# Data and Methods

## Conservation Lands Network 2.0

# Contents

# Introduction

The Conservation Lands Network 2.0 Report ("CLN 2.0 report", BAOSC 2019) includes information on the methodology behind the Conservation Lands Network (Chapter 3). The CLN 2.0 report also refers readers interested in methods to the original report ("CLN 1.0 report", BAOSC 2011), including its Appendix B, since the methods were retained for CLN 2.0. This appendix discusses only those datasets updated or developed for CLN 2.0.

# CLN 2.0 Network Design Methodology

The design of CLN 2.0 followed the same process used in the design of CLN 1.0. All input data were updated for new information and to include Santa Cruz County. A summary of the updates, processing notes, and brief discussions of issues for future versions follows. Unless noted, all data preparation, analysis, post-analysis steps followed the methodology described in CLN 1.0.

## Configuring Marxan

As in CLN 1.0, the conservation planning software [Marxan](#) (Ball *et al.* 2009) was used to create a draft CLN 2.0 Network design. Marxan is designed to meet user-defined conservation targets for the minimum "cost."

## Planning Units

Marxan requires a grid of consistently-sized planning units covering the entire study area. CLN 2.0 used a grid of 100-hectare (250-acre) hexagons originally created for CLN 1.0 but expanded by Heller *et al.* 2015 to include Santa Cruz County.

*Difference(s) from CLN 1.0:* Added planning unit hexagons to include Santa Cruz County.

## Cost (Inverse of Suitability)

Marxan uses a cost value in its selection of planning units for the network design. As in CLN 1.0, cost was defined via scores from three factors: Distance to Roads, Population Density, and Parcelization. Methods are discussed in Appendix B of the CLN 1.0 report. CLN 2.0 updates are presented below.

### Population Density

Description: An estimate of average population per acre for each planning unit hexagon (Figure 1).

*Difference(s) from CLN 1.0:* CLN 1.0 used dasymetric population density data prepared by the USGS for the 2000 Population Density - San Francisco Bay Area Project (Sleeter 2008). Updated dasymetric population density data from the USGS were not available for CLN 2.0 and the 2000 Population Density data did not include Santa Cruz County. The Dasymetric Mapping Tool (USGS 2014), the 2016 American Census Survey block groups, and the 2011 National Land Cover Database (Homer et al. 2012) were used to re-create the population density.

### Analysis Steps

**1. Prepared land use layer input**

The 2014 National land Cover Database was downloaded and reclassed to match requirements for Dasymetric Mapping Tool: 1 (High Density Residential) = NLCD Developed High Density and Developed Medium Intensity; 2 (Low Density Residential) = NLCD Developed Low Intensity; 3 (Non-Urban

Inhabited) = NLCD Developed Open Space, 4 (Uninhabited) = all other NLCD classes, and 0 (Uninhabited Land Use Class) = NLCD Water.

2. **Ran Dasymetric Mapping Tool to determine density**

3. **Determined average population per acre for each hexagon**

A raster population density (Dasymetric Mapping Tool output) was generated. Average population per pixel for each hexagon was calculated using the Zonal Statistics as Table Esri ArcGIS tool. For each hexagon, the average population per pixel was converted to average population per acre.

4. **Normalized population per acre values**

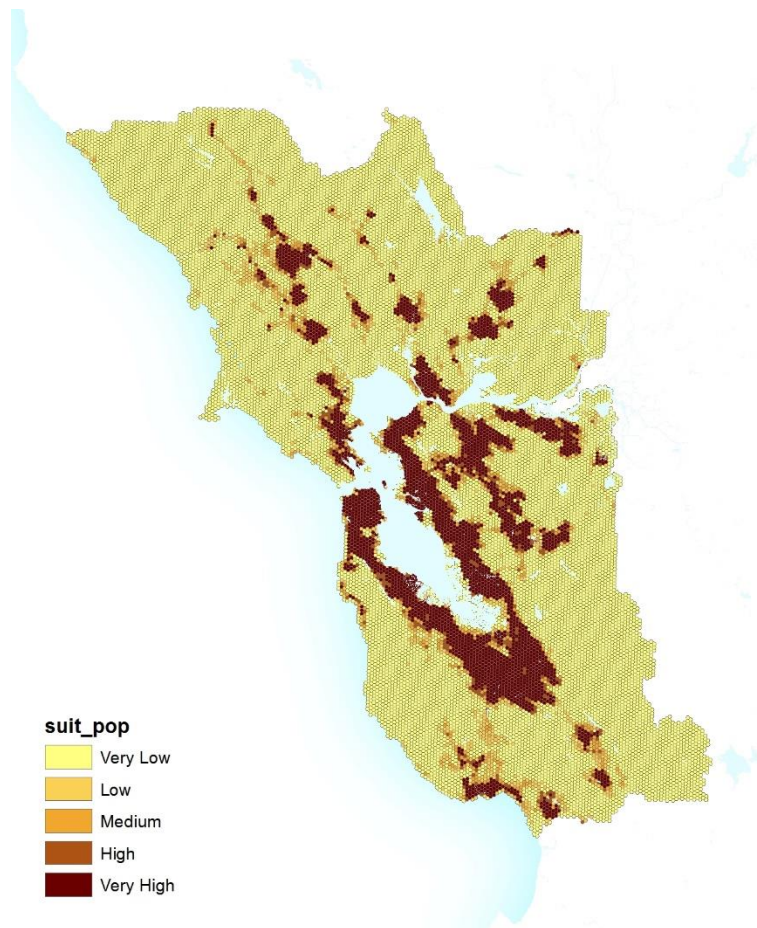Population per acre was normalized using the methods described on page 3 of Appendix B of the CLN 1.0 report.



