

THE ART OF CLIMATE SCIENCE

A CASE STUDY & PRIMER FOR APPLYING CLIMATE
CHANGE PROJECTION DATA TO DESIGN DEVELOPMENT
IN LANDSCAPE ARCHITECTURE

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TERMS & ABBREVIATIONS

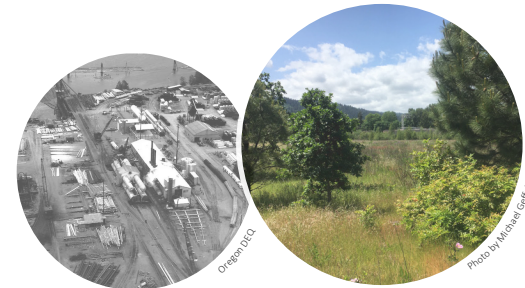
- Botanic Garden:** Documented collection of living plants for the purpose of scientific research, conservation, display, and education
- Climate Forcing:** Changes in the balance of energy that the Earth receives from the sun and radiates back into space, leading to changes in the Earth’s climate
- Climate Projection Model:** Computational model which uses future climate forcing scenarios to estimate changes in climate variables such as temperature, precipitation, or radiation at global, regional, or fine spatial scales over time
- Differential Horizontal Radiation:** The portion of solar radiation received on a horizontal surface that is scattered by the atmosphere, excluding the direct beam. It contributes to the diffuse component of total solar radiation
- Direct Normal Radiation:** Solar radiation received in a straight line from the sun on a surface perpendicular to the sun’s rays
- DCPD - Downscaled Climate Projection Data:** Climate data that has been refined from coarse-resolution global models to finer spatial scales using statistical or dynamical techniques
- Dry-bulb Temperature:** The ambient air temperature measured without consideration of humidity
- Environmental Simulation:** The use of software models to predict environmental conditions (e.g., temperature, solar exposure, airflow)
- fTMY - Future Typical Meteorological Year:** A constructed weather data file representing a statistically typical year in a specific future time period, constructed from downscaled climate projections for use in environmental simulations
- GCM - General Circulation Model:** A climate model that simulates atmospheric and oceanic processes on a global scale, used to project long-term climate change under various emission scenarios
- Horizontal Infrared Radiation:** Longwave radiation emitted by the atmosphere and received on a horizontal surface
- Ladybug:** An open-source environmental plugin for Grasshopper/Rhino that enables designers to perform climate analysis and simulation using real weather data and visualization tools
- Optimization:** The process of adjusting variables in a simulation or model to achieve the best performance based on defined goals
- OCS - Oregon Climate Service:** The official state climate office for Oregon, providing access to historical weather data, climate summaries, and research to support climate-related planning and decision-making
- Parametric Design:** Design method in which design features and relationships between features are shaped through algorithmic processes using variable parameters

- Primer:** An introductory document or guide designed to provide essential background information on a subject
- RCM - Regional Climate Model:** A high-resolution climate model used to simulate atmospheric processes over a limited geographic area, often nested within a General Circulation Model (GCM) to produce localized climate projections
- Relative Humidity:** The percentage of moisture in the air relative to the maximum amount the air can hold at a given temperature
- Remediation:** The process of cleaning up or mitigating environmental contamination (e.g., soil, water, air) to restore a site for safe use or ecological health
- Resolution:** In climate and simulation contexts, it refers to the spatial or temporal detail of a model or dataset. Higher resolution means finer detail and smaller grid cells or time steps
- Rhino:** Short for Rhinoceros 3D, a 3D modeling software widely used in architecture, industrial design, and environmental simulation
- Seasonality:** The predictable variation in climate or environmental conditions associated with different seasons, such as changes in temperature, sunlight, or precipitation patterns
- Thermal Comfort:** A state in which a person feels neither too hot nor too cold. It is influenced by temperature, humidity, air movement, radiation, and personal factors like clothing and activity level
- TMY - Typical Meteorological Year Data:** A constructed weather dataset representing average or “typical” climate conditions over a year, based on historical observations. Commonly used in building performance simulations
- UHI - Urban Heat Island:** A phenomenon where urban areas experience higher temperatures than surrounding rural areas due to dense materials, reduced vegetation, and human activities that store and emit heat
- UTCI - Universal Thermal Climate Index:** A scientifically standardized index for assessing outdoor thermal comfort, combining temperature, humidity, wind speed, and radiation to express the physiological response of the human body
- Weather Data:** Recorded or modeled atmospheric conditions over time, including variables like temperature, humidity, solar radiation, and wind speed
- Wind Velocity:** The speed and direction of wind at a given location and height
- XYM - Extreme Meteorological Year:** A constructed weather file representing extreme climatic conditions (e.g., unusually hot or cold years), used to test the resilience of buildings or systems under worst-case scenarios

PROJECT CONTEXT

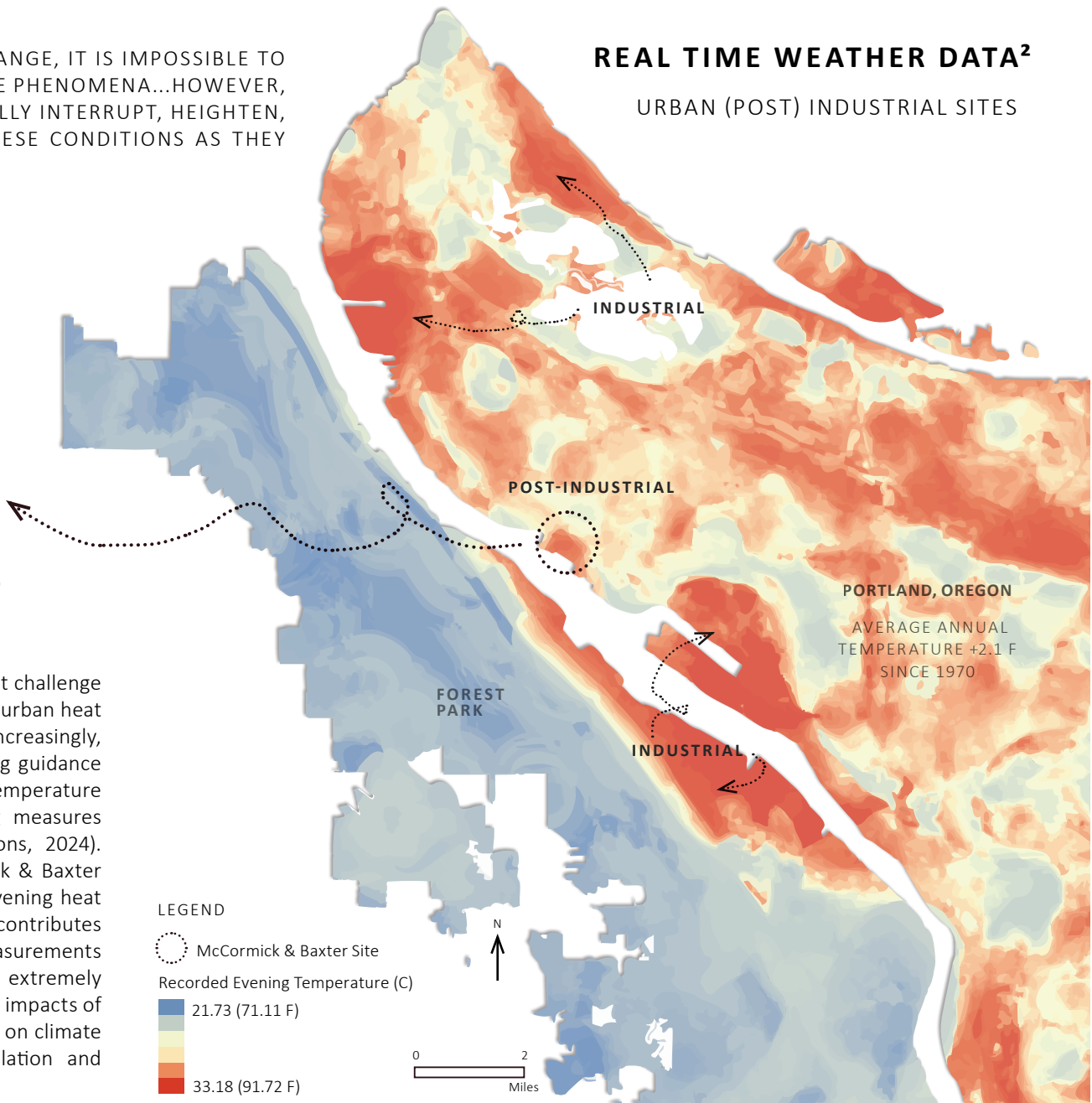
RESPONDING TO URBAN HEAT

"GIVEN THE COMPLEXITY OF CLIMATE CHANGE, IT IS IMPOSSIBLE TO DIRECTLY AFFECT THE EXTREMES OF THESE PHENOMENA...HOWEVER, AS DESIGNERS IT IS POSSIBLE TO TACTICALLY INTERRUPT, HEIGHTEN, OR MINIMISE DIFFERENT ASPECTS OF THESE CONDITIONS AS THEY PLAY OUT AT THE SCALE OF THE SITE"¹



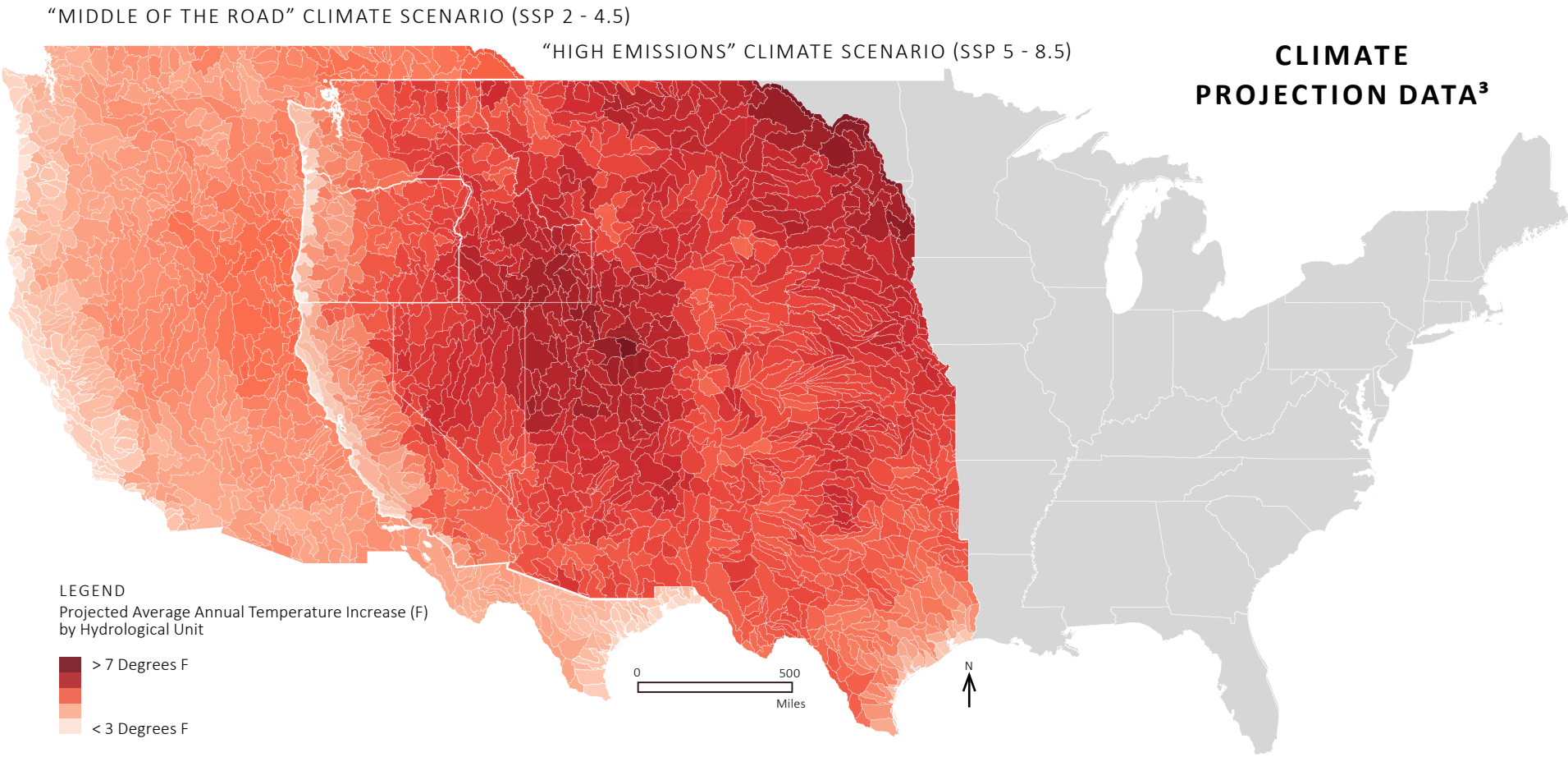
MCCORMICK & BAXTER SUPERFUND CASE STUDY SITE

In many urban areas, summer heat is a significant challenge to human health and quality of life as a result of urban heat island (UHI) effect (Hirschfeld & Guenther, 2024). Increasingly, landscape architects are studying and publishing guidance on the collection and utilization of real-time temperature data to inform the design of heat mitigating measures in the urban environment (Lindquist & Gibbons, 2024). The case study site in this work, the McCormick & Baxter Superfund Site in North Portland, holds onto evening heat which is a characteristic of urban form which contributes to UHI effect. Although fine-scale, real-time measurements of temperatures in the urban environment are extremely important for understanding and adapting to the impacts of urban heat on public health, this project focuses on climate projection data to drive environmental simulation and design development.



¹Cantrell, Bradley, & Adam Mekies, eds. Codify : Parametric & Computational Design in Landscape Architecture. Abingdon, Oxon ; Routledge. 2018. Print.
²Map Courtesy of Jackson Voelkel & Vivek Shandas from Voelkel, J., & Shandas, V. (2017). Towards Systematic Prediction of Urban Heat Islands: Grounding Measurements, Assessing Modeling Techniques. Climate, 5(2), 41. <https://doi.org/10.3390/cli5020041>

CLIMATE PROJECTION DATA & DESIGN



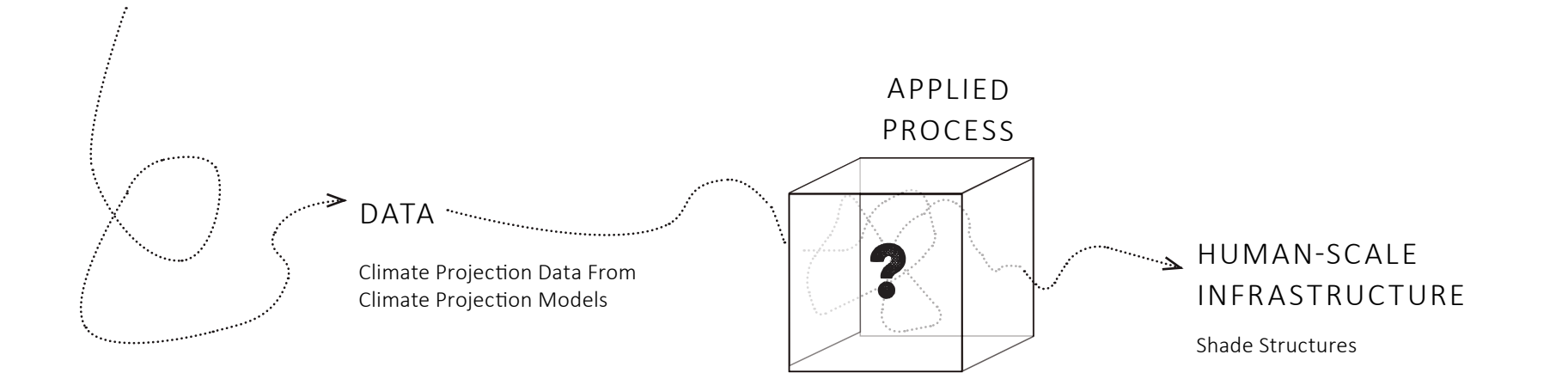
While historic and real-time weather data are commonly used in environmental simulations for design development and testing, climate projection data is not (Laxo et. al., 2023). Analysis and simulation tools like Ladybug typically rely on averaged weather data from the past 15 - 30 years, which does not reflect future conditions under various climate change scenarios. Global climate models, or General Circulation Models (GCMs), provide information at a large spatial scale - too large for designers to use at the site-scale in design development (O’Malley & Laxo, 2019). In contrast, downscaled climate projection models can provide projected weather data at fine spatial scales, which designers can use to understand plausible future conditions and test design performance (Chowdhury et. al., 2023). This project explores one, novel scenario for utilizing projected weather data from climate projection models to respond to future heat in Portland, Oregon, drawing on empirical research from landscape architecture to propose shade structure interventions.

³Reclamation (Bureau of Reclamation). (2021). Water Reliability in the West - 2021 SECURE Water Act Report. Prepared for the United States Congress. Bureau of Reclamation, Water Resources & Planning Office. Denver, Colorado

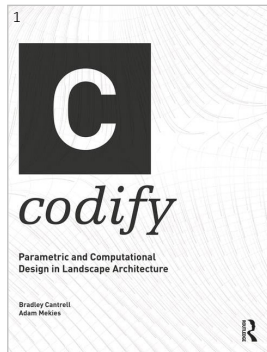
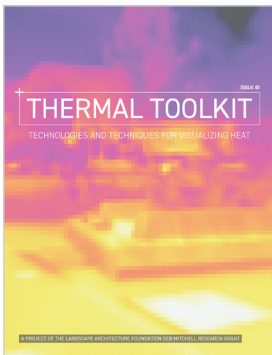
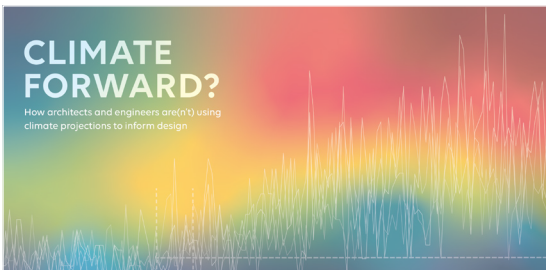
STEP ZERO
BACKGROUND

GUIDING QUESTION

HOW CAN QUANTITATIVE DATA ABOUT FUTURE CLIMATE CONDITIONS BE UTILIZED IN LANDSCAPE ARCHITECTURE TO DRIVE DESIGN DEVELOPMENT OF SHADE INFRASTRUCTURE AT THE HUMAN-SCALE?



GUIDING RESOURCES



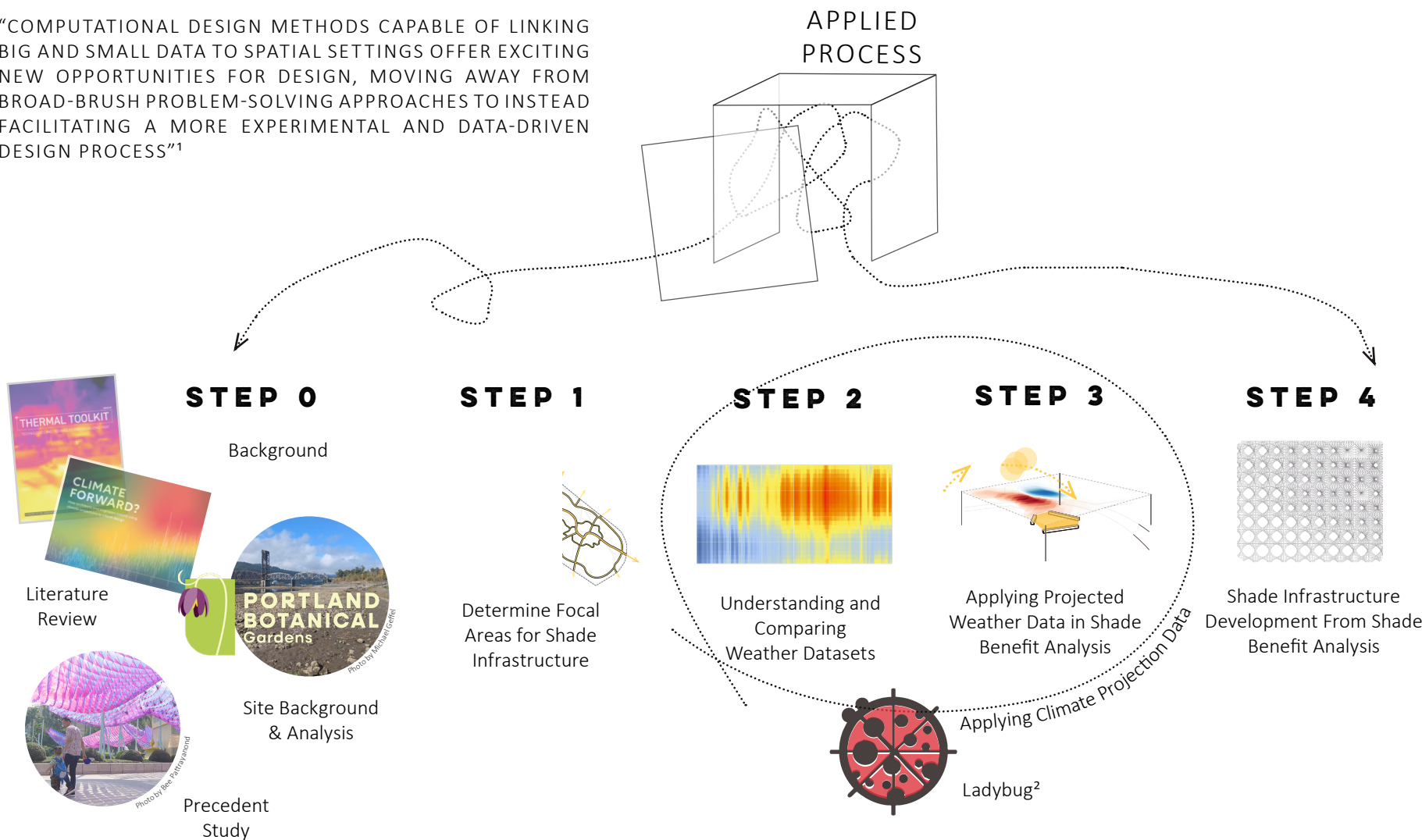
Despite its potential, **data from downscaled climate projection models is rarely used in professional design practice to inform design development**, with uncertainty and lack of guidance cited as key hurdles (Laxo et. al., 2023).

