ABSTRACT

Title of Thesis:	COOL COMMUNITIES: IMPROVING PEDESTRIAN THERMAL COMFORT IN WEST ALEXANDRIA
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Thesis Directed By:	Naomi Sachs, Associate Professor, Landscape Architecture

Extreme heat is the leading cause of weather-related death in the United States, and heat-related morbidity and mortality are expected to continue to increase due to climate change. People living in cities are particularly vulnerable due to the impact of urban heat island, which has intensified over the past two decades. This project aims to answer the question of how landscape design can play a role in mitigating urban heat and improving pedestrian thermal comfort. A mixed-methods approach was used to assess the microclimate and outdoor comfort in an urban shopping center in Alexandria, Virginia. The site was evaluated through in-situ air and surface temperature measurements, a survey questionnaire, and environmental modeling with a combination of Rhino and Grasshopper (Ladybug) tools. Findings from the microclimate analysis and the questionnaire informed the design of a multi-functional heat-resilient landscape, which incorporated tree canopy, vegetated areas, bioretention gardens, shade structures, and alternative surface materials. The proposed design was then evaluated using the same modeling approach, demonstrating its potential to reduce direct solar radiation by 4 hours on average and improve outdoor thermal

comfort by 4°F on average – with “cool corridors” improved to feel at least 8°F cooler. The project can serve as a template for how to map, analyze, and then address outdoor thermal comfort in the landscape, particularly in exposed sites like strip malls, streetscapes, or large parking lots.

COOL COMMUNITIES: IMPROVING PEDESTRIAN THERMAL COMFORT IN WEST ALEXANDRIA

by

Caitlin Garlow

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List of Abbreviations

EPW – EnergyPlus Weather File

MLA – Master of Landscape Architecture

MRT – Mean Radiant Temperature

HVI – Heat Vulnerability Index

ST – Surface Temperature

UHI – Urban Heat Island

UTCI – Universal Thermal Climate Index

Chapter 1: Introduction

Cities around the world are grappling with a growing climate crisis and more intense summer heat waves, calling attention to the urgent need for more heat-resilient infrastructure in our cities and neighborhoods. The summer of 2024, with its searing temperatures, was a personal wake-up call for me as I regularly sought out the most shaded routes on my walk to and from the DC Metro while traveling to my summer internship at Smithsonian Gardens. I am a lover of cities and urban exploration, and walking is central to how I experience and understand places; yet, with how oppressive the summer heat was, I felt myself constantly considering if this would devastate public life in cities in the long term.

Then in my studio class in the fall of 2024, I had the opportunity again to explore the impact of climate change, analyzing data related to urban heat island and flooding in Baltimore. The data analysis and mapping work I did further underscored how the impacts of climate crises are most devastating for marginalized communities and vulnerable members of the population. In Baltimore, the poorest neighborhoods, many of which were redlined in the 1930s, have significantly hotter surface temperatures and lower tree cover compared to wealthier neighborhoods. At the same time, the people living in these neighborhoods are more likely to rely on public transportation and walking to get around, leaving them more exposed to the health impacts of extreme heat. This reality, which is not unique to Baltimore, but can also be seen in cities across the nation, reminds us that addressing inequities must be central to the work of mitigating and adapting to a changing climate.

Recent scientific research on climate data over the past three years suggests that the rate of warming may be increasing even more rapidly than what scientists predicted several years ago, meaning it is even more imperative to plan now for a future that includes more extreme heat (Press, 2026).

Places with warm climates have always been a source of innovative techniques for addressing and surviving the heat. From the densely built cities of ancient Mesopotamia, to the covered porticoes in Bologna, Italy, to the fabric canopies (*toldos)* of Seville, Spain, ancient cities "know the wisdom of shade" (Bloch, 2025, p. 16). Rediscovering these historic precedents, as well as looking at cities like Phoenix, AZ, Los Angeles, CA, and Miami, FL that are stepping up their heat resilience efforts with bigger (and long overdue) investments in shade, public green space, and transit infrastructure, provide inspiration for how other cities could be reshaped for the future.

I began this thesis project with an overarching question: **How can design mitigate urban heat and improve pedestrian thermal comfort?**

As I began to review the literature and narrow the focus of my project, I recognized that urban heat can be assessed and addressed at many different levels: city, neighborhood, block, site. I decided to look closely at an individual site design, with the following sub-questions:

- **What tools, methods, and metrics can be used to analyze and represent the microclimate of a site?**
- **How can design strategies be selected and combined to address the site's microclimate?**

Conducting a review of the literature, interviewing experts, and reviewing case studies provided me with a strong foundation and understanding of today's best practices for designing heat-resilient landscapes. At the same time, I had the opportunity to test and learn from several different methods and tools to understand the microclimate of my chosen site – input which supported the development of my vision, goals, and subsequent design.

Chapter 2: Literature Review

2.1 The Impact of Climate Change

2024 was the hottest year on record in the U.S. (World Meteorological Organization, 2025) and scientists predict that summers will continue to get hotter. For example, in Alexandria, Virginia, climate models project there will be 70 days above 90 degrees each year by 2050, compared to an average of 30 days each year above 90 degrees between 1994-2013 (Figure 1, City of Alexandria, 2022a).

The Intergovernmental Panel on Climate Change (IPCC) has explicitly stated that human contributions to greenhouse gas emissions are the source of the changes we are witnessing with extreme temperatures and other climate events (Intergovernmental Panel on Climate Change, 2021). Without swift and dramatic reductions in emissions, extreme heat and other types of extreme weather patterns are expected to continue around the world (Intergovernmental Panel on Climate Change, 2021).

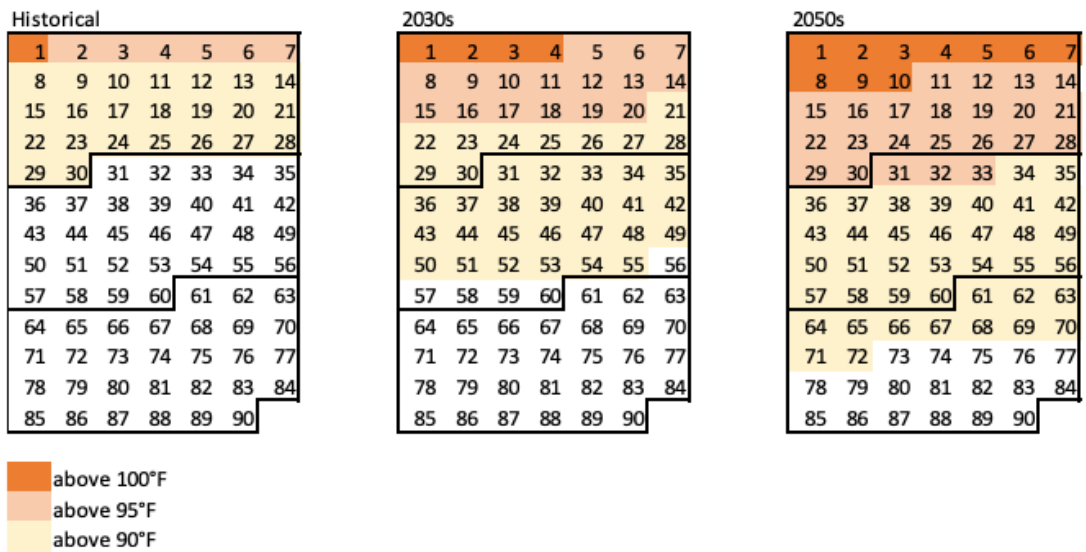


Figure 1: Average Annual Number of Hot Days in Alexandria, VA. Source: City of Alexandria, 2022.

2.1.1 Heat: A Growing Public Health Concern

Extreme heat is a growing public health concern. According to the National Weather Service, extreme heat is the number one cause of weather-related deaths in the U.S., leading to more deaths than hurricanes, tornadoes, and floods combined (US Department of Commerce, n.d.). When a major heat wave hit the Pacific Northwest in 2021 – a region that typically does not experience that type of hot weather – hundreds of people died (Press, 2021). Some were elderly, many were found alone in homes without air conditioning or fans, and many experienced "sudden and unexpected deaths" (Press, 2021). That's because, in addition to heat exhaustion or heat stroke, extreme heat also increases mortality from other causes, such as cardiovascular and respiratory events (Basu & Samet, 2002).

2.1.2 Vulnerable Populations at Risk

Some people are more vulnerable to heat than others, namely children, the elderly, those with pre-existing health conditions, pregnant women, and outdoor workers (Luber & McGeehin, 2008). Underserved communities are also more vulnerable to heat due to the likelihood of living in substandard housing, working in jobs that are labor intensive or expose them to heat, and the economic burden that purchasing and paying for air conditioning puts on them (Elliott et al., 2020). Far from impacting only humans, extreme heat creates disruption across the ecosystem, affecting the health and livelihood of animals and plants, encouraging drought and wildfire, and stressing biodiversity (Christofaro, 2024; Parker et al., 2020).

2.1.3 Urban Heat Island

Cities are more impacted by heat than surrounding suburban and rural areas. Dense buildings, roads, and other impervious surfaces are excellent at absorbing and then radiating heat. Lack of cooling vegetation, plus an excess of waste heat generated by air conditioners, cars, and other sources combine to exacerbate the heat. This phenomenon, where cities are significantly hotter than surrounding suburban and rural areas, is known as **urban heat island** (Oke, 1981; Rizwan et al., 2008)

Further research has demonstrated that the "island" is more like an "archipelago," as cities often contain significant disparities in exposure to heat within their bounds (Gibbon & Lindquist, 2024). Certain neighborhoods are hot spots, while cooler neighborhoods and areas can be found, such as those with a higher percentage of parks and more trees (Gibbon & Lindquist, 2024). These disparities within cities have been linked to race and socioeconomic status. In 2021, researchers found that in all but 6 of 175 of the largest urban areas, the average person of color lived in a neighborhood with a higher surface temperature than the average white person (Hsu et al., 2021). Formerly redlined neighborhoods also have significantly hotter surface temperatures than non-redlined areas, a trend that is consistent across the nation (Hoffman et al., 2020). The American Forests' Tree Equity Score data shows that poor communities have 41% less tree cover than wealthier ones (American Forests, n.d.).

2.1.4 The Impact of Air Conditioning

Since the mid 20th century, air conditioning has helped humans tolerate warm climates by creating cooler temperatures indoors. However, our reliance on air conditioning to create comfortable indoor climates has come at a cost: more stress on electrical grids, waste heat, a reduction in our ability to acclimate to heat, and an increasing cost burden on individuals – leading to greater inequities between rich and poor citizens (Lundgren-Kownacki et al., 2018; Olson, 2014). Furthermore, cooler indoor environments shift preference away from outdoor spaces and the associated social interactions that happen in the public realm. According to Sam Bloch, author of *Shade: the Promise of a Forgotten Natural Resource*, "by bringing people inside, air conditioning robbed shade of one of its most critical historical functions: a place where people gather" (Bloch, 2025, p. 54). Thus, the hotter it gets outside, the more people must seek refuge indoors with air conditioning, which in turn adds more waste heat to the outdoors, perpetuating a vicious cycle.

2.1.5 Government Response to Heat

With growing awareness of what is at risk, planners and public health officials are investing more energy and funding to address the problem of extreme heat with a combination of adaptation and mitigation efforts. Heat mitigation efforts are "strategies [that] aim to cool cities, neighborhoods, and heat-vulnerable locations by reducing contributions from the built environment and waste heat to the urban heat island (UHI) effect" (Keith & Meerow, 2022, p. 48). These efforts focus on urban design, parks, tree canopy, and other efforts to cool the environment in cities. Meanwhile, adaptation strategies "help communities prepare for and respond to chronic and acute heat risks" such as with public education campaigns or energy bill assistance (Keith & Meerow, 2022, p. 62).

Heat vulnerability assessments help governments synthesize the risk factors for poor health outcomes during extreme heat events and identify where resources and infrastructure should be focused. A **heat action plan** summarizes and unites the policies, actions, and departments collaborating during periods of extreme heat (Atlantic Council, n.d.). Cities like Miami-Dade, FL, Phoenix, AZ, and Athens, Greece have appointed **chief heat officers** to drive a unified response to extreme heat (Atlantic Council, n.d.).

Acknowledging the critical role that shade plays in reducing heat, some cities have established standards, policies, and guidelines related to blocking the sun. Phoenix, AZ, for example, requires all new sidewalks to be 75% shaded at noon (City of Phoenix, n.d.); Singapore requires that plazas be 50% shaded (Bloch, 2025); and in Israel, Tel Aviv's Shade Planning Guidelines recommend continuous shade on 80% of public streets, paths, and walkways (Turner et al., 2023). Addressing one of the worst contributors to UHI – surface parking lots – local governments in Los Angeles, CA and Montgomery County, MD have incorporated shade requirements of 50% and 30%, respectively (Bloch, 2025; Montgomery County Department of Transportation, n.d.), and in France, large parking lots must be at least 50% covered by solar panels (Birnbaum, 2023).

2.2 Heat and People: Thermal Comfort

Heat is more complicated than just the high air temperature for the day, though it is typical to look at this metric as a proxy for human comfort. However, many additional environmental and personal variables play a role in a person's comfort outdoors, including ambient temperature, humidity, solar radiation, wind, radiant heat, and reflected radiation (Figure 2).

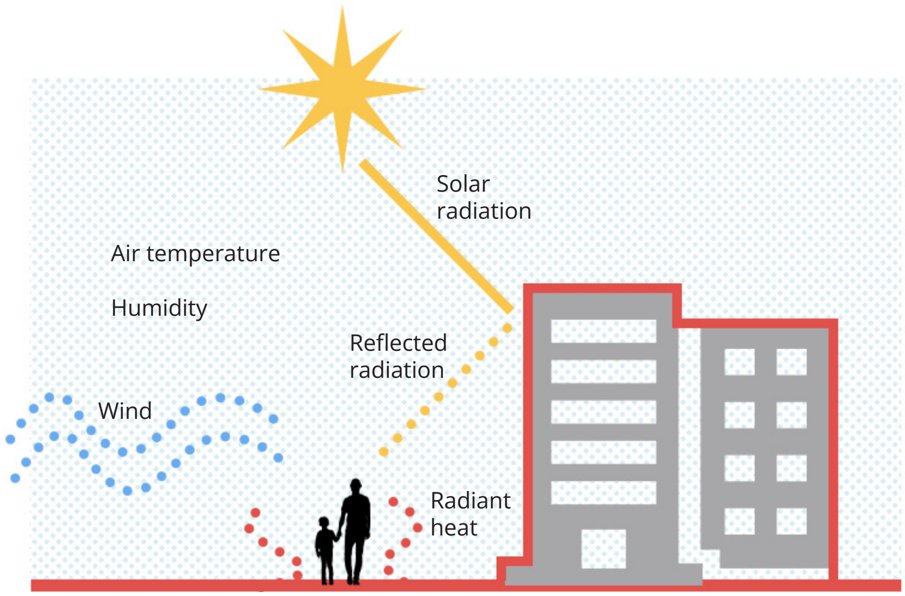


Figure 2: Environmental variables contributing to how people experience heat. Source: Garlow, 2026.

One way of understanding the confluence of these factors is with the "The Schematic Bioclimatic Index." Developed by architects and brothers Victor and Alagar Olgyay, the schematic shows the impact of wind, humidity, air temperature, and solar radiation on human comfort (Figure 3). The man reading a newspaper on the lounge chair represents the approximate temperature in which most people are comfortable resting in the shade: between 70 and 80 degrees Fahrenheit at 20-50% relative humidity. However, if the temperature rises above 80 degrees, some wind is needed to maintain that same comfort level. If the temperature decreases, solar radiation is needed to increase comfort (Olgyay & Olgyay, 1963, p. 23). This chart was an early way to describe **thermal comfort,** or **"**the condition of mind that expresses satisfaction with the surrounding environment's temperature" (Gibbon & Lindquist, 2024, p. 17).

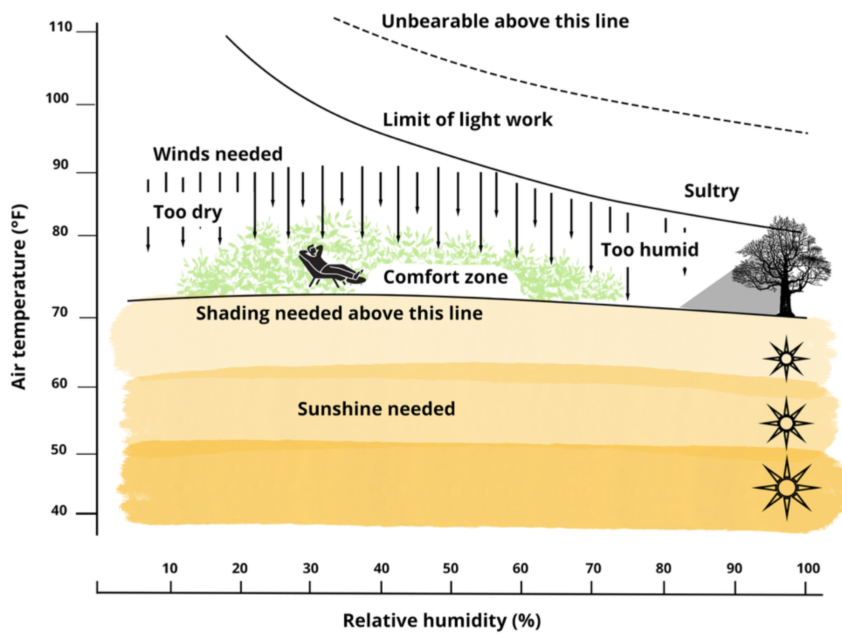


Figure 3: Schematic Bioclimatic Index. Source: Olgyay and Olgyay, 1963. Graphic by Garlow, 2026.

In addition to the impact of air temperature, humidity, wind, and solar radiation, thermal comfort also depends on the human being. A person's health status, gender, clothing, activity level, and acclimation to the local weather can impact their thermal comfort (Keith & Meerow, 2022, p. 22-23).

2.2.1 Methods and Indices for Thermal Comfort

With so many variables that can impact an individual's thermal comfort, researchers have developed various methods and indices that can summarize the effects of environmental conditions on a person's comfort. The **heat index** incorporates air temperature and humidity to generate a "feels like" temperature (Gibbon & Lindquist, 2024). **Wet Bulb Globe Temperature (WBGT)** is similar but also incorporates wind speed and direct solar radiation. It is easy to measure and is often used to make decisions about outdoor work or athletics. Other thermal comfort indices used by scientists and researchers include **Physiologically Equivalent Temperature (PET)**, **Standard Effective Temperature (SET), Predicted Mean Vote (PMV),** and the **Universal Thermal Climate Index (UTCI)**. Of these, UTCI has been validated as a reliable tool for assessing outdoor thermal comfort in urban environments, making it more attractive to planners, landscape architects and others working on iterative designs for urban areas (Jing et al., 2024).

UTCI and other thermal comfort indices can be also used at the site scale to account for the impact of shading and vegetation, material choice, wind, solar radiation, as well as air temperature and humidity; thus, they are more appropriate measures for understanding and prioritizing pedestrian comfort outdoors than relying on surface temperature or air temperature data alone (Engel et al., 2025).

Additionally, surveys and questionnaires can be used to collect feedback from the relevant population; according to Gibbons and Lindquist (2024), surveys are "often used in conjunction with objective measurements to gain a comprehensive understanding of thermal comfort" (p. 19).

2.3 Measuring & Mapping Heat in the Landscape

There are many existing ways to measure, map, and analyze heat in the landscape, to better understand and analyze urban heat islands. A few of the most common methods to visualize heat are included in Table 1. A clear understanding of scale and goals and objectives are required to select the most appropriate methods and metrics to visualize heat in the landscape.

Table 1: Methods for Visualizing Heat in the Landscape. Source: Gibbons & Lindquist, 2024, edited by the author

Method	**What It Is**	**Heat Metric**	**Scale**
Landsat Imagery	A series of earth-facing satellites that capture data across multiple spectral bands, from visible light to thermal infrared.	Land Surface Temperature	Urban area
UAV Infrared Imaging	Unmanned Aerial Vehicles (UAVs), commonly known as drones, equipped with thermal imaging cameras to capture and analyze heat patterns from an aerial perspective.	Surface Temperature	Neighborhood
Handheld Thermal Imaging	Portable thermal imaging cameras that capture infrared radiation emitted by surfaces, providing a more detailed and granular examination of specific surfaces and materials at close range.	Surface Temperature	Site
Mobile Biometeorological Instrument Platform	A mobile research station developed by Arizona State University (ASU) that measures and analyzes various aspects of thermal comfort and heat exposure in urban environments, making it a valuable tool in the study of urban microclimates.	Mean Radiant Temperature	Site
Vehicle-Traverse Collection	A dynamic method used to assess the urban heat island (UHI) effect by equipping vehicles with thermal imaging technology to capture surface temperature data across an urban area.	Surface Temperature	Urban area
Environmental Simulation	Using software tools (such as SOLWEIG, Rhino/Grasshopper, ENVI-Met) to understand and predict various conditions such as temperature, humidity, wind flow, solar radiation, and their	Multiple	Urban area, neighborhood, site

	effects on buildings, landscapes, and urban spaces.		
Community Assessment	Surveys, questionnaires, mapping exercises or heat workshops that integrate qualitative feedback from members of the community and provide insights about the perceived experience of heat	Qualitative	Neighborhood, site

2.4 Landscape Solutions to Cool Urban Areas

Given the certainty of living in a much hotter climate, landscape architects, planners, architects, and others have an imperative to recognize and address extreme heat when designing or planning for changes to the built environment. Addressing heat requires consideration at many scales, from regional to city, neighborhood, site, and building, as graphically shown in Figure 4. Although this thesis project will focus primarily on the site scale, solutions to heat should ideally span across the urban gradient.

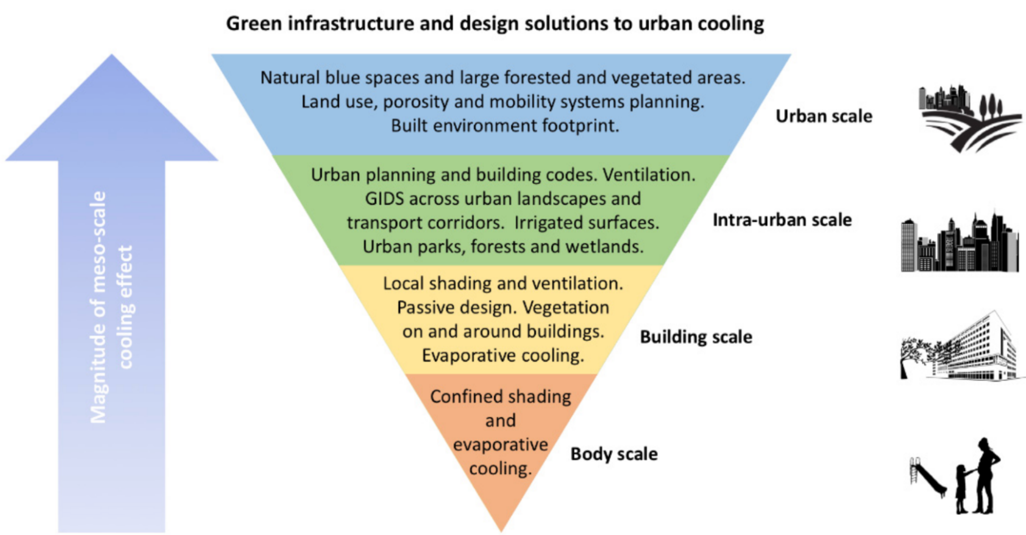


Figure 4: Application of Green Infrastructure within the Urban Fabric. Source: Elliot et al., 2020

Designers and researchers have investigated many different types of landscape strategies to understand their cooling impacts. A recent systematic literature review, conducted by Hirchfeld and Guenther (2024), catalogued research on nature-based solutions to heat (Figure 5).

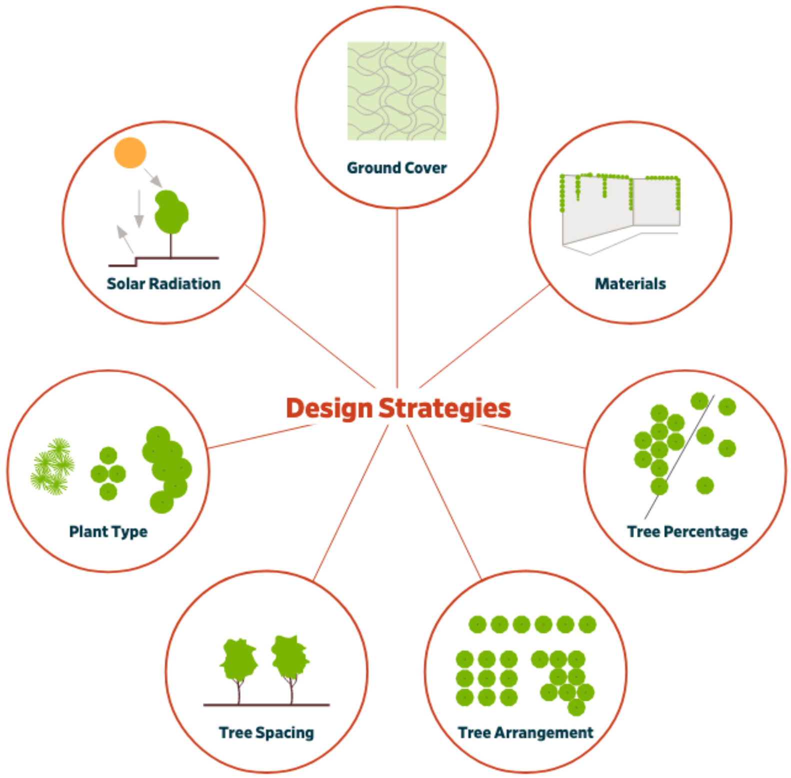


Figure 5: Typologies of landscape design interventions featured in a literature review. Source: Hirchfeld and Gunther, 2024

The researchers summarized their key takeaways, noting "increasing the number of nature-based solutions within a city, the size of these solutions, and the amount of greenery or trees will decrease urban heat islands" (p. 4). Additionally, they provided four strategies which they noted consistently yielded positive results for cooling in landscape design:

1. Increase tree percentage in parks and green spaces to reduce temperature and increase thermal comfort;
2. Provide shade, which decreases solar radiation, to reduce local temperatures and increase thermal comfort;

3. Reduce hardscape, and use plant material and water instead, to improve local cooling benefits;
4. Switch to green ground cover, such as grasses and shrubs, which have a positive cooling impact on local temperatures.

Another toolkit, developed in 2023 by AtlasLab, provides a high-level overview of design strategies to consider at the site, neighborhood, and city levels, noting whether the intervention will provide immediate or long-term impact and whether it will impact surface or ambient temperatures, or both (Table 2). The design interventions included range from general (e.g., urban greening) to more specific (e.g., cool roofs, shade structures).

Table 2: Cool-Kit Overview of Cooling Impact of Landscape Solutions. Source: AtlasLab, 2023.

Cool Impact	SURFACE	AMBIENT	IMMEDIATE	LONG-TERM
Urban Greening	●	●	●	●
Best Practices for Healthy Urban Trees	●	●		●
De-paving	●		●	
Shade Structures	●		●	
Green Roofs	●	●	●	
Cool Roofs	●		●	
Misting Systems		●	●	
Vertical Greening	●	●	●	
Cool Surface	●		●	
High-Albedo Pavement Coatings	●		●	
Cool Corridors	●	●		●
Cool Canyons		●	●	
Site Planning + Solar Orientation	●		●	
Street Trees	●	●		●
Access to Greenspace	●	●		●
Access to Water		●	●	
Green Schools	●	●	●	●
Heat Reduction in Parks	●	●	●	●

Designing landscapes with a goal of reducing the impacts of extreme heat thus requires a multi-factorial approach.

Urban Geometry

Street orientation, aspect ratio, and building heights/footprints play an important role in site shading and wind patterns (Kim & Brown, 2022). Urban geometry is particularly important to consider during city and neighborhood planning, and when proposing a fully new development.

Wind

Wind is part of the local microclimate and has an impact on pedestrian thermal comfort (Bu et al., 2009). Research suggests that creating wind paths by modifying urban geometry – such as building heights, street orientation and aspect ratio – can help to cool temperatures, even in humid climates. For example, in Palava City near Mumbai, India, the community's intentional design to harness westerly winds (among other strategies like increased tree canopy), led the city to be 2-3 °C cooler than comparison cities nearby (LODHA GROUP, 2024).

Water

According to the landscape architecture author, educator, and illustrator Chip Sullivan, the use and manipulation of water in the garden has been used throughout history by every culture: "not only for its inherently cooling abilities, but to produce aesthetic affects as stillness, movement, sound and light" (Sullivan, 2002, p. 192). Nishimura et al. (1998) identified the ability for artificial water sources, such as fountains, waterfalls and canals, to significantly cool the microclimate. Evaporative misting systems, have been found to reduce air temperature and human skin temperature (Huang et al., 2025).

Trees and Vegetation

A significant body of research has shown how trees and vegetation impact cooling. Trees provide both shading and transpiration, cooling both surface and air temperatures (Wong et al., 2021). According to a review by Alonzo et al. (2025), trees "consistently outperform other vegetation types in cooling" (p. 1). The same review found that trees with denser, broader crowns increase cooling, that a tree's height affects its ability to cool, and that overall canopy coverage area was more important than spatial arrangement (Figure 6). Although trees are the most critical for cooling, multi-layered landscapes with trees, shrubs, and turf grass offered more cooling than single-species plantings (Duncan et al., 2019).

However, there are still many gaps in understanding exactly how to use trees in urban areas to mitigate heat because so many factors play a role, and much of the research published thus far is small in scale. Additionally, research on the topic of trees and cooling has been done in a range of different climates and using many different metrics or methods, which make comparisons and generalizations difficult. These gaps point to the importance of local data collection to validate assumptions about the cooling role of trees as related to pedestrian comfort.