*Figure 1. CLN 2.0 Population Density.*

## Road Density

Description: The weighted average of the average distance to the nearest road per planning unit hexagon (Figure 2).

*Difference(s) from CLN 1.0:* CLN 1.0 used distance raster from the 2004 USGS National Overview Road Metrics - Euclidean Distance (NORM-ED) model. Updated distance to road data were not available for CLN 2.0. Using the same methods as the NORM-ED model, a new distance to roads raster was created using the Euclidean Distance tool in ArcGIS and roads from TIGER/Line (US Census, accessed 3/2018).
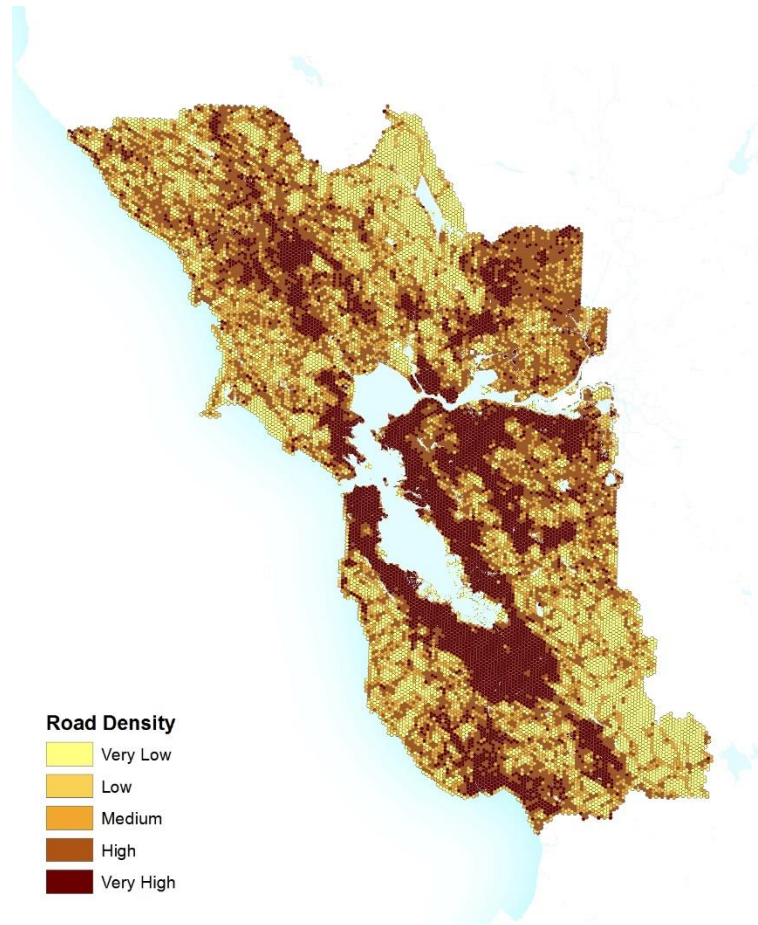


*Figure 2. CLN 2.0 Road Density.*

## Parcel Density

Description: The total number of parcels that intersect each planning unit hexagon (Figure 3).

*Difference(s) from CLN 1.0:* Used updated parcels from each county, including Solano County (for which data were not available digitally at the time of CLN 1.0) and Santa Cruz County (new in CLN 2.0).