With this gap in knowledge as a primary catalyst, this project builds on parametric design methods to demonstrate how such data can inform landscape architecture. A novel application of Ladybug Thermal Shade Benefit Analysis (Mackey et. al., 2015), utilizing projected weather data constructed from climate projection models, is used to explore

how climate projection data can guide design decision-making. **The applied design process explored in this work speaks to the power of landscape architecture to bridge disciplines and translate data into infrastructure.** Beyond the specific site, *The Art of Climate Science* positions landscape architects as translators of complex environmental data into site-specific spatial and experiential interventions. In doing so, this project contributes to a broader conversation on the role of simulation and climate projection in the future of landscape architecture. By articulating a clear workflow and showcasing tangible outcomes, this work will provide a primer for practitioners and educators interested in integrating climate projection into the design of shade infrastructure.

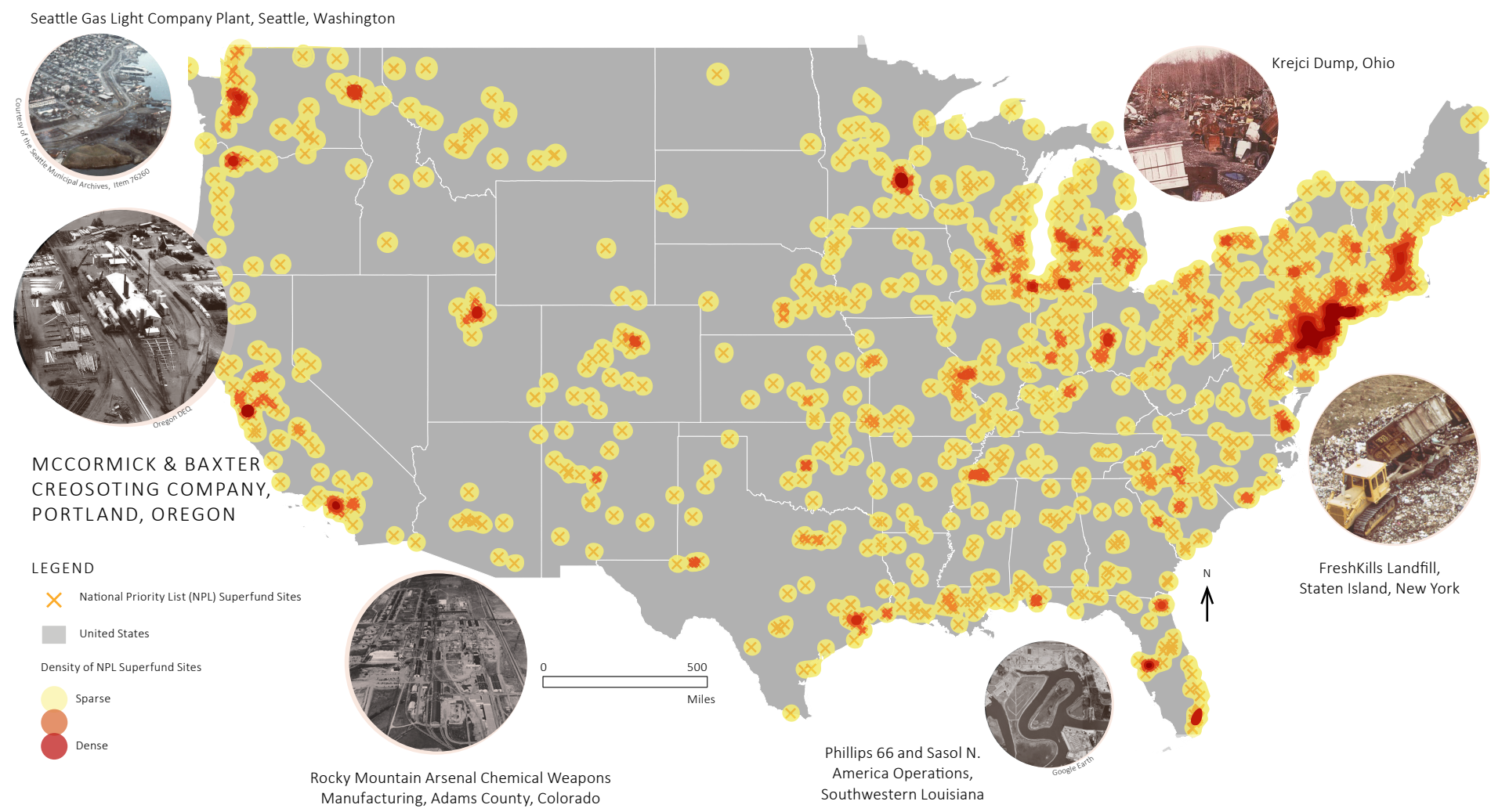
UNTANGLING THE PROCESS

“COMPUTATIONAL DESIGN METHODS CAPABLE OF LINKING BIG AND SMALL DATA TO SPATIAL SETTINGS OFFER EXCITING NEW OPPORTUNITIES FOR DESIGN, MOVING AWAY FROM BROAD-BRUSH PROBLEM-SOLVING APPROACHES TO INSTEAD FACILITATING A MORE EXPERIMENTAL AND DATA-DRIVEN DESIGN PROCESS”¹

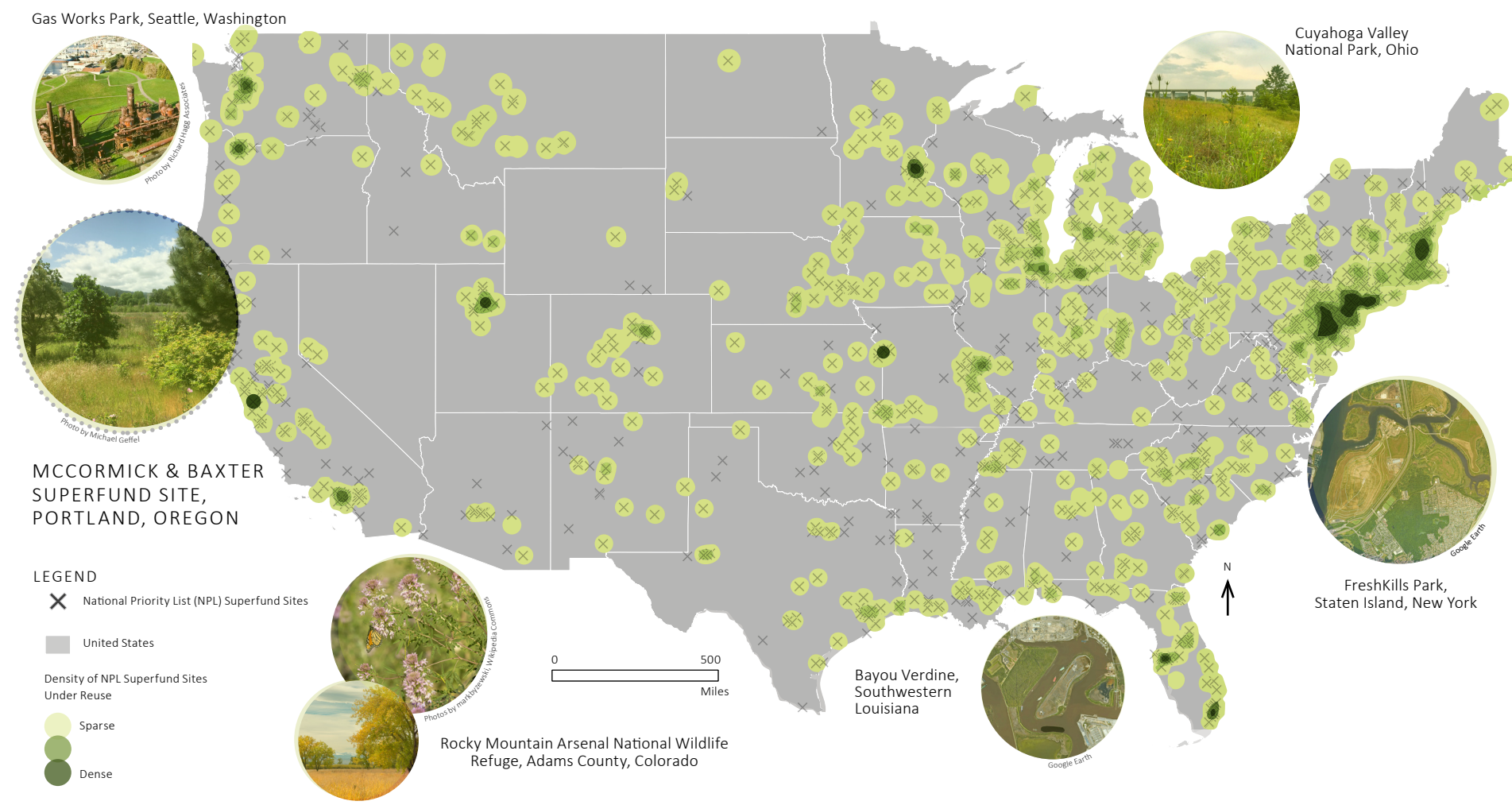


The applied, experimental design process explored in this work is organized step-by step, broken into (0) background, (1) focal area determination, (2) introduction of weather datasets, (3) application of Thermal Shade Benefit Analysis using projected weather data, and (4) development of shade infrastructure. This process can be applied anywhere for which downscaled climate projection data exists. The new weather datasets from climate projection models used in this work have been created for nearly all counties in the United States (Chowdhury et. el., 2023) and downscaled weather data can be retrieved from state-specific climate services (O’Malley & Laxo, 2019).

¹Cantrell, Bradley, & Adam Mekies, eds. *Codify : Parametric & Computational Design in Landscape Architecture*. Abingdon, Oxon ; Routledge, 2018. Print.
²Sadeghipour Roudsari, Mostapha; Pak, Michelle, 2013. Ladybug: a parametric environmental plugin for grasshopper to help designers create an environmentally-conscious design. In: *Proceedings of the 13th International IBPSA Conference Held in Lyon, France Aug 25–30th*. http://www.ibpsa.org/proceedings/BS2013/p_2499



Industrial zones, which contribute significantly to Urban Heat Island (UHI) effect, line urban waterways and pose significant challenges and opportunities for post-industrial urban development and climate change adaptation (Wu & Lu, 2023). Their legacy has left behind concentrations of pollution and contamination, contributing to environmental degradation and exacerbating urban challenges. As cities seek to adapt to climate change and revitalize post-industrial areas, these sites offer unique opportunities for remediation and transformation (Mclean, 2020).



In the United States, post-industrial landscapes are increasingly viewed as opportunities to reclaim public space and adapt urban areas to climate change (Wu & Liu, 2023). Notable landscape architecture projects, including Freshkills Park in Staten Island, New York and Gas Works Park in Seattle, Washington are examples of industrial site which have been repurposed as recreational and ecological assets in urban areas. The area of study in this project, the McCormick & Baxter Site in Portland, Oregon, is designated as a National Priority List Superfund site and has been proposed as the future home of the Portland Botanical Gardens. Not all of the examples of reuse shown here are Superfund designated sites, but not all heavily contaminated land gains federal designation. Each illustrates the opportunities presented for remediation and post-industrial recovery in the United States.

MCCORMICK & BAXTER SITE

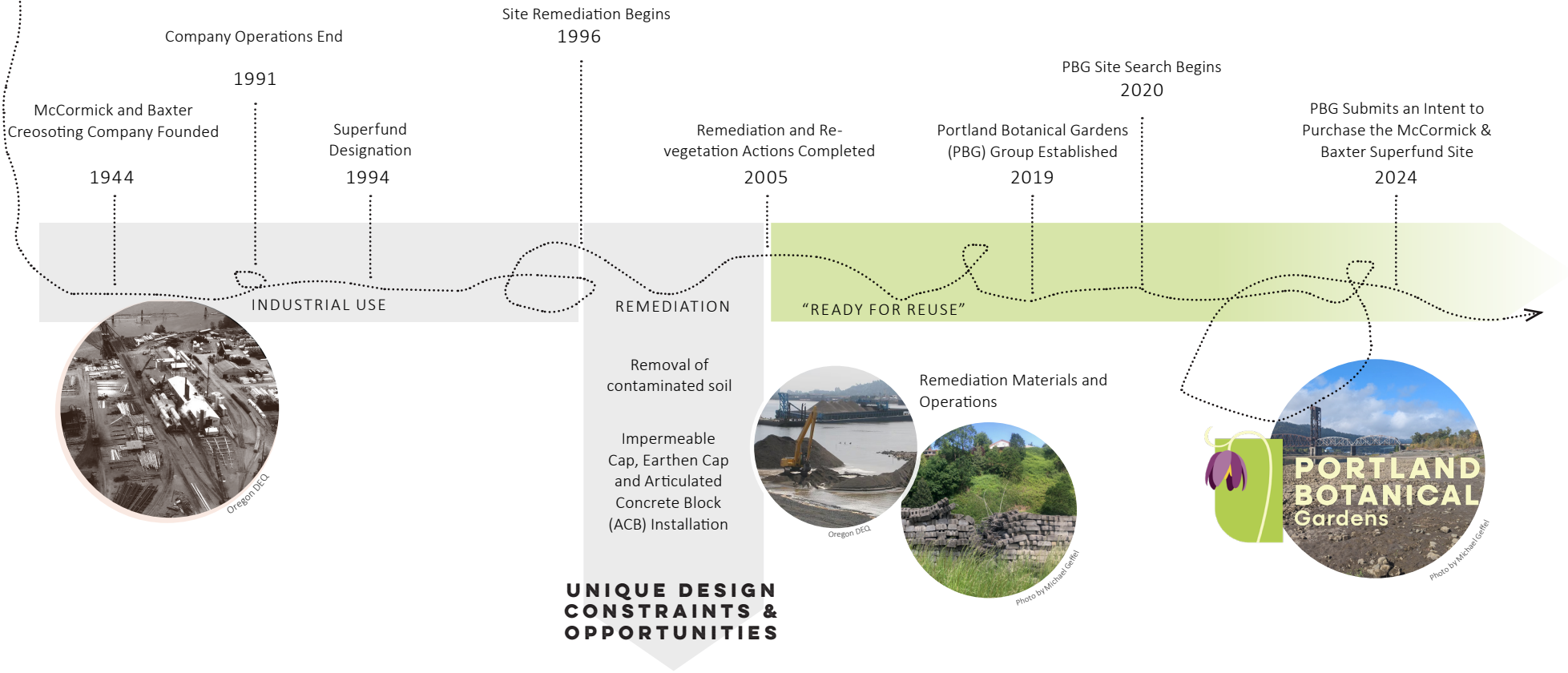
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As a former industrial property and proposed botanic garden, the study area could be a significant asset to the surrounding community and a small piece of a larger effort to alleviate UHI effect in Portland, Oregon. As a result of contamination and remedial action, soil composition on the site has been heavily altered from pre-industrial conditions and constructed drainage away from the impermeable and earthen caps has altered water flow (Hill, 2006). In combination, these alterations result in a significant portion of the site experiencing drought stress which could be further exacerbated by increasing temperatures and seasonal extremes as a result of climate change.

SITE TIMELINE

0 - 1 - 2 - 3 - 4



The McCormick & Baxter Creosoting Company operated on the site between 1944 and 1991. In that time, creosoting activities by the company leached toxic non-aqueous phase liquids (NAPLs) into the soil, groundwater, and river sediments (EPA, 2002). The McCormick & Baxter Site was designated a National Priority List Superfund site by the Environmental Protection Agency in 1994. In 1999, over 32,600 tons of contaminated soil within 4 feet of the ground surface were removed and over 33,000 tons of sand were deposited in its wake. Remedial actions were completed in 2005 (Parrett & Terada, 2021).

SITE CONSTRAINTS | REMEDIATION ZONES



“EACH (POST-INDUSTRIAL) SITE HAS A UNIQUE SET OF CONDITIONS AND QUALITIES THAT REQUIRE AN ENGAGED, RESPONSIVE, AND REVELATORY APPROACH...”³

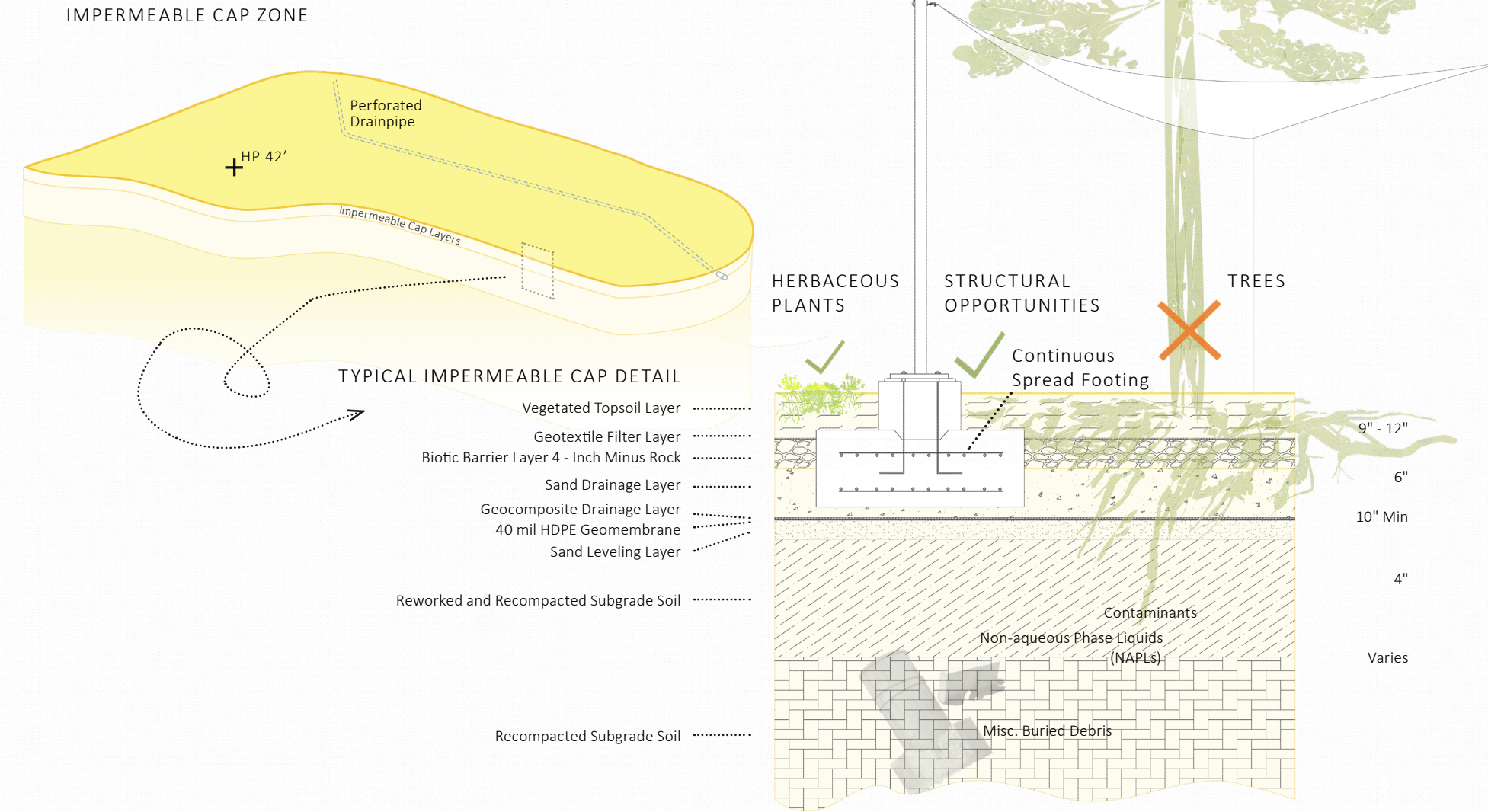
Several thousands of plants were planted in the riparian and earth cap zones in 2006. There was no woody vegetation planted on the impermeable cap, and the area is monitored closely for the emergence of new trees, which are removed to maintain the integrity of the impermeable cap layers (Parrett & Terada, 2021).