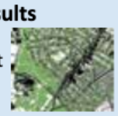
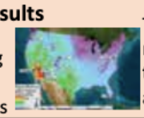
Individual tree-scale	Large patch & cityscape-scale	Regional-scale
Consensus results Greater water availability increases air cooling  Denser, broader crowns increase cooling	**Consensus results** Canopy area is more important than canopy configuration  Canopy has a convex relationship with air temperature	**Consensus results** Trees have stronger cooling magnitudes in hot, dry climates  Trees offer more cooling than grass alone
Key drivers of cooling: • High leaf area index • Soil moisture availability • Short/wide crowns shade best but tall trees cool most overall	**Key drivers of cooling:** • Citywide tree canopy amounts • Large tree patches cool more than small • Multiple layers of vegetation (e.g., tree over grass) enhances air cooling	**Key drivers of cooling:** • Climate (background temperature and humidity) moderate tree cooling efficiency • Maritime effects in coastal cities overall dampen tree cooling efficiency
Knowledge gaps: • How much water is used to increase transpirational cooling • Species choice: native vs introduced; survival under future climate scenarios • What species shut down under heatwave conditions	**Knowledge gaps:** • Cooling thresholds: how many trees does it take to cool? • How to direct cooling to hotter and more underserved neighborhoods • Do trees cool more or less in impervious dominated zones	**Knowledge gaps:** • Lack of consistent data for land cover and tree demography (tree species, function type, and sizes) • Converting multi-city or global findings to local planting plans

Figure 6: Key takeaways from Urban Trees and Cooling Literature Review by Alonzo et al. (2025)

Hardscape

Manufactured materials such as roads, sidewalks, buildings and other impervious, heat-absorbing surfaces are significant contributors to urban heat by absorbing heat, replacing vegetation, and reducing permeability (Mohajerani et al., 2017). As such, many of the design strategies to address urban heat island recommend removing hardscape and replacing or covering it with vegetation. Other options include shading it, “cooling” it – such as with reflective or higher albedo coatings that absorb less solar radiation – or making it more permeable, thus cooling it through evaporation.

Reflective "cool" pavements have been tested in Arizona, California and Texas, among other states, and New York City has a "Cool Roofs" pilot project (Smart Surfaces Coalition, 2025). In the heat of the day, reflective "cool" surface temperatures have been 12-16° F cooler than traditional asphalt (Smart Surfaces Coalition, 2025). However, careful consideration needs to be given to appropriate use for reflective pavements, as some research has also shown they can increase reflective heat load on pedestrians (Braswell, 2020).

In a review of cool pavements and their potential to mitigate urban heat island, Qin noted: "Permeable pavements or water-retentive pavements perform cooling because the water retained at the pavement layers evaporates" (2015, p. 455). However, if water is not available, these paved surfaces can be as hot or hotter than impervious pavements (Qin, 2015). Qin concludes that reflective pavements are likely the most applicable in hot and arid climates in wide open areas that have significant exposure to sunlight. Meanwhile, evaporative pavements are more applicable in areas that are wet or humid.

2.5 The Importance of Shade

For hundreds of years, shade was an integral consideration in the design of early cities. Buildings were packed tightly together and streets were narrow. Ancient Rome had miles of porticoes providing coverage over pedestrian paths. Fabric canopies, called "toldos," shade the streets of old cities like Seville in Spain. But concerns over density and disease, the widespread adoption of air conditioning, and car-oriented development are some forces that have led the US and cities around the world to abandon the early wisdom of investing in shade.

According to landscape architect Robert Brown, from Texas A&M University, of all the sources of environmental heat gain, solar radiation is the most influential and easiest to control, thus making shade one of the most important strategies for a designer (Bloch, 2025). Whether it comes from trees, buildings, or other structures, shade blocks the sun's light and heat and reduces the impact of reflected and radiant heat (Figure 7).

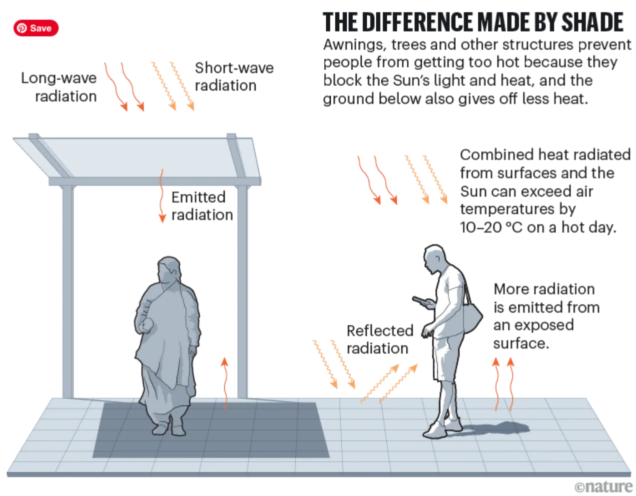


Figure 7: Controlling solar radiation with shade. Source: Turner et al., 2025

Places with more shade also offer benefits for city vitality. Huang et al. found that shade has staying power, with people in shaded locations being more likely to engage in leisure activities and sit or stay longer (eating, talking, reading, etc.) while those in sunny locations are more likely to engage in dynamic behaviors walking or passing through, for shorter durations (2015).

2.6 Significance of This Project to the Profession

In their systematic review, Hirchfeld and Guenther (2024) concluded that "for landscape architects and allied professionals, there remains uncertainty about precisely which site design and community-wide planning strategies provide the greatest reductions in temperature" (p. 3). Heat researchers acknowledge the fact that there is no "one size fits all" solution for extreme heat and that the best solution is typically a combination of many different strategies (Global Heat Health Information Network, 2021).

Although future research may continue to clarify the best strategies, or combinations of strategies, designers must in the meantime acknowledge the realities of a future that includes more days of extreme heat, and incorporate the best available tools and strategies to address it in the built environment.

This thesis project explores site-level assessment of microclimate, proposes a new design, and simulates the impact on pedestrian thermal comfort.

Chapter 3: Case Studies

To ground my work in real practice, I looked for case studies of landscapes which set goals for heat reduction or mitigation, or which used practices and techniques that improve thermal comfort. Furthermore, I looked at examples of retail or mixed-use sites that integrated surface parking, pedestrian amenities, or green space – which aligned with the existing character of my chosen site. I looked at more than a dozen projects, and the four case studies I referred to most frequently – Edison Eastlake in Phoenix, Arizona; Canoga Park in Los Angeles, California; Swope Plaza Campus in Kansas City, Missouri; and San Jacinto Plaza in El Paso, Texas – are summarized below.

3.1 Edison Eastlake

Edison Eastlake is a 9.8 acre mixed-income neighborhood currently being rebuilt by the Housing Department in Phoenix, Arizona. Its vision is to be a heat-resilient, affordable neighborhood. The community was red lined from the 1930s to 1950s, leading to lower rates of homeownership than can be seen in other parts of the city (Urban Land Institute, 2025). Surface temperatures are also hotter in Edison East Lake than in other parts of Maricopa County, with surface temperatures measuring as hot as 130°F on extreme heat days. A Health Impact Assessment survey also revealed that residents felt significantly impacted by urban heat island, as many walked and took public transit.

The planning of Edison Eastlake, led by Mithun, incorporated strategies including increasing shade (notably addressing the new zoning code in Phoenix which requires 75% shading of public walkways), encouraging wind, and using “cool” building materials. Additionally, strategic green space was incorporated throughout the community, and back-up water supply and generators were incorporated into community spaces as climate resilience strategies.

The community plan also showcases use of shade structures, photovoltaics, safe pedestrian crossings, biking infrastructure, public art and more as part of a comprehensive heat-resilient approach (Figure 8, Mithun, 2025). Because the Edison Eastlake project is still under construction, we do not yet know the impact that these design strategies will have.

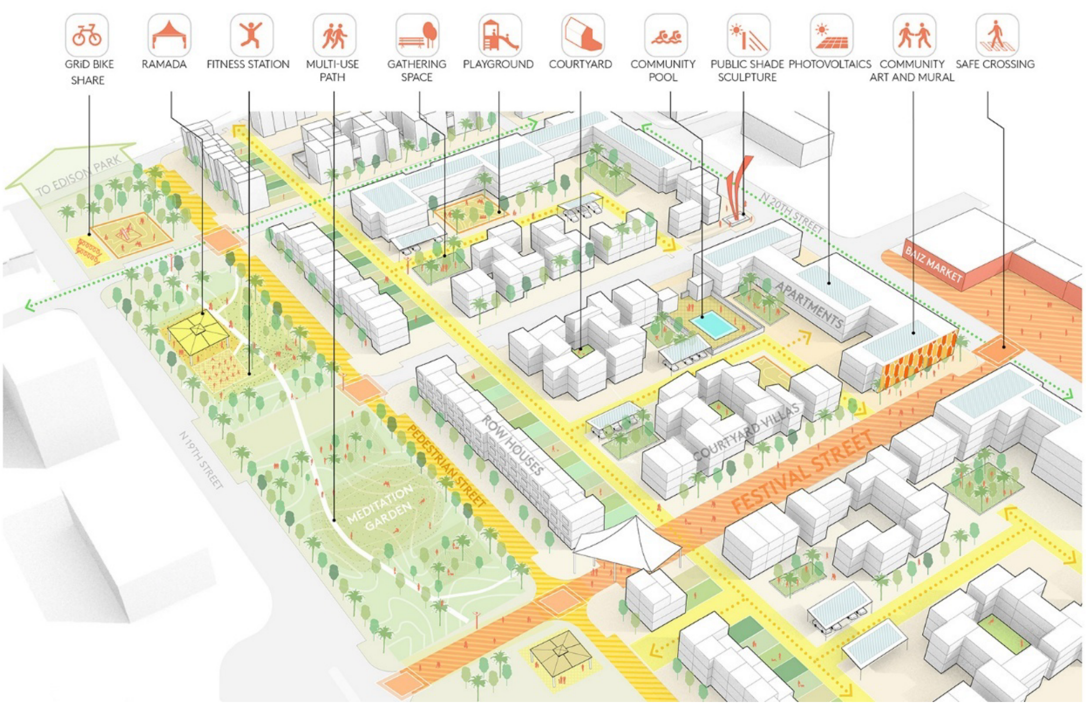


Figure 8: City of Phoenix Edison-Eastlake One Vision Plan. Source: Mithun.

3.2 Canoga Park Conceptual Plan

The Canoga Park neighborhood in Los Angeles, California, is another jurisdiction implementing holistic solutions to extreme heat along key transit corridors (Alta, 2021). StreetsLA (Bureau of Street Services in Los Angeles) hired Alta Planning + Design to study transit access and urban cooling strategies that could be replicated across the neighborhood. Alta followed a selection process that included both site analysis and community engagement to identify three typologies of streets to include in the study: a major arterial road, a neighborhood road, and a multi-use trail. Cooling strategies recommended in their conceptual plan for these three typologies included native plantings, stormwater retention facilities, protected bikeways, and safer pedestrian crossings (StreetsLA, Alta Planning + Design, 2020).

Figure 9: Perspective views of proposed designs for Canoga Park. Source: Alta Planning + Design

Additionally, their process for prioritizing design strategies considered the opportunity to maximize co-benefits of different interventions. They noted that trees and green infrastructure would provide the most co-benefits, but that those benefits would take time to realize. Thus, consideration was given to how to incorporate engineered shade and cool pavements for more immediate heat reduction while trees and vegetation matured (Figure 9). The design received a historic $30 million in funding for implementation, but construction has yet to begin (CD3, City of Los Angeles Los Angeles, 2023).

3.3 Swope Campus Parking Lot and Plaza Entry

Because my chosen site included considerable parking, I selected a case study that demonstrated best practices for green parking design. The Kansas City Water Department in Kansas City, MO, recently replaced their aging parking lot with a new design that serves as a demonstration for stormwater best management practices (BMPs) including raingardens and bioretention, and an opportunity to learn more about the performance of materials including permeable pavers, porous asphalt, pervious concrete, grasscrete, and more.

The parking lot includes four pervious parking bays adjacent to vegetated islands. An employee patio with pervious pavers and a bosque of trees were added, as were pedestrian walking paths around and through the parking lot, to encourage walking and use of the parking lot as an amenity (Figures 10 and 11).

A Landscape Architecture Foundation landscape performance case study was completed after the project was installed and surface temperatures of the different materials were measured (Hahn & Kellams, 2016). Interestingly, typical concrete and white painted concrete had the lowest surface temperatures of all the hardscape materials, including grasscrete. Pervious pavers had a higher surface temperature than asphalt. These findings are applicable as they show that pervious hardscaping materials can be successful in addressing stormwater but may do very little to improve UHI (Figure 12).

Figure 10: Site plan for Swope Campus Parking Lot. Source: Hahn & Kellams, 2016.


Figure 11: Photos of Swope Campus Parking Lot. Source: Hahn & Kellams, 2016.

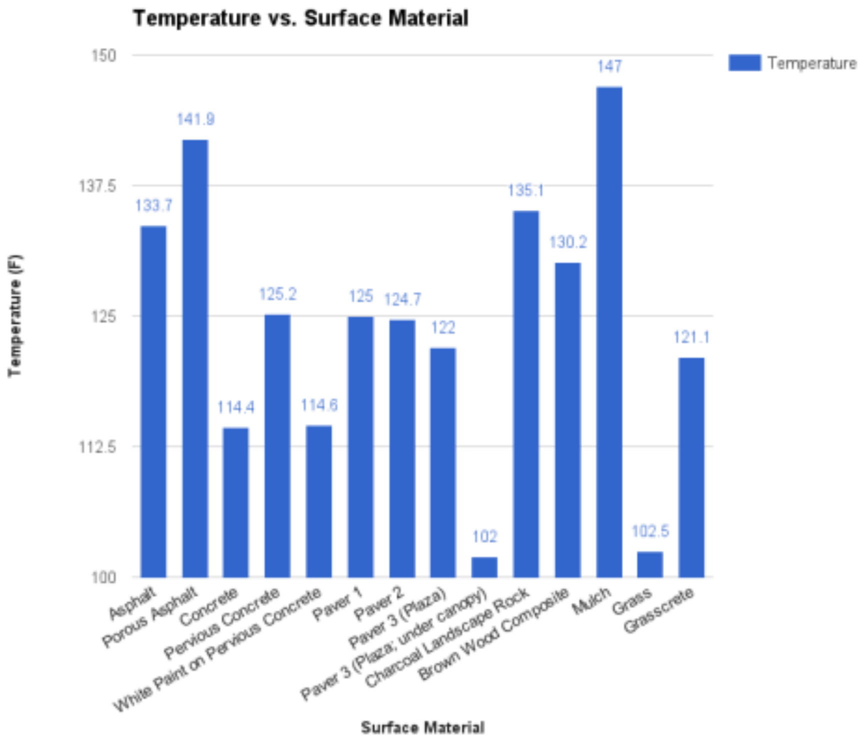


Figure 12: Surface Material Temperature at Swope Campus Parking Lot on July 1, 2016. Source: Hahn & Kellams, 2016.

3.4 Pedestrian Pathways in El Paso

El Paso Pedestrian Pathways in El Paso, Texas is a series of projects intended to link key destinations and improve walkability in the city's arts district (Cheng & Kaur, 2022). The projects included a large urban park, a streetscape, and a pedestrian promenade (Figures 13, 14 and 15).

Figure 13: Before and after photos of San Jacinto Plaza. Source: Cheng & Kaur, 2022.

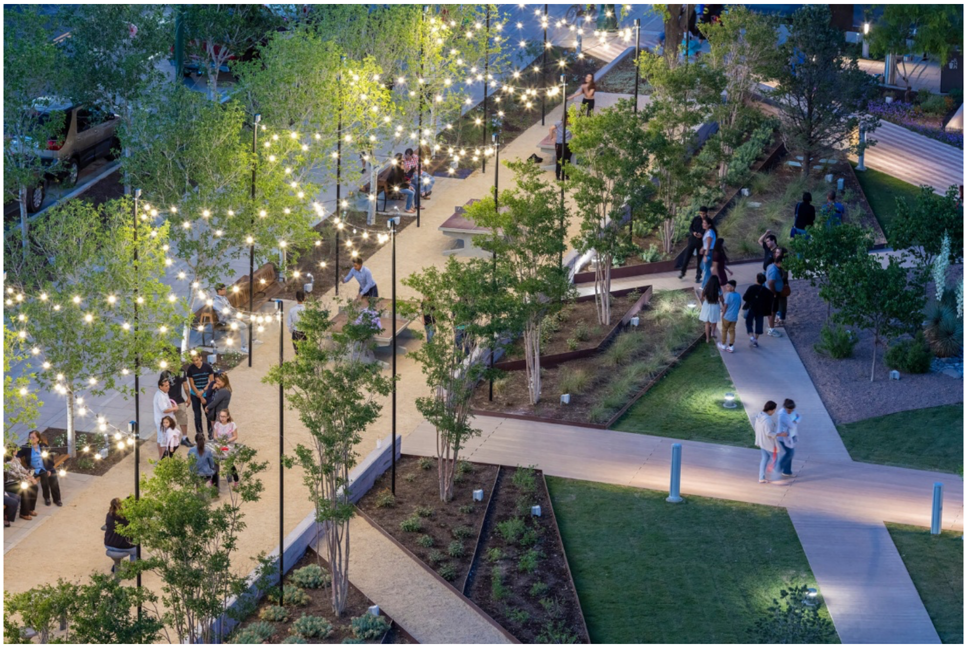


Figure 14: New amenities at San Jacinto Plaza. Source: SWA Group, 2022.

Figure 15: Durango Street Bridge Comparison of Traditional and Painted Asphalt. Source: Cheng & Kaur, 2022.

The redesign of the San Jacinto Plaza by SWA Group included removing paving/hardscape material and incorporating more than 230 new shade trees that also offer benefits of carbon sequestration and increased biodiversity. A large 2,500 square foot-shade structure was added over the fountain and art installation, and a splash pad was added for children. More than 40 benches were added to accommodate visitors, and more than 6,000 square feet of recreation space was added including table tennis, bocce courts, and more to create a welcoming environment for visitors.

In San Jacinto Plaza, researchers found that engineered shade from the structure over the fountain reduced surface temperatures by up to 23°F and trees reduced surface temperature by up to 40°F (Cheng & Kaur, 2022). Painted pink asphalt on the pedestrian promenade across the Durango Street Bridge reduced surface temperatures in full sun by up to 23°F, compared to traditional asphalt (Cheng & Kaur, 2022).

The case study of pedestrian pathways in El Paso shows the cooling benefits of combining engineered and tree shade in public space. The case study findings also suggest that painted asphalt may be one tool in a designer's toolkit for reducing surface temperatures when few other options exist.

Chapter 4: Methods

This MLA thesis project used mixed methods, including expert interviews, site inventory and analysis, microclimate analysis, an anonymous survey questionnaire, environmental simulation software, case studies, and meetings with City of Alexandria officials, as outlined below. By relying on a combination of quantitative and qualitative methods, I hoped to gain a more comprehensive understanding of thermal comfort and how to use it as a goal throughout the design process.

4.1 Site Context and Selection

As a resident of Alexandria, Virginia, I wanted to focus my thesis project on a site in my own community. To identify a site in need of improved pedestrian thermal comfort, I first reviewed the City of Alexandria's Heat Vulnerability Index (HVI) (Figure 16, City of Alexandria, 2022a). The City's HVI is an index which combines three indicators to reveal the areas of highest heat vulnerability within the City: 1) exposure to heat (based on land surface temperatures); 2) sensitivity (considers characteristics of the population most likely to be at risk, including older adults, minority status, and poverty status); and 3) adaptive capacity (considers tree canopy coverage, proximity to cooling centers, and green spaces). Two areas of high vulnerability were in the Landmark/Van Dorn and the Eisenhower Valley neighborhoods.

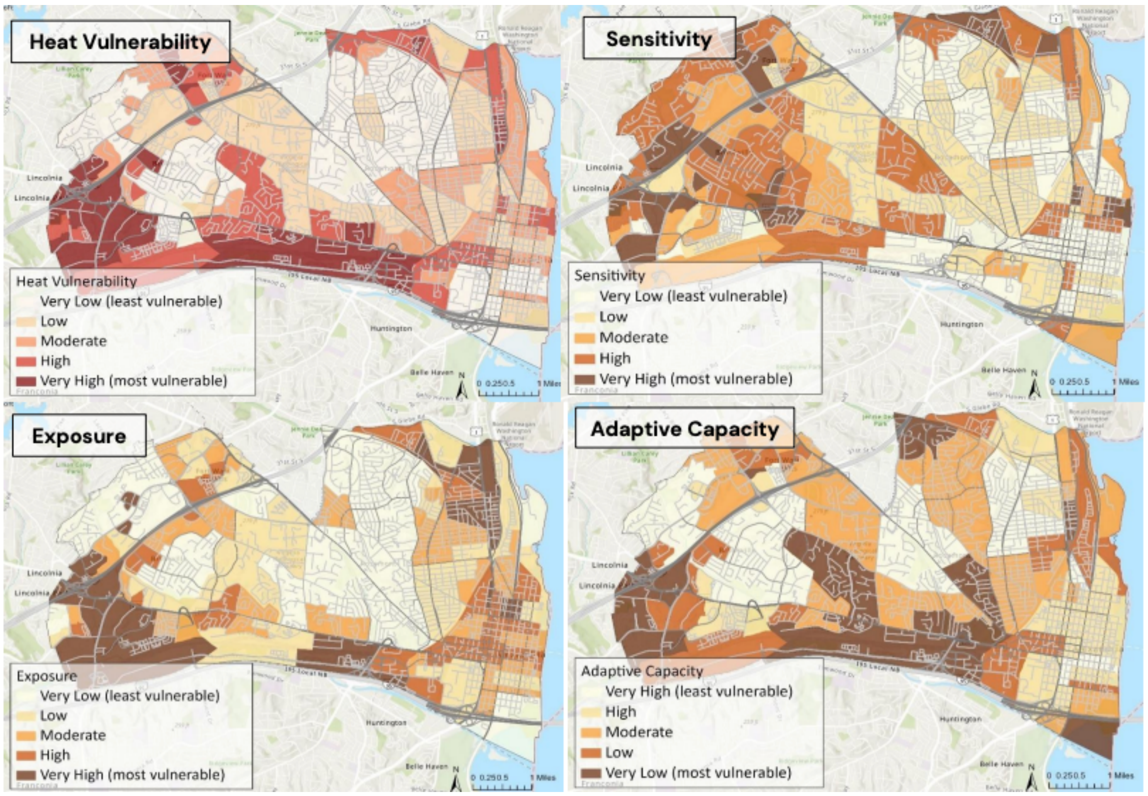


Figure 16: Results for Alexandria's heat vulnerability assessment. Heat vulnerability (top left) is composed of separate scores for sensitivity (top right), exposure (bottom left), and adaptive capacity (bottom right). Source: City of Alexandria, 2023.

Using the HVI mapping as my starting point, I identified six potential project sites within the areas of "very high" heat vulnerability. I visited each site and assessed whether it could provide: 1) sufficient access to support my research; 2) an opportunity to address thermal comfort through design; and 3) sufficient visitor/foot traffic to be a priority for improved design. After visiting six different sites, I selected the upper level of the **Van Dorn Station Shopping Center** in Alexandria's West End as my project site (Figure 17).

The shopping center has an upper level and a lower level. To keep the scope of the thesis project manageable, I selected the upper level of the shopping center for my site, knowing that my findings and subsequent design could be applicable to the lower level as well. The upper level of the shopping center is approximately 3.85 acres and includes three buildings with more than 29 active retail establishments (Figure 18). Further detail on the site will be outlined later in this section.

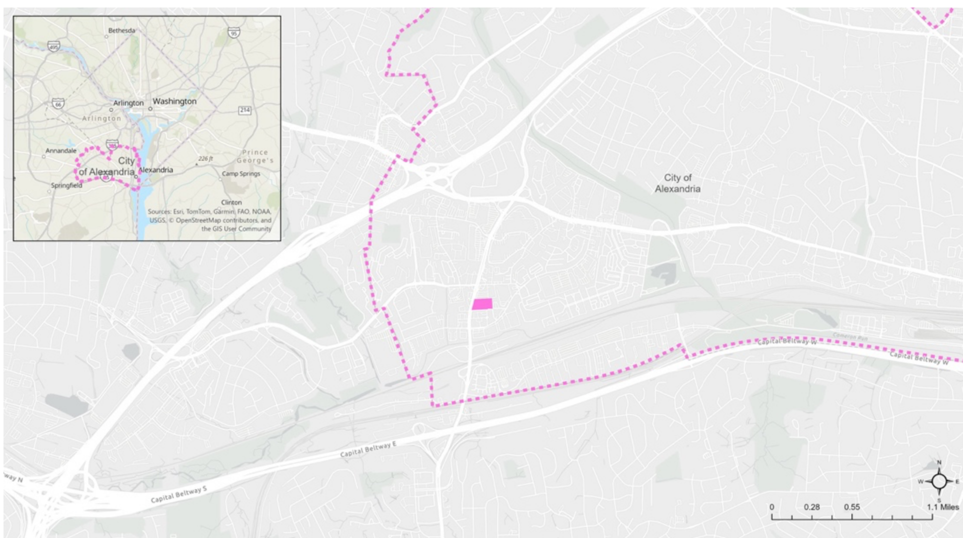


Figure 17: Van Dorn Station Shopping Center context within Alexandria and Washington, DC area. Source: Garlow, 2026.

Figure 18: Aerial Image of Site. Source: Garlow, 2026

4.2 Expert Interviews

In the summer of 2025, I conducted focused interviews with four experts on the topic of extreme heat, microclimate analysis, and landscape architecture to hear their insights and suggestions on my thesis approach. I interviewed Matthew Baker, professor of Geography and Environmental Systems at the University of Maryland Baltimore Campus; Michael Alonzo, associate professor of Environmental Science at American University; Chingwen Chen, professor of landscape architecture and Director of the Stuckeman School at Penn State University; and Ariane Middel, associate professor and Director of the SHaDE lab at Arizona State University. Some notable takeaways from these conversations included:

- **“Heat is one of the hardest things to measure”** – Experts noted that measuring heat is not a straightforward task. There are many different methods for quantifying heat. Experts recommended including an overview of these in the literature review.

- **Thermal comfort indices** – Experts recommended reviewing the different indices currently used to measure thermal comfort, including standard effective temperature (SET), universal thermal climate index (UTCI), physiological equivalent temperature (PET), and mean radiant temperature (MRT).
- **Date for microclimate study** – Experts recommended a hot, clear day without much wind.
- **Time of day for microclimate measurements** – Experts recommended taking measurements at 2pm and 5pm and that measurements should be completed within 30 minutes.
- **Site locations for microclimate measurements** – Experts recommended taking measurements on different surfaces as well as with different types of shade (e.g., unshaded versus tree shade versus building shade).
- **Tool selection** – Experts recommended collecting data like Wet Bulb Globe Temperature (WBGT), which accounts for humidity, in addition to using a thermal camera to measure surface temperatures.
- **Survey questionnaire** – An expert recommended additional questions for the anonymous survey, such as how participants felt about the heat and the way they arrived at the site.
- **Data analysis** – Experts noted that difference in surface temperature between materials/surfaces is one aspect to analyze. They recommended collecting additional data sources to validate the data, including from sources like Weather Underground. Finally, experts noted that modelling programs, including ENVI-met, can be used to understand the results of different design interventions.

4.3 Site Inventory

I referred to James LaGro's method for site inventory and analysis, gathering and assessing physical, biological, and cultural attributes of the site, and integrating these elements into the design program (Lagro, 2013).

4.3.1 History

The name "West End" is a historical name associated with the first suburb of Alexandria. It is directionally west of Alexandria, and the name also comes from the West family, who were its early owners and 18th Century developers. John West owned large tracts of land in what is now the Van Dorn corridor. The large tracts with plantations and slave quarters were subdivided over the years into smaller farmsteads.

Until the mid-20th Century, the area was part of Fairfax County and home to farmhouses (Figure 19). Construction of I-395 (formerly, Shirley Highway) began in 1944 from Woodbridge, VA to the 14th Street Bridge to Washington, DC, creating an opportunity for development along the highway.

Figure 19: Aerial footage of the project site pre-development in 1937. Source: Fairfax County GIS, 2026.

In 1952, Alexandria annexed land from Fairfax County, including the Landmark/Van Dorn neighborhood, almost doubling the size of the city and giving it its current shape. This annexation spurred development, both residential and commercial. At the time, all north-south streets in Alexandria were renamed after Confederate generals. A roadway known as Old Lincolnia Road was renamed Van Dorn Street to honor Confederate Major General Earl Van Dorn in 1953 (Franconia History LLC, n.d.).

By the 1960s-1970s, residential high rises and strip shopping centers replaced the remote farmhouses. The Landmark Mall was a center piece of the area for many years. Located at the intersection of Duke and Van Dorn streets, just one mile from the project site, it was an open-air shopping center featuring three large department stores. After large malls fell out of favor, the mall closed in 2017. Today, the city is redeveloping the site into a mixed-use center.

Aerial imagery from Fairfax County shows that the project site was converted from farmland to a warehouse before being rebuilt as a shopping center in 1990 (Figures 20 and 21). The layout of the shopping center today is identical to what was built 35 years ago and includes many of the attributes of shopping centers built in that time: one-story shops (approximately 50,000 sq ft of retail in the upper level) surrounded by a large 196-space parking lot. The significant amount of parking space makes it easy for patrons to quickly visit on their way home from work.

Figure 20: In 1972, the site was used as a warehouse and shipping facility. Source: Fairfax County GIS, 2026.

Figure 21: In 1990, the site was rebuilt into a one-story shopping center. Source: Fairfax County GIS, 2026.

4.3.2 Demographics

The City of Alexandria (2025) reports that residents living close to Van Dorn Station Shopping Center are ethnically diverse, younger renters. Approximately 30% of residents in the Census block area were born outside the U.S. (including countries like Afghanistan, Ethiopia, and El Salvador) and 20% speak another language. The population is 45% white, 27% Black/African American, 11% Asian/Pacific Islander, and 13% who count themselves as 2 or more races. Compared to the City at large, the area has a high percentage of renters (86%) compared to those who own their homes (4%) and fewer school age children (just 15% of the population is under 18). The median household income in the area is $97,000, slightly lower than the median for the City at large.

4.3.3 Physical Attributes: Terrain

The topography within the Landmark/Van Dorn Corridor is "sufficiently hilly to make it an issue in development and circulation" according to the Landmark/Van Dorn Corridor Plan (City of Alexandria, 2022b, p. 5). The site is relatively flat but has some steeper areas along the north-west and southern sides. Elevations on the project site range from approximately 100'-120' (Figure 22).

The area is visible for about a mile in all directions, and the group of high-rise apartments and condominiums north of the site, often referred to as "condo canyon," can be seen from the Woodrow Wilson Bridge five miles to the east (City of Alexandria, 2022b). Many of the steepest natural contours have been terraced to accommodate development.

