Heat and Air Quality Resilience Mapping

2023

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Purpose

Heat and air quality issues caused by climate change and gas-powered vehicles affect San Francisco communities differently. Tree canopy that would buffer the effects is not equally distributed due to historic racial inequities in infrastructure investment.

To positively affect public health and leverage new federal funding sources, the City and other stakeholders are planning for green infrastructure investments, such as tree planting, sidewalk landscape zones, cool pavement, structural shading, green schoolyards, and increased areas of stormwater management. This project identifies locations where these strategies could have the highest benefit to community health and make the most effective use of City investment.

Overview

SF Public Works mapped a combination of environmental and health data to identify the priority zones. The study layers exposure to fine particulate matter (PM2.5), satellite temperature readings from a recent heat wave, and tree canopy data to identify where exposure is the highest. To further refine the prioritization zone, data was added for residents experiencing asthma or diabetes hospitalizations which are both exacerbated by heat and air quality issues. This created two final maps focused on heat and air quality that combine environmental data and human health.

The assessment includes an overview of the streetscape typologies prevalent in the priority zones to highlight opportunities, constraints, and associated recommendations.

Who Should Use This Resource

This information can be used by public agencies to support grant applications, funding requests, or policymaking. It can also be a resource for community organizations for fundraising, advocacy, or education efforts.

Acknowledgements

The Heat and Air Quality Resilience Green Infrastructure Priority Zone was developed through a partnership between the San Francisco Office of Resilience and Capital Planning (ORCP), San Francisco Public Works, and the San Francisco Department of Public Health Climate and Health Program. This resource supports the implementation of the HAQR Implementation Plan which includes strategies to increase the equitable distribution of green infrastructure across the city.

Jennifer Cooper, Ava Ross, Winnie Chang, and John Seagrave (SF Public Works); Matt Wolff (DPH); Brian Strong, Melissa Higbee and Alex Morrison (ORCP)
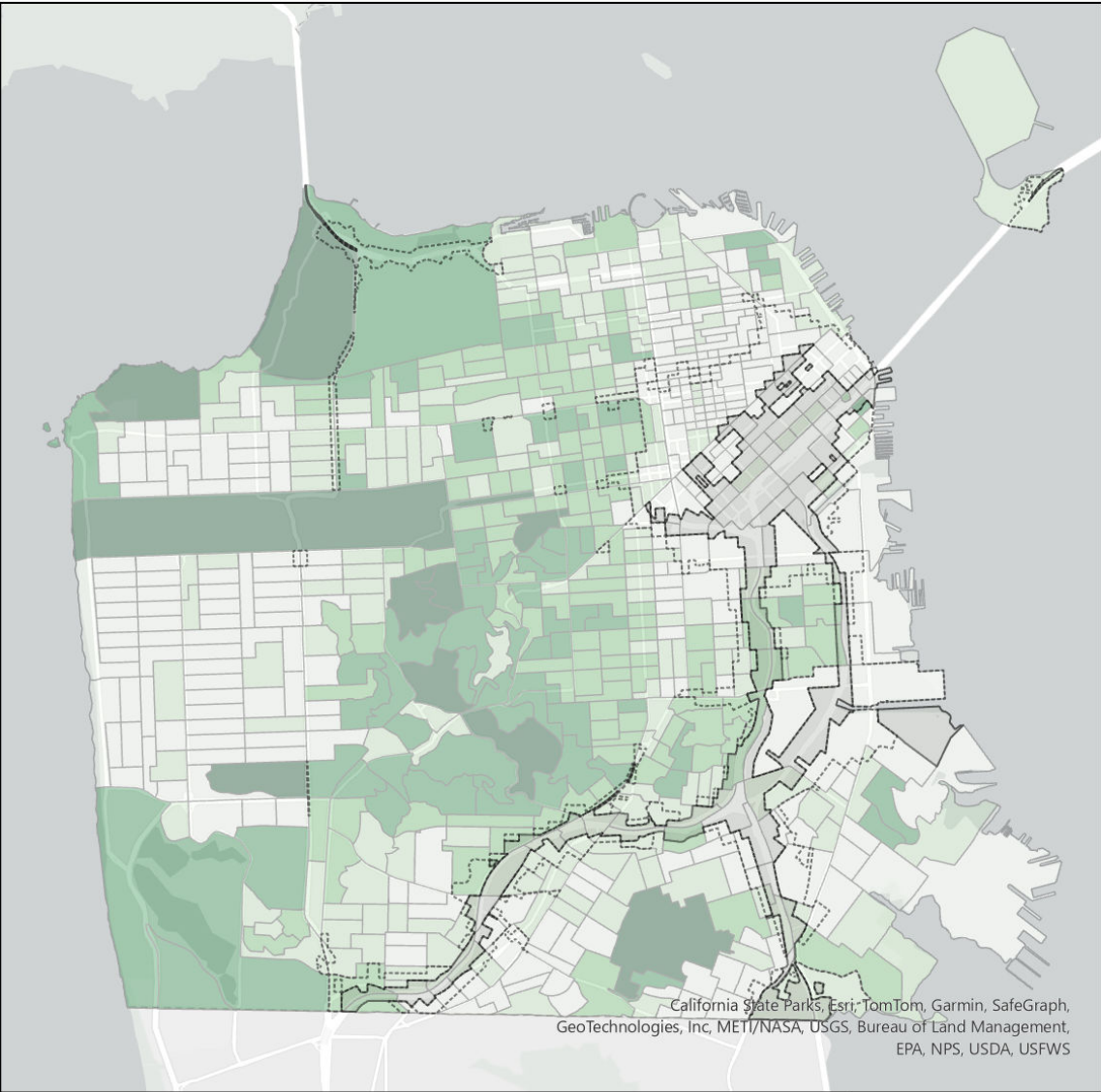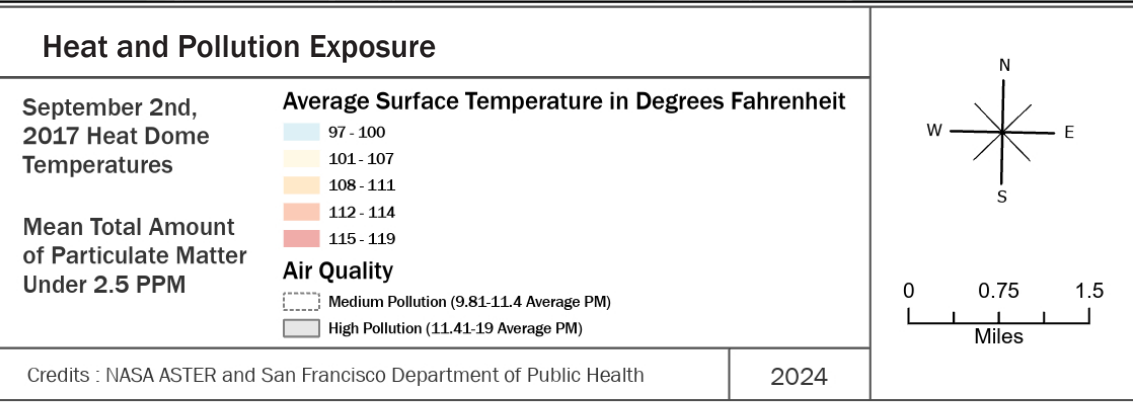
Heat and Air Quality Resilience Mapping
Citywide Exposure
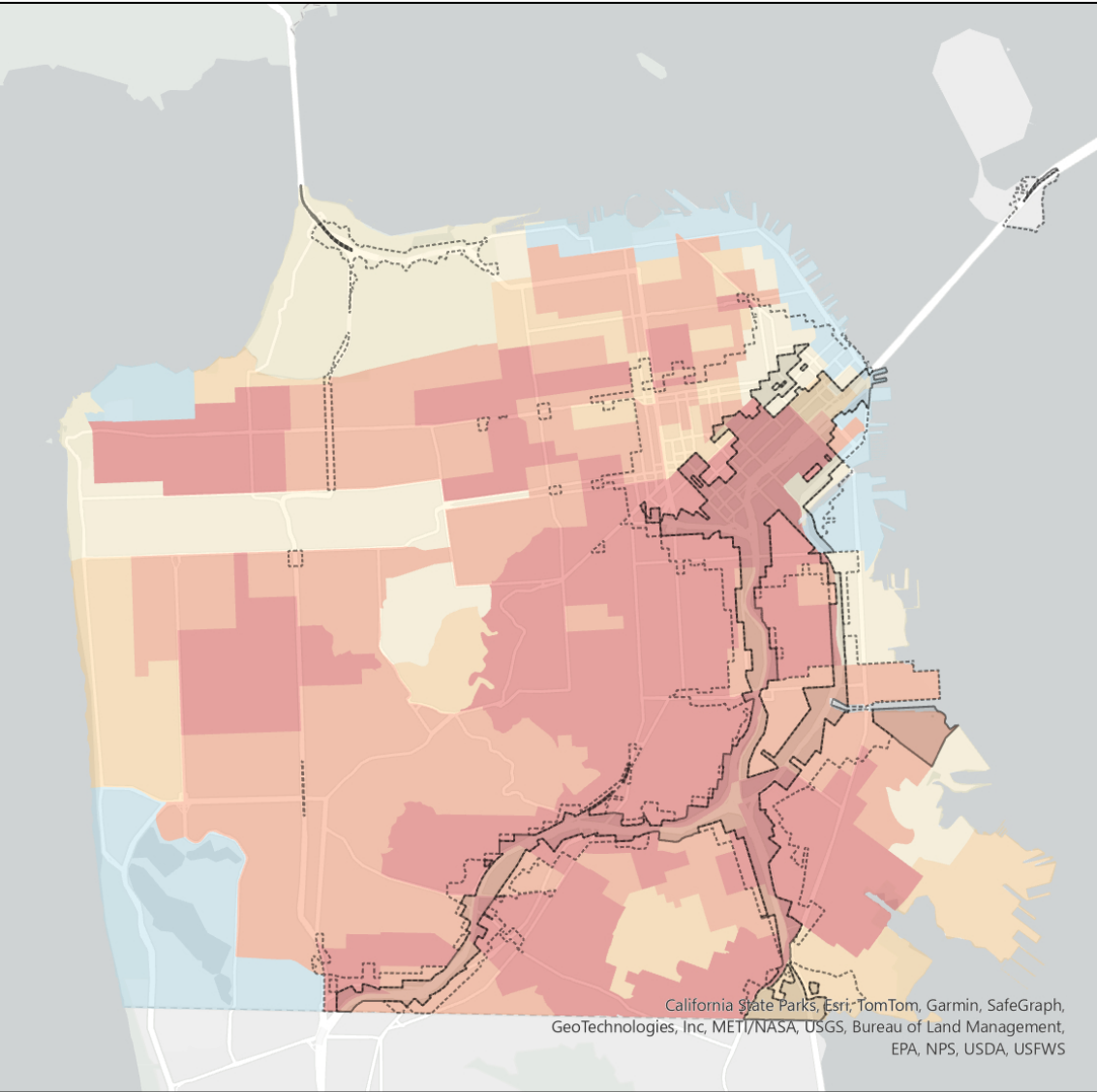
The first map in this series identifies where heat waves and air pollution are most pronounced.

