Past, Present, and Future Tree Canopy Conditions in San Mateo County

DRAFT

Prepared for the Tree Ordinances Steering Committee

COUNTY OF SAN MATEO
PLANNING AND BUILDING

Table of Contents

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Figure 1: Map of San Mateo County unincorporated jurisdictional areas.

Introduction

The quality of our tree canopy in San Mateo County has changed dramatically over the years as a result of development and our changing climate. This report will attempt to outline those changes by summarizing historic county data, modern data resources, and a review of recent scientific literature. We hope this report will aid the Steering Committee in its efforts to guide the revisions of Section 11000, San Mateo County Ordinance: Regulation of the Removal of Heritage Trees, and Section 12000, San Mateo County Ordinance: Regulation of Removal of Significant Trees, as well as the revisions to the Resource Management and Planned Agricultural District zoning ordinances.

It is the intention of the County to strengthen tree protection measures and clarify the policies allowing tree removal. These changes will improve the quality of life for current and future generations by preserving the ecosystem services trees provide, clarifying the conditions under which trees can be removed and improving the permit process. The first objective stated in Chapter 1 of the County General Plan is to "Promote the conservation, enhancement, protection, maintenance and managed use of the County's Vegetative, Water, Fish and Wildlife Resources." This objective and the related General Plan policies guide what we do with respect to protecting, planting or removing trees within County jurisdiction.

The natural tree canopy in any area is constantly changing, with degrees of elasticity and vulnerability one would expect from living things. Over time, trees establish patterns of growth that are directly influenced by changing geological, climatic and hydrological conditions, and biotic activities around them. Humans have an astounding ability to change the natural world around us, and we have certainly affected patterns of tree growth. The rate at which we change environmental conditions has continuously accelerated up to this modern era. There isn't an acre of land in San Mateo County that hasn't been affected by people. It is important to understand our history and the environmental conditions of the past to ensure the policies we develop are informed by the best information. It is also important to contemplate future tree canopy conditions and understand the forces that bring about change. We cannot reproduce the historic ecological setting, but we can steer our management of the county's trees in a direction that will promote sustainability and environmental health. Through better understanding, we can respond to changing circumstances in more effective and efficient ways.

Tree canopy provides a plethora of ecological services, such as wildlife habitat, watershed friction, and oxygen production. In the process of producing oxygen, large trees consume and store large amounts of carbon dioxide, which reduces greenhouse gas concentrations in the atmosphere. There are a number of benefits associated with the shade provided by trees. All members of the animal kingdom, including humans, benefit from cooler temperatures in the shade. Fish like Coho Salmon and Steelhead Trout require stream temperatures to be within a certain range, and shade producing tree canopy in riparian corridors makes it possible for those fish to survive during hot summer months. Even the earth itself benefits from shade because soil moisture is better retained at moderate temperatures, which allows soil microorganisms to thrive and produce the soil structure and quality required for vigorous vegetative growth. Trees also improve heating and cooling efficiency when positioned appropriately in residential areas, and can act as noise barriers. In fact, studies have shown that greener neighborhoods have less violence and more civic pride, according to treepeople.org. The number of services provided by healthy trees is truly impressive, and essential to maintaining life as we know it.

Agents of Change

200 years ago, the peninsula looked very different. Prior to European settlement, industrialization and urbanization from the mass migration of people into this area, seven native plant communities dominated the landscape: perennial grassland, oak savanna, oak woodland, chaparral, riparian, mixed conifer/montane hardwood forest, and coastal scrub (Hynding, 1982). These plant communities were naturally distributed throughout the county according to the movement of surface water, gradients in slope, soil characteristics, precipitation, temperature, and elevation. They were also managed by native people using fire. Based on detailed journals kept by Padre Juan Crespi from the 18th century Spanish expedition to the Bay Area, and other research, we know that native people's fire management significantly shaped the plant communities that thrived here. Once established, the Spanish forbade the use of fire as a management tool, promoting European-influenced practices that have evolved over time into our present day management practices.

> *In her landmark book "*Tending the Wild: Native American Knowledge and the Management of California's Natural Resources*," culture historian and ethnoecologist Kat Anderson describes how California Indians used an array of sophisticated ecosystem engineering techniques to manage their environment in order to sustainably provide for the survival needs of their clans and tribes. Along with burning, they pruned, coppiced, sowed and weeded to intervene in the life cycle of plants and animals and to direct their growth and reproduction.*[1]

Coniferous forestlands, primarily composed of coastal redwood and Douglas fir, occupied the higher elevations of the Santa Cruz Mountains traversing the middle of the peninsula. Grassland and oak woodland and oak savannas covered the semiarid foothills and the alluvial plains on the bayside. Large expanses of chaparral used to occupy the land between savanna and forest, and played an important role in reducing erosion and conserving soil moisture. Coastal scrub and grassland covered the marine terraces on the coastside (Hynding, 1982). Riparian

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[1] Hannibal, Mary Ellen "Rekindling the Old Ways, the Amah Mutsun and Recovery of Traditional Ecological Knowledge" in Bay Nature, April-June 2016, p. 31

vegetation habitats occurred wherever natural waterways formed on the land surface. These habitat types are still present today, although major alterations have taken place due to development, land management changes, invasive species encroachment and other forces.

Native grasslands have been diminished through the elimination of fire management and development and mostly replaced with non-native, annual grasses brought by Europeans. The oak woodlands and chaparral have also been diminished and made sparser as a result of development. Ranching activity in communities like Emerald Lake Hills would have caused changes in habitat distribution due to grazing, the trampling of young oaks and other cattle related impacts. Over the years, oak woodland has evolved to oak savanna in some places because of the reduced water availability in areas like West Menlo Park and North Fair Oaks. Coastal scrub habitats are still plentiful and have even spread into areas that once sustained chaparral or forest, though some have been planted with Australian eucalyptus. The redwood forest was almost entirely harvested for lumber and shakes from 1850 to 1880, with smaller operations continuing until 1920. The high quality lumber was used for construction throughout the Bay Area and the State, and to rebuild San Francisco after the 1906 earthquake. There are a few small groves of old growth forest remaining in San Mateo County, but most of the mountainous area is now covered in second and third growth forest. These changes had profound effects on ecological functions and tree canopy characteristics, and the changing climate will further compound those effects. Future shifts in species distributions and reduced sustainability of native tree populations are some of the outcomes we must consider, and must try to avoid or mitigate.

