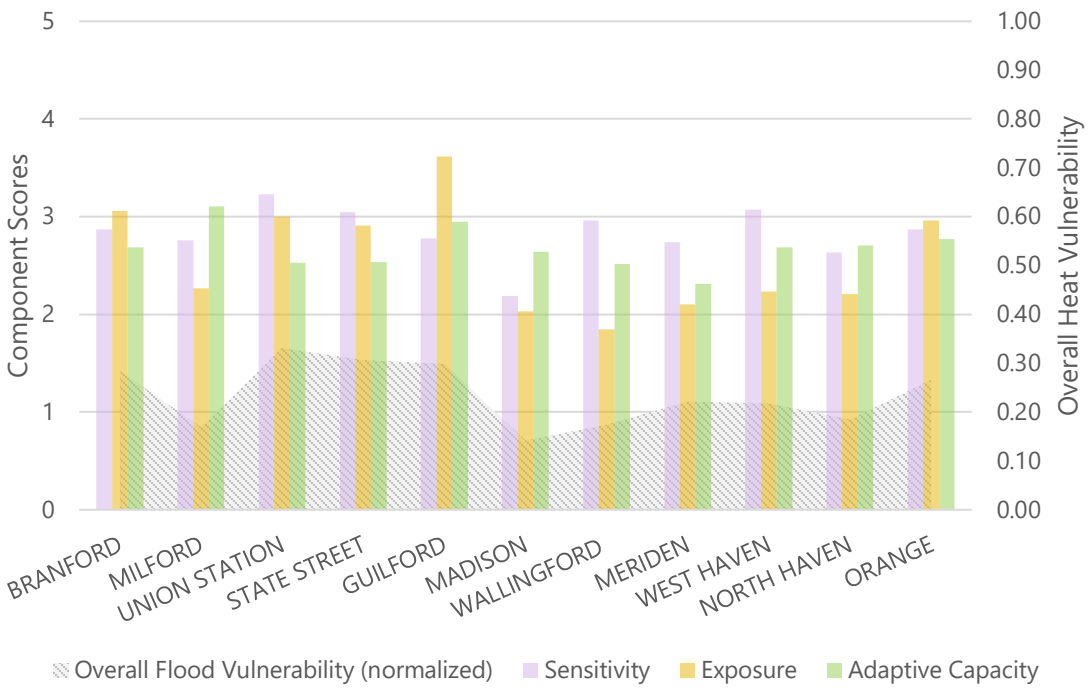


FIGURE 41: SCRCOG TODS OVERALL FLOOD VULNERABILITY AND COMPONENT SCORES

Union Station, which has the highest flood vulnerability, does not have any of the highest sensitivity or exposure indicator scores. However, all indicator scores are consistently high and outweigh adaptive capacity. Both New Haven TODs have similar high scores across the board with high ecological sensitivity, physical, and climate exposure. Both also score low for ecological and social adaptive capacity, potentially indicating lower levels of owner-occupied housing, fewer insurance policies in force, residents with little disposable income, and less resilient landscapes.

The Guilford TOD has the highest overall exposure and scores highest for both climate and physical exposure. High exposure indicates characteristics such erosion susceptibility, increased impervious surfaces, poor soil drainage, and/or within a storm surge area. All these factors combined increase the area's flood exposure.

Madison, which has the lowest overall vulnerability and one of the highest adaptive capacity scores, has strong social and built adaptive capacities, but low ecological. Strong built adaptive capacity equates to close proximity to shelters, main highway access, public utilities, or open space in flood zones. Across all TODs, ecological adaptive capacity is low indicating less resilient landscapes or, where present, lower marsh migration potential.

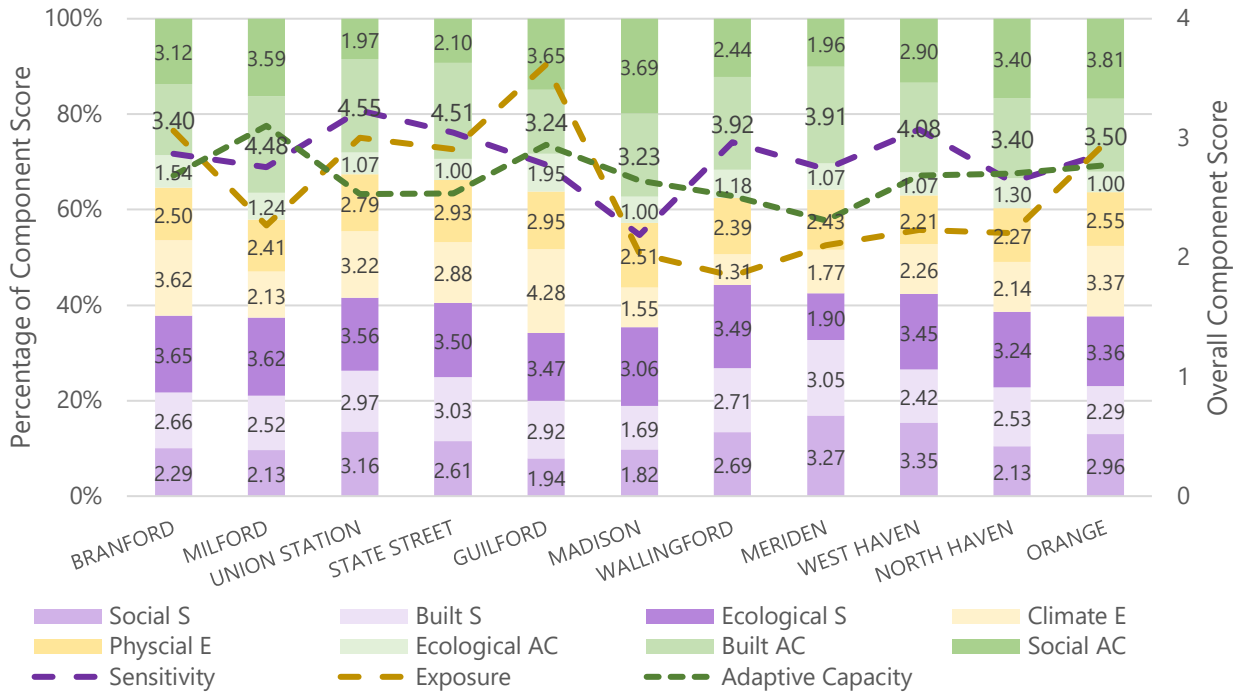


FIGURE 42: SCRCOG TODS FLOOD COMPONENT AND INDICATOR SCORES

Of the SCROCG region TODs, Meriden has the highest heat vulnerability (0.45) and Madison the lowest (0.15), as seen in Figure 43. Ten of the eleven TODs score highest for exposure, with only Madison having an adaptive capacity that slightly outweighs the exposure score. West Haven, Meriden, and Union Station in New Haven all score lowest for adaptive capacity.

With relatively high exposure scores across all TODs in the SCRCOG region, it can be interpreted that climate and development play a larger role in heat vulnerability than the social characteristics. Ultimately, development or redevelopment strategies may be able to address or alleviate some of the heat-related vulnerabilities.

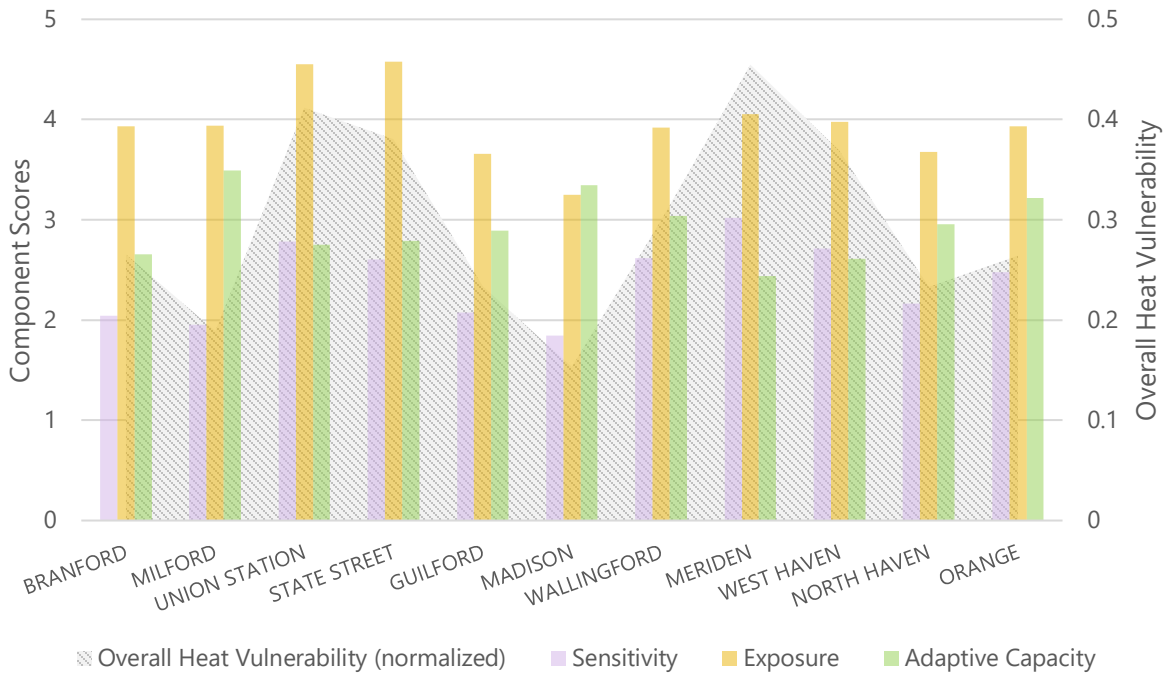


FIGURE 43: SCRCOG TODS OVERALL HEAT VULNERABILITY AND COMPONENT SCORES

While Meriden has the highest vulnerability, both Union Station and State Street stations have the highest exposure in the region (Figure 44). Both stations score the highest for physical and climate exposure, identifying high extreme temperatures, high emissivity numbers, and poor air quality. However, in comparison to Meriden, the two New Haven stations have better built adaptive capacities, with low social and ecological capacities. The high built capacity in New Haven indicates proximity to health facilities and cooling centers. Low social and ecological capacities indicate little greening in the TOD areas, populations underserved relative to health insurance, and low owner-occupied housing.

The North Haven and Orange numbers present an opportunity to address certain vulnerabilities in future design or planning standards for each TOD. Both have similar scores across the board with high climate and physical exposure and low ecological adaptive capacity. The design and development of these TODs should incorporate strategies to reduce the exposure, for example materials that have low heat emittance and increasing greening and vegetation to increase ecological adaptiveness.

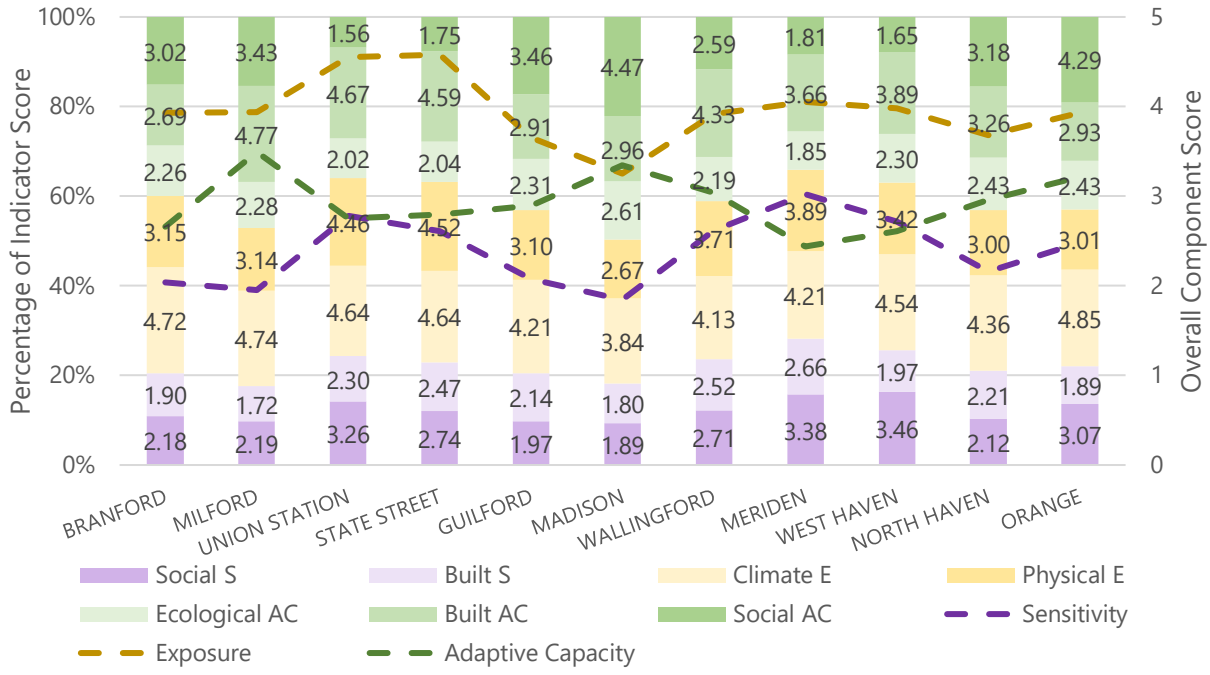


FIGURE 44: SCRCOG TODS HEAT COMPONENT AND INDICATOR SCORES

8.1.1.4 WestCOG

The WestCOG region has the most TOD areas of the four COGs in New Haven and Fairfield counties. In total there are 26 TODs with three of the analyzed sites (Georgetown and two alternates Brookfield TOD areas) representing potential TOD. Therefore, 23 of the areas analyzed for heat and flood vulnerability are currently represented by existing passenger rail stations.

Many of the WestCOG TODs show similar vulnerability scores when comparing heat and flood. However, there are a few that have drastic differences between the stressors. The Danbury TOD has the highest heat vulnerability, and the Stamford area has the highest flood vulnerability. Of the least vulnerable, both Redding and Cannondale score lowest for heat and Talmadge Hill in New Canaan has the lowest flood vulnerability.

With a large number of TOD areas and a variety of characteristics, sensitives and degrees of exposure vary greatly, in addition to adaptive capacities found within each community. To further explore some of the driving factors associated with heat and flood vulnerabilities, the subsequent narrative and figures explore some of the findings in greater depth.

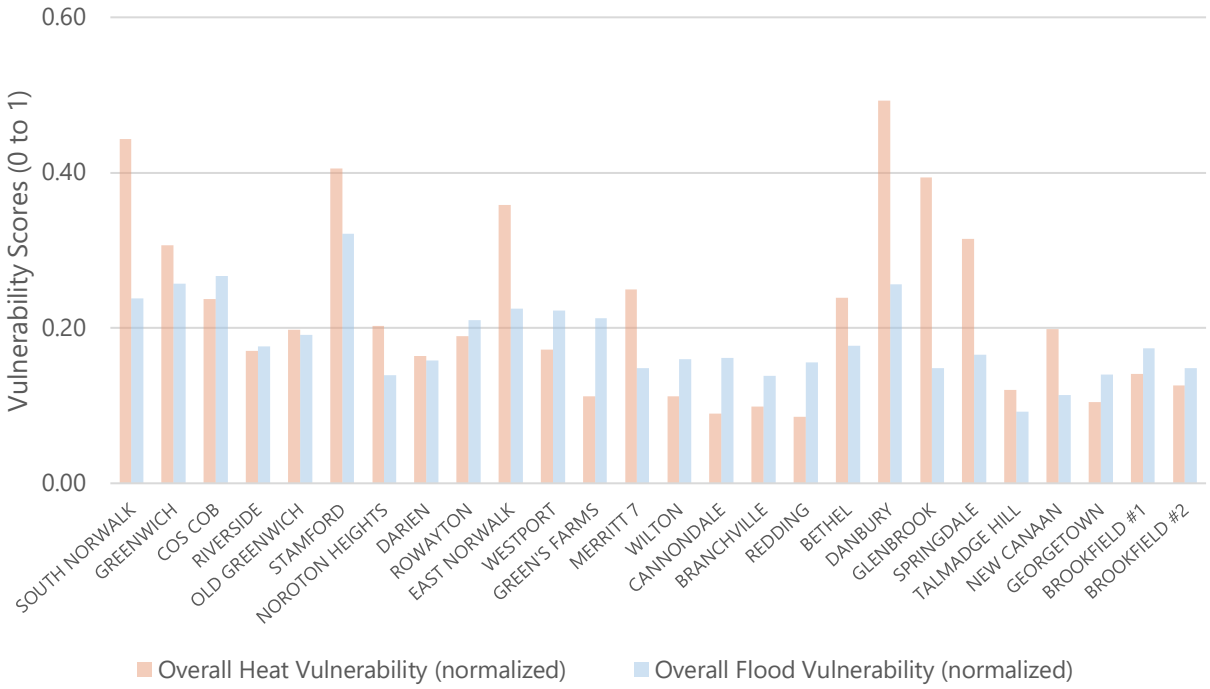


FIGURE 45: WESTCOG TODS OVERALL FLOOD VERSUS HEAT VULNERABILITY

Flood vulnerability varies amongst the TOD areas in the region (Figure 46). The Stamford TOD has the highest vulnerability (0.32), and Talmadge Hill has the lowest (0.09). While Stamford does not have the highest exposure or sensitivity score, both indicators are *among* the highest in the region; adaptive capacity in the Stamford TOD is also one the lowest throughout the region, attributing to the high overall vulnerability score. Of the TODs in WestCOG, Green's Farms has the highest exposure, Danbury has the highest sensitivity, and Redding has the greatest adaptive capacity.

Exposure throughout WestCOG varies widely. Talmadge Hill, New Canaan, and Norton Heights are among the least exposed, while Green's Farms, Stamford, and Cos Cob are the top three for exposure. Almost all TODs have a higher climate related exposure than physical indicating high temperatures across all TODs.

Danbury has the highest sensitivity in the region which is likely due to characteristics common between the flood and heat CCVI as this TOD is the most sensitive to both stressors. Social sensitivity outweighs the built at several of the more urbanized communities including Danbury, South and East Norwalk, Stamford, and Glenbrook. While social sensitivity is also higher in some of the more suburban communities, such as Wilton, Bethel, and Brookfield, this can indicate vulnerable populations *or* merely a lack of certain heat sensitive infrastructure.

In addition, adaptive capacity is highest in Redding but lowest in Danbury. Seventeen of the 26 TODs have a higher adaptive capacity score than exposure or sensitivity. Depending on whether

this is social, built, or ecological, many of these areas have populations, programs, or infrastructure in place to help communities adapt or recover after a flood event.

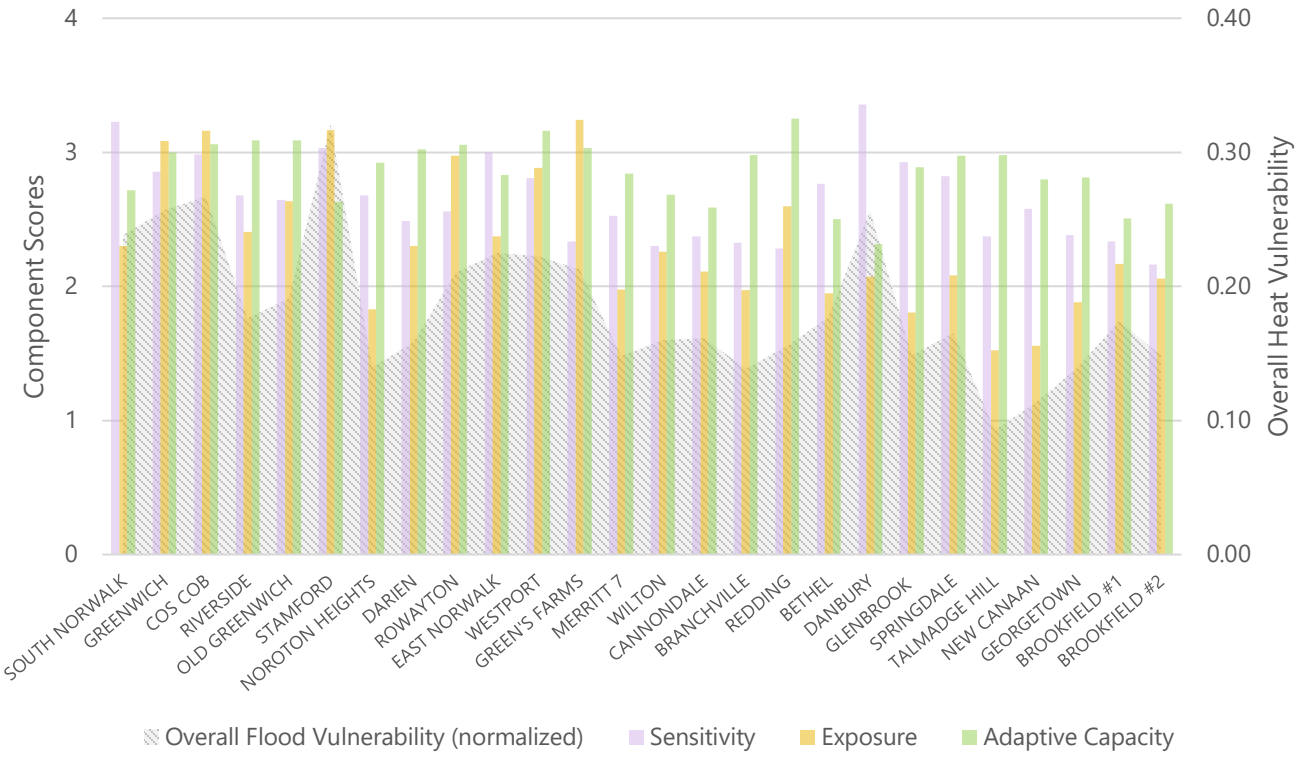


FIGURE 46: WESTCOG TODS OVERALL FLOOD VULNERABILITY AND COMPONENT SCORES

The TODs that have the highest exposure scores have a higher climate exposure versus physical (Figure 47). This higher climate score indicates a direct flood risk, so in proximity to flood zones, surge areas, or tidal range areas, versus the physical exposure which are characteristics that exacerbate flooding, like impervious surfaces. While these TODs cannot remove the inherent flood prone areas, there are strategies to address or reduce the physical exposure which may reduce flood vulnerabilities.

Sensitivity in the region is highest in Danbury, an inland community, and in Stamford and both Norwalk stations, all coastal stations. All three coastal TODs score highest for ecological sensitivity, with Danbury scoring highest for social sensitivity; ecological is a close second. Danbury also scores the highest for built sensitivity, with Cos Cob and Greenwich having the second and third highest scores, respectively. These high sensitivity score indicate possible ecological related challenges within some of the shoreline TODs. This means potentially fewer resilient landscapes

and marsh migration in the more urbanized TODs, built infrastructure and social challenges being a concern for inland Danbury, while most coastal TODs have higher built sensitivities.

Many of the TODs in WestCOG have strong adaptive capacity scores with Redding having the highest and Danbury scoring the lowest. Redding has a significantly higher ecological adaptive score than the other WestCOG TODs, apart from Branchville which also has a relatively high score. A high ecological adaptive capacity means these TODs may have resilient ecosystems in the TOD area or open space in flood risk areas. While Danbury specifically has one of the lower ecological adaptive scores and the lowest social score, the TOD does have strong built adaptive capacity. A low social adaptive capacity indicates low owner-occupied housing or fewer flood insurance policies in the area. However, strong built adaptive capacities, which a many of the WestCOG TODs score high for, shows these areas are near shelters or major roadways, presence of coastal structures, or higher regulatory standards programs.