## Final Cost

Each table from the Distance to Roads, Population Density, and Parcelization analyses was joined to the hexagon layer to create the final suitability layer. In the attribute table of the layer, these three fields were summed, divided by 3, and converted to an integer that served as the final cost index, from 100 (low cost/highly suitable for conservation) to 1000 (high cost/very unsuitable for conservation) (Figure 4).
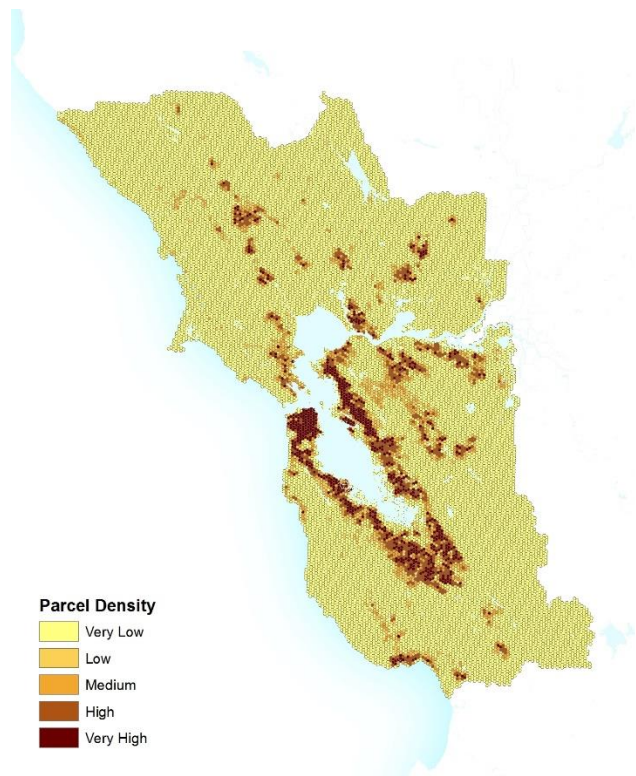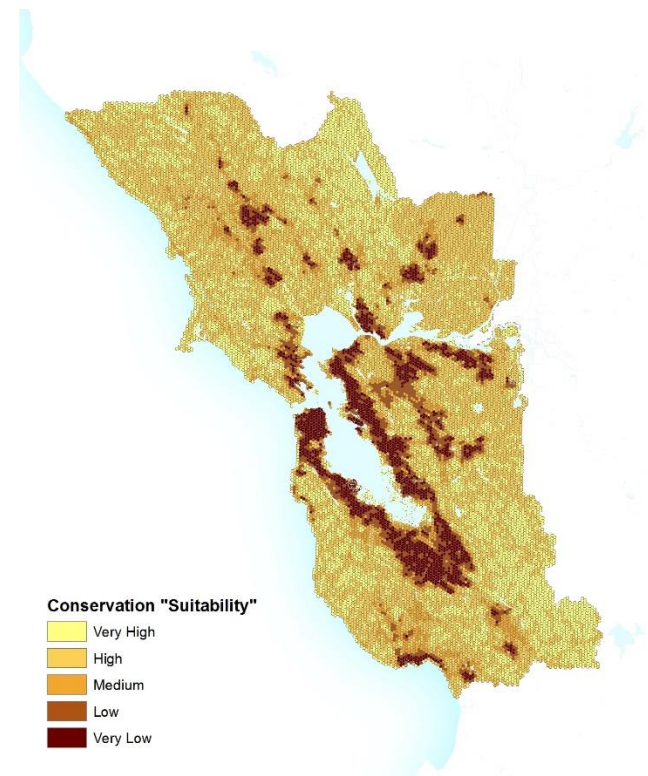
*Figure 3. CLN 2.0 Parcel Density.*　　　　　　　　*Figure 4. CLN 2.0 Conservation Suitability (inverse of Cost).*

## Locked-in Analysis Units

Description: Marxan allows the user to "lock in" (or ensure the inclusion of) specific planning units prior to running the model. To promote future contiguity among protected areas, existing protected lands were "locked in" for CLN 1.0 and 2.0.

*Difference(s) from CLN 1.0:* The 2018 edition of the Bay Area Protected Areas Database was used for CLN 2.0.

## Marxan Settings

Marxan settings, specifically the Boundary Length Modifier and Penalty Factor Value, were kept the same as CLN 1.0 (see page 4 of Appendix B of the CLN 1.0 report); these were 0.1 and 800, respectively.

*Difference(s) from CLN 1.0:* None.

## Landscape Units

To localize conservation targets, the study area was separated into 36 biogeophysical settings called landscape units (Figure 5).

*Difference(s) from CLN 1.0:* Two additional landscape units were added to include Santa Cruz County. The southern boundary of the CLN 1.0 Santa Cruz Mountains North, which previously was coincident with the county boundary, was moved slightly north to the Pescadero Creek/Waddel Creek Watershed boundary. An additional landscape unit (Pacheco Pass) was added in the southeastern corner of Santa Clara County to reflect the transition from oak- and chaparral-dominated Mount Hamilton to the more grassland-dominated area surrounding Pacheco Peak.

*Figure 5. CLN 2.0 Landscape Units.*

## Coarse-filter Targets

Coarse-filter conservation targets were generated by combining the CLN 2.0 vegetation map and the CLN 2.0 landscape units, generating a total of 1,282 localized conservation targets. The vegetation map is described in Chapter 3 of the CLN 2.0 report. Specific data issues are discussed below.