Riparian corridors are unique plant communities consisting of the vegetation growing near creek channels. These transition zones are characterized by greater biodiversity and perennial streams sustain life in magnitudes of abundance that are rarely achieved in other plant communities. Intermittent and ephemeral streams also give rise to booms in biotic activity on a more seasonal basis. Due to the presence of fresh water and dense tree canopy, these areas were highly coveted when establishing new settlements (Hynding, 1982). Of all the vegetation habitat types, riparian communities were subject to the most environmental degradation over time because of the integral role they played in daily human life. Streams have been used for water supply, waste disposal, recreation and transportation at the same time, eventually causing widespread damage to riparian flora and fauna. Characteristic woody riparian vegetation species that occur in riparian corridors include (but are not limited to):

- Various types of willow (Salix spp.)
- Red alder (Alnus rubra)
- Boxelder (Acer negundo)
- Black cottonwood (Populus trichocarpa)
- Bigleaf maple (Acer macrophyllum)

- Western sycamore (Platanus racemosa)
- Coast live oak (Quercus agrifolia)
- California bay laurel (Umbellularia californica)

The continued settlement of the Bay Area has been accompanied by the introduction of many exotic species, including trees. The introduction of landscape irrigation in areas with low annual rainfall has enabled a wider variety of trees to flourish in the Bay Area. Throughout San Mateo County neighborhoods, one finds a wide variety of trees from around the world, such as trees from Asia (Gingko biloba, Lagerstroemia and Cedrus deodara), Europe (Prunus domestica, Ceratonia siliqua and Cupressus sempervirens), Australia (Eucalyptus sp., Callistemon sp, Acacia sp.), Africa (Plumeria sp, and Rhus lancea), South America (Jacaranda mimosifolia and Araucaria araucana), and trees from other parts of the US, including Liquidambar, Ulmus, and Robinia to name a few.

Past Conditions

The unincorporated communities of the northern coastside of San Mateo County were almost completely devoid of native tree canopy. The marine terraces and sand dunes from Miramar to Olympic Country Club were naturally covered in perennial grasses, coastal scrub, maritime scrub, or pioneer dune plant communities. Trees typically only grew in narrow bands along creek channels, even in the mountainous parts of this area. Unincorporated communities in the southern coastside had significantly more canopy cover, possibly because the creeks draining the mountains in this area are much larger and originate at higher elevations. Pescadero and San Gregorio watersheds drain extensive sections of the Santa Cruz Mountains, where mixed redwood forest became very dense. The southern bayside communities, including Menlo Oaks, Devonshire, and portions of Emerald Lake Hills were home to the most vigorous native oak habitats in unincorporated San Mateo County. Creeks draining east out of the Santa Cruz Mountains, such as San Francisquito and Redwood Creeks, formed large alluvial plains over time. The alluvial plains contained rich soils necessary for oak woodlands to thrive. Oak savanna, perennial grassland, and wetland habitats were also prevalent in this area. Ladera and Sequoia Tract were primarily covered in grassland and savanna. The northern bayside region contained various vegetative communities, from oak savanna and chaparral in the San Mateo Highlands and Burlingame Hills areas, to wetlands along the bay and grassland in the San Bruno area.

Riparian plant communities throughout the county were home to dense multi-storied canopy. Often large thickets of willow, called sausal, formed along streams and stabilized channel banks while creating valuable habitat for aquatic and terrestrial wildlife. Aspirin was originally derived from willow trees and the Native Americans had many uses for this flexible plant. “An infusion of willow bark or flowers was used to cure a variety of ailments from fevers to itchiness to diarrhea. The inner bark was made into rope, the shoots used for baskets, and stakes provided structure for thatched houses" (Golden Gate National Parks Conservancy, 2012). Riparian habitats were also home to rich herbaceous and woody groundcover composed of numerous species from cow parsnip to sneezeweed. There are over 75 riparian plant species native to San Mateo County (California Native Plant Society, 2014).

Logging of the Santa Cruz Mountains became San Mateo County's first industry around 1850. "The first water-powered sawmills came into use around Woodside and Portola Valley" (Hynding, 1982). There was an incredible demand for lumber in San Francisco and the numerous mining areas in the Sierras and Nevada, making San Mateo County one of California's first important sources for lumber. Smaller steam mills were set up in the mountains to process logs that were too big to be pulled out by teams of oxen to the larger mills below. Entrepreneurs did whatever necessary to exploit this seemingly inexhaustible resource. The heartwood of an old redwood tree was highly prized at that time, as it is now, due to its amazing water repellency and resistance to rot. Tanoak was also harvested extensively for its bark, which was brought to Redwood City to extract tannins for making leather. The resulting environmental degradation from logging activity is not easily quantified. Topsoil was quickly eroded in rain events of the 1860's and 70's. Accidental fires spread across the mountains and destroyed vast stands of timber (Hynding, 1982). The few remaining old growth trees in the county are fortunately being preserved.

Aerial photographs provided a snapshot of the tree canopy from 60 to 70 years ago. We have examined USDA-DDB and Hatfield aerials in birds-eye and oblique framing, respectively. The Planning and Building Department reviewed its own set of DDB prints from 1956. Some images from the 1943 DDB flight were found on the UCSC Archive website. The oblique Hatfield prints from the early 1950's were found in the County History Museum Archive. These photos are helpful when trying to understand what the natural, historic canopy looked like in San Mateo County and specifically within certain jurisdictional boundaries. We also examined the Wieslander Vegetation Type Mapping (VTM) project maps from the early 1930's, which have been digitized by UC Berkeley and UC Davis. These maps have detailed information on species composition throughout the County.

We outlined the community boundaries of county unincorporated lands on the 1956 USDA-DDB aerials to compare these photos side by side with recent satellite imagery. This made it possible to identify general areas where tree canopy has changed. By the 1940's, there had already been significant development and alteration of the natural environment in many parts of the county, particularly in the north surrounding the El Camino Real. We have done our best to hypothesize what conditions were like prior to development, based on examination of adjacent areas which had yet to be developed, along with surveying history books and research articles. In the 1950's, creek channels were still easy to spot from the air, or the ground, because dense brush and tree canopy followed the path of the water, and the surrounding areas were covered in grassland. It is counter-intuitive but, the truth is that California in general was lacking in tree canopy when Europeans came here. There were obviously great forests of redwood along the northern coast and mixed conifer in the Sierra Nevada Range, but the rest of the state was covered in grassland, scrubland, chaparral, wetland and oak savanna, with few places having dense oak woodland quality (Santos, 1997). This is one of the main reasons why so many exotic trees were brought here, aside from the favorable Mediterranean climate. Eucalyptus was likely the most frequently planted non-native genus, and has certainly become naturalized to many parts of the county.

Figure 2: 1943 DDB Aerial image (left) and 2016 Satellite image from Google Earth (right), both showing the Devonshire community and surrounding central bayside area.

The images in Figure 2 are an example of the comparison process we conducted. It is readily discernable from these images that drastic changes in vegetation and canopy cover have taken place in communities like Devonshire. The distribution and density of tree canopy, as well as the connectivity of habitat units, have all been altered from their natural conditions. In fact, every community in the county has seen anthropogenic changes in vegetative quality. The 1943 image was taken in autumn and the 2016 image was taken in spring, but they are still useful comparisons of tree canopy, and can help us understand the biogeographic explanation for tree distribution.

Many communities in the county were naturally dominated by grassland habitat with sparse oak woodland. Careful examination of the historic images reveals tendencies for native trees to grow vigorously only along waterways, in canyons on slopes with northern aspect, or on the alluvial plains where soil structure allows for higher available water capacity. According to the Natural Resources Conservation Service, coast live oak grows "in well-drained soils on bluffs, gentle slopes, and canyons" (USDA - NRCS, 2009). Valley oaks in the county occur in the lower elevation areas where deep, alluvial soil creates rich growing conditions. Oaks develop deep taproots as seedlings in order to reach substrate with high moisture content, which allows them to survive extended periods of drought conditions (Giusti, 2005). Blue and valley oaks also have the ability to shed leaves in the middle of summer if conditions are too dry, called summer deciduousness, which gives them the ability to conserve internal moisture by reducing transpiration.