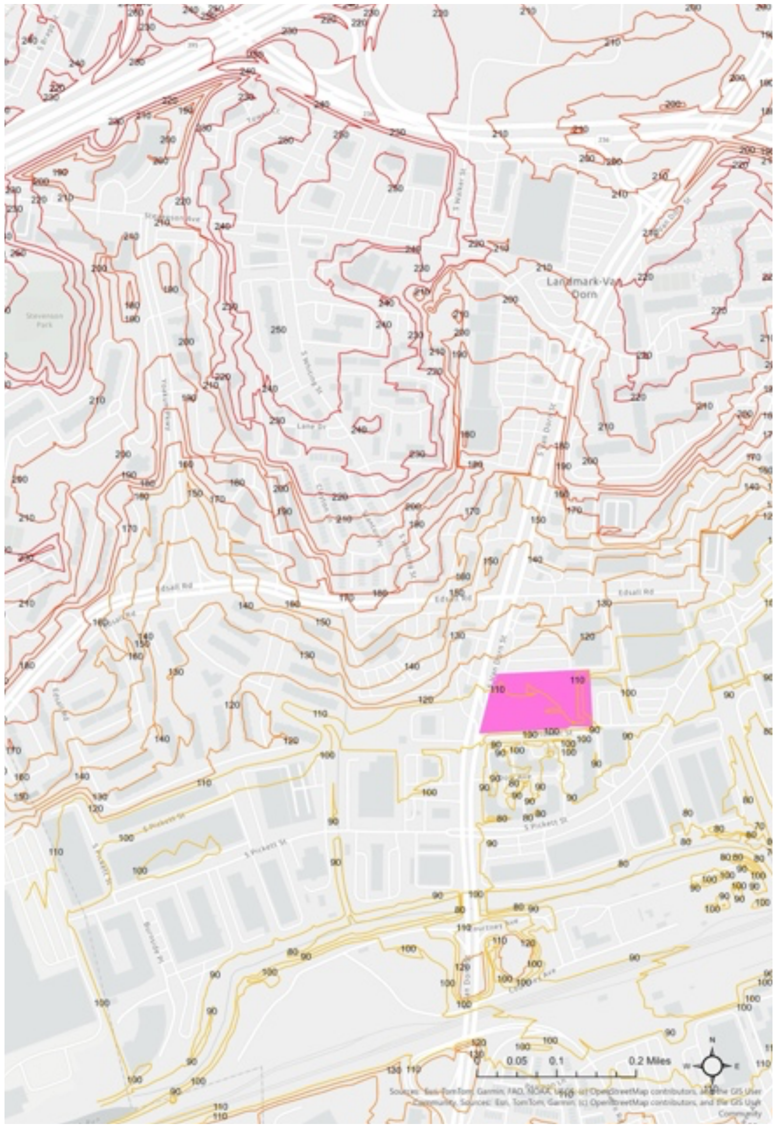


Figure 22: Topography Near Van Dorn Station Shopping Center. Source: Garlow, 2026

3.3.4 Physical Attributes: Soils

Soils on the site are categorized as “Urban Land” by the USDA and NRCS Web Soil Survey (Figure 23). There is no assigned Hydrologic Soil Group (HSD) rating for this area. However, because of the dominance of “high shrink-swell clay minerals” in most of Alexandria’s soils, green stormwater infrastructure projects are expected to use a rating of HSG D soils unless a soil engineer shows otherwise, according to the City’s Green Streets and Sidewalks Stormwater Design Guidelines (City of Alexandria, 2020, p. 27).

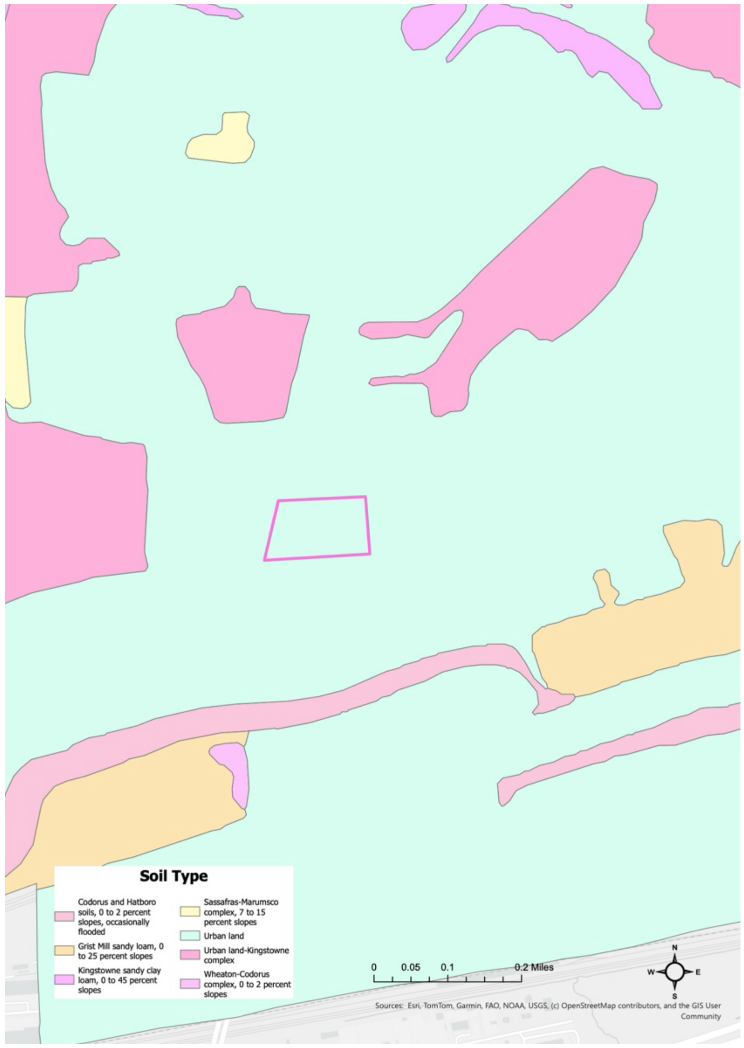


Figure 23: Soil Classification for Landmark Van Dorn Shopping Center, Source: Garlow, 2026

4.3.5 Physical Attributes: Hydrology

The site is within the Potomac River watershed, which is the second largest sub-watershed in the Chesapeake Bay watershed (Figure 24). The Potomac River watershed stretches across four states (West Virginia, Pennsylvania, Virginia, and Maryland), and the District of Columbia. The project site drains to a stream called Backlit Run, which connects to Cameron Run before entering the Potomac River. The project site is not within a "resource protection area," designated as 100 feet from a streambed (Figure 25); however, absorbing and filtering more of the stormwater runoff from the site's parking lot could still positively impact the health of Backlit Run and its larger watersheds.

Within the context of the site, the overland flow moves south-west toward S. Van Dorn Street where storm inlets are located. There are also inlets located within the shopping center, which also likely direct stormwater to S. Van Dorn Street. Drainage does not appear to be a significant challenge on the site, though I did not visit the site after any significant rainstorms to check for ponding.

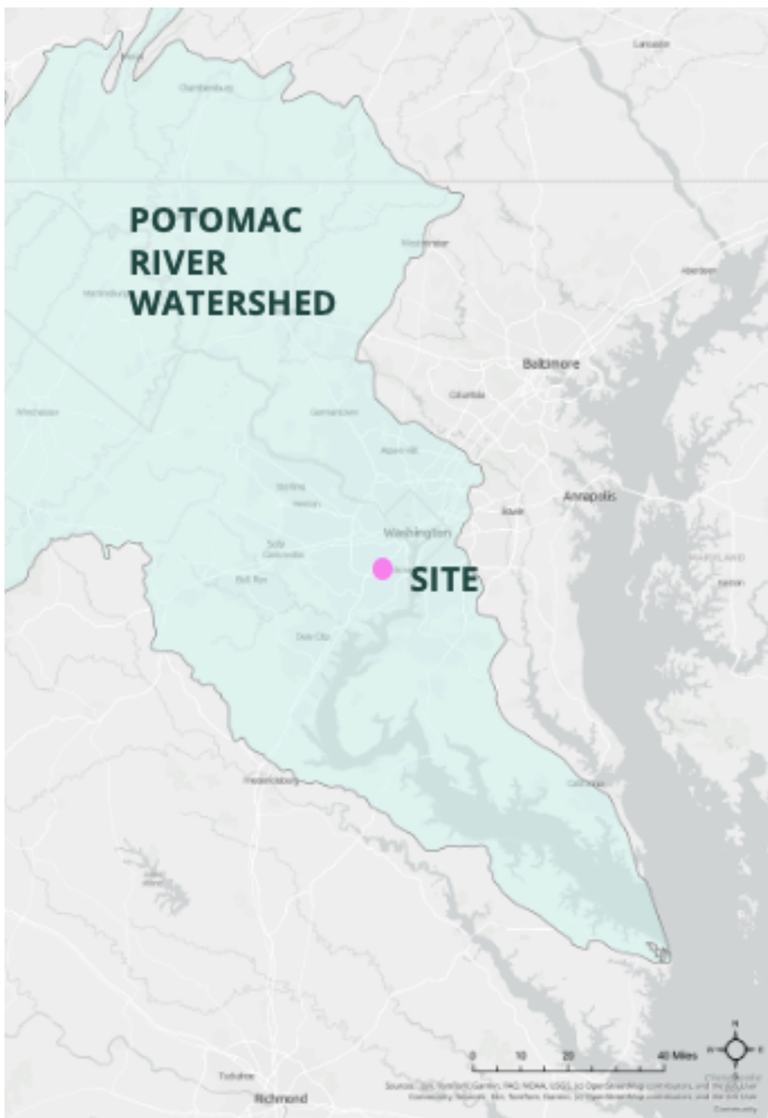


Figure 24: Potomac River Watershed with Project Site Context, Source: Garlow, 2026

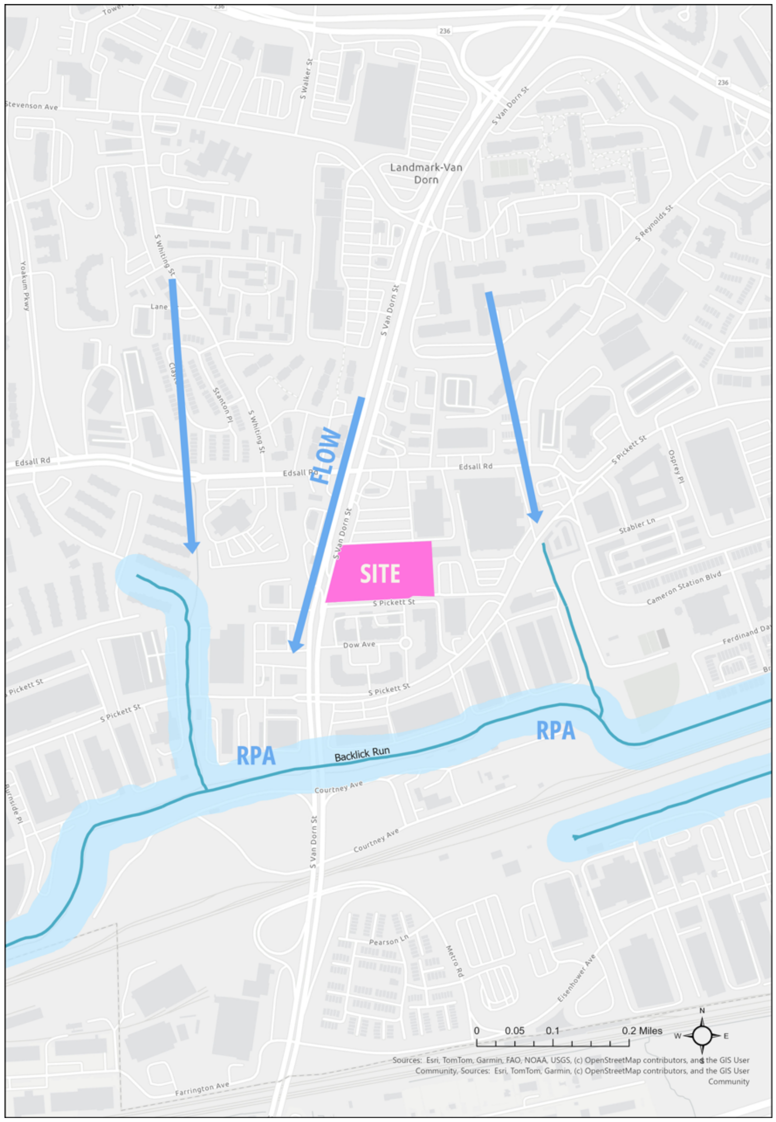


Figure 25: Backlit Run, Resource Protection Areas and Proximity to Project Site, Source: Garlow, 2026

4.3.6 Physical Attributes: Climate Risks – Flooding and Urban Heat Island

The higher elevation of the project site provides some protection from potential flooding around Backlit Run. The site is not within the 100- or 500-year flood zones surrounding Backlit Run; however, preventing run-off from the site during a high-intensity rainfall event could be important to flood prevention for neighboring properties to the south (Figure 26).

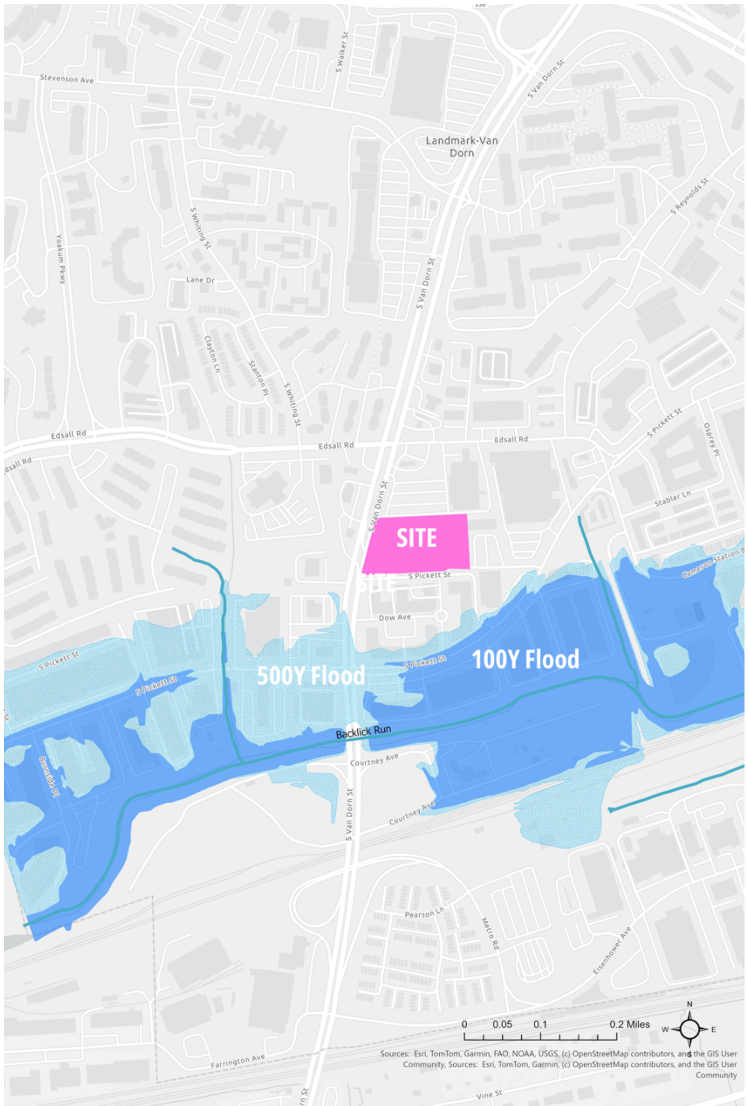


Figure 26: 100- and 500-year flood zones near project site. Source: Garlow, 2026

Considering the impact of heat is the focus of this project. Surface temperature data from July 13, 2020 show that the Van Dorn Station Shopping Center is at the center of a local heat island (Figure 27). A deeper analysis of the site's microclimate (including direct sunlight analysis, surface temperature, and wind patterns) will be detailed in a subsequent section.

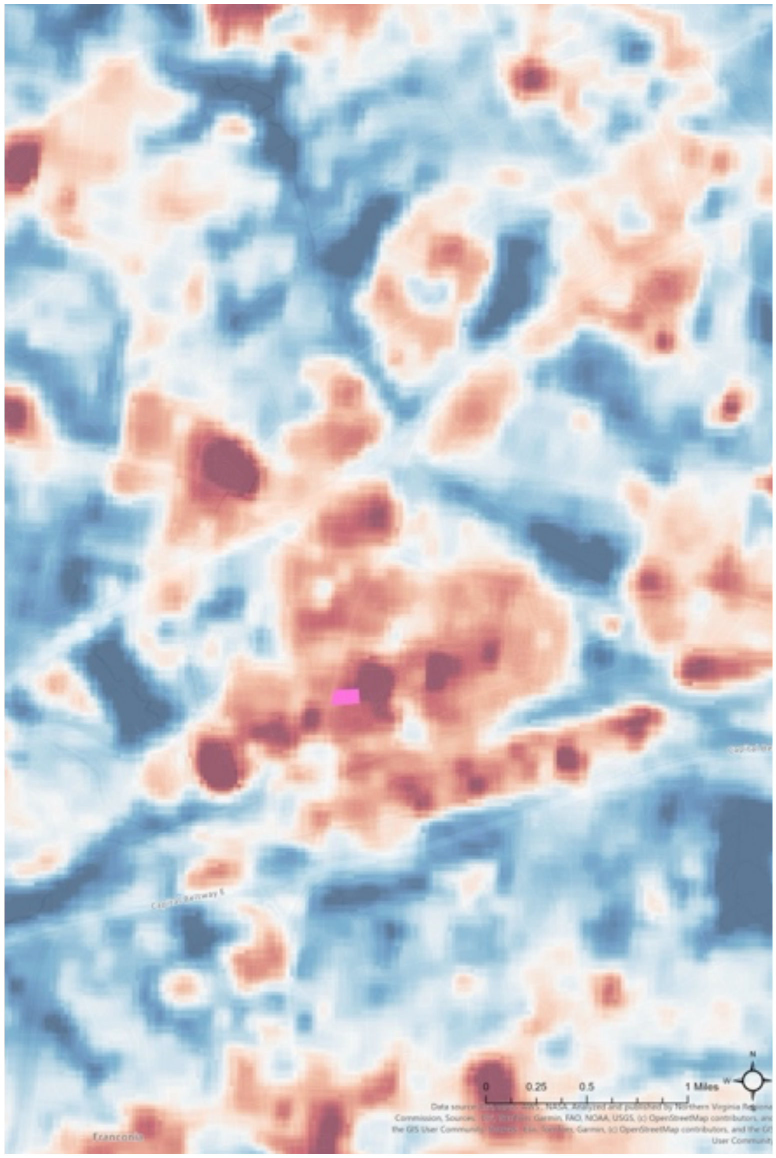


Figure 27: Surface temperature from July 13, 2020. Source: Garlow, 2026

4.3.7 Biological Attributes: Tree Canopy Coverage

The project site and surrounding area have very low tree canopy coverage (Figure 28), and according to TreeEquityScore.org, the Census area around the site has only 5% tree canopy coverage and is considered a “High Priority” area for improved coverage. TreeEquityScore.org provides a 30% goal for canopy coverage for this specific Census area (American Forests, n.d.). This target was developed by the USDA Forest Service and The Nature Conservancy and it suggests the minimum tree canopy cover required to deliver the full benefits of trees to a Block Group (American Forests, n.d.).

Alexandria's goal is to achieve 40% tree canopy coverage across the entire City, and while progress has been made, the goal has not been met. Additionally, much of the City's dense tree canopy is located within parks and protected natural areas, meaning that many spaces in the urban realm, like the project site, are severely lacking in tree canopy. The City of Alexandria currently does not set a minimum goal for canopy coverage for commercial development sites.

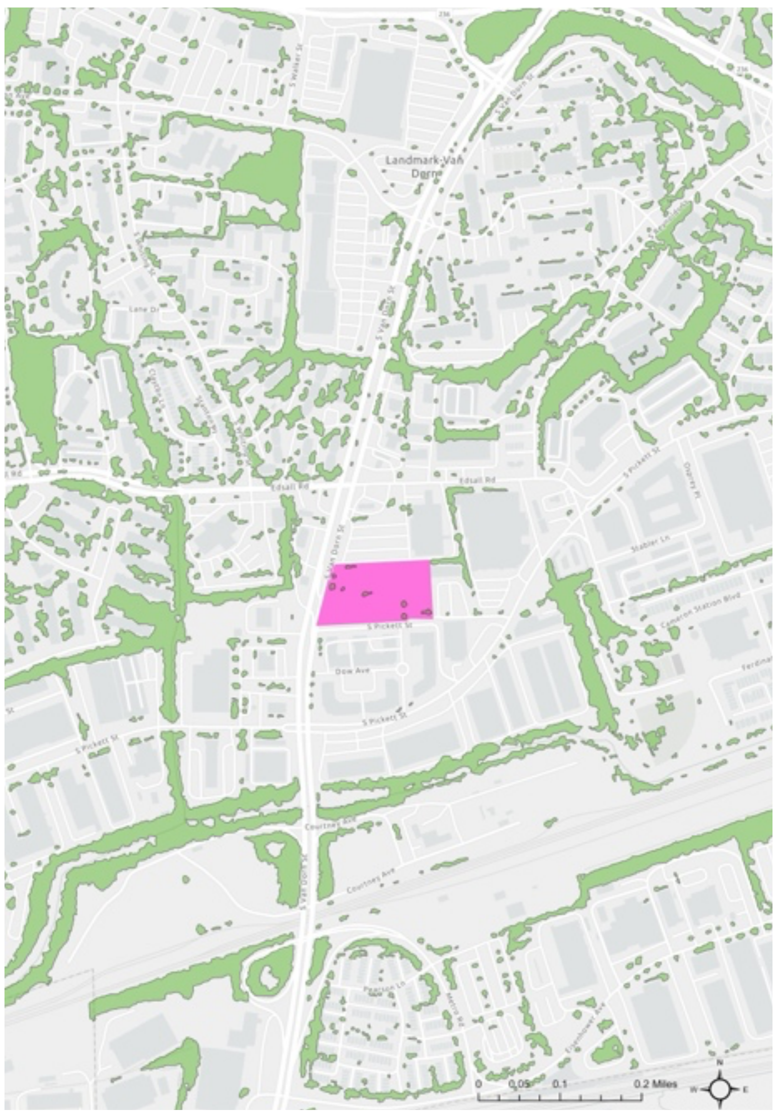


Figure 28: Tree canopy coverage surrounding project site, Source: Garlow, 2026

4.3.8 Biological Attributes: Site Vegetation

There is limited vegetation at Van Dorn Station Shopping Center. I conducted a tree inventory in July 2025 and counted approximately 22 trees from eight different species, including golden raintree (*Koelreuteria paniculata*), Willow oak (*Quercus phellos*), Pin oak (*Quercus palustris*), Red oak (*Quercus rubra*), Redbud (*Cercis canadensis*), and eastern red cedar (*Juniperus virginiana*), as noted in Figure 29. Most of the trees on the site are in poor health and appear to have both stunted growth and branch die-back (Figure 30). That said, some trees are in good health and provide canopy coverage to the site. These would be valuable to retain in future plans.

Other vegetation observed at the site is a mix of turf grass, intentional landscaping – such as shrubs like euonymous (*Euonymous japonicus),* winter jasmine *(Jasminum nudiflorum)* and juniper (*Juniperus horizontalis*) – and opportunistic/invasive plants – such as black locust (*Robinia pseudoacacia),* English ivy *(Hedera helix),* Poison ivy (*Toxicodendron radicans*), mulberry (*Morus* spp.), Callery pear (*Pyrus calleryana*), and Staghorn sumac (*Rhus typhina*), as noted in Figure 31.

Figure 29: Tree inventory for Van Dorn Station Shopping Center. Source: Garlow, 2026.

Figure 30: Photos of trees at Van Dorn Station Shopping Center. Healthy mature Quercus rubra (left) and stunted Quercus palustris (right). Source: Garlow, 2026

Figure 31. Photos of site vegetation. Mass of opportunistic trees and shrubs (left) and planted Euonymus (right). Source: Garlow, 2026

4.3.9 Biological Attributes: Green Roof Potential

The Northern Virginia Regional Commission (NVRC) conducted a study to assess the potential and value of adding green roofs to existing buildings across the region. Buildings were selected as green roof candidates if the usable green roof area was greater than 5,000 sq. ft. or 30% of total roof area. Based on their analysis, the buildings in Van Dorn Station Shopping Center are suitable candidates for green roofs (Figure 32, Table 3). At this site, a green roof would function both to reduce UHI and stormwater runoff.

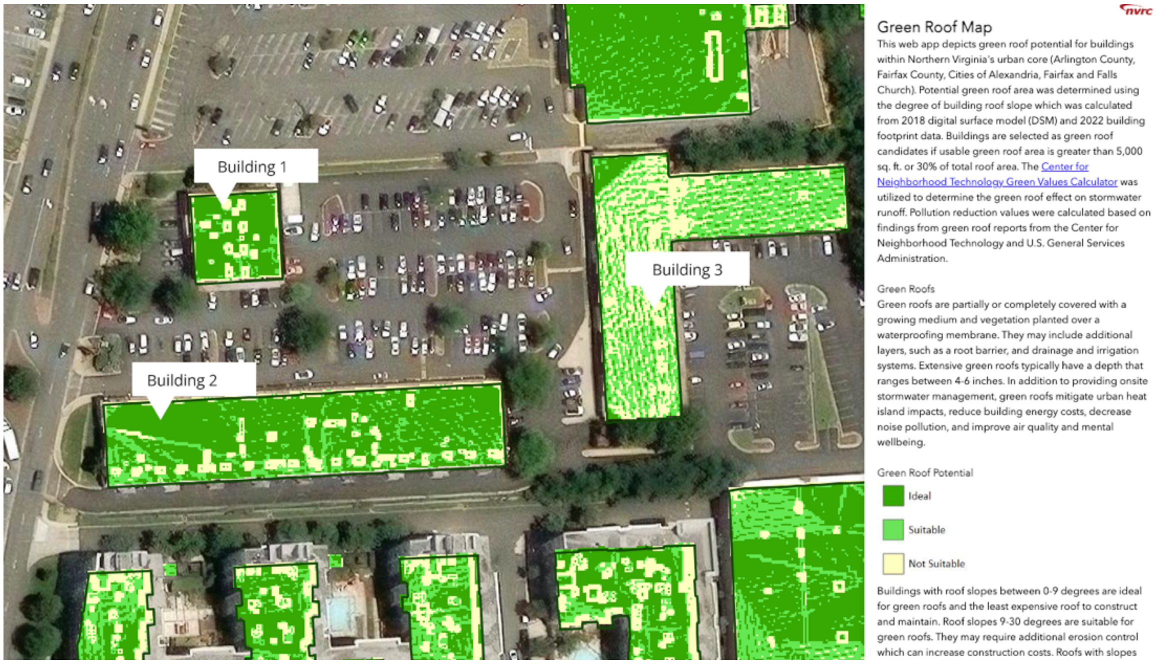


Figure 32: Green Roof Potential for Buildings in Van Dorn Station Shopping Center. Source: NVRC, n.d.

Table 3: Potential benefits of green roofs in Van Dorn Station Shopping Center. Source: NVRC, n.d.

Building 1		Building 2		Building 3 (Includes building in lower level of shopping center)	
TOTAL ROOF AREA	6,146 ft^2	TOTAL ROOF AREA	26,440 ft^2	TOTAL ROOF AREA	25,193 ft^2
USABLE GREEN ROOF AREA	4,504 ft^2 (73%)	USABLE GREEN ROOF AREA	21,791 ft^2 (82%)	USABLE GREEN ROOF AREA	14,287 ft^2 (57%)
EVENT VOLUME CAPTURE CAPACITY	6,440 gal.	EVENT VOLUME CAPTURE CAPACITY	31,161 gal.	EVENT VOLUME CAPTURE CAPACITY	20,431 gal.
ANNUAL VOLUME CAPTURE CAPACITY	73,096 gal.	ANNUAL VOLUME CAPTURE CAPACITY	353,668 gal.	ANNUAL VOLUME CAPTURE CAPACITY	231,880 gal.
ANNUAL CO2 AVERTED	1,986 lbs.	ANNUAL CO2 AVERTED	9,610 lbs.	ANNUAL CO2 AVERTED	6,301 lbs.
ANNUAL AIR POLLUTANTS REMOVED	6 lbs.	ANNUAL AIR POLLUTANTS REMOVED	31 lbs.	ANNUAL AIR POLLUTANTS REMOVED	20 lbs.
ANNUAL STORMWATER INTERCEPTION VALUE	$439	ANNUAL STORMWATER INTERCEPTION VALUE	$2,122	ANNUAL STORMWATER INTERCEPTION VALUE	$1,391
ANNUAL ENERGY SAVINGS	$1,216	ANNUAL ENERGY SAVINGS	$5,884	ANNUAL ENERGY SAVINGS	$3,858

4.3.10 Cultural Attributes: Neighborhood Fabric

The fabric of the Landmark/Van Dorn neighborhood can be defined as dispersed, irregular, and lacking spatial definition. Streets are not arranged in a grid, roads are winding, and buildings are generally set back a fair distance from the streets (Figure 33). The feeling of the neighborhood is both urban and industrial, but it is not dense. This dispersed urban fabric also affects the microclimate; buildings spaced further apart offer less in terms of shading to streets and sidewalks.