## Vegetation Map

### Data Sources

The USFS Existing Vegetation (Eveg) dataset was used as the primary source of the vegetation communities map for CLN 2.0. The spatial resolution of Eveg is 5 meters as opposed to 30 meters of the CLN 1.0 vegetation map (Figure 6). The CLN 2.0 study area intersects with four Eveg tiles: North Coast Mid, North Coast West, Central Coast, and Central Valley. Eveg uses the same classification system as the CLN 1.0 coarse-filter target map (Calveg). Because Eveg does not cover the entire study area, the CLN 1.0 vegetation map was used for approximately 5% of the study area; the CAL FIRE "Fveg" vegetation map filled a gap of less than 1% of the study area that was not covered by either Eveg or Fveg (Figure 7).
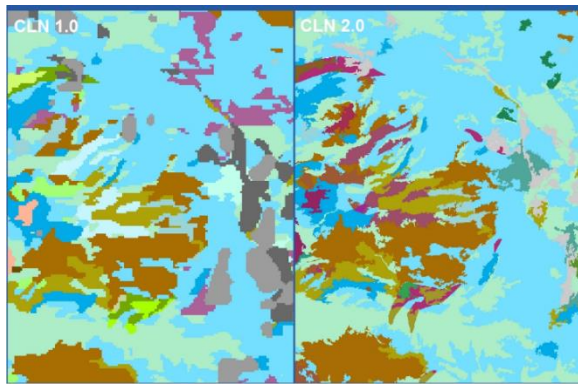
*Figure 6. Spatial resolution differences between CLN 1.0 (30 meters, at left) and 2.0 (5 meters, at right) vegetation maps. Map symbol colors correspond to the same vegetation classes.*
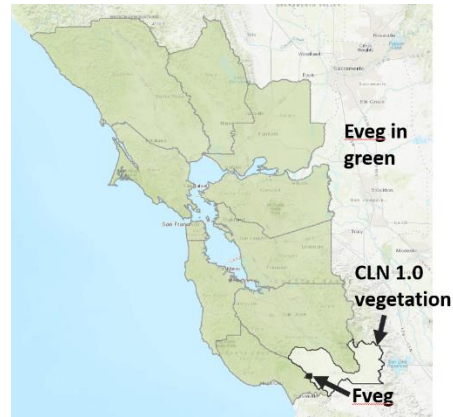


*Figure 7. CLN 2.0 vegetation map composite.*

## Riparian Vegetation Classes

Eveg featured a larger set of riparian vegetation classes than CLN 1.0. Eveg contained 10 riparian vegetation classes (see Figure 3.4 in the CLN 2.0 report), compared to just two classes in CLN 1.0. Eveg also featured greater coverage of riparian vegetation (Figure 8).
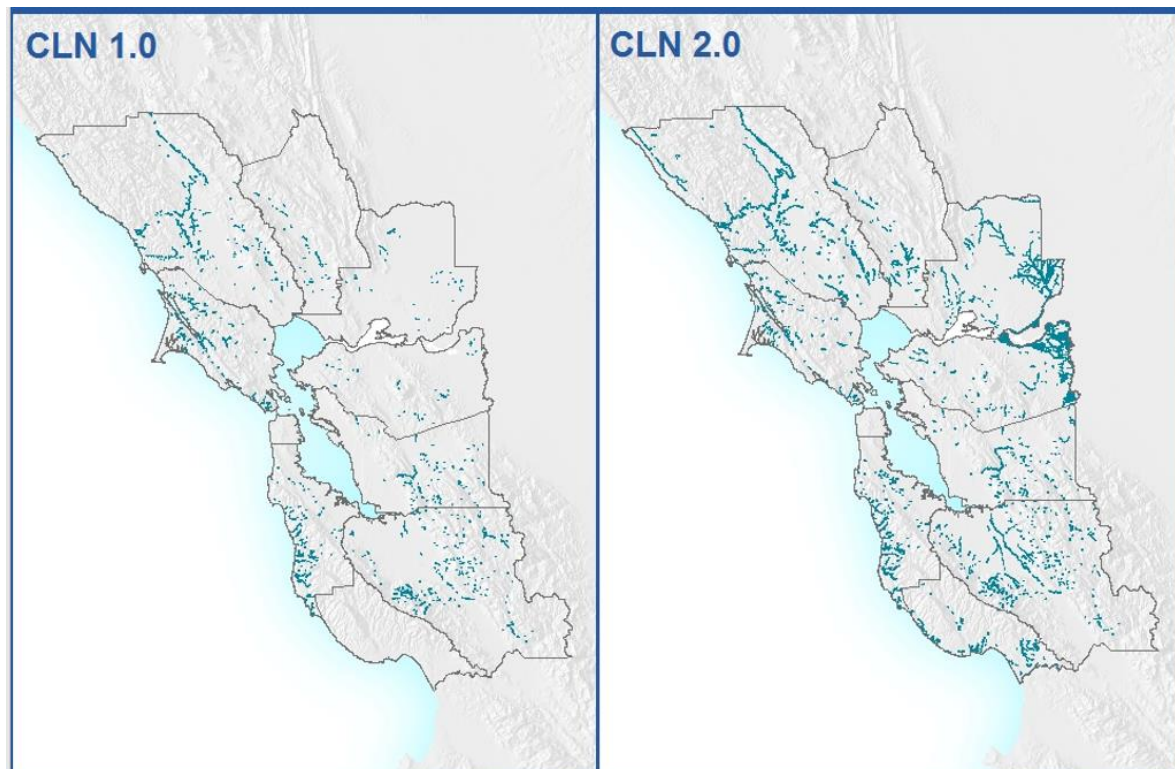


*Figure 8. Difference between CLN 1.0 and 2.0 in coverage of riparian vegetation.*

Future versions of CLN should consider using the Stream Valleys data to delineate riparian vegetation instead of relying on vegetation data derived from medium-resolution imagery to capture riparian

vegetation. The vetting required to delineate riparian vegetation from Stream Valleys was beyond the scope of the CLN 2.0 project.