Air pollution measured is Particulate Matter Under 2.5 Parts Per Million, also known as fine particulates. This particulate matter type is created by vehicle exhaust, burning of gas or other fuel, and wild fires. Breathing an unhealthy concentration of fine particulates can increase the risk for health problems like asthma and heart disease.
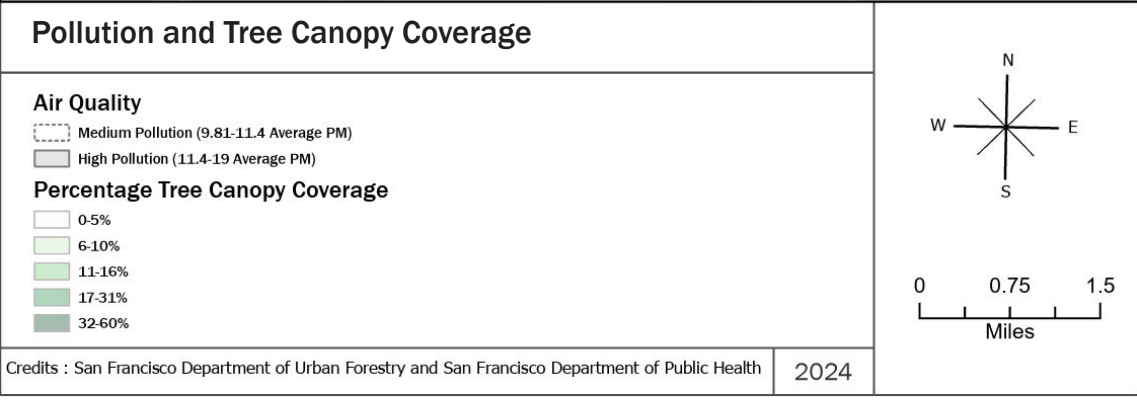
Heat waves can lead to heat stroke in vulnerable populations, including the elderly and can exacerbate existing health conditions like cardiovascular diseases, respiratory disorders, kidney diseases, and diabetes (CDC).

California State Parks, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS

Heat and Pollution Exposure

September 2nd, 2017 Heat Dome Temperatures

Mean Total Amount of Particulate Matter Under 2.5 PPM

Average Surface Temperature in Degrees Fahrenheit
- 97 - 100
- 101 - 107
- 108 - 111
- 112 - 114
- 115 - 119

Air Quality
- Medium Pollution (9.81-11.4 Average PM)
- High Pollution (11.41-19 Average PM)

Credits : NASA ASTER and San Francisco Department of Public Health

2024

0   0.75   1.5
Miles

The second map in this series visualizes tree canopy coverage overlayed with the highest concentrations of fine particulate matter.
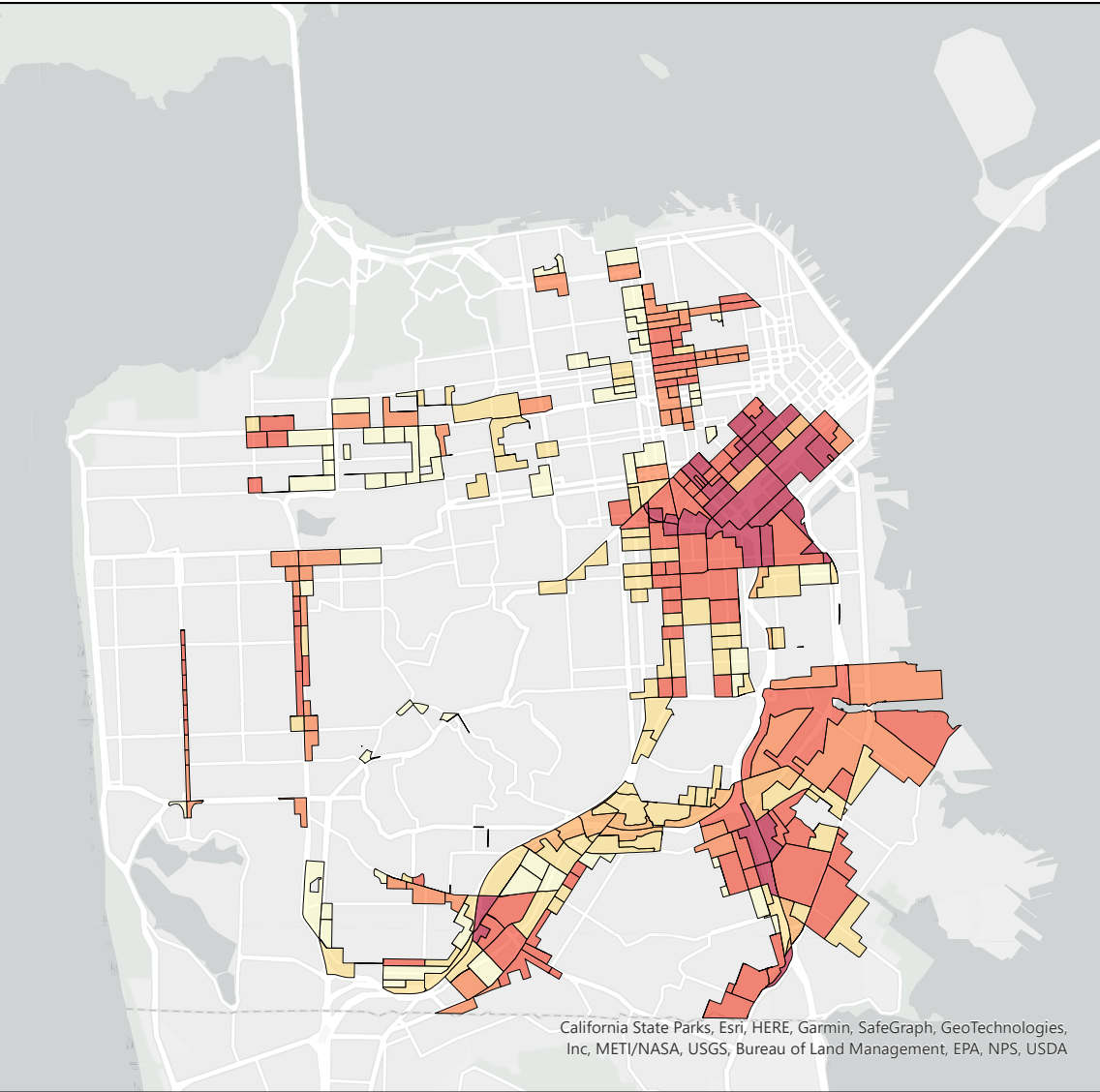
One way to combat fine particulate matter is with vegetation, which can disperse and intercept particulates before they reach humans.