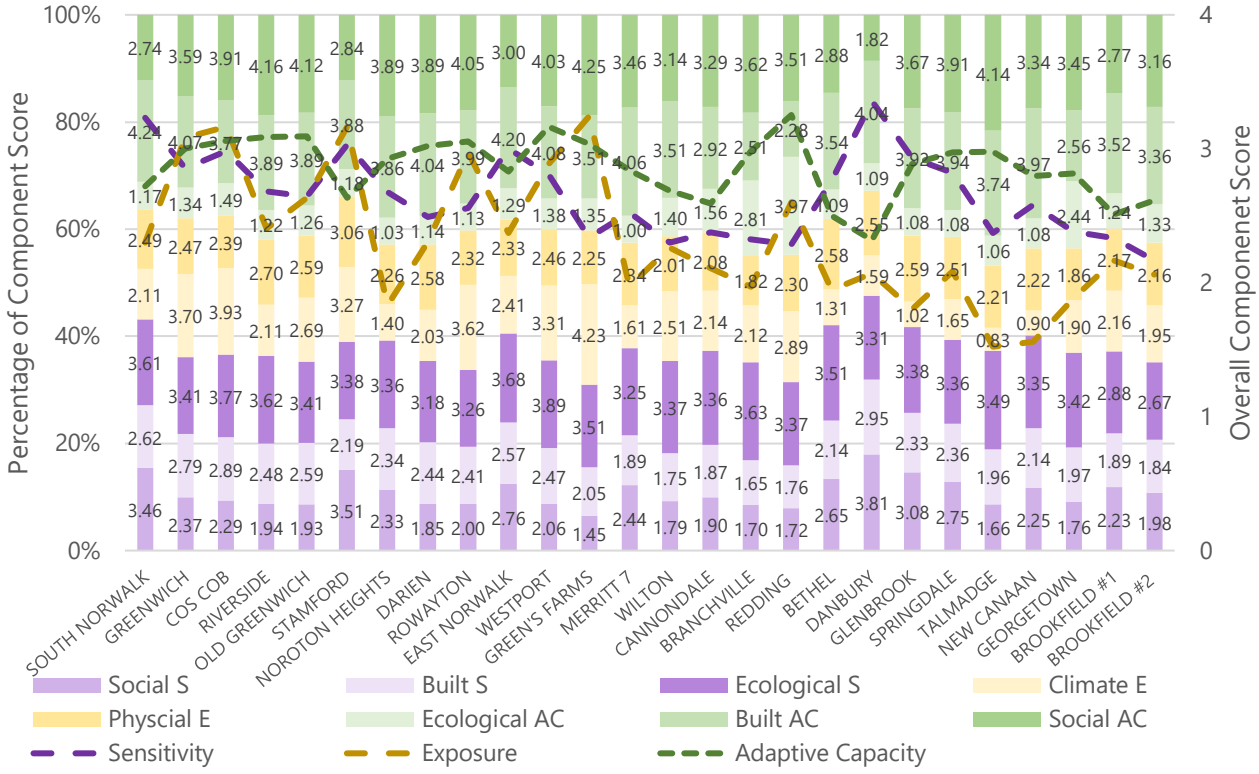


FIGURE 47: WESTCOG TODS FLOOD COMPONENT AND INDICATOR SCORES

In regard to heat vulnerability (Figure 48), the Danbury TOD has the highest overall heat vulnerability (0.49), and Redding and Cannondale (Wilton) both have the lowest (0.09). The Danbury area scores he highest for heat sensitivity and third highest for exposure. Stamford and South Norwalk have the highest and second highest exposure, respectively. All TODs in the

WestCOG region have a higher exposure than sensitivity. The Redding station has the smallest difference between the two component scores, while the Stamford area has great difference. Both TODs however have relatively similar sensitivity scores.

Adaptive capacity also varies throughout the region with eleven sites scoring highest for adaptive capacity, and only two, South Norwalk and Stamford, scoring lowest. With both exposure and adaptive capacity varying greatly throughout the region there are likely several strategies that can boost adaptiveness while reducing levels of exposure. Figure 48 represents the component scores at the indicator level.

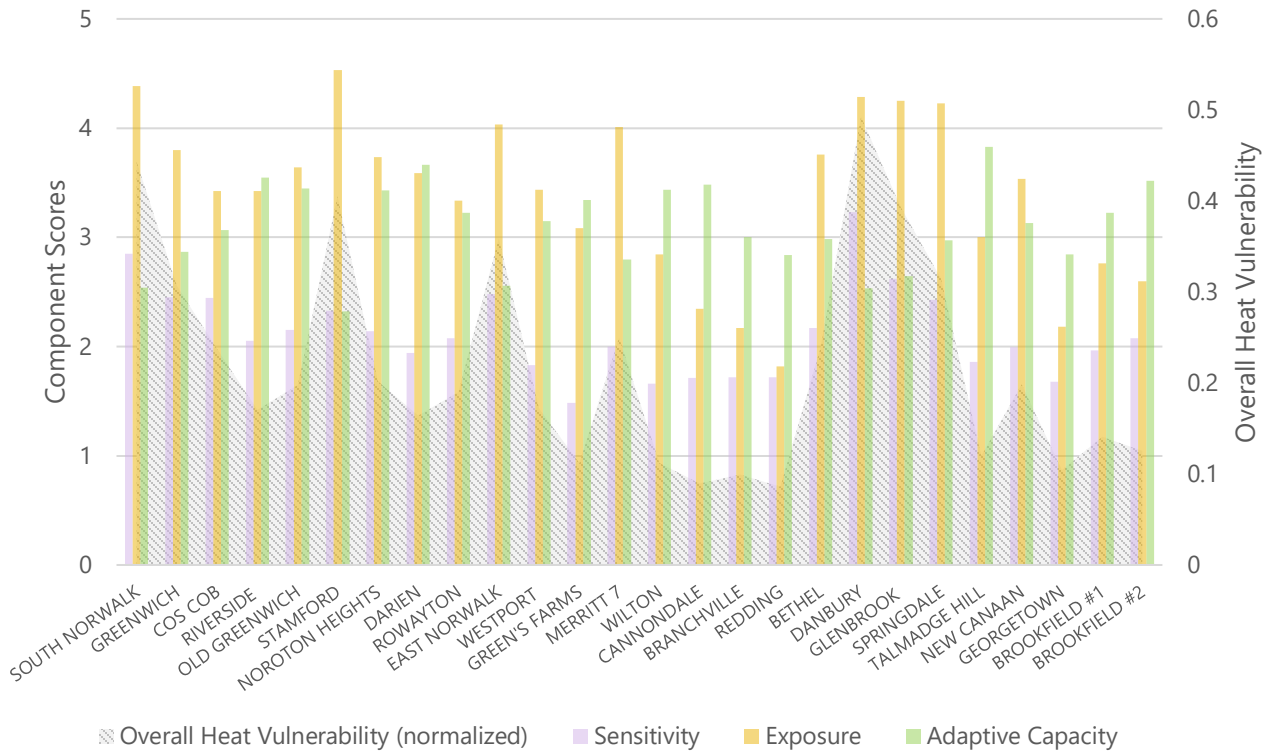


FIGURE 48: WESTCOG TODS OVERALL HEAT VULNERABILITY AND COMPONENT SCORES

Danbury, which has the highest heat vulnerability, also has the highest heat sensitivity (Figure 49). In general, the TOD area also scores high for both physical and climate exposure, as well as highest for social and built sensitivity. A high exposure for Danbury and other TODs in WestCOG indicates recent trends of extreme land surface temperatures, high emissivity, and poor air quality. In addition, the high sensitivity scores for built and social mean populations with certain heat related health risks, high population density, typically older homes, and potentially private well reliance.

Most of the WestCOG TODs have strong adaptive capacity scores with a majority scoring high for social and built, with ecological typically being the lowest score of the three. Talmadge Hill in New Canaan has the highest overall adaptive capacity with the highest social adaptive score and two of the highest built and ecological. These scores identify high numbers of health insurance policies and owner-occupied housing, proximity to health facilities and cooling centers, and typically more vegetation and tree coverage. While there are certain exposures and sensitivities throughout Talmadge Hill area, as well as other TODs that have high adaptive capacity, these high scores indicate certain characteristics that provide certain benefits to populations during extreme heat events.

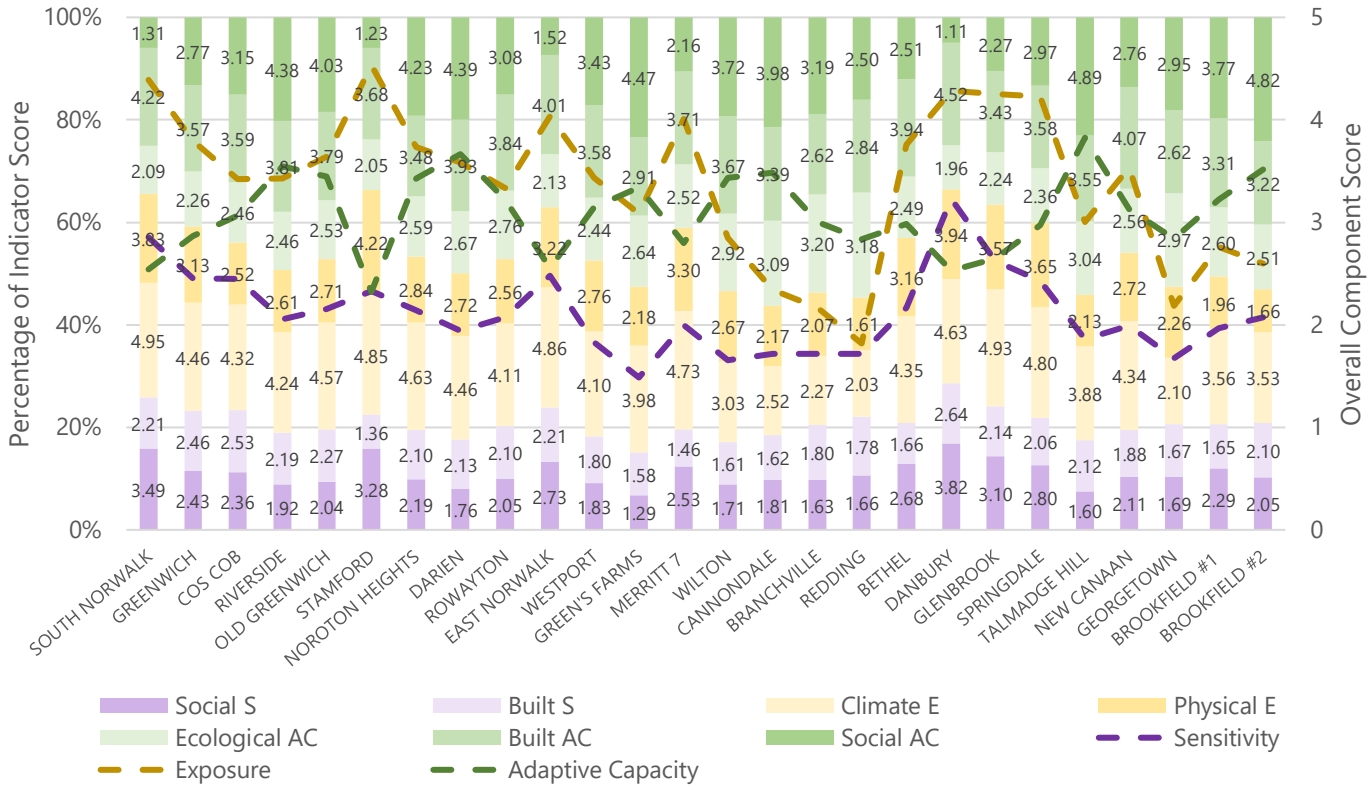


FIGURE 49: WESTCOG TODS HEAT COMPONENT AND INDICATOR SCORES

8.1.2 ZSR Analysis for TOD Areas

In addition to the vulnerability analysis for TOD areas, it is also important to understand whether certain types of shared risks are present in each TOD areas and what stakeholders should be involved when discussing future planning and development of adaptation and resilience projects.

The use of flood ZSR concepts can identify a type of flood-related risk, the watershed region, whether the zone is nested within a larger zone, and in general the types of stakeholders encompassed by this area (e.g., residents or businesses owners). ZSR methodology and documentation for the ZSRs throughout the planning region can be found in Appendix F.

To highlight some of the ZSR-related characteristics within each TOD, an analysis has been conducted to locate the zones of shared risk that intersect with a the 0.75-mile TOD boundary used in the previous CCVI analysis. Graphics have been generated for each of the TOD areas throughout both counties. These graphics show the ZSR within a TOD to help identify the stakeholders present in each ZSR. This is an important step in understand who should be involved in project development and design whether it is a Resilient Connecticut opportunity area or for future development and redevelopment. Figure 51 is an example of these graphics which are found in Appendix G.

The potential P.T. Barnum TOD area contains five locational ZSR. Two of these zones are entirely within the TOD, and three are only partially within the area. Some of the stakeholders in these ZSR that might be involved in projects include American Medical Response (AMR), Bridgeport Hospital, Connecticut Department of Transportation, Barnum School, as well as the residents and other business owners in the area.

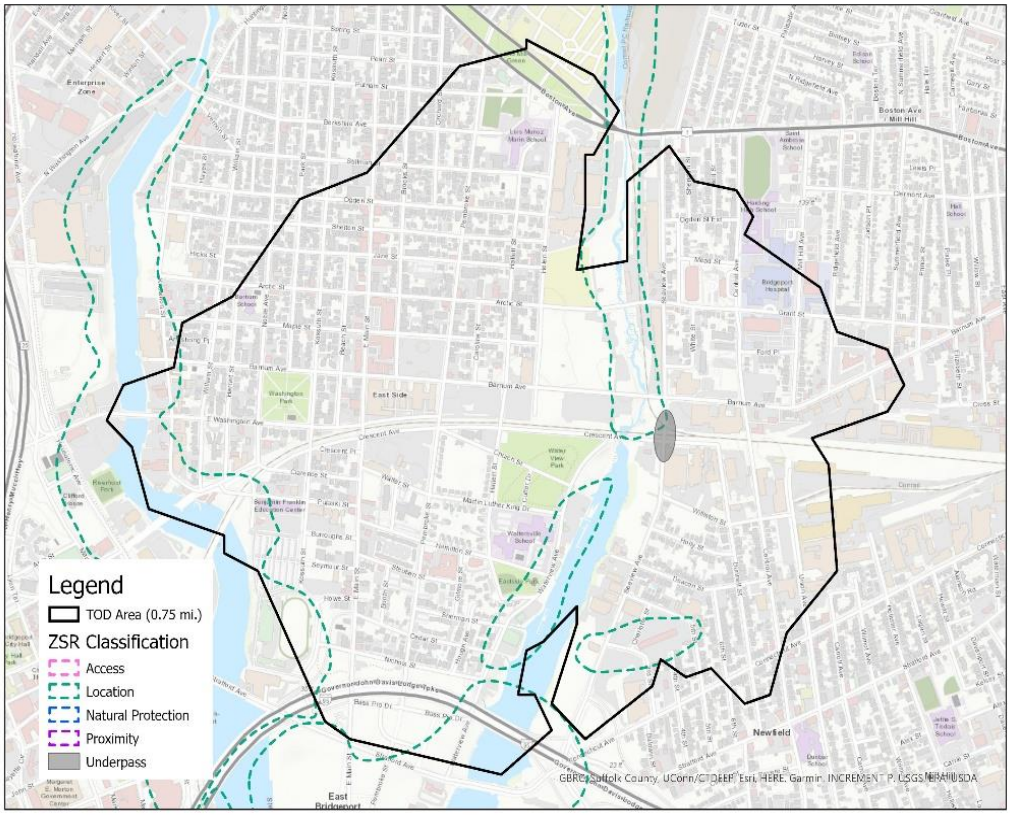


FIGURE 50: P.T BARNUM STATION TOD AREA AND ZSR

9 Infrastructure and Asset Analysis

While the SV mapping, CCVI, and ZSRs are a comprehensive way of characterizing and presenting vulnerabilities and risks for Resilient Connecticut, several other key considerations in the context of regional systems that may be vulnerable to climate change should be considered in adaptation and resilience projects. As noted elsewhere, critical infrastructure supports critical infrastructure. Community assets like historic and cultural resources do not fit the typical definition of infrastructure, but they are part of the fabric of the State and are supported by traditional infrastructure. To evaluate additional types of assets and infrastructure in the region that may affect vulnerability or adaptive capacity, several other factors have been evaluated and analyzed for the role they may play in a community by way of vulnerability or adaptation.

How to Understand this Chapter

Resilient Connecticut attempts to develop a baseline inventory of the regional infrastructure and assets of Fairfield County and New Haven County. Regional infrastructure and assets serve numerous communities from one location, span several communities, or possess some alternate interest of regional significance. Regional infrastructure and assets can include a roadway, a passenger rail station, a hospital, an historic district, a state park, or a major employer.

As climate change unfolds, infrastructure and assets will be impacted by flood and heat events as well as other severe weather events. The failure of one piece of infrastructure or a community asset can lead to cascading effects. Therefore, understanding specific vulnerabilities can help identify potential solutions in the future.

The vulnerability analysis undertaken for these specific assets (or asset types) is another critical step to identifying, characterizing, and developing resilient opportunity areas. Some of these assets, such as critical facilities, are not necessarily regional in need or use, but play a vital role in communities. Other infrastructure, such as public water or sewer, are comprised of so many system components that each piece's vulnerability should be evaluated when assessing project design and development.

9.1 Critical Facilities

While most of these municipal critical facilities are not "regional", they do play a vital role in municipal operations, which if disrupted could have regional impacts. Critical facilities in the context of Resilient Connecticut also include State-owned critical facilities.

Flood vulnerability (Figure 51) for critical infrastructure varies more in comparison to heat. The MetroCOG region again has the most vulnerable facilities with an average overall score of 0.26. NVCOG again has the lowest vulnerability with an overall score of 0.14. Exposure varies the most

amongst the four COGs with NVCOG average infrastructure scoring 1.79 and MetroCOG being highest with 2.72; indicating an increased climate or physical exposure for facilities within the COG region.

While this high-level assessment is based on the CCVI at the specific location of these facilities, the degree of floodproofing at each site likely varies and needs to be taken into consideration for each facility. Various facilities, such as emergency response, shelters, and municipal buildings have been updated and redeveloped to incorporate flood mitigation strategies to ensure services are not disrupted during and event.

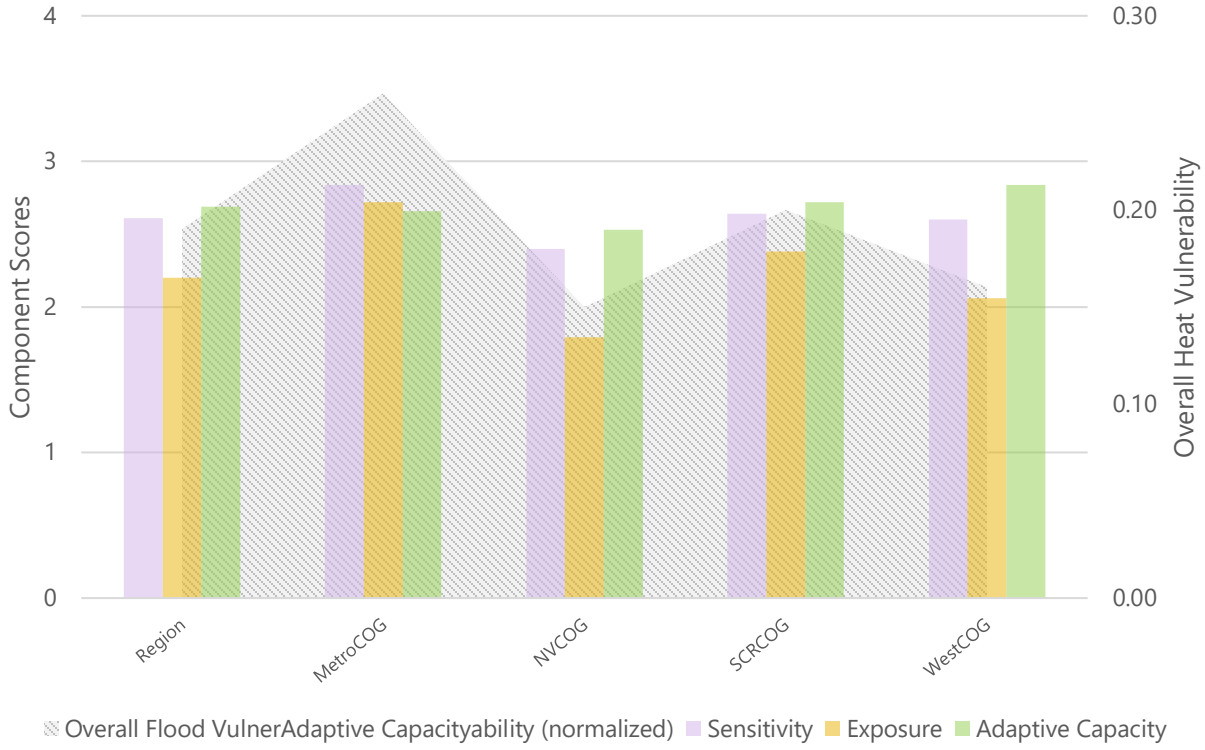


FIGURE 51: REGIONAL CRITICAL INFRASTRUCTURE OVERALL FLOOD VULNERABILITY AND COMPONENT SCORES

To evaluate the potential vulnerabilities of these facilities throughout the region, average heat and flood vulnerability scores have been calculated based on a facility's parcel boundary. In general, the average heat vulnerability region wide for critical infrastructure is 0.14, and the average flood vulnerability score is 0.12 (Figure 52). Overall heat vulnerability and component scores across the region only vary slightly. MetroCOG has the highest average locational heat vulnerability with a score of 0.16, and NVCOG the lowest with 0.13. It appears that sensitivity and exposure scores are comparable across the region for heat, however, adaptive capacities have the most variation but is the highest scoring component for the region and each COG.