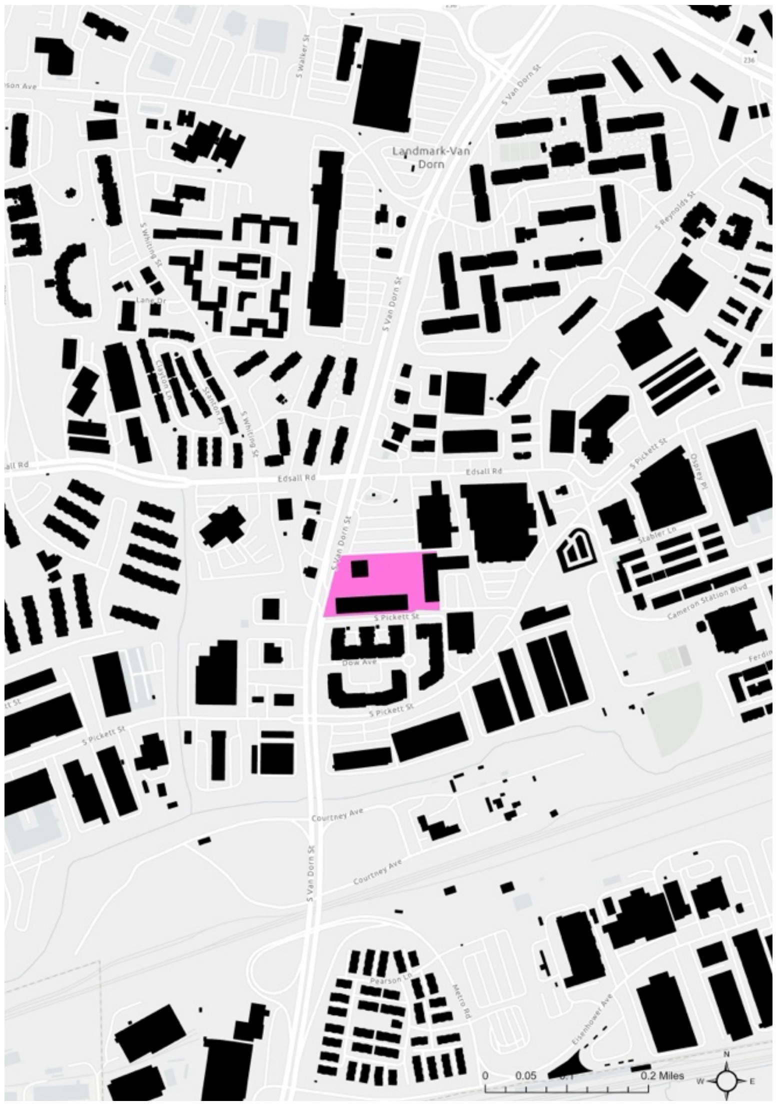


Figure 33: Figure-ground showcases a neighborhood with dispersed development where buildings do not provide much spatial definition. Source: Garlow, 2026

4.3.11 Cultural Attributes: Zoning

Van Dorn Station Shopping Center and other retail areas to the north and east are zoned as CDD#27, part of a Coordinated Development District (CDD). CDDs were created in the City's small area plans. They require consistency with the overall master plan and there are required approvals. The types of uses permitted for CDD#27 in the future include multi-unit family dwelling, recreation/entertainment use, day care center, hotel, medical office, outdoor dining, public building, public park, and more. The shopping center is surrounded by areas that are zoned as commercial (red) and industrial (purple) in Figure 34.

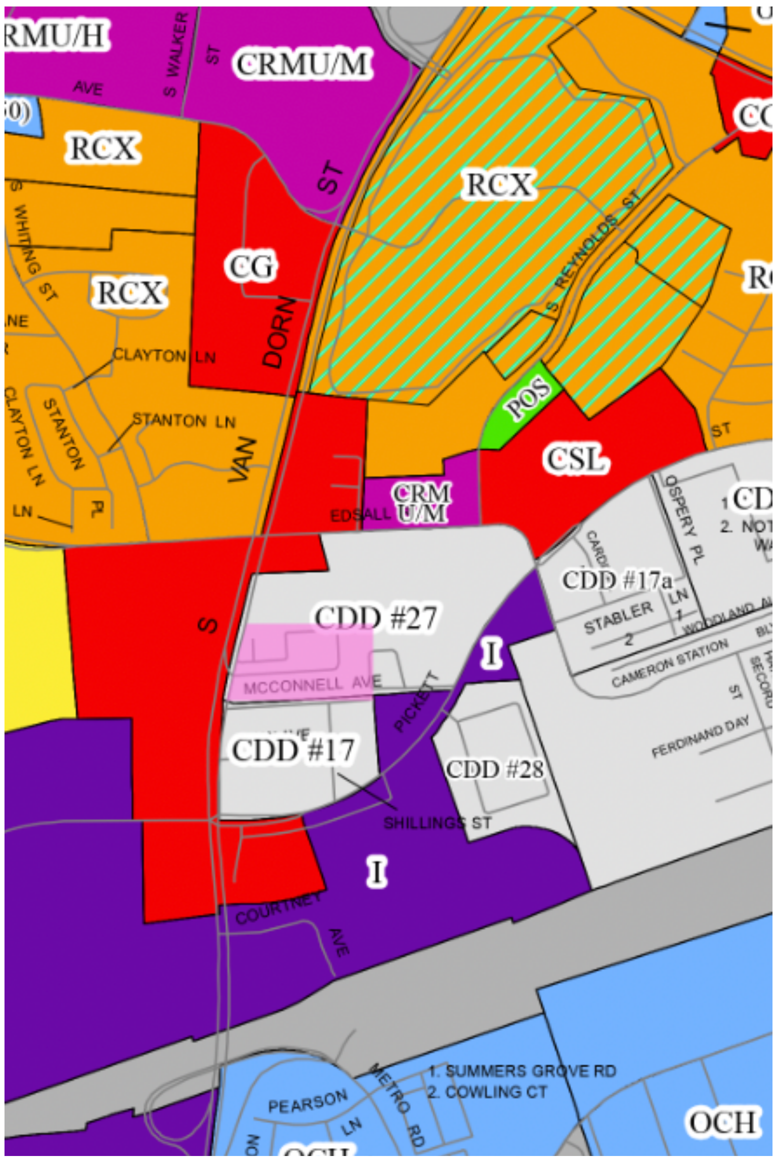


Figure 34: Zoning for Van Dorn Station Shopping Center and Surrounding Areas. Source: City of Alexandria, 2023

4.3.12 Cultural Attributes: Land Use and Neighborhood Character

The neighborhood around the project site is dominated by car-oriented services and apartment-style buildings. Apartments include low and high-rise style buildings and retail tends to be one-story. Examples of businesses within about a block of the project site include an international grocery store (LA Mart), a tire shop, truck and car rental businesses, a bank, self-storage, and a car wash (Figure 35). Most of the businesses and residential options are surrounded by parking with limited pedestrian amenities such as sidewalks, benches, shade, pedestrian-scale lighting, or trash cans (Figure 37). Van Dorn Station Shopping Center is one of a few shopping centers where various small businesses are clustered together. Most other retail establishments are in single buildings that require large space for inventory with less need to accommodate foot traffic.

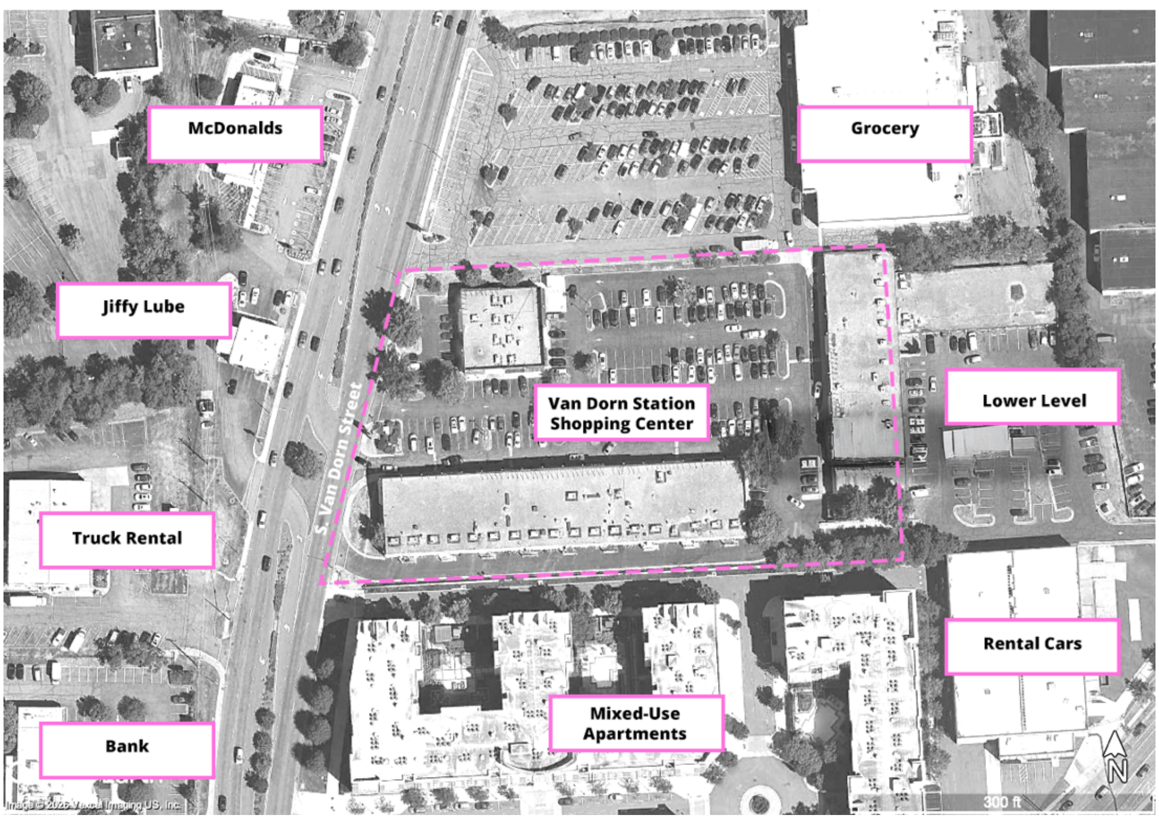


Figure 35: Land Use Surrounding Van Dorn Station Shopping Center. Source, Garlow, 2026

Contempo NOVA apartments, a mixed-use development built recently on the lot just south of the site, has a different style than the rest of the land near the site, and it is more aligned with the City's vision for future development (Figure 36). The development has restaurants on the first floor, four floors of apartments/condos, and wider sidewalks set back from the street by a planting zone.

Figure 36: Contempo NOVA apartments (left), a mixed-use development near the site provides a more well-defined public realm compared to older retail development such as LA Mart (right) that are typical of the neighborhood. Photos: Google Maps, 2026.

Figure 37: Pickett Square (left), another low-level strip mall, south of the site, and Eastern Motors (right), another example of car-oriented services in the immediate area. Photos: Google Maps, 2026.

4.3.13 Cultural Attributes: Access to Transit

The project site and other local neighborhood amenities are primarily accessible by car, given the ample parking, four-to-six lane roads, and lack of comfortable pedestrian or bike paths.

“Pickett Triangle,” where the project site is located, is surrounded by three major roads, each with 4-6 lanes of traffic: Edsall Road, S. Van Dorn Street, and S. Pickett Street.

To get around the triangle, pedestrians must walk long distances (between 1,150-1740 ft) before seeing an opportunity to cross the street at a crosswalk (Figure 38). Urban planner Jeff Speck has observed that people will jaywalk if the nearest crosswalk is more than 300 to 400 feet away (Speck, 2022). I observed this behavior at Pickett Triangle, suggesting there could be opportunities to increase safety with additional pedestrian crosswalks.

Google Maps also recognizes the minor or access roads as opportunities for cars to get around Pickett Triangle faster; however, these roads are less formalized and often lack appropriate visibility for pedestrians, creating risks for conflict or accidents.

Figure 38: Major and minor roads surrounding project site. Source: Garlow, 2026

The neighborhood is an "advanced transit corridor" – an area targeted by the City for Bus Rapid Transit (BRT) enhancements and stronger connections to the Metro. There are five different bus routes within 1,000 feet of the site, with access to DASH, Metro, and Fairfax Connector buses (Figure 39). The closest Metro station is .81 miles away and is accessible via bus down S. Van Dorn Street. A BRT line is planned to run along S. Van Dorn Street with a stop just to the south of the site, though no date has been put forth.

Some bike infrastructure is emerging near the site: a dedicated bike lane was built along part of S. Pickett Street, and the City plans to expand the bike lane to include all of S. Pickett Street and part of S. Van Dorn Street as well. There is a Capital Bikeshare rental kiosk near the Contempo NOVA mixed-use development (Figure 40).

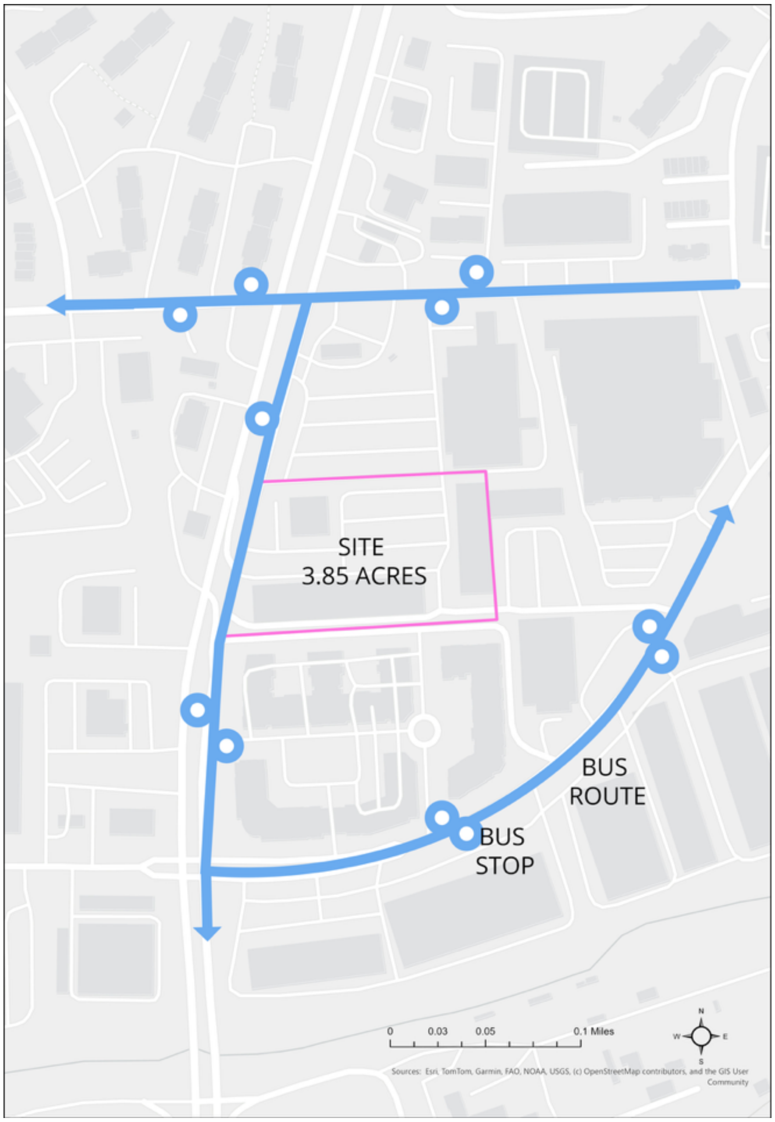


Figure 39: Bus routes and stops near the project site. Source: Garlow, 2026.

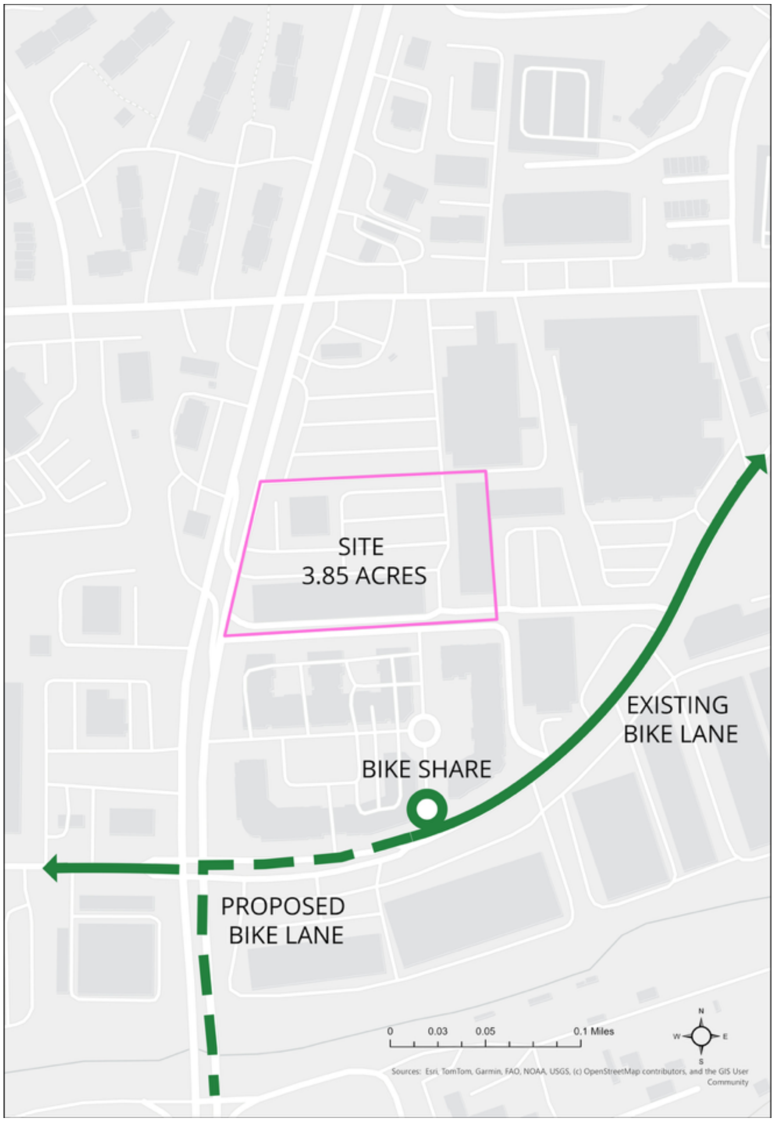


Figure 40: Current and planned bike lanes near the project site. Source: Garlow, 2026.

4.3.14 Cultural Attributes: Shopping Center Circulation

Circulation *within* Van Dorn Station Shopping Center could use improvement. Within the site, a mix of one-way and two-way access roads for cars and five different entrances/exits often creates confusion, wrong turns, and potential conflicts (Figure 41). There is limited pedestrian infrastructure beyond a disconnected network of sidewalks that flank the sides of the buildings and S. Van Dorn Street. There are no clear pedestrian paths through the parking lot; instead, shoppers must navigate between parked cars and traffic lanes to get to their destination (Figure 42).

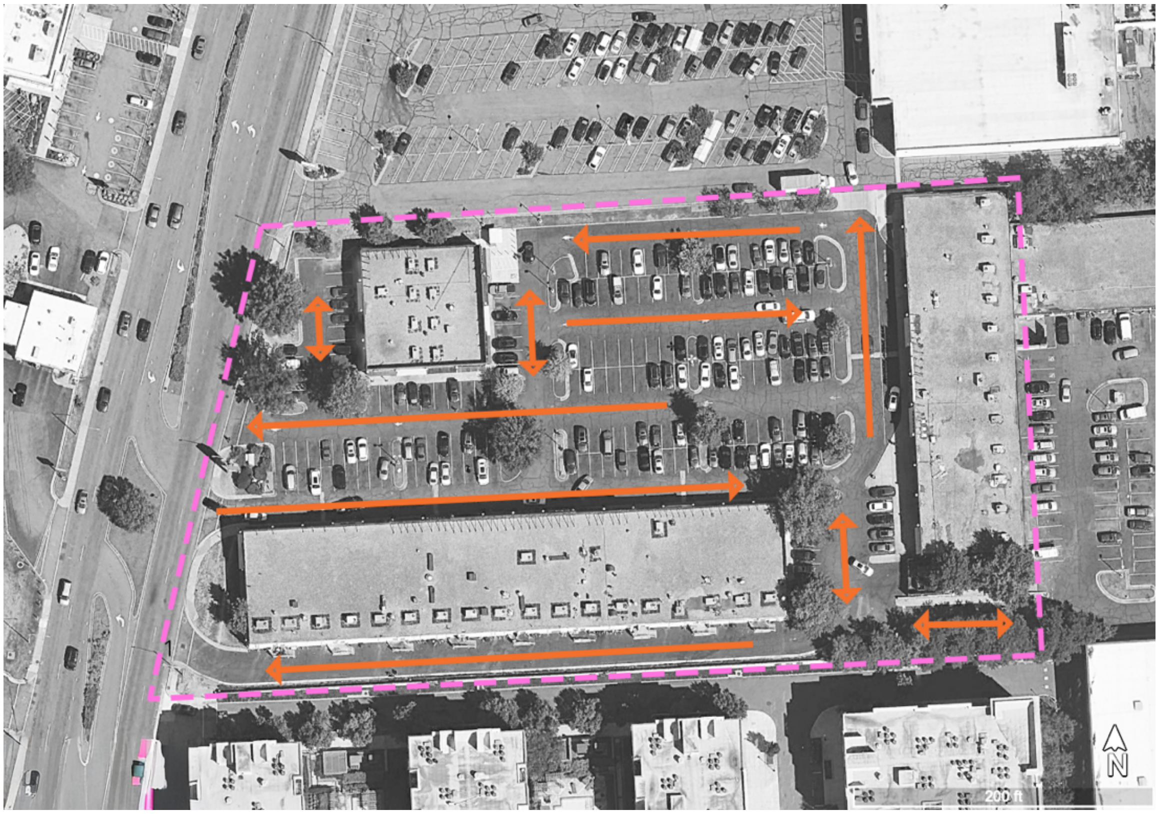


Figure 41: Vehicular circulation at the project site. Source: Garlow, 20206

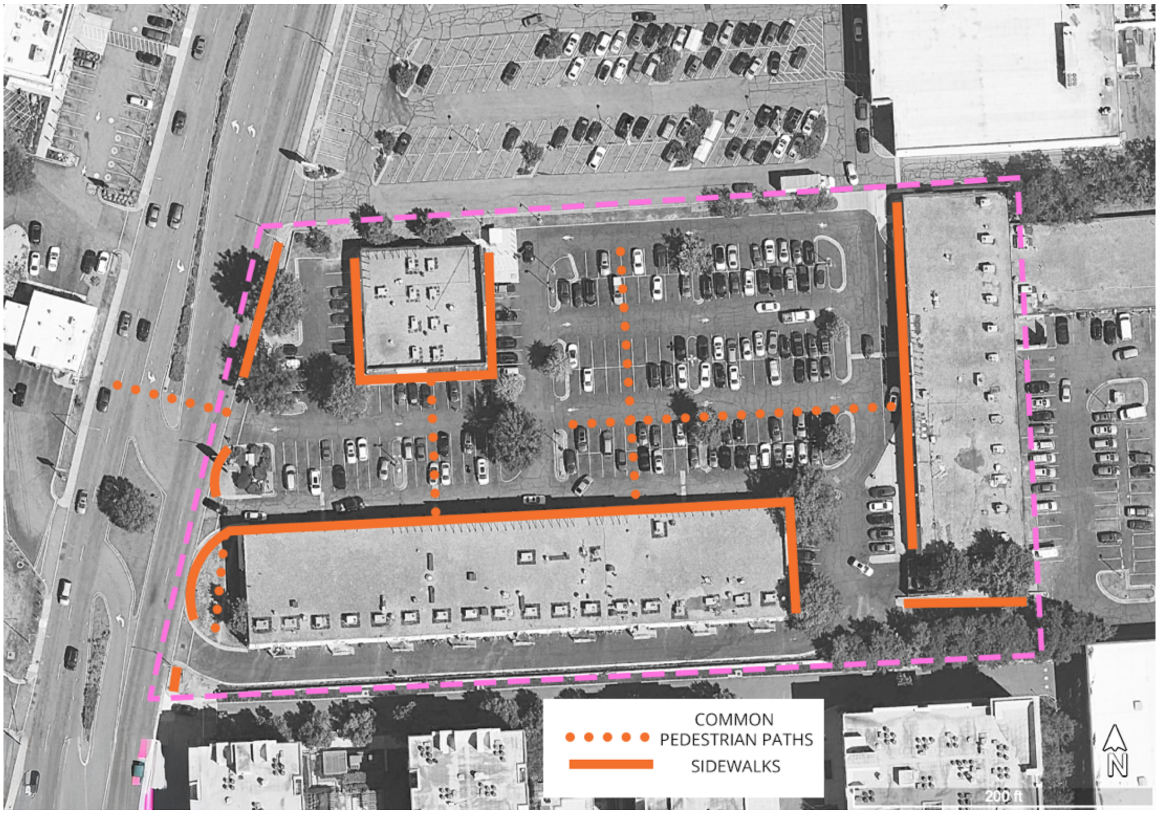


Figure 42: Sidewalks are not aligned with desired pedestrian routes at the project site. Source: Garlow, 2026

4.3.15 Cultural Attributes: Retail Mix

Van Dorn Station Shopping Center is home to approximately 51,000 sq feet of retail with 29 different stores (Table 4). The shopping center offers a diverse mix of retail options, with an emphasis on restaurants and beauty salons/barber shops. There are only four vacancies in the shopping center, all located in the smallest building (Figure 35).

Table 4: Stores in Van Dorn Shopping Center. Source: Garlow, 2026

Number	Store Name	Store Category
1	CasaMigos	Restaurant
2	First Cash Pawn	Pawn Shop
3	Makeda Ethiopian	Restaurant
4	Peking Restaurant	Restaurant
5	El Texano Bar and Grill	Restaurant
6	Barber Shop	Beauty
7	Calabash African Cuisine	Restaurant
8	Pho Viet Restaurant	Restaurant
9	Kabob Express	Restaurant
10	Laundromat	Laundromat
11	Zeke Hookah	Hookah/Smoke

12	Feru Bar and Restaurant	Restaurant
13	Hair Links Salon	Beauty
14	ZeMeda Market and Restaurant	Restaurant
15	Mumbai Indian	Restaurant
16	ALIVE!	Food Bank/Market
17	Smoke Stop	Hookah/Smoke
18	Weyone Foods	Market
19	Hanna Market	Market
20	Eyebrow Threading	Beauty
21	Queen Nails	Beauty
22	Le Chic Salon	Beauty
23	Emylls Beauty Supply	Beauty
24	New Look Hair and Nail Spa	Beauty
25	Mart and Tobacco	Market/Smoke
26	Thai Lemon	Restaurant
27	Dunkin Donuts	Restaurant
28	Dollar Market Plus	Market
29	Bank of American (ATM)	Bank

Figure 43: Retail mix at Van Dorn Station Shopping Center. Source: Garlow, 2026

4.3.16 Cultural Attributes: Ownership

The shopping center has been owned by W&R Investments LP since 1993 and the current property value is approximately $25 million, according to City's real estate data (City of Alexandria, Virginia, n.d.). The owner paid just over $316,000 in taxes in 2025.

4.3.17 Cultural Attributes: Development Proposals

Several development proposals have been put forth over the past 10-15 years for the shopping center and surrounding Pickett Triangle area. The City of Alexandria provided one proposal in 2009 as part of the Landmark Van Dorn Corridor Plan (Figure 44). Greenhill Realty Company also worked with Michael Winstanley Architects and Planners in 2016 to put together several other development proposals for Pickett Triangle, which include a grid network for streets, building parcels closer to the street, and higher density, mixed-use buildings (Figures 45 and 46). Given the interest by both developers and the City in alternate schemes for Pickett Triangle, it seems likely that Van Dorn Shopping Center and neighboring commercial/industrial areas will be redeveloped in the future.

Figure 44: Development proposal in 2009 Landmark Van Dorn Corridor Plan. Source: City of Alexandria, 2022.

Figure 45: Development proposal for Pickett Triangle. Source: Greenhill Realty Company, 2016.

Figure 46: Model of proposal for Pickett Triangle. Source: Greenhill Realty Company, 2016

4.4 Community "Walk and Talk"

In April 2025, I had the opportunity to participate in a community "walk and talk" meeting hosted by the City of Alexandria Department of Public Health. The location of the walk and talk was Pickett Triangle. Thus, Van Dorn Station Shopping Center was included in the walk and talk. I took notes during the walk and talk and reviewed the City's subsequent summary, which was posted in June 2025. Key themes that emerged from the "walk and talk" meeting included (City of Alexandria, 2025a):

- There are many **diverse, small businesses** in the Landmark/ Van Dorn area.
- The area **does not have enough recreation, community programming, and play areas**, particularly for **youth**.
- Getting around can be difficult and dangerous because there are **not enough safe, maintained, and available crosswalks and sidewalks**.
- The area has a mixed layout, with industrial, residential, and commercial spaces**. More green spaces, shade, and public spaces** would give this area more of a neighborhood feel.

The focus on safe pedestrian access (particularly crosswalks and sidewalks) and need for more "third spaces" with greenery and shade were key themes that I also integrated into the development of my own qualitative survey.

4.5 Microclimate Analysis

Given the focus on designing for heat and improving pedestrian thermal comfort, I completed additional site inventory and analysis of the shopping center's microclimate.

4.5.1 Site Surface Temperature

To understand the impact of material selection and shade within the existing site, I conducted a microclimate analysis on August 22, 2025. Using an infrared thermometer with a built-in camera (Perfect Prime Imaging Camera), I took surface temperature measurements of four different surfaces (asphalt, concrete, gravel, and grass) at Van Dorn Station Shopping Center in both shaded and unshaded locations at two different times of day, 2pm and 5pm (Table 5, Figure 47). I also collected air temperature, humidity, and wet bulb globe temperature using a heat stress meter (Triplett HS10 Heat Stress WBGT) and the weather app on my phone (iPhone 14 Pro). I compared the surfaces temperatures at my project site to a local "cool island," the nearby Armistead Boothe Park, where I took measurements of grass, asphalt, and concrete in sun and shade conditions.

August 22, 2025, was a sunny and clear day with a high of 84°F and relatively low wind at 4mph, with gusts up to 6mph. Humidity was low, measuring 27-34% throughout the afternoon, creating a comfortable "feels like" temperature. For example, at 5pm, the Tripplett WGBT reading was 84.0°F air temperature, 33.9% humidity, and a "feels like" temperature of 73.8°F.

Table 5: Surface Temperature Measurements at Van Dorn Station Shopping Center on August 22, 2025. Source: Garlow, 2026.