*Redwood Vegetation Classes*

In the Central Coast Eveg subsection (Peninsula and South Bay), Eveg mapped vegetation differently, introducing two artificial distinctions in redwood distribution. First, in Santa Cruz County, map units were labeled as Redwood (CALVEG code RW) if any redwood was present, which is why that veg type is so prominent in that county. In the rest of the study area, unless it was deemed a pure stand, redwood was labeled as Redwood - Douglas-fir (CALVEG code RD). This resulted in an abrupt change in the mapping for north Santa Cruz County and south San Mateo County (Figure 9). For the CLN, this artificial distinction affected distribution and acreage — and thus rarity ranking and network design. To mitigate this issue, the project team decided to keep the original CLN 1.0 vegetation labeling, and instead draw a new Landscape Unit (already planned) to coincide with the artificial boundary. The artificial redwood boundary matched the boundary separating the Pescadero Creek and Waddell Creek watersheds, an appropriate geophysical boundary to use for the delineation of the new Landscape Unit. Since vegetation-based conservation targets are defined and ranked by Landscape Unit, the redwood mapping differences did not affect the ranking process.
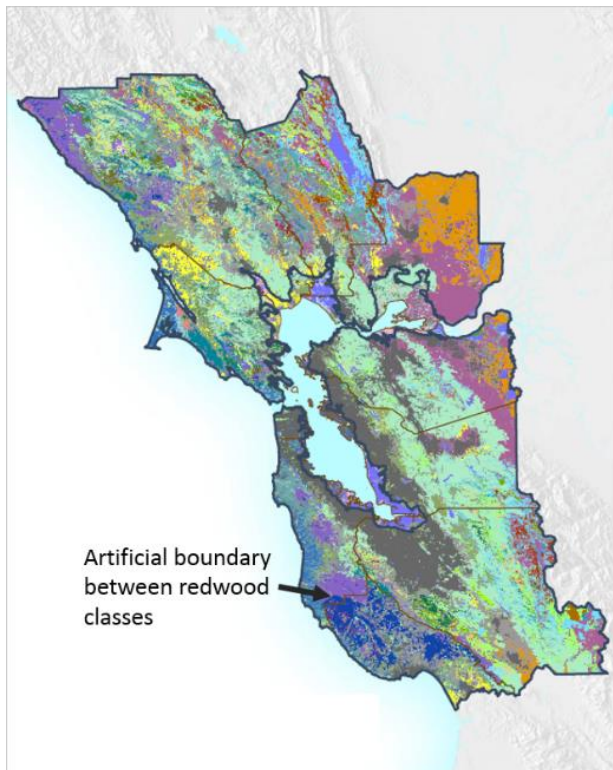


*Figure 9. Artificial distinction between Redwood (blue) and Redwood – Douglas-Fir (purple).*

The second artificial distinction was that Eveg mapped the majority of redwoods in Santa Cruz County as a mixed conifer/hardwood lifeform, with tanoak and coast live oak as the primary understory hardwoods, while adjoining stands are mapped as conifer lifeform. This introduces the possibility that the same kinds of redwood forests are mapped in two different ways without a clear definition/distinction between the two. Figure 10 shows the distribution of the different lifeforms of