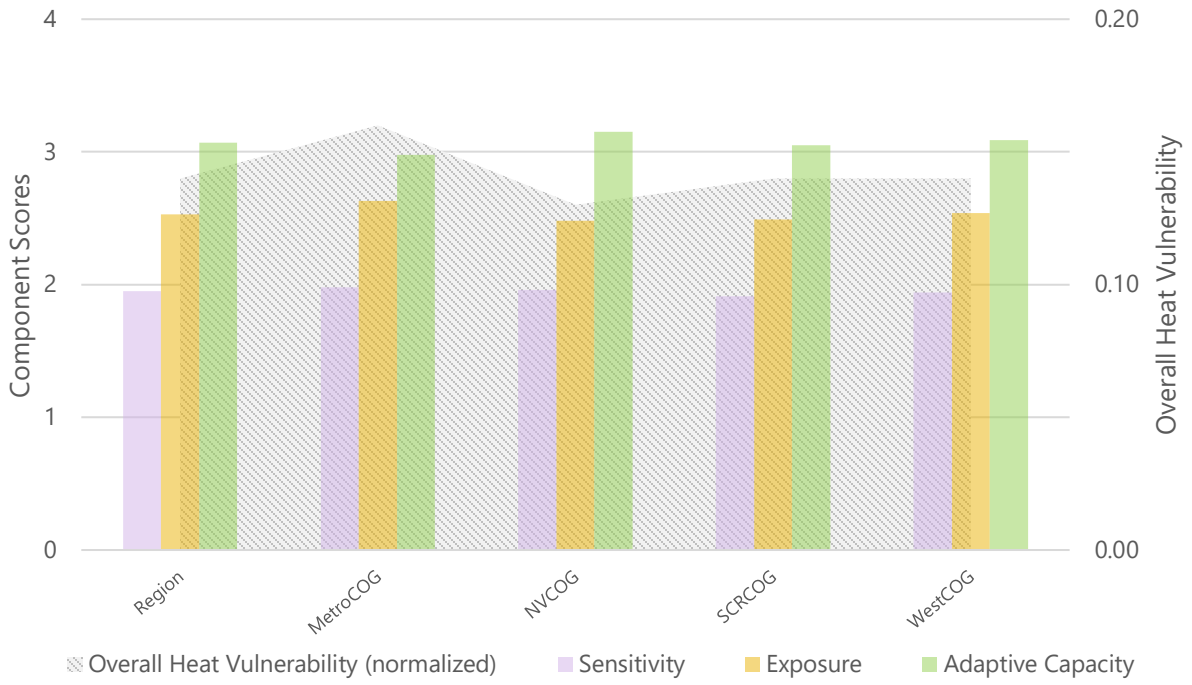


FIGURE 52: REGIONAL CRITICAL INFRASTRUCTURE OVERALL HEAT VULNERABILITY AND COMPONENT SCORES

9.1.1.1 Shelters & Cooling Centers

In Connecticut, municipalities typically select and designate locations that can be used for temporary sheltering of residents during extreme weather events and natural disasters. These are informally called "shelters" and are typically listed whenever a municipality updates its hazard mitigation plan and/or LEOP. Cooling centers are used by municipalities to offer temporary comfort during heat events. Cooling centers are opened during heat waves and typically located in municipal libraries or senior centers to provide refuge during the daytime hours to residents. They are not necessarily inside shelters, although a shelter can sometimes be used as a cooling center.

A majority of the shelters and cooling centers throughout the region are designated for municipal use and may not be considered "regional." However, these facilities provide safe shelter for high risk and vulnerable populations throughout the region, and it can be assumed if the need arose, a facility could be opened to neighboring communities. The shelters in the region can provide space to residents during or after a flood or during an extreme heat event. Many of these shelters are often equipped with backup power and other facilities that provide comfort to shelter-seeking

residents. Cooling centers are typically not as equipped as a shelter for extended use; however, they do provide immediate short-term relief from extreme heat.

There are 170 identified shelters throughout the region. These shelters have been identified from State resources and municipal Hazard Mitigation Plans; of these at least 50 have back-up power. A majority of the shelters in the region are schools, while others are identified as community centers, municipal facilities, or fire stations. In total, 4 shelters are located in a high flood vulnerable area, and 13 are in a high heat vulnerable area; only 2 are located in a ZSR. Three shelters in Bridgeport are located in high flood and high heat vulnerable areas (Table 3). While the flood vulnerability may impact the facility itself, heat does not typically pose an infrastructural threat to the facility; instead, heat poses a social challenge in the vicinity of the facility.

TABLE 3: MUNICIPAL SHELTERS IN HIGH FLOOD OR HIGH HEAT VULNERABLE LOCATIONS

Facility Name	Municipality	COG	Flood Vulnerability	Heat Vulnerability	ZSR ID & Type
Springdale Fire Department	Stamford	WestCOG	Moderate-Low	High	N/A
Columbus School	Bridgeport	MetroCOG	High	High	N/A
Edison School	Bridgeport	MetroCOG	Moderate	High	N/A
Geraldine W. Johnson School	Bridgeport	MetroCOG	Moderate	High	N/A
Hall School	Bridgeport	MetroCOG	Moderate-Low	High	N/A
High Horizons Magnet School	Bridgeport	MetroCOG	Moderate-High	High	N/A
Jettie S. Tisdale School	Bridgeport	MetroCOG	High	High	N/A
Luis Munoz Marin School	Bridgeport	MetroCOG	Moderate-High	High	N/A
Multicultural Magnet School	Bridgeport	MetroCOG	High	High	N/A
Former Warren Harding High School	Bridgeport	MetroCOG	Moderate	High	N/A
Shelter: East Haven Senior Center	East Haven	SCRCOG	Moderate-High	High	N/A
Hill Career High School	New Haven	SCRCOG	Moderate-Low	High	N/A
Muravnick Senior Center	Meriden	SCRCOG	Moderate-High	High	5206-00-249-0 (Proximity)
Hooker School	Bridgeport	MetroCOG	High	Moderate-High	7103-02-58-0 (Location)

In total, 108 cooling centers (excluding splash pads and public pools, which provide cooling benefits in a different way) have been identified and mapped in New Haven and Fairfield counties based on past openings during heat waves.[15] Of these 108 centers, 12 are in a high flood vulnerable area and 27 are in a high heat vulnerable area; 11 of these are in a high flood *and* high heat area (Table 4).

TABLE 4: COOLING CENTERS IN HIGH FLOOD AND HIGH HEAT VULNERABLE AREAS

Cooling Center	Municipality	Flood Vulnerability	Heat Vulnerability	ZSR ID & Type
Doyle Senior Center*	Ansonia	High	Moderate	6900-00-422-0 & 6900-00-422-100 (Location)
Black Rock Senior Center*	Bridgeport	High	High	
Bridgeport Public Library Black Rock Branch*	Bridgeport	High	High	
Bridgeport Public Library Main Branch*	Bridgeport	High	High	
Greater Bridgeport Transit Bus Terminal (Water St.) *	Bridgeport	High	High	7105-00-31-0 (Location)
East Side Senior Center*	Bridgeport	High	High	
Meriden YMCA*	Meriden	High	High	
Meriden Police Department*	Meriden	High	High	5206-00-249-0 (Location)
Atwater Senior Center	New Haven	High	High	5200-00-392-89 (Access)
Stamford Town Center*	Stamford	High	High	7000-40-236-0 (Location)
CHD Hospitality Center	Waterbury	High	High	
Brass Mill Center	Waterbury	High	High	
Greater Bridgeport Transit (Cross St.)	Bridgeport	Mod-Low	High	
Bridgeport Public Library Newfield Branch	Bridgeport	Mod-High	High	
Elmwood Senior Center*	Danbury	Mod-Low	High	
ML Keefe Center	Hamden	Moderate	High	

[15] Data compiled from two methods: CT DPH/CIRCA Survey to Emergency Management Directors and Health Departments about cooling centers in use in 2019 (in addition to emergency shelters) and data collected from news services advertising cooling centers in 2019. Laura Hayes (DPH), Joanna Wozniak-Brown (UConn CIRCA), and Nicholas Elton (Yale graduate student) prepared and collected the survey. Nicholas Elton collected the information from the news sources and identified the longitude and latitude.

Brundage Community Branch Library	Hamden	Mod-Low	High	
Taking Initiative Center	New Haven	Mod-Low	High	
Courtland Seymour Wilson Branch Library*	New Haven	Mod-High	High	
Fair Haven Branch Library	New Haven	Moderate	High	5200-00-392-89 (Access)
The 180 Center*	New Haven	Mod-High	High	
Fellowship Place	New Haven	Mod-Low	High	
Youth Continuum*	New Haven	Mod-High	High	
Norwalk Police Department*	Norwalk	Mod-High	High	7000-25-146-0 (Location)
Chester Addison Community Center	Stamford	Moderate	High	
Ferguson Library*	Stamford	Mod-High	High	
Westfield Trumbull	Trumbull	Mod-High	High	7106-02-55-0 (Location)
Silas Bronson Library (Grand St.) *	Waterbury	Mod-Low	High	
***** **Cooling center located within 0.75 mi. TOD service area**				

Given that the primary use for a cooling center is for refuge during a heat wave, flood vulnerability may not be as great a concern as access to the center itself during a heat event. However, if a heat event were to coincide with a flood event, recognizing the vulnerability of these cooling centers is critical to protecting those seeking heat relief.

To better understand access to these cooling centers and their proximity to public transit, centers have been assessed for their distance to a public bus route. At least 84 cooling centers are within a 0.5-mile distance of a bus route, eight centers within one mile distance, and 16 centers that are between one and 6.3 miles away from a bus route. Those that are furthest from a bus route are in more suburbanized communities (Table 5).

TABLE 5: COOLING CENTERS GREATER THAN 1 MILE FROM BUS ROUTES

Cooling Center	Address	Municipality	Distance from Bus Route (mi.)	Flood/Heat Vulnerability
Southbury Senior Center	561 Main Street South	Southbury	1.03	Mod-High Flood, Mod-Low Heat
Ridgefield Parks & Recreation	195 Danbury Road	Ridgefield	1.23	Mod-High Flood, Mod-Low Heat

Black Rock Church	3685 Black Rock Turnpike	Fairfield	1.35	Mod Flood, Mod-Low Heat
Atwater Memorial Library	1720 Foxon Rd	North Branford	1.83	Mod Flood, Mod-Low Heat
Westport Weston Family YMCA	14 Allen Raymond Ln	Westport	1.96	Mod-High Flood, Mod-Low Heat
New Canaan Community YMCA	564 South Ave	New Canaan	2.04	Low Flood, Mod-Low Heat
Oxford Town Hall	486 Oxford Road	Oxford	2.77	Low Flood, Mod-Low Heat
Edward Smith Library	3 Old Post Rd	Northford	3.00	Mod Flood, Low Heat
Bethany Town Hall Senior Center	40 Peck Road	Bethany	3.04	Mod-Low Flood, Mod-Low Heat
Mark Twain Library	439 Redding Road	West Redding	3.22	Low Flood, Mod-Low Heat
North Branford Recreation Department	1332 Middletown Ave	Northford	3.33	Mod-Low Flood, Low Heat
New Canaan Library	151 Main St	New Canaan	3.42	Mod-Low Flood, Mod-Low Heat
Easton Senior Center	650 Morehouse Rd	Easton	3.47	Mod-Low Flood, Mod Heat
Cyrenius H Booth Library	25 Main Street	Newtown	4.14	Low Flood, Mod-Low Heat
Redding Community Center	37 Lonetown Road	Redding	4.58	Low Flood, Mod-Low Heat
Newtown Municipal Center	3 Primrose Street	Newtown	4.65	Mod-Low Flood, Low Heat

Many of the cooling centers that are not within close proximity to a bus route, as seen in Figure 53, are located in more suburban or rural communities; urban communities have a high density of bus routes and stops which inherently increases relative access to a center. While comparing this figure to the above heat CCVI results, these cooling centers are also typically is less heat vulnerable locations. Regardless of this, it is still critical to ensure that cooling centers can be easily accessed during a heatwave by all populations.

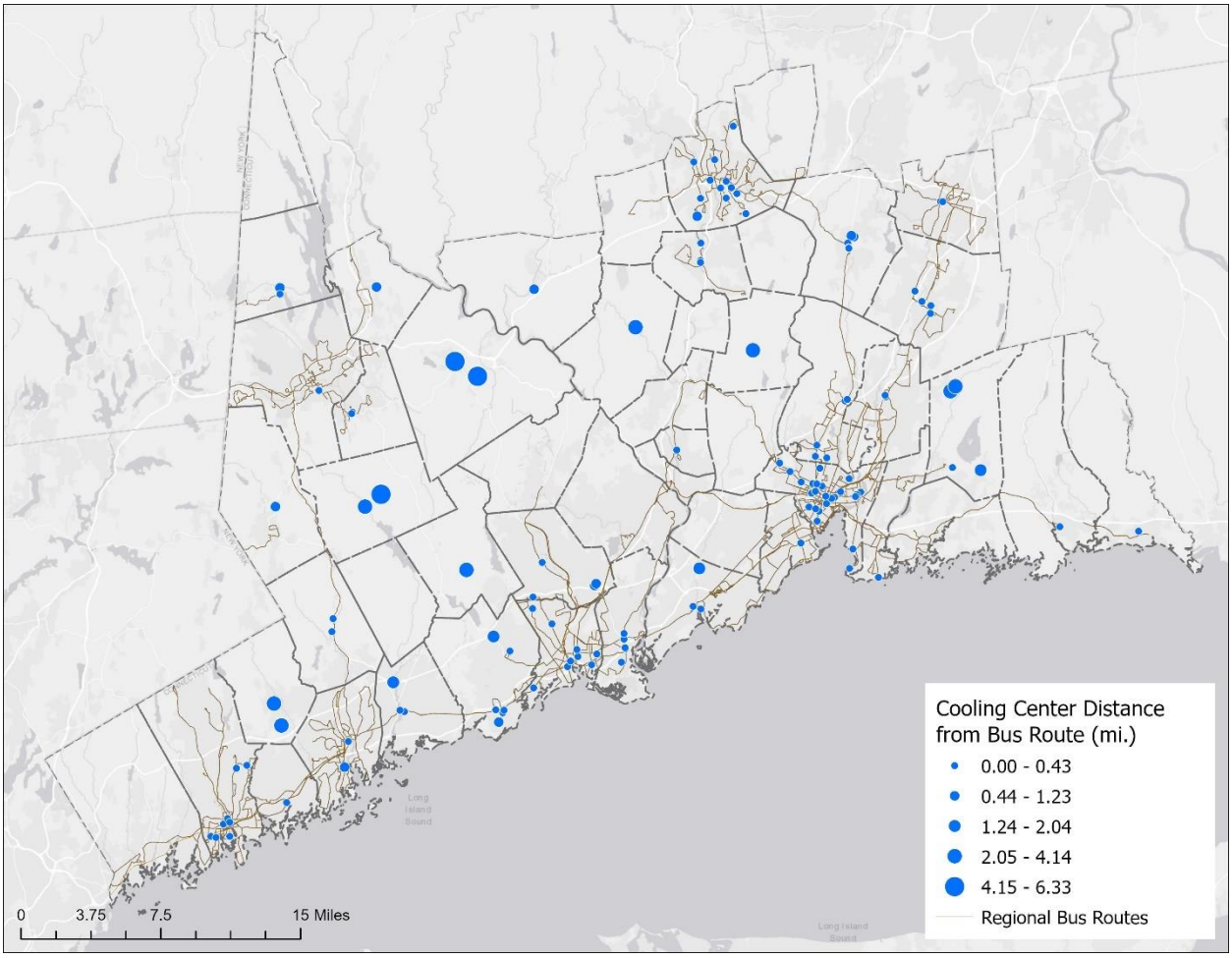


FIGURE 53: COOLING CENTERS AND THEIR DISTANCE FROM BUS ROUTES

9.2 Rail Assets

The primary passenger railroads in New Haven and Fairfield counties include the Metro-North/Amtrak line that runs along the shoreline from Greenwich to New Haven (including the New Canaan, Danbury, and Waterbury branches), Shoreline East which runs from New Haven to Madison, and the CT Rail line running from New Haven to Meriden. Several segments of each of these lines lie within the FEMA special flood hazard area (SFHA). These rail segments were evaluated separately from the CCVI by (1) identifying location inside the SFHA followed by (2) identification of rail segment elevations lower than the corresponding potential flood elevations.

The initial two-dimensional analysis did not consider rail elevation, but identified the stretch of line and which flood zone it lies in. In total, 57 miles of railroad lie within a FEMA designated flood zone. Of these vulnerable stretches, 18 miles lie within the 0.2% annual chance hazard area, 33 miles lie within the 1% annual chance hazard area, three miles are in a floodway, and two miles

are in an area with reduced risk due to a levee. Figure 54 represents where these segments are located throughout the region.

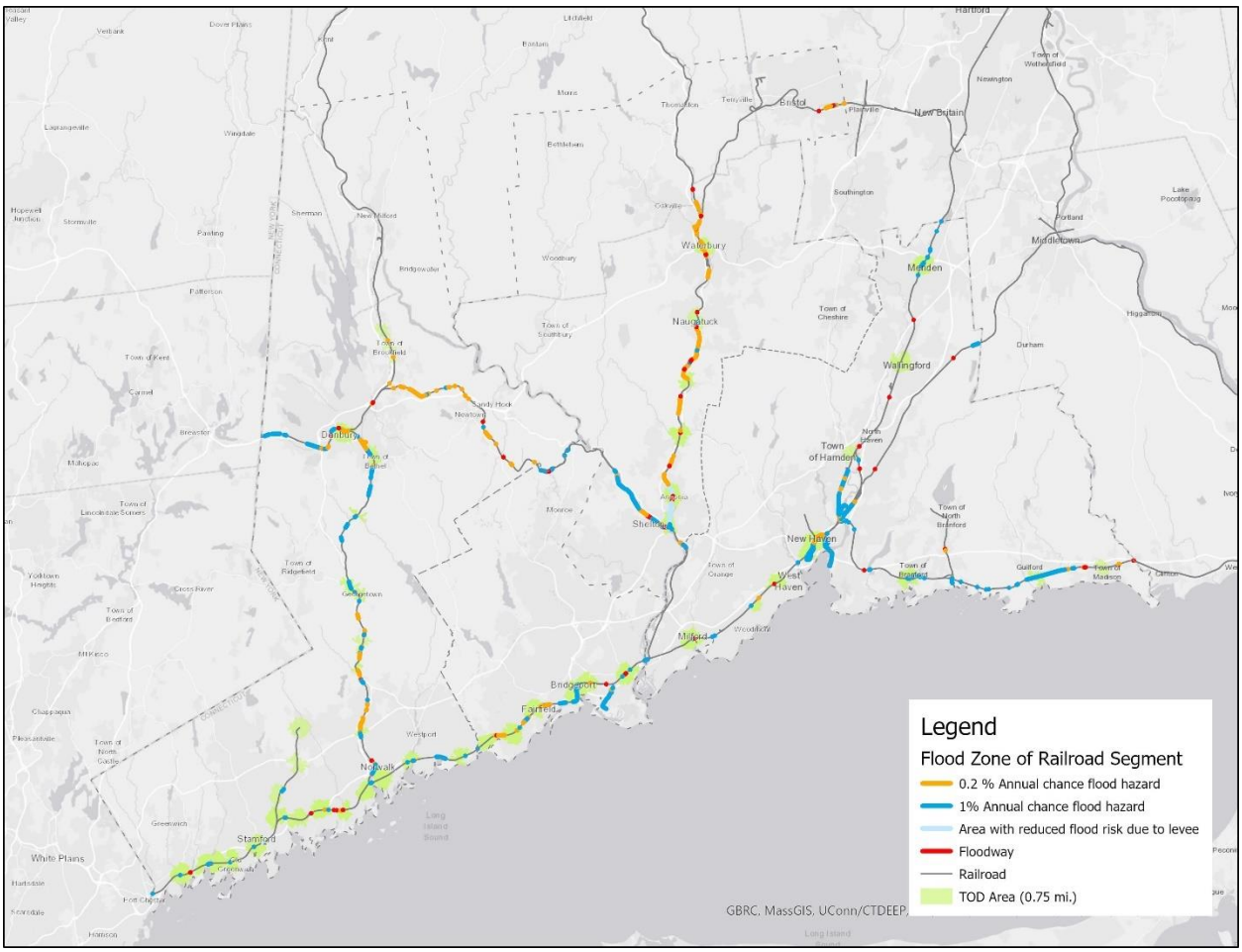


FIGURE 54: RAILROAD SEGMENTS WITHIN SPECIAL FLOOD HAZARD AREAS

One additional consideration when analyzing these vulnerable segments is to consider both site and roadway access near these segments. Oftentimes these vulnerable portions of track are located in, or are adjacent to, a 0.75-mile TOD area. Flooded tracks may delay train departure or arrival and limit user access to the station, impacting both daily and/or emergency travel. [INSERT]

Next, rail segments were analyzed to determine flood vulnerability based on elevation. Using LIDAR, an elevation was assigned to specific rail segments that intersect the 1% annual chance flood hazard areas *and* have a static base flood elevation (BFE). To accomplish this evaluation, lines were converted to points. These points have been derived at the beginning, end, and middle of an intersected rail segment. In total, 363 points in Fairfield and New Haven counties along the railroad were assigned an elevation and a BFE. This analysis was an automated GIS analysis process that relies on the precise location of rail line location and its alignment with elevation data points. It appears that land-based rail segment elevations have fewer discrepancies than those segments that are bridge crossings. While there is room for improvement, this analysis provides

foundational insight into potential vulnerable railroad segments. At some point in the future, the process should be repeated manually through direct comparison of rail segment elevations to flood elevations.

There are 27 points in Fairfield County that are above BFE. These elevations range from 0.14 to 26.12 feet above the flood elevation (Figure 55). The remaining 51 points are below BFE ranging from -0.22 to -15.03 feet. There are six major waterway crossings in Fairfield County: Greenwich over the Byram River and Cos Cob Harbor, in Norwalk over the Norwalk River, in Westport over the Saugatuck River, Bridgeport over the Pequonnock River, and in Stratford/Milford over the Housatonic River. Of these major crossings, the Byram River and the western end of the Housatonic River crossings were found to be over 20 feet above BFE. The eastern point of the Saugatuck River crossing is an estimated over 6 feet above BFE and the Norwalk River crossing is identified as between 1.3 and 3.4 feet above BFE. The remainder of the major crossings are identified as below BFE. These numbers may vary with more advanced analysis or ground truthing.

Of the minor waterway crossings or land-based stretches, the length of rail along the Norwalk River (MetroNorth Danbury line) is an estimated 0.5 feet above BFE, with some of this section below BFE. In Norwalk there is rail line that cuts through Sherwood Millpond and over Mill Creek and is adjacent to some wetland systems. This section of SFHA intersecting is estimated to be between -3.0 and -0.8 feet below BFE, making this segment of rail vulnerable to inundation during a 100-year event. In Fairfield there is a stretch of rail between the Fairfield and Fairfield Metro stations that is between -3.9 and -0.9 feet below BFE. The tracks along the western bank of the Pequonnock River range from 17 feet above and almost 13 feet below BFE. While some of these elevations may be accurate, this variation along the roughly three-quarter mile stretch will eventually require additional analysis or ground truthing. However, this stretch of rail is directly along the river therefore presenting a threat of inundation, or potentially washout. Commercial rail that services the Sikorsky Airport in Stratford is between roughly 0,4 and 3.6 feet below BFE.

Ultimately there are several railroad stretches in Fairfield County that intersect the SFHA and are close to, or below, BFE. While the tracks themselves may be at or above BFE, the rail bed may be below BFE presenting a challenge in regard to track stability.