	Concrete (Sidewalk) SUN	Concrete (Sidewalk) SHADE	Asphalt (Road) SUN	Asphalt (Road) SHADE	Gravel (Tree Pit) SUN	Gravel (Tree Pit) SHADE	Grass (Median) SUN	Grass (Median) SHADE
2:15 PM	**106.0 F**	**78.2 °F**	**114.8 °F**	**82.5 °F**	**116.7 °F**	**81.3 °F**	**103.6 °F**	**82.0 °F**
5:15 PM	**108.1 F**	**82.5 °F**	**113.9 °F**	**81.3 °F**	**114.6 °F**	**93.9 °F**	**95.0 °F**	**84.0 °F**

Legend

- Yellow = 70-90°F
- Light Orange = 90-100°F
- Dark Orange – 100-110°F
- Red – 110°F or greater

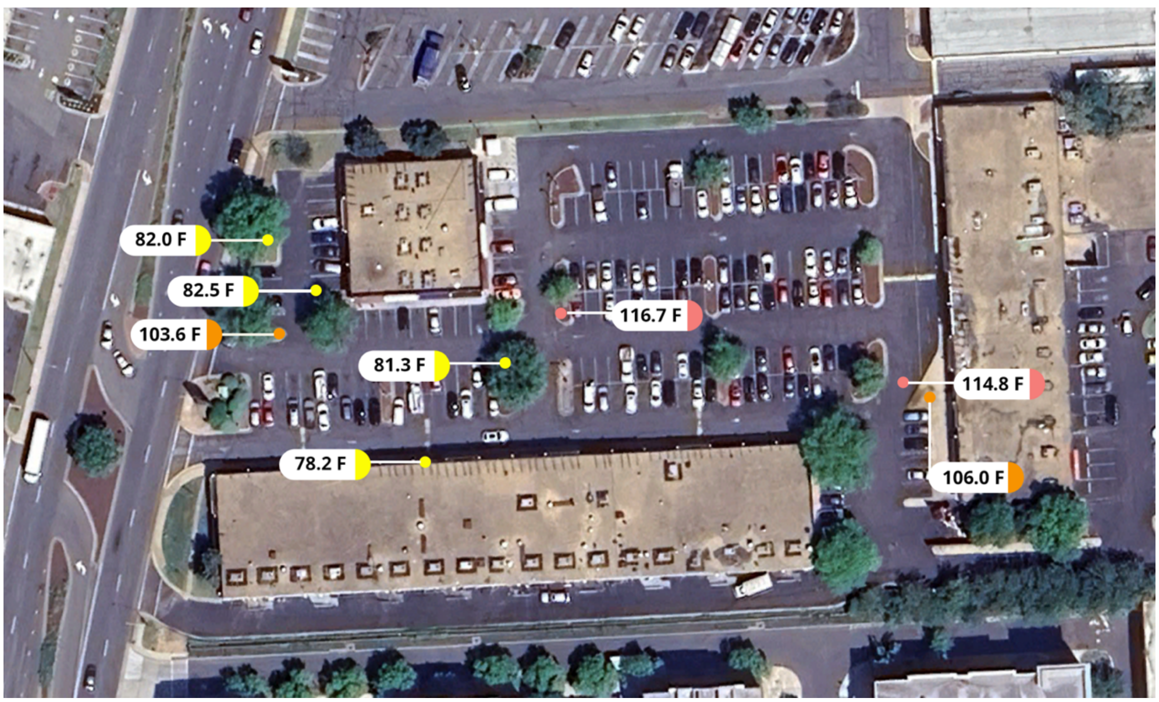


Figure 47: Surfaces Temperatures by Location at Van Dorn Station Shopping Center on August 22, 2025. Source: Garlow, 2026.

At Van Dorn Station Shopping Center, shaded surfaces were an average of 25.8 °F cooler than unshaded surfaces (Figure 50), with up to a 35.4 °F difference in the surface temperature of gravel in shaded versus unshaded surfaces. The tree pit gravel and the asphalt were the hottest surfaces measured in the sun (Figure 48 and 49), while grass was the coolest, by up to almost 20°F at 5pm. In the shade, concrete was the coolest surfaced measured at both times of day.

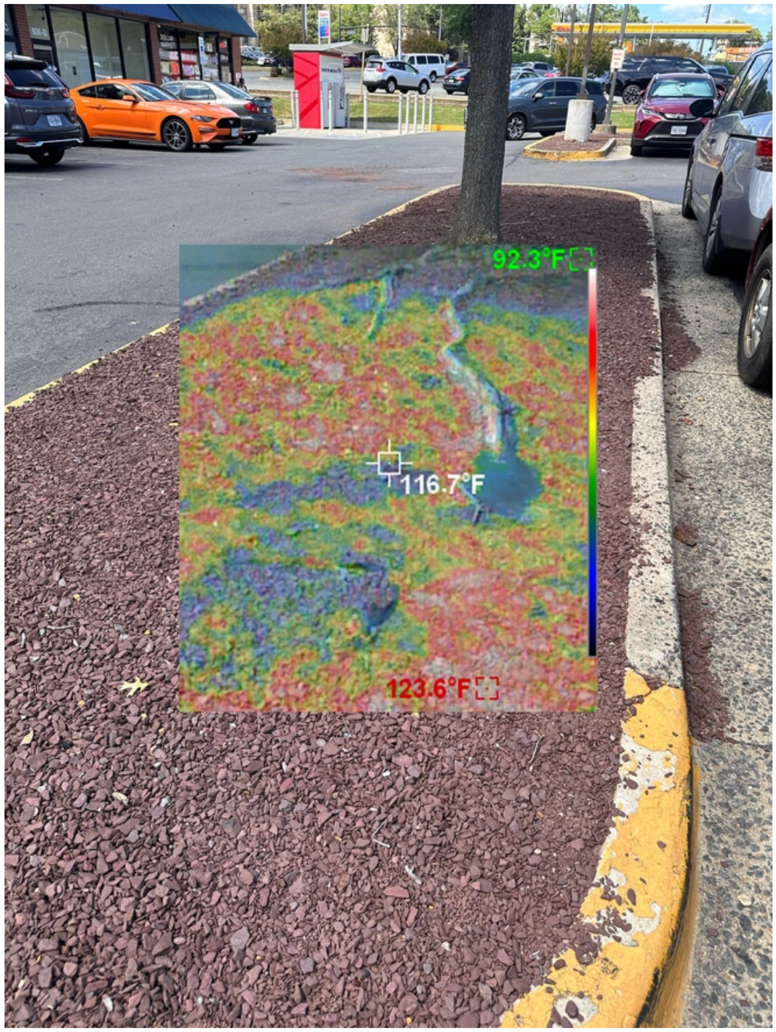


Figure 48: Surface Temperature of Gravel Tree Pit at Van Dorn Station Shopping Center at 2pm. Source: Garlow, 2026.

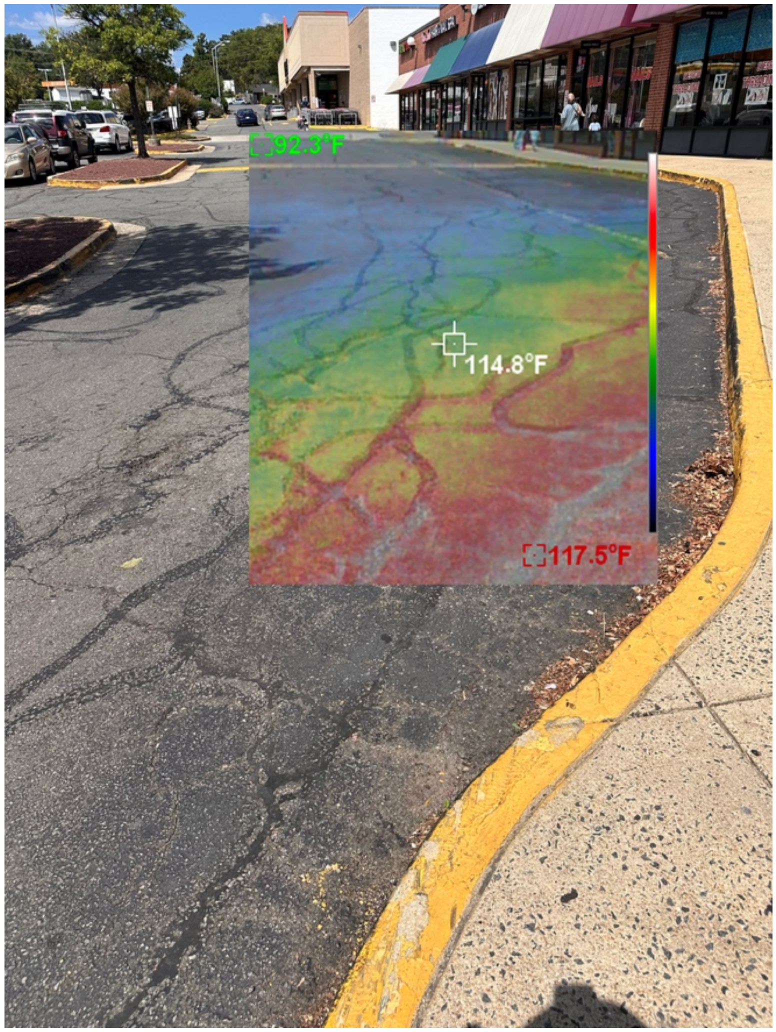


Figure 49: Surface Temperature of Asphalt at Van Dorn Station Shopping Center at 2pm. Source: Garlow, 2026

Figure 50: Visualization of the Impact of Tree Shade on Asphalt Surface Temperature at Van Dorn Station Shopping Center at 2pm. Source: Garlow, 2026.

Table 6: Surfaces Temperatures at Armistead Boothe Park on August 22, 2025. Source: Garlow, 2026.

Legend

- Yellow = 70-90°F
- Light Orange = 90-100°F
- Dark Orange – 100-110°F
- Red – 110°F or greater

	Concrete SUN	**Concrete SHADE**	**Asphalt SUN**	**Asphalt SHADE**	**Gravel N/A**	**Grass SUN**	**Grass SHADE**
2:00 PM	**N/A**	**81.8 °F**	**120 °F**	**N/A**	**N/A**	**114 °F**	**78.8 °F**
5:00 PM	**N/A**	**81.3 °F**	**114 °F**	**N/A**	**N/A**	**103 °F**	**77.1 °F**

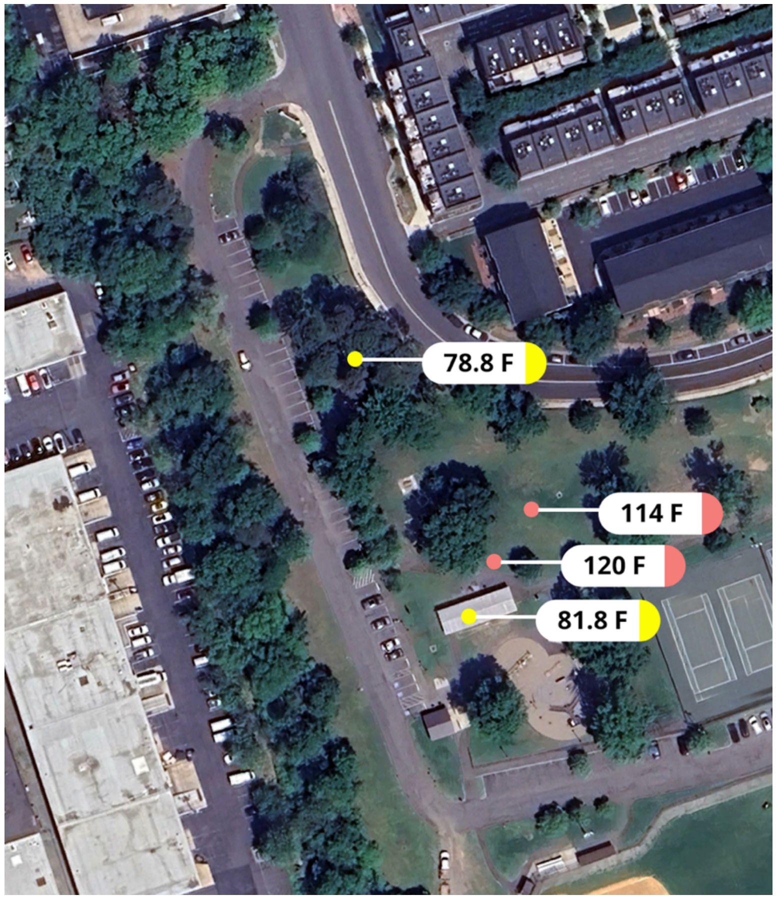


Figure 51: Surfaces Temperatures by Location at Armistead Boothe Park on August 22, 2025. Source: Garlow, 2026.

At Armistead Boothe Park, shaded surfaces were also 20 to 40 °F cooler than unshaded surfaces. The grass under a large group of trees was 41.2 °F cooler than an asphalt path in the sun (Figure 51, Table 6).

3.5.2 Sun Path Diagram

I conducted several environmental analyses using a combination of two software programs: Rhino, for 3d modeling, and Grasshopper (specifically the Ladybug toolset) to analyze the impact of climate on the site. First, I created a sun path diagram (Figures 52 and 53) to provide a clear picture of where the sun is overhead in the summer months during the hottest part of the day. The visualization below shows the sun's location from 12:00-5:00pm on August 25th, which is the same as one of the days I fielded a survey questionnaire.

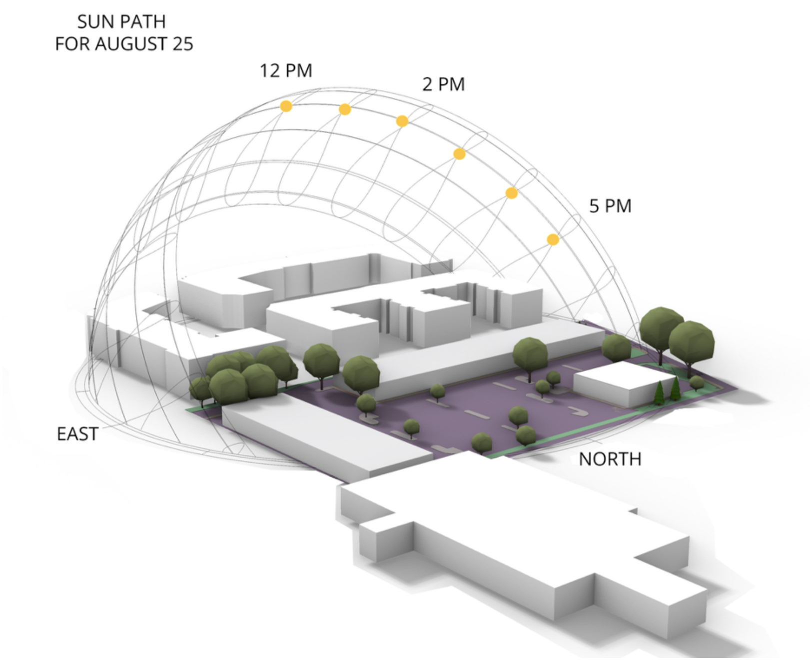


Figure 52: Sun path diagram for Van Dorn Station Shopping Center. Source: Garlow, 2026.

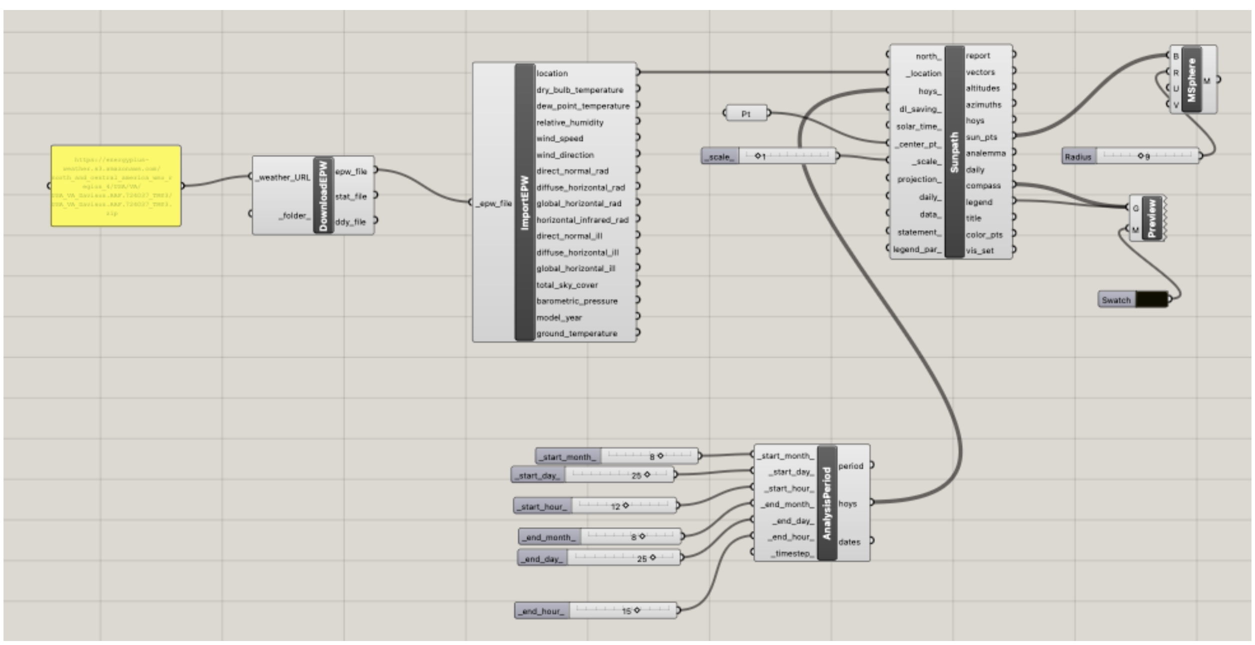


Figure 53: Sun path script in Grasshopper (Ladybug). Source: Garlow, 2026.

4.5.3 Direct Sunlight Analysis

To understand the impact of existing trees and buildings in shading the site, I used Rhino and Grasshopper (Ladybug) to develop direct sunlight analysis diagrams (Figures 54, 55 and 56). I analyzed conditions on June 21 (summer solstice), May 1 (mid-point between spring equinox and summer solstice) and August 1 (mid-point between summer solstice and fall equinox). Analyses are for a 24-hour period. The average hours of direct sunlight across the site are 9.58 (May 1), 10.82 hours (June 21), and 10.23 hours (August 1), which demonstrates that the site is very exposed to direct sunlight throughout the year. The one-story buildings and lack of canopy trees lead to significant areas of exposure, with the most exposed areas close to the entrance at S. Van Dorn Street and the parking between all three buildings. The areas with the healthiest and largest groups of trees – including the oaks along S. Van Dorn Street and in the south-east corner of the site – do the most work at blocking the direct sunlight that hits the site.

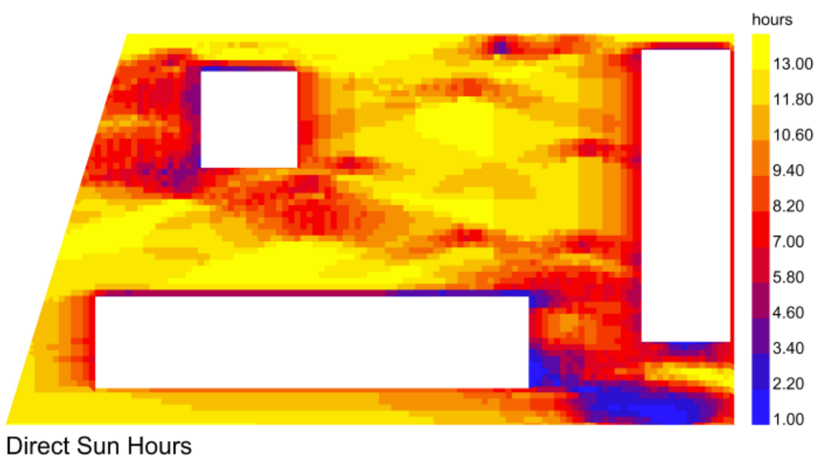


Figure 54: Direct sunlight analysis for May. Source: Garlow, 2026.

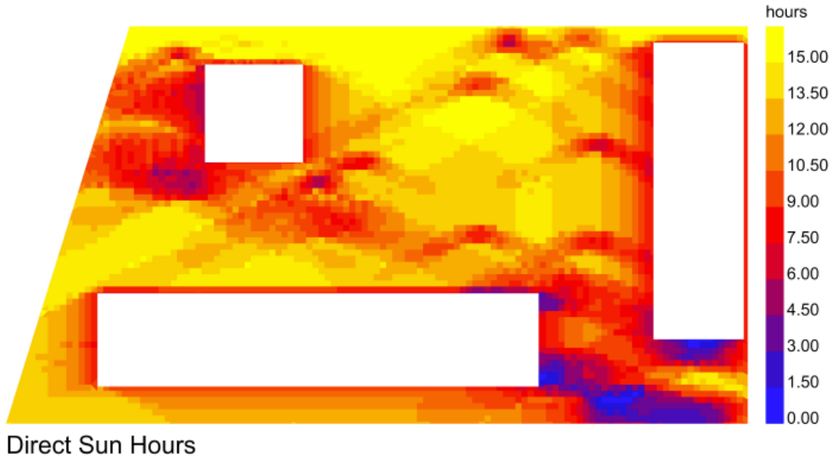


Figure 55: Direct sunlight analysis for June 21. Source: Garlow, 2026.

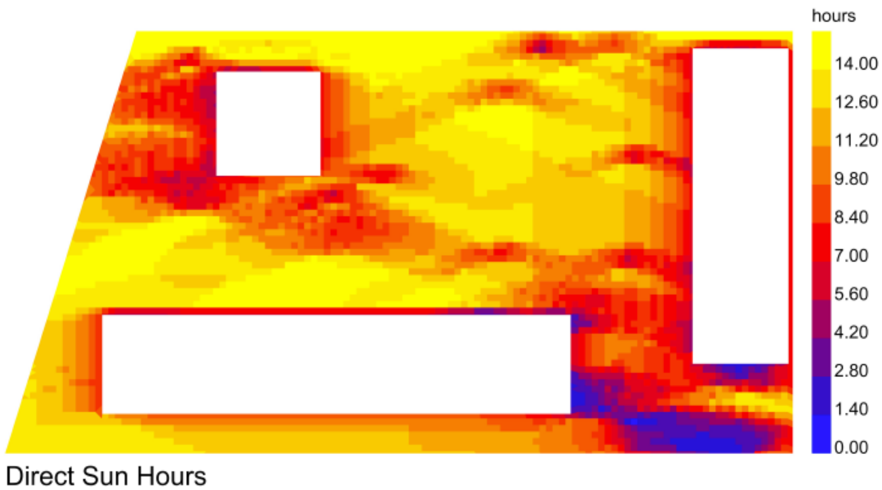


Figure 56: Direct sunlight analysis for August 1. Source: Garlow, 2026.

4.5.3 Wind Rose

Next, I used Rhino and Grasshopper (Ladybug) to generate a wind rose, which shows how much and at what speed and direction the wind comes toward and through the site throughout the full year (Figure 57). I used wind data from the Davison Army Airfield, which is about 9 miles from the site (Figure 60).

I generated a second wind rose to assess the wind during the summer months, using the period of May 15th – October 1st (Figure 58). Finally, I generated a third wind rose to assess the wind during the summer months with a focus on the hottest time of day, using 11am to 5pm (Figure 59). The predominant winds in the area flow along a NW/SE axis, with a focus on winds coming from the SE in the summer afternoons. These data reveal a potential design opportunity if the prevailing summer winds could be harnessed for their cooling powers.

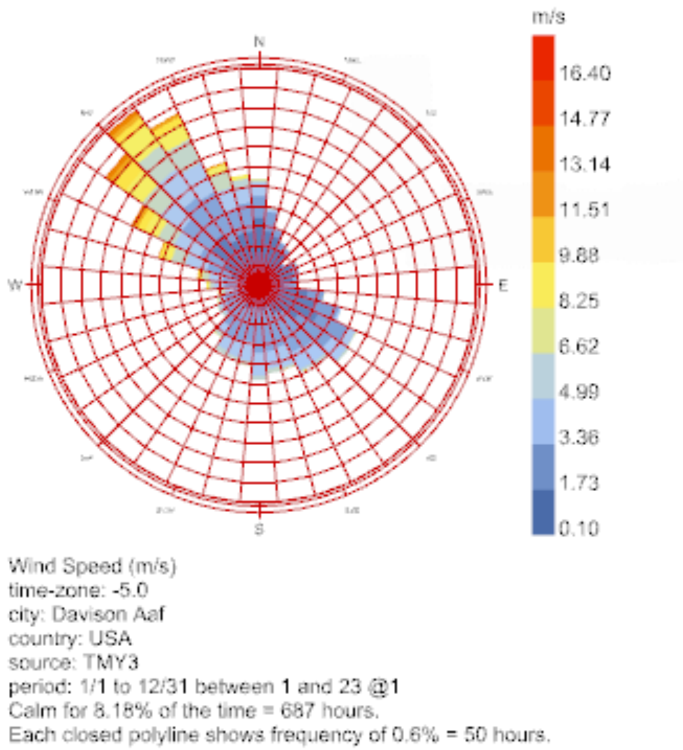


Figure 57: Wind Rose from Davison Army Airfield. Source: Garlow, 2026.

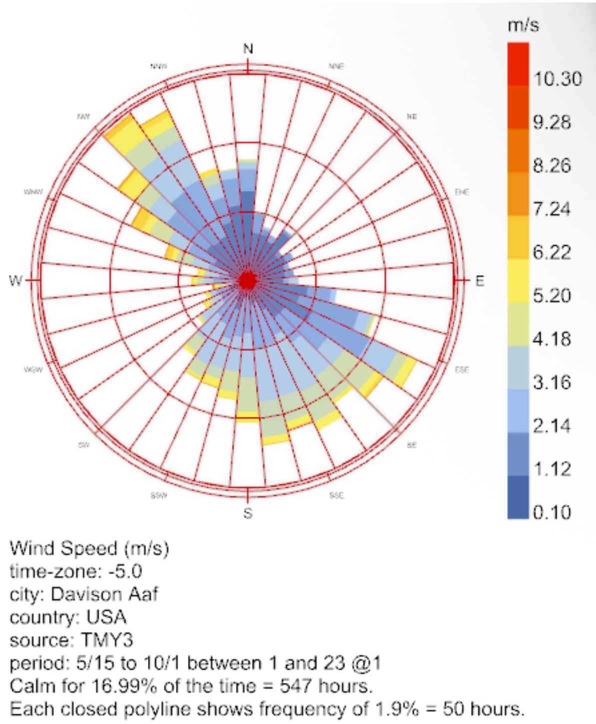


Figure 58: Wind Rose from Davison Army Airfield, from May 15 - October 1. Source, Garlow, 2026.

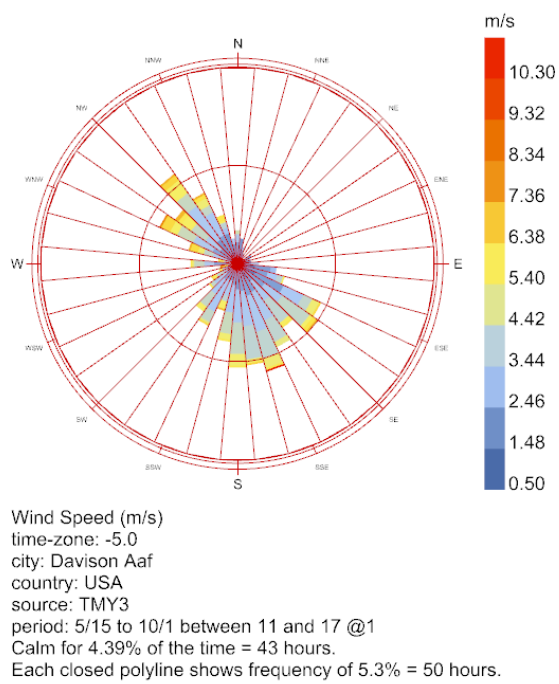


Figure 59: Wind Rose from Davison Army Airfield, from May 15 - October 1, from 11am-5pm. Source, Garlow, 2026.

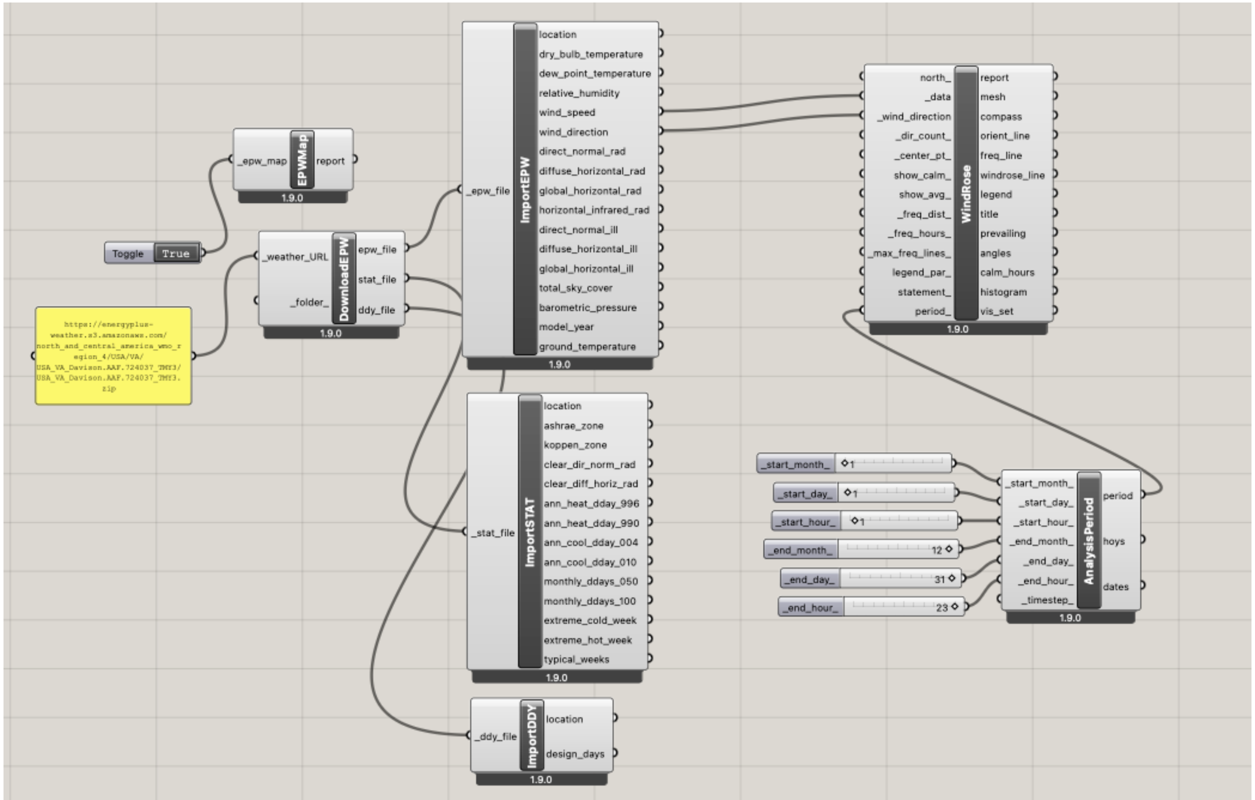


Figure 60: Ladybug script to generate wind rose. Source: Garlow, 2026.

4.5.4 Universal Thermal Climate Index (UTCI)

As a final step in assessing the microclimate of the site, I used Rhino and Grasshopper (Ladybug) to estimate the universal thermal climate index (UTCI). UTCI is an internationally recognized standard for evaluating heat stress developed by the International Society of Biometeorology. It is based on a complex model that incorporates air temperature, wind speed, humidity, and radiation to create a "feels like" temperature (Jing et al., 2024). The UTCI model assumes a person walking at a comfortable pace and wearing clothing adapted to the weather conditions.