The coastal mountains on the peninsula have long been home to lush temperate forest composed of coast redwood, Monterey and knobcone pine, white fir and Douglas-fir, incense cedar, California nutmeg, madrone, buckeye, coast live oak, tanoak, black oak, big leaf maple, red alder, bay laurel, and many other tree species. The Wieslander VTM maps are very helpful when analyzing habitat distribution patterns. Redwood and Douglas-fir tend to grow in the canyons where water availability and fog is maximized, while knobcone pine and tanoak prefer the ridgelines (Berkeley Ecoinformatics Engine, 2015). "Although many redwood stands are close to the sea, they do not seem to tolerate ocean winds or salts and so do not grow on exposed hillsides that face the ocean. Redwood trees grow smaller in size and are replaced by other tree species as altitude, dryness, and slope increase" (University of California Agriculture and Natural Resources, 2016). Coastal scrub and grassland habitats can be found right on the coast and up at the highest elevations in the county. Chaparral habitats often form in pockets within the forested areas, or as a transition between forest and grassland areas.

The forests, chaparrals, scrublands, wetlands, and grasslands, all have unique vegetation that play important roles in ecosystem functions. Coast live oak can be considered the most ecologically valuable tree in San Mateo County because it is so widespread and so many species of wildlife depend on it. By the 1950's, development had already diminished natural habitats considerably. Keeping up with demand for development translated into a lot of cutting and grading for many decades. Trees with great cultural and ecological value were frequently removed to build residential, commercial, and industrial developments. Extensive water resource development and depletion has reduced the amount of water available in the environment for vegetation to use. It wasn't until April 5, 1977 that the County Board of Supervisors passed an ordinance to define and protect heritage and significant trees.

Current Conditions

San Mateo County occupies a very large and diverse area of over 455 square miles. The majority of the County's population lives in urban and suburban settlements on the bayside. These areas reflect the most substantial environmental changes made by humans on the peninsula. Much of the bayside has been covered in cement, steel, and wood. It is a small wonder that trees have survived as well as they have and a testament to their resilience. Since the start of the 20th Century, extensive grading and tree removal occurred throughout the county to accommodate droves of newcomers migrating to the Bay Area. A booming economy has constantly enticed people from around the country, and the world. In the late 19th and early 20th centuries, San Mateo County became the home to many wealthy families with interests in the railroads, timber, resources of the bay, and in politics (Hynding, 1982). The population did not grow quickly at first, actually slower than any other county in the Bay Area through the end of the 19th century. In 1870 there were only 6,000 inhabitants, and that only increased to 12,000 by 1900. Even with the railroads connecting San Francisco to San Jose, and the ports of the peninsula established, population growth was slow (Hynding, 1982). After the 1906 earthquake and subsequently WWII, “Suburban” sprawl occurred at a staggering pace on the peninsula and the population grew to 235,000 in 1950, and now over 750,000 people call San Mateo County home (Association of Bay Area Governments, 2010).

Ground and surface water resources were intensively developed in order to sustain population and economic growth. Irrigation infrastructure was built to establish vast orchards on the alluvial plains of the southern bayside, as well as agriculture up and down the peninsula. Trace chemicals from our cars and emissions settling out of the atmosphere from factories and power-plants have been mobilized on the ground during rain events and transported into the soil. Salt water was pulled into our unconfined aquifer from the bay at least 100 years ago as a result of intense groundwater use for the orchards (Carr, 2016). “Maximum groundwater overdrafts generally occurred in 1965. After 1965 increases in surface water deliveries were used to reduce demand for groundwater, restoring groundwater levels to pre-1960 conditions. Imported surface water currently meets approximately 90% of the demand in San Mateo County” (California Department of Water Resources, 2004).

The impacts from our water use and consumption are not immediately apparent. A great deal of that water has been used to increase the greenery in and around the communities of the county. Tens of thousands of trees have been planted in places that are not compatible with the particular species planted without developed water. In some cases, exotic trees are planted in spots that will require heavy watering to sustain them and the benefits from their canopy. In some cases, landscape irrigation water kills native trees that did not evolve in constantly damp soils. Sometimes native trees are planted in communities where they would not naturally grow, such as coast redwoods in San Mateo Highlands or West Menlo Park, where native oaks naturally grew based on native soil and precipitation. The amount of water and care necessary to sustain canopy in these circumstances is far greater than when endemic trees are planted in their native habitats.

The distribution of canopy cover in San Mateo County relative to pre-settlement conditions is highly altered, but in different ways in different regions of the county. In communities like Broadmoor in the northwest part of the county or El Granada on the Coastside, there is more canopy cover now than historic levels. There are now native and non-native trees in Broadmoor where there previously weren't any trees at all. In El Granada, there is a stand of eucalyptus where previously there were only coastal scrub plants, such as coyote brush and black sage. In Pescadero and the mountains east of there, canopy cover has been diminished from clear-cutting over a century ago. At lower elevations along Pescadero Creek, trees were not allowed to grow back following removal because settlers wanted land for agriculture, ranching, and homesteading. However, most of the mountains in the southern coast-side of the County have recovered dense canopy cover of second and third growth forest, although legacy effects of logging and road construction limit the ecosystem functions of these areas.

In Menlo Oaks and North Fair Oaks, aerial imagery from the present shows canopy cover slightly increased over 1940's and 1950's levels. However, the modern canopy in the communities of the southern bayside is composed of less native oaks and more exotics. West Menlo Park was naturally oak savanna and aerial photos from 1948 in Google Earth Pro show very little canopy cover (Google Inc., 2015). Current satellite imagery shows much more canopy there in the form of street trees, most of which are non-native. Weekend Acres is partially in the floodplain of San Francisquito Creek and riparian habitat and grassland would have thrived there, but that area is now covered in native and exotic trees. Emerald Lake Hills and Palomar were naturally oak woodland, oak savanna, and grassland habitats, and they still have very similar amounts of oak canopy compared to pre-development levels, however significant areas of grasslands habitat was converted to suburban housing and planted with a mix of exotic and native trees. Devonshire generally seems to have more canopy cover throughout the community than it once did, but, as with Emerald Lake Hills and Palomar, there are many exotic trees and less oaks. To the delight of gardeners, the Mediterranean climate in the Bay Area in conjunction with irrigation allows for trees from many parts of the world to grow here. With the advent of the State's Water Efficient Landscape Ordinance in response to drought, the amount of allowable irrigation water for new construction and rehabilitation is substantially reduced, ushering in a new era and direction in Bay Area landscaping.