In a meta-review, Kumar et al. (2024) found botanic gardens to be the most efficient green infrastructure strategy for cooling air temperatures in urban areas, followed by wetlands, green walls, and street trees. However, since tree planting is restricted on the cap, the cooling impacts of diverse vegetative cover is limited other parts of the site. **This constraint creates an opportunity to introduce shade structures as alternatives for summer comfort in the proposed botanic garden meadow to be constructed on the impermeable cap.**

³McLean, Ross. Transformative Ground: A Field Guide to the Post-Industrial Landscape. Abingdon, Oxon; Routledge, 2020. Print.

0 - 1 - 2 - 3 - 4

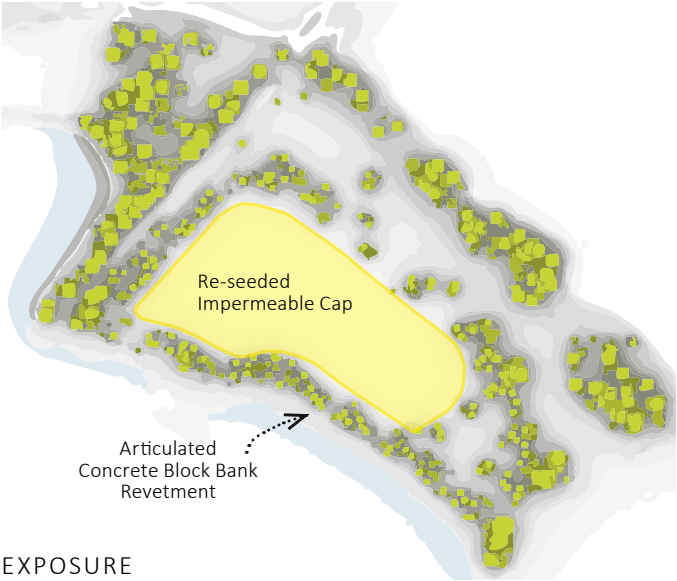
SITE CONSTRAINTS | IMPERMEABLE CAP DETAIL



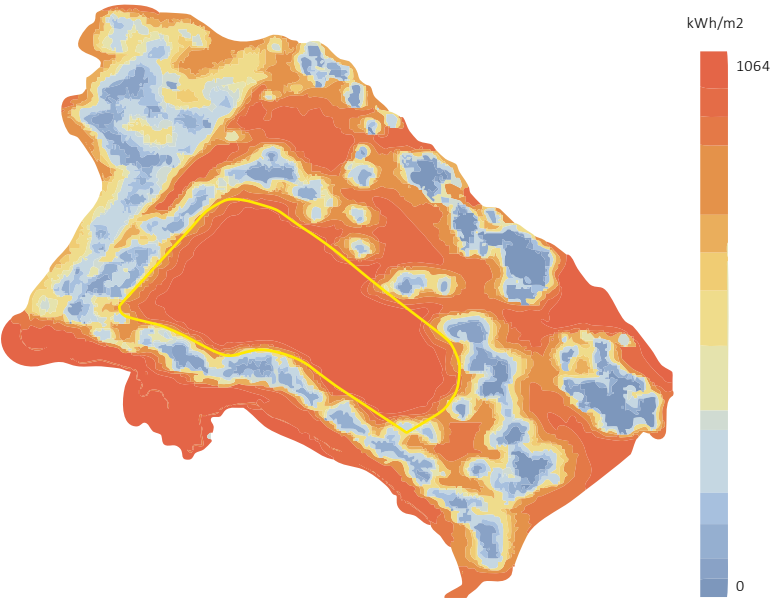
On the impermeable cap, there is concern that woody vegetation would threaten the integrity of an impermeable geomembrane liner. The liner exists to prevent water infiltration - which could move contaminants from past creosoting activities into the Willamette River and surrounding groundwater (EPA, 2021).

SITE EXPOSURE

VEGETATION
Current Conditions



EXPOSURE
Solar Irradiance | Current Conditions



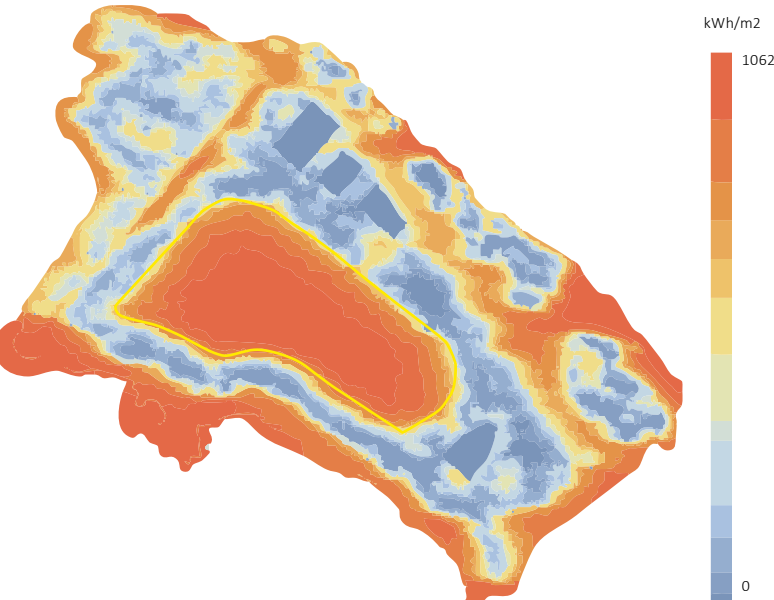
With no shading intervention, future conditions in the constructed meadow will remain dry and exposed. The 15 acre impermeable cap makes up a large portion of the site, necessitating large scale interventions for the comfort of future botanic garden visitors in the summer months.

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Future Conditions

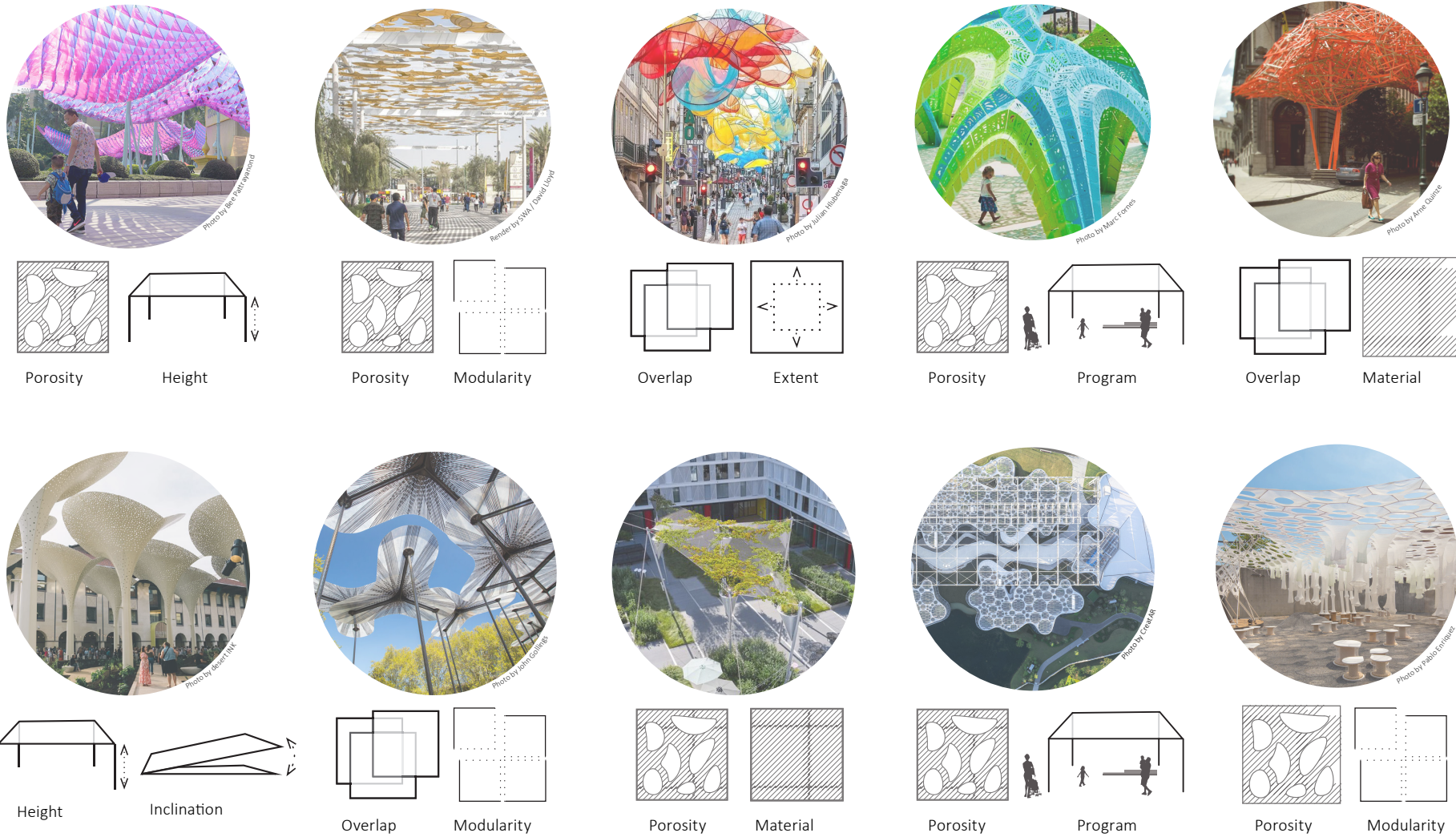


Solar Irradiance | Future Conditions, No Intervention



SHADE STRUCTURE PRECEDENTS

0 - 1 - 2 - 3 - 4



This precedent study helped to create a frame of reference for creative shade structures. Eight primary design variables for shade structures were determined from this exploration - Structural porosity, height variability, modularity, overlap, extent, program, material, and inclination. Each precedent exemplifies these eight variable to varying degrees. These variables help guide design iteration of shade structures later in the design process.

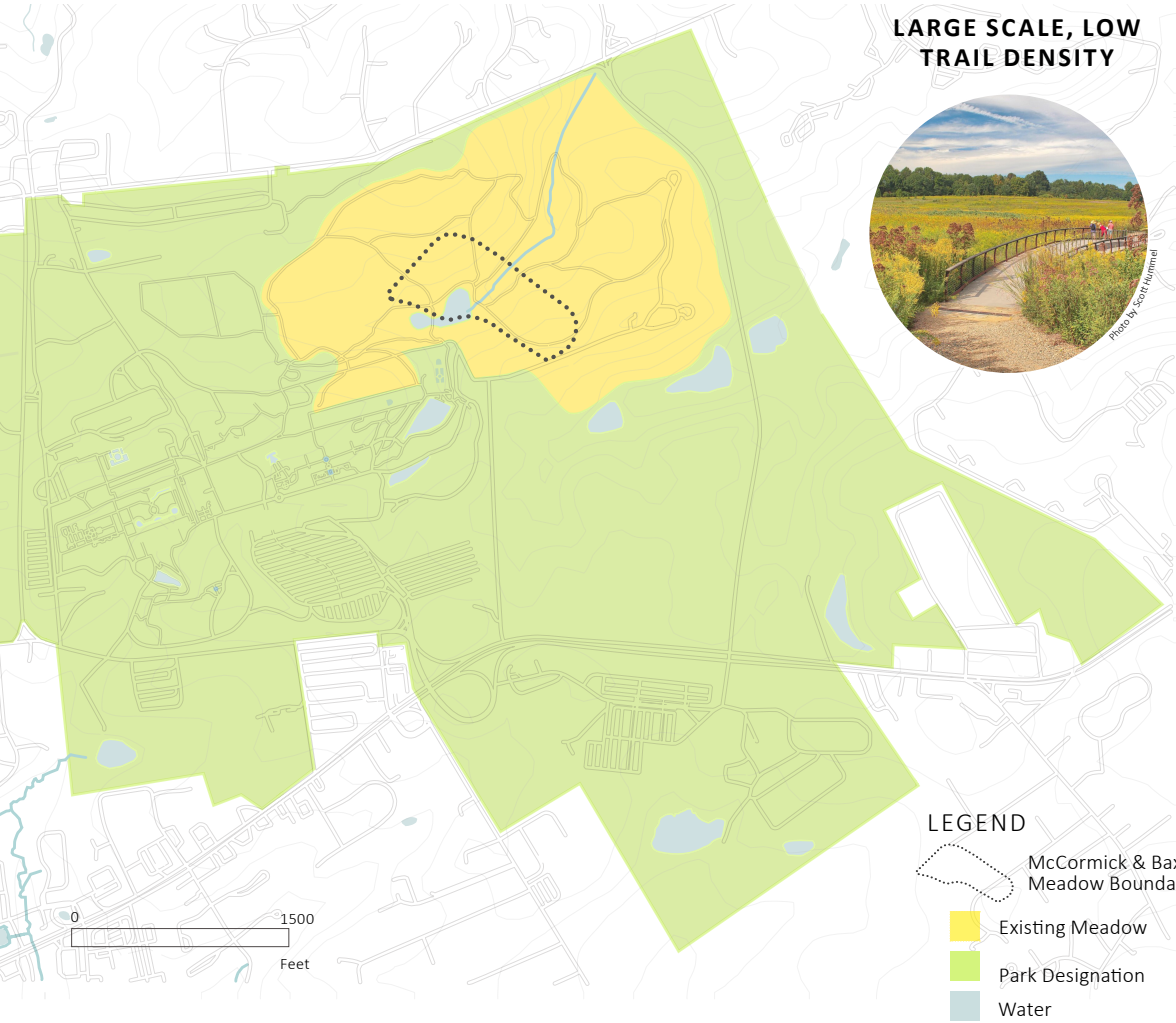
STEP ONE

DETERMINING FOCAL AREAS FOR SHADE INFRASTRUCTURE

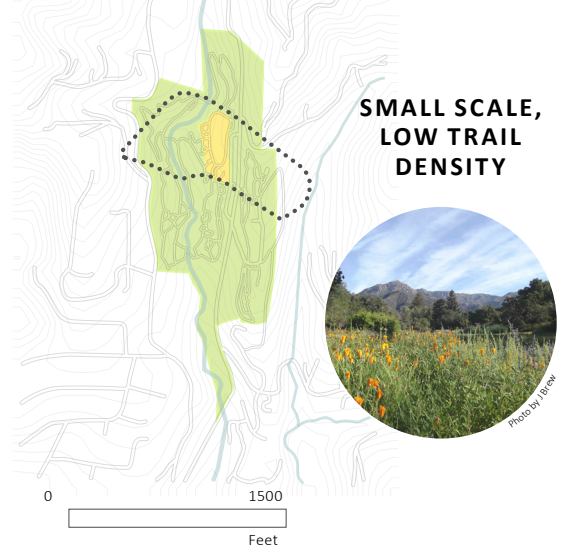
MEADOW PRECEDENTS

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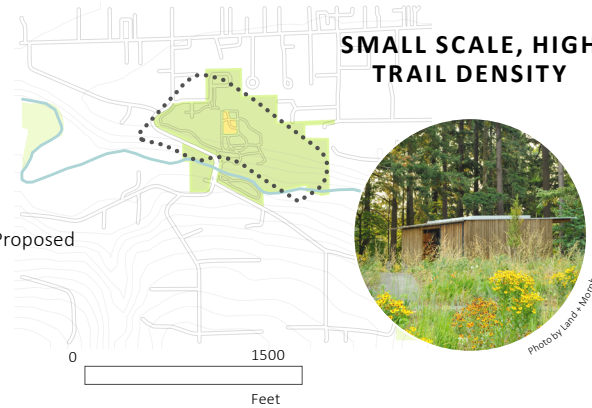
LONGWOOD GARDENS, KENNETT SQUARE, PA



SANTA BARBARA BOTANIC GARDEN, SANTA BARBARA, CA



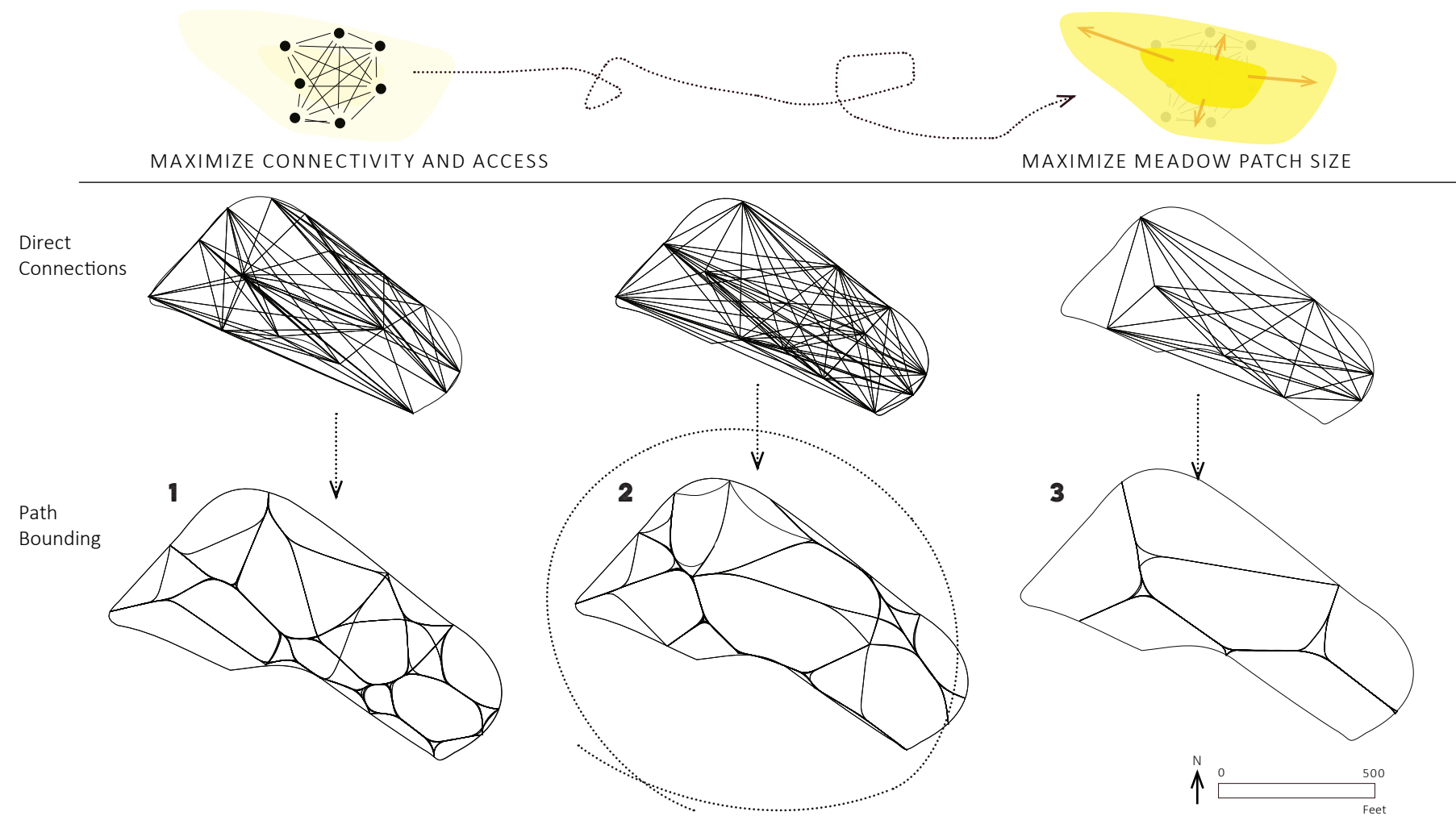
LEACH BOTANIC GARDEN, PORTLAND OREGON



A site circulation plan is necessary for deciding on specific focal areas at which to apply downscaled climate projection data. Precedents of botanic gardens with meadows were collected to frame the upper and lower limits of trail density, which guides the development of site circulation. Access for visitors and employees will be of importance in the future meadow, but botanic gardens have the potential to address biodiversity loss and promote ecological restoration by providing large, uninterrupted spaces for diverse plant communities (Ponzi et. al., 2024). This establishes a fundamental trade-off between the density of trails and meadow patch size.