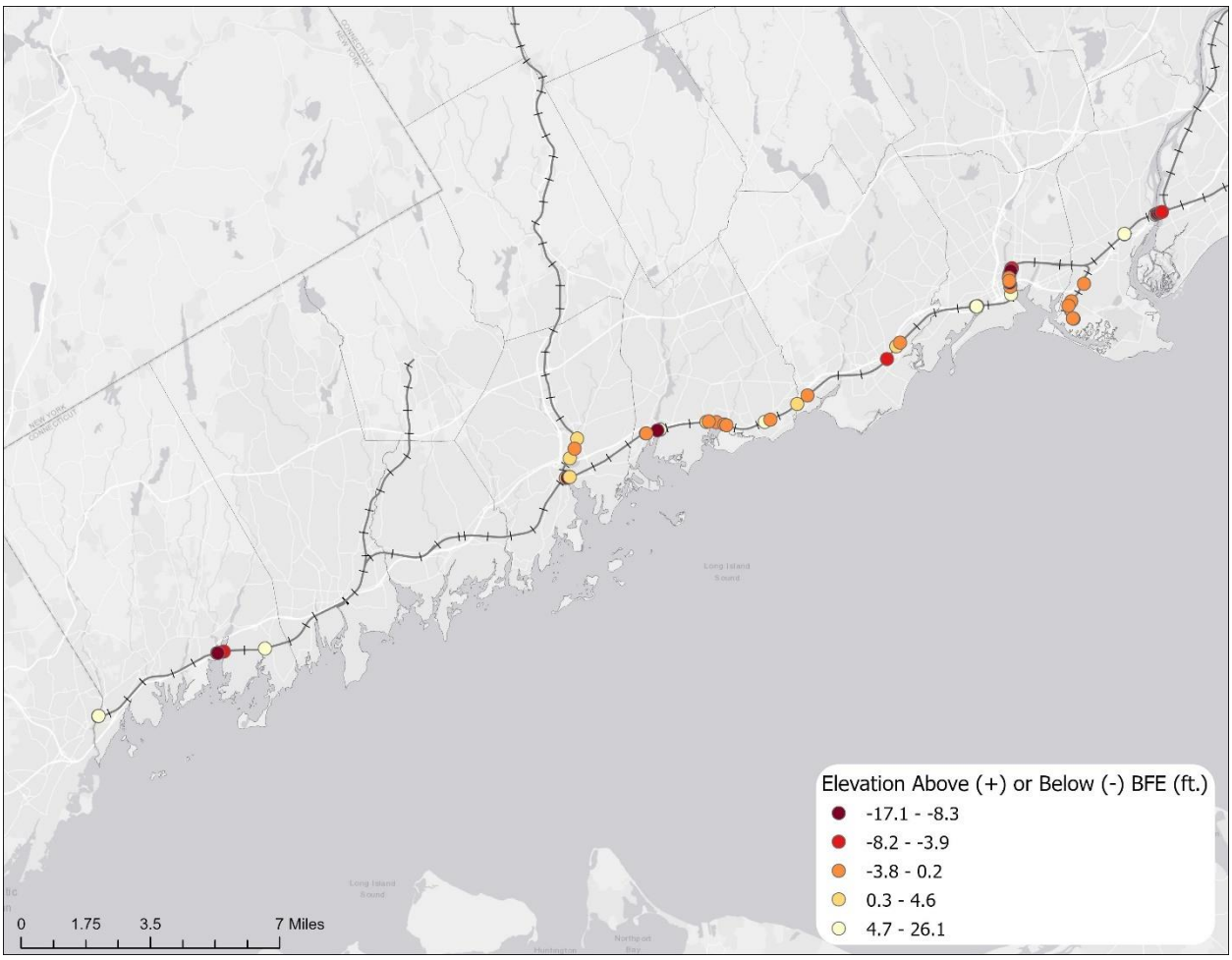


FIGURE 55: FAIRFIELD COUNT RAILROAD SEGMENTS IN SFHA AND ELEVATION IN RELATION TO BFE

Nine major waterway rail crossings were identified in New Haven County: in Milford over Gulf Pond, New Haven over the West River, Mill River, Quinnipiac River, and over New Haven Harbor, in Branford over the Branford River, in Guilford over the West and East Rivers, and Madison over the Hammonasset River. There are several other water crossings in the region that extend over small streams and marsh systems. Of the major crossings, the West River (New Haven), the western point of the northernmost Quinnipiac crossing, the western side of the Mill River, and the eastern side of the West River (Guilford) are all above BFE by between 1 and 6.5 feet. The remaining points at these crossings are between 0.3 and 17 feet *below* BFE.

A high density of rail tracks intersects the SFHA in the City of New Haven, with several locations at or below BFE (Figure 56. Those surrounding Union Station are on average about one foot below the BFE. Those sections just to the north of Union Station from the State Street Station are on average 5 feet below BFE. The density and elevation of these tracks makes this area of the Metro-North/Amtrak system vulnerable to inundation and other flood related challenges. Those sections in eastern New Haven in the Port Area average slightly below BFE with an average of about 0.4 feet below BFE; this is a spur that services the port area facilities. North of New Haven there are

several stretches of rail that run through and along the Quinnipiac River Marsh. The average elevation of the tracks in this area is -1.4 feet below BFE with the maximum of 5.9 feet above BFE and low of -12.8 feet. The remaining stretches of rail between Branford and Madison have varying elevations with several locations adjacent to marshes and the shoreline. The tracks within the Branford TOD area are within the SFHA and are about one foot above BFE. The small crossing in Branford in the Pine Orchard Marsh Wildlife Area is approximately 12 feet below BFE. In Guilford, the crossing found in the Great Harbor Wildlife Area is found to be almost -12 to the BFE. Between this crossing and the Madison Hammonasset River crossing there are several stretches of rail that intersect the SFHA. The average of these segments is about 2.4 feet below BFE with the greatest elevation being 1.4 above and the lowest being -13 feet below BFE.

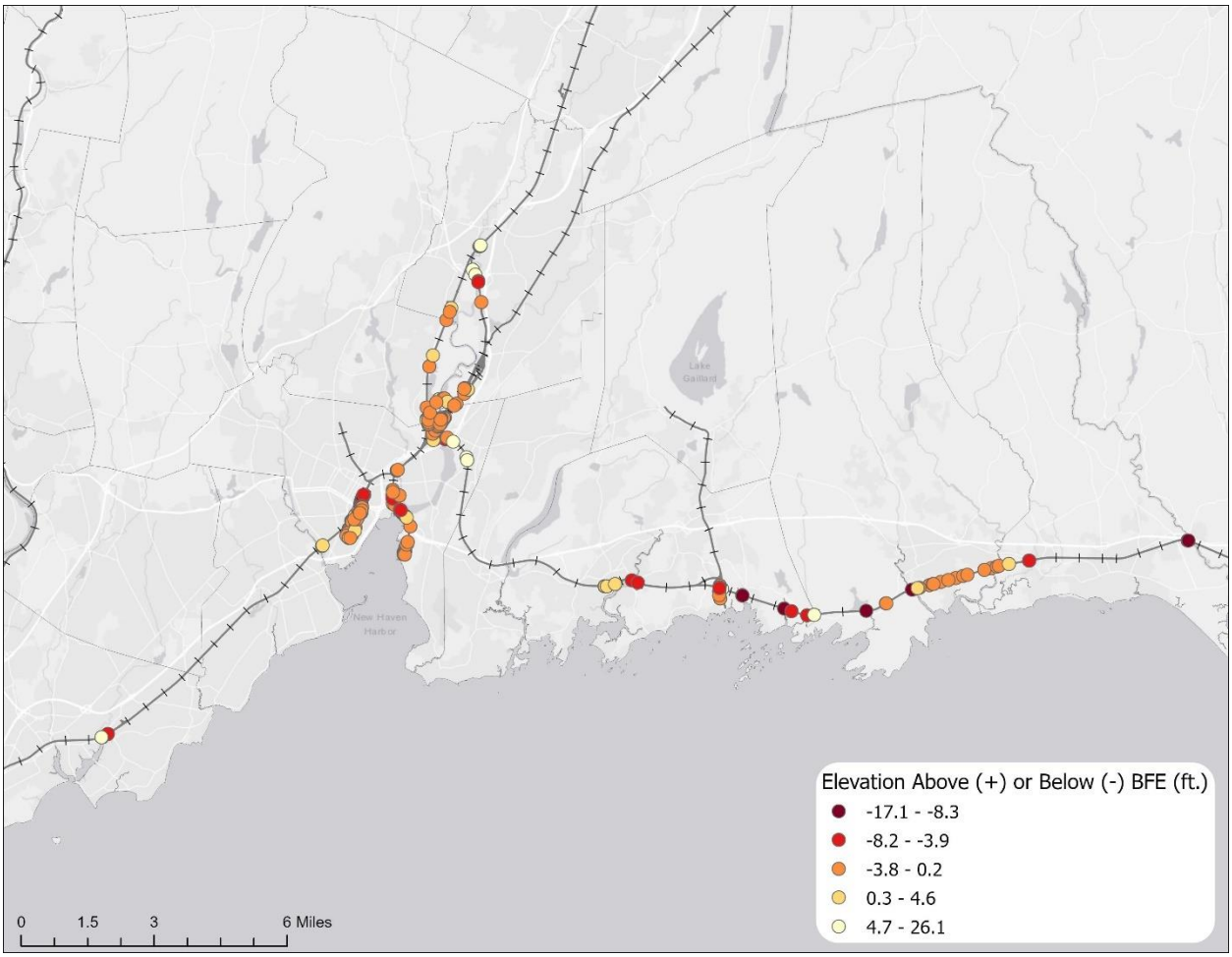


FIGURE 56: NEW HAVEN COUNTY RAILROAD SEGMENTS IN SFHA AND ELEVATION IN RELATION TO BFE

9.3 Bus Assets

Hundreds of bus stations without buildings or terminals are located throughout New Haven and Fairfield Counties. Determining which bus stations should be elevated to a status of intense

evaluation is a judgment call beyond the scope of this study, as many of them are not mapped in a GIS and must be inferred as locations where two bus lines intersect or end. However, several key "bus hubs" have been identified throughout the region. These hubs are locations where numerous bus routes intersect or join, ultimately offering greater transit accessibility in one location. Oftentimes a bus hub can also be found at a passenger train station (i.e., Derby and Meriden) and therefore they are well-aligned with TOD goals in the State and inherently included in the analysis described earlier. However, many hubs represent major stops throughout the region that are not located at passenger rail stations. These are typically found in centralized settings in urban areas. Some of the hubs are located adjacent to passenger rail stations (i.e., Stamford) and some are not (i.e., New Haven Green). These hub locations have been identified by the consultant team's transportation planners and subsequently mapped. Whether a bus hub is located "at" or "adjacent" to a rail station is a judgment call that should be recognized in this report. Finally, this may not be an exhaustive list, however bus hub locational and vulnerability data mapping may continue to evolve as additional bus hubs are identified through future stakeholder engagement.

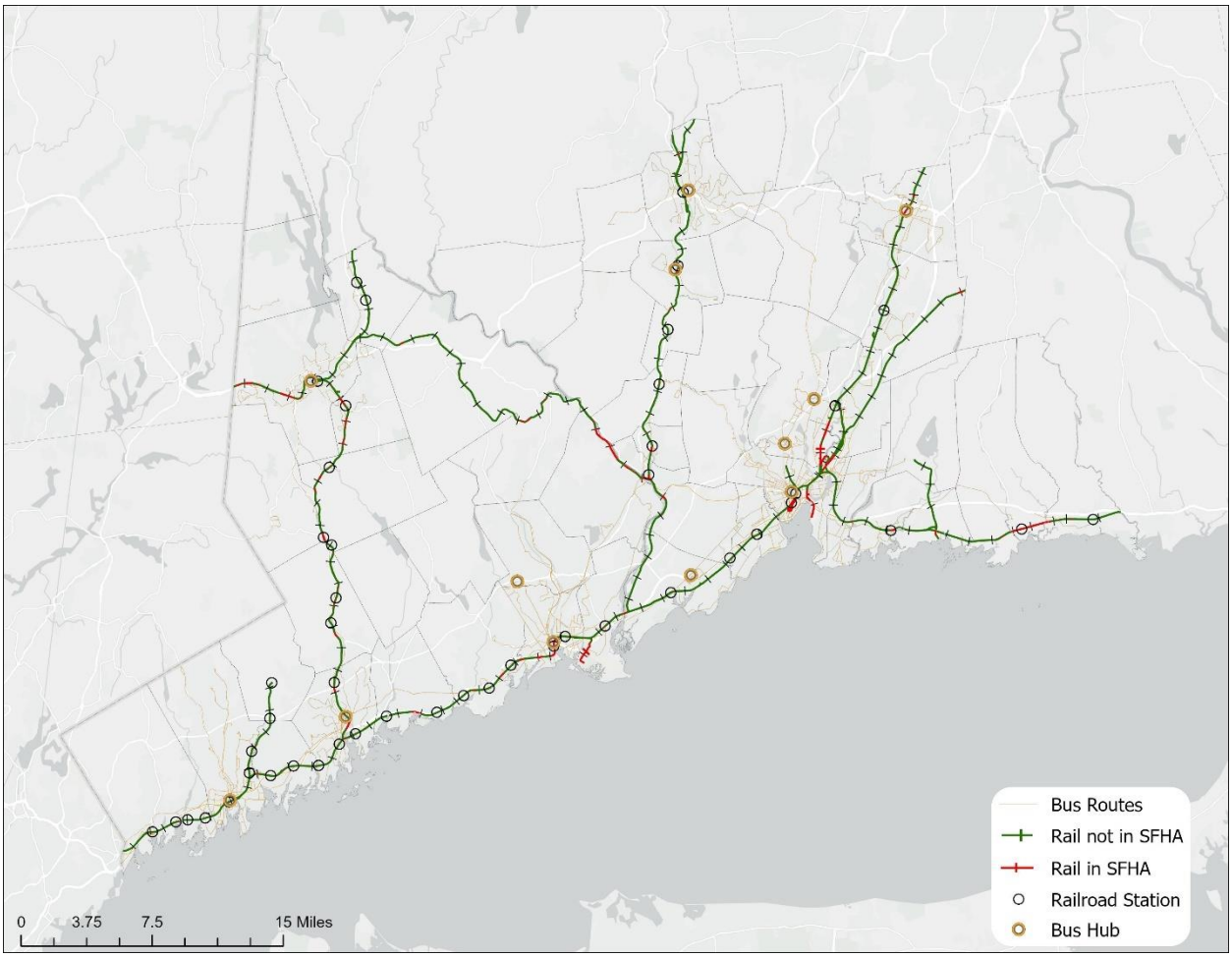


FIGURE 57: REGIONAL BUS HUBS AND RAIL STATIONS

In summary, twelve bus transit hubs have been identified and mapped. Of these, six are in a ZSR and ten are in a high flood/high heat area (Table 6). These hubs, along with the regional rail stations, are found in Figure 57. The Bridgeport Transportation Center is only the location located in a high heat and high flood area; however, the others are at least moderately high for either flood, heat, or both. Most of these areas are located in relatively urban or commercialized parts of the region.

TABLE 6: BUS HUB ZSR AND COMBINED VULNERABILITY

Hub Name	Municipality	Flood & Heat Vulnerability	ZSR ID & Type
Stamford Transportation Center	Stamford	Mod-High Flood, Mod-High Heat	7000-40-236-0, Location
Norwalk Wheels Hub	Norwalk	Mod-High Flood, Mod-High Heat	7300-00-159-0, Location
Bridgeport Transportation Center	Bridgeport	High Flood, High Heat	7105-00-31-0, Location
Danbury Pulse Point	Danbury	Mod-High Flood, High Heat	
New Haven Green	New Haven	Mod-High Flood, High Heat	
Meriden Transit Center	Meriden	High Flood, Moderate-High Heat	5206-00-249-0, Location
Waterbury	Waterbury	Mod-Low Flood, High Heat	
Hamden 1	Hamden	Mod-Low Flood, Mod-High Heat	
Hamden 2	Hamden	Mod-Low Flood, Mod-High Heat	
Trumbull Mall	Trumbull	Mod-High Flood, Mod-High Heat	
Milford Mall	Milford	Mod Flood, Mod-Low Heat	5306-00-391-0, Location
N. Church and Maple	Naugatuck	Mod Flood, Mod-High Heat	6900-00-412-0, Location

CTFastrack, which is a rapid bus transit system, services Hartford and surrounding communities and provides rapid transit to the New Haven-Waterbury rail line in Waterbury, CTRail line in Hartford, and regional employers and other destinations in the area. Waterbury and Cheshire are both serviced by CTFastrack by way of six stops along an express route.

Cheshire Fastrack stop locations include the Cheshire Milldale Park and Ride and the Cheshire Route 70 Park and Ride. The four Waterbury stops are located at the Metro-North station, at the

Waterbury Green, St. Mary's Hospital, and the Hamilton Avenue Park and Ride. Three of four Waterbury stops are located in the Downtown Waterbury opportunity area; the Hamilton Avenue stop is just outside of the boundary; however, this does not mean this location should be discounted from any potential adaptation endeavors that may occur in this opportunity area. To create a more resilient system all locations need to be taken into consideration.

These locations have varying degrees of heat and flood vulnerability, with two Waterbury stops also located in a ZSR (Table 7: CTFastrack stops ZSR and combined vulnerability); these locations also have the highest heat vulnerability according to the CCVI. The Waterbury Rail station location, and Hamilton Avenue Park and Ride also have moderate flood vulnerability, which is the highest of the six locations. Sites should be assessed for potential access challenges during a flood event, and green aspects should be incorporated into future redevelopment to provide shade and refuge to those waiting at a stop during heat waves.

TABLE 7: CTFASTRACK STOPS ZSR AND COMBINED VULNERABILITY

CTFastrack Stop	Flood & Heat Vulnerability	ZSR ID & Type
Route 70 Park and Ride	Low Flood, Mod-Low Heat	
Milldale Park and Ride	Mod-Low Flood, Mod-Low Heat	
St. Mary's Hospital	Mod-Low Flood, High Heat	6900-22-409-0, Location
Waterbury Green	Mod-Low Flood, High Heat	6900-00-405-0, Location
Waterbury Rail Station	Mod Flood, Mod-High Heat	
Hamilton Avenue Park and Ride	Mod Flood, Mod-High Heat	

Express System services also operate in the region. This transit system provides peak hour transit options between Hartford and Waterbury and Cheshire (utilizing the CTFastrack stops), Meriden North Haven, and New Haven. Meriden Express stops includes the Meriden Transit Center, outlined above, and the Bee Street Park and Ride. The Bee Street location, which is located at the confluence of several major roadways, is not located in a ZSR but in a moderate-high flood/moderate heat area. The New Haven Express stop is located at the Metro-North Union Station, and the North Haven site is at the Devine Street Park and Ride. This park and ride, which is in close proximity to the proposed North Haven TOD area, is not located in a ZSR and is in a moderate flood/moderate heat vulnerable area.

9.4 Affordable Housing

Several affordable housing types have been evaluated for overall flood and heat vulnerability. While there are hundreds throughout the region, and the dataset used may not be comprehensive, this analysis can provide foundational insight into vulnerable sites and neighborhoods regarding these two stressors. The subsequent analysis provides a brief overview of some of the more vulnerable locations.

A general vulnerability analysis identifies affordable housing units as often more vulnerable due to several different factors. The first is the social component. Those individuals that live in affordable housing may not have the financial means to prepare for or recover from flood events, implement energy efficiency or structural upgrades to reduce heat impacts, and may have other reduced capacities that inhibit preparedness and recovery. Many affordable housing units or complexes are also located in urbanized areas which are typically at a higher heat risk due to impervious surfaces and high building density. In addition, these housing unit types often house elderly or disabled populations. These populations may need additional assistance with evacuations, response, or recovery in addition to financial challenges.

To identify more specific vulnerabilities and populations in the region, United States Department of Housing and Urban Development (HUD) and locally developed affordable housing data has been analyzed for flood and heat vulnerability using the CCVI. The HUD data consisted of multifamily housing properties and public housing developments. The multifamily dataset consists of rental properties with five or more units such as apartments of townhouses, and can sometimes include nursing homes, mobile home parks, elderly housing, hospitals, or retirement service centers. Public housing developments can be larger, multi building developments, however HUD provides resources and assistance in the planning, development, and management of these development properties.

9.4.1 Multifamily Housing

According to HUD data, there are 81 multifamily, affordable housing locations in the region. The sites identified in Table 8 are ranked in the top 20% most vulnerable of the multifamily housing in the region as identified by HUD. In total there are 31 vulnerable sites in 10 municipalities, with three of these sites in flood *and* heat vulnerable locations.

TABLE 8: HUD MULTIFAMILY AFFORDABLE HOUSING SITES VULNERABLE TO FLOOD AND HEAT

Multifamily Complex in Flood Vulnerable Location	Municipality	Multifamily Complex in Heat Vulnerable Location	Municipality
38 Crown Street	New Haven	Willard Manor	Stamford
The Towers, Formerly Tower I-Tower East	New Haven	**Fair Haven Elderly**	New Haven
333 State St. Apts.	Bridgeport	**Fairmont-Ruoppolo**	New Haven
Fairmont-Ruoppolo	New Haven	Westfield Glen Apts	Meriden
Quarry Knoll II	Greenwich	Ludlowe Center for Health and Rehabilitation	Fairfield
Harboursite Apts.	Stamford	**Farnam 9%**	New Haven
Farnam 9%	New Haven	Broad River Homes	Norwalk
Parkside Apts	Meriden	Bishop Curtis/Augustana Homes - Bridgeport	Bridgeport
Brewery Square Apartments	New Haven	Nsa I Enterprise/Abbott Apts	Waterbury
Greenwich Close Apts	Greenwich	Miss Laura Raymond Homes	Norwalk
Village Park II	New Haven	Seacrest Retirement Center	West Haven
Bella Vista E	New Haven	Sycamore Place	Bridgeport
Bella Vista Cd	New Haven	Belltown School Elderly Housing	Stamford
Bella Vista A	New Haven	Apple Rehab - T.A. Coccomo Memorial	Meriden
Hemingway Place	East Haven	West River Health Care Center	Milford
Fair Haven Elderly	New Haven	Stamford Cross Road	Stamford
Athena 13 - Northbridge Health Care Center	Bridgeport	Milford Health Care Center	Milford

Bolded identifies a site that is vulnerable to both stressors

9.4.2 Housing Developments

U.S. HUD has identified 85 affordable housing development complexes throughout New Haven and Fairfield counties. Of these locations throughout the region a total of 29 are among the most vulnerable to flood or heat, with five complexes ranking among the top 20% for flood and heat vulnerability. Half of these complexes are located within the City of Bridgeport, including four of the facilities that are vulnerable to both stressors. Some of these complexes are also designed to house vulnerable populations such as disabled or elderly, which may increase social vulnerability. Table 9 identifies the 29 complexes that are in the highest vulnerable areas.

TABLE 9: HUD HOUSING COMPLEXES VULNERABLE TO FLOOD AND HEAT

Housing Development in Flood Vulnerable Location	Municipality	Housing Development in Heat Vulnerable Location	Municipality
Meadow Gardens	Norwalk	Soundview Landing Phase 1	Norwalk
Park City - Supportive	Bridgeport	**Park City - Supportive**	Bridgeport
Park City - Elderly	Bridgeport	**Park City - Elderly**	Bridgeport
Brookside Phase I	East Haven	Wt Rowe	New Haven
Marina Village	Bridgeport	**Harbor View Towers**	Bridgeport
Presidential Village	Bridgeport	3 Eighth Av	Danbury
Charles T. Mcqueeney Twr	New Haven	Family Scattered Sites	Milford
Waverly Townhouses	New Haven	**P.T. Barnum Apts.**	Bridgeport
Farnum Courts	New Haven	20 West Avenue	Norwalk
Spring Heights	West Haven	11 May Street	Ansonia
Brookside Phase II	New Haven	**Charles T. Mcqueeney Twr**	New Haven
Albion Street	Bridgeport	Norman Ray House	Seymour
Essex Townhouses	New Haven	Scattered Sites	Danbury
Harbor View Towers	Bridgeport	Eden Drive	Danbury
P.T. Barnum Apts.	Bridgeport	Surfside 200 Highrise	West Haven
Boston Commons	Bridgeport	Crosby Manor	Danbury
Charles F. Greene Homes	Bridgeport	Riverside Apartments	Ansonia

Bolded identifies a site that is vulnerable to both stressors

9.4.3 COG Identified Affordable Housing

SCRCOG and MetroCOG provided affordable housing spatial data for analysis. While all four COGs in the region have some degree of affordable housing tracking, these two specific datasets leant themselves to spatial vulnerability analysis.