Many of the trees in San Mateo County are young and/or exotic. There have been major declines in the number of large, older native trees, while smaller non-natives have become more commonplace. Much of the bayside was cleared of native trees for the building of residential, commercial, and industrial developments, although luckily, many native tree stands and individual specimens remain. Vast swaths of land were graded to build the communities we inhabit today. Roads were made for the transport of goods and to connect settlements, and have been upgraded continually to keep up with growth. Logging roads and trails were widespread in the mountains because they were necessary to reach every canyon and stand of timber that could feasibly be accessed. Creek channels were enhanced to accommodate heavy storm flow and reduce the risk of flooding. All of these activities led to watershed impairments throughout the county. We don't have enough green infrastructure, such as bioretention areas and vegetated swales, on the bay-side especially, to handle stormwater impacts (San Francisco Estuary Institute, 2015).

The annual amount of fog in the Bay Area has decreased by 33% over the last century (Johnstone, 2010). While water vapor in the stratosphere is a contributor to warming trends, water vapor in the troposphere is an essential contributor to available moisture for local vegetation. Loss of available moisture in the air and in the soil will make it harder to sustain healthy tree canopy, particularly with redwoods. Utilizing areas with naturally sufficient amounts of available moisture will become more important as time goes on. The higher level of water availability and soil moisture in natural riparian habitats lends to their intrinsic ecological value, and makes them prime locations for sustaining dense canopy cover and wildlife habitat in the county. The upper watersheds are still capable of supporting healthy tree growth in riparian corridors. However, most of the lower reaches of creeks that run through urbanized areas are so modified from their natural condition that they do not contribute to ecosystem services the way they used to (EAO, Inc., 2007). Creek water is not able to seep into the ground when the channel is made entirely of concrete.

Climate change since the late 19th century has likely caused the prolonged drought conditions and extreme heat we have experienced in California over the last five years. Given that San Mateo County meets 90% of its water demand with imported surface water from Sierra Nevada snowmelt, and the amount of snowmelt captured annually in surface reservoirs is decreasing, it seems the county is in danger of not being able to sustain current water use through conventional methods in the near future (Sustainable San Mateo County, 2010). Population growth and increased rates of evapotranspiration will also increase the water demand in the years to come as temperatures rise. From July 2005 to June 2006, San Mateo County residents used an average of 89.1 million gallons of water per day from water agencies, and 95% of that water came from the San Francisco Public Utilities Commission. Demand is estimated to be 25% higher by 2030 due to population and climate change factors (Sustainable San Mateo County, 2010).

Future Conditions: Climate Change, Population, Development

Yogi Berra said "It's hard to make predictions, especially about the future." Despite this wisdom, certain projections can be studied and used for the purpose of improving our general understanding and to guide decision-making. Over the last several decades scientists have developed models and other tools to use in projecting future climate conditions. Some of this work focused on California, and produced tools for the public to utilize in planning efforts such as this tree removal ordinance revision. San Mateo County utilized these tools and the overall body of climate research in order to characterize potential impacts of climate change on tree canopy. Water management initiatives, population growth and urban infill can be effective ways of reducing our footprint on the environment. By characterizing future climate, population, water and development conditions, and understanding past and present conditions, we are better able to understand which tree species will be able to thrive in the county and sustain the highest quality tree canopy.

Significant and heritage trees and the County's tree canopy are going to be more important as time goes on. Large trees with established root systems that spread out and tap deep into the ground are better prepared for future hydrologic conditions. Human activities that increase atmospheric concentrations CO_2, CH_4, NO_x, SO_x, VOC's, CFC's and HCFC's will lead to changes in the hydrologic cycle because more heat energy will be trapped on the surface and in the troposphere. More energy means higher temperatures, which directly impacts precipitation type and frequency. We are likely to see more drought conditions during summer months, with more rainfall occurring in torrential events that cause rapid runoff and erosion in winter months (Trenberth, 2011). The combination of those two climatic changes will create more stress on vegetation and will have implications for our current water management systems. Long-term suppression of wildfire coupled with extensive drought is also creating extreme fire risk, which is evinced by the massive fires burning around the state right now.

Climate change is represented mathematically through General Circulation Models (GCM's), which take into account the complex interactions between the atmosphere, the oceans, the cryosphere (land ice), and land-surface. There are many GCM's currently being used by dozens of teams around the world to make projections of future climate conditions. They are not used to predict the future, but rather to explore potential future conditions based on certain assumptions about development and emissions trajectories and feedback effects on global climate. Although there are many projected futures, the Intergovernmental Panel on Climate Change (IPCC) has defined two broad categories of climate-related assumptions, known as A2 and B1, that are widely cited as effectively bracketing our potential futures (Cal-Adapt, 2016).

Table 1: Descriptions of IPCC-defined emissions scenarios

A2: IPCC title for the medium-high emissions scenario. A2 projects continuous population growth and uneven economic and technological growth. The income gap between now-industrialized and developing parts of the world does not narrow. Heat-trapping emissions increase through the 21st century; atmospheric CO_2 concentration approximately triples, relative to pre-industrial levels, by 2100

B1: IPCC title for the lower emissions scenario. B1 characterizes a world with high economic growth and a global population that peaks by mid-century and then declines. There is a rapid shift toward less fossil fuel-intensive industries and introduction of clean and resource-efficient technologies. Heat-trapping emissions peak about mid-century and then decline; CO_2 concentration approximately doubles, relative to pre-industrial levels, by 2100.

Both of these scenarios are being run through the many climate models to compare and contrast results. This helps validate and enhance modeling tactics, which in turn can improve the capacity of climate modeling to guide policy decisions. California Landscape Conservation Cooperative (CA LCC) has produced a website, called calcommons.org, that puts multiple GCM's to work in their Basin Characterization Model of the California Hydrologic Region. CA LCC developed an interactive map tool which gives the public access to the most current climate change data.

Figure 3: 1981-2010 Average high summer temperature in ˚C (Historic Baseline)

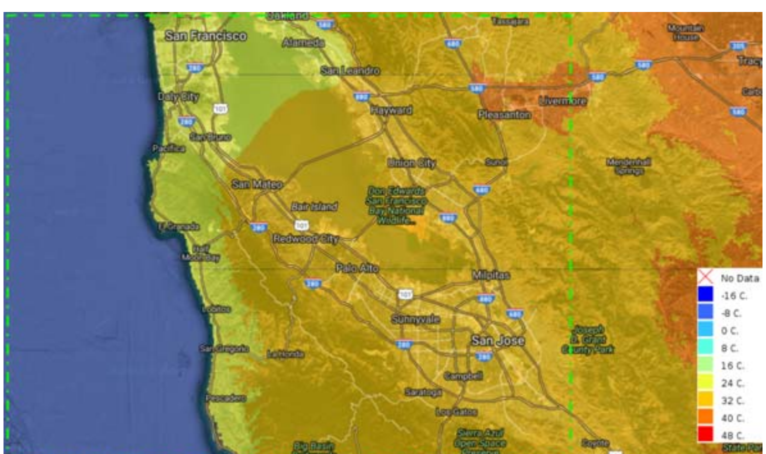

Figure 4: 2070-2099 PCM B1 Projected average high summer temperature

PCM, or Parallel Climate Model, is one of the GCM's one can use on calcommons.org. The developers of the map tool also included historic climate data to give the user the ability to compare historic conditions to projected future conditions. Figures 3-5 were created using the map tool.