Places exposed to the highest density of fine particulate matter do not have the highest tree canopy coverage in San Francisco.

California State Parks, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS

Pollution and Tree Canopy Coverage

Air Quality
- Medium Pollution (9.81-11.4 Average PM)
- High Pollution (11.4-19 Average PM)

Percentage Tree Canopy Coverage
- 0-5%
- 6-10%
- 11-16%
- 17-31%
- 32-60%

Credits : San Francisco Department of Urban Forestry and San Francisco Department of Public Health

2024

0   0.75   1.5
Miles

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Heat and Air Quality Resilience Mapping
Citywide Exposure

The third map in this series combines the first two maps to determine which areas of San Francisco are most exposed to extreme heat wave temperatures and high pollution. The areas with the lowest tree canopy coverage are then added as an addtional prioritization metric.

This map highlights which areas of San Francisco would most benefit from additional trees. The darkest red represents locations with the greatest exposure to both heat and pollution with the lowest tree canopy density.

California State Parks, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

Hea Heat and Pollution Exposure with Tree Canopy Coverage

- 5-10% Tree Canopy Coverage with Some Exposure
- 5-10% Tree Canopy Coverage with More Exposure
- 5-10% Tree Canopy Coverage with Most Exposure
- 0-5% Tree Canopy Coverage with Some Exposure
- 0-5% Tree Canopy Coverage with More Exposure
- 0-5% Tree Canopy Coverage with Most Exposure

Exposure to Pollution with a Particle Size Below 2.5PPM

Temperature Data From September 2nd, 2017 Heat Dome

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0   0.75   1.5
Miles

Credits : NASA ASTER, San Francisco Department of Public Health

2023

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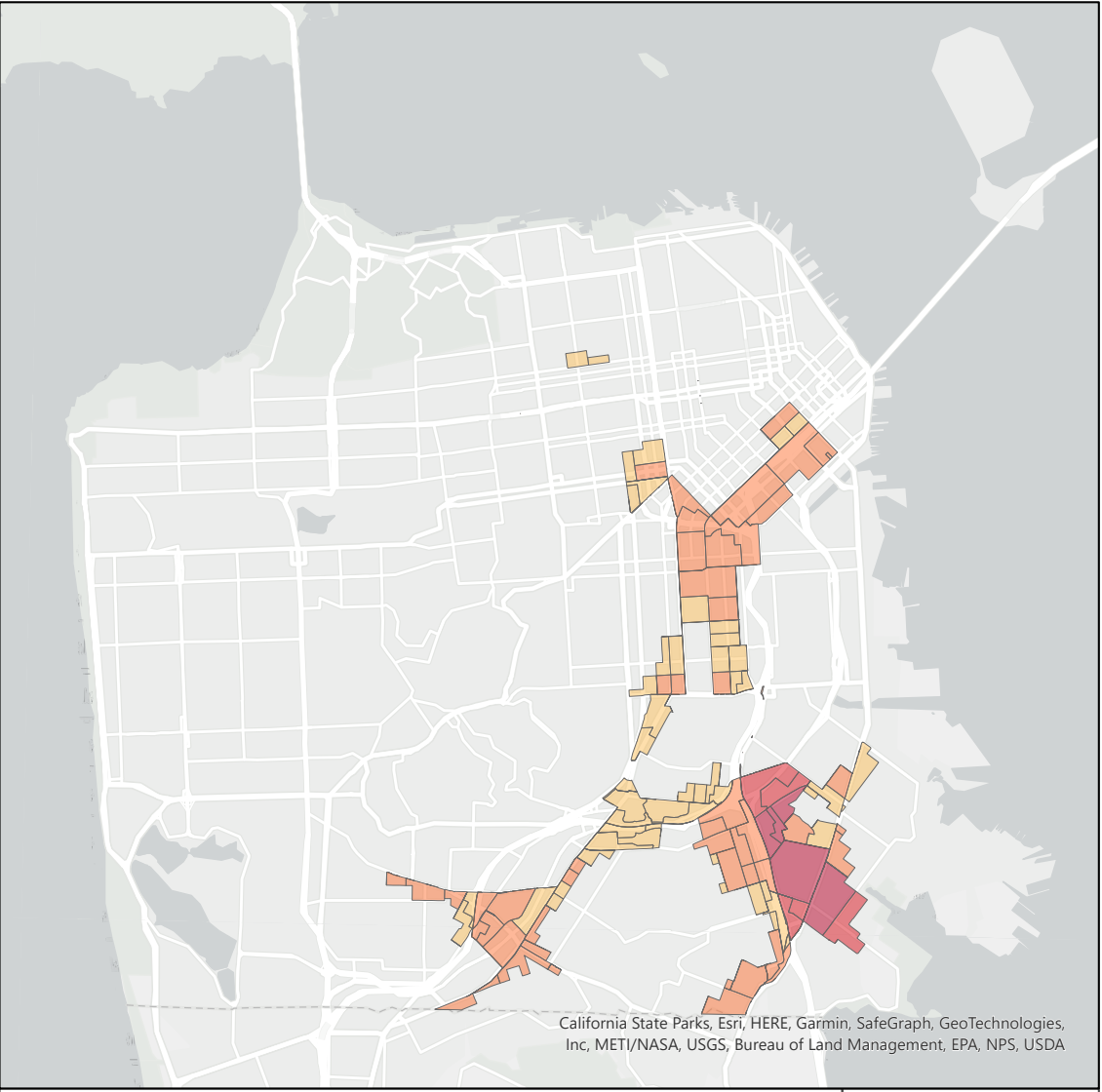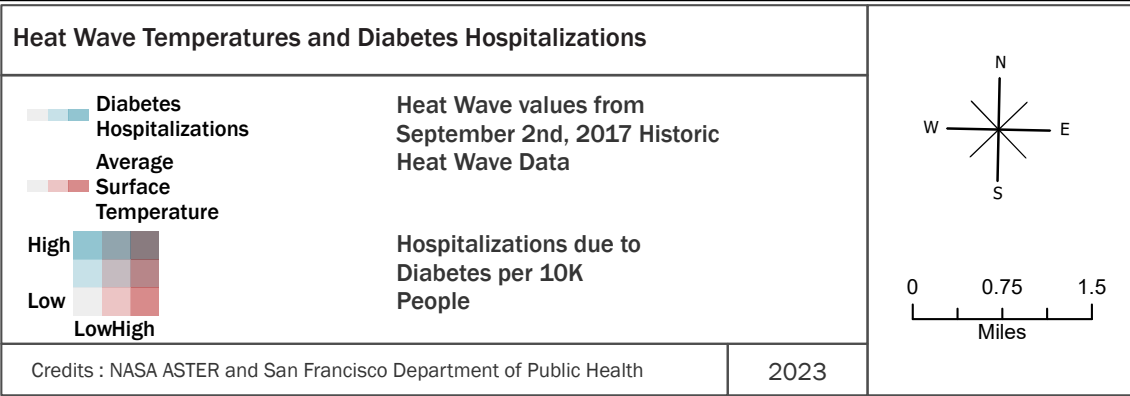
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Heat and Air Quality Resilience Mapping
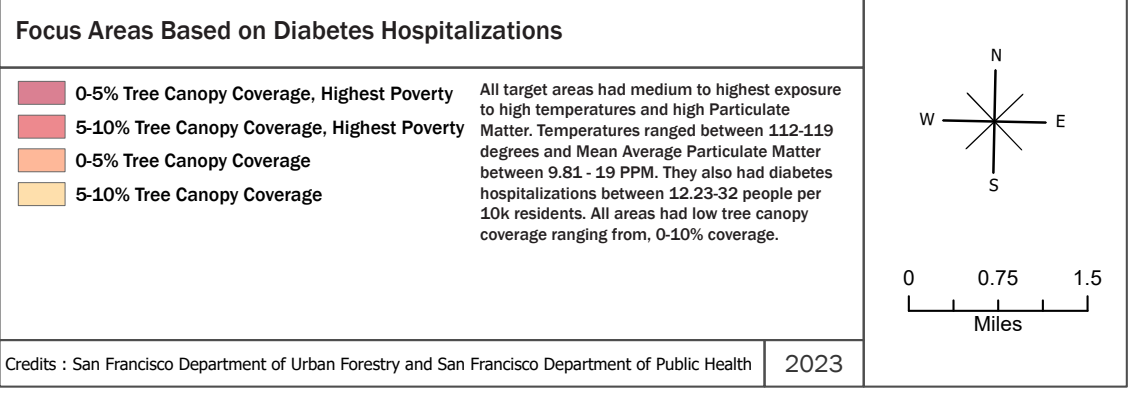## Health Focus: Diabetes
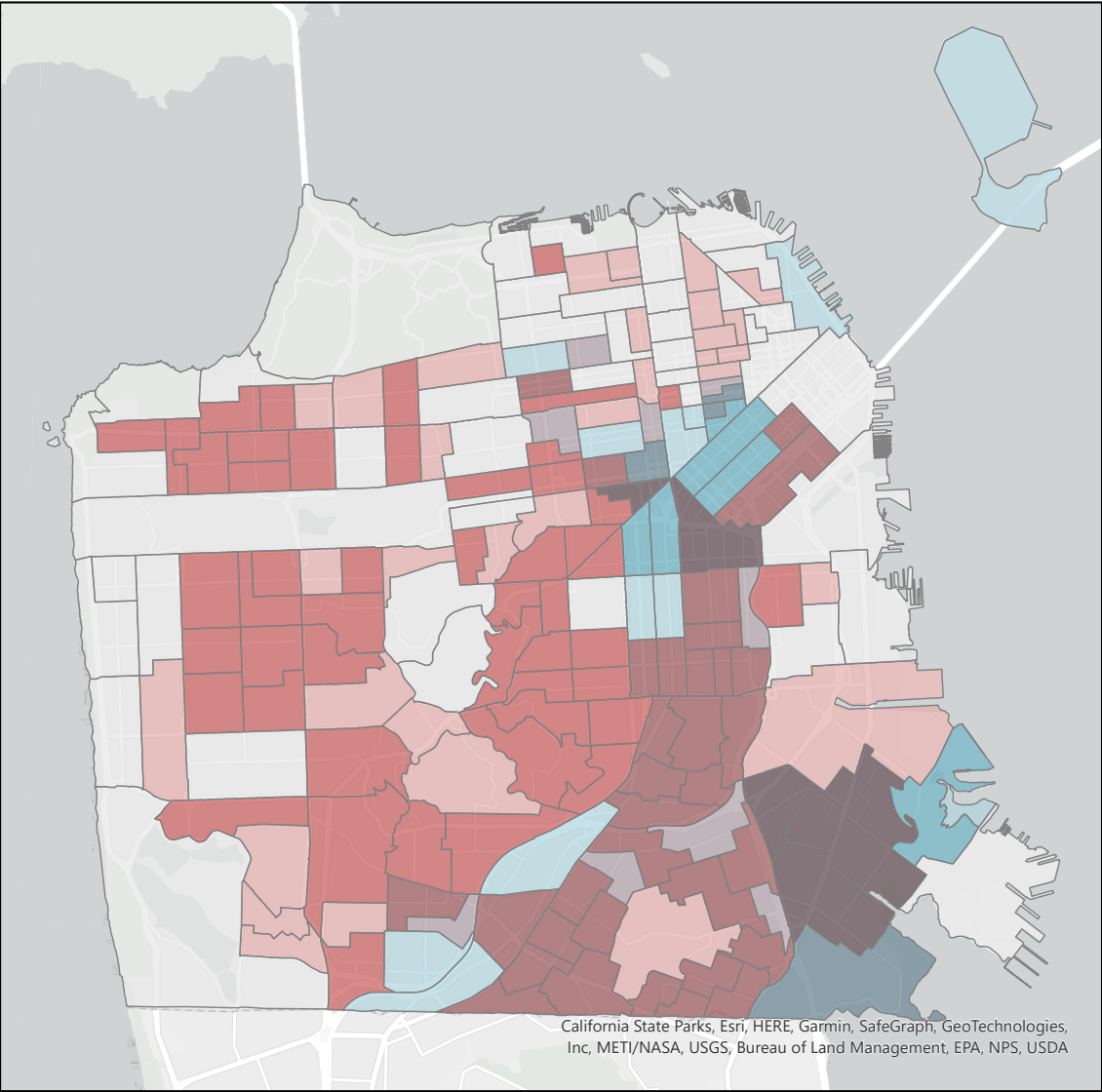
To further prioritize greening, health metrics were added as an additional layer of data. Heat waves can exacerbate symptoms of diabetes and lead to hospitalizations for those who cannot manage their condition.