CIRCULATION SCENARIOS

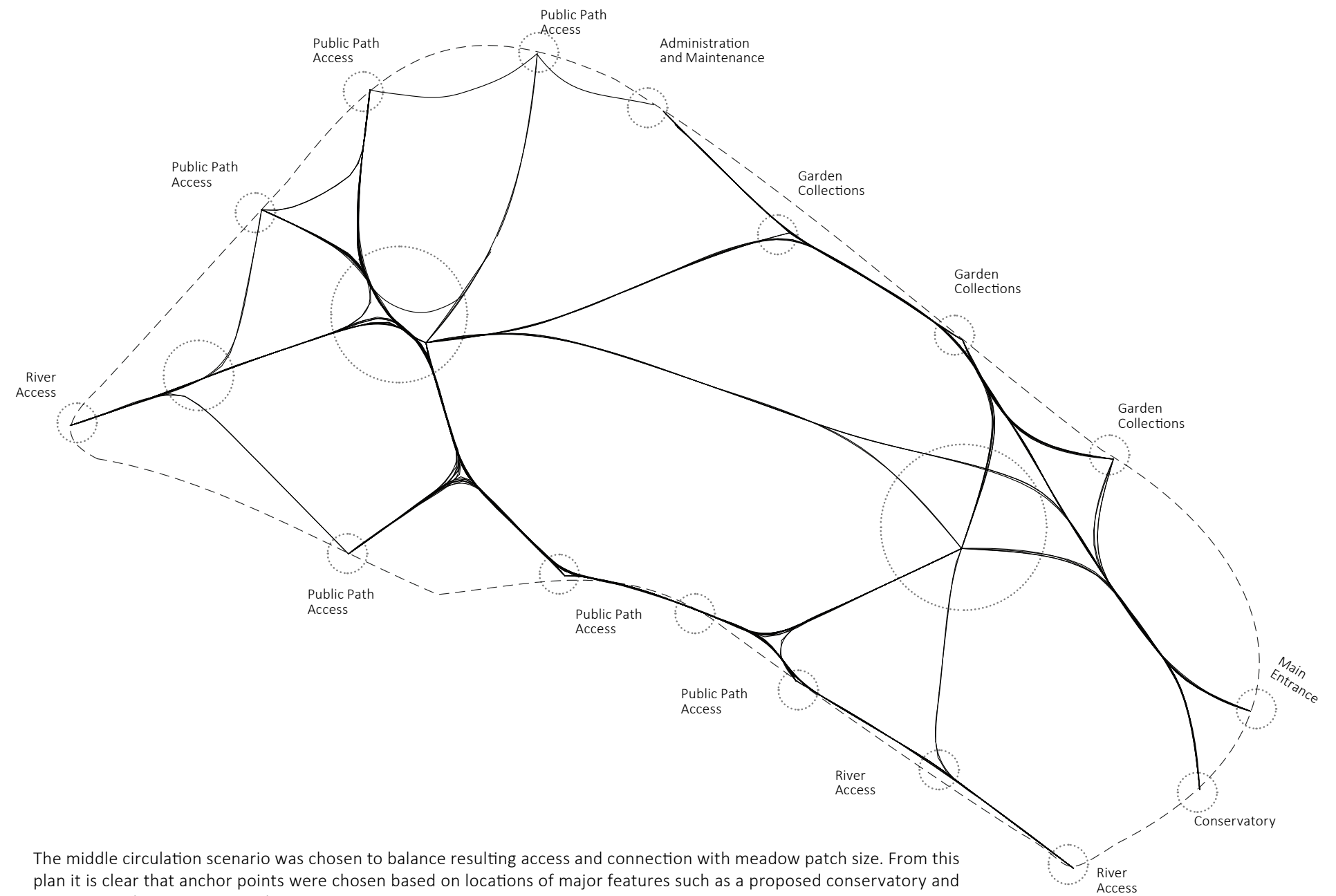
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The method used to create trail scenarios in this work is called “edge bounding”. Edge bounding relies on anchors and connection lines. The “anchors” are trail entry points on the perimeter of the meadow and the connection lines are the direct paths from every anchor to every other anchor. The direct connection lines are “pulled” together by a parametrically set attractive force in order to bundle the lines together onto an averaged pathway. Three primary scenarios were created on a spectrum from high connectivity and high number of trail anchors to low connectivity and low number of trail anchors.

TRAIL SCENARIO TWO

0 - 1 - 2 - 3 - 4



The middle circulation scenario was chosen to balance resulting access and connection with meadow patch size. From this plan it is clear that anchor points were chosen based on locations of major features such as a proposed conservatory and current site characteristics such as water access points.

0 - **1** - 2 - 3 - 4



-  Estimated Exposure Time
-  Primary Meadow Entrances
-  Primary Circulation (10' wide)
-  Secondary Circulation (8' wide)
-  Tertiary Circulation (5' wide)

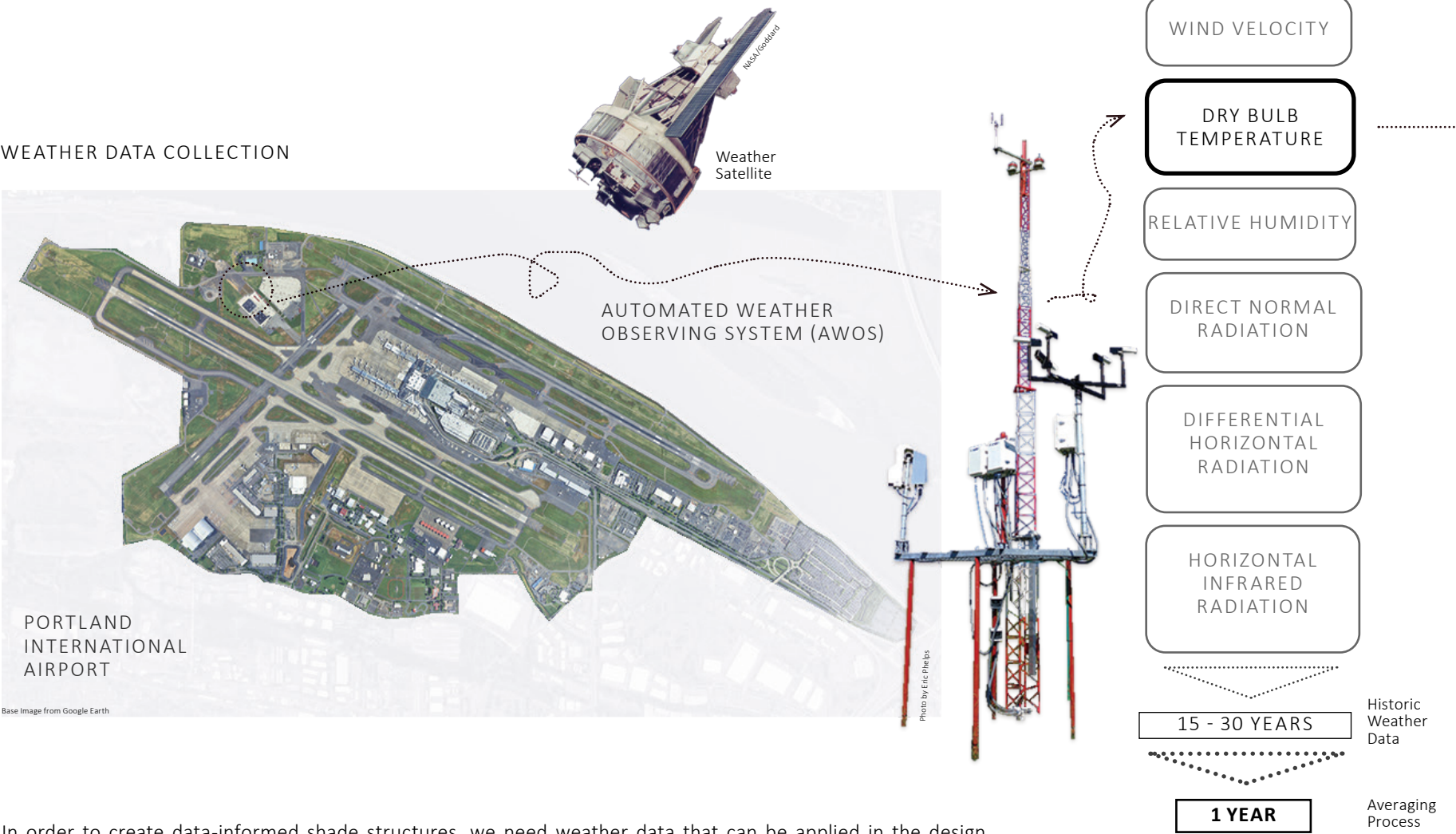
From the averaged pathways, a softened circulation system was created. The new meadow is bounded by a meadow edge trail and crisscrossed by primary, secondary, and tertiary trails. After determining circulation, focal areas could be chosen for further development. Two focal areas with differing programmatic scenarios were chosen in order to compare how differences in focal area design could influence final shade structure design. With these focal areas determined, we have spatially explicit spaces where we can apply climate projection data to the design process.

CASE STUDY FOCAL AREAS

STEP TWO

COMPARING WEATHER DATA

COLLECTING WEATHER DATA



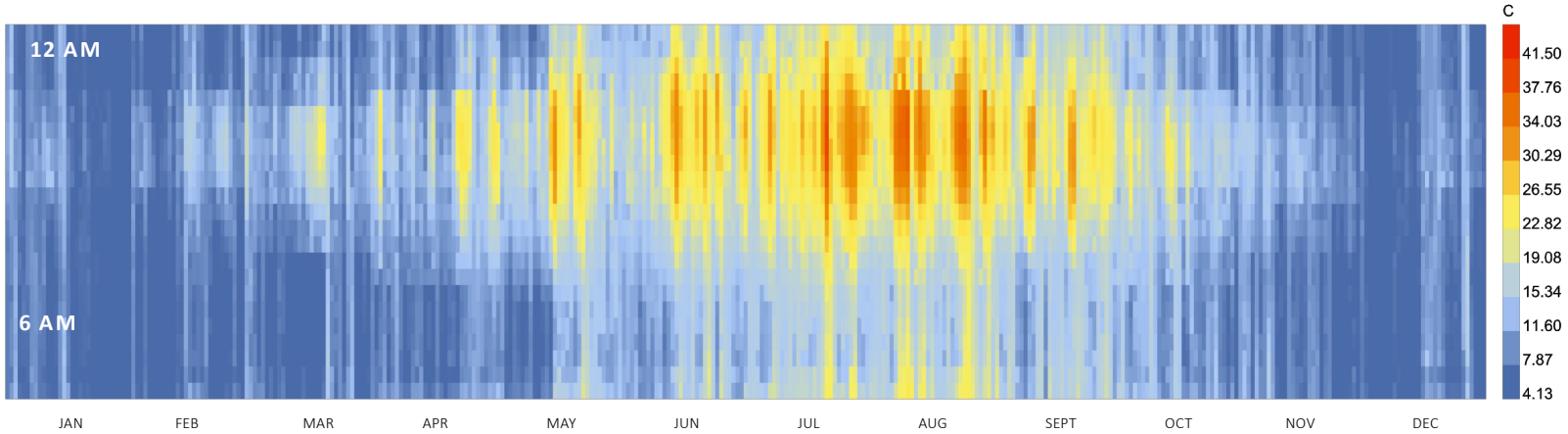
In order to create data-informed shade structures, we need weather data that can be applied in the design process. Typical Meteorological Year (TMY) datasets are a form of weather data that are compiled into datasets that can be utilized in design software for modeling and environmental simulation.

Real-time weather data is collected at locations such as the Portland International Airport. 15 to 30 years of collected weather data is used to construct a representative, or “typical”, year. **With alterations to weather patterns associated with climate change, including more intense seasonal extremes and longer and more frequent heat waves, the “typical” years constructed from historic weather data fail to account for the range of plausible future conditions** (Rastogi et. al., 2022).

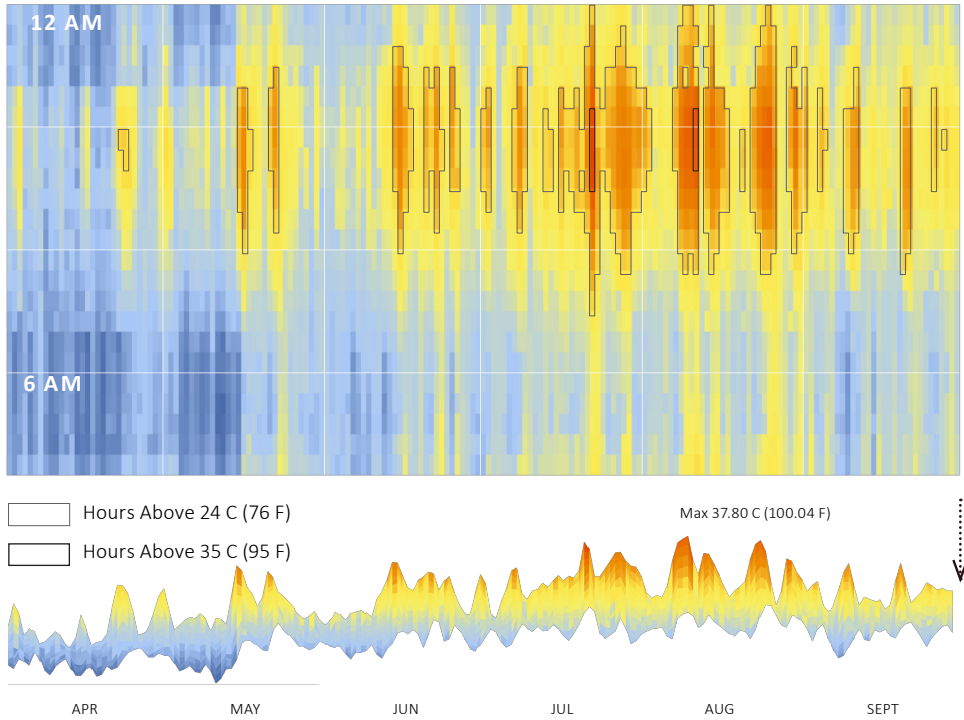
A TYPICAL METEOROLOGICAL YEAR DATASET

DRY BULB TEMPERATURES | HOURLY PLOT

HISTORIC WEATHER DATA



SUMMER ANALYSIS PERIOD OF INTEREST



This chart shows an example of a constructed, typical meteorological year of dry-bulb temperatures displayed by hour.

An analysis period corresponding to the proposed botanic garden’s highest visitation and programming times was applied. 24 C (76 F) is considered the upper limit denoting “No Thermal Stress” in the Universal Thermal Climate Index, above which thermal discomfort is expected. In this constructed weather dataset from historic weather measurements, the number of hours above 35 C (95 F) is only 7 hours total. From this dataset, we might expect a pleasant summer with one or two advisory days. This is not the data that will be used in this work. **To achieve environmental simulations that are more representative of plausible future conditions, we need to use Future Typical Meteorological Year (fTMY) datasets.**

Architects have been grappling with the issue of representative datasets for many years and have made strides in accounting for the impacts of climate change in modeling and simulation for testing building performance. Efforts to create future weather data projections for the design field using a strategy called “morphing” began nearly 20 years ago (Belcher et. al., 2005). “Morphing” combines present-day TMY observations with climate projection model outputs. In 2015, eXtreme Meteorological Year (XMY) datasets were proposed to account for extreme weather conditions which are removed from TMY datasets (Crawley & Lawrie, 2015). The use of these XMY datasets has become widespread in assessing building performance and efficiency. The projected weather datasets used in this project are “Future Meteorological Year (fTMY)” datasets which are developed from six downscaled climate change models for almost all counties in the United States (Chowdhury et. al., 2023).

The primary motivation for applying downscaled climate projection data to design is to accurately consider future climate conditions under climate change to test design performance (Crawley & Lawrie, 2015).

The field of landscape architecture lags behind in the application of downscaled climate projection data¹.

¹Laxo, Ariane. Personal interview. 4 November 2024.

“...WE ARE NOT GOING TO HAVE THE PERFECT INFORMATION WHEN IT COMES TO CLIMATE PROJECTIONS AND WE HAVE TO USE OUR PROFESSIONAL EXPERTISE TO MAKE PLAUSIBLE RECOMMENDATIONS ...WHAT COULD WE DO TO HELP SUPPORT (THE CLIENT) IN THAT FUTURE CLIMATE CONDITION”¹

Ariane Laxo, HGA Director of Sustainability

Climate projection data is derived from global climate models (GCMs), which simulate Earth’s climate system based on specific climate scenarios defined by “climate forcing”. Climate forcing refers to changes in the balance of energy in the Earth’s system due to factors like greenhouse gas concentrations, aerosols, or land use changes. These scenarios are often represented by pathways such as Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs), which outline different futures based on human activity (IPCC, 2013).

GCMs operate at coarse spatial scales (typically 100–300 km), which are insufficient for local or regional planning. **To make the data usable at finer scales, “downscaling” techniques are used.** There are two main types, dynamical and statistical. Dynamical downscaling uses regional climate models (RCMs) to simulate climate at higher resolutions over a specific area, nested within the GCM. Statistical downscaling uses observed historical relationships between large-scale climate patterns and local conditions to infer future local climates based on GCM outputs (Mearns et. al., 2003).

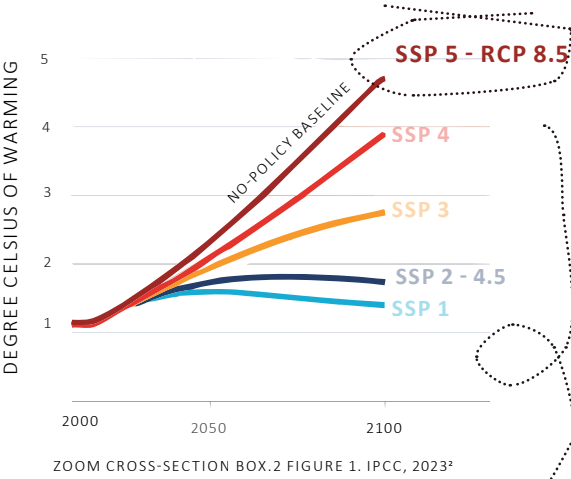
The result is downscaled data that incorporates the influence of global climate forcing while capturing local features such as topography, land cover, and urban effects - making it more relevant for local scenario planning, design development, and design performance testing. **Future Typical Meteorological Year (fTMY) datasets used in this work are created from six downscaled climate models** and can be easily utilized by designers in environmental simulation software such as Ladybug (Chowdhury et. al., 2023).