Figure 5: 2070-2099 PCM A2 Projected average high summer temperature

The 32˚C and 40˚C areas are clearly expanding westward in the future.

32˚C = 89.6˚F

40˚C = 104˚F

These images clearly show how average summer temperatures in San Mateo County could increase over time. The Woodside area and Portola Valley are especially vulnerable to extreme heat in the higher emissions scenario (Figure 5), with summer heat waves expanding throughout most of the county. Even in the lower emissions scenario (Figure 4) we still end up with a hotter environment, which has many implications for trees. Climate change has been happening for decades. Sea level has risen 8 inches in the Bay over the last century. As noted earlier, fog has decreased 30 percent during the same period. The Bay Area is experiencing the warmest years ever recorded and each year is warmer than the prior year. These changes will likely accelerate unless drastic reductions in the amount of atmospheric carbon are achieved.

Climatic Water Deficit (CWD) is defined as "…cumulative annual excess of potential evapotranspiration versus actual evapotranspiration. CWD is an integrative measure of water demand relative to availability" (McIntyre, 2015). "This calculation [CWD] is an estimate of drought stress on soils and plants and recent studies suggest it may serve as an effective control on vegetation cover types in the Bay Area" (Ackerly, 2010). When CWD is low, the environment is in good shape with sufficient available water for healthy growth and maintenance of vegetation. When CWD is high, the environment suffers.

The drought conditions we have been experiencing lately are a direct result of changing climate. As a baseline average from 1981-2010, annual CWD in the mountainous and coastside regions of the county ranged from 400-600mm H_2O, and annual CWD in the bayside region ranged from 700-900mm H_2O (Terrestrial Biodiversity and Climate Change Collaborative, 2013). Drought directly implies high climatic water deficit, and unfortunately the climate models point towards CWD continuing to rise while precipitation decreases or becomes more irregular. We will have some water years that match average historic levels over the decades to come, but that does not excuse us from the obligation to conserve water wherever possible.

Climate change models from the Geophysical Fluid Dynamics Laboratory and the National Center for Atmospheric Research are projecting changes to the climate in California that will affect forest canopy in San Mateo County. The distributions of certain tree species will shift and/or shrink due to changing precipitation, temperature, and soil moisture content (Point Blue Conservation Science, 2016). These conclusions are based on the assumptions that economic and population growth will continue along current trends and that carbon dioxide concentrations will reach >600ppm levels by the year 2100 as a result.

The redwood, montane hardwood-conifer, and Douglas-fir habitats that have occurred for millennia in the mountainous central region of the peninsula will be reduced to small groves closer to the coast if the model assumptions hold true. This will cause montane hardwood, chaparral, and coastal scrub habitats to expand into the areas where redwood and Douglas-fir are retreating, which will impact native wildlife and microclimate conditions. These potential changes highlight the importance of preserving significant and heritage trees, and replacing them with the right species when such trees are removed.

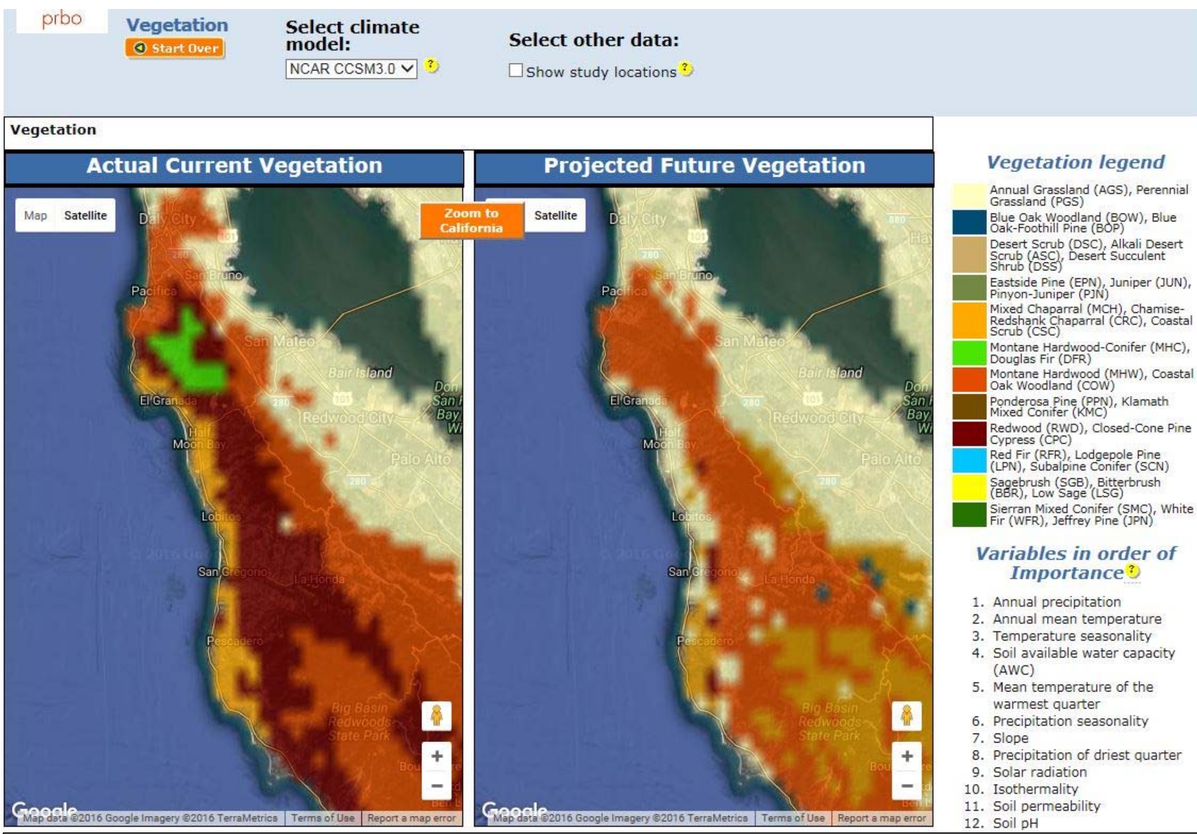

Figure 6: Maps of current and projected vegetation habitat distributions in San Mateo County, produced by Point Blue Conservation Science in 2016. The current vegetation map (left) is based on averaged data from 1971 to 2000. Map of projected future vegetation (right) is based on the National Center for Atmospheric Research's CCSM3.0 general circulation model and the A2 emissions scenario, with the CO_2 concentration reaching 610ppm by 2069.

Groundwater recharge is incredibly important going forward. The best areas to focus on groundwater recharge will be west of El Camino Real, but below 150 feet elevation, because the coarse alluvial deposits in the lower foothills are directly connected to the deep aquifer (Carr, 2016). In the Department of Water Resources' 2003 Bulletin 118 update, secondary inorganics were the only contaminant group to be recorded as exceeding maximum contaminant levels in samples taken from test wells, and that only occurred in 2 of the 10 wells sampled (California Department of Water Resources, 2004). Thus, the quality of our groundwater will not impede healthy tree growth, but the quantity might if we do not develop green infrastructure to increase recharge.