mapped Redwood (RW) (Redwood – Douglas-fir [RD] class is not included in Figure 10). Although this second mapping difference likely had a small effect on the Network since the vegetation types were encapsulated within Landscape Units, it raises the need for consistent mapping across the region for accurate inventorying and habitat modeling.
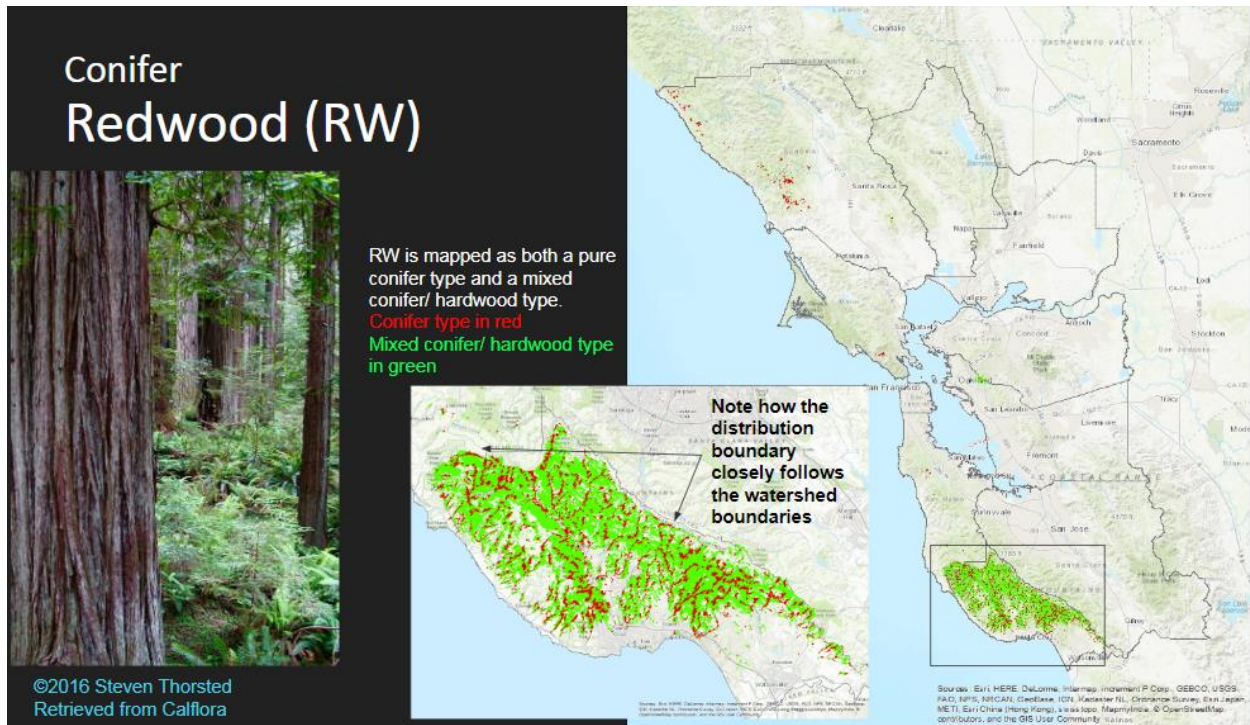


*Figure 10. Redwood distribution as mapped in Eveg.*

### Agriculture (general) classification

Another confounding vegetation class was 'Agriculture (general)' as it contained both cultivated/tilled areas and pasture/grassland. Two large areas mapped as Agriculture (general), one in western Marin County and the other in southeastern Solano County, were mapped as grassland in CLN 1.0 (marked by blue arrows in Figure 12). These two areas were considered and ranked as grasslands by the CLN 2.0 Vegetation Focus Team. There are likely other, smaller grassland patches classified as Agriculture (general) in the study area, but identifying all was not possible under the time circumstances of the CLN 2.0 project. The CLN framework would benefit from more accurate vegetation and land cover mapping.

## Enhancements to Vegetation Map

### Grasslands Temperature Stratification

Grasslands cover a significant portion of the CLN 2.0 study area. Despite their diversity, virtually all grasslands are mapped as a single class in Eveg. As in CLN 1.0, in order to reflect the diversity of grasslands on the ground, the CLN 2.0 team stratified grasslands into four temperature classes (15-23 °C = "cool grasslands", 24-27 °C = "moderate grasslands", 28-31 °C = "warm grasslands", 32-36 °C = "hot grasslands") using 30-year averages (1981-2010) of July maximum temperatures (Figure 11). See Appendix B of the CLN 1.0 report (p. 9) for methods to select the four temperature classes.

*Difference(s) from CLN 1.0:* Downscaled temperature data from the California Basin Characterization Model (BCM; USGS 2014) were available for CLN 2.0. These data were derived from the same source

data used in CLN 1.0 (PRISM) but were downscaled from 800 meters to 270 meters by the USGS using methods described in Flint and Flint (2014). The results of the stratification are shown in Figure 11. Note that an increase of 1° C was needed to match the spatial footprint of the CLN 1.0 class breaks.
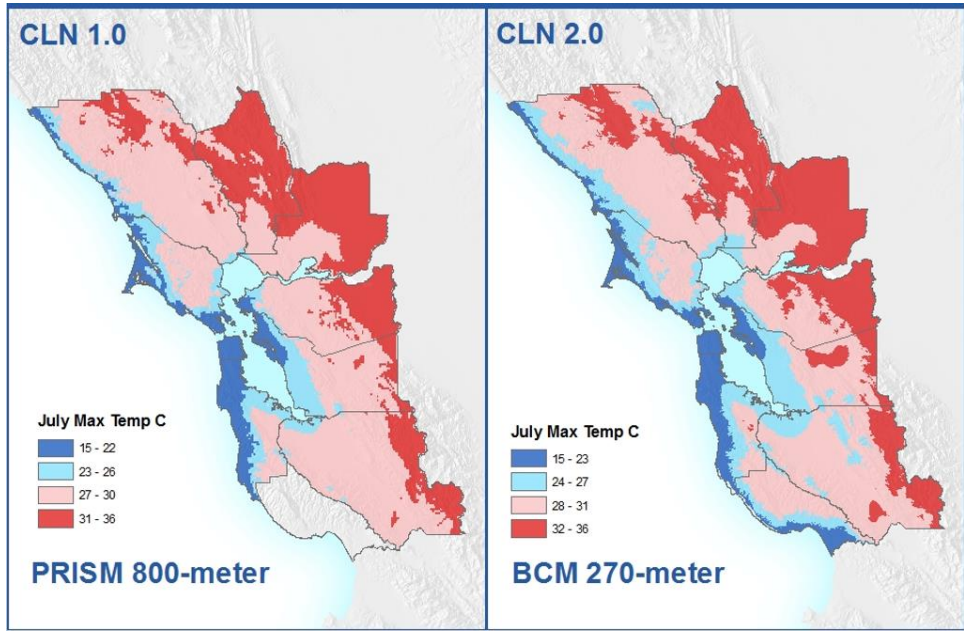