WEATHER DATA FROM DOWNSCALED CLIMATE MODELS

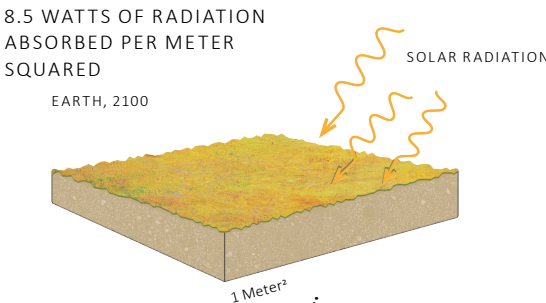
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CLIMATE SCENARIOS

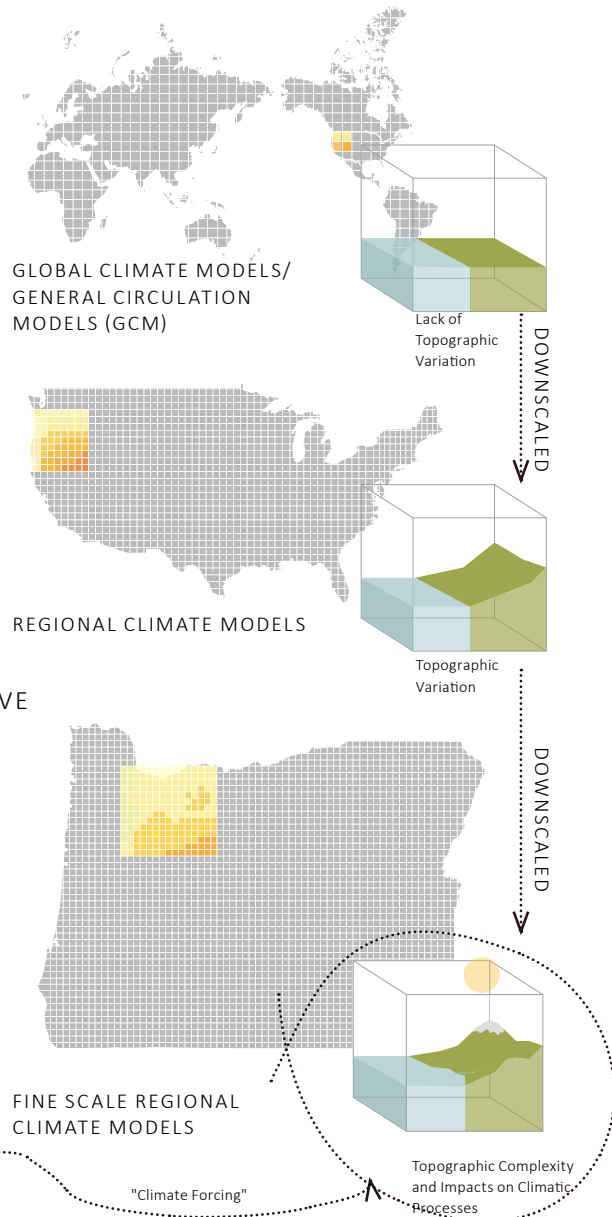
DEGREE CELSIUS OF WARMING PER SOCIOECONOMIC PATHWAY (SSP) SCENARIO BY 2100



SOCIOECONOMIC PATHWAY (SSP) 5 - REPRESENTATIVE CONCENTRATION PATHWAY (RCP) "8.5"

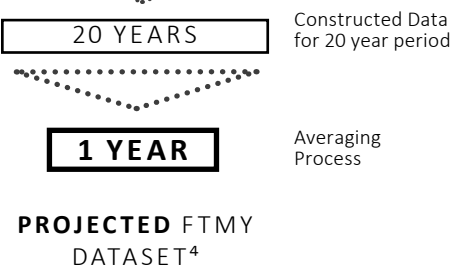


CLIMATE MODELS³



PROJECTED WEATHER DATA FROM DOWNSCALED CLIMATE MODELS

- WIND VELOCITY
- DRY BULB TEMPERATURE
- RELATIVE HUMIDITY
- DIRECT NORMAL RADIATION
- DIFFERENTIAL HORIZONTAL RADIATION
- HORIZONTAL INFRARED RADIATION

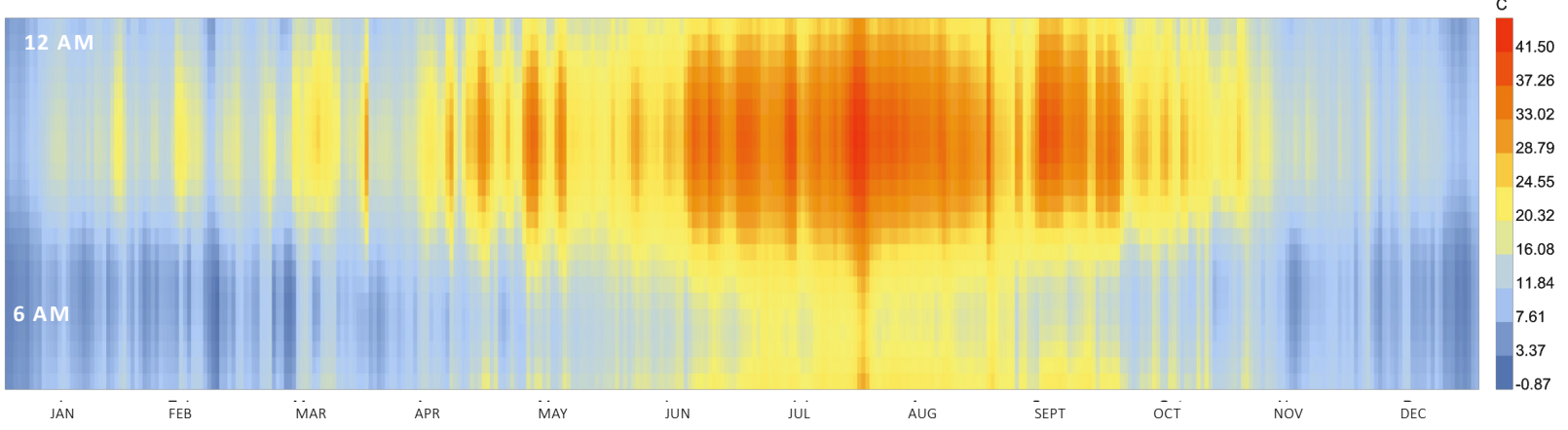


A FUTURE TYPICAL METEOROLOGICAL YEAR DATASET

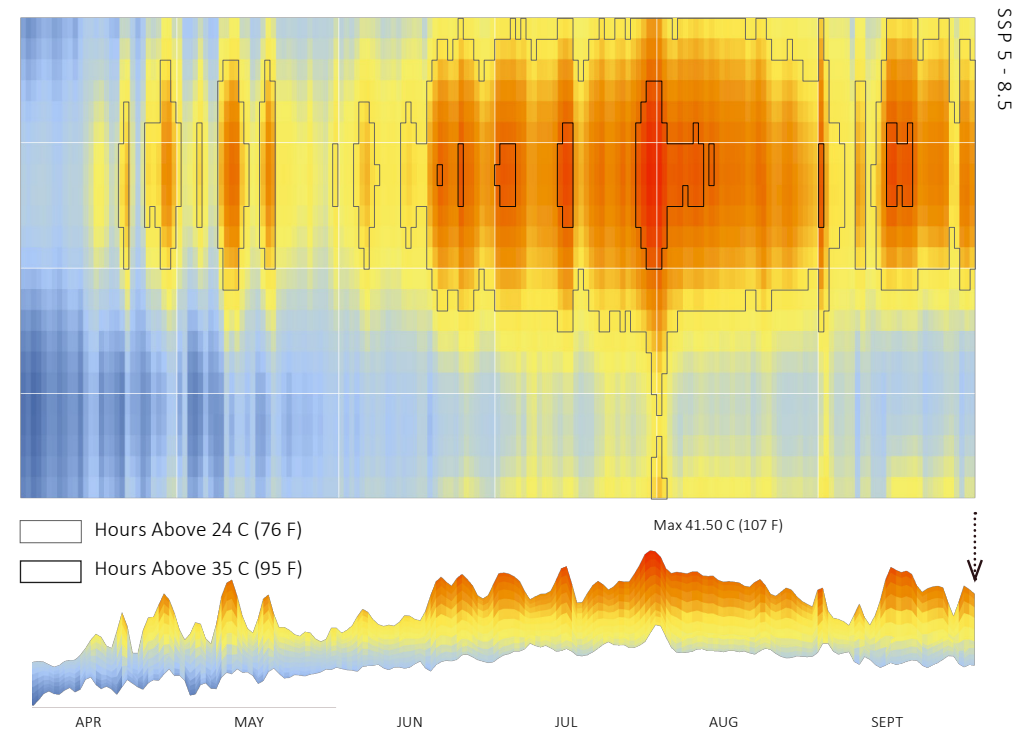
0 - 1 - 2 - 3 - 4

DRY BULB TEMPERATURES | HOURLY PLOT

+55 YEARS, 2080 - 2099 | WEATHER DATA FROM HIGH EMISSIONS CLIMATE SCENARIO



SUMMER ANALYSIS PERIOD OF INTEREST



This fTMY data *will* be used for environmental simulation in this work. The Oregon State Climatologists typically reference SSP 2 - 4.5 in downsampled climate models for Oregon State (Oregon Climate Service, Personal interview, 2024). In this project, scenario **SSP 5 - 8.5, or the high emissions scenario, is used in order to explore the projected upper limits of warming trends.** Projected weather datasets are created through the same averaging process as historic datasets, failing to account for extreme events. However, projected datasets still better describe plausible future conditions and extreme events can be accounted for in design recommendations.

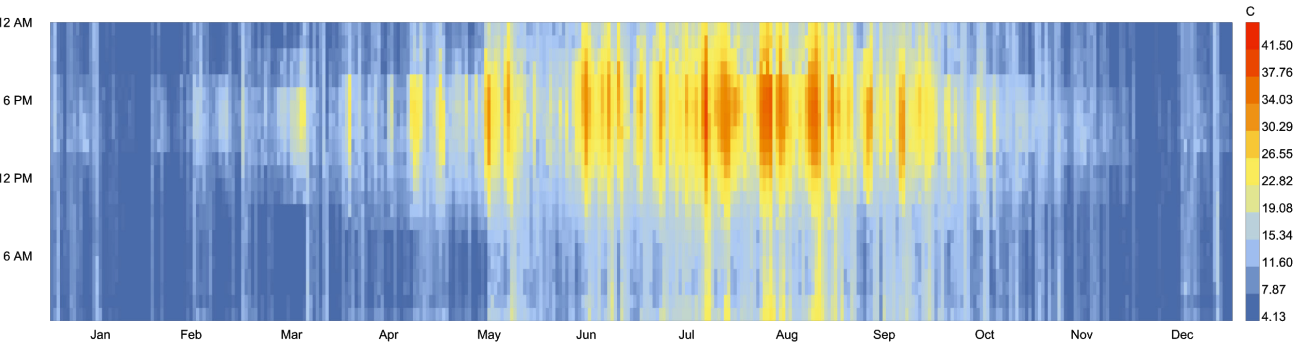
The number of hours above 35 C (95 F) rises considerably between the historic TMY dataset (7) and the projected fTMY dataset (over 180). This dataset gives a helpful indication of the magnitude of change we could expect between historic temperature measurements and plausible, future, temperature measurements. This produces a range of possibilities which allows for more informed scenario planning.

The projected fTMY datasets produce discrete numbers as outputs. The discrete weather data outputs, such as single air temperature measurements, are less important than understanding the magnitude of plausible change.

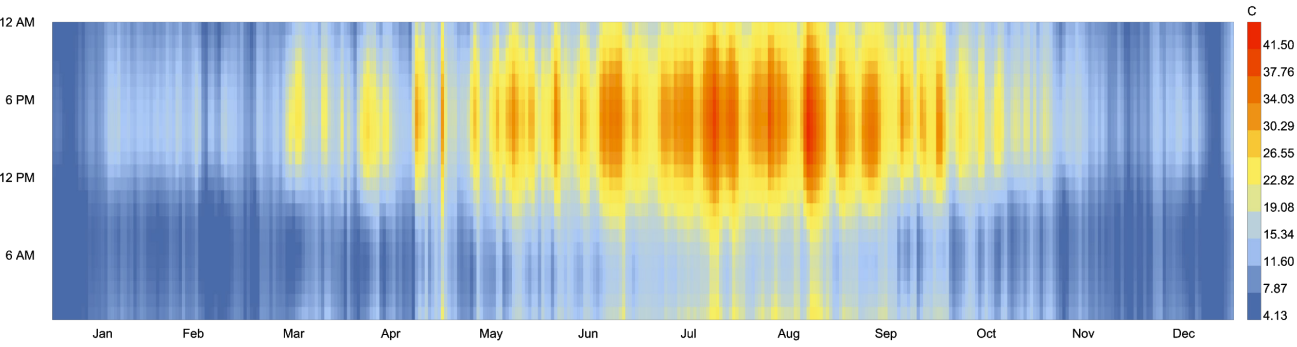
³Figure adapted from IPCC, 2023: Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II & III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee & J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647. ⁴Figure adapted from Commonwealth Science Industrial Research Organisation (CSIRO). "Key Concepts." Climate Change in Australia, climatechangeinaustralia.gov.au/en/projects/esri/learning-support/esri-key-concepts. Chowdhury, S., Li, F., Stubbings, A., New, J. R., (2023). Multi-Model Future Typical Meteorological (fTMY) Weather Files for nearly every US County. The 3rd ACM International Workshop on Big Data & Machine Learning for Smart Buildings & Cities & BuildSys '23. The 10th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, & Transportation, Istanbul, Turkey, November 15-16, 2023. DOI: 10.1145/3600100.3626637

COMPARING WEATHER DATASETS

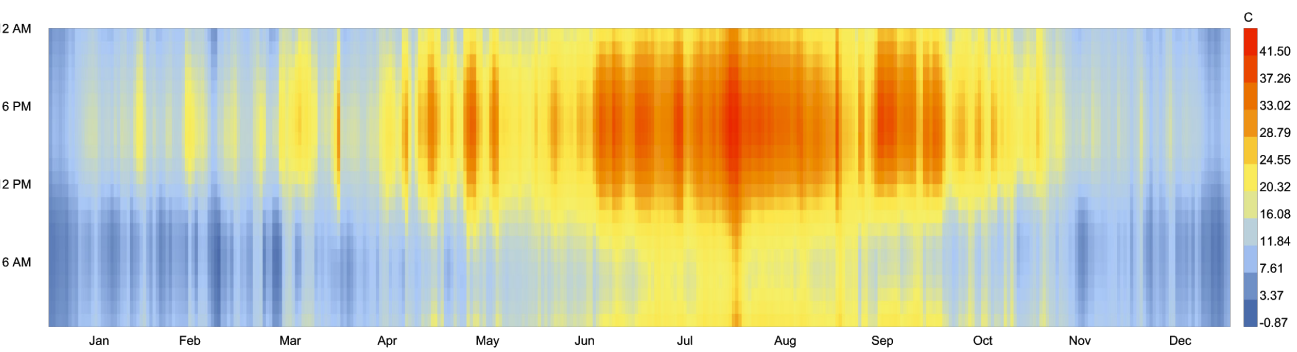
DRY BULB TEMPERATURES | HOURLY PLOTS



TYPICAL METEOROLOGICAL YEAR



PROJECTED FTMY, SSP 2 - 4.5



PROJECTED FTMY, SSP 5 - 8.5

The datasets created from climate projection models paint a different picture than the historic dataset, indicating that in the future, botanic garden visitors could more frequently be exposed to dangerous heat during the months of highest programming and visitation.

0 - 1 - 2 - 3 - 4

STEP THREE
APPLYING PROJECTED WEATHER DATA

THE COMFORTCOVER METHOD

Published in 2015, the ComfortCover Method (Mackey et. al., 2015) is a computational approach designed to optimize the design of outdoor shading structures for human thermal comfort using the program Ladybug. Unlike traditional shading strategies that focus primarily on reducing building energy loads, the **ComfortCover Method emphasizes enhancing outdoor human comfort by evaluating the thermal impact of shade** throughout the year. This method calculates adjusted radiant temperature received by someone in the environment, determines thermal comfort on an hourly basis, and maps the impact of shade on thermal experience.

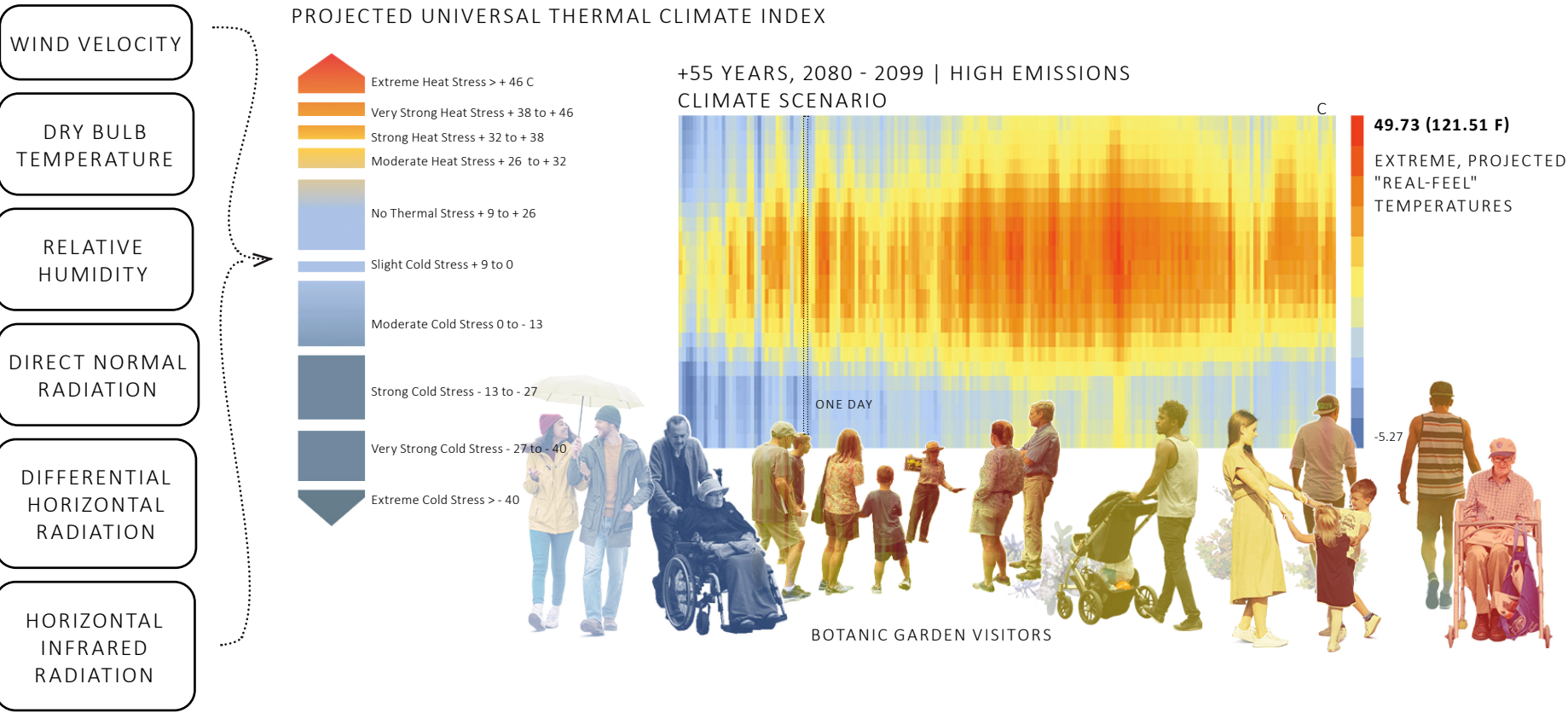
The ComfortCover Method has been employed or altered for use in a number of published studies to address shading requirements in urban areas experiencing urban heat island (UHI) effect (Elrefai & Nikolopoulou, 2023; Vartholomaïos & Kalogirou, 2020). Elrefai & Nikolopoulou (2023) produced a new simplified outdoor shading assessment method (OSAM) based on the ComfortCover Method to respond to a persistent lack of guidance and computational tools for the process of outdoor shade structure design. Vartholomaïos & Kalogirou (2020) similarly altered the ComfortCover Method to assess the usefulness of shading at the Venetian Port of Chania and weigh a set of scenarios. Neither study uses climate projection data in analysis.

AMENDED COMFORTCOVER METHODOLOGY



PROJECTED THERMAL EXPERIENCE

PROJECTED FTMY WEATHER
DATA FROM DOWNSCALED
CLIMATE MODELS

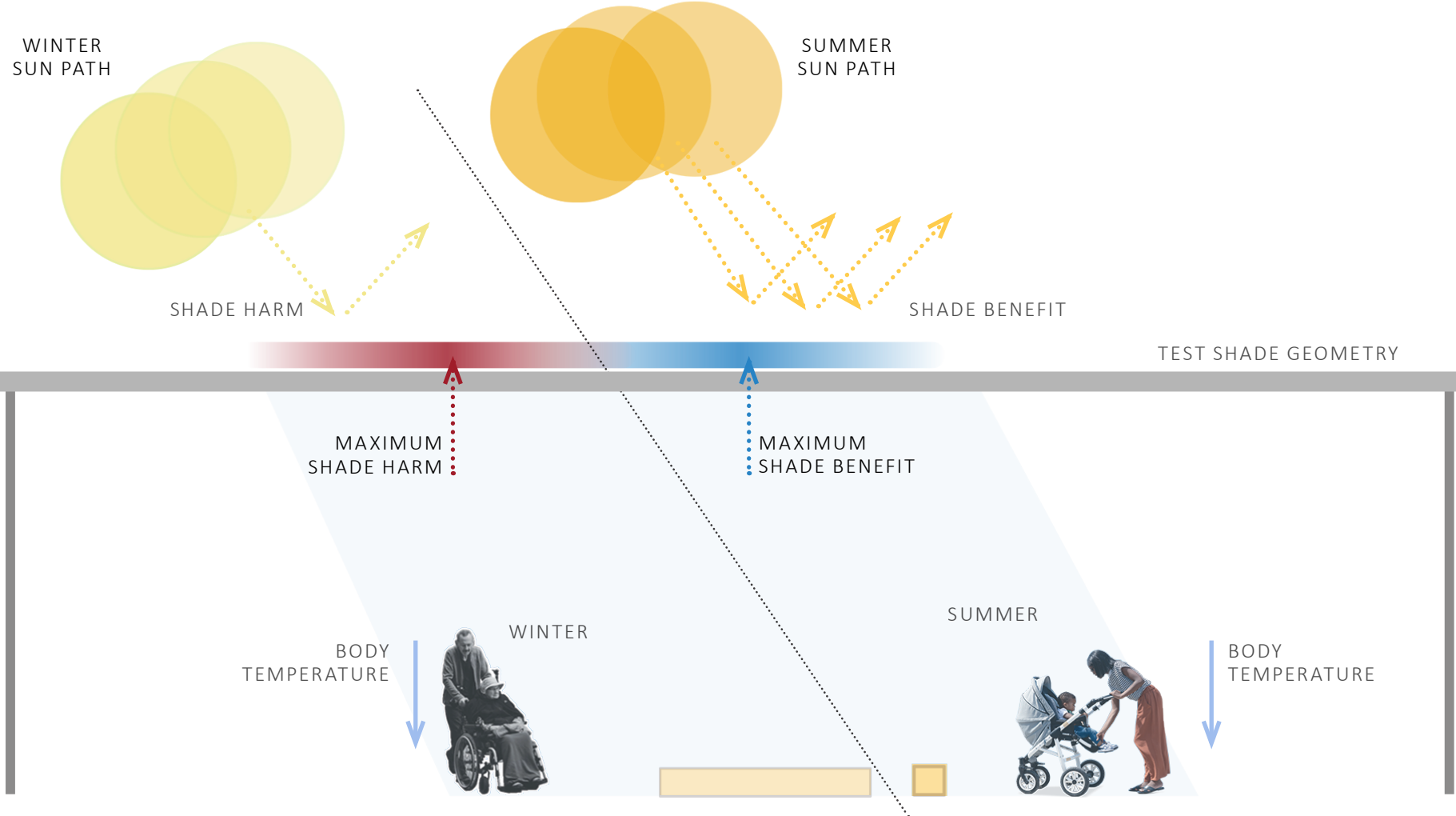


The ComfortCover Method uses the Universal Thermal Climate Index (UTCI) as the measure of thermal experience. The UTCI is a widely accepted index describing the presence or absence of stress related to “real-feel” temperature that was developed through, “international co-operation between leading experts in the areas of human thermophysiology, physiological modeling, meteorology, and climatology” (Błażejczyk et. al., 2013, p.5). The index uses the 6 weather variables shown above to produce measures of thermal experience.