The California Department of Water Resources filed chapter 2.7 Model Water Efficient Landscape Ordinance (WELO) in the summer of 1992, and updated it in 2015. WELO requires that local agencies reduce water use for landscape irrigation. The purpose is to "establish a structure for planning, designing, installing, maintaining and managing water efficient landscapes in new construction and rehabilitated projects by encouraging the use of a watershed approach that requires cross-sector collaboration of industry, government and property owners to achieve the many benefits possible", among other things (California Department of Water Resources, 2015).

San Mateo County has adopted the state's model WELO and implements it on most landscaping that it approves. The 2015 WELO features more stringent requirements, such as reducing the landscape size threshold for compliance from 2,500 sq. ft. to 500 sq. ft., requiring tilling in compost to make soil more friable, using a minimum 3 inch layer of mulch on exposed soil surfaces, and installing climate adapted plants that require little or no summer watering. These practices will help to reduce the amount of water used while maintaining beautifully landscaped areas in the county.

Population growth will fuel new development. The Bay Area is one of the most economically successful regions on Earth, constantly creating new jobs that attract migrants and immigrants in large numbers. To house the new residents that will work the new jobs produced by the Bay Area economy, we will continue to densify the developed footprint of the region, raising the need for greener streets and new urban open spaces to avoid the heat island effects of climate change and to create the complete communities envisioned in the region's sustainable communities strategy *Plan Bay Area*.

The California Sustainable Communities and Climate Protection Act of 2008 requires metropolitan regions in the state to "reduce greenhouse gas emissions from cars and light trucks", and to "promote compact, mixed-use commercial and residential development" (planbayarea.org, 2014). Plan Bay Area expects population in the Bay Area to grow from 7 million to 9 million by 2040. Thus, smart decision-making will be critical if we are to maintain our high quality of life. Priority Development Areas (PDA's) have been identified based on walking distance to transit service, variety of housing options, and available amenities such as grocery stores and parks.

Plan Bay Area will help fund mixed-income housing and locally-based planning efforts in PDA's with federal, state, and local money. The goal of infill is to create denser settlements that provide all of the services a healthy community needs, while slowing urban sprawl and the destruction of remaining natural spaces. The Association of Bay Area Governments and the Metropolitan Transportation Commission have set this plan into motion with the hope that it will reduce our climate footprint while building healthier communities and a stronger economy. Ensuring the viability of new tree canopy in PDA's and throughout the county is a high priority.

Future climate conditions are not certain, but we have sufficient evidence to guide our decisions with respect to the conservation of heritage and significant trees in the county. We also have a sound basis for determining which trees to plant in the various jurisdictional areas of the county when historically or ecologically valuable trees are removed. The steps we take now can help to sustain healthy tree canopy for centuries to come.

Opportunities & Challenges

We have a number of opportunities to improve environmental conditions in the county. Planting more native and/or drought-tolerant trees along streets will help to beautify any community while promoting diverse urban forest. Green infrastructure can be implemented throughout the county to restore watershed function and improve water quality, and these strategies can include planting trees. Watershed planning is a holistic approach to development oversight and water quality protection that employs Best Management Practices and preserves ecosystem services. In combination with the redevelopment envisioned in *Plan Bay Area*, these practices will help us get through the many challenges we are facing.

In 2000, Sudden Oak Death (SOD) became a serious problem in the San Francisco Bay Area. SOD is a fungus-like pathogen that likely originated in Asia and made its way into coastal California forests after escaping from commercial nurseries, according to Cindy Roessler, a Senior Resource Management Specialist from the Midpeninsula Regional Open Space District (Midpen) (Bartholomew, 2016). 19 of the 24 Midpen preserves have been affected by SOD. Unfortunately, the California bay laurel has been used by the pathogen as a means of reaching oak trees. SOD behaves like a water mold and has the ability to move up the bay tree, which it can't penetrate and infect, but it can launch spores from the bay leaves to access nearby oaks. This has led to the removal of all bay trees within 15 feet of oak trees in test plots within affected preserves. Tactics like this are controversial but have already shown some promise in the reduction of oak mortality.

Impervious land cover is another major problem for the county's trees. Before extensive development took place, precipitation was able to percolate into the ground naturally. In modern times, the percent pervious area has been extremely reduced along the Highway 101 corridor and throughout most bayside communities. This causes accelerated runoff, erosion, and contamination of surface water resources. For example, the Pulgas Creek watershed, which drains approximately 3.5 square miles and flows through San Carlos, has an estimated 54% impervious area and 90% of the channel has been modified (EAO, Inc., 2007). Drastic alterations to natural conditions can make tree survival rates more unpredictable. The local climate has also been, and will continue changing, increasing unpredictability.

The process of water falling onto the earth and percolating through soil and rock into the water table, or recharging groundwater aquifers, supports many ecological services. The 54% impervious area in the Pulgas Creek watershed is undoubtedly causing losses in soil moisture and a drop in the water table because less water is able to penetrate the surface. This occurs all throughout the bayside of the county in all of the bayside watersheds. The value of green infrastructure will become more and more obvious as time goes on. Slowing down the movement of water by creating areas of high permeability will facilitate groundwater recharge and the cleaning of stormwater. We must also consider the power of severe storms to destroy property and cause dangerous flooding. "Changing weather patterns are expected to produce wetter storms with higher peak flows in the future, resulting in more intense flooding in creeks and rivers that drain the Bay Area's watersheds" (Bay Area Council Economic Institute, 2015). It has been 154 years since the last 150-year storm event and our flood protection facilities are sorely lacking for many low elevation communities.