MetroCOG has identified and mapped 88 affordable housing properties in the towns of Fairfield and Stratford. These properties consist of group homes, apartment or townhome complexes, and duplexes; some of which are governmentally assisted. Almost all the most flood vulnerable properties are in the Town of Stratford, with over half of the heat vulnerable sites located in Fairfield. Given that this spatial data only represents two of the six MetroCOG municipalities these findings are only comparable between the two towns discussed.

TABLE 10: METROCOG AFFORDABLE HOUSING PROPERTIES VULNERABLE TO FLOOD AND HEAT

HIGH VULNERABILITY LOW

Property Name or Location in Flood Vulnerable Location	Municipality	Property Name or Location in Heat Vulnerable Location	Municipality
Parkview Commons	Fairfield	Whole Life Inc.	Stratford
Raymond E. Baldwin Apartments	Stratford	Luxe Apartments	Fairfield
496 Sedgewick Ave	Stratford	Fairchild Apartments	Fairfield
35 Agresta Ter	Stratford	18 Garden Dr	Fairfield
33 Agresta Ter	Stratford	20 Garden Dr	Fairfield
Meadowview Manor	Stratford	18 Garden Dr	Fairfield
Hearthstone Apartments	Stratford	FHA Trefoil Court	Fairfield
Elm Terrace Gardens	Stratford	Beacon View Apartments	Fairfield
87 Ryan Ave	Stratford	Shakespeare Estates	Stratford
Robert F. Kennedy Apartments	Stratford	58 Agresta Ter	Stratford
75 Agresta Ter	Stratford	56 Agresta Ter	Stratford
73 Agresta Ter	Stratford	48 Agresta Ter	Stratford
65 Agresta Ter	Stratford	46 Agresta Ter	Stratford
63 Agresta Ter	Stratford	38 Agresta Ter	Stratford
55 Agresta Ter	Stratford	36 Agresta Ter	Stratford
53 Agresta Ter	Stratford	149 Grasmere Ave	Fairfield
45 Agresta Ter	Stratford	141 Grasmere Ave	Fairfield
43 Agresta Ter	Stratford	Grasmere Avenue Apartments	Fairfield

Bolded identifies a site that is vulnerable to both stressors

Affordable housing spatial data for SCRCOG appears to be more comprehensive with housing sites identified in several municipalities throughout the region. In total, 189 housing locations have been identified by SCRCOG in 14 communities. Many of the locations identified in the SCRCOG dataset are income restricted or income based, with several locations being supportive of the elderly and others providing homelessness assistance. There are 70 affordable housing properties ranked in the vulnerable top 20% of all SCRCOG sites; eight of which are vulnerable for both flood and heat. Table 11 identifies those that are most vulnerable in the region.

TABLE 11: SCRCOG AFFORDABLE HOUSING PROPERTIES VULNERABLE TO FLOOD AND HEAT

HIGH VULNERABILITY LOW

Property Name or Location in Flood Vulnerable Location	Municipality	Property Name or Location in Heat Vulnerable Location	Municipality
Howard Apartments	New Haven	**Farnam Courts New Haven Public Housing Apartments**	New Haven
Mountain Valley Place	New Haven	Woodbridge Elderly Housing	Woodbridge
Hart Residences, Inc	New Haven	Legion Woods	New Haven
Waverly Townhouses New Haven Public Housing Apartments	New Haven	Legion Avenue Court	New Haven
Richard Street Coop	New Haven	Mckenna Court	Meriden
Fellowship Commons Westville	New Haven	Ulbrich Heights & Extension	Wallingford
Fellowship Commons Whalley	New Haven	William T Rowe (The Rowe)	New Haven
Morrissey Manor	West Haven	Antillean Manor Cooperative	New Haven
Matthew Ruopollo Manor	New Haven	63 Washington Street	Milford
Park Ridge Towers I	New Haven	Renaissance Hill	New Haven
Park Ridge Towers II	New Haven	McGuire Court	Wallingford
Scattered Sites - II	New Haven	Beechwood Gardens - CT	New Haven
Leeway Welton Apartments	New Haven	Whalley Terrace	New Haven
Carmen Romano Apartments	North Haven	Whalley Avenue Housing II	New Haven
Trinity New Haven Housing II	New Haven	**Waverly Townhouses New Haven Public Housing Apartments**	New Haven
Columbus West Apartments	New Haven	Wheelers Woods	Orange
Winslow-Celentano Apartments	New Haven	Gulf Street Commons	Milford
Meriden Commons	Meriden	Gulf Street Commons II	Milford
Meriden Commons II	Meriden	Parkside Village I	Branford
Harbor Towers	Meriden	Winchester Lofts Apartments	New Haven
The Towers at Tower Lane	New Haven	Johnson Farms	Meriden
Towers East	New Haven	Hill Central Homes	New Haven
River Run Apartments	New Haven	Margaret B. Mack Supportive Housing	New Haven
East Farm Village	East Haven	**Bella Vista E**	New Haven
Charles T. McQueeny	New Haven	**Bella Vista Cd**	New Haven
Waverly Townhouses New Haven Public Housing Apartments	New Haven	Constance B. Motley	New Haven

Farnam Courts New Haven Public Housing Apartments	New Haven	**River Run Apartments**	New Haven
Parkside Apartments	Meriden	St. Martin's Townhouses	New Haven
Brewery Square	New Haven	**Charles T. McQueeny**	New Haven
Rolling Ridge Apartments	West Haven	Rollin Meadows of Milford	Milford
Town Homes at Eastview Terrace	New Haven	**Park Ridge Towers I**	New Haven
Bella Vista B	New Haven	**Park Ridge Towers II**	New Haven
Bella Vista A	New Haven	Ferry Street	New Haven
Essex Townhouses New Haven Public Housing Apartments	New Haven	Island View Park	Milford
Hanover Towers	Meriden	Monterey 2	New Haven
Bella Vista E	New Haven	Foran Towers	Milford
Bella Vista Cd	New Haven	Surfside 200 Highrise	West Haven
Katherine Harvey Terrace	New Haven	Monterey Place	New Haven
Fair Haven Elderly	New Haven	Monterey 5	New Haven

Bolded identifies a site that is vulnerable to both stressors

Several of the affordable housing sites identified in the above tables are found in multiple datasets. For example, Farnam Courts in New Haven has been identified in the three data sets (HUD multifamily, complex, and SCRCOG data layers). This does not increase the vulnerability; however, it does show that this site is more vulnerable in comparison to the other properties of its kind found in each relative dataset.

In addition to identifying the locational vulnerability for each of these sites and characterizing general vulnerabilities associated with affordable housing, it is worth identifying which of these properties are in proximity to a TOD and may ultimately benefit from or be incorporated into an adaptation scenario or TOD development project.

9.5 Evacuation Routes

The identification and representation of evacuation routes throughout the region has proven to be a challenge as most communities, including those who participated in the Resilient Connecticut regional workshops, have noted that these routes are typically not publicized ahead of time. Some communities have shared information regarding certain roadways as these specific instances often serve as a "one way in, one way out." Many of the isolation-type ZSRs, particularly those that contain a regional asset, likely have fewer options for evacuation. These isolation-based ZSRs should be evaluated on a case-by-case basis to assess challenges or vulnerability concerns.

With evacuation routes being a localized designation, this does not present a direct relation to a regional resilience opportunity. However, many of these evacuation routes could potentially be

candidates for resilient corridor designation, and they could come into play during prioritization of opportunity areas.

9.6 Public Water and Sewer Infrastructure

There are innate vulnerabilities associated with both public water and public sewer infrastructure. Because of the intricate nature of these systems, along with the numerous pieces and types of system components, spatial vulnerability analysis is not comprehensive due to data gaps. Ultimately there are two methods for evaluating these systems for this spatial assessment; identifying public water systems wells, and wastewater treatment plant and pump station locations and their relation to flood vulnerable areas.

9.6.1 Public water Systems

The Resilient Connecticut planning process included a review of recent planning efforts. The Connecticut Drinking Water Vulnerability and Resilience plan[16] (DWVARP) is a recent planning effort that identifies specific flood vulnerabilities associated with various types of drinking water system infrastructure.

More generally speaking, there are various vulnerabilities associated with certain types of water system components. Public water supply wellheads are often located in undeveloped or sparsely developed areas within proximity to a stream. The installation of these wells is strategic as the environmental conditions in these areas lend themselves to ample groundwater supply. However, with these wellheads in such proximity to flood zones, there are certain vulnerabilities. Older wellheads which are not constructed with certain sanitary standards are at risk of contamination during a flooding event. Most wellheads constructed with flood zones in mind are elevated above base flood elevations and with proper equipment, however small water systems or infrastructure with dated equipment may be vulnerable. While some wellheads may be elevated or equipped to prevent contamination, there can also be a risk of damage from flood debris.

There are over 920 public water system (PWS) wells in Fairfield and New Haven Counties. This includes community, non-community, and non-transient non-community system wells. There are thirteen PWS wells that are located in high flood vulnerable areas (Table 12). Of these, three are a community water system, six are a non-community water system and four are a non-transient non-community water system.

The three community PWS wells are owned by two large public water suppliers: Aquarion and Regional Water Authority.

TABLE 12: PUBLIC WATER SYSTEM WELLS IN HIGH FLOOD VULNERABLE AREAS

PWS Name	PWS Type	Municipality	Well Name

[16] https://circa.uconn.edu/drinking-water-vulnerability-assessment-and-resilience-plan/

Plaza At 382-390 Wolcott Rd-Wolcott	NC	Wolcott	Well
St. Pius X Church	NC	Wolcott	Well
531 Forest Road - N. Branford	NC	North Branford	Well
Aquarion Water Co of Ct-Newtown System	C	Newtown	Well, #1
Aquarion Water Co of Ct-Newtown System	C	Newtown	Well #2
Regional Water Authority	C	New Haven	Derby Well 1
Heritage Plaza	NTNC	New Fairfield	Well 3
Fairwood Professional Building	NTNC	New Fairfield	Well
Route 34 Plaza	NC	Monroe	Well #1
Subway	NC	Danbury	Well
Kentucky Fried Chicken of Danbury, Inc.	NC	Danbury	Well
Country Kids Club	NTNC	Brookfield	Well #1
Country Kids Club	NTNC	Brookfield	Well #2

Surface water supply infrastructure also has certain vulnerabilities as it is associated with, or near, reservoirs and streams. Intense precipitation can lead to flooding conditions which can stress or damage certain water system infrastructure. While a majority of surface water supply dams are considered high risk, these systems are also regularly maintained and inspected to prevent and mitigate flooding impacts.

Heat has also proved to be a challenge to public water systems. With increased temperatures comes increased severity or frequency of algal blooms. Water systems are familiar with monitoring and treating algal blooms, however with temperatures increasing future blooms and their impacts are a potential issue for these systems.

9.6.2 Sanitary Sewer Systems and Wastewater Infrastructure

Assets and infrastructure associated with sanitary sewers and wastewater collection and treatment systems can be impacted by high precipitation and flood events because they lie at relatively lower elevations that allow for gravity flow and drainage within the systems.

Specifically, wastewater treatment facilities, sewer pumping stations, and related infrastructure are oftentimes developed near a waterbody. Many of the WWTPs in Connecticut are located in flood zones along rivers, streams, tidal estuaries, and Long Island Sound. The moderate and high flood vulnerabilities are not surprising, as these facilities are designed to discharge to (and therefore be located near) watercourses or tidal waters. Sewer pumping stations are designed to collect sanitary sewage at a natural low pint and then pump it somewhere else; the low elevations associated with pumping stations make them more likely to be flooded by intense precipitation, riverine floods, or coastal floods.

Wastewater treatment plants (sometimes called sewer treatment plants or water pollution control facilities [WPCFs] in Connecticut) and sanitary sewer pumping stations with more than low flood vulnerability (i.e., moderate, moderate-high, and high) are listed below. Names have not been modified for consistency; in other words, one entry may be "wastewater treatment plant" and another may be "WWTP" or "WPCF" as they are derived from the GIS.

TABLE 13: WASTEWATER SYSTEM INFRASTRUCTURE AND COMBINED HEAT AND FLOOD VULNERABILITY

Facility Name	Facility Type	Town	Combined Heat-Flood Vulnerability
Johnsons Point Pump Station	Pump Station	Branford	Mod-High Flood, Low Heat
Summer Island Pump Station	Pump Station	Branford	Mod-High Flood, Mod-Low Heat
Beckett Ave Pump Station	Pump Station	Branford	Mod-High Flood, Mod-Heat
Pawson Rd Pump Station	Pump Station	Branford	Mod-High Flood, Mod-Low Heat
Lanphier Season Pump Station	Pump Station	Branford	Mod-High Flood, Low Heat
Sunrise Cove Pump Station	Pump Station	Branford	Mod-High Flood, Mod Heat
Pages Pump Station	Pump Station	Branford	Mod-High Flood, Mod Heat
Sybil Pump Station	Pump Station	Branford	Mod-High Flood, Mod Heat
WWTP (Inter) Pump Station	Pump Station	Branford	Mod-High Flood, Mod Heat
Treatment Plant	Wastewater Treatment Plant	Branford	Mod-High Flood, Mod-High Heat
Harbor St Pump Station	Pump Station	Branford	Mod-High Flood, Mod-High Heat
So Montowese Pump Station	Pump Station	Branford	Mod-High Flood, Mod- Heat
Central Pump Station	**Pump Station**	**Branford**	**High Flood, Mod-High Heat**
Rice Terrace Pump Station	Pump Station	Branford	Mod-High Flood, Mod Heat
Bradley Ave Pump Station	Pump Station	Branford	Mode-High Flood, Mod-High Heat
Blocks Pump Station	Pump Station	Branford	Mod-High Flood, Mod Heat
Lanphier Cove Pump Station	Pump Station	Branford	Mod-High Flood, Mod Heat
Little Bay Lane Pump Station	Pump Station	Branford	Mod-High Flood, Low Heat
Maltby Pump Station	Pump Station	Branford	Mod-High Flood, Low Heat

Hotchkiss Grove Pump Station	Pump Station	Branford	Mod-High Flood, Mod-Low Heat
East Side Sewage Treatment Plant	**Sewage Treatment Plant**	**Bridgeport**	**High Flood, High Heat**
West End Sewage Treatment Plant	**Sewage Treatment Plant**	**Bridgeport**	**High Flood, High Heat**
Fairfield Sewage Treatment Plant	Sewage Treatment Plant	Fairfield	Mod-High Flood, Mod Heat
Wastewater Treatment Plant	Sewage Treatment Plant	Fairfield	Mod-High Flood, Mod Heat
Sewer Pump Station	**Pump Station**	**Hamden**	**High Flood, High Heat**
Sewer Pump Station	Pump Station	Hamden	Mod-High Flood, Mod-High Heat
Sewer Pump Station	Pump Station	Hamden	Mod-High Flood, Mod-High Heat
Branford Road PS (sewer)	Pump Station	North Branford	Mod-High Flood, Mod-Low Heat
White Hollow Rd PS (sewer)	Pump Station	North Branford	Mod-High Flood, Mod-Low Heat
Wastewater Pump Station	Pump Station	Oxford	Mode-High Flood, Low Heat
Wastewater Treatment	**Wastewater Treatment Plant**	**Wallingford**	**High Flood, Mod-High Heat**
Trumbull PS	Pump Station	West Haven	Mod-High Flood, Low Heat
Baybrook PS	Pump Station	West Haven	Mod-High Flood, Mod Heat
Woodycrest PS	Pump Station	West Haven	Mod-High Flood, Mod-High Heat
Woodmont Road PS	Pump Station	West Haven	Mod-High Flood, Mod-Low Heat
Dawson Av PS	Pump Station	West Haven	Mod-High Flood, Mod Heat
Oyster River PS	Pump Station	West Haven	Mod-High Flood, Mod-High Heat
Savin Av PS	Pump Station	West Haven	Mod-High Flood, Mod-High Heat
East Ave PS	Pump Station	West Haven	Mod-High Flood, Mod Heat
Main Pump Station	Pump Station	West Haven	Mod-High Flood, Mod-High Heat
Cove River PS	Pump Station	West Haven	Mod-High Flood, Mod-Low Heat
Jones St PS	Pump Station	West Haven	Mod-High Flood, Mod-High Heat

WWTP	Wastewater Treatment Plant	West Haven	Mod-High Flood, High Heat
Front Av PS	Pump Station	West Haven	Mode-High Flood, Mod-High Heat
Bolded indicates high combined vulnerability			

The heat vulnerabilities listed in the table vary from low to high. Heat vulnerability is not necessarily a key consideration in addressing climate risks, as the infrastructure can be designed and constructed with low sensitivity to anticipated heat variations. They are merely noted above because they help demonstrate the variation in conditions (whether dense development or natural systems) that affect heat vulnerability.

The following table (Table 14) lists the WWTPs in the Resilient Connecticut planning area with the corresponding flood and heat vulnerability. Zones of shared risk are cross-referenced. Note that several WWTPs were not delineated into zones of shared risk, either because of their specific position relative to ZSR types (access, location, etc.) or because they are located in communities in which ZSRs were not delineated.

TABLE 14: WATER POLLUTION FACILITIES ZSR AND COMBINED VULNERABILITY

NAME	CITY	ZSR ID	ZSR Classification	Combined Heat-Flood Vulnerability
Ansonia WPCF	**Ansonia**	**6900-00-422-0**	**Location**	**High Flood, Moderate-High Heat**
Beacon Falls WPCF	Beacon Falls			Mod Flood, Mod Heat
Branford WPCF	Branford	5000-38-297-0	Access	Mod-High Flood, Mod Heat
Bridgeport (East) WPCF	**Bridgeport**	**7000-04-57-0**	**Location**	**High Flood, High Heat**
Bridgeport (West) WPCF	Bridgeport	7000-07-22-0	Location	Moderate-High Flood, Moderate-High Heat
Cheshire WPCF	Cheshire			Mod-High Flood, Mod Heat
Danbury WPCF	Danbury			Moderate-Low Flood, Moderate-High Heat
Derby WPCF	**Derby**	**6900-00-422-0**	**Location**	**High Flood, Moderate-High Heat**
Fairfield WPCF	Fairfield	7000-09-36-0	Location	Mod-High Flood, Mod Heat
Greenwich WPCF	Greenwich	7409-00-66-0	Location	Mod-High Flood, Mod Heat
Meriden WPCF	Meriden			Mod-High Flood, Mod Heat
Milford (Beaver Bk) WPCF	Milford	6000-89-376-0	Location	Mod-High Flood, Mod Heat
Naugatuck WPCF	Naugatuck	6900-00-441-0	Location	Mod-Low Flood, Mod Heat
New Canaan WPCF	New Canaan	7401-00-192-0	Location	Mod-High Flood, Mod-Low Heat
New Haven-East Shore WPCF	New Haven	5000-47-274-0	Location	Mod-High Flood, Mod-High Heat
North Haven WPCF	North Haven			Mod-High Flood, Mod Heat
Norwalk WPCF	Norwalk	7300-00-148-0	Location	Mod-High Flood, Mod-High Heat
Ridgefield (Rt 7) WPCF	Ridgefield	7300-00-201-0	Location	Mod Flood, Mod-Low Heat
Ridgefield (Main) WPCF	Ridgefield	7300-01-247-0	Location	Mod-High Flood, Mod-Low Heat
Seymour WPCF	Seymour	6900-00-442-0	Location	Mod-High Flood, Mod-Low Heat
Shelton WPCF	Shelton			Mod-High Flood, Mod-Low Heat
Stamford WPCF	**Stamford**	**7000-40-236-0**	**Location**	**High Flood, Low Heat**
Stratford WPCF	**Stratford**	**7101-00-2-0**	**Location**	**High Flood, High Heat**
Wallingford WPCF	Wallingford	5200-00-258-0	Location	Mod Flood, Mod-Low Heat

Waterbury WPCF	Waterbury	6900-00-440-0	Location	Mod Flood, Mod Heat
West Haven WPCF	West Haven	5000-49-350-0	Access	Mod-High Flood, High Heat
Westport WPCF	Westport			Mod Flood, Mod-Low Heat
Hammonasset State Beach	Madison	5000-13-330-0	Natural Protection	
Milford (Housatonic) WPCF	Milford	6000-00-443-0	Location	Mod Flood, Mod-Low Heat
Newtown WPCF	Newtown			Mod-High Flood, Low Heat
Georgetown (Redding)	Redding	7300-00-246-0	Location	Mod-High Flood, Mod-Low Heat

Bolded indicates high combined vulnerability

As explained above, the heat vulnerabilities listed in the table vary from low to high. Heat vulnerability is not a key consideration in addressing climate risks, as WWTPs/WPCFs can be designed and constructed with low sensitivity to anticipated heat variations.

9.6.3 Areas Dependent on Subsurface Sewage Disposal Systems (Septic Systems)

Numerous areas in Fairfield County and New Haven County are served by sanitary sewer systems (Figure 58). Areas not served by sanitary sewer systems must rely on subsurface sewage disposal systems, known informally as septic systems. The State Water Plan should be consulted for a detailed discussion of the subtle differences between types of subsurface sewage disposal systems and septic systems. For the purpose of this report, this discussion will refer to them as septic systems. Septic systems are vulnerable to many types of flooding but relatively insensitive to heat-related vulnerabilities.

The areas in Fairfield County and New Haven County served by septic systems are determined by subtracting the areas served by sewer systems. However, the DEEP sewer service areas GIS layer is relatively aged and has not been subject to updates. This was noted during the development of the Southeastern Connecticut Wastewater Management Plan in 2018 (although southeastern Connecticut is outside Fairfield County and New Haven County. This is a key data gap that will need to be addressed for future resiliency planning.