Using projected weather data from the high emissions climate scenario (SSP 5 - 8.5) results in an extreme, maximum, projected UTCI value in the summer months.

THERMAL SHADE BENEFIT ANALYSIS

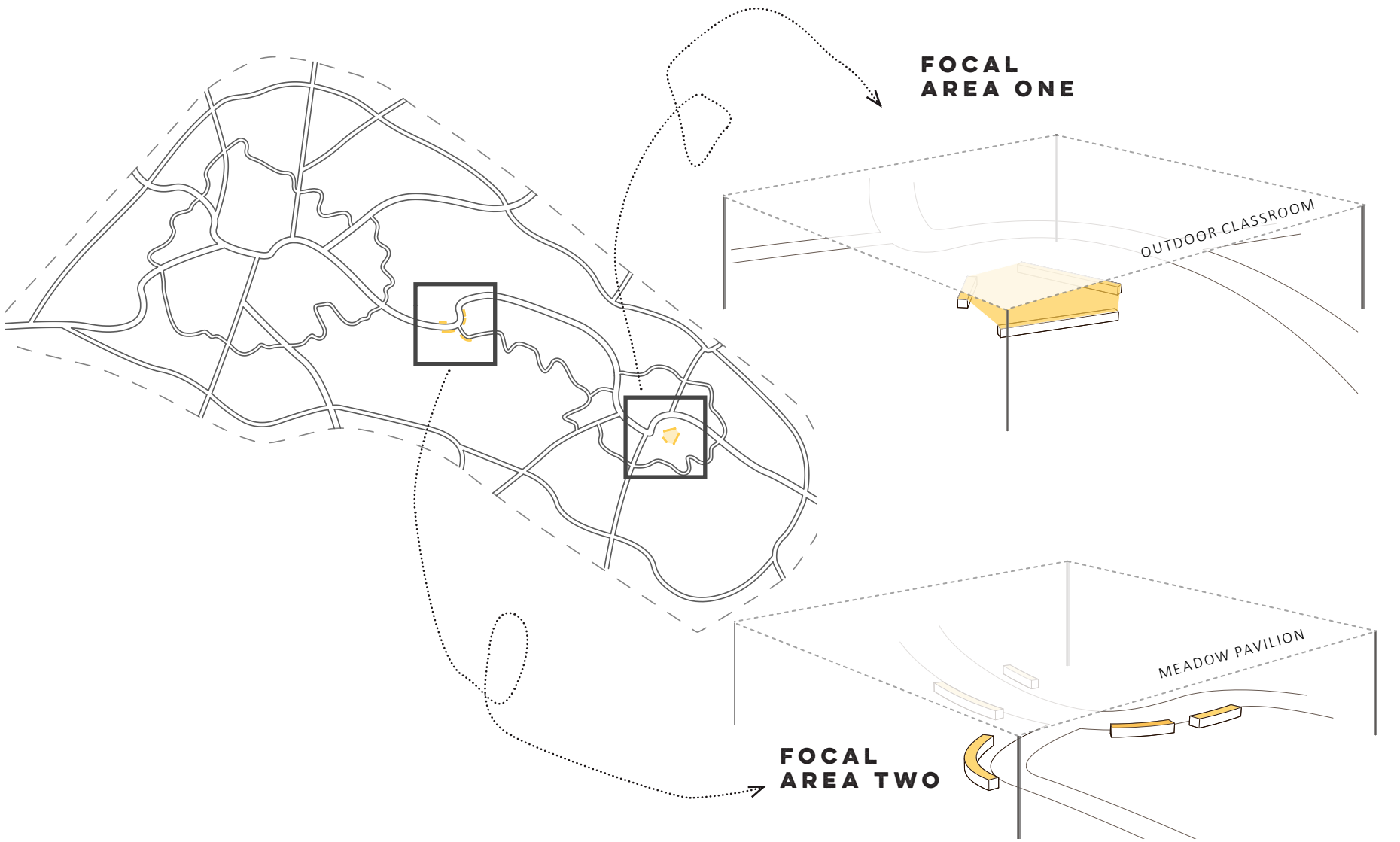
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From projected UTCI values, Thermal Shade Benefit Analysis determines the magnitude and coverage of shade benefit versus shade harm in an area of interest. For example, in the summertime, the presence of shade reduces body temperature, resulting in **shade benefit** when exposure to radiation is reduced and thermal experience drops within the range of “no thermal stress”. The presence of shade in the wintertime, relative to a space where people are gathering, similarly lowers body temperature, producing **shade harm** when exposure to radiation is reduced and thermal experience drops outside of the range of “no thermal stress” .

APPLYING THERMAL SHADE BENEFIT ANALYSIS

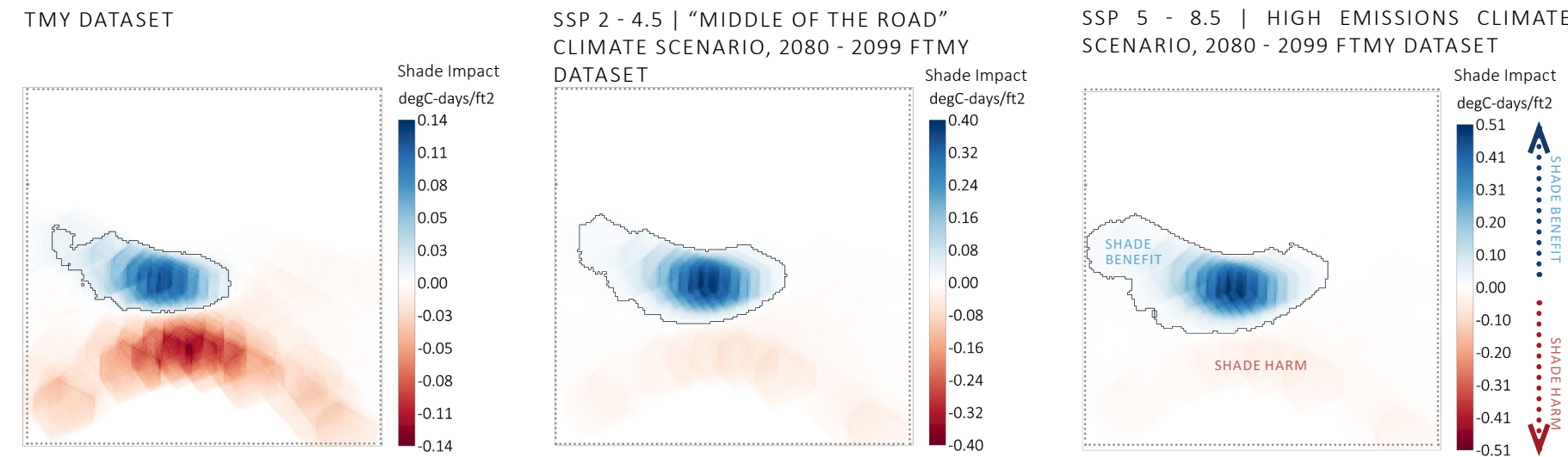
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Thermal Shade Benefit Analysis was applied to the two focal areas determined from trail scenario two. Each focal area has a differing study area design based off of proposed programming. The outdoor classroom provides a space where people might gather for longer periods of time for garden-related educational experiences. In contrast, the waypoint covers a smaller area, where people might rest for shorter periods of time. The same overhead shade geometry area was applied to both sites to providing a mapping area for the Thermal Shade Benefit Analysis.

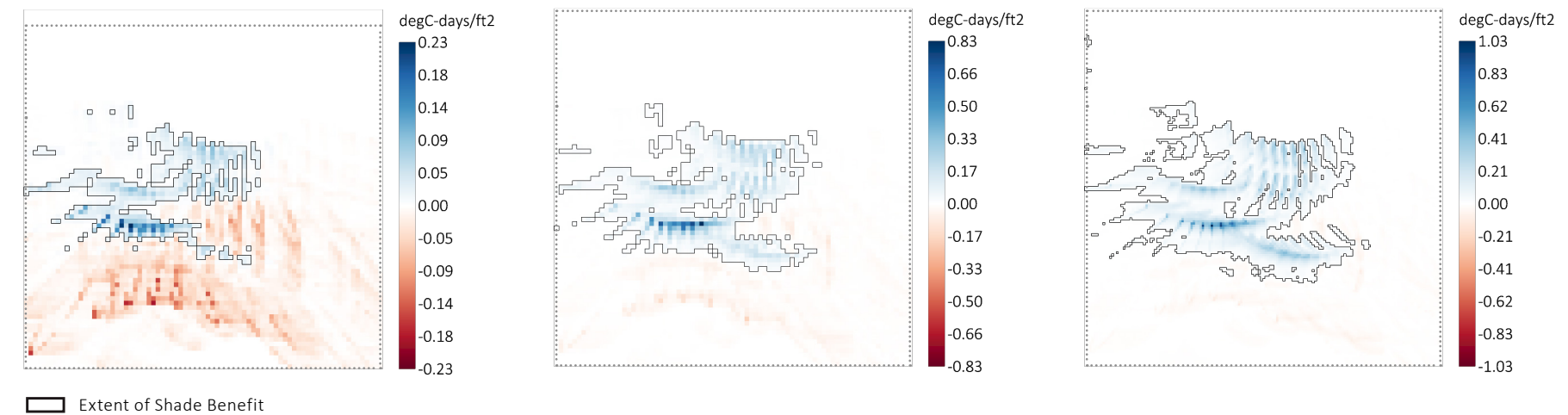
COMPARING RESULTS BETWEEN DATASETS

0 - 1 - 2 - 3 - 4



PLAN VIEW

INCREASING SHADE BENEFIT MAGNITUDE AND EXTENT



The high emissions climate scenario (SSP 5 - 8.5) indicates the greatest magnitude of shade benefit. The area of shade harm is reduced significantly between the TMY and high emissions fTMY dataset. In each analysis, the total extent of shade benefit is marked in order to show how the total area of shade benefit marked in blue increases between the TMY dataset and the fTMY datasets.

DISCUSSING CONSTRAINTS & LIMITATIONS

0 - 1 - 2 - 3 - 4

The modeling and simulation tools used in this work are commonly employed by landscape architects to inform design decisions and evaluate performance outcomes. Tools such as Thermal Shade Benefit Analysis are valuable for simplifying complex environmental conditions, but their accuracy is inherently tied to the quality of input data (Lindquist & Gibbons, 2024). Despite these limitations, environmental simulation remains a critical component of both design and engineering practices. For example, environmental simulation with the tool Ladybug for Rhino3D has been studied and validated for accuracy when compared to real-world site outcomes (Nicholson et. al., 2022).

The selection of the SSP 5 - 8.5 TMY weather dataset for utilization in the ComfortCover methodology is based on two key assumptions. First, it assumes that a high emissions climate projection scenario provides a useful basis for anticipating future site conditions. Second, it presumes that the six climate projection models used to generate the dataset produce plausible future outcomes for this site. The plausibility of model outcomes is a broad topic of climate research. In an analysis of climate projection models from 1970 to the early 2000’s, Hausfather et. al. (2019) found that these models were skillful in predicting changes to global mean surface temperatures when validating them against actual change. While larger ensembles, typically comprising more than ten climate models, can increase confidence in predictions, such datasets are often inaccessible to design professionals (O’Malley & Laxo, 2019). Nevertheless, the use of six, downscaled climate models provides greater reliability than single-model projections.

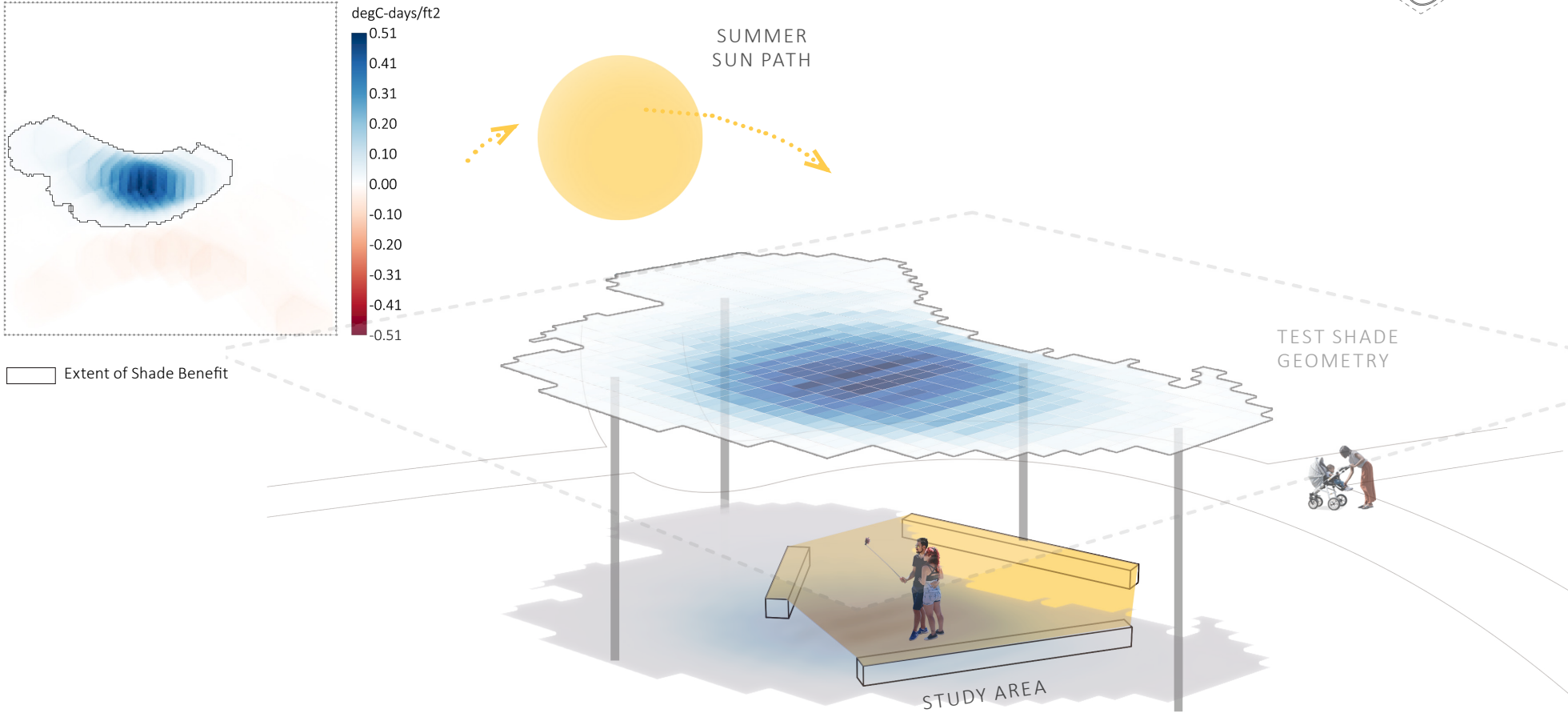
A final limitation of the dataset is that its hourly weather metrics are averaged across many years of projected data. This process smooths out extreme weather events, potentially under representing their future impact. My interest in this topic was partly sparked by the 2021 Heat Dome event in the Pacific Northwest, an example of the kinds of extreme heat events that are projected to become more frequent and prolonged due to climate change (Bartusek et al., 2022). These extreme events should be considered as possible “worst case scenarios”, informing how landscape architecture can help mitigate health risks for the public under future climate conditions.

STEP FOUR

SHADE INFRASTRUCTURE DEVELOPMENT FROM THERMAL
SHADE BENEFIT ANALYSIS

DETERMINING STRUCTURAL EXTENT

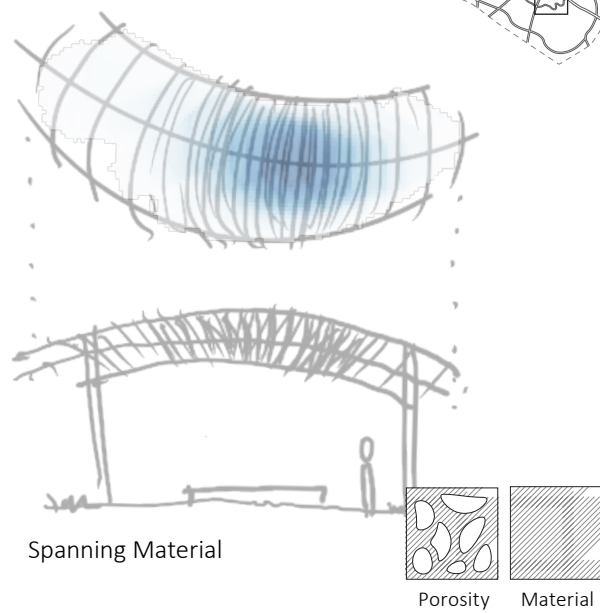
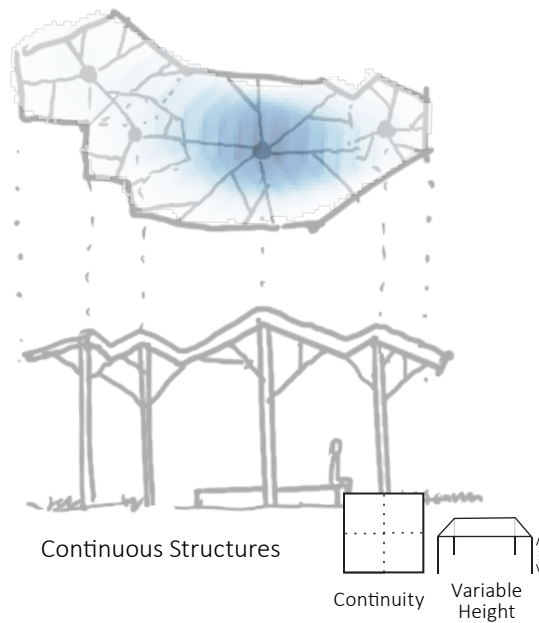
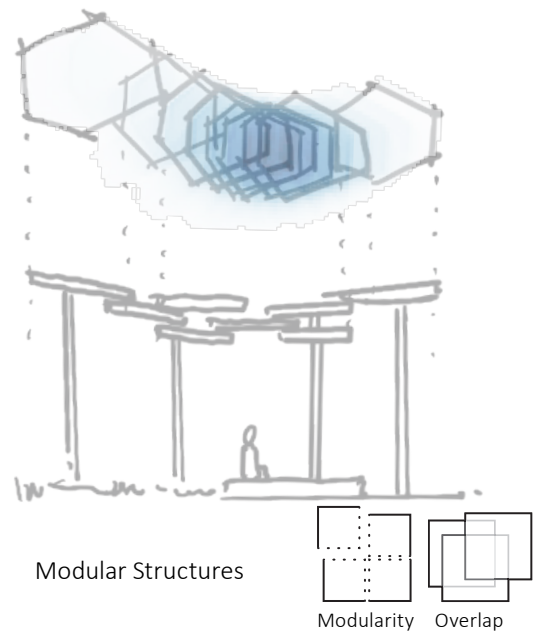
SSP 5 - 8.5 | HIGH EMISSIONS
CLIMATE SCENARIO, 2080 - 2099 DATASET



The analysis identifies where and how much shade creation would meaningfully improve human thermal comfort under the high-emissions climate scenario (SSP 5 - 8.5). This mapping of shade impact becomes the basis for the extent and positioning of a final shade structure.