The areas in purple are places where high heat wave temperatures and high diabetes hospitalizations co-occur. Other parts of San Francisco may have residents with diabetes, but the hospitalization data shows where people are not able to manage their symptoms during a heat event and therefore those are given a higher priority in this study.

California State Parks, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

Heat Wave Temperatures and Diabetes Hospitalizations

Diabetes Hospitalizations

Average Surface Temperature

High
Low
Low   High

Heat Wave values from September 2nd, 2017 Historic Heat Wave Data

Hospitalizations due to Diabetes per 10K People

N
W   E
S

0   0.75   1.5
Miles

Credits : NASA ASTER and San Francisco Department of Public Health   2023
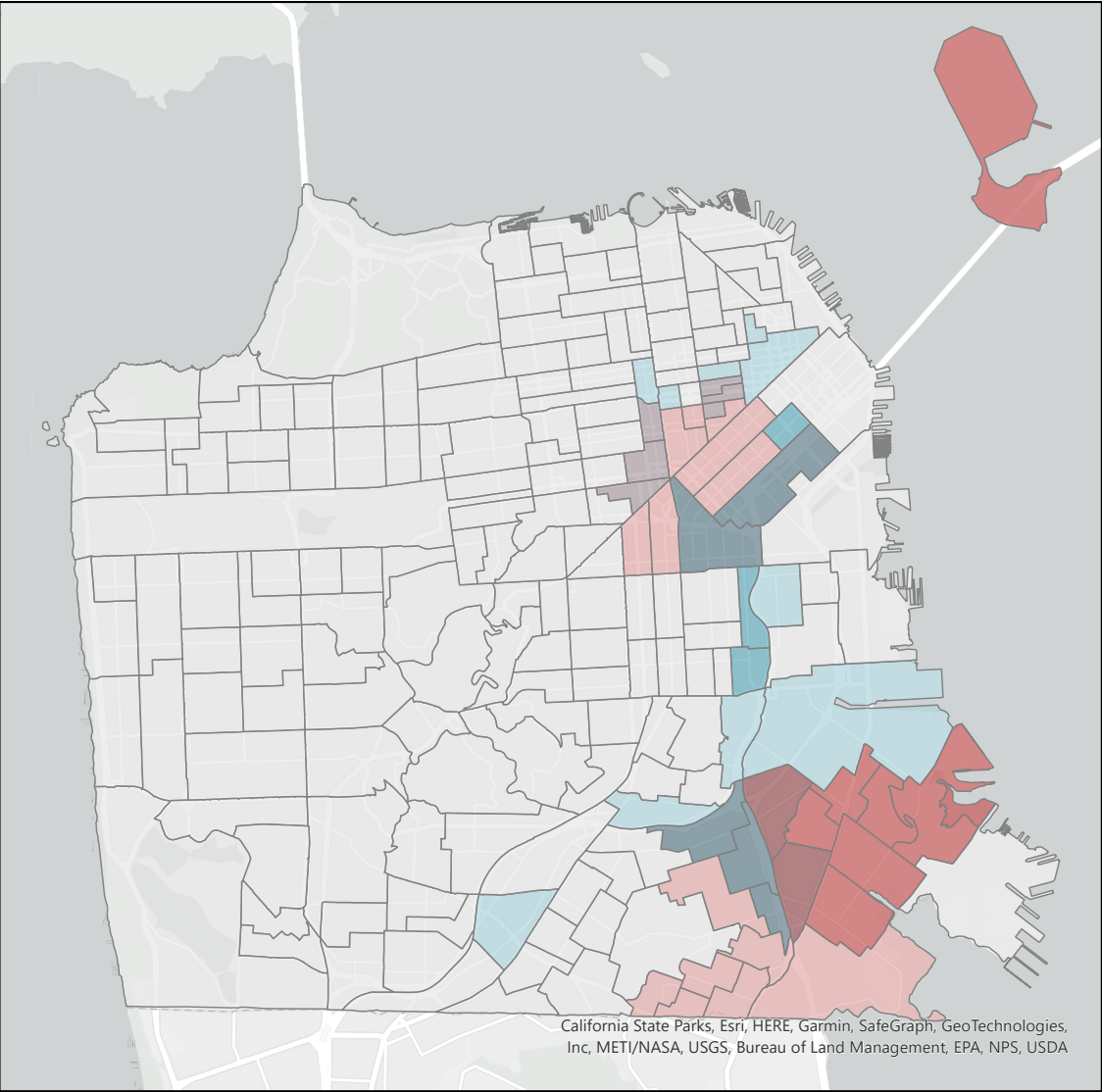

By adding areas of lowest tree canopy and highest poverty to the priority zones for diabetes, heat, and air pollution, a more specific priority zone for tree plantings is created.