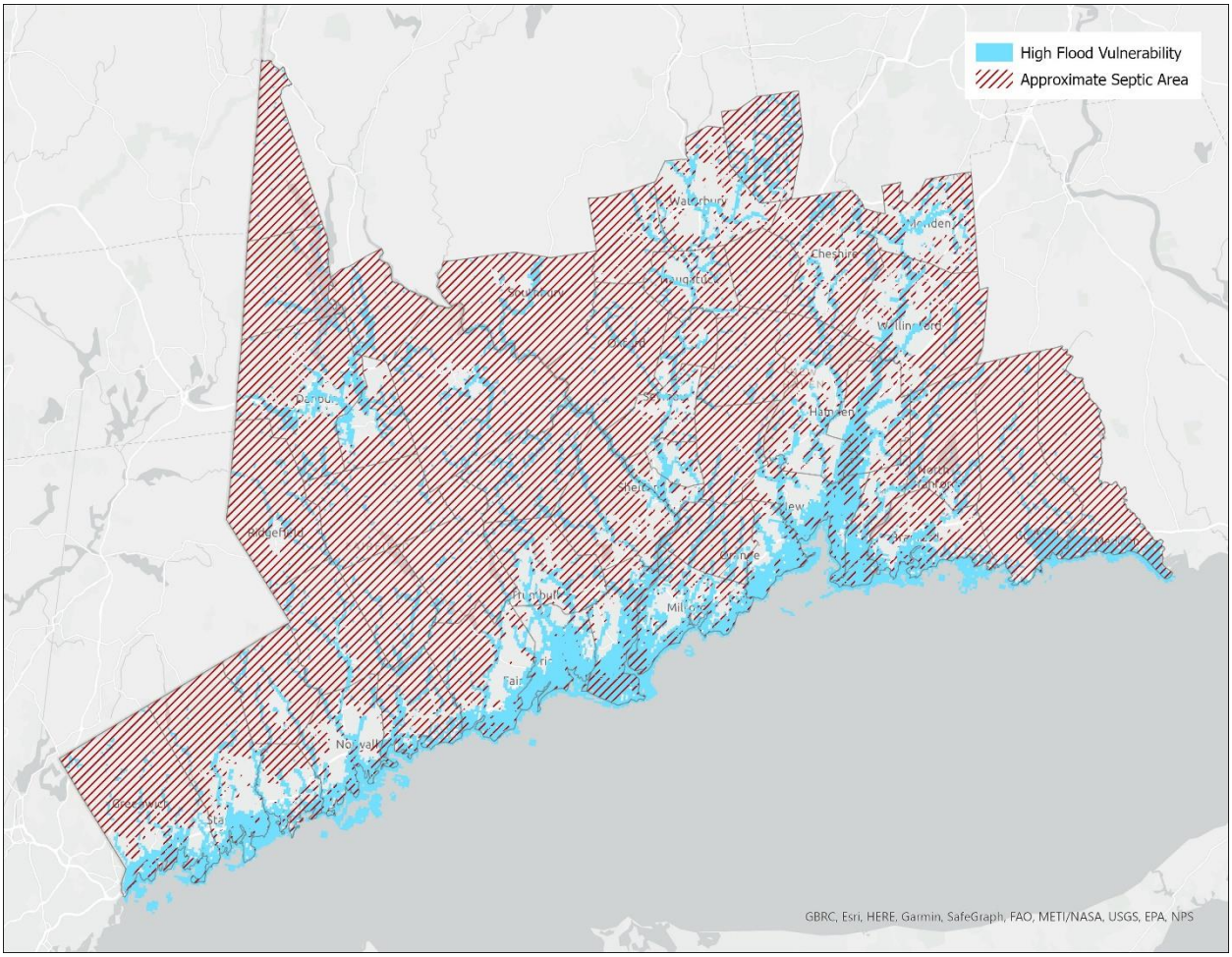


FIGURE 58: APPROXIMATE SEPTIC SYSTEM AREAS WITH UNDERLYING FLOOD VULNERABILITY

Identification of small pockets of septic system service within communities served by sewer systems is not instructive for regional resilience planning, as some of these small areas can eventually be addressed through sewer system extensions to foster resiliency.

Towns such as Sherman and New Fairfield, which are not served by sewer systems, will inherently encompass areas of septic systems that are coincident with moderate to high flood vulnerability. These communities should be considered moderately vulnerable relative to dependence on septic systems, as numerous properties likely rely on septic systems where moderate to high flood vulnerability is mapped.

Communities that are unable to rely on extension of sewer service in the current regulatory climate are sometimes referred to as "sewer avoidance" communities. Two such communities (Guilford and Madison) are located in the planning area. Along with the eastern third of Branford which lacks sewer service, this stretch of shoreline is across three towns is dependent on septic systems and is highly vulnerable to coastal flooding. The Guilford Coastal Resilience Plan (publication dates 2012-2014) explains that the eventual loss of septic systems to coastal hazards may result in the loss of use of individual developed properties. While sewer avoidance may impose development-related challenges such as the inability to foster TOD at high densities in Guilford and Madison, the flood-related challenges are anticipated to increase over time and combined with these other challenges.

9.6.4 Critical Habitats and Natural Diversity Data Base Areas

The Connecticut critical habitats data represents 25 types of specialized habitats throughout the state. These habitats largely contribute to specific coastal and inland ecosystems, with some of these systems more resilient to hazards and the effects of climate change than others. These areas throughout the study region (Figure 59). May be optimal targets for land conservations and protection and may be significant for maintain species diversity.

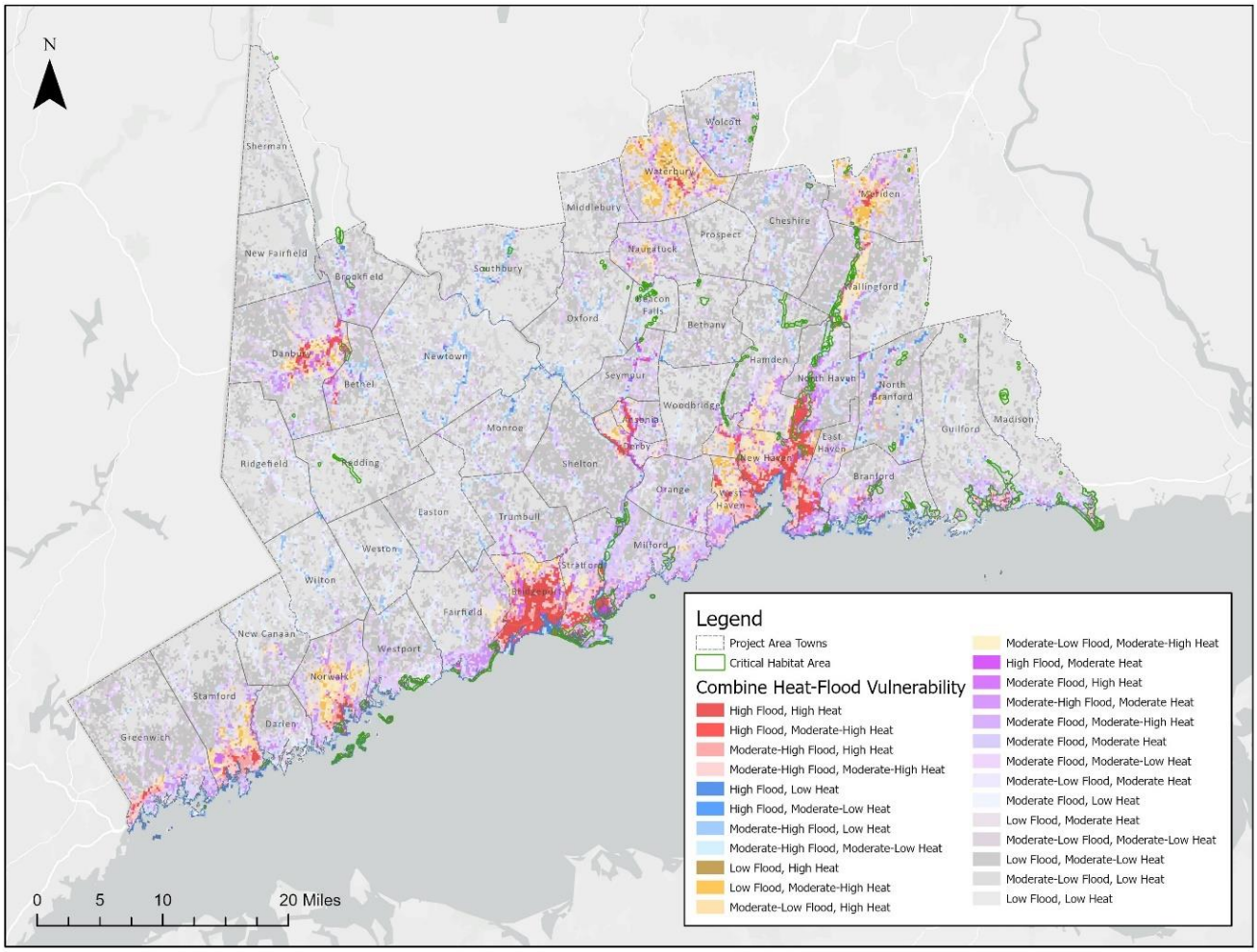


FIGURE 59: CRITICAL HABITATS THROUGHOUT THE RESILIENT CONNECTICUT STUDY REGION

To understand which of these habitats are more vulnerable to flooding, and potentially at higher risk of impact from floods or conditions that cause flooding, those located within high and moderately high flood vulnerable areas have been highlighted. To evaluate vulnerabilities further this data from DEEP can and should be used in conjunction with other data sets for planning or development purposes.

There are 34 different critical habitat sites within the high flood vulnerable areas (Table 15). Many of these contain either a freshwater or salt marsh; other habitats include scrub oak habitat, floodplain forests, grassy glades, or swamps overlying alluvial deposits. Many of these habitat types provide both critical habitat to their respective ecosystem and some degree of buffering from flood waters. Vegetated freshwater marshes, forests, and glades can, reduce bank erosion, and retain or detain flood waters. Tidal marshes and associated critical habitats can attenuate wave action and reduce risks from storm surge through the benefits identified by The Nature Conservancy and others. Many of these sites also provide other regional benefits such as locations for shade or water access during heat waves, and/or serve as economic stimulators to surrounding communities being tourist attractions,

TABLE 15: CRITICAL HABITAT SITES AND TYPES IN HIGH FLOOD VULNERABLE AREAS

Site	Habitat Type[17]	
Ash Creek	Intertidal Marsh	Salt Marsh
Ash Creek	Beachshore	Salt
Carting Island	Intertidal Marsh	Brackish Marsh
Cove Island Park	Beachshore	Salt
Cytec Corp	Dry Acidic Forest	Stratified Sand and Gravel
Cytec Corp	Sand Barren	Sparsely Vegetated Sand
East River	Intertidal Marsh	Salt Marsh
Fairfield Beach	Beachshore	Salt
Farmill River, Pine Rock Park	Intertidal Marsh	Freshwater Marsh
Fayerweather Island	Intertidal Marsh	Salt Marsh
Fayerweather Island	Beachshore	Salt
Frash Pond	Intertidal Marsh	Other/Unique
Great Meadows	Intertidal Marsh	Salt Marsh
Hammonasset State Park	Coastal Woodland/Shrubland	Woodland/Shrubland
Hammonasset State Park	Beachshore	Salt
Hammonasset State Park, Hammonasset River	Intertidal Marsh	Salt Marsh
Jennings Beach	Beachshore	Salt
Kelsey Island	Beachshore	Salt
Kelsey Island	Coastal Bluffs and Headlands	Pitch Pine/Post Oak
Kelsey Island Marsh	Intertidal Marsh	Salt Marsh
Limekiln Brook	Floodplain Forest	Alluvial Swamp
Long Beach/Pleasure Beach	Beachshore	Salt
Long Point	Intertidal Marsh	Salt Marsh
Lordship Beach	Beachshore	Salt

[17] http://www.cteco.uconn.edu/guides/resource/CT_ECO_Resource_Guide_Critical_Habitat.pdf

Lordship Beach	Coastal Woodland/Shrubland	Woodland/Shrubland
Manresa Island	Intertidal Marsh	Salt Marsh
Milford Point	Beachshore	Salt
Morse Point Beach	Beachshore	Salt
Naugatuck State Forest	Acidic Rocky Summit Outcrop	Grassy Glade/Bald & Scrub Oak
Nells Island	Intertidal Marsh	Salt Marsh
Norwalk Islands	Coastal Grassland	
Norwalk Islands	Beachshore	Salt
Oronoque	Intertidal Marsh	Freshwater Marsh
Quinnipiac R - Wharton Brook	Floodplain Forest	Undifferentiated
Quinnipiac River/Walco Park	Floodplain Forest	Undifferentiated
Quinnipiac River	Intertidal Marsh	Brackish and Freshwater Marsh
Sasco Hill Beach	Beachshore	Salt
Seaview Beach	Beachshore	Salt
Silver Sands Beach	Beachshore	Salt
Stony Creek Marshes	Intertidal Marsh	Salt Marsh
Stratford Great Meadows	Beachshore	Salt
West River	Intertidal Marsh	Salt and Freshwater Marsh

In addition to the critical habitats, the Natural Diversity Data Base (NDDB) maps were reviewed. The NDDB maps are less specific than critical habitat data relative to implying a type of habitat, but represent important approximate locations for endangered, threatened, or species of special concern. The purpose of the NDDB is to identify these locations during preliminary planning endeavors.

NDDB areas throughout the region are located in both high and low flood vulnerable areas (Figure 60). All of the critical habitats in Table 15 intersect an NDDB area; this means that while those critical habitats above serve many purposes, they may also contain endangered, threatened, or species of special concern.

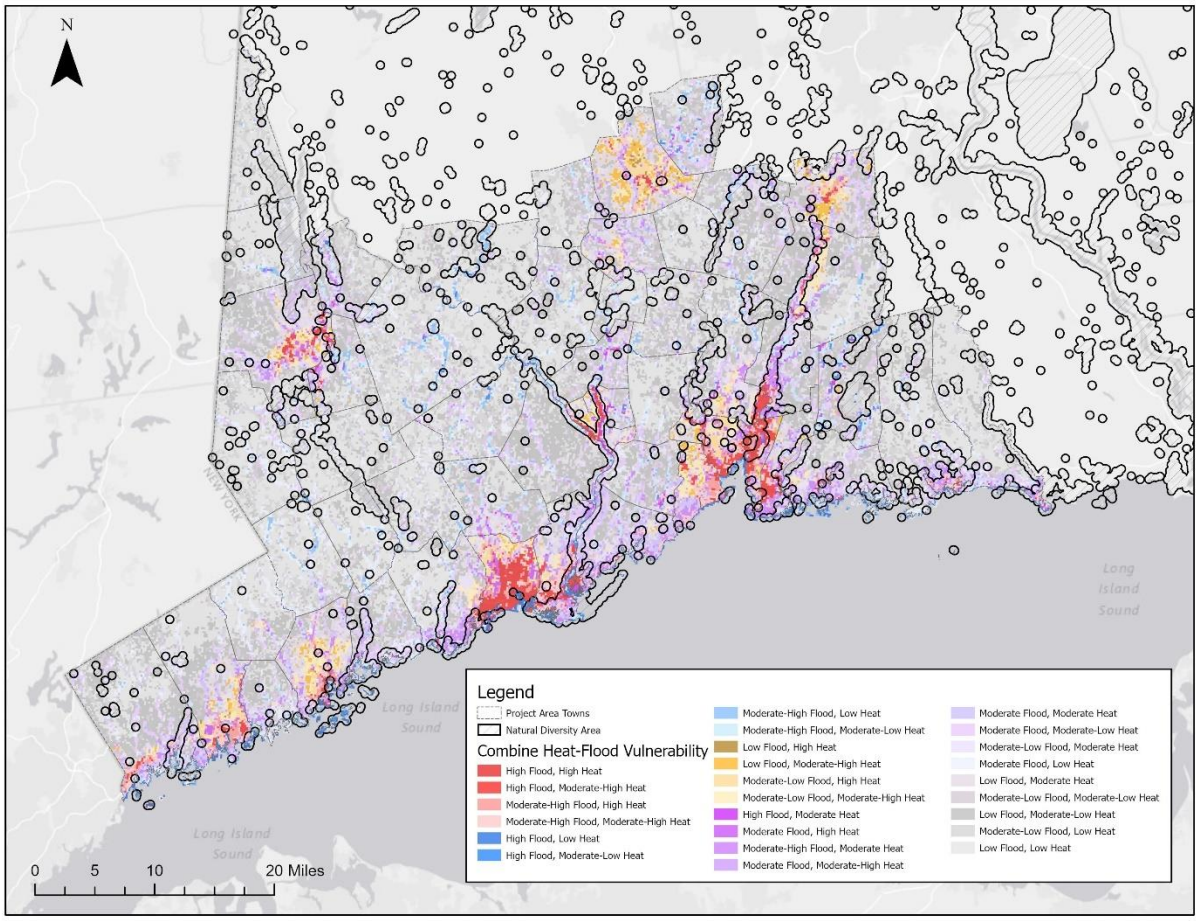


FIGURE 60: NDDB AREAS AND COMBINED VULNERABILITY

Both the NDDB and critical habitat areas, in conjunction with, other built and social components, should be taken into consideration during future resilience planning efforts, by conserving or potentially restoring some of the ecosystems, resilience may be increased to the benefit of communities, infrastructure, and the critical habitats.

9.6.5 Regional Employment Centers

While ecological and infrastructural resilience are integral components of a resilient community, economic resilience is also important. There are numerous economic aspects that can be taken into consideration; one major economic lens is evaluating to continuity of employment throughout the region. To assess the vulnerability of major employment, 269 major employment centers have been identified and assessed for their location-based physical vulnerability.

In addition to physical location and providing a source of continuous income for the local community, a majority of these employment centers *also* provide services that would play a critical role in recovery after a flood or other natural hazard event. In the event that a site is inaccessible or damaged during a flood, certain services, such as grocery, building supply, or municipal

operations may be interrupted, and employees could experience financial difficulties if the facility is experiencing an extended closure.

Throughout both New Haven and Fairfield Counties there are 59 employment centers that are located in a high flood and heat vulnerable location; Table 16 identifies the 14 centers that are located in the highest combined flood and heat vulnerable locations. ZSRs are cross-referenced when applicable.

TABLE 16: REGIONAL EMPLOYMENT CENTERS LOCATED IN THE HIGHEST FLOOD AND HEAT VULNERABLE LOCATIONS

Employment Center	Municipality	ZSR ID & Type
Allied Universal	Bridgeport	7106-00-35-0, Location
Bimbo Bakeries USA	Greenwich	
Bridgeport Fire Fighters Local	Bridgeport	7105-00-31-0, Location
Bridgeport Health Care Ctr	Bridgeport	
Lindley Food Svc	Bridgeport	
Nbc Sports Group	Stamford	
People's United Financial Inc	Bridgeport	7105-00-31-0, Location
Trefz Corp	Bridgeport	7105-00-31-0, Location
UPS Customer Ctr	Stratford	7101-00-2-0, Location
Visiting Nurse Svc of Ct Inc	Bridgeport	
American Medical Response	New Haven	
Ct Transit	Hamden	
St Mary's Hospital	Waterbury	6900-22-409-0, Location
Walmart Supercenter	New Haven	

Because extreme heat may not have the same deleterious impacts as a flood, it is important to identify those facilities that have a high flood risk regardless of heat vulnerability. Neglecting the heat vulnerability, 70 employment centers are in a high flood vulnerable location; Table 17 shows those locations that have the highest flood vulnerability. ZSRs are cross-referenced when applicable.

TABLE 17: EMPLOYMENT CENTERS WITH THE HIGHEST FLOOD VULNERABILITY REGARDLESS OF HEAT VULNERABILITY

Employment Center	Municipality	ZSR ID & Type
Bridgeport Police Dept	Bridgeport	
Bridgeport Police Traffic Div.	Bridgeport	

Day Pitney LLP	Stamford	7000-40-236-0, Location
Purdue Pharma LP	Stamford	7000-40-236-0, Location
Sikorsky Aircraft Corp	Stratford	6000-00-15-0, Location
Stew Leonard's	Danbury	6600-00-223-0, Location
William B Meyer Inc	Stratford	7101-00-2-0, Location & 7101-00-51-24, Location
Fire Lite	North Branford	
Macdermid Inc	Waterbury	6900-00-405-0, Location
New Haven Police Dept	New Haven	5000-48-273-0, Location
New Haven Register	New Haven	
SARGENT Manufacturing Co	New Haven	5000-48-273-0, Location
Ue Union	New Haven	5000-48-273-0, Location
Stop & Shop Supermarket	East Haven	5112-00-287-0, Location
Kerite	Seymour	6919-00-419-0, Location
Target Corporation	Ansonia	6900-00-422-0, Location & 6900-00-422-97, Location
Derby City Hall	Derby	6900-00-422-0, Location & 6900-00-422-95, Location
Town Fair Tire	East Haven	5000-44-283-0, Access & 5000-46-283-54, Location

These centers that are located in high flood and high combined vulnerable areas are primarily found in urbanized communities; these communities are also those with some of the higher social vulnerabilities identified by Resilient Connecticut. While identifying those segments of the population that are employed by these centers would require a more in-depth analysis, it is possible that several of these centers employ individuals that face hardships reflected in the social vulnerability mapping.

10 Resilience Opportunity Area Identification

The preceding vulnerability analysis provides insight regarding the locations, assets, and populations with the highest potential flood and heat vulnerability in the study area. The findings will have an important role in both the identification of regional resilience opportunity areas as well as specific project design and development.

Climate adaptation and resilience opportunities exist throughout the region; this has been documented through numerous prior planning efforts such as the Regional Framework for Coastal Resilience in Southern Connecticut. However, assembling resilience opportunities into geographic "areas" requires an additional level of analysis; the key to identifying these resilience opportunity areas (ROARs) lies within the many variables previously described. By focusing on areas that directly have TOD potential or support nearby TOD, highlighting community and regional vulnerabilities or strengths, and locating regional assets and infrastructure, ROARs have been identified. Because resilience opportunities are not limited to only the parts of a community with TOD potential, additional ROARs have been identified outside of these transit areas. ROARs have been identified using affordable housing assets, wastewater systems, and drinking water infrastructure as the focus of identification.

A crucial concept to underscore at this point in the Resilient Connecticut planning process is that opportunity areas have been *identified* with the most regionally important assets and infrastructure. Opportunity areas have not undergone a selection or screening process. Future screening will be undertaken to prioritize the opportunity areas that may be advanced to further planning and concept design as comprehensive resilience projects. Stakeholder engagement will be included in this prioritization process.

10.1 TOD Resilience Opportunity Areas

Given that accessible transit systems can often be an integral component of a more resilient system, the primary opportunity areas have been identified using proximity to a TOD as a major factor. In addition to TOD, several other components have been incorporated into the identification process. The steps to identify a TOD opportunity area are:

1. **Regional Relevance:** From the initial list of 656 ZSR in the region, the ZSR with regional assets, or Regional ZSR (RZSR), were identified. In total, 626 RZSR were identified, based on having at least one regional asset within the ZSR boundary.
2. **High Asset density:** The 626 RZSR was further narrowed based on which contain the greatest number of assets within RZSR boundaries. Percentiles were used to narrow down those RZSR that encompassed the greatest number of assets. Eighty-six (86) RZSR were identified as containing between 6 and 16 regional assets, which represents the top 20% in terms of total number of regional assets.
3. **Overlapping High Vulnerability and Development**: The 86 RZSR were then overlaid with identified areas of high flood and high heat vulnerability, TOD areas, and areas that have been outlined for planned future development. The result was 40 TOD Resilience Opportunity Areas (Figure 61).

How to Use this Chapter

Resilient Connecticut recognizes that the most significant heat and flood vulnerabilities in Fairfield County and New Haven County overlap in numerous areas where the highest densities of regional infrastructure and assets are located. In most cases, these areas are coincident with transit and transportation nodes and therefore overlap with the locations where transit-oriented development (TOD) is feasible. In some cases, TOD potential is not where the highest flood and flood vulnerabilities are located, but is nearby. These spatial patterns suggest that communities can align State, regional, and local TOD and transit priorities with efforts to become more resilient through adaptation. Resilient Connecticut anticipates that adaptation and resilience projects can be incorporated into community development, redevelopment, and infrastructure investment. While reviewing the opportunity areas in the communities where you live and work, think about the heat and flood vulnerabilities inside these areas and nearby; envision community development and redevelopment efforts that are planned for these areas, and think about the infrastructure present. Can common goals and objectives be found within opportunity areas and among opportunity areas?