The visualizations below provide a simplified model for the UTCI of the existing site during three points in time: 2pm EST on May 1, June 21, and August 1 (Figures 62, 63, 64 and 65). The Grasshopper (Ladybug) script incorporates humidity, wind, air temperature, and direct solar radiation. However, other variables, notably surface temperature and the materials of the ground plane (radiant heat), which impact the UTCI, are estimated in this script, rather than directly pulled from the data about the existing site's conditions. This was a limitation to this environmental model.

The visualizations provide a "feels like" temperature for each point on the site along a 10'x10' grid, and demonstrate that much of the site experiences moderate to very strong heat stress, based on the UTCI equivalent temperature chart (Figure 61, Bröde et al., 2009). On June 21, the average UTCI across the site at 2pm is 38.7°C (101°F), which is considered "very strong heat stress" according to the scale. Furthermore, considering the limitations cited above such as the fact that surface temperature was estimated when most of the site is asphalt, it is reasonable to assume that the real "feels like" temperature of the site may be even hotter.

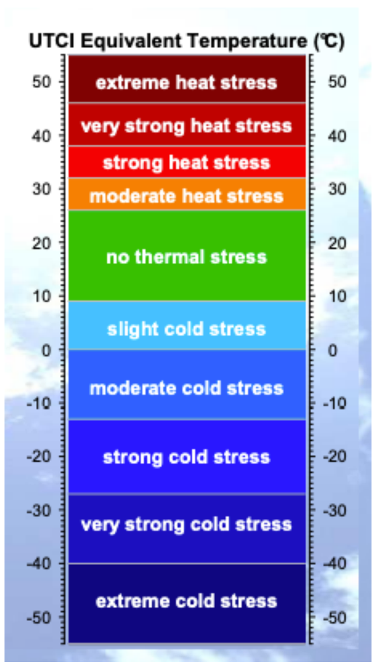


Figure 61: UTCI Equivalent Temperature. Source: Bröde et al., 2009

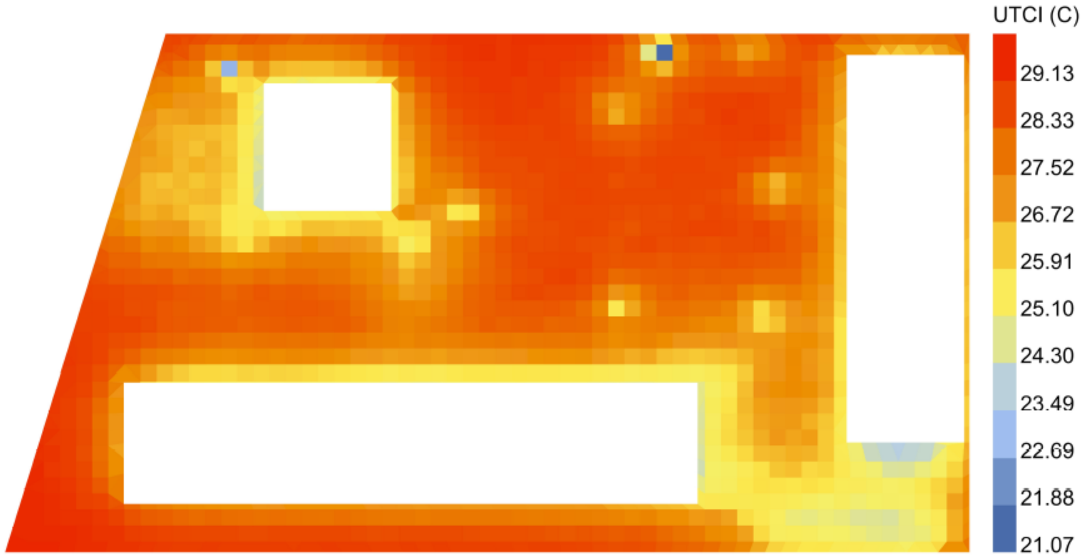


Figure 62: UTCI for Site on May 1 at 2pm ET. Source: Garlow, 2026

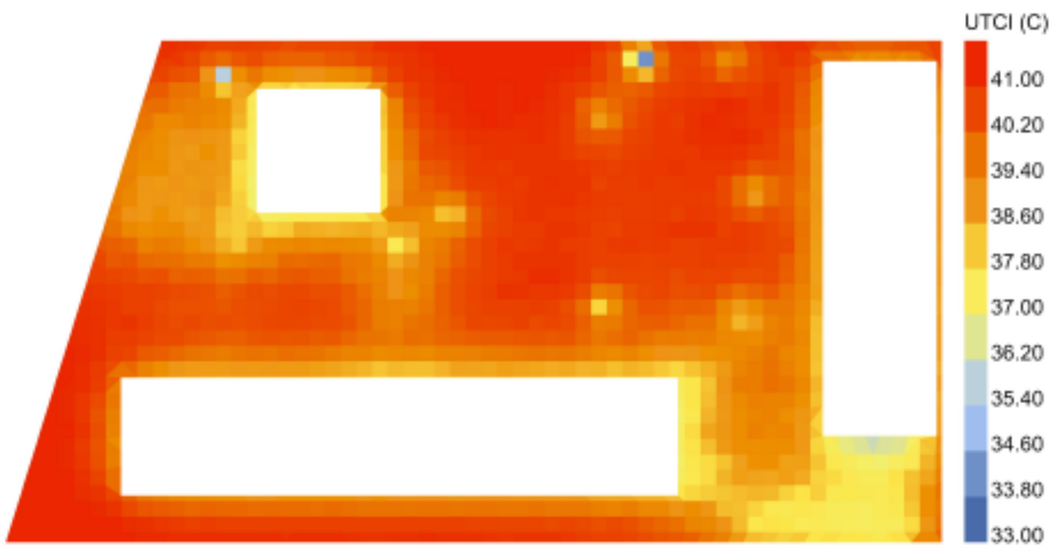


Figure 63: UTCI for Site on June 21 at 2pm ET. Source: Garlow, 2026

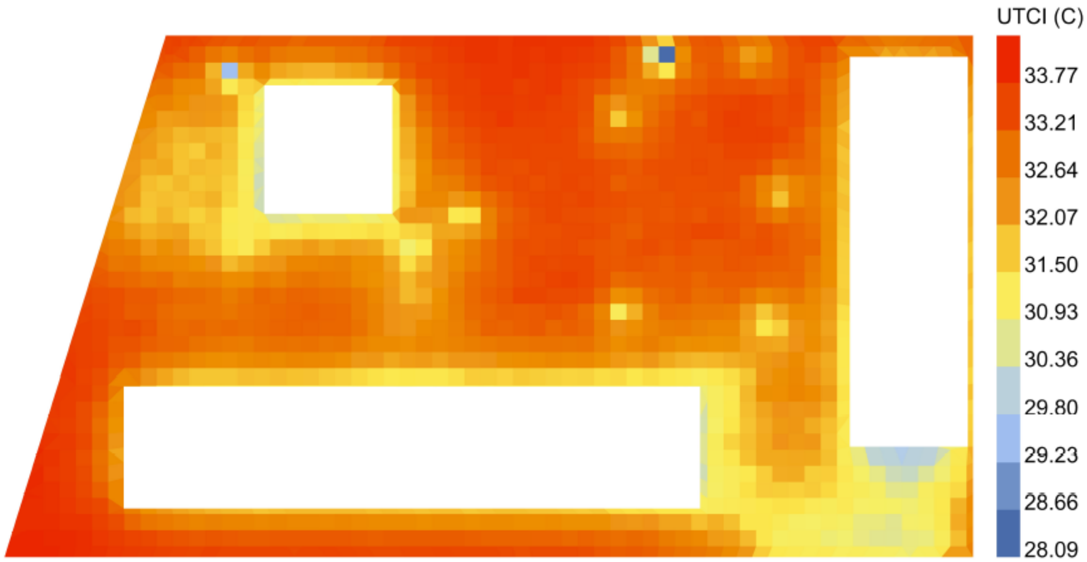


Figure 64: UTCI for Site on August 1 at 2pm ET. Source: Garlow, 2026

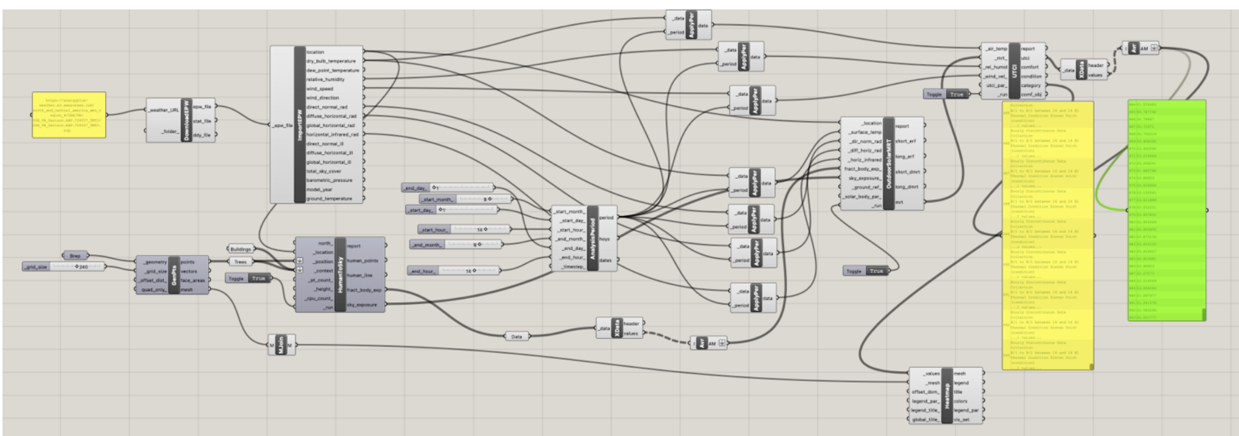
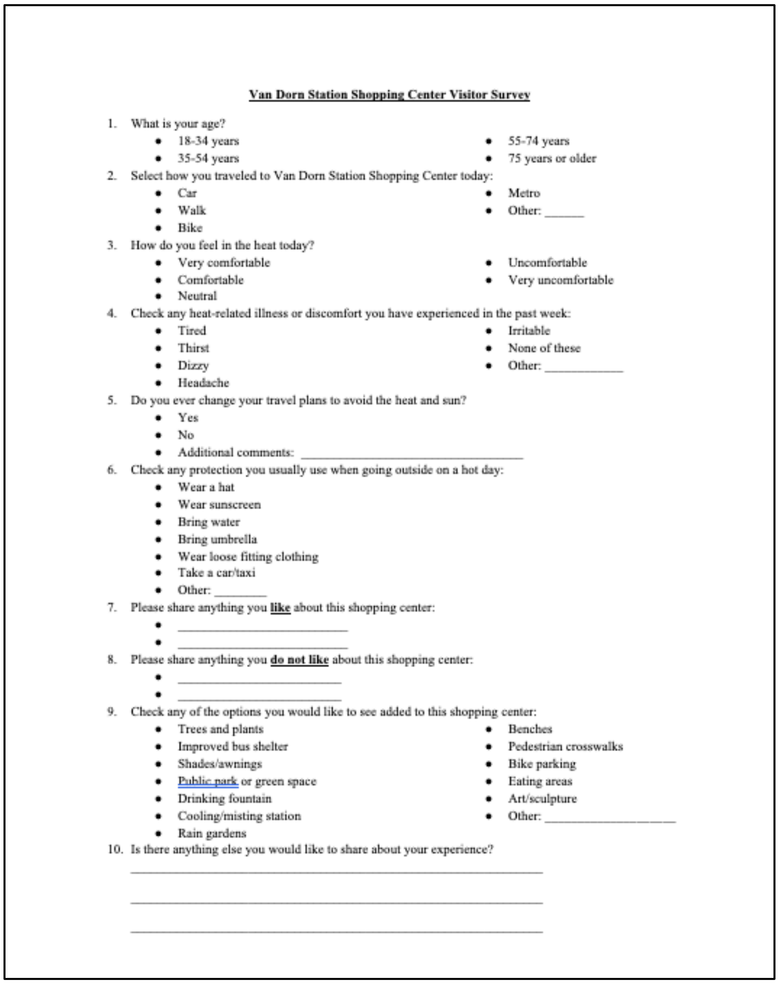


Figure 65: Ladybug script to generate UTCI. Source: Garlow, 2026.

4.6 Survey Questionnaire

Much of the research done on urban heat island effect and heat relies on quantitative measures to understand and compare changes to the climate. However, understanding the human aspects of thermal comfort is also important. Qualitative methods, such as community engagement events, heat walks, and questionnaires, can be used in conjunction with quantitative methods to create a clearer picture of the burden and impact of heat in the community. Thus, to better understand the impact of heat on people at Van Dorn Station Shopping Center, I developed and administered an anonymous survey questionnaire to shopping center visitors. The questionnaire was approved by the University of Maryland's Institutional Review Board on August 4, 2025, with exemption category # 45CFR46.104(d)(2)(i-ii).

I administered the survey questionnaire (see Appendix 1 and Figure 66) on three separate days: August 25, September 9 and September 19. I selected warm days, with highs over 80 degrees. I originally intended to offer the questionnaire on a day(s) with a high temperature above 90 degrees; however, August 2025 was much cooler than average for the DC area (Samenow, 2025). This was reflected in the results. A total of 20 people opted in to complete the survey, which asked about the visitor's age, how they got to the shopping center, their experience with heat, and general recommendations for the shopping center's landscape (Figure 67).



Van Dorn Station Shopping Center Visitor Survey

1. What is your age?
   - 18-34 years
   - 35-54 years
   - 55-74 years
   - 75 years or older
2. Select how you traveled to Van Dorn Station Shopping Center today:
   - Car
   - Walk
   - Bike
   - Metro
   - Other: ______
3. How do you feel in the heat today?
   - Very comfortable
   - Comfortable
   - Neutral
   - Uncomfortable
   - Very uncomfortable
4. Check any heat-related illness or discomfort you have experienced in the past week:
   - Tired
   - Thirst
   - Dizzy
   - Headache
   - Irritable
   - None of these
   - Other: ___________
5. Do you ever change your travel plans to avoid the heat and sun?
   - Yes
   - No
   - Additional comments: ______________________________
6. Check any protection you usually use when going outside on a hot day:
   - Wear a hat
   - Wear sunscreen
   - Bring water
   - Bring umbrella
   - Wear loose fitting clothing
   - Take a car/taxi
   - Other: _______
7. Please share anything you **like** about this shopping center:
   - ______________________
   - ______________________
8. Please share anything you **do not like** about this shopping center:
   - ______________________
   - ______________________
9. Check any of the options you would like to see added to this shopping center:
   - Trees and plants
   - Improved bus shelter
   - Shades/awnings
   - Public park or green space
   - Drinking fountain
   - Cooling/misting station
   - Rain gardens
   - Benches
   - Pedestrian crosswalks
   - Bike parking
   - Eating areas
   - Art/sculpture
   - Other: _________________
10. Is there anything else you would like to share about your experience?
   ____
   ____
   ____

Figure 66: Anonymous survey provided to shopping center visitors on August 25, September 5 and September 19, 2025. Source: Garlow, 2026.

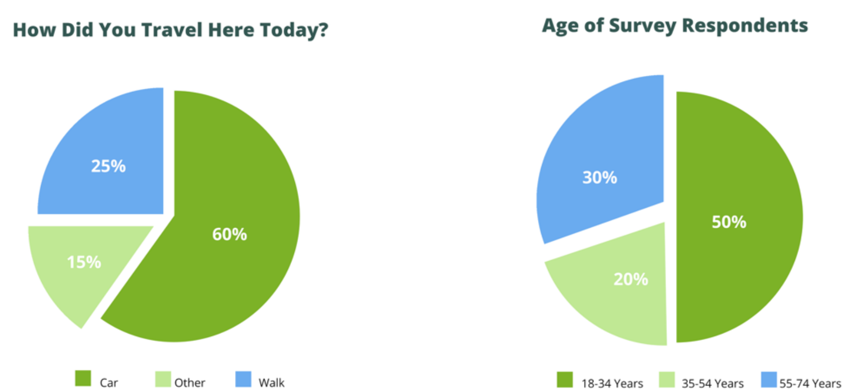


Figure 67: Age and Mode of Travel for Survey Respondents. Source: Garlow, 2026

The survey was administered on warm days with "moderate" heat stress per the UTCI. The majority of survey respondents felt "comfortable" or "very comfortable" with air temperatures in the 80s and humidity less than 50% (Figure 68). However, there was a range of responses, showcasing how individual factors (e.g., age, expectations, clothing, health status) may lead people to feel more or less comfortable in the same conditions. A key takeaway from this part of the survey is that air temperatures within the mid-80s (in conditions of low humidity) are comfortable to Van Dorn Station Shopping Center visitors and as such this level of comfort might be a goal for heat reduction or mitigation efforts, where possible.

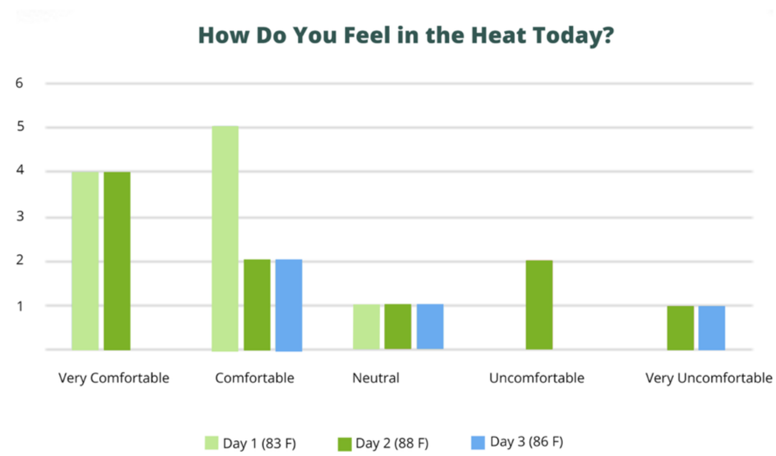


Figure 68: Survey Response to Comfort in the Heat. Source: Garlow, 2026.

Survey participants were also asked about how they adapted to hot weather, with half saying they changed their plans to avoid the heat and sun (10/20). Half of respondents (10/20) also said they brought water and a hat for protection if going out on a hot day, with other common responses including using sunscreen (8/20) and wearing loose fitting clothing (8/20).

Participants provided feedback on what they liked about the shopping center, with key themes including the restaurants (5 mentions), the nearby LA Mart grocery store (3 mentions), as well as the convenient location (3 mentions), as noted in Figure 69. Participants also mentioned of the diversity of stores (2 mentions) and the cleanliness of the shopping center (2 mentions).

The parking lot design and access was the biggest complaint among respondents (5 mentions), with pedestrian safety (2 mentions) and maintenance/aesthetics (2 mentions) as other negatives, as noted in Figure 70.

Figure 69: Word Cloud with Survey Responses to "What do you like about this shopping center?" Source: Garlow, 2026

Figure 70: Word Cloud with Survey Responses to "What don't you like about this shopping center?" Source: Garlow, 2026

When survey respondents were asked to select from a list of features or amenities they would like to see in Van Dorn Station Shopping Center, trees/plants and benches were the most frequently selected amenity, with 12 and 11 votes, respectively (Figure 71). Bike parking, pedestrian crosswalks, and shades/awnings were also popular selections (7 votes for all). These responses reinforce many of the key themes already noted from visual analysis of the site: lack of shade, need for additional vegetation, need for additional pedestrian amenities, and need for increased safety.

Figure 71: Survey responses reflecting desired changes to the shopping center landscape. Source: Garlow, 2026

4.7 Stakeholder Engagement: City Planning Department

Throughout this thesis project, I engaged with the City of Alexandria Department of Planning and Zoning. I held an initial meeting in January 2025 with one planner to brainstorm my project topic and possible sites. This contributed to my initial focus on possible project sites in West Alexandria. I held a second consultation with two planners to confirm my site selection and share my design program. Both planners supported the overall design program, and they helped me to track down additional information that supported the development of my designs, such as by confirming tree canopy coverage targets and parking minimums/maximums. They recommended that I review various City of Alexandria design guidelines, and suggesting other case studies to review, such as the Silver Spring Cool Streets Guide. Finally, I shared my concept designs with one of the planners for feedback, and she provided thoughts about the road width, crosswalks, and protection of the plaza along S. Van Dorn Street. These inputs were factored into my final concept design.

4.8 Summary of Site Opportunities and Constraints

After completing my site inventory and analysis, I compiled a SWOT (strengths, weaknesses, opportunities, and threats) diagram (Figure 72). Overall, the SWOT demonstrates that there are significant opportunities to improve comfort, safety and circulation within the site – particularly for pedestrians. The completion of this inventory and development of the summary SWOT provided a strong basis for the development of the design program.

Strengths	**Weaknesses**
Neighborhood is affordable and diverse Variety of stores offer something for everyone The shopping center gets good visitor traffic Limited flooding risk at project site	Maintenance is bare minimum Limited shade during heat of day, lots of hot/direct sun Parking lot design is confusing Pedestrian circulation feels unsafe/insufficient Too much impervious surface, limited landscaping Inadequate space for existing trees, most in poor health Building facade is in poor condition, needs upgrade
Opportunities	**Threats**
Increase tree canopy coverage and engineered shade Right-size parking to fit new City guidelines Preserve existing oak trees in good health Simplify vehicular circulation in the parking lot Improve connection to site from nearby apartment building Add outdoor dining for restaurants Encourage biking to the site	Changing climate Gentrification and development make long-term future of small businesses unknown

Convert existing rooftops to green roof or solar Add play and/or lounge spaces for community, address lack of these spaces Curb stormwater runoff to protect health of local waterways Create stronger identify and character for shopping area	

Figure 72: SWOT Diagram for Van Dorn Station Shopping Center. Source: Garlow, 2026

Chapter 5: Design

5.1 Vision and Goals

Based on my synthesis of the literature, case studies, and site analysis, I created a vision, goals, and strategies to guide design of the future of Van Dorn Station Shopping Center.

Vision: Van Dorn Station Shopping Center is a shaded, walkable, neighborhood retail hub where visitors can eat, gather, and shop in all seasons.

I also developed a set of **design goals** and associated **strategies** to guide my design process. I created icons to highlight where various strategies appear in the site design, as shown below in Table 7.

Table 7: Themes, goals and strategies guiding the design of Van Dorn Station Shopping Center. Source: Garlow, 2026.

Goal Theme	Goal	Strategies
Heat Resilience 	Improve pedestrian thermal comfort during summer months	• Reduce impervious surfaces, particularly asphalt, that have high surface temperatures, and increase pervious and green surfaces • Add shade over pedestrian paths and gathering spaces using a combination of trees and engineered shade • Integrate bioretention gardens, permeable paving, cool roofs, and other solutions that reduce surface temperatures
Accessibility	Increase accessibility and connectivity to and	• Create attractive, safe, walkable entrances to and paths through the shopping center that provide

	within the shopping center	convenient access and connections to stores and surrounding neighborhoods • Improve access and infrastructure for cyclists and micromobility riders • Reduce surface parking to prioritize active pedestrian use • Integrate best practices for green parking design • Add pedestrian crosswalks and traffic calming solutions to improve safety • Maintain access for vehicular traffic and service trucks
Identity 	Establish the identity, character, and sense of place in the shopping center landscape	• Provide amenities such as seating, shade, lighting, and trash receptacles that add to the character of the shopping center • Create public gathering spaces to promote informal social contact and small events that could encourage business for retail shops • Address the deteriorating facades of the buildings

In addition to using these goals and strategies to develop the final design, I also aimed to integrate and account for many of the City of Alexandria's development standards and requirements. I reviewed and integrated requirements and recommendations from the City's Landscape Guidelines (2019), Green Streets and Sidewalk Stormwater Design Guidelines (2020), and parking requirements within the zoning code.

5.2 Concept Designs

I began the design process by deciding to maintain a similar use for and access to the site. The existing one-story retail buildings, connections to neighboring streets and properties, and some of the surface parking were preserved. This decision provided a narrower focus of rethinking the circulation patterns and landscape around the retail buildings to meet the overall design goals.

Thus, the new design represents opportunities for retrofitting strip mall-style shopping centers, rather than a complete tear-down approach that is typical in a redevelopment scenario, often creating new challenges such as gentrification and loss of neighborhood character.

After developing my design program and goals, I created three concept designs for a new landscape surrounding the retail buildings at Van Dorn Shopping Center.

5.2.1 Concept 1: Bioretention Parking with Shaded Community Space and Walking Loop

The first concept design (Figure 73) emphasized parking that was aligned with the orientation of the existing site but reduced to 64 spaces, all of which would be permeable paving, and surrounded by bioretention gardens. Shading on the western side of each building was a priority, as was incorporating safer pedestrian crossings along the north-south axis of the site. Finally, this concept incorporated a walking "loop" that passed through two community spaces, encouraging wellness and healthy activity, one of the priorities of the community "walk and talk."

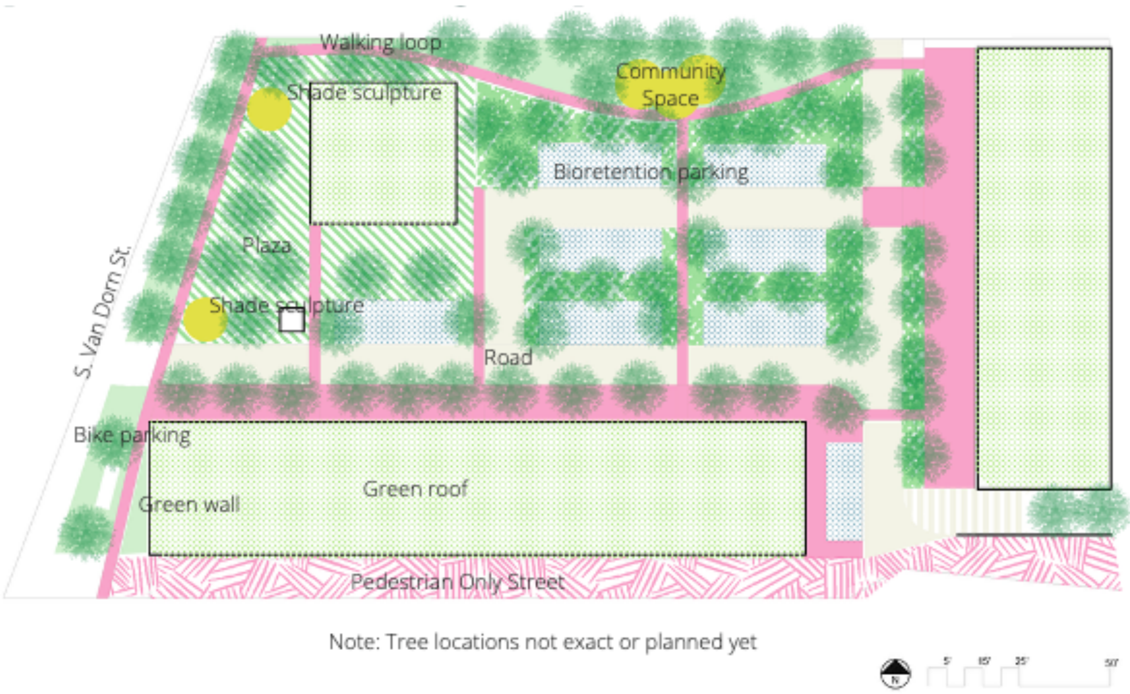


Figure 73: Concept Design 1 – Bioretention Gardens with Shaded Community Space and Walking Loop

5.2.2 Concept 2: Central Pedestrian Allée with Bioretention Parking

In my second concept design (Figure 74), I continued with bioretention parking and shading the western sides of the retail buildings, but instead of prioritizing north-south pedestrian axes, I experimented with an east-west corridor through the site, connecting S. Van Dorn Street to Building C on the east side of the site. This concept also incorporated a wind tower – a structure historically used in the Middle East to capture cooling winds and transfer them down to the human level. This concept design provided the most parking of the three concepts I developed, with 70 spaces – still fewer than the current 196 spaces.

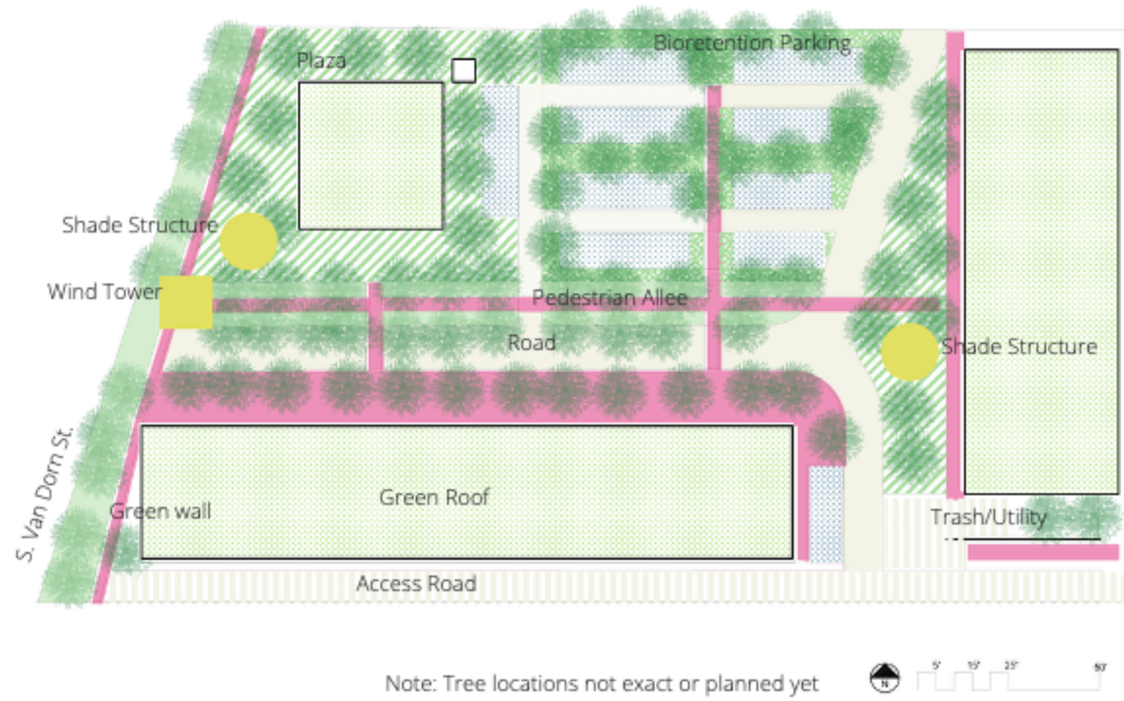


Figure 74: Concept Design 2 - Central Pedestrian Allée with Bioretention Parking

5.2.3 Concept 3: Curvilinear Pedestrian Path and Central Plaza

The idea behind the third concept (Figure 75) was to create a community space in the center of the site, accessed by a curvilinear walking path. Parking was integrated along the inner street to create more of an urban feel and increase the feeling of walkability. Most of the surface parking was incorporated at the north end of the site, covered with solar canopies to provide shade. This concept also incorporated a misting station close to S. Van Dorn Street.