SHADE STRUCTURE DESIGN ITERATIONS

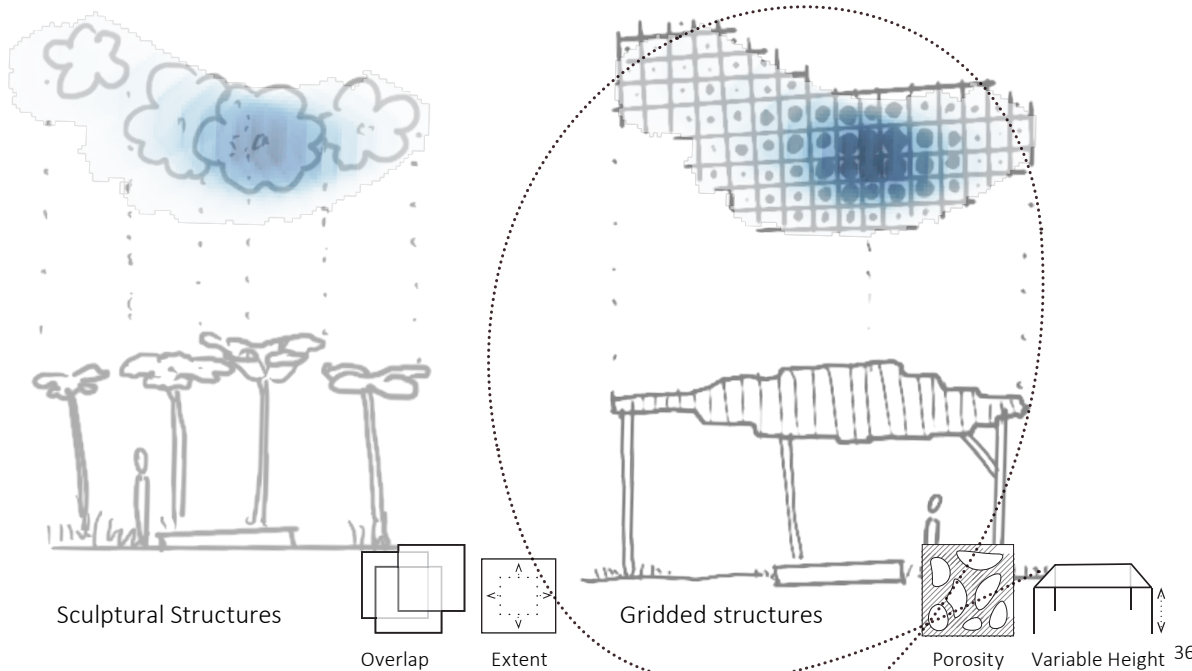
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“TECHNOLOGY IN ITSELF DOES NOT INSPIRE DESIGN INNOVATION. INSTEAD IT IS THE QUESTIONS OR INTENT THAT DRIVES THE DESIGNER IN THEIR USE OF TECHNOLOGY THAT PROVIDES THE FOUNDATION FOR NOVEL OUTCOMES”¹

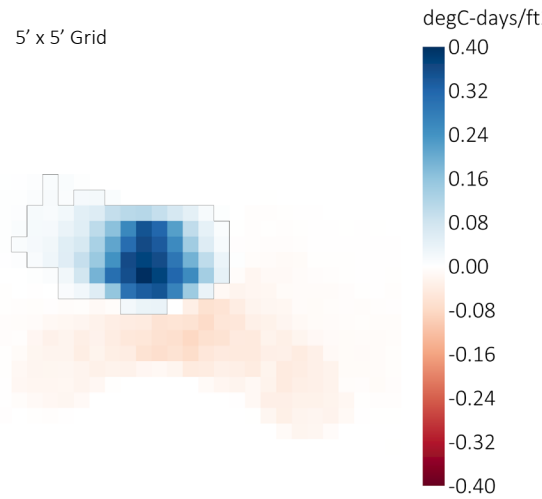
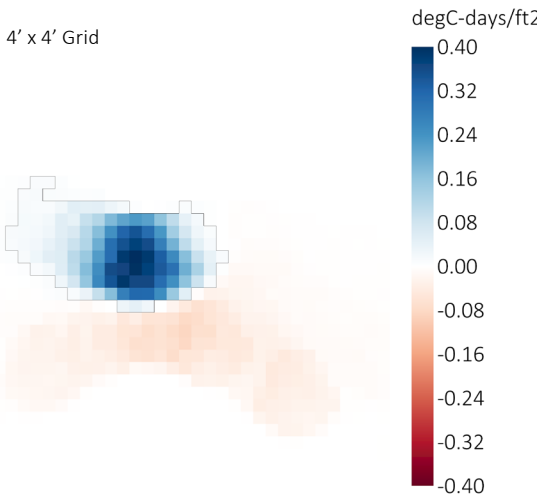
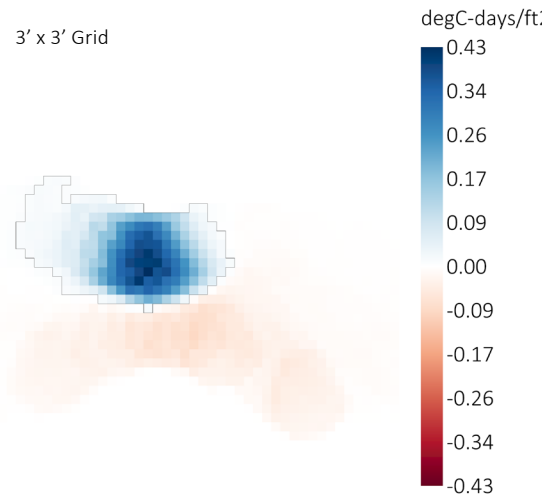
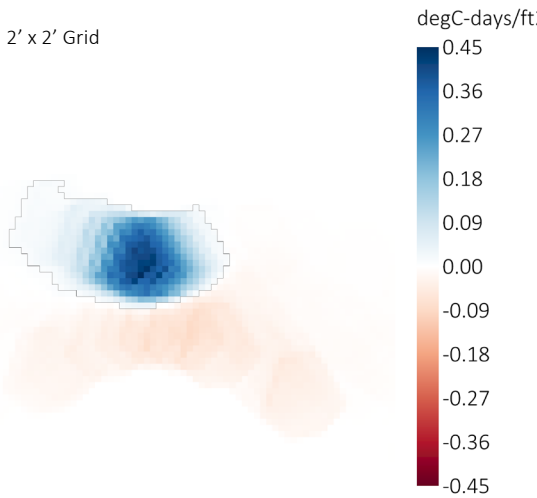
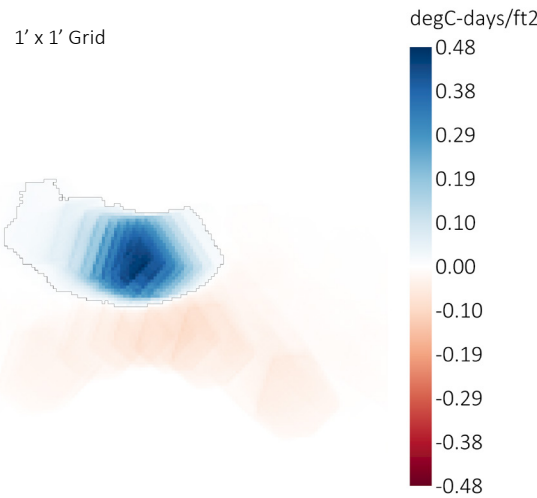
The translation of climate data into design begins here with shade structure design iterations. The shade structure design characteristics gained through precedent study were used to iteratively explore different categories of shade structure options.

¹Walliss, Jillian, and Heike Rahmann. Landscape Architecture and Digital Technologies : Re-Conceptualising Design and Making. Routledge, 2016.



GRID RESOLUTION

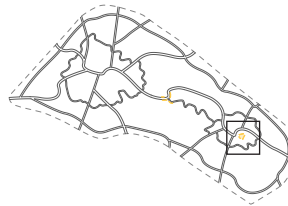
0 - 1 - 2 - 3 - 4



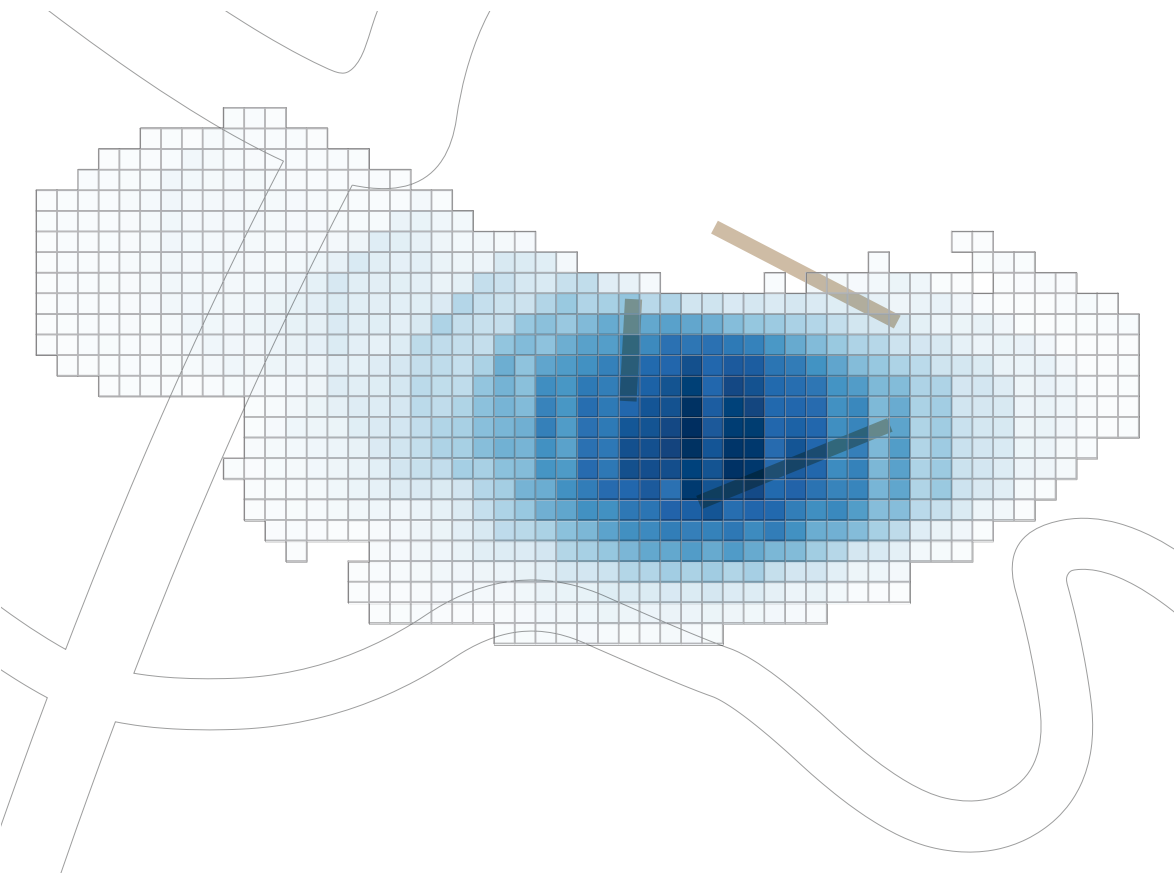
The Thermal Shade Benefit Analysis can be conducted at different spatial resolutions. The resolution, or data grid size, can be directly translated into dimensions for each built unit of the final infrastructure. The 2' by 2' grid was chosen as the final unit dimensions as it produces a fine-scale Thermal Shade Benefit Analysis and is an easily constructible unit dimension.

OUTDOOR CLASSROOM DEVELOPMENT

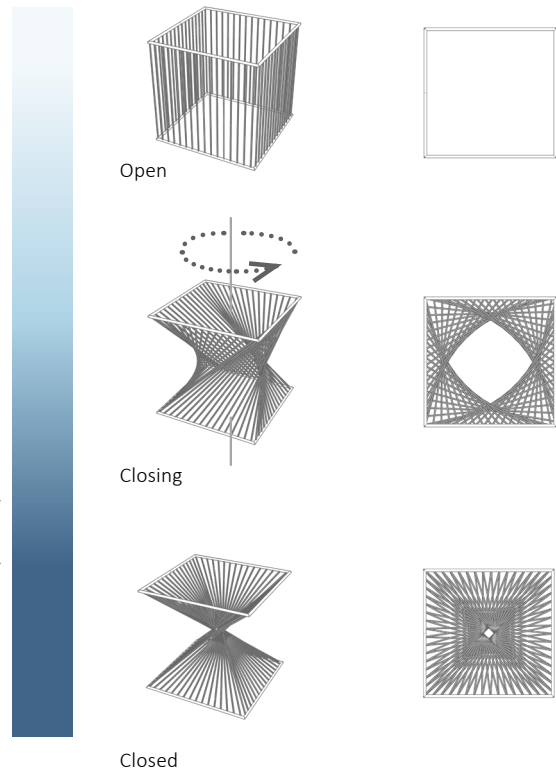
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VARIABLE SHADE BENEFIT



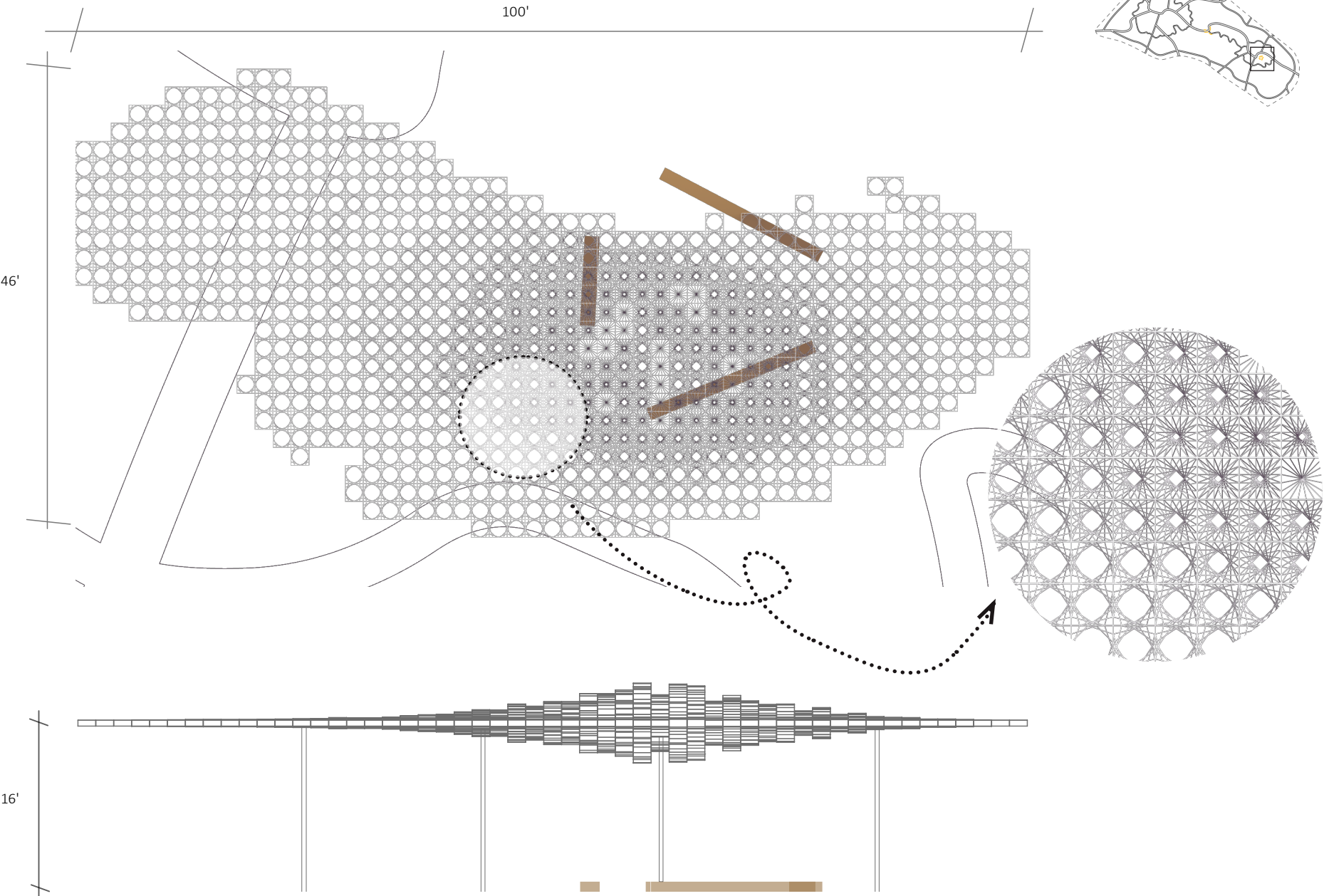
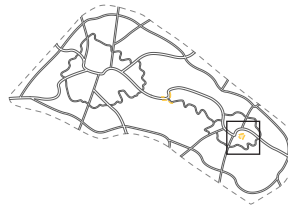
VARIABLE UNIT CLOSURE



The grid frame contains 2' by 2' square units. Using Grasshopper for Rhino 3D, it is possible to translate the shade benefit value directly into the level of closure for each unit of the grid. The open unit aperture allows the most sunlight through while the closed aperture lets the least amount of sunlight through, thus producing variable shading across the shade structure based on shade benefit value. The height of each unit is similarly informed by the shade benefit value.