This process is further described below.

A RZSR is a zone that contains regional infrastructure and assets. For Resilient Connecticut three types of assets were considered:

- An asset or infrastructure that serves numerous communities by spanning the region

- An asset or infrastructure that serves numerous communities from one location
- An economic asset that serves numerous communities from one location

An asset or infrastructure that spans communities can be thought of as major roadways, electric transmission lines, public water systems, or railroads. These assets run throughout multiple communities and are important for regional transportation and operation. An asset or infrastructure that serves from one location can be thought of as a critical facility as they provide a critical service and/or are important to regional operations. These might include state facilities, hospitals, major ports, distribution centers, and colleges or universities. The third asset type is a major economic source. This type of asset attracts visitors and without its operation may impact the local economy in a negative way. These assets include major retail locations, historic resources, or economic hubs like Long Wharf or Steel Point. With these assets and infrastructure defined and spatially located, each was cross-referenced with the existing zones of shared risk to flag a ZSR as a RZSR.

Because of the numerous types of assets and infrastructure used, and due to the span of most, a majority of the ZSR have been flagged as a RZSR (as mentioned above 626 out of 656 in the region). While most RZSR have between one and five assets or infrastructure within its boundaries, several have over a dozen regional assets and infrastructure within their boundaries. Therefore, only those with the greatest number of assets or infrastructure within their borders were selected to identify opportunity areas.

Ultimately, the intersection of an RZSR with a high heat and high flood vulnerable area and a planned development area, that is in proximity to TOD, were identified as a TOD ROAR, as can be seen in Figure 61. The presence of a RZSR highlights a shared risk among several regional infrastructural components. This might include transit, utilities, or economic assets. The intersection of high flood and high heat vulnerability reinforces that certain assets are vulnerable to flood and heat impacts. With planned future development areas also identified in proximity to these vulnerable assets and risk areas, Resilient Connecticut ROAR development can coordinate with, and build upon, local efforts that may already exist.

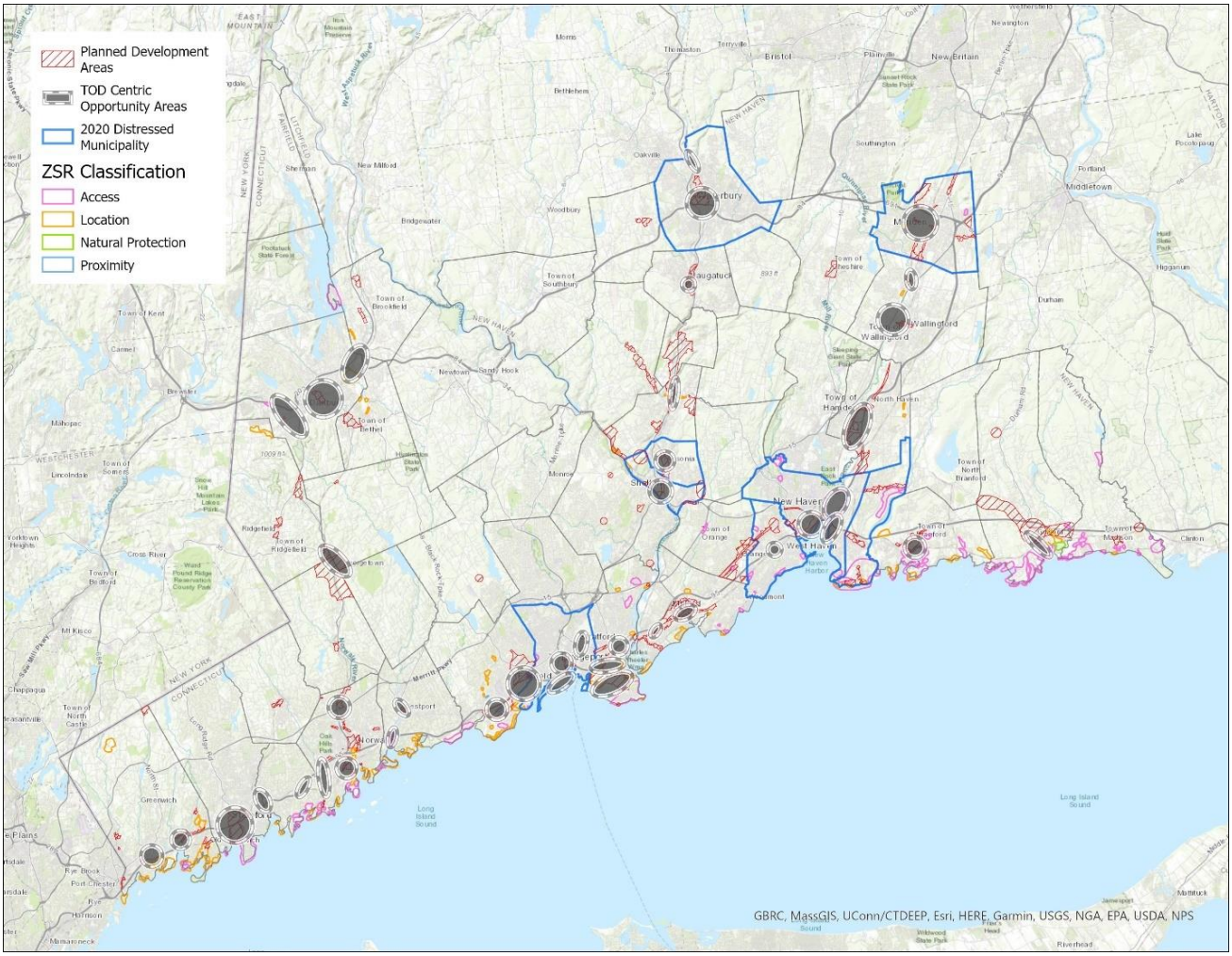


FIGURE 61: TOD RESILIENCE OPPORTUNITY AREAS

10.2 Affordable Housing Opportunity Areas

One component of Resilient Connecticut is to identify opportunities for more resilient affordable housing throughout the region. Of the methods for evaluating vulnerability and risk for housing, however, the focus for Phase II is centered around the physical location of the housing asset in relation to projected flood and heat events and identifying those housing locations most distant from a bus route, as this is a measure of accessibility to cooling during heat waves.

Several of the TOD ROARs already encompass vulnerable affordable housing within their boundary. As such, the following analysis ultimately only identified a small number of new opportunity areas that are outside of the TOD areas.

The identified affordable housing ROARs reveal several characteristics about the underlying community. First there is vulnerable affordable housing that would likely benefit from an adaptation initiative addressing flood and heat related climate stressors. The specific source of flooding, degree of heat exposure, and appropriate resilience strategy likely varies among the areas (in addition to those assets in TOD centered areas) and should be explored further for project development.

Second, these general areas in each community may be suitable for *future* development of affordable housing that is less vulnerable to heat or flood whether that be due to location, or resilience minded development. While subsequent areas identified have not taken land use or zoning into consideration, several of the areas have both high and low vulnerable assets in close proximity, which may be an indication of a certain level of suitable zoning.

How to Use this Chapter

Resilient Connecticut recognizes that heat and flood vulnerabilities in Fairfield County and New Haven County do not always overlap where the highest densities of regional infrastructure and assets are located. In many cases, specific assets such as affordable housing and specific types of infrastructure such as wastewater treatment plants are offset – or distant from – the areas of densely developed infrastructure and assets. There may have been reasons for these assets and types of infrastructure to be placed where they are located; because of this, the adaptation and resilience projects that are incorporated into community development, redevelopment, and infrastructure investment may not directly benefit these specific assets through adjacency. Resilient Connecticut therefore applied alternate lenses for identifying the opportunity areas associated with other assets and infrastructure. While reviewing these additional opportunity areas in the communities where you live and work, think about the heat and flood vulnerabilities inside these areas and nearby; can common goals and objectives be found within opportunity areas and among different types of opportunity areas?

These areas may also reflect high densities of vulnerable populations. Residents of affordable housing may face increased vulnerability to climate change stressors due to age, pre-existing health conditions, financial or other challenges. The identification of these vulnerable assets may also highlight hyper-local communities vulnerable to climate change and require additional analyses to determine specific opportunities to support.

10.2.1 Affordable Housing Flood and Heat ROARs

By utilizing the available HUD and COG provided data, there are 143 housing locations that are within a high flood *and* high heat area. Many of these vulnerable assets are located either in, or in close proximity to, a TOD centric opportunity area; these assets should be incorporated into these resilience strategies where possible and considered for future TOD development projects outside of the Resilient Connecticut scope. There are however some assets that are not in proximity to TOD areas and present a different type of opportunity specifically for affordable housing in the absence of TOD.

Excluding the vulnerable assets in proximity to TOD, four affordable housing ROARs (Figure 62) have been identified encompassing 36 heat and flood vulnerable housing assets located in a ZSR. Some of these opportunity areas intersect a municipal area of planned development, are within a federal opportunity zone, or are centered in a distressed municipality. Each opportunity area encompasses at least one vulnerable housing asset, with several low vulnerable assets in proximity.

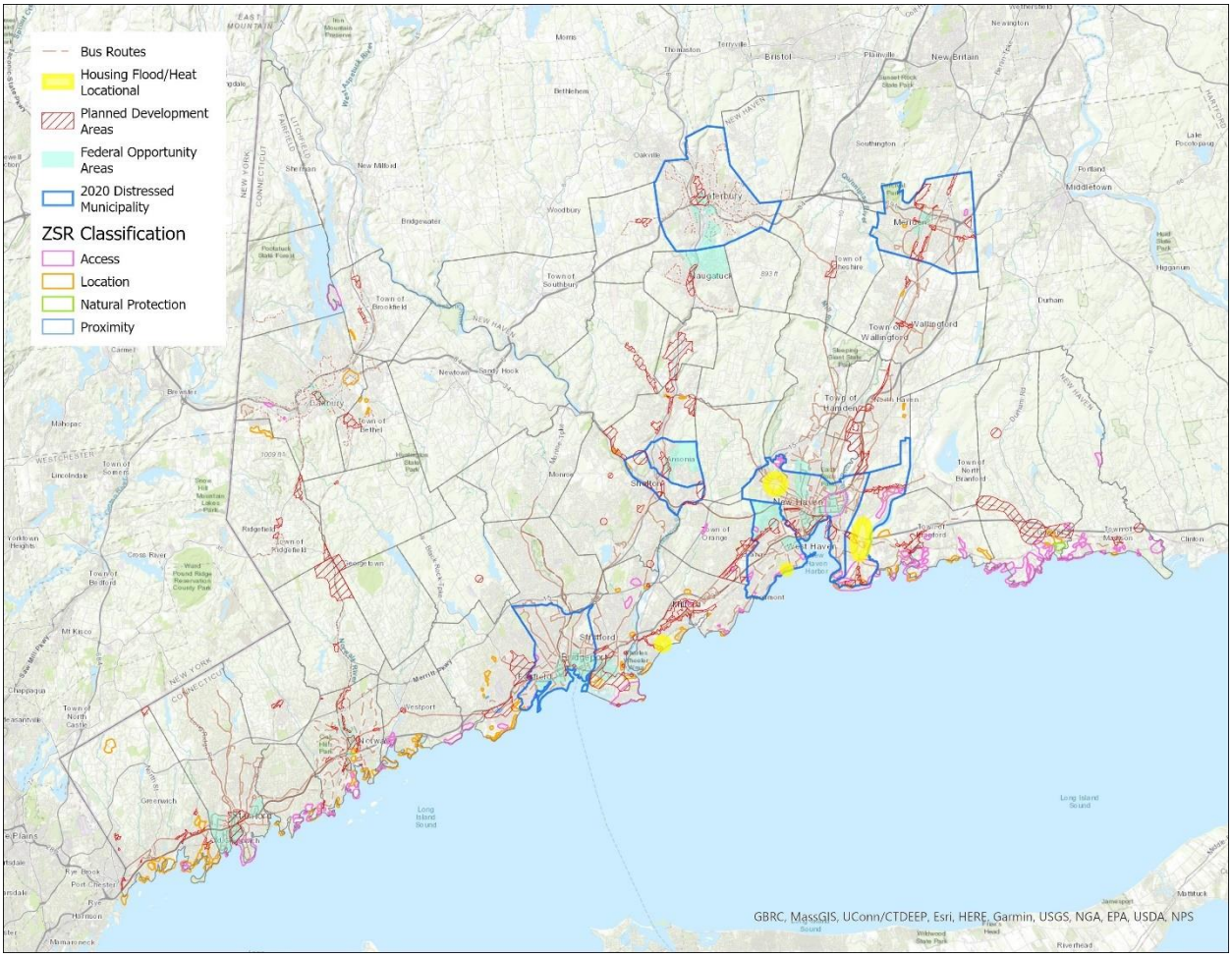


FIGURE 62: AFFORDABLE HOUSING HIGH FLOOD AND HEAT LOCATIONAL OPPORTUNITY AREAS

10.2.2 *Affordable Housing Flood ROARs*

In addition to combined heat and flood vulnerability discussed above, housing asset location opportunity areas have been identified for those that are in high flood vulnerable areas regardless of heat vulnerability. Heat vulnerability-focused only opportunity areas have been identified in the subsequent section based on refuge accessibility. While opportunities in these affordable housing opportunity areas exist for individual structures, they also exist for the homes, infrastructure, and ecosystems in the surrounding neighborhoods to play a role in system wide resilience.

A majority of the 47 flood vulnerable assets are in New Haven County, but outside of TOD centric opportunity areas, with a few located in Fairfield County. These 47 housing sites face a higher risk from flooding than from heat related impacts; these areas are moderate to low heat vulnerability. To further opportunity area identification, these vulnerable assets have been cross-referenced with ZSR to identify potential shared risks. While those assets outside of ZSR still have a level of flood vulnerability, the proximity to a ZSR reflects a broader flood risk within the community and implies the presence of shared solutions.

As a result of this analysis five affordable housing flood ROARs have been identified (Figure 63). The areas are located along the shoreline in Fairfield, Milford, and East Haven, and along the Quinnipiac River corridor in North Haven and Wallingford.

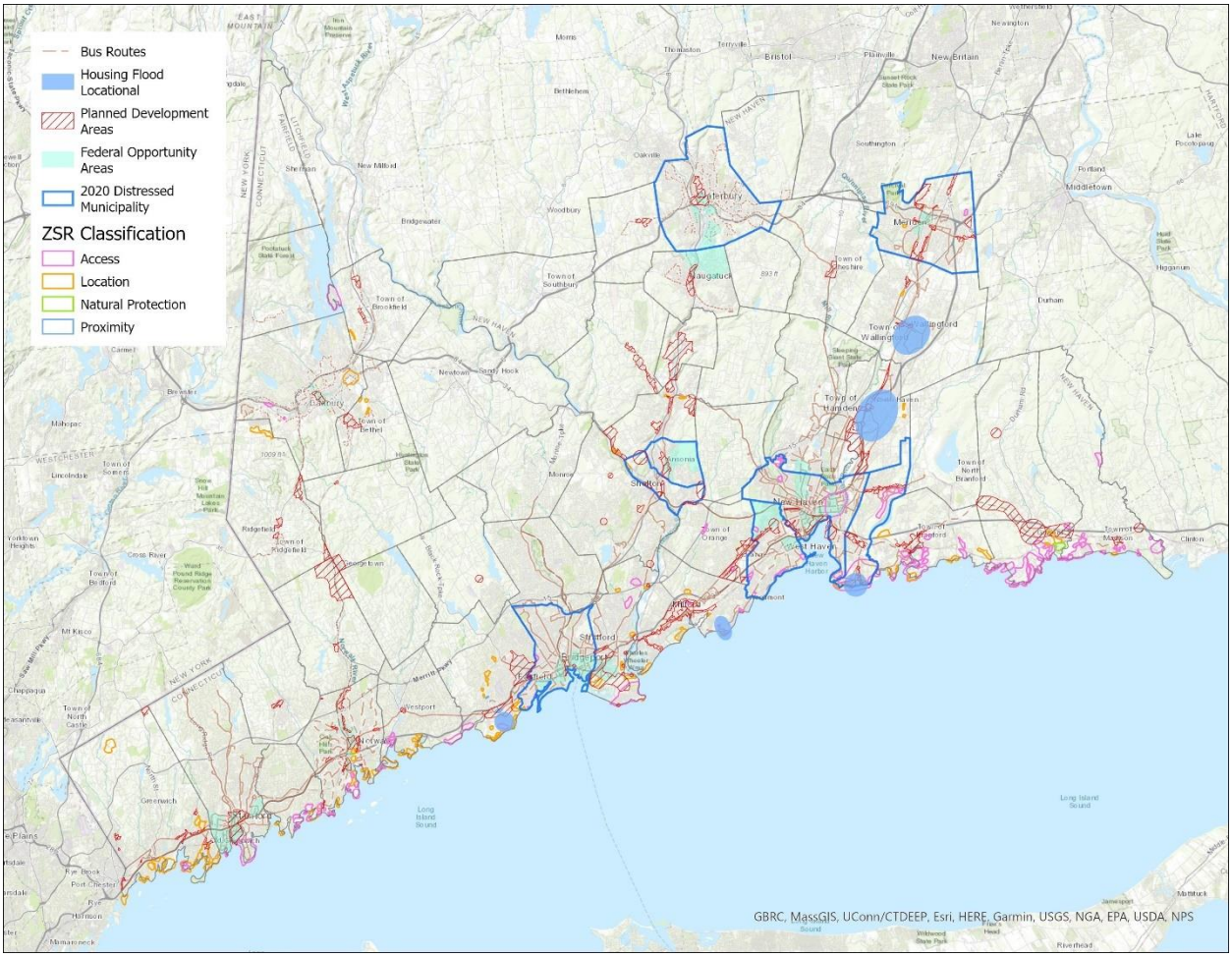


FIGURE 63: AFFORDABLE HOUSING FLOOD LOCATIONAL OPPORTUNITY AREAS

10.2.3 Affordable Housing Accessibility ROARs

In addition to identifying assets that are vulnerable to heat and flood based on location, it is also important to understand resident accessibility, or in this case, lack of accessibility to refuge from heat events. Residents that are in certain affordable housing units throughout the region may face varying degrees of extreme heat exposure; these residents also likely have varying degrees of access to cooling capabilities.

One critical component of heat relief is either having cooling capabilities at home, or easy access to municipal and regional cooling centers. While some residents have personal vehicles that allow them easy transport to a center, some residents may not have the same transportation available. To identify cooling center or public transit opportunities, those affordable housing assets that are within high heat areas and are *not* within 500 meters of a public bus route or cooling center have been identified.

To begin the analysis, all the affordable housing assets in high heat vulnerable areas were located; this process identified 170 assets in high heat areas (regardless of flood vulnerability). However, many these assets are located on or near a public transit bus route. A buffer was then used to locate those assets that are both greater than 500 meters from a bus route *and* from a cooling center. By using this buffer, it is assumed that residents living in these housing locations are not within a comfortable walking distance to transit access or a heat refuge location. Ultimately 19 assets have been identified as being distant from transit and cooling centers. Some assets are near a TOD opportunity area and therefore should be taken into consideration for these particular adaptation scenarios. Others are standalone assets that should be considered on a case-by-case basis for either transit system connections, cooling center designation, or energy related upgrades to ensure that the housing is adequate for residents during a heat wave.

Two opportunity areas have been identified in Fairfield and Stratford due to density of several assets (Figure 64). The Fairfield opportunity area encompasses four assets that are high heat and distant from transit and cooling, in addition to at least six other affordable housing assets within immediate proximity. This area also intersects with a municipal planned development area. The Stratford opportunity area encompasses four housing facilities that are limited relative to cooling and transit access, as well as at least six other affordable housing assets.

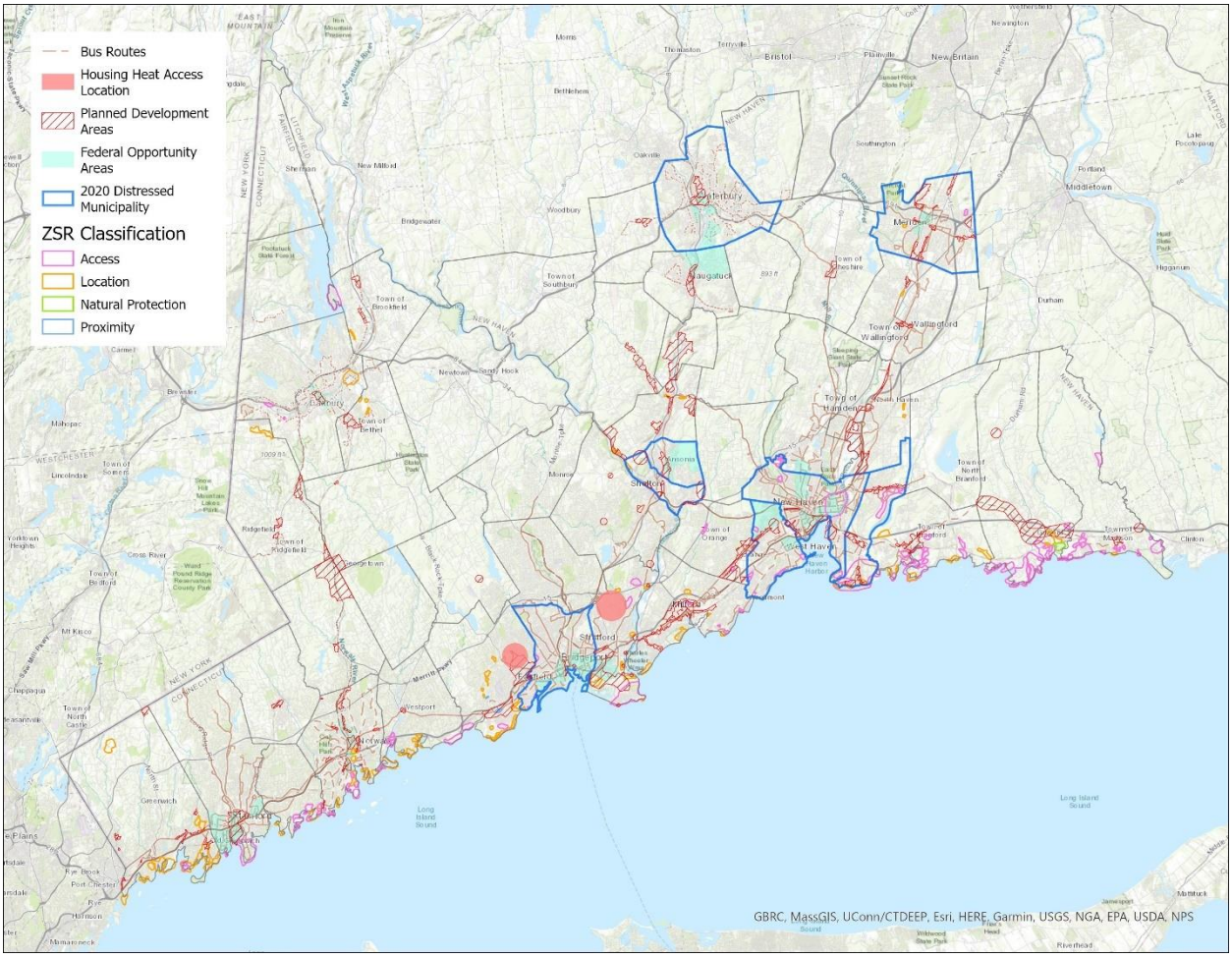


FIGURE 64: AFFORDABLE HOUSING TRANSIT AND COOLING ACCESS OPPORTUNITY AREAS

10.3 Wastewater Infrastructure ROARS

Of the 142 wastewater system (i.e., sanitary sewer systems) components mapped throughout the region, 66 assets are located within a ZSR boundary and in a moderate to high flood vulnerable location; 31 are treatment plants and 35 are pump stations. However, to further identify wastewater infrastructure opportunity areas, the 31 vulnerable treatment facilities were cross referenced with the Connecticut Plan of Conservation and Development balance priority funding areas (BPFA); 19 facilities are located within a BPFA. The BPFA was utilized for this methodology to highlight the eligibility and priority of these areas for public funding.