*Figure 11. Average July maximum temperature in four classes: Hot, warm, moderate, and cool.*



*Figure 12. Grassland stratified by four classes of average maximum July temperature. Blue arrows on the right panel indicate where grasslands were mapped as 'Agriculture (general)' in Eveg.*

### Serpentine Overlay

Unique assemblages and morphologies of vegetation species occur on serpentine soils due to the relatively low availability of nutrients. As in CLN 1.0, in order to reflect the distribution of serpentine

vegetation variants, spatial data of serpentinite geology distribution (Figure 13) were overlaid on the vegetation map.

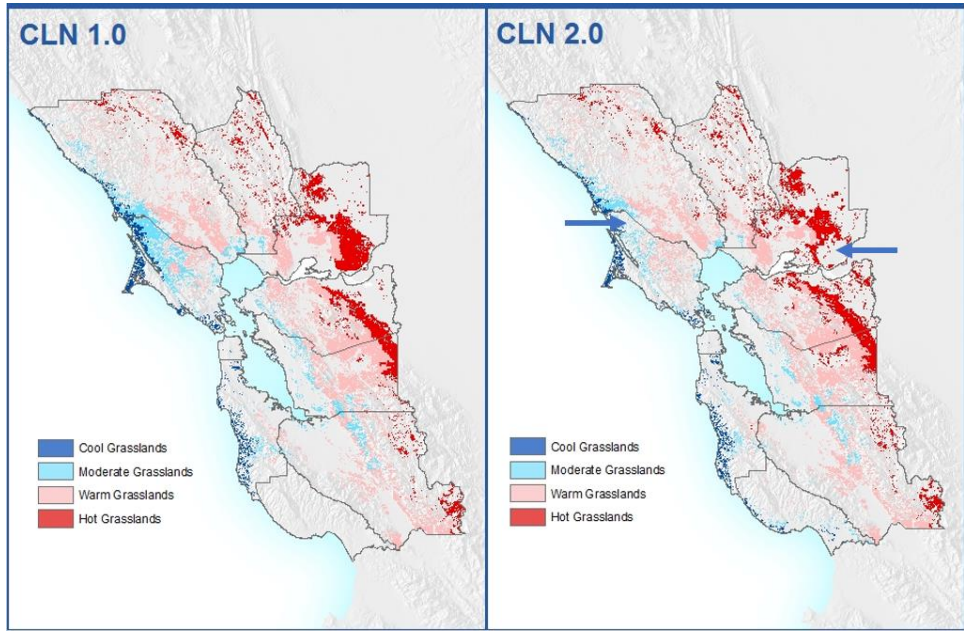*Difference(s) from CLN 1.0:* A new geology layer, published by the California Geological Survey (CGS) in 2017, replaced the USGS geology layer used in CLN 1.0 (Figure 12). The Vegetation Focus Team visually inspected the two datasets and determined the CGS map better represented known stands of serpentine habitat.
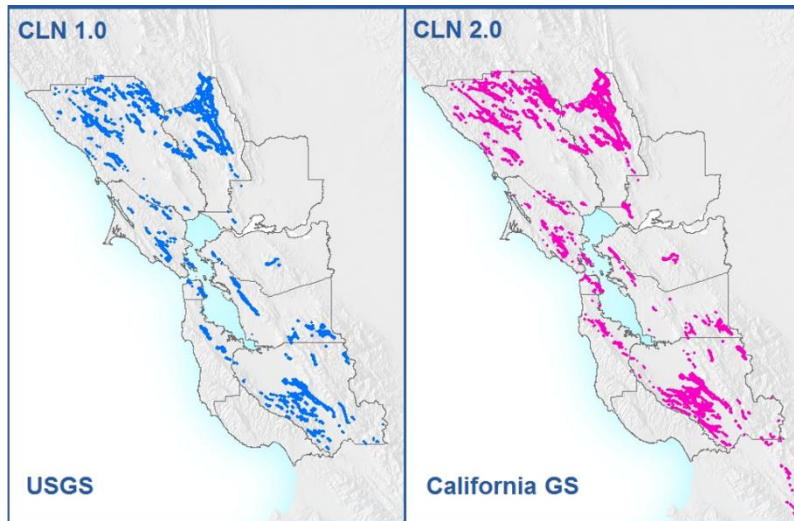


*Figure 13. Serpentine Geology.*

## Urban, Cultivated, and Rural Residential Add-in

The last step in the development of the CLN 2.0 vegetation map was the addition of Urban and Cultivated Agriculture areas from the Farmland Mapping and Monitoring Program (FMMP, 2016 edition), and Rural Residential areas with parcels less than 10 acres (Figure 14). The FMMP data were more current than similar land use types in Eveg. Urban, Cultivated Agriculture and Rural Residential areas are collectively referred to as Converted Lands and are of lower conservation value.