Appendix

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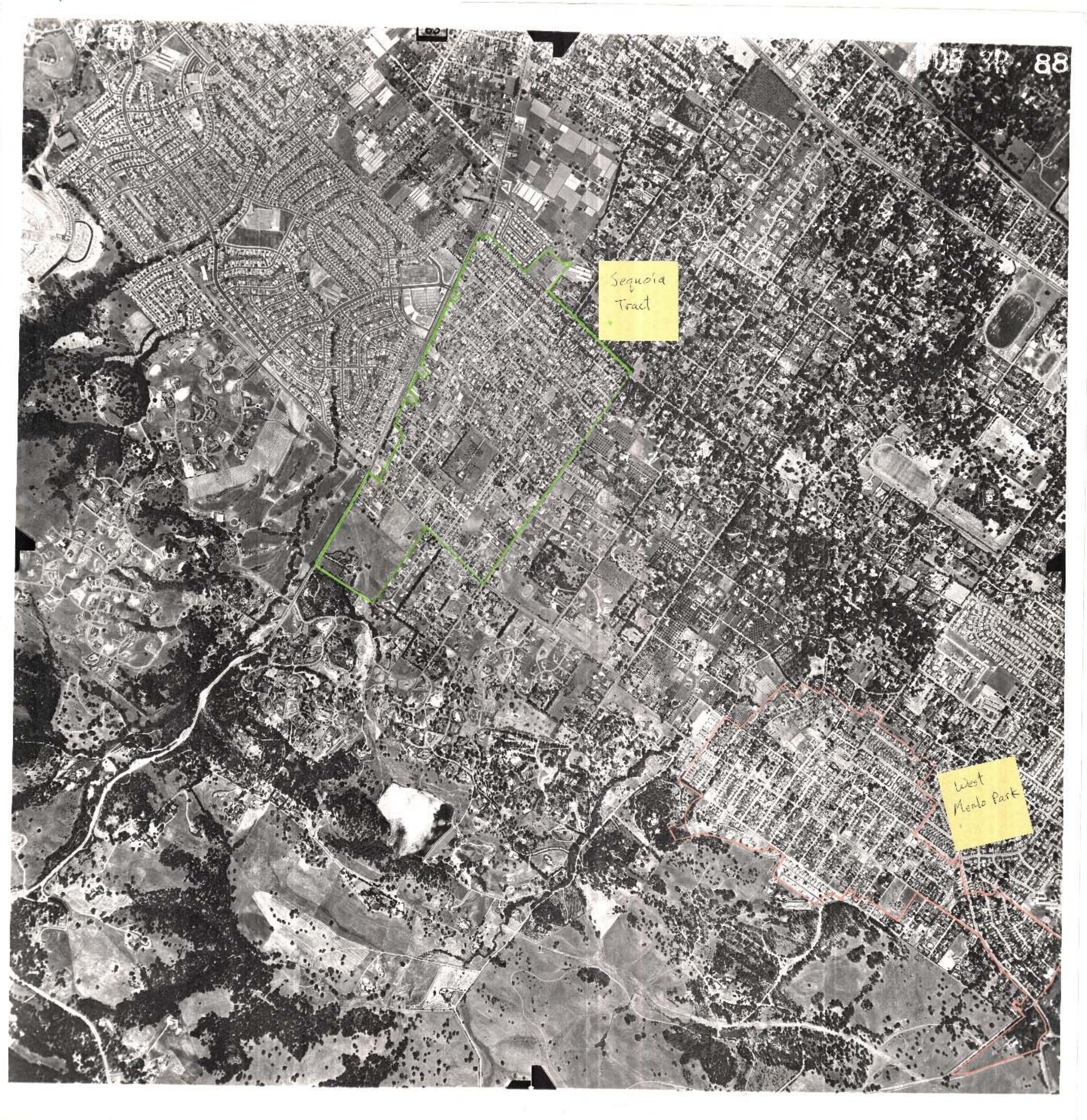
Example Aerial Photos




9-56
DDB-3R-106
North Fair Oaks
Menlo Oaks


5-27-'56
DDB-1R-37
El Granada
Miramar


6- 9-'56
DDB-3R- 31
Devonshire
175

Past Canopy Characteristics Table

To be added upon completion…

Present Canopy Characteristics Table

The following tables characterize the current canopy and watershed characteristics of each Bayside and Coastside community, based on staff's use of street view in Google maps and select site visits.

Neighborhood	Current Canopy Characteristics	Watershed Characteristics
Olympic Country Club	Olympic Country Club: evergreen conifers and broadleaf trees at the margins of fairways; Coastal scrub w/o trees; some scattered canopy trees in rear yards of homes-mostly mixed exotics; relatively sparse canopy	Lower reaches of southern portion of watershed draining to Lake Merced.
Broadmoor	Several wide swaths of mixed conifers Monterey Pine/Cypress or Eucalyptus located in rear yards, and/or on land-locked lots: (N. of 87th; Pinehaven-Maddux; Gilman to McArthur; Larchmont to Nimitz; Beechwood to Thornhill;	Headwaters of southern portion of watershed draining to Lake Merced.
Colma	Small copse of Eucalyptus and Monterey Pines behind Mid-Pen's Colma Ridge housing project; Small copse of Eucalyptus at the western terminus of A Street, and Acacia and Monterey Pine near west side Colma BART station	Headwaters of Colma Creek
California Golf Club	Mix of broadleaf and conifer evergreens on golf course; dense copse of trees along southern edge of Westborough Boulevard mainly Monterey Pine/Cypress; Corner of Westborough and Junipero Serra, Dense stand of Monterey Pine/Cypress, Eucalyptus, Oaks and Acacia	Westborough Blvd. built atop Twelve Mile Creek-tributary of Colma Creek.
Country Club Park	Large-lot Single family neighborhood with ½-acre lots with large mature trees in most rear yards- Eucalyptus, Monterey Pine/Cypress, some street trees adjoining rolled curbs w/no sidewalks	Drained to Colma Creek wetlands

Neighborhood	Current Canopy Characteristics	Watershed Characteristics
SFO Airport/San Bruno	San Antonio Avenue, eastern street edge west of Bayshore property: between San Felipe and San Juan Avenues: Dense stand of mixed evergreen with Monterey Pine/Cypress, Eucalyptus, some Oaks; and Acacias along eastern side of street; no street trees small stands of Monterey Pine/Cypress and Eucalyptus along San Bruno Creek just south of I380/US101 interchange; No trees on SFO. Lower reaches of San Bruno and Colma Creeks.	Built atop Colma, San Bruno and El Zanjon Creeks wetlands
San Francisco Watershed Lands	Mix of Coastal Scrub, and mixed Evergreen Forest—no need to regulate?	Drain mostly to reservoirs (e.g., San Mateo Creek), and include headwaters of Pilarcitos Creek, and southern half of San Pedro Creek Watershed
Burlingame Highlands	Very similar in character to Emerald Lake Hills and San Mateo Highlands, except the tree canopy is more diverse. Considerable number of Oak, Redwood, Monterey Pine, Eucalyptus, some Cedar and Cypress, Acacia and lots of exotics, e.g., palms, olives, magnolia. Headwaters and northern flank of Easton Creek watershed.	Headwaters/northern half Easton Creek Watershed
San Mateo Highlands	Very similar in character to Emerald Lake Hills, except Monterey Pines predominate instead of Oaks, although many oaks present; mix of ornamentals/exotics; some street trees at front property line behind sidewalk on some streets-mainly deciduous.	Entire Polhemus Creek Watershed, tributary to San Mateo Creek
Peninsula Golf and Country Club	Evergreen conifers and broadleaf trees at the margins of fairways-mainly Monterey Pine and Redwood. Dense canopy at margin along Hwy 92, Madera Lane and western edge adjoin US Postal Facility.	Drains to Borel Creek, no stream channel
Devonshire	Mixed Oak/Buckeye/Madrone/Bay/Monterey Pine, Redwood with some exotics in landscaped yards	Headwaters Pulgas Creek
Palomar Park	Oak studded grasslands; coastal scrub; Monterey Pine, exotics in yards; in easternmost parts, e.g., along Scenic and Palomar, Acacia, Redwood, Liquidambar, Magnolia and other exotics	Partial Headwaters Cordilleras Creek