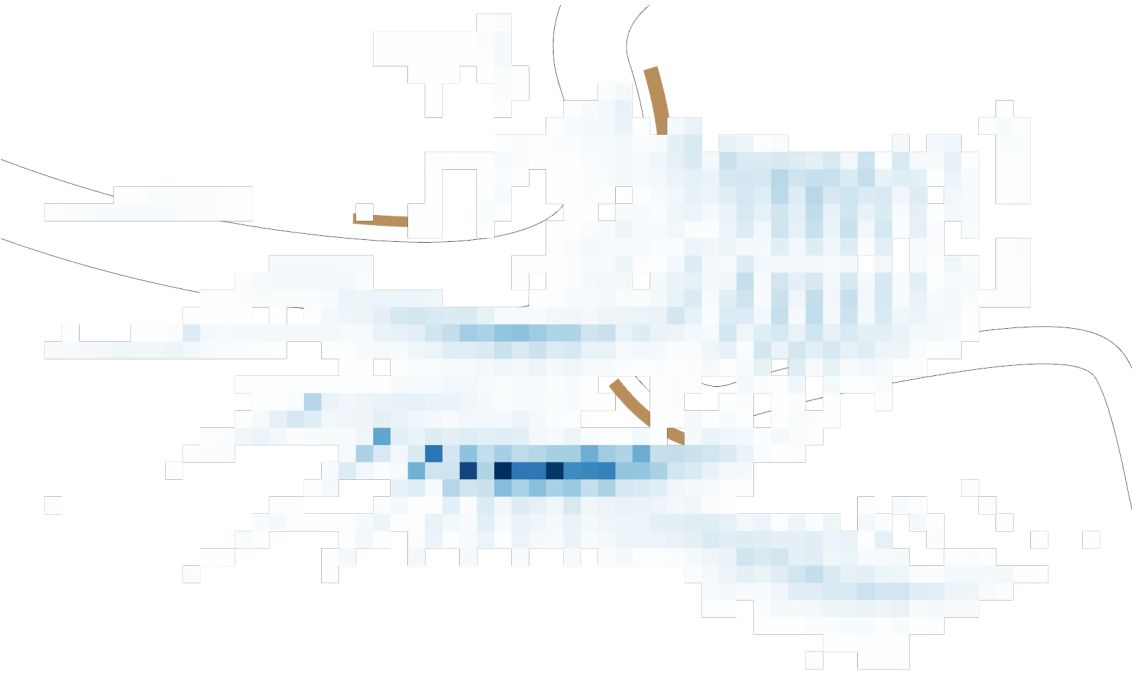
VARIABLE POROSITY AND SHADING

0 - 1 - 2 - 3 - 4

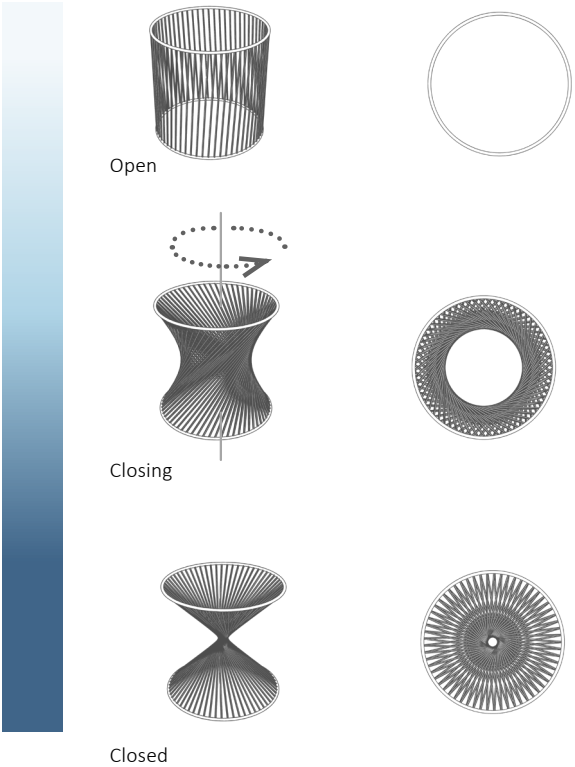


WAYPOINT DEVELOPMENT

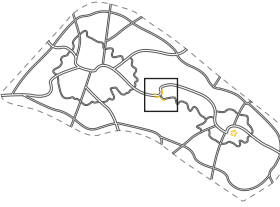
VARIABLE SHADE BENEFIT



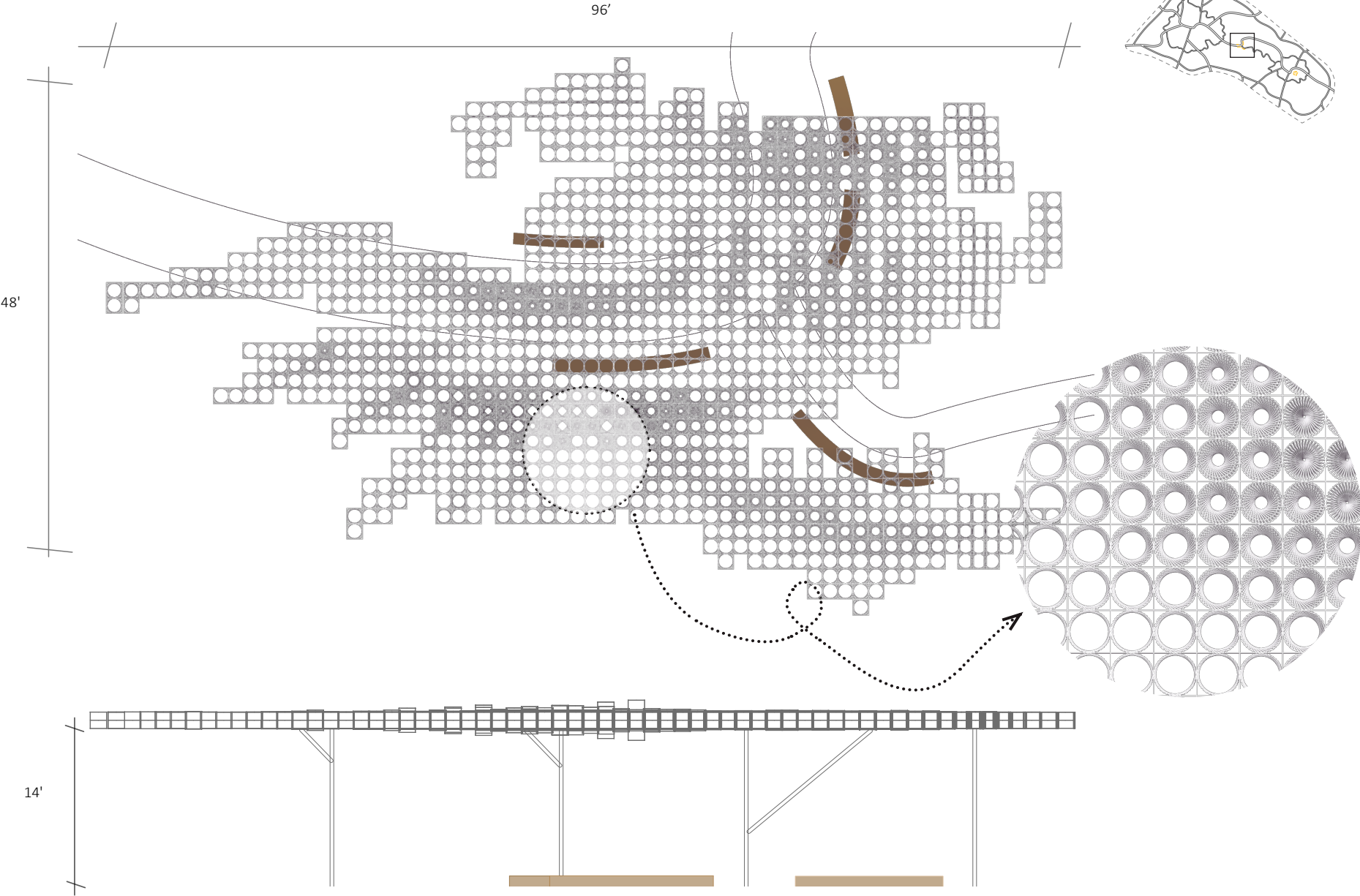
VARIABLE UNIT CLOSURE



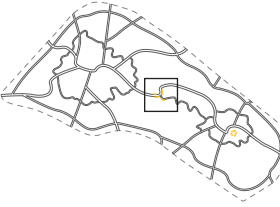
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VARIABLE POROSITY AND SHADING



0 - 1 - 2 - 3 - 4

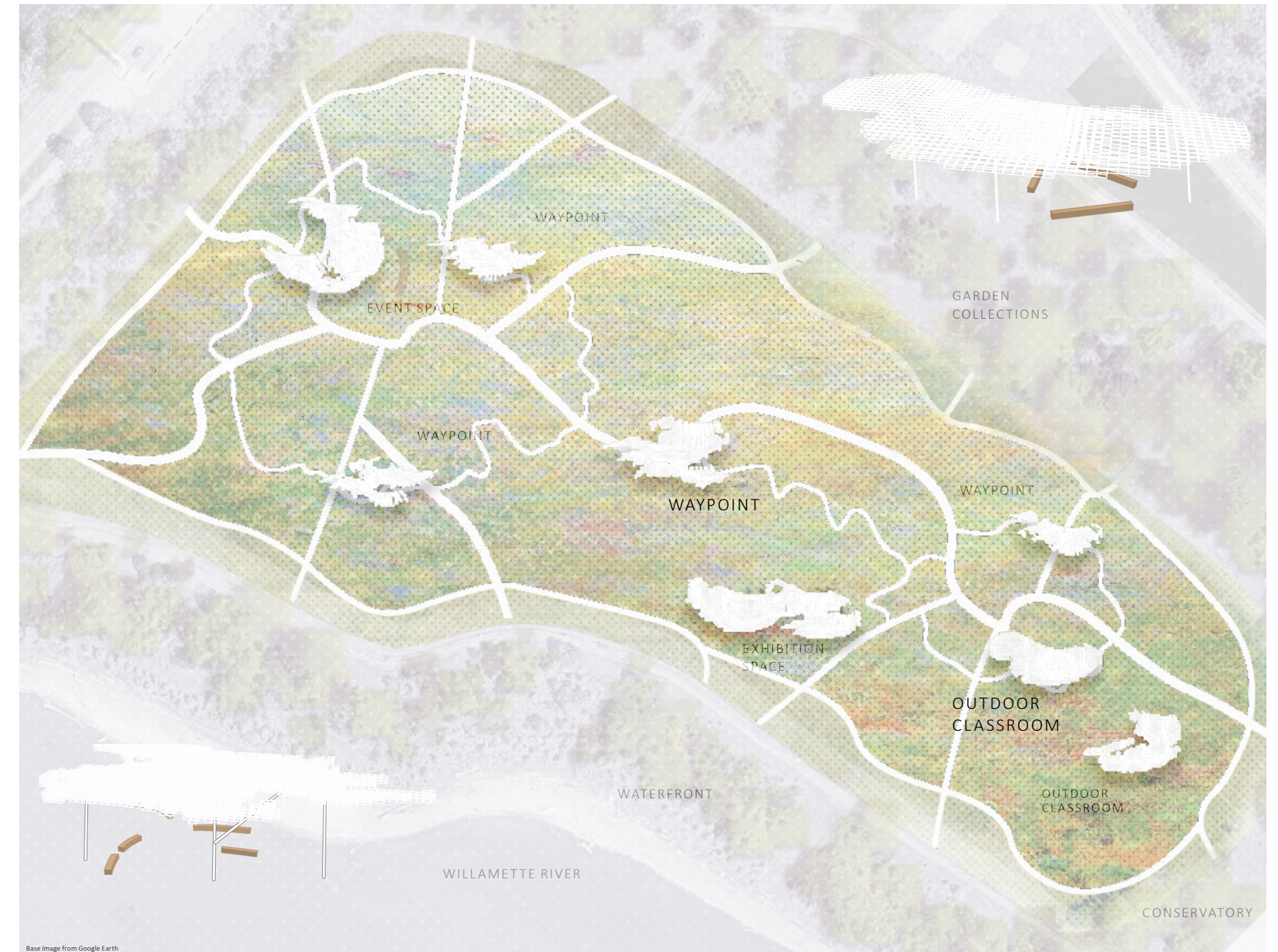


The resulting structures are informed by data but artistic in execution. The gridded frame has infinite potential for supporting botanic garden related installations.

CLOUD FORMATIONS

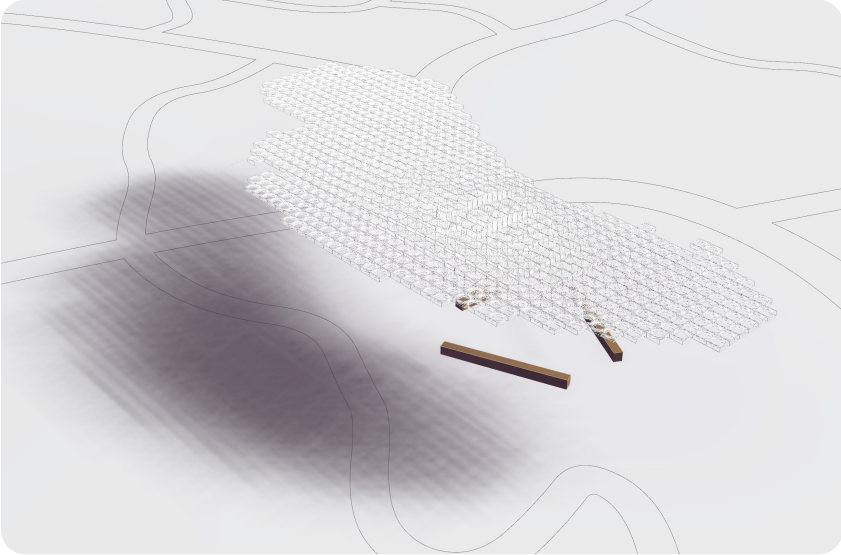
DATA INFORMED SHADE INFRASTRUCTURE AT THE
PORTLAND BOTANICAL GARDENS

SITE WIDE APPLICATION

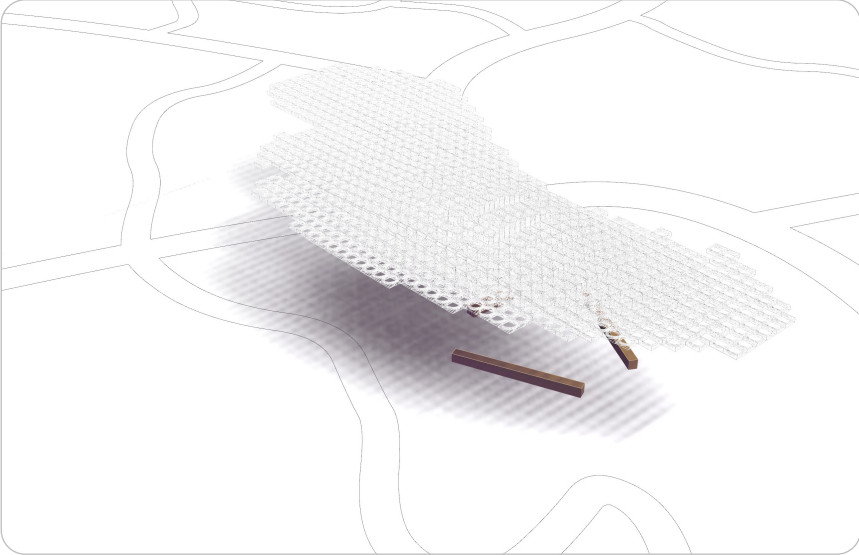


SEASONAL DIFFERENCES

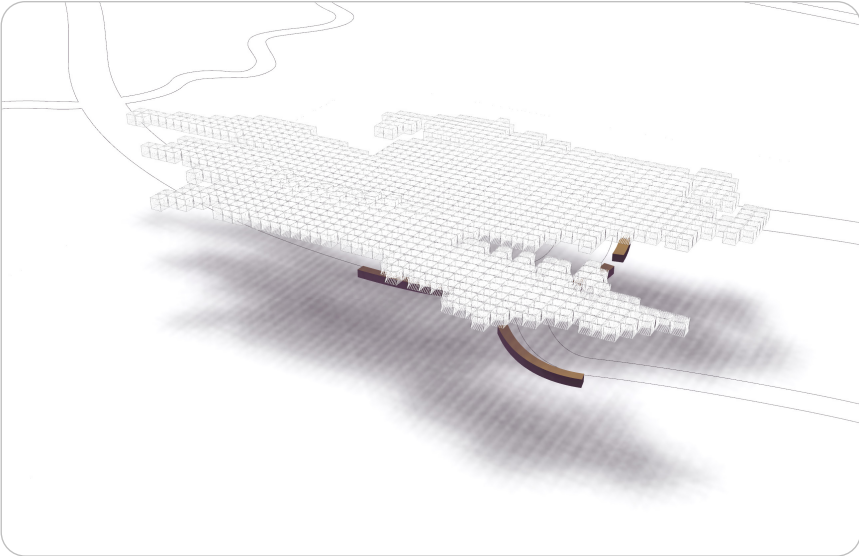
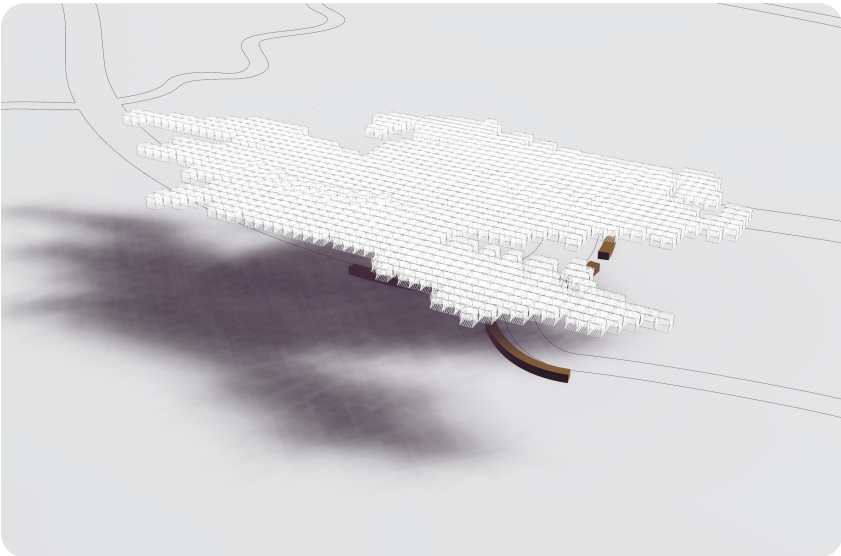
GREATER SUN EXPOSURE, WINTER, FEB 22ND



REDUCED SUN EXPOSURE, SUMMER, AUG 22ND



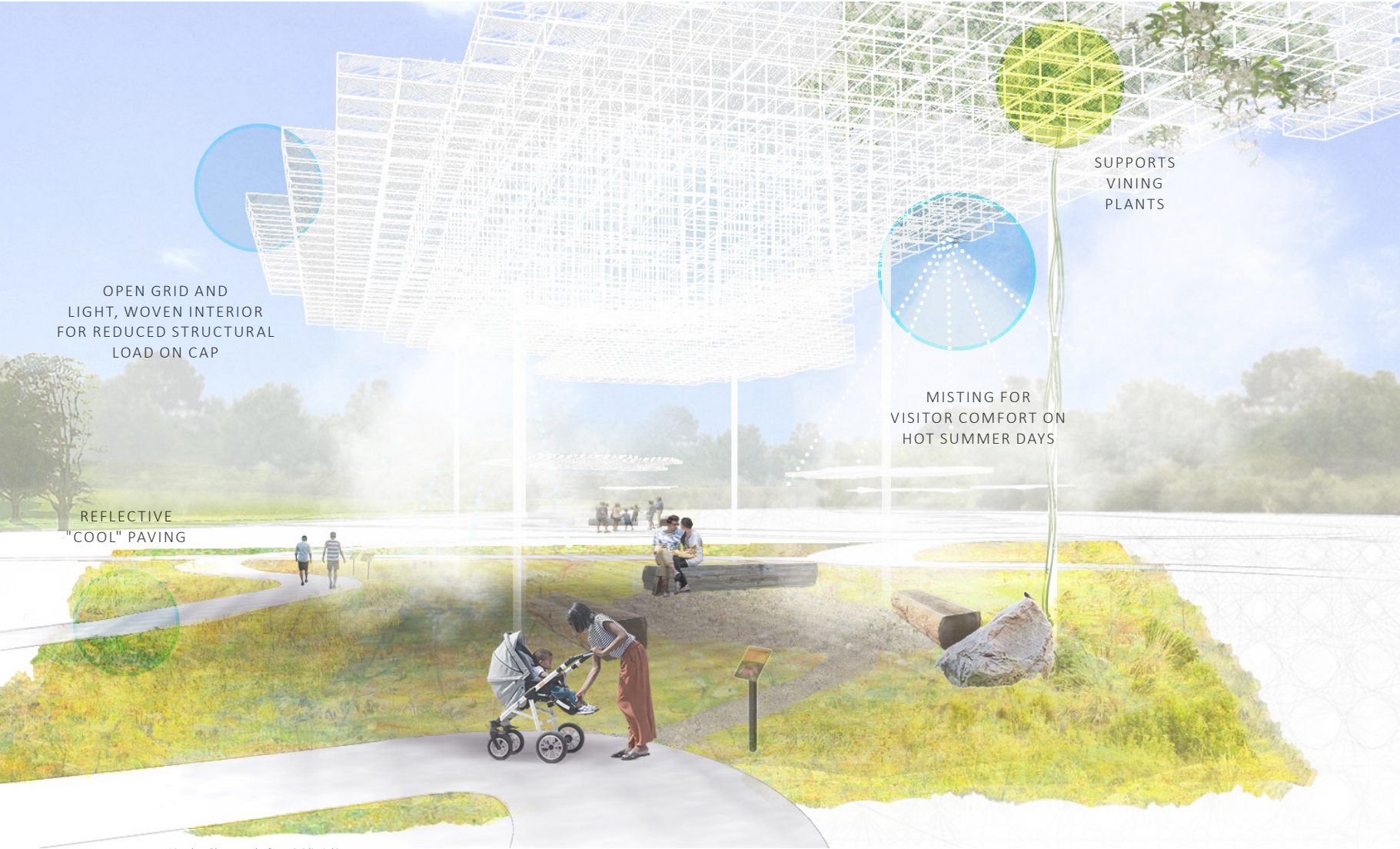
OUTDOOR CLASSROOM



MEADOW WAYPOINT

This shading study helps illustrate how sun exposure is greater in the wintertime in comparison to the summertime, which is a primary goal of using Thermal Shade Benefit Analysis to guide decisions about the form and extent of shade structures.

HUMAN-SCALE EXPERIENCE



These structures serve not only as functional elements to reduce heat stress but also as sculptural expressions of climate data, visible & experiential to future botanic garden visitors. Future summer temperatures necessitate interventions beyond, and complementary to, the shade structure. Misting and overhead vegetation are additional heat mitigating measures that can be supported by the gridded frame. The new structures resemble clouds dotted across the landscape, representing the physical manifestation of climate projection data.



CONCLUSION

“LANDSCAPES PLAY A PIVOTAL ROLE IN MEDIATING URBAN MICROCLIMATES, INFLUENCING TEMPERATURE VARIATIONS, AND MITIGATING THE IMPACTS OF EXTREME HEAT EVENTS. ...FURTHERMORE, AS CITIES GRAPPLE WITH THE ESCALATING EFFECTS OF CLIMATE CHANGE, **LANDSCAPE ARCHITECTURE SERVES AS A CRITICAL TOOL FOR CLIMATE ADAPTATION AND RESILIENCE.**”¹

This project bridges the gap between global climate models and human-scale design, presenting a novel application of downscaled climate projection data in landscape architecture. Using a remediated Superfund site as a case study, it translates future-focused data into innovative shade infrastructure that addresses urban heat and site constraints. Post-industrial sites present unique challenges for adaptive development, often presenting constraints that limit the use of green infrastructure interventions. Despite these constraints, this project provides a case study for creatively incorporating data about future climate conditions into site design processes in order to positively impact future exposure and thermal experience for botanic garden visitors. This research-driven design approach offers a replicable model for site-responsive climate adaptation, situating landscape architecture as a vital bridge between data, infrastructure, and public comfort in a warming world.

¹Lindquist, S., & Gibbons, K. (2024, September). Thermal Toolkit: Technologies and techniques for visualizing heat. Landscape Architecture Foundation. <https://www.lafoundation.org/media/thermal-toolkit-technologies-and-techniques-for-visualizing-heat>

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