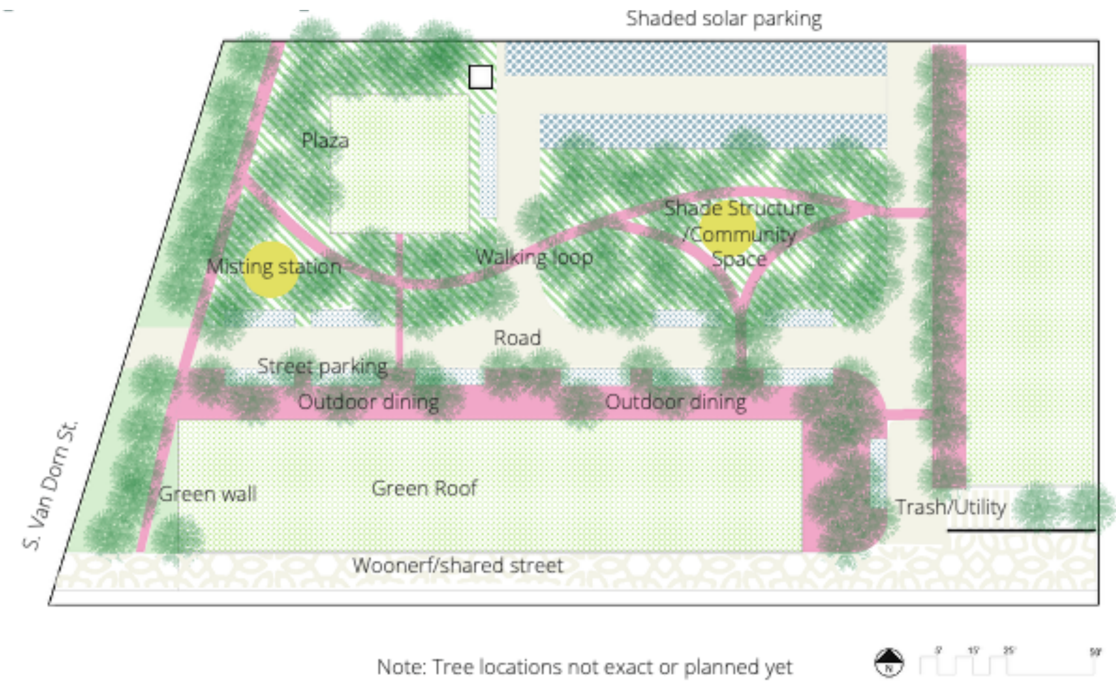


Figure 75: Concept Design 3 - Curvilinear Pedestrian Path and Central Plaza

5.2.4 Concept 4: Unification of Three Concepts

For my final concept design (Figure 76), I pulled through the elements that I predicted would have the most impact on pedestrian thermal comfort, the primary goal of this thesis project, into one concept. The central pedestrian path – a “cool corridor” – provides a clear and comfortable connection from S. Van Dorn Street, across the site, and to the retail buildings.

I combined the approaches of concept designs 1 and 2 leading to more shaded pedestrian paths along north-south and east-west axes, which further reinforces the rectilinear geometry of the site. I incorporated typologies from the City of Alexandria’s Green Streets Design Guidelines, such as the mid-sidewalk bioretention along Building C.

I chose to incorporate a misting sculpture rather than a wind tower after completing the analysis of summer wind patterns and recognizing that harnessing wind from the south-east would be very challenging due to the existing building geometry. This analysis led me to prioritize misting as a more effective and visible cooling solution. I selected bioretention and green parking solutions over solar canopies due to the co-benefits of stormwater management and transpiration from trees and vegetation, which will do more to aid in cooling the entire site, not just those areas that were shaded from solar radiation.

Although the idea of a centralized community gathering space had appeal, it seemed too large and too disconnected from the retail buildings. The dedicated plaza space closer to S. Van Dorn Street has more opportunity to be activated.

Figure 76: Unification of Three Concept Designs

5.3 Final Design

The intention of the final design (Figure 77) for Van Dorn Shopping Center is "centering and shading the pedestrian." The final site plan incorporates a mix of green (vegetation), gray (built), and blue (water) infrastructure with cooling benefits, as well as strategies that provide both adaptation to and mitigation of heat.

Figure 77: Van Dorn Station Shopping Center Site Plan

5.3.1 Addressing Heat Resilience

Addressing heat and improving pedestrian thermal comfort during summer months was my top priority for this MLA thesis and the new design, shown in Figure 77. The final design implements several interior "cool corridors" – shaded urban pathways designed to provide relief from heat for pedestrians – to create clear connections from S. Van Dorn Street to retail buildings.

In addition to the cool corridor that connects S. Van Dorn Street to Buildings B and C, additional cool corridors are included on the north end of the site between Buildings B and C, alongside the north side of Building A, and along the west side of Building C, ensuring there are many shaded ways to approach the retail shops.

The design includes 140 new trees for the site. Trees are one of the most critical tools for heat resilience (Hirchfeld & Guenther, 2024). Trees provide both mitigation and adaptation to heat. They provide cooling through their shade and evapotranspiration, and they also absorb and sequester carbon. A tree planting plan, detailed in the next section, also responds to community's input via the questionnaire on the top improvements people wanted to see to the site.

The proposed design includes several shaded gathering spaces that replace the existing surface parking with more space for community interaction. On the west side of the site along S. Van Dorn Street, a plaza protected by trees and a low retaining wall provides a space of respite and a connection between the retail shops and the busy road. To the north, two wood structures with louvered roof and side slats provide both shade and screening from the road to the north while also encouraging ventilation and breezes from the south-east (Figure 78).

Figure 78: Community space and bioretention parking. Source: Garlow, 2026

Near the main pedestrian entrance, a misting sculpture comprised of 28 3" stainless steel misting poles of various heights grouped together offers a functional and artistic cooling solution to the site (Figure 79). Misters create a fine mist of water droplets that instantly evaporate, cooling the air and human skin temperatures in both hot/dry climates and hot/humid climates (X. Huang et al., 2025a). Misters also use less water than traditional fountains or splash pads, and are useable and attractive to all ages groups, making them a promising "blue" solution to extreme heat.

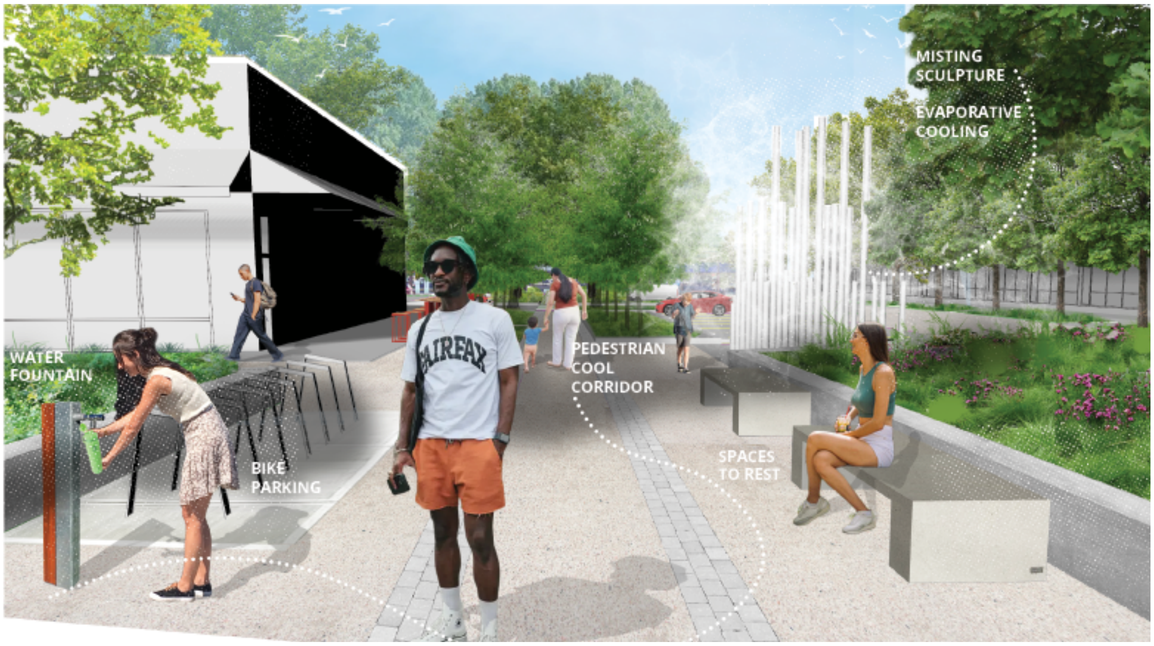


Figure 79: Pedestrian Cool Corridor at Van Dorn Shopping Center. Source: Garlow, 2026

Awnings extending 5 feet from the edge of the building and movable umbrellas were incorporated into the design to provide additional shading and cover from wet weather for shoppers. The Sunbrella acrylic fabrics selected for both showcase bright colors that provide strong protection from UV rays.

A drinking fountain is sited close to the entrance in a visible and easy-to-reach location for shoppers, bikers, or pedestrians walking along S. Van Dorn Street. Dehydration contributes to heat exhaustion and having available water is one of the critical ways to prevent illness caused by heat. As climate change continues to pose greater risks with respect to heat, drinking fountains should be considered an essential site furnishing – just as trash cans and lighting are – that belongs in many more settings than a public park.

5.3.2 Addressing Accessibility

For visitors arriving to the site on foot, by bike, or by vehicle, entrances have been improved and simplified. A vegetated buffer and a row of street trees have been added along S. Van Dorn Street, protecting pedestrians and encouraging use of the sidewalk. The design includes 12 painted pedestrian crosswalks, and cool corridors are integrated throughout the site to promote walking between the retail shops and parking areas.

Bike parking with 14 available spaces is located near the shaded plaza by S. Van Dorn Street, close to the main pedestrian entrance. The emphasis on multi-modal access to the site is part of the effort to reduce reliance on cars, which contribute fuel climate change, and generate waste heat that warms the microclimate.

For drivers, the internal road has been simplified to a two-way loop with a narrower width to naturally slow traffic down for the safety of pedestrians. The internal road maintains the existing connections to the grocery parking lot to the north of the site and to the lower level of the shopping center to the east. The roadway below Building A has been converted to a shared street that is welcoming to pedestrians and bikers, while still maintaining access for service vehicles or deliveries via the rear of Building A. The shared street has been reduced to a width 15', creating more room for a row of street trees along the south of Building A.

Notably, the number of parking spaces on the site was considerably reduced from 196 spaces to 56 spaces, of which 4 are handicap accessible spaces. This 71% parking reduction is aligned with the City's current zoning guidelines, which set a minimum of 1 space and a maximum of 3 spaces per 1,000 sq feet of restaurant retail within a transit enhanced zone (City of Alexandria, n.d.). Furthermore, the reduced surface parking incorporates best practices of green parking design, the use of "sustainable techniques and green infrastructure to manage stormwater, reduce urban heat island effects, and improve water quality" (U.S EPA, 2021).

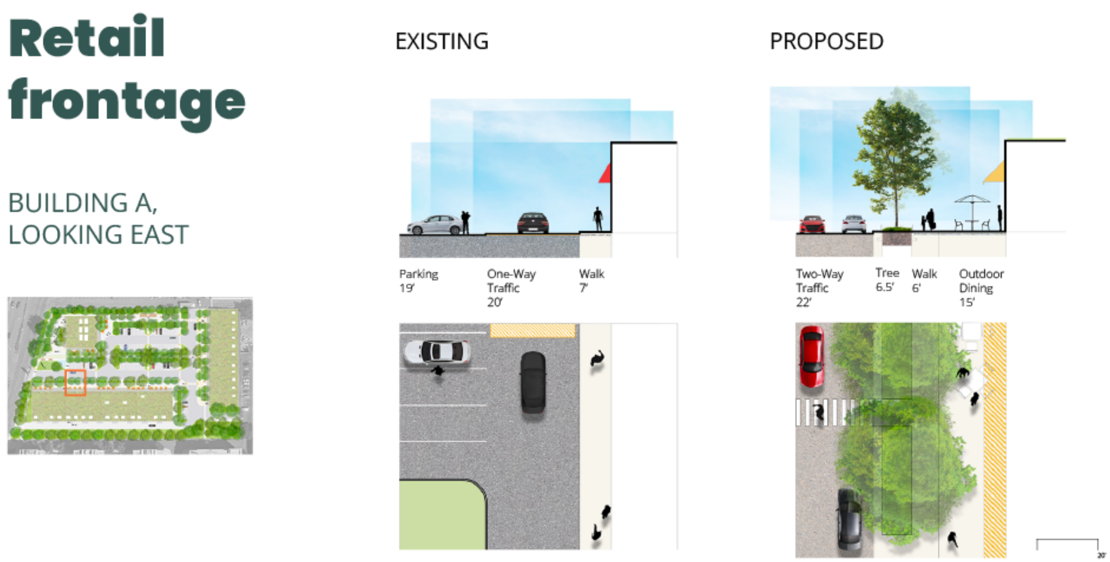
Parking spaces are specified as permeable concrete, which increases the perviousness of the site. Bioretention gardens or planting beds with canopy trees have been sited next to the parking areas to offer both stormwater management and shade.

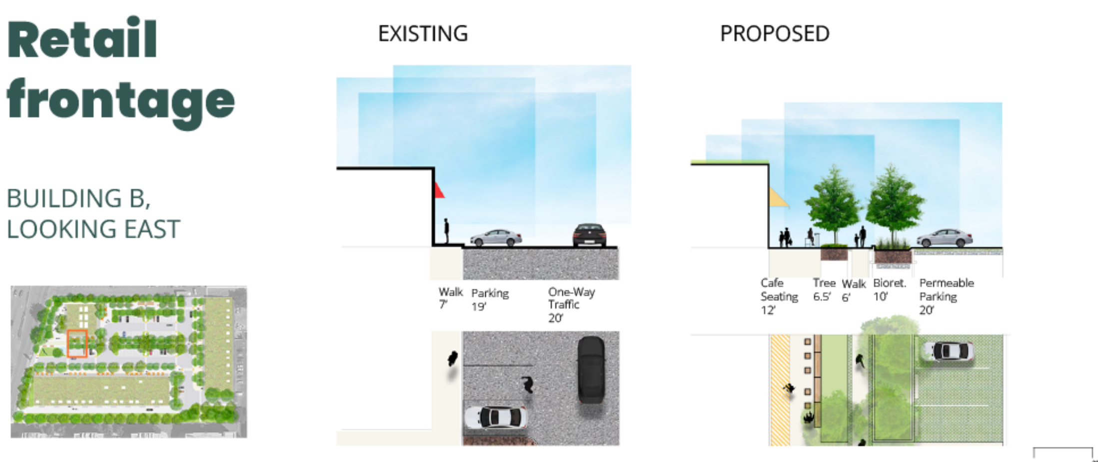
5.3.3 Addressing Identity

Several additional site features, furnishings, and material selections help to create a refreshed identity for the Van Dorn Station Shopping Center. On the west side of the site, a central welcome garden and an eye-level signage area is visible to pedestrians, drivers, and cyclists, replacing the existing signage, which was tall and designed primarily for drivers (Figure 80).

Figure 80: Entry Garden at Van Dorn Shopping Center. Source: Garlow, 2026.

The retail frontage zone and pedestrian access to all three buildings have been updated (Figure 81). Alongside Buildings A and B, which house most of the shopping center's restaurants, space for outdoor dining has been incorporated, extending the retail frontage by more than 7,000 sq ft, and thus increasing their economic opportunity. In front of Building C, which houses most of the shopping center's salons and markets, a mid-block bioretention garden and street trees provide two shaded alleys with more interesting views for patrons. These new shaded spaces provide visitors, shoppers, employees, and passing pedestrians with comfortable, beautiful places to walk, gather and dine, encouraging an evolution of the shopping center from one where "people come and go" to one where people are invited to linger.





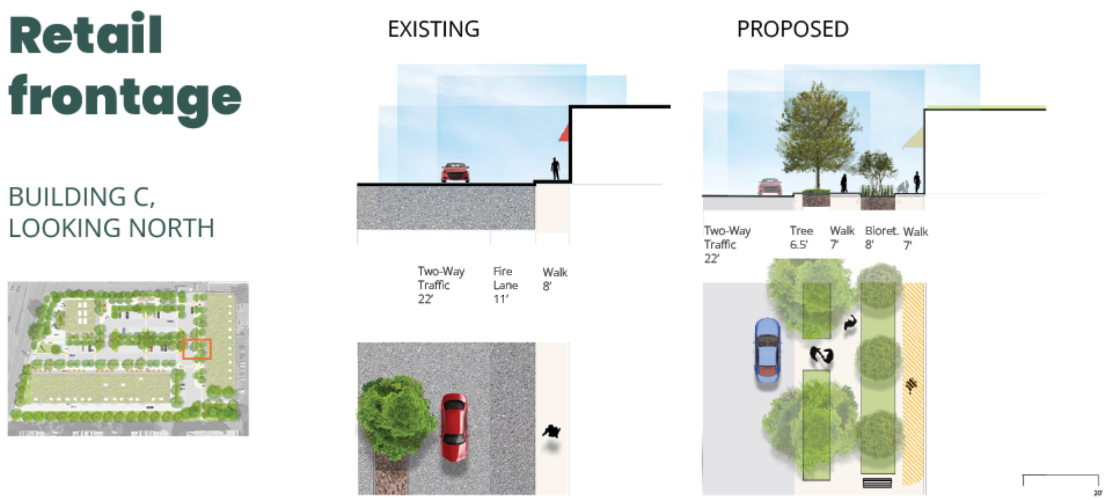


Figure 81: Comparison of retail frontages in proposed design. Source: Garlow, 2026

The proposed site design adds seating and places to rest that are missing is in the existing site and desired, per the results of the questionnaire. More than 20 benches are included in the proposed design, and are integrated into the gathering spaces such as in the plaza along S. Van Dorn Street, and under and around the shade structure on the north end of the site. Additionally, several benches are integrated around the mid-block bioretention gardens to the west of Building C.

A neutral palette of materials was selected for these furnishings, as noted in Figure 82. I considered the albedo and thermal properties of site furnishings. Light-colored concrete and wood were selected for furniture. Wood has lower thermal conductivity and thus heats up more slowly than other materials. Light-colored concrete/cast stone has a lower albedo score than other darker-colored surfaces. Other materials incorporated into the site's furnishings align with a neutral and clean approach, such as stainless steel used in the misting sculpture, and powder coated aluminum used for some furnishings and light fixtures (Figure 83).

I selected off-the-shelf site furnishings to expand my familiarity with the specifications of furnishings that could satisfy my project requirements. Additionally, selecting off-the-shelf products is a realistic approach for this type of retail environment, which would not commonly have the budget or need for custom site furnishings.

Figure 82: Site furnishings palette. Source: Garlow, 2026.

At the ground level, light asphalt, light concrete paving, and painted pedestrian crosswalks add to the identity of the site as one that joyfully prioritizes the health and safety of people.

Changes to the existing buildings were not a significant focus of the design process, but recommendations to improve them in the context of the design include: painting the red brick white or a lighter color; integrating larger, 5' wide awnings outfitted in bright Sunbrella acrylic fabric to provide more shade and UV protection directly over the building's windows; and incorporating an extensive (3-6") green roof of sedum and other light-weight, drought-tolerant plantings to reduce urban heat island and capture and filter stormwater. Cool roof coatings could be an alternate option to reduce surface temperature and increase energy efficiency of the buildings, if green roofs were not practical or feasible to implement.

Figure 83: Materials palette for proposed site. Source: Garlow, 2026.

A final recommendation for enhancing the site's identity is to incorporate wayfinding, such as parking signs and pedestrian-level directional signs to give more visibility to the local businesses in the shopping center and to ensure that availability of parking is advertised, given that it has been moved further back from the street (Figure 84).

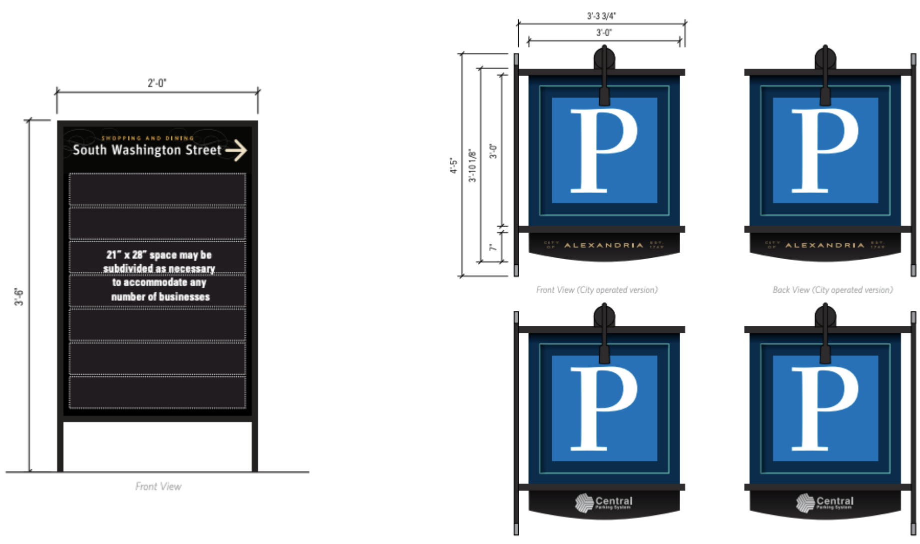


Figure 84: Examples of wayfinding signage recommended for the site, in alignment with the City of Alexandria Wayfinding Design Guidelines Manual. Source: City of Alexandria, 2010

5.3.4 Tree Planting Plan

Because tree canopy was a significant focus on my efforts to improve the microclimate at Van Dorn Station Shopping Center, I developed a tree planting plan with a dozen different species of trees (Figure 85). The selection criteria for the tree species was informed by my literature review and included crown width/form (dense, oval/round, pyramidal), foliage type (mostly deciduous), growth pattern (medium to fast), adaptations (including salt, flooding, drought, urban pressure, bioretention) and hardiness zones (considering climate change), as noted in Table 8.

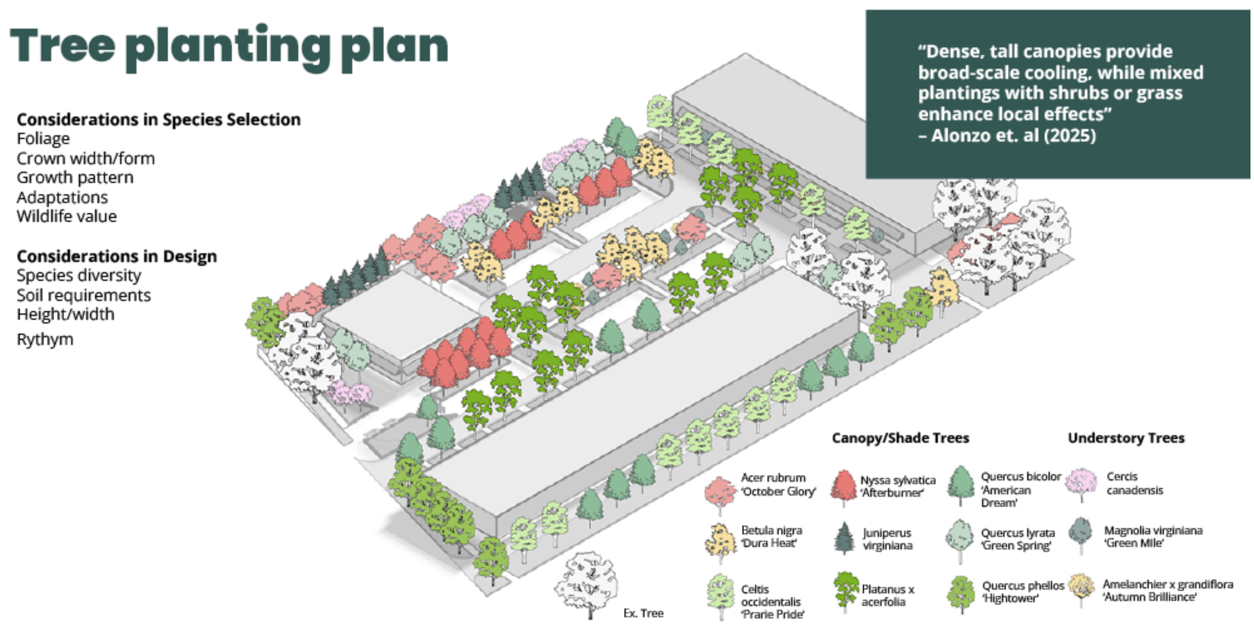


Figure 85: Isometric tree planting plan. Source: Garlow, 2026

Within the context of the design, trees were spaced to ensure a minimum of 450 ft^3 of soil per tree, or 600 ft^3 of soil per two trees, per the requirements of the City's Landscape Guidelines. Also, per the City's guidelines, no species of tree represents more than 10% of the overall total; this effort to ensure diversity adds to the site's resilience. Finally, I factored repetition and rhythm along the building frontages and cool corridors into the design.

The existing site has approximately 30 trees, and most are significantly stunted or in declining health. The proposed design recommends removing the declining trees and keeping only the mature and healthy specimens, such as the two *Quercus phellos* along S. Van Dorn Street. Overall, the planting plan increases the number of trees on site by 366%. The new trees are all native to the Eastern US, which adds to the biodiversity of the area.

Table 8: Tree Planting Plan. Source: Garlow, 2026

Quantity (Percent)	Botanical Name	Common Name	Height/Width	Texture	Form	Growth Rate
11/140 (7.8%)	*Quercus lyrata 'Green Spring'*	Overcup Oak	50' H 45' W	Medium	Pyramidal, Upright	Fast
13/140 (9.3%)	*Quercus bicolor 'American Dream'*	Swamp White Oak	50' H 40' W	Medium	Pyramidal to Rounded	Medium
12/140 (8.6%)	*Celtis occidentalis 'Prairie Pride'*	Hackberry	50' H 40' W	Medium-Coarse	Oval	Medium
11/140 (7.8%)	*Betula nigra 'Dura Heat'*	River birch	30-40 H 25-35 W	Medium -Fine	Pyramidal to Rounded	Fast
14/140 (10%)	*Nyssa sylvatica 'Afterburner'*	Black Tupelo	35' H 20' W	Medium	Pyramidal	Medium
12/140 (8.6%)	*Cercis canadensis*	Redbud	20-30' H 25-35' W	Medium-Coarse	Rounded	Medium
9/140 (6.4%)	*Amelanchier x grandiflora 'Autumn Brilliance'*	Serviceberry	15-25' H 15-25' W	Fine	Upright, Vase shaped	Medium
13/140 (9.3%)	*Magnolia virginiana*	Sweetbay magnolia	25' H 20' W	Medium	Oval	Medium
14/140 (10%)	*Platanus x acerifolia 'Morton Circle'*	London Planetree	55-70' H 35' W	Coarse	Upright, Pyramidal	Fast
13/140 (9.3%)	*Acer rubrum 'October Glory'*	Red Maple	40-50' H 30-40' W (30)	Medium-Fine	Oval, Rounded	Fast
9/140 (6.4%)	*Quercus phellos 'Hightower'*	Willow Oak	40-70' H 20-40' W	Medium-Fine	Upright, Oval	Fast
9/140 (6.4%)	*Juniperus virginiana*	Eastern Red Cedar	40' H 20' W	Medium	Erect, Pyramidal, Columnar	Medium

Chapter 6: Evaluating the Design

This chapter focuses on evaluation of the potential impact of my site design. I used several methods, including modeling, to compare my proposed design with the site's existing conditions. This is an appropriate approach for an unbuilt project. However, a post-occupancy evaluation using quantitative and qualitative analysis is the best way to test whether a design functions the way it was intended. Eventually, if my project were to be built, the results of the modeling could be compared to the realities on the ground.

Importantly, I focused on the performance benefits that were most directly linked to my design program goals: improving pedestrian thermal comfort, increasing connectivity, and strengthening the site's identity and character. There are many more performance metrics that were not evaluated given the short timeline for the project. For example, the stormwater capacity and pollution reduction impacts of the bioretention gardens and green roofs would be important to calculate and use in refining the design. The benefits of the tree plantings beyond their cooling impact, such as their ability to sequester carbon, manage stormwater, improve building energy efficiency, and add wildlife habitat, would also be valuable to understand, though they were not calculated for this project. Finally, the success of the design in improving access for pedestrians and fostering a stronger identity and sense of place cannot be assessed without a post-occupancy evaluation involving both quantitative and qualitative methods.

6.1 Landscape Performance Benefits

The key strategies for improving the pedestrian thermal comfort of the site focused on reducing asphalt and road space, increasing space for people, and including more pervious and vegetated surfaces.

To evaluate the potential impact of my design, I first took area measurements, using AutoCAD, of both the existing and proposed sites. The existing site is 180,000 square feet with four main categories of land use (and associated surface material): road (asphalt), sidewalks (concrete), buildings (brick/plaster), and landscaping (mix of gravel tree beds, turf grass, and shrubs). Only 11% of the existing site has a pervious surface.

Additionally, the sidewalks are the only areas of the existing site dedicated to people; there are no existing plazas, building frontage zones, or gathering spaces that could not otherwise be categorized as road, building, or landscaping. Therefore, in the existing site, the area of the sidewalks is equivalent to the area dedicated to the pedestrian – just 5.6% of the total site.

Table 9: Use/Material Allocation of Existing Site and Proposed Design. Source: Garlow, 2026.

Use	**Material**	**Existing Area (%)**	**Proposed Area (%)**
Road & Parking	Asphalt	97,059 sq ft (54%)	43,650 sq ft (24.3%)
Sidewalk, Plazas and Building Frontage Zones	Concrete	10,085 sq ft (5.6%)	32,399 sq ft (18%)
Building - Impervious	Plaster, Brick	51,609 (28.8%)	18,171 sq ft (10%)
Landscaping	Tree Beds, Grass, Planting Beds	20,437 (11%)	30,887 sq ft (17.2%)
Building - Green Roof (*Proposed Only*)	Sedum	N/A	33,438 sq ft (18.6%)
Permeable Parking (*Proposed Only*)	Permeable Pavers	N/A	10,392 sq ft (5.7%)
Bioretention Gardens (*Proposed Only*)		N/A	11,063 sq ft (6.1%)

The proposed design represents a more balanced approach to multi-modal accessibility and prioritizes materials and surfaces that will improve thermal comfort. In the new design, road and parking surfaces comprise 30% of the site, compared to 54% in the existing conditions. Meanwhile, areas dedicated to sidewalks, plazas, and zones for pedestrians have been increased from 5.6% to 18%. Planted areas, including both bioretention areas and planting beds, have increased to 23.3% of the overall site, up from 11% in the existing conditions.