California State Parks, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

Focus Areas Based on Diabetes Hospitalizations

0-5% Tree Canopy Coverage, Highest Poverty
5-10% Tree Canopy Coverage, Highest Poverty
0-5% Tree Canopy Coverage
5-10% Tree Canopy Coverage

All target areas had medium to highest exposure to high temperatures and high Particulate Matter. Temperatures ranged between 112-119 degrees and Mean Average Particulate Matter between 9.81 - 19 PPM. They also had diabetes hospitalizations between 12.23-32 people per 10k residents. All areas had low tree canopy coverage ranging from, 0-10% coverage.

N
W   E
S

0   0.75   1.5
Miles

Credits : San Francisco Department of Urban Forestry and San Francisco Department of Public Health   2023

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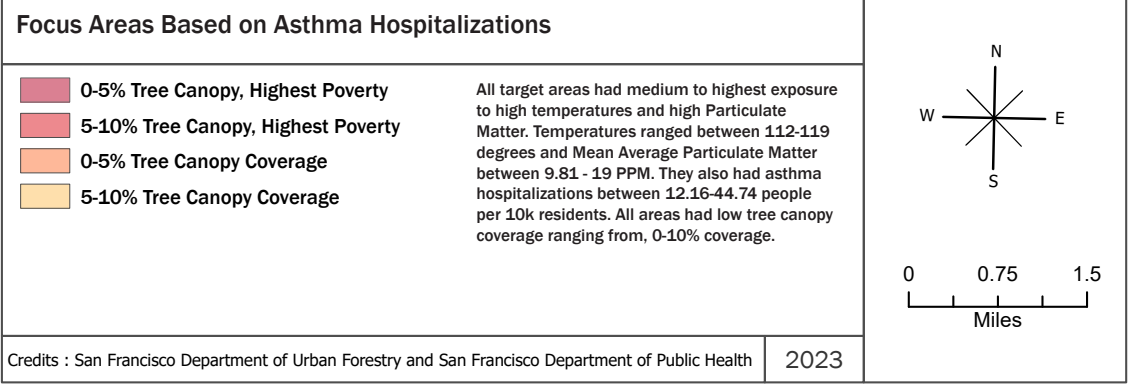# Heat and Air Quality Resilience Mapping
Health Focus: Asthma

Particulate matter exposure can exacerbate symtoms of asthma and lead to hospitalizations for those who cannot manage their condition.

The areas in purple are locations where the highest concentrations of fine particulate matter and high asthma hospitalizations co-occur. Other parts of San Francisco may have residents with asthma, but the hospitalization data shows where people are not able to manage their asthma symptoms.
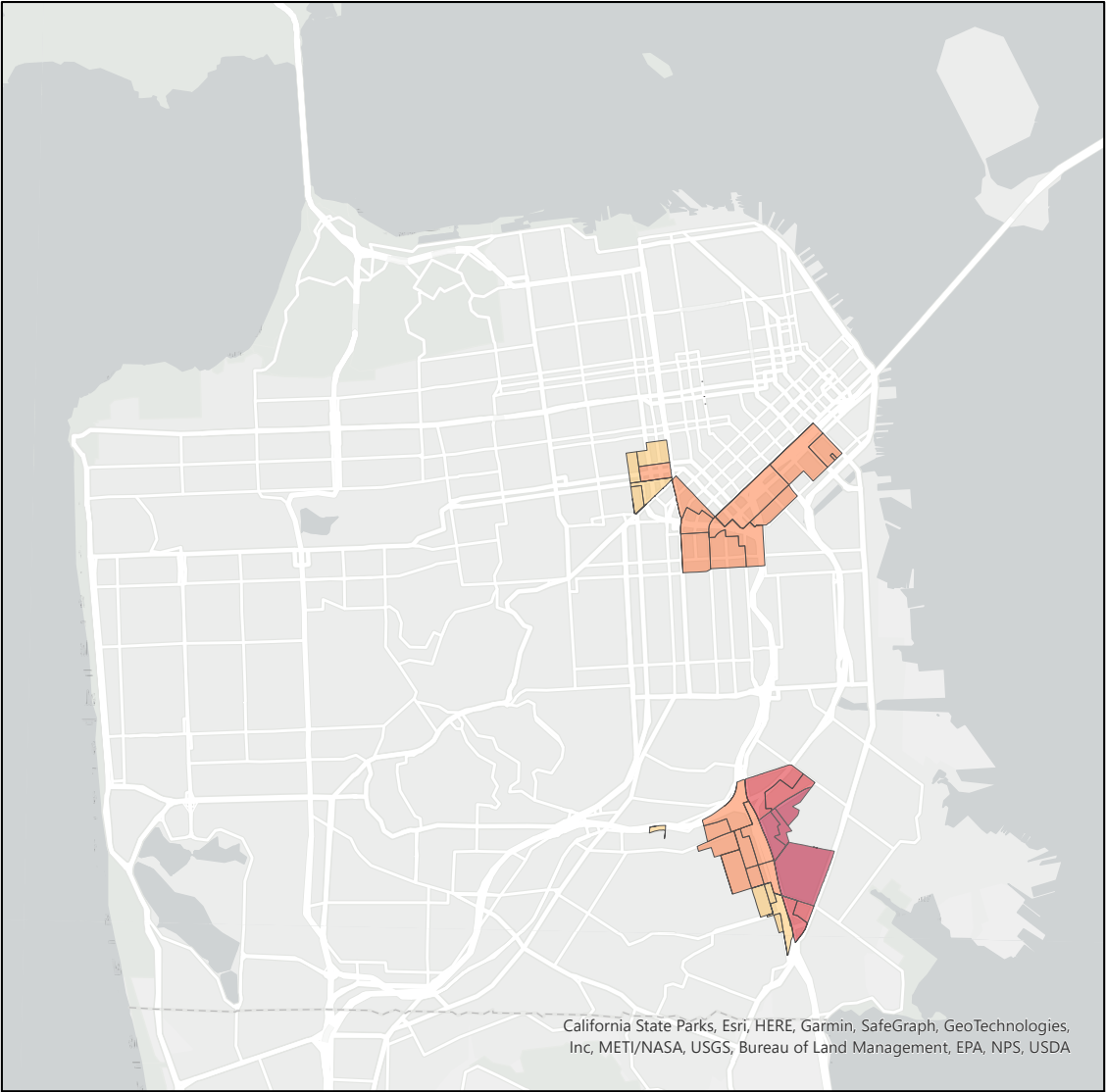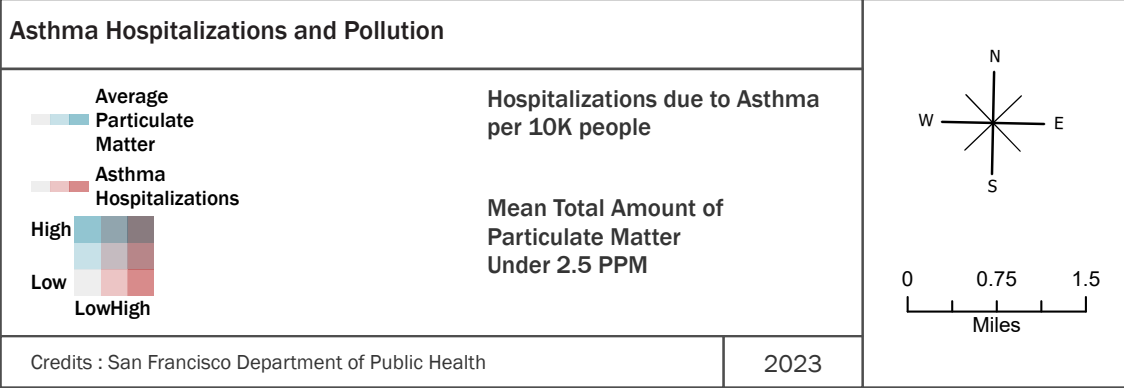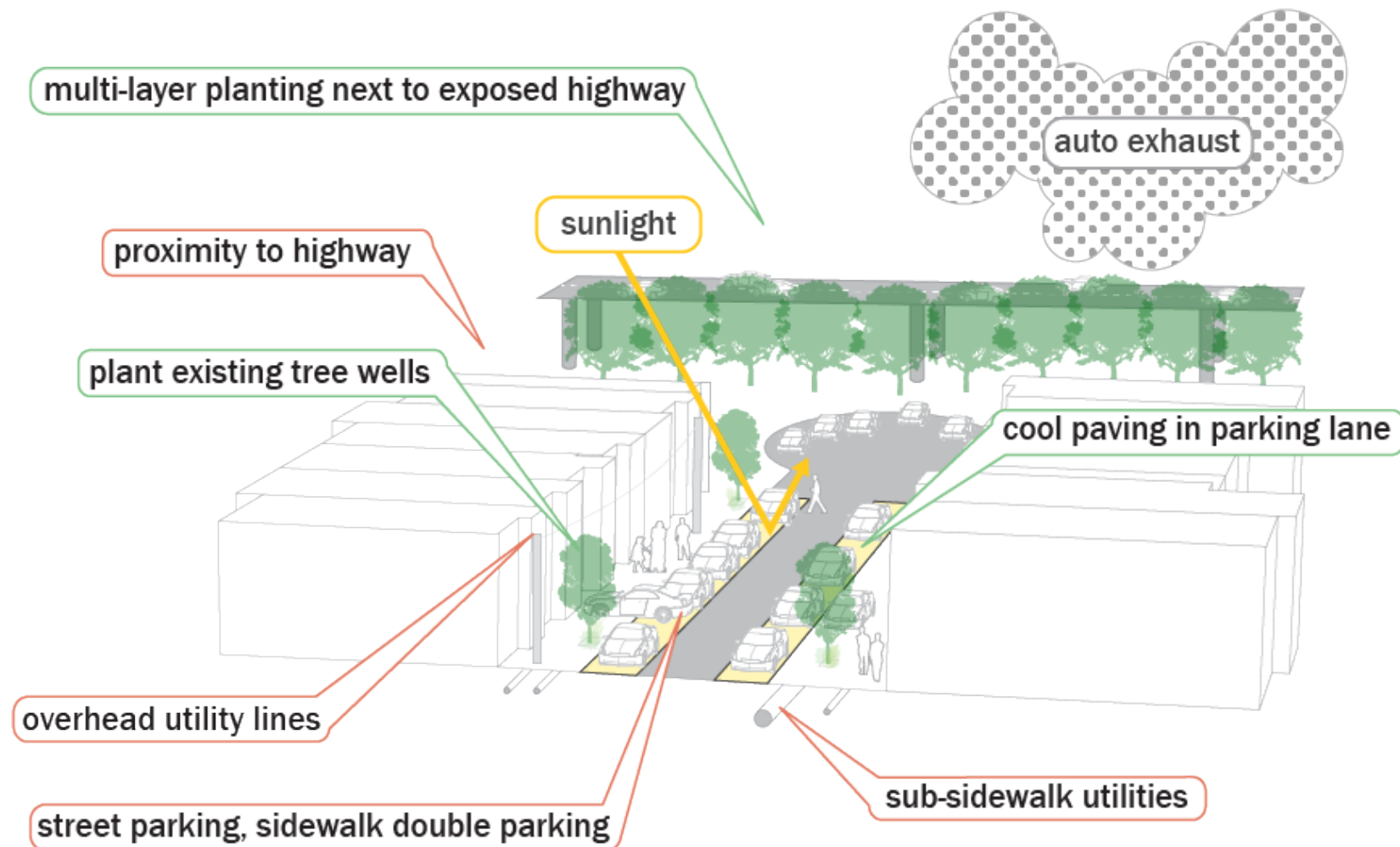
By adding areas of lowest tree canopy and highest poverty to the priority zones for asthma, heat, and air pollution, a more specific priority zone for tree plantings is created.