Neighborhood	Current Canopy Characteristics	Watershed Characteristics
Emerald Lake Hills	Oak Woodland with some Monterey Pine and Redwood as well as exotics, including some dense areas of Acacia	Headwaters Arroyo Ojo de Agua
Kensington Square	Sparse suburban tree canopy. Mix of primarily exotics, and a few large redwoods. Short segment of Arroyo Ojo de Aqua creek (concrete channel). Few street trees.	Segment of Arroyo Ojo de Agua
North Fair Oaks	Patchwork of industrial areas with no trees (+/- 25% of area), suburban tree cover with trees mostly in yards front and/or rear with few (<40%) street trees (+/- 50%) and areas with Dense canopy, w/many (.40%) street trees (+/- 25% of area); tree species vary widely although dense areas have many oaks, redwood and exotics. Suburban areas mostly exotics w/some remnant heritage oaks	Scattered oaks in southern portion, draining partially to Redwood Creek but mostly to the bay.
Menlo Oaks	Very Dense Oak canopy (Coast Live and Valley) mixed with Redwood, Monterey Pine and exotics	Moderately dense oak woodland, drainage to the bay
Sequoia Tract	Suburban tree canopy with varying density. Some streets have street trees, most do not. Some areas have dense canopy, in others canopy is sparse. Many Redwood, some Oak and Monterey Pine, many exotics	Partially drains to Redwood Creek
West Menlo Park	Suburban tree canopy, with substantial number of Oaks (Coast Live and Valley), Redwood, some Monterey Pine, and wide variety of exotics. Some street trees, but most outside public ROW.	Drainage to San Francisquito and Atherton Creeks. Scattered oaks, especially in southeastern portion
Stanford Lands	Horse Park, Jasper Ridge, SLAC and related buildings, and open grasslands. Natural Oak woodland, coastal scrub and oak studded, non-native grasslands. Riparian corridor, oak covered, tributary to San Fancisquito Creek.	Predominantly savanna with large patches of dense oak woodland. Corte Madera Creek supported marsh habitat in western portion, which feeds San Francisquito Creek
Ladera	Suburban tree canopy, predominantly Coast Live Oak, Redwood and exotics. Some Valley Oak, Heteromeles, and Monterey Pine. Separated from creek corridor by Alpine Rd. and commercial uses.	Steep slopes drain to Los Trancos Creek

Neighborhood	Current Canopy Characteristics	Watershed Characteristics
Weekend Acres	Suburban tree canopy, predominantly Coast Live Oak. Adjoins San Francisquito Creek with characteristic riparian corridor tree density. Some Valley Oak, Redwood, Monterey Pine and exotics	Drainage to San Francisquito Creek
Skyline North - Bayside	Dominated by Conifers west of Crystal Springs Reservoir, including Monterey pine and cypress. Stand of eucalyptus, scrub and chaparral. Areas east and south of the reservoir are mostly grassland with some chaparral	Natural drainage to Crystal Springs Reservoir basin
Los Trancos Woods, Skyline South-Bayside and Vista Verde	Approximately 50% dense forest made up of redwood, doug-fir, pines, oaks, laurel, buckeye, etc., and 50% grassland	Drainage feeds Corte Madera and Los Trancos Creeks
Loma Mar - Bayside	Approx. 90% conifer canopy cover and some exposed grassland	Drains to Pescadero Creek

Coastside Neighborhood	Current Canopy Characteristics	Watershed Characteristics
Montara	Built atop portions of Kanoff, Montara and Dean Creeks watersheds.	Built atop San Bruno and Dean Creeks wetlands
Moss Beach	Mix of Coastal Scrub, and mixed Evergreen Forest—no need to regulate? Stands of eucalyptus and cypress	Drain mostly to reservoirs (e.g., San Mateo Creek), and include headwaters of Pilarcitos Creek, and southern half of San Pedro Creek Watershed
El Granada	Primarily grass and scrubland with stands of eucalyptus. West portion is mostly agricultural	El Granada Creek is primary drainage and empties into the ocean. Native tree canopy only occurs along the creek
Princeton	Half Moon Bay Airport and agricultural land, two stands of Monterey pine, some coastal scrub habitat	Denniston Creek drains to the ocean, coastal scrub
Miramar	Stands of eucalyptus and cypress throughout residential areas	Arroyo De En Medio drains into the ocean. Native tree canopy only occurs along the creek

Coastside Neighborhood	Current Canopy Characteristics	Watershed Characteristics
Rural Mid-Coast	Ecologically valuable watershed lands with varying traits. Some portions have rolling hills with hummocky topography near the coast, while other areas are steep and moderately dissected. Many reservoirs have been created in stream valleys to serve agricultural and municipal needs. Tree canopy is dense with native conifers in many portions, but scrubland dominates elsewhere	Green Valley Creek, Martini Creek in the north portion. Headwaters of Montara, San Vicente, Denniston, El Granada, Arroyo De En Medio, Locks, Frenchmans, Apanolio, Corinda Los Trancos, Nuff, Pilarcitos, Mills, Arroyo Leon, Whittemore, and Arroyo Canada Verde Creeks
San Gregorio	Lower watersheds sustain densely vegetated riparian corridors. Small groves of redwood trees can be found but eucalypti are more prevalent. Landscape is generally open with agriculture and ranching as primary land use. Upper watersheds are home to healthy redwood forest with full canopy. Large sections of rolling hills and grassland	Walker Gulch drains to Whittemore Creek. Lobitos Creek and Purisima Creek are the primary watersheds in the north and both drain to the ocean. Tunitas Creek drains to the ocean. El Corte De Madera, Bogess, Clear, and Coyote Creeks all contribute to the San Gregorio Creek watershed, which has a natural lagoon before emptying into the ocean
Pescadero-East and West	-Pescadero West is dominated by agricultural and ranching lands as well as grassland. Scattered pines and cypress throughout, dense riparian vegetation along stream corridors -Pescadero East is dominated by redwood forest with full canopy	Bradley Creek and Honsinger Creek feed into lower Pescadero Creek, which empties into the ocean. Butano Creek empties into the same lagoon as Pescadero Creek. Arroyo De Los Frijoles feeds into Bean Hollow Lakes and then to Lake Lucerne on the coast. Whitehouse, Cascade, and Green Oaks Creeks drain the southern portion
La Honda	Dense tree canopy composed of redwood, pine, fir, madrone, and others	La Honda Creek and Alpine Creek converge to form San Gregorio Creek
Loma Mar- Coastside	Agricultural lands surrounded by dense mixed redwood forest with full canopy	Pescadero Creek runs through
Dearborn Park	Dense redwood forest with full canopy surrounding small family gardens. Some exotic trees lining the streets	Drainage to Pescadero Creek

Coastside Neighborhood	Current Canopy Characteristics	Watershed Characteristics
Skyline North – Coastside	Primarily forested, mountainous terrain with large portions of dense canopy and many patches of grassland. Forest composed of many native species, conifer and deciduous. Small communities scattered around with some exotic trees	Headwaters of San Gregorio, El Corte De Madera, and Purisima Creeks. Large area draining into the southern end of Crystal Springs Reservoir.
Skyline South - Coastside	Primarily forested, mountainous terrain with large portions of dense canopy and several large patches of grassland. Forest composed of many native species, conifer and deciduous. Small communities scattered around with some exotic trees	Headwaters of San Gregorio, Pescadero, and Butano Creeks.