Finally, the overall site is significantly more pervious, as permeable parking spaces and green roofs can absorb rainwater, along with the planted areas. With the proposed design, more than half of the site (57.8%) has a pervious surface, up from just 11% with the existing conditions.

6.2 Direct Sunlight Analysis

As outlined in the methods chapter, a direct sunlight analysis study calculates the number of hours of sunlight that a specific defined area receives. This type of calculation can provide information on how much sun versus shade particular areas of a site may receive at different times of year, making it a useful analysis for understanding the shade cast by buildings, the sunlight conditions for a planting plan, and more.

Direct solar radiation contributes to thermal heat stress, so to compare the potential benefit of my design in blocking solar radiation, I used Rhino and Grasshopper (Ladybug) to compare the direct sunlight (over a 24 hour period) for the existing site to a model of my proposed site on May 1, June 21, and August 1 (Figures 86, 87 and 88, respectively). The visualizations show a clear difference in the average amount of direct sunlight hitting the ground, with notable reductions along the designed "cool corridors."

The proposed design reduces the number of direct sunlight hours by an average of 4 daylight hours. Across the existing site, the average amount of direct sunlight hours on June 21 is 10.8 hours; for the proposed site the average is 6.7 hours. The total number of daylight hours on June 21, the longest day of the year, is approximately 15 hours.

May 1

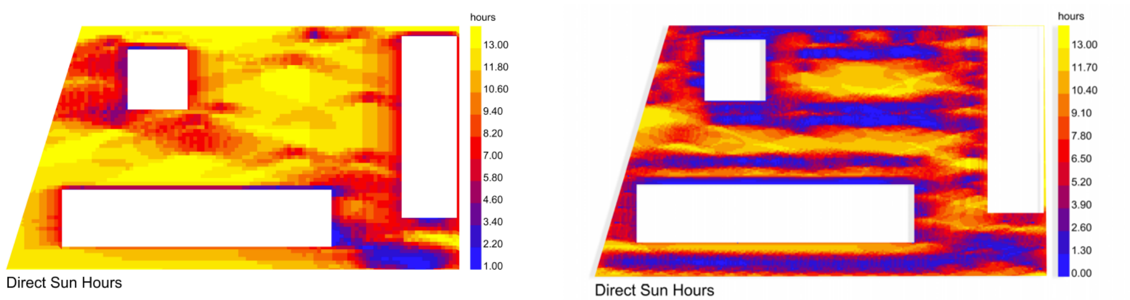


Figure 86: Comparison of Direct Sun Hours for Existing and Proposed Site on May 1. Source: Garlow, 2026.

June 21 – Summer Solstice

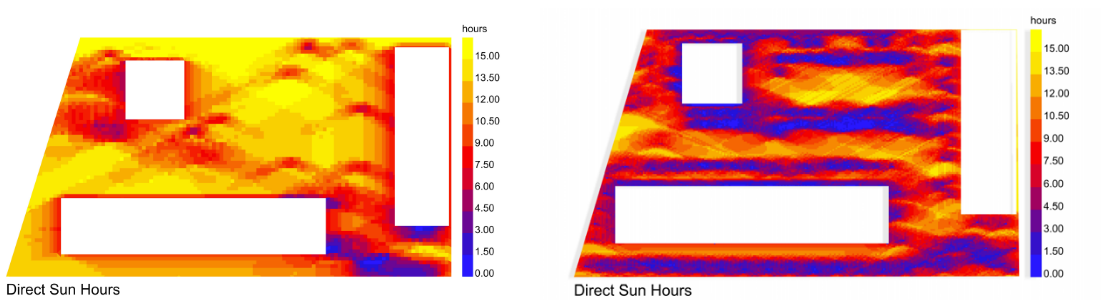


Figure 87: Comparison of Direct Sun Hours for Existing and Proposed Site on June 21. Source: Garlow, 2026.

August 1

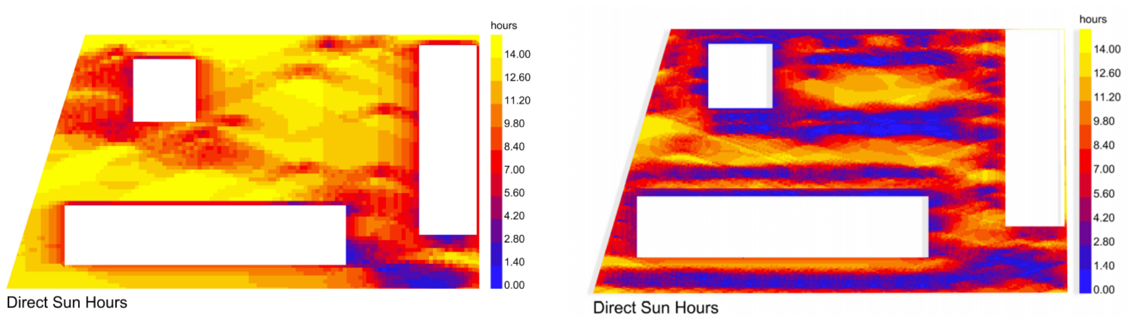


Figure 88: Comparison of Direct Sun Hours for Existing and Proposed Site on August 1. Source: Garlow, 2026.

6.3 Universal Thermal Climate Index (UTCI)

As with the direct sunlight analysis, I repeated the universal thermal climate index (UTCI) analysis for the proposed site using Rhino and Grasshopper (Ladybug), as shown in Figures 89, 90 and 91. With the proposed design, the entire site is an average of 4°F cooler, with areas prioritized for pedestrian activity (the “cool corridors”) feeling at least 8°F cooler, per the results of the environmental analysis (Figure 92). The proposed design creates a site with a much greater range of "feels like" temperatures compared to the existing site, with more variation between areas exposed to direct sunlight and those that are more shaded throughout the day. For example, the average UTCI at 2pm on June 21 is 36.8°C (98.2°F), compared to 39.4°C (102.9°F) for the existing site (Table 10).

May 1

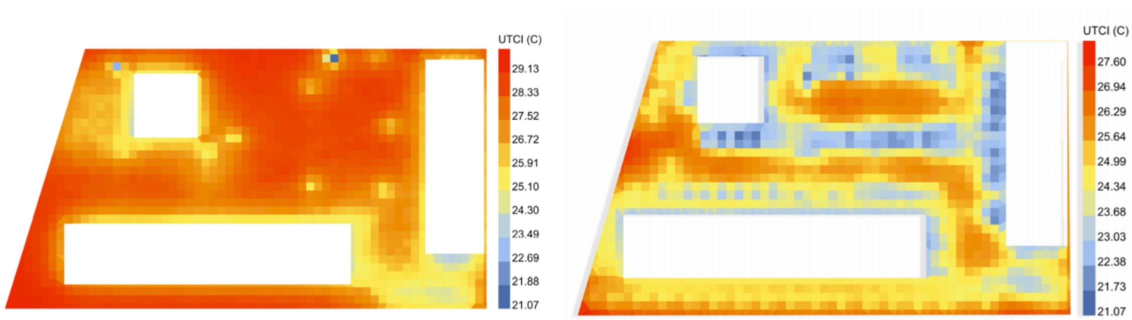


Figure 89: Comparison of Existing and Proposed UTCI on May 1. Source: Garlow, 2026

June 21 – Summer Solstice

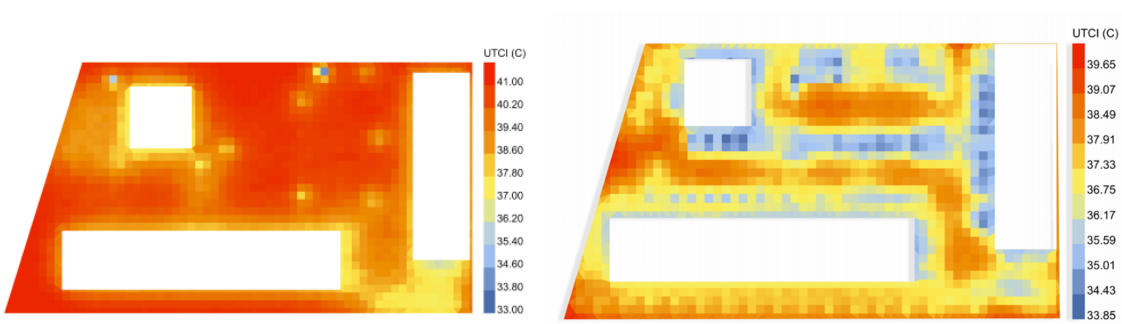


Figure 90: Comparison of Existing and Proposed Site on June 21. Source: Garlow, 2026.

August 1

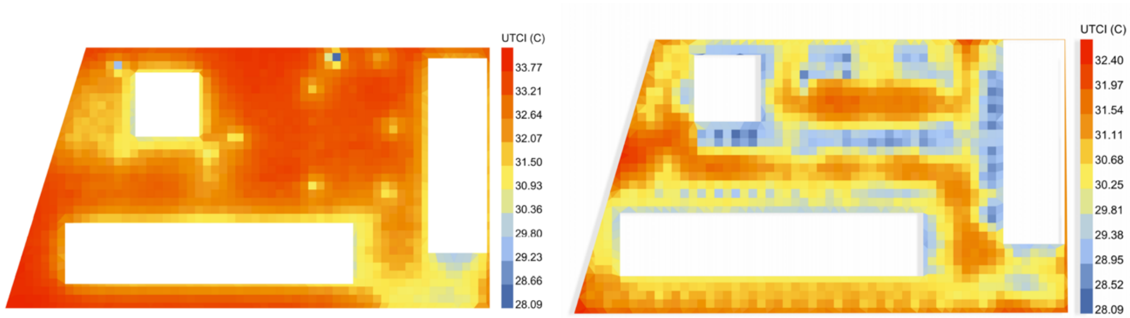


Figure 91: Comparison of Existing and Proposed Site on August 1. Source: Garlow, 2026

Cool Corridor Comparison

Figure 92: Comparison of UTCI along proposed cool corridor in existing versus proposed design. Source: Garlow, 2026

Estimates were used for surface temperatures and ground plane materials in the Grasshopper (Ladybug) script (Figure 93). In other words, true measurements for surface temperatures and the accurate properties of surface materials (which impact the mean radiant temperature) for the proposed site were not included in the model. However, we can assume based on the literature discussed in Chapter 2 that the proposed design would in fact cool the site even more than the simulation suggests, given the significant shift toward lighter colored (higher albedo) surfaces, increased overall vegetation, and many more added trees, which would cool the site not only through blocking direct radiation, but also through transpiration.

Table 10: Comparison of UTCI Equivalent Temperatures for Existing Site versus Proposed Design. Source: Garlow, 2026

	May 1		**June 21**		**August 1**	
	Existing	**Proposed**	**Existing**	**Proposed**	**Existing**	**Proposed**
Highest UTCI (°F)	84.43	81.66	106.66	103.37	92.79	90.32
Lowest UTCI (°F)	69.92	69.92	92.93	92.93	82.56	82.56
Average UTCI (°F)	80.69	75.95	102.94	98.40	90.01	86.70

Grasshopper Script

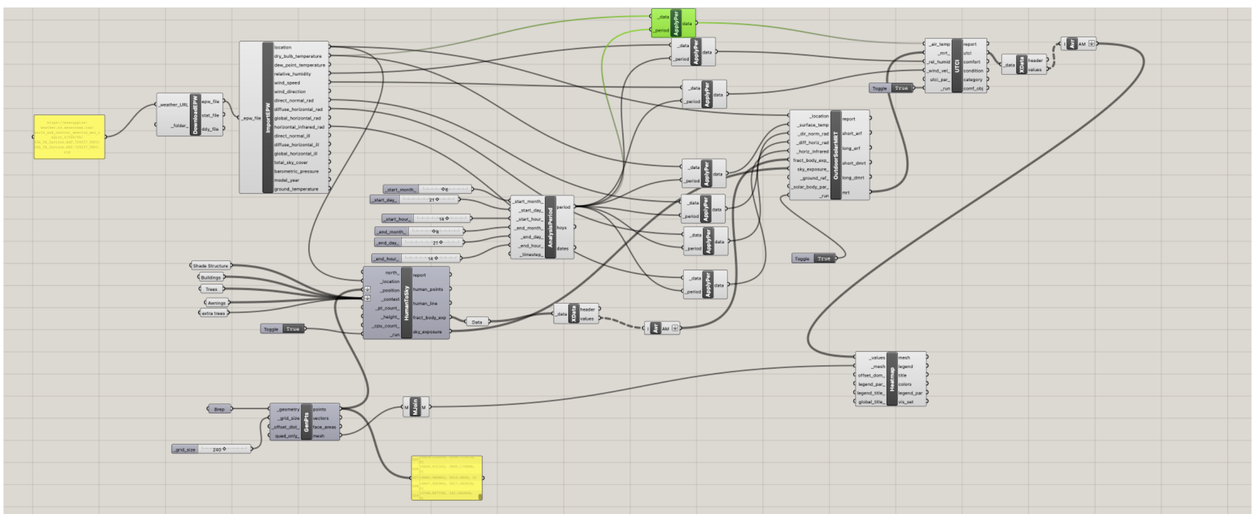


Figure 93: Ladybug script to generate UTCI for proposed design. Source: Garlow, 2026.

Chapter 7: Discussion

The primary research question guiding this MLA thesis project was, "How can design mitigate urban heat and improve pedestrian thermal comfort?" In this chapter, I will reflect on the lessons learned throughout the project, as well as strengths and limitations of my methodology and proposed design.

7.1 Strengths and Limitations of the Methodology

Early on, I recognized that I needed to learn as much as possible about the science of heat and the ways it can be measured and modelled in the landscape. As such, I outlined a key sub-question for my research: "What tools, methods, and metrics can be used to analyze and represent the microclimate of a site?"

A strength of the mixed-methods approach in this project was that, as the researcher, I was able to test and learn from several different quantitative and qualitative approaches for measuring and modeling heat. Throughout the project, I analyzed satellite data (and its relationship to Alexandria's heat vulnerability assessment), collected my own in-situ temperature measurements using a handheld thermal imaging camera, conducted an anonymous survey to capture qualitative input of how people on the site experience heat, and used environmental analysis with a combination of Rhino and Grasshopper to model the impact of the climate on the existing and proposed site.

The City's heat vulnerability assessment, which relies on LandSat satellite data as the key input for high heat exposure, provided a good starting point and a list of potential project sites. However, upon visiting many of these places, I found most to be comprised of large parking lots – some of which were privately-owned with restricted access and some of which were industrial sites and therefore not public-facing. Therefore, I had to incorporate an additional layer of prioritization (considering both access to the site as well as active use) to select a site that would be suitable for my project and have an impact on the population. One key takeaway from the work to identify suitable sites for heat mitigation efforts was the importance of combining satellite data (and heat vulnerability mapping, if available) with other criteria to provide maximum benefit for vulnerable communities, such as identification of active pedestrian corridors, last-mile connections, or proximity to important community resources.

I took in-situ temperature measurements using the Perfect Prime thermal cameras during the month of August 2025. The handheld cameras were intuitive to learn, easy to carry, and generated quality images that could be used for data capture and visualization. Using this tool for heat mapping is beneficial at the site scale. Contrary to my expectations and past weather patterns, August 2025 had much cooler temperatures than June or July – in fact, temperatures were the coolest they had been over the past 25 years (Samenow, 2025) – so the findings from this part of my research do not dramatically showcase the impact of site materials at the hottest point in the summer. That said, the results from this data collection effort could be extrapolated to other similar projects in the City and help to clarify the importance of material selection for the urban microclimate. For example, the finding that the brown gravel covering the tree pits was the hottest surface temperature on the site might be a useful data point to support landscape architects in suggesting alternative groundcovers rather than landscape fabric and gravel or rocks to cover tree pits – which is something clients may desire as it has a perception of lower maintenance.

If I were to repeat this type of data collection in the future, I would aim to collect the in-situ surface temperature measurements targeting the extreme hot week(s) but also using the 10-day weather forecasts to identify a date with a high temperature above 90 degrees and clear conditions. In Alexandria, the hottest week of the year is generally between July 17-23, according to Ladybug's analysis of EPW weather data.

Additionally, a limitation of focusing on in-situ temperature measurements of the existing site was that I did not collect sufficient data to allow me to understand the impact of proposing new materials in a future design. Surface temperatures are particularly important to consider when thinking about where people may sit or what they may touch. Very little information is available directly from manufacturers to allow for comparison of materials or specific furnishings in terms of their surface temperature in shade versus direct sun. This gap seems to be an opportunity for future research or for a broader analysis of measurements collected from post-occupancy studies.

From the survey questionnaire, I learned how challenging it is to encourage people to take even a quick survey. Because the survey was designed to be a low effort ask of a shopper, the results are not very detailed or directional. This was also a very time-consuming exercise. In total, I spent more than 6 hours on the site collecting 20 survey responses, and this does not include time spent on designing the survey, or running it through the UMD institutional review board, or analyzing the data. A more robust qualitative approach could have included collecting more survey responses throughout the summer to better understand the impact of heat and feelings of the community especially on the hottest days.

However, the qualitative feedback I received did inform my design decisions, and information from the questionnaires added to the body of qualitative research on the lived experience of people and heat. Community input is incredibly important when undertaking big changes to an area and I made a conscious decision not to engage the community more deeply in the design process given the academic nature of the project and the project timeline. Other options for community engagement may yield more detailed and directional guidance – using techniques like heat walks, mapping, or co-design exercises could help with community education, investment, and long-term ownership. If a project like this were really undertaken at Van Dorn Station Shopping Center, community engagement would be a very important aspect of the process, and using one of the vacant storefronts as a “hub” to collect community feedback could be an interesting option.

In looking at relevant case studies, I noticed that there were very few examples of projects or landscapes designed with heat resilience as a key priority. Those that were, such as Edison East Lake and Canoga Park, were in the conceptual or early stages of development and thus did not yet have clear results to show. Other case studies of built projects provided lessons learned in terms of the impact of shade and material selection on surface temperature but did not provide insight in terms of overall pedestrian thermal comfort. This gap suggests opportunities to better measure and model the impact of thermal comfort in post-occupancy studies, using methods and tools like the team at Arizona State University has with their mobile human biometeorological station, MaRTy (Middel et al., 2021).

7.2 Strengths and Limitations of the Design

My second research sub-question was, “How can design strategies be selected and combined to address the site’s microclimate?” I made progress in understanding how design strategies can be selected through review of the literature and site inventory and analysis. However, the second part of the question – how strategies can be combined – is still not completely answered. This thesis project used a before/after approach to understanding the impact of combining different design strategies; however, an iterative design process would provide more insight on how different strategies work together to improve outdoor thermal comfort.

By reviewing the literature and collecting in-situ temperature measurements, I focused in on several key opportunities to influence the site’s microclimate. For example, a recent systematic literature review provides clear, albeit broad, guidance for what strategies to prioritize to cool the landscape: add shade, trees, and green groundcover while removing hardscape (Hirchfeld & Guenther, 2024). Images from my thermal camera clearly showed that lack of shade and significant presence of high-albedo materials like gravel and asphalt contributed to the site's uncomfortable thermal climate. Thus, I responded to both the literature and my own quantitative measurements by incorporating shade and lighter-colored albedo materials in my proposed design.

Other available research drove me to consider elements such as wind and water that could influence the microclimate. A closer look at wind patterns using Grasshopper showed there were limits to harnessing the cooling powers of wind as a strategy unless I planned to change building geometry, which was not within the scope of this project. However, I incorporated a misting sculpture into my design based on research from Huang et al. (2025) showing that misting could lower both air temperature and human skin temperature, even in hot and humid climates.

Using modeling to simulate the impact of climate on the existing site and the proposed design was a "stretch goal" for this thesis project that I achieved. The benefit of using tools like Rhino and Grasshopper is that they can add a data-driven, iterative approach to the design process. However, I discovered the software combination of Rhino and Grasshopper more than halfway through the thesis project in late December 2025, so I was already too far along to use it in an iterative fashion. Instead, I used it to demonstrate the impact of my proposed design by comparing it with the existing site. In a future project, I would consider the opportunity to select a smaller site, or a representative portion of a site, and model 2-3 concepts to see which concept performed best. An iterative approach like this would provide more lessons learned about how to combine strategies, or even the best approach for one strategy – like tree placement – for optimal cooling.

Additionally, the analysis I completed with Rhino and Grasshopper did not account for all the variables that impact the microclimate. For example, the full impact of the trees (including their evaporative cooling, not just their ability to block solar radiation), the impact of material selection, and the benefits of green groundcover, the green roofs, and the misting sculpture were not factored into the model. Grasshopper (including its toolsets Ladybug and Honeybee) does offer more options and capabilities than I was able to learn and incorporate in this project. Future efforts using this software combination might involve incorporating LandSat land surface data, or the qualities of various surface materials into the UTCI calculations, for example. Still, if I wanted to have the most accurate understanding of my design, including all the strategies I included in my site plan, I would need to consider a more robust tool like ENVI-met, which can model the impact of more of these adaptation strategies than Rhino and Grasshopper (Ladybug) can (Vurro & Carlucci, 2024).

Through this project, I gained a clearer understanding of the available design strategies that can improve the microclimate of an urban area, and how they can be prioritized considering the site's conditions. At the same time, my methods and experience using environmental modeling demonstrated that a project like this can benefit from an approach that incorporates testing and refinement. Although my project timeline was too short for an iterative approach, the before/after approach I did take demonstrates the value of a data-driven design. Ultimately, it seems that the question of how to best combine strategies for heat resilience is less about one answer and more about adopting a design methodology that allows for testing and adjusting.

By various measures, including the reduction in direct solar radiation and in UTCI equivalent temperatures, the proposed design is successful in providing a cooler microclimate than the existing conditions. The design responded to quantitative data collection, findings from the literature, case studies, and qualitative feedback from the community. The project demonstrates how infill opportunities could yield more shaded and walkable neighborhoods, doing more to prepare vulnerable communities for a changing climate, even without major redevelopment.

Chapter 8: Conclusion

This MLA thesis project investigated how landscape architects can design for a changing climate with more extreme heat. Using a heat-vulnerable site in Alexandria, Virginia, I demonstrated methods for mapping heat at the site scale using satellite data, thermal imaging, a community survey and software simulation. I then showed how software simulation and modeling can help to predict the cooling impact of a proposed design. The methods and key takeaways from this project are relevant and applicable to heat mitigation projects beyond Alexandria and could be valuable in rural and urban areas, across different climates.

Although extreme heat has the most profound and damaging impact on our most vulnerable populations, it affects all of us. Children, elders, and people with pre-existing health conditions will be at increased health risk when going outside. Laborers who build and maintain the projects we design will face greater risks of heat-related illness. Projects underway will face risks of delay and added costs. Heat will affect our broader ecosystem, stressing the health of plants and species whose livelihood and futures we aim to protect with biodiversity initiatives. Heat will also have significant implications for the vitality of public life. Without sufficient countermeasures, the streets, parks, and shopping districts that are the center of urban society may be abandoned on hot days as people retreat indoors for air conditioning – exacerbating the underlying problem.

As Keith and Meerow (2026) note, we are entering a "heatshed moment, a critical turning point at which heat must be rapidly addressed to protect health and livelihoods worldwide." The work designers and planners undertake today – expanding shade, increasing vegetation, and reducing heat-absorbing materials – will directly shape the livability of our communities tomorrow.

Heat resilience must be prioritized across scales, from the site to the regional level. Encouragingly, strategies for mitigating heat align with broader urban development goals: walkability, transit use, tree canopy expansion, vibrant public spaces, and effective stormwater management. While past design decisions have contributed to current climate challenges, the tools to address them are within reach. The question is no longer whether we can design for heat – but whether we will do so with the urgency and scale this moment demands.

Appendices

Appendix A: Full Text of Survey Questionnaire

Van Dorn Station Shopping Center Visitor Survey

Survey Overview & Consent to Participate

You are invited to participate in an **anonymous** research survey examining your experience at the Van Dorn Station Shopping Center on a hot summer day.

Firstly, please consider your own comfort and health when deciding to take this survey outside. You may opt to finish your survey inside, skip any questions you prefer not to answer, or stop the survey at any time. The survey will take approximately 5 minutes to complete, and a cold beverage is provided to anyone who takes the survey.

The results of this survey will be included in a master's thesis project for the department of Plant Sciences and Landscape Architecture at the University of Maryland, College Park. This survey may provide the researchers with insights on how to address urban heat island or improve the pedestrian shopper experience at the Van Dorn Station Shopping Center. There are no direct benefits to participants for completing the survey.

Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate or if you stop participating at any time, you will not be penalized.

By proceeding with the survey, you indicate that you are at least 18 years of age; you have read this consent form or have had it read to you; your questions have been answered to your satisfaction, and you voluntarily agree to participate in this research study. You may keep your own copy of this consent form.

If we write a report or article about this research project, your identity will be protected to the maximum extent possible. Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if you or someone else is in danger or if we are required to do so by law.

Responses to this research survey will be stored securely in a locked storage clipboard and will be scanned and secured digitally on a password-protected computer. Printed copies will be shredded once they are converted to digital files.

If you have questions about your rights as a research participant or wish to report a research-related injury, please contact:
University of Maryland College Park
Institutional Review Board Office
1204 Marie Mount Hall
College Park, Maryland, 20742
E-mail: irb@umd.edu
Telephone: 301-405-0678

For more information regarding participant rights, please visit:
https://research.umd.edu/research-resources/research-compliance/institutional-review-board-irb/research-participants

This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.

If you have any questions or comments about this research, you may contact the researcher: Caitlin Garlow, MLA Candidate, at cgarlow@umd.edu.

Van Dorn Station Shopping Center Visitor Survey

1. What is your age?
   - 18-34 years
   - 35-54 years
   - 55-74 years
   - 75 years or older
2. Select how you traveled to Van Dorn Station Shopping Center today:
   - Car
   - Walk
   - Bike
   - Metro
   - Other: ______
3. How do you feel in the heat today?
   - Very comfortable
   - Comfortable
   - Neutral
   - Uncomfortable
   - Very uncomfortable
4. Check any heat-related illness or discomfort you have experienced in the past week:
   - Tired
   - Thirst
   - Dizzy
   - Headache
   - Irritable
   - None of these
   - Other: ____________
5. Do you ever change your travel plans to avoid the heat and sun?
   - Yes
   - No
   - Additional comments: ___________________________________
6. Check any protection you usually use when going outside on a hot day:
   - Wear a hat
   - Wear sunscreen
   - Bring water
   - Bring umbrella
   - Wear loose fitting clothing
   - Take a car/taxi
   - Other: ________
7. Please share anything you **like** about this shopping center:
   - __________________________
   - __________________________
8. Please share anything you **do not like** about this shopping center:
   - _________________________
   - _________________________
9. Check any of the options you would like to see added to this shopping center:
   - Trees and plants
   - Improved bus shelter
   - Shades/awnings
   - Public park or green space
   - Drinking fountain
   - Cooling/misting station
   - Rain gardens
   - Benches
   - Pedestrian crosswalks
   - Bike parking
   - Eating areas
   - Art/sculpture
   - Other: ____________________

10. Is there anything else you would like to share about your experience?

____

____

____

Appendix B: IRB Exemption Letter

UNIVERSITY OF MARYLAND

INSTITUTIONAL REVIEW BOARD

1204 Marie Mount Hall
College Park, MD 20742-5125
TEL 301.405.4212
FAX 301.314.1475
irb@umd.edu
www.umresearch.umd.edu/IRB

DATE:	August 4, 2025
TO:	Caitlin Garlow, MLA
FROM:	University of Maryland College Park (UMCP) IRB
PROJECT TITLE:	[2337695-1] COOL CORNERS AND CORRIDORS: USING DESIGN TO IMPROVE PEDESTRIAN THERMAL COMFORT IN ALEXANDRIA'S WEST END
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	August 4, 2025
REVIEW CATEGORY:	Exemption category # 45CFR46.104(d)(2)(i-ii)

Thank you for your submission of New Project materials for this project. The University of Maryland College Park (UMCP) IRB has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will retain a copy of this correspondence within our records.

If you have any questions, please contact the IRB Office at 301-405-4212 or irb@umd.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Maryland College Park (UMCP) IRB's records.

- 1 -

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Glossary

Cool corridors: Shaded urban pathways designed to provide relief from heat for pedestrians and cyclists

Cool islands: A phenomenon where some areas within a city exhibit significantly lower surface temperatures than other parts of the surrounding urban area

Direct solar radiation: The energy emitted by the sun, which affects surface temperatures and can be mitigated by reflective or shaded surfaces.

Direct sunlight hours: An analysis in Grasshopper (Ladybug) which shows the number of hours of sunlight that hits a surface over a period of time, using EPW weather data and sun vectors.

Heat index: A measure that combines air temperature and relative humidity to determine how hot it feels to the human body

Heat resilience: The ability for communities to withstand, recover from, and adapt to extreme heat.

Heat Vulnerability Index (HVI): A tool used to identify populations or regions most at risk of adverse health outcomes from extreme heat.

In-situ: from the original place

Mean radiant temperature (MRT): A measure of the average temperature of all surrounding surfaces that contribute to the radiant heat exchange experienced by a person or object. It reflects how the temperature of the environment (e.g., walls, ground, buildings) affects thermal comfort through radiation. MRT is a key factor in human thermal comfort models because it accounts for the heat radiated from surfaces, which can significantly impact how hot or cold a person feels, especially in outdoor urban environments where surfaces like pavement or buildings may absorb and emit heat.

Surface temperature (ST): The temperature of the ground or any other surface, which can be significantly higher than air temperature during heat events.

Thermal comfort: A condition of mind that expresses satisfaction with the thermal environment; influenced by temperature, humidity, and air movement.

Urban Heat Island (UHI): The phenomenon where an urban area experiences higher temperatures than its rural surroundings due to human activities and the concentration of buildings and infrastructure.

Universal thermal climate index (UTCI): An index that is used to assess the linkages between outdoor environment and human well-being, providing an equivalent temperature as a measure of the human response to the thermal environment

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DYx*_ga_249CRKJTTH*czE3NDc4NTU1MzkkbzQ3JGcxJHQxNzQ3ODU2OTAwJGowJGwwJGgw

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