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California State Parks, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

Asthma Hospitalizations and Pollution

Average Particulate Matter

Asthma Hospitalizations

High
Low
Low High

Hospitalizations due to Asthma per 10K people

Mean Total Amount of Particulate Matter Under 2.5 PPM

N
W E
S

0   0.75   1.5
Miles

Credits : San Francisco Department of Public Health | 2023

Focus Areas Based on Asthma Hospitalizations

- 0-5% Tree Canopy, Highest Poverty
- 5-10% Tree Canopy, Highest Poverty
- 0-5% Tree Canopy Coverage
- 5-10% Tree Canopy Coverage

All target areas had medium to highest exposure to high temperatures and high Particulate Matter. Temperatures ranged between 112-119 degrees and Mean Average Particulate Matter between 9.81 - 19 PPM. They also had asthma hospitalizations between 12.16-44.74 people per 10k residents. All areas had low tree canopy coverage ranging from, 0-10% coverage.

N
W E
S

0   0.75   1.5
Miles

Credits : San Francisco Department of Urban Forestry and San Francisco Department of Public Health | 2023

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Urban Typologies in Identified Priority Zones
Silver Terrace: Residential Typology

- multi-layer planting next to exposed highway
- sunlight
- auto exhaust
- proximity to highway
- plant existing tree wells
- cool paving in parking lane
- overhead utility lines
- street parking, sidewalk double parking
- sub-sidewalk utilities

Existing Conditions

Scotia Ave & Quint St

Elmira St & Augusta St

Opportunities:
-Plantings in residential areas have a direct impact on residents, can reduce electric bills, and improve health outcomes.
-Roads tend to be narrower and traffic volumes low.
-Residential areas have more "eyes on the street" and residents can more actively assist in ensuring long-term tree health.

Constraints:
-Many residential areas have overhead utility lines that limit the size of trees that can be planted.
-Narrower sidewalks also limit the size of trees that can be planted.
-Parking is often happening is a non-standard manner due to unmet housing and transportation needs.
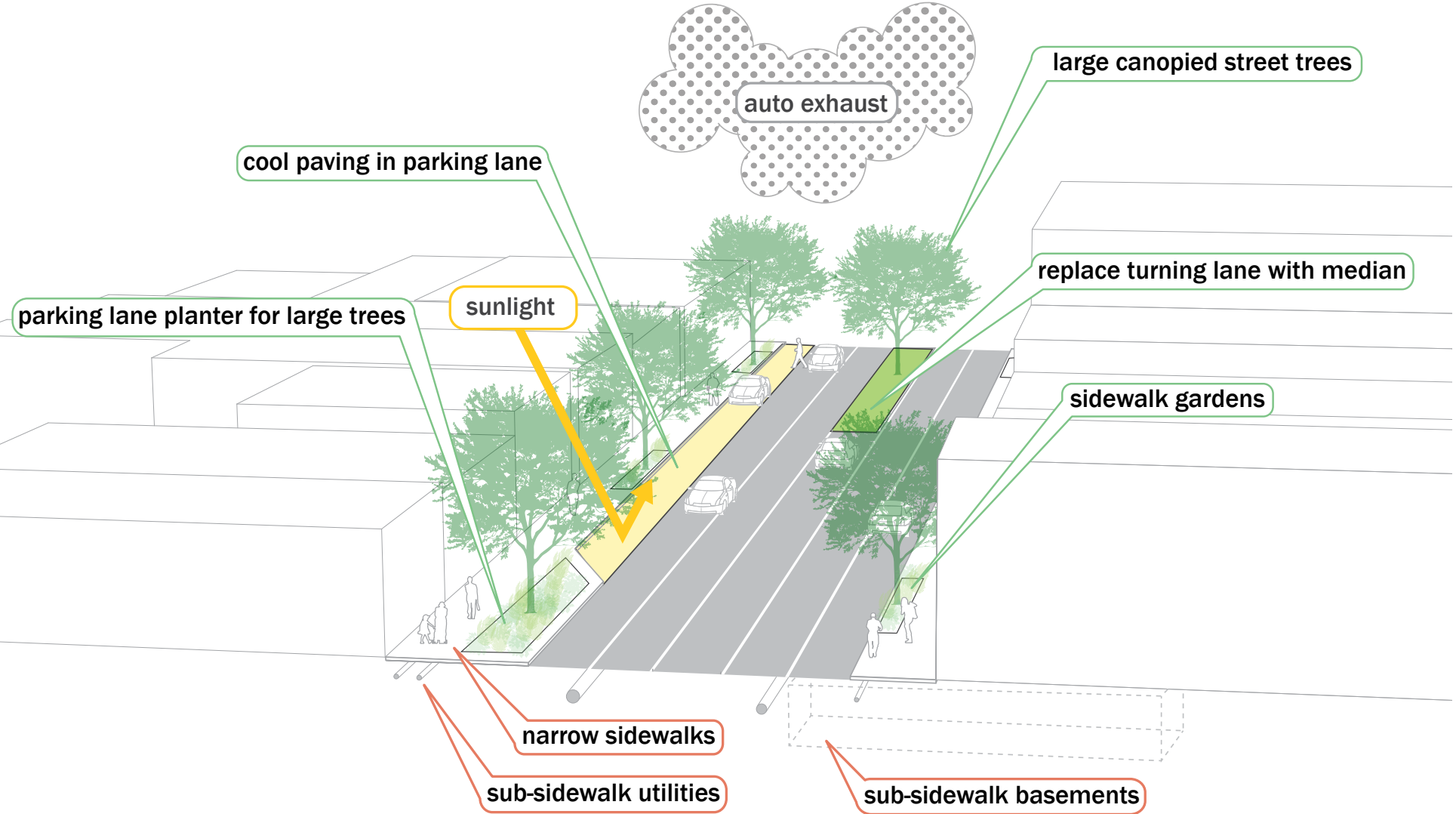-Some residential areas are adjacent to Caltrans right-of-way that is not under City control.