Most of these 19 facilities are located in, or are in close proximity to, a TOD resilience opportunity area and therefore this facility should be incorporated into adaptation or resilience scenarios pertaining to that opportunity. However, four new opportunity areas have been identified based on the degree of flood vulnerability and proximity to a BPFA (Figure 65). These areas, with two near an affordable housing opportunity area and one in a distressed municipality, present an

opportunity for potential facility or system adaptation. The areas are located in Ridgefield, New Canaan, Milford, and West Haven.

FIGURE 65: WASTEWATER OPPORTUNITY AREAS

10.4 Drinking Water Infrastructure Opportunity Areas

Public water systems in Connecticut include community water systems served by groundwater supply wells and reservoirs, transient non-community water primarily systems served by wells, and non-transient non-community water systems primarily served by wells. While Connecticut benefits from a long history of strong and comprehensive source water protection laws, a handful of climate-driven impacts are possible in source water areas. The Drinking Water Vulnerability Assessment and Resilience Plan, the State Water Plan, and the Coordinated Water Systems Plans address climate change to varying degrees and include climate-informed actions to continue protecting public water systems and their sources. A few combinations of flood and heat vulnerabilities and other factors were examined to identify potential adaptation and resilience opportunities that might protect public water supply sources.

The State's public water supply reservoir watersheds enjoy strong protections. Nevertheless, a few of these watersheds in Fairfield County and New Haven County contain potential toxic or hazardous waste site considerations in locations of high flood vulnerability. The intersection of flood vulnerability, type of site, and location in a public water supply watershed implies an opportunity to reduce risks associated with climate change such as more frequent flooding.

Although many of the public water supply wells in the State are appropriately sited, specific areas in Fairfield County and New Haven County are characterized by high densities of wells located in areas of high flood and high heat vulnerabilities. This raises questions about whether multiple climate-induced hazards such as flooding and flashy drought could lead to impairment of groundwater supply in areas where so many wells are present. The intersection of flood and heat vulnerability and a high density of public water supply wells implies an opportunity to reduce risks associated with climate change.

The project does not attempt to address all climate risks to public water systems and sources. For example, the important points in the Drinking Water Vulnerability Assessment and Resilience Plan about power redundancy for water system facilities and toxic algal blooms in reservoirs must be addressed throughout the State, and therefore do not lend themselves to identifying specific spatial areas that imply unique opportunities for adaptation and resilience.

The three types of drinking water opportunity areas that have been identified include shelters that rely on their own well for drinking water, high density non-community well areas, and public drinking watersheds that encompass vulnerable hazardous material sites.

10.4.1 Shelters and Vulnerable Wells

As noted previously in this assessment, municipal shelters may not always be considered a regional asset, however at times they may be used regionally. Furthermore, they serve a critical function during and after a flood and other emergency events. To ensure that sheltering services are not compromised during or in the wake of a flood event, all shelters across the region have been cross-referenced with non-transient non-community wells in the region. By cross referencing shelters and wells, those that lack redundancy of service from community water systems can be identified. As a result, seven shelters and one cooling center have been identified as having a single well system as their primary source of drinking water. While all these locations may face challenges during droughts, locating those in high flood vulnerable areas identifies those that are at greater risk of physical damage or contamination during an event, potentially impacting the shelter's water supply. Of these eight locations, only one is in a high flood vulnerable area. This opportunity area (Figure 66) which is centered on the John Read Middle School in Redding.

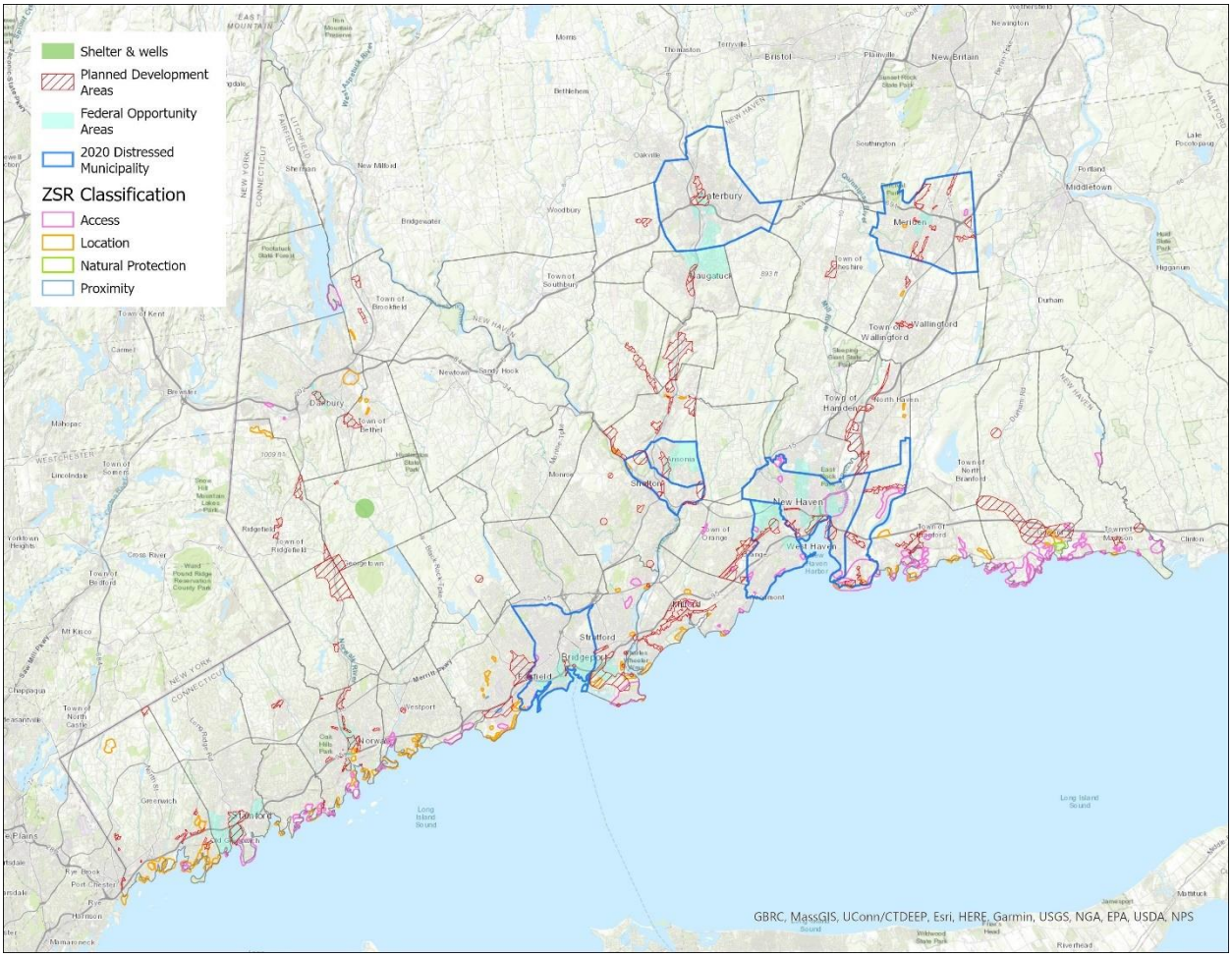


FIGURE 66: SHELTERS AND NON-COMMUNITY WELLS OPPORTUNITY AREAS

10.4.2 Non-community Well Dense ROARs

Community water systems are not present throughout the entire region; therefore, many municipal facilities, businesses, schools, and churches rely on non-community wells as their primary source of drinking water. These wells exist throughout the region, however several communities in Fairfield and New Haven counties have a high density of these wells. To identify these higher density areas, a one-half mile radius was used to identify well density hot spots. As a result, three areas have been identified (Figure 67) in Brookfield, Monroe, and New Fairfield for having the highest density of non-community wells. While these three areas are not relatively the highest flood or extreme heat vulnerable locations in the region, there may be long-term challenges with these locations in relation to increased heat or drought occurrences, in addition to physical damage to those wells that are in higher flood vulnerable areas.

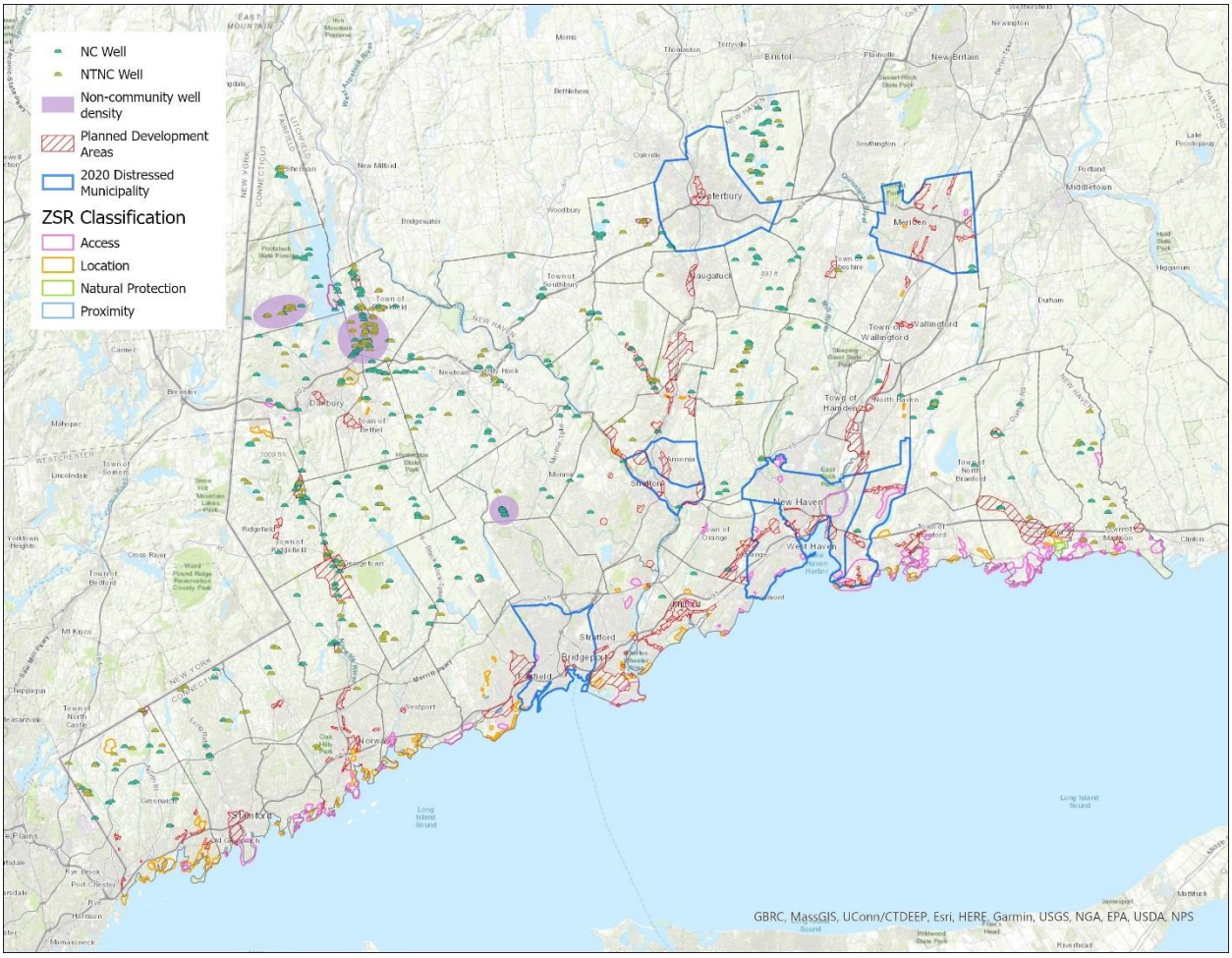


FIGURE 67: NON-COMMUNITY WELL DENSE OPPORTUNITY AREAS

10.4.3 Potentially Hazardous Sites and Public Drinking Water Watersheds

The third group of drinking water related opportunities areas have been identified by locating hazardous material sites that are in high flood areas and also located in public drinking water supply watershed. Three types of hazardous sites have been used:

- brownfields (CT DEEP),
- registered toxic release sites (EPA)
- hazardous substance or chemical storage sites, also known as EPCRA Tier II Emergency and Hazardous Chemical Inventory sites (CT DEEP)

While there are programs and regulations to monitor these sites, their activity, and potential contaminants, it is also important to realize potential contamination sources during a flood event that may impact regional drinking water supplies.

To identify these vulnerable sites and watersheds, first the hazardous sites were cross-referenced with high flood vulnerable areas to locate those most vulnerable to flood events. These vulnerable locations were then identified for whether they lie within a public drinking water supply watershed. It was found that four public water supply watersheds contain potentially hazardous sites that could serve as potential contaminant sources in the event of a flood (Figure 68).

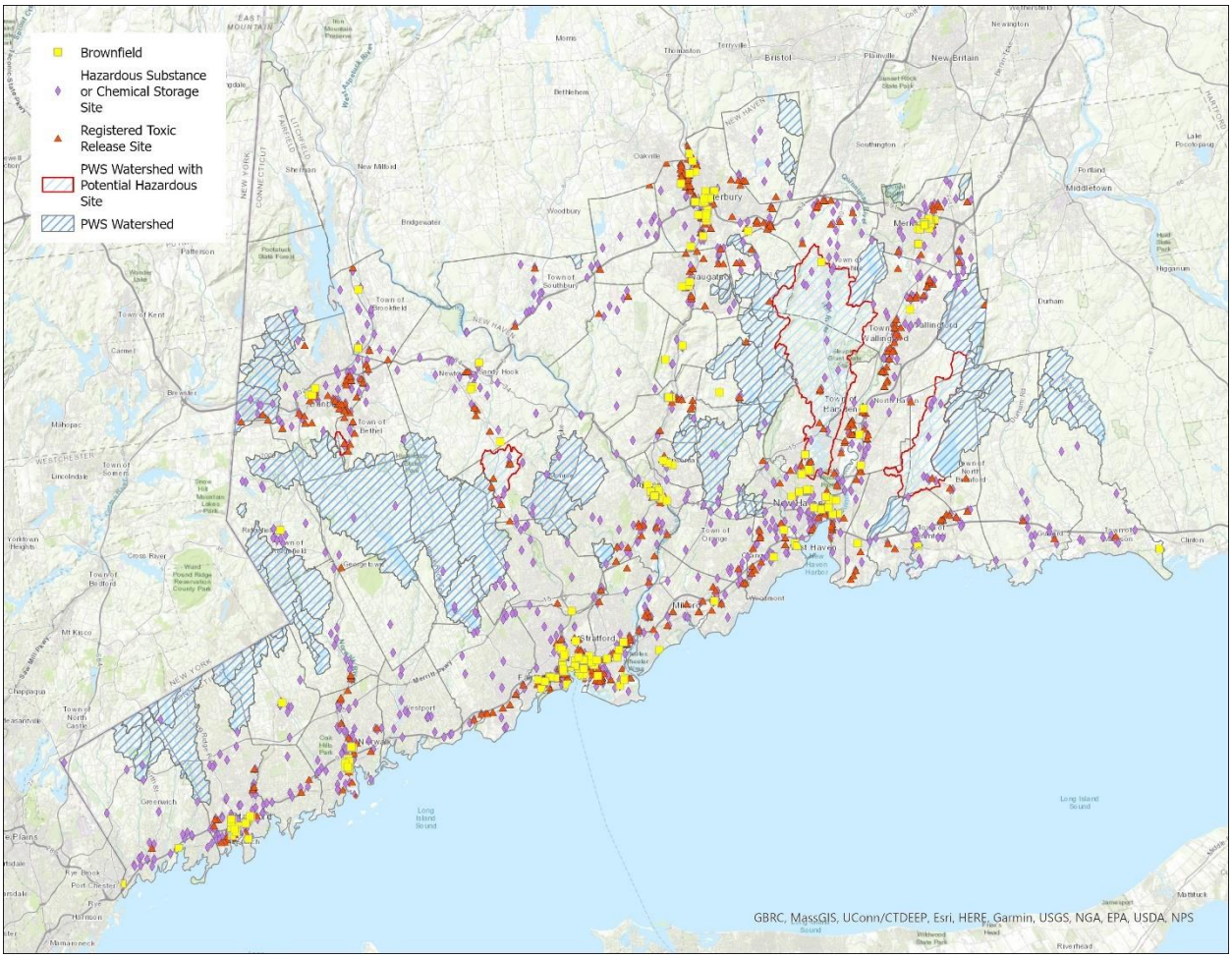


FIGURE 68: PUBLIC WATER SUPPLY WATERSHED ROARS

10.5 Opportunity Areas for Future Consideration

During the process of opportunity area identification, many other methodologies and area types were considered but not pursued due to data gaps, the need for more in-depth analysis, or because the opportunity was potentially too broad for the Resilient Connecticut objective. It is important however to discuss these potential methodologies, where there is need for improvement, and how some of these components are to be integrated into other aspects of Resilient Connecticut.

10.5.1 Ecological Opportunity Areas

Healthy buffering ecosystems are an important component of resilient systems and therefore were evaluated for opportunity area identification. Marshes were heavily evaluated with priority as they are widespread along the coast of Long Island Sound and can provide resilience benefits. However, during the ecological evaluation process, numerous other questions arose that were to be considered in area identification. For example:

- What is the resilience opportunity that is being sought in an ecosystem opportunity area?
- Is the goal to restore certain habitats, or capitalize on existing?
- What size habitat is too big or small to consider?

It was found that the possibilities for ecological resilience opportunities were heavily dependent on numerous other factors such as type of ecosystem, existing and projected health or extent of the ecosystem, proximity to roadways or railroads, or the type of development adjacent to the system. In order to identify an ecological opportunity area, under the Resilient Connecticut framework, it is important to have a focused goal in mind.

While these questions and factors are important and can and should be explored further, it was determined that the use of healthy ecosystems was better suited as a prioritization component and will be taken into consideration during adaptation scenario development wherever possible. Assuming that resilience opportunity areas will result in a system wide adaptation scenario, nearby ecosystems will be evaluated on a case-by-case basis for each particular prioritized area for their services and potential adaptation capabilities.

10.5.2 Infrastructural Opportunity Areas

A majority of the 63 identified ROARs contain significant physical assets and have a primary focus around the types of infrastructure, as described above. However, it was important to explore additional infrastructural opportunities in addition to the TOD, wastewater, and drinking water areas already identified, as well as the numerous infrastructure components and assets that were counted toward identifying the TOD ROARs.

One additional system discussed was power grid infrastructure and how opportunities can be identified using available data such as transmission line and substation locations. While it is important to identify substations and electrical infrastructure in high flood vulnerable areas, it is challenging to identify which specific areas in a community may be impacted by a compromised power line or substation in the event of a flood.

Power-supply vulnerability and resilience considerations will be incorporated into this project on a case-by-case basis for different opportunity areas. Understanding local power-related challenges that have regional impacts (i.e., a shelter that is without backup power can impact a community, but also stress adjacent communities as evacuees look for refuge elsewhere) can be foundational to reducing power supply disruption, enhancing grid resilience and identifying

redundant power supply needs and opportunities, such as through solar installations or micro-grid development.

10.5.3 Resilient Corridors

One large data gap is the lack of posted or mapped evacuation routes for flooding events. Given that no two storms are the same, many communities find it beneficial to be able to make road closures and evacuation decisions as storms are forecast or as they evolve. Resilient corridor opportunity areas have been explored, however due to the lack of evacuation route data, and the number of roadways that are in the SFHA or have been identified for potential drainage related issues, identifying a practical number of areas was proven challenging.

Instead, resilient corridors should be further defined (i.e., what are the critical characteristics that define a resilience corridor) so that they can be clearly identified with specific beginning and end points. These corridors serve an important regional purpose, including as evacuation routes for low-lying communities to evacuate to higher ground during an event. Different communities will have different options for evacuation routes; it is important to identify where these corridors are, and where they should lead people evacuating.

11 Vulnerability Assessment Utilization

There are multiple uses for this vulnerability assessment, both in the context of Resilient Connecticut and for regional and municipal planning. With the development of vulnerability and risk tools, compilation of social vulnerability maps, and the identification of vulnerable assets, many of these findings can be utilized and incorporated into various types of planning efforts and contribute to enhancing local and regional climate resilience.

11.1 Resilient Connecticut Utilization

As Phase II of Resilient Connecticut sets the found for and transitions into Phase III this vulnerability assessment will be incorporated into the conceptualization of design elements for prioritized adaptation and resilience opportunity areas. Key findings from these analyses will be taken into consideration when designing adaptation scenarios. For example, if heat vulnerability is the driver in addressing the needs of an opportunity area, design elements may include building retrofits or reconstruction, provision of shade through planting trees or built solutions, and strengthening of community efforts to provide cooling stations and shelters. On the other hand, if flood vulnerability is the driver, traditional and/or innovative flood mitigation and flood protection strategies may be incorporated into designs.

Next Steps

This Resilient Connecticut planning process has identified widespread areas of vulnerability and risk to climate-affected hazards in Fairfield County and New Haven County. The focus of adaptation and resilience projects in specific opportunity areas will help communities become more resilient over time. This report concludes with a presentation of 63 specific geographic areas where adaptation and resilience opportunities can be identified to address flood-related risks, extreme heat, or both. In the coming months, the Resilient Connecticut planning effort will turn to screening of these opportunity areas coupled with stakeholder engagement to determine which could be advanced to conceptualization in Phase III of Resilient Connecticut. Next, a report will be developed to describe additional facets of the Resilient Connecticut planning process and its recommendations.

The CCVI and ZSR are two tools that serve as the foundation for resilience opportunity area identification and characterization. Social vulnerability mapping, asset and infrastructure vulnerability analysis, and planning effort reviews will also play a role in prioritization and further characterization of these areas. Each component of this vulnerability assessments takes into account the numerous factors that make up a regional system. By understanding and identifying the vulnerabilities present within the system, adaptation scenarios and design can be tailored to address the vulnerability drivers throughout the final areas.

11.2 Municipal and Regional Planning Utilization

Several interactive tools have been developed as a result of this vulnerability assessment to encourage public access to the data and information for municipal staff, consultants, and the general public. Both the CCVI and ZSR are available for informational and planning purposes in interactive ArcGIS online mapping tools to identify some of the flood and heat vulnerabilities that are present and might be addressed by way of mitigation and adaptation projects or incorporated into redevelopment.

It is anticipated that both tools, along with the SV maps, will evolve over time to incorporate additional data as it becomes available, and possibly be extended statewide depending on funding. The expansion and further development of these tools, and the progression of the asset and infrastructure analysis will only provide further information for adaptation and mitigation planning, while also providing a baseline for flood and heat vulnerability.