Recommendations:
-Select a palette of smaller trees that can do well under utility lines and in smaller tree basins.
-Plant large tree species wherever possible.
-Enlarge tree basins wherever possible or use chicanes to add trees and slow traffic.
-Explore school yard greening with SFUSD to increase tree canopy and reduce pavement.
-Support MTA's Community Mobility planning to ensure resident's have access to the transportation they need for daily life to reduce car use.
-Support citywide housing initiatives to increase affordable housing that can decrease crowded living conditions which also causes multiple cars per household.
-Partner with Caltrans to explore greening in priority zones within their right-of-way.

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Urban Typologies in Identified Priority Zones
SoMa: Urban Typology

auto exhaust

large canopied street trees

cool paving in parking lane

replace turning lane with median

parking lane planter for large trees

sunlight

sidewalk gardens

narrow sidewalks

sub-sidewalk utilities

sub-sidewalk basements

Opportunities
-Large right-of-way
-Less overhead utilities.

Constraints:
-High traffic volumes
-Narrow sidewalks
-Sub-sidewalk basements and major underground utilities more frequently found in these corridors.

Recommendations:
-Plant trees wherever possible along the curbside.
-Create additional space for trees using bulbouts.
-Study the potential of adding a central median to accommodate large shade trees.

Existing Conditions

8th St & Folsom St

Bryant St & Morris St

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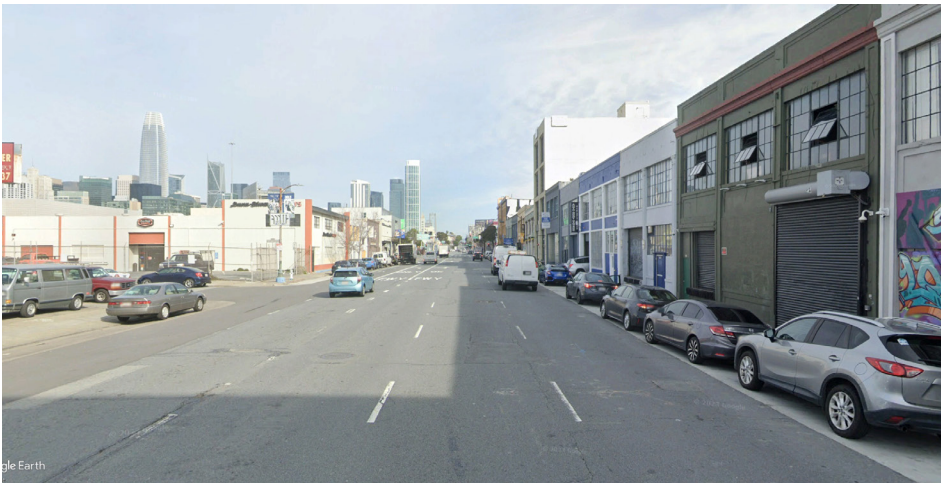
Urban Typologies in Identified Priority Zones
Bayview: Industrial Typology

sunlight

large canopied street trees

replace turning lane with median

cool paving in parking lane

sunlight

auto exhaust

large vehicle clearance

sub-surface utilities
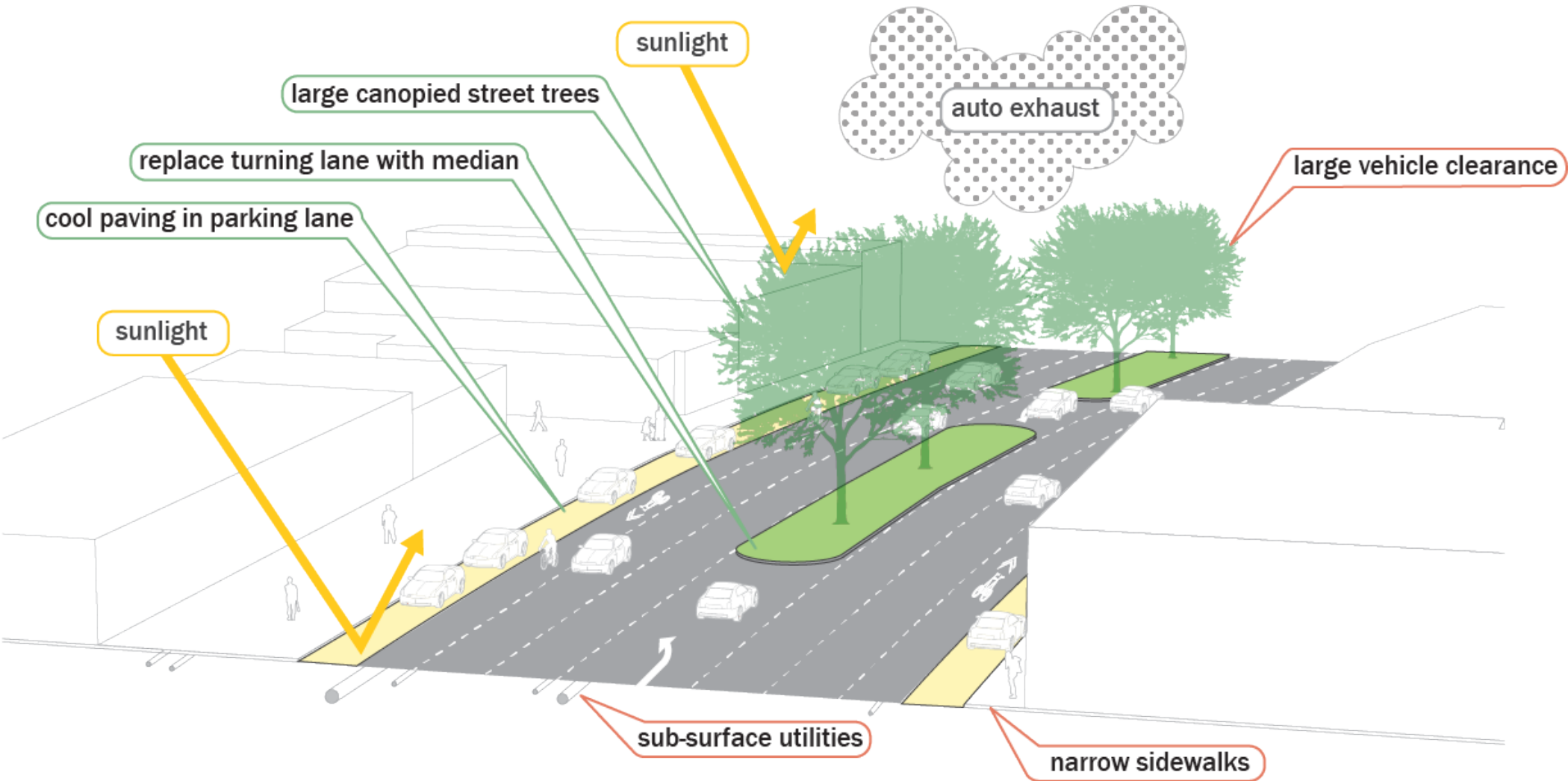
narrow sidewalks

Opportunities:
-Large right-of-way
-Less overhead utilities.
-Often overlaps with bicycle infrastructure that could use improvement.

Constraints:
-High traffic volumes
-Narrow sidewalks
-Sub-sidewalk basements and major underground utilities more frequently found in these corridors.

Recommendations:
-Plant trees wherever possible along the curbside.
-Explore how improved bicycle and pedestrian infrastructure could be combined with additional tree planting to create safer streets for all.
-Study the potential of adding central medians to accommodate large shade trees and create pedestrian refuge at crossings.

Existing Conditions

Cesar Chavez St & Kansas St

Bayshore Boulevard & Oakdale Ave

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Heat and Air Quality Mapping Methodology

Heat and Pollution Exposure:

The heat data in the heat and pollution map was sourced from the NASA Aster Data (SFDPH). The classes were created using Natural Breaks and are as follows:

97-100 Degrees Fahrenheit
101-107 Degrees Fahrenheit
108-111 Degrees Fahrenheit
112-114 Degrees Fahrenheit
115-119 Degrees Fahrenheit

The pollution data was created using the 2019 Bay Area Air Quality Management District Data, the classes are sorted as follows:
7.8-8.7 PM
8.8-9.8 PM
9.81-11.4 PM
11.41-14 PM
14.1-19 PM

The two pollution categories were generalized using the bottom three classes.

Medium Pollution: 9.81-11.4 PM
High Pollution: 11.41-19 PM

Tree Canopy And Pollution

The tree canopy coverage layer was sourced from a 2018 Forest Service Canopy Raster, ran through raster to polygon tool in ArcGIS Pro and is sorted via Census Block group, it was sorted using Natural Breaks.

The classes for the data are as follows:
0-5%
6-10%
11-16%
16-31%
32-60%

Then the two pollution categories from **Heat and Pollution Exposure** were added:

Medium Pollution: 9.81-11.4 PM
High Pollution: 11.41-19 PM

Heat and Pollution Exposure Combined with Tree Canopy

To accurately capture the true need of communities, this map combines the previous heat and pollution map with the current tree canopy coverage of the city.

The hottest areas (those with temperature measurements between 112-119 degrees during the September 2nd, 2017 heat wave) and the highest pollution scores (places with a mean value between 9-19) were overlaid and intersected.

Then, a tree canopy coverage percentage map using census tracts was overlaid. The two designated lowest canopy zones either had 0-5% tree canopy coverage or 5-10% tree canopy coverage. An important distinction was that overall tree canopy was chosen, not street tree canopy. We did not want to discredit the impact canopy from large parks had on certain neighborhoods.

Areas across the city are impacted by heat, pollution and low tree canopy, but the impacts of heat and pollution are less manageable by certain groups depending on a multitude of factors (See Map 1, Heat Vulnerability Index). The goal of this study is to identify places that are disproportionately impacted by environmental impacts

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Asthma Hospitalizations and Average Particulate Matter

This map uses the Average Particulate Matter measurements from SFDPH. The Particulate Matter map from the Heat and Pollution Map is sorted into census blocks, this map has particulate matter sorted into census tracts so it can be used in conjunction with Asthma Hospitalizations per 10K People which were sorted by census tracts as well.

Asthma Hospitalizations
Low: 0-12.15
Medium:12.16-18.57
High:18.58-44.74

Average Particulate Matter
Low: 0-9.7
Medium: 9.81-11.4
High: 11.41-13.6

Asthma Focus Area Map:

To prioritize neighborhoods that are suffering the impacts of heat and pollution disproportionately, this map selects areas using the lowest tree canopy coverage, highest pollution, highest heat wave data, and medium to high asthma hospitalizations. Then poverty is overlaid to find who has the least resources to address these problems.

This map uses the two lowest categories of tree canopy coverage from the Tree Canopy And Pollution Map page. Tree Canopy Coverage was either

0-5%
5-10%

The Mean Average Particulate Matter fell into one of these categories:

High Pollution: 11.41-19 PM
Medium Pollution: 9.81-11.4

The Heat Wave Temperature fell into one of two categories:

112-114 Degrees
115-119 Degrees

The Asthma Hospitalizations followed the categories laid out in the Asthma Hospitalizations and Average Particulate Matter Map.

Medium:12.16-18.57
High:18.58-44.74

Poverty data as defined by SFDPH as "Percent of population with an income under 400% of the federal poverty rate by census tract, 2017-2021." It was sorted into classes using Normal Breaks, then the High Class ranking was used in this map.

Poverty:
Low: 0-47.08%
Medium: 47.09%-65.12%
High: 65.13-100%

Heat Wave Temperatures and Diabetes Hospitalizations

This map was created with the Diabetes Hospitalizations per 10,000 People using the San Francisco Department of Public Health Data. The Average Surface Temperature data was from the San Francisco Department of Public Health Data set as well and refers to the September 2nd, 2017 Heat Wave Data collected by the NASA ASTER Radiometer.

The bivariate colors are classified to reflect the class divisions from earlier heat and pollution map.

Temperature
Low: 0-111
Medium: 111.1-114
High: 114.1-119

Diabetes Hospitalizations
Low: 0-12.22
Medium: 12.23-20.6
High: 20.7-32

Diabetes Focus Area Map:

To prioritize neighborhoods that are suffering the impacts of heat and pollution disproportionately, this map selects areas using the lowest tree canopy coverage, highest pollution, highest heat wave data, and medium to high diabetes hospitalizations. Then poverty is overlaid to find who has the least resources to address these problems.

This map uses the two lowest categories of tree canopy coverage from the Tree Canopy Additions page. Tree Canopy Coverage was either

0-5%
5-10%

The Mean Average Particulate Matter fell into one of these categories:

Medium Pollution: 9.81-11.4
High Pollution: 11.41-19 PM

The Heat Wave Temperature fell into one of two categories:

112-114 Degrees
115-119 Degrees

The Diabetes Hospitalizations followed the categories laid out in the Heat Wave Temperatures and Diabetes Hospitalizations map.

Medium: 12.23-20.6
High: 20.7-32

Poverty data as defined by SFDPH as "Percent of population with an income under 400% of the federal poverty rate by census tract, 2017-2021." See the Heat and Poverty map for classification and histogram.

High: 65.13-100%

Heat and Air Quality Mapping Sources

Poverty data:

Definition: Percent population with an income under 400% of the federal poverty rate
Data source: U.S. Census Bureau's 2017 – 2021 American Community Survey 5-year estimates

Visualizing climate health impacts in San Francisco | San Francisco (sf.gov)

Tree Canopy Coverage:

2018 United States Forest Service Canopy Raster

https://data.fs.usda.gov/geodata/rastergateway/treecanopycover/#table1

Asthma Hospitalizations per 10K People:

Population with asthma and chronic obstructive pulmonary disease (COPD)
Definition: Age-adjusted rate of ED visits for asthma and COPD per 10,000 residents
Data source: California Department of Health Care Access and Information, Emergency Department data, 2013 – 2017

Visualizing climate health impacts in San Francisco | San Francisco (sf.gov)

Diabetes Hospitalizations per 10K People:
Definition: Age-adjusted rate of ED visits for diabetes per 10,000 residents
Data source: California Department of Health Care Access and Information, Emergency Department data, 2013 – 2017

Visualizing climate health impacts in San Francisco | San Francisco (sf.gov)

PM 2.5 Parts Per Million:

Definition: Annual average PM2.5 concentration in micrograms per meters cubed
Data source: San Francisco Department of Public Health, and San Francisco Planning Department, The San Francisco Citywide Health Risk Assessment: Technical Support Documentation, September 2020

Visualizing climate health impacts in San Francisco | San Francisco (sf.gov)

Heat Wave Data:

Surface temperature was collected using land surface kinetic temperature data from NASA's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite for September 2, 2017, a record-breaking heat wave in the San Francisco Bay Area.

https://sf.gov/data/visualizing-climate-health-impacts-san-francisco

Enviroscreen Data:

SB 535 Disadvantaged Communities (2022 Update)

SB 535 Disadvantaged Communities | OEHHA (ca.gov)

Empty Treewells and Potential Tree Wells:
2023 Bureau of Urban Forestry Internal File

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