*Differences from CLN 1.0:* Added Santa Cruz County. Parcels were available for Solano County; parcels were not available digitally for CLN 1.0. Urban areas grew between 2008 and 2016 (Figure 15).

*Figure 14. Rural Residential (parcels less than 10 acres).*
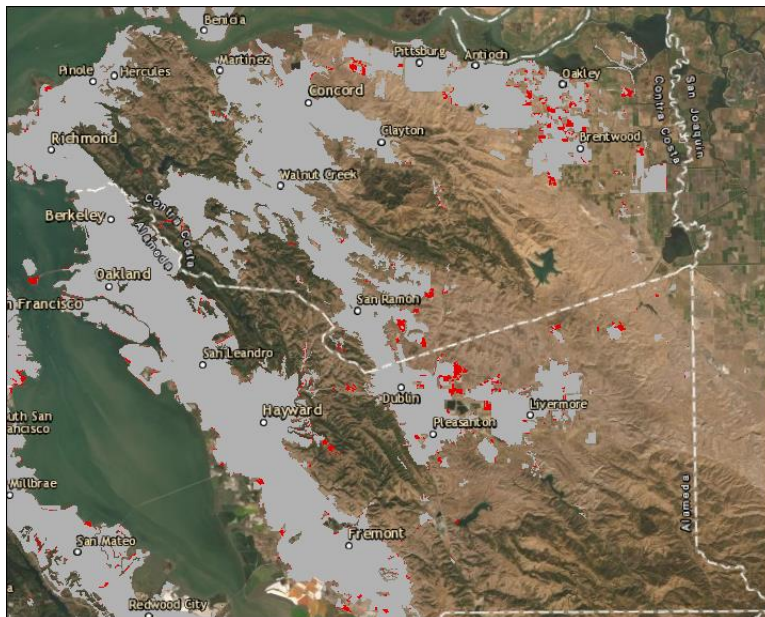


*Figure 15. East Bay urban expansion in red between 2008 (grey) and 2016.*
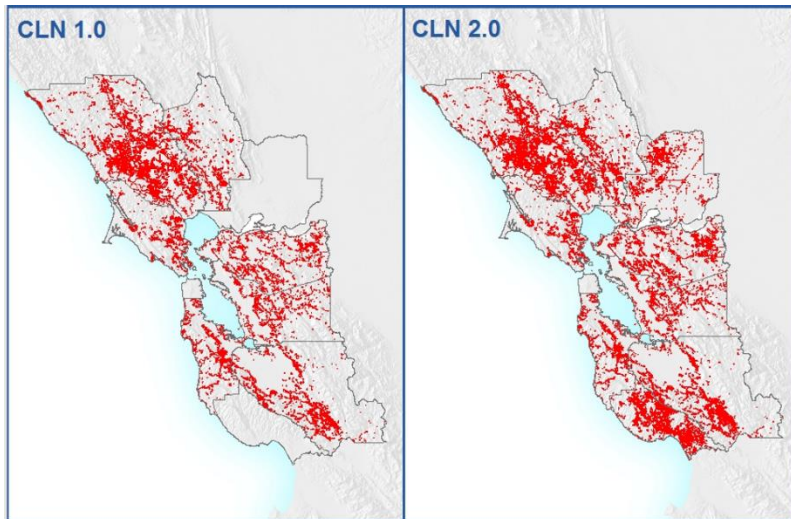
## Post-processing

After the reserve design software Marxan produced the draft network design, the team made several modifications. First, the results of a least-cost paths analysis between large patches of the draft network were added as 'Connectors' to ensure network connectivity. Second, the results from an analysis of stream valleys were added as 'Essential'. Finally, converted lands were removed from the Network.

## Ensuring Network Connectivity: The "Connectors" Land Class

### Background

Using Marxan, the CLN 2.0 project team produced a compact network of areas that comprise and meet the acreage and occurrence goals for each the CLN 2.0 conservation targets (ranked coarse- and fine-filter habitats and species occurrences). Marxan does not, however, explicitly target connectivity of the

network, neither from a species movement or a network analysis standpoint. As a result, the draft network contained gaps of natural land that, although not selected for the network, are likely important to overall connectivity and integrity of the network.

To address network connectivity for CLN 1.0, the project team manully selected (via visual inspection) 34 gaps in the Marxan-generated network. The areas were called "Areas for Further Consideration" (AFCs). Explanations for each AFC were included in Chapter 10 of the CLN 1.0 final report (BAOSC 2011, page 235). The AFCs comprised 700 analysis units (hexagons) and totaled approximately 160,000 acres (3.3% of the study area).

The method to identify important network connectivity areas for CLN 2.0 was a topic of discussion at the May 22, 2019 Steering Committee meeting. The CLN 2.0 steering committee recognized the shortcoming of the Marxan analysis with respect to network connectivity. The committee recommended developing an objective method for adding areas important for network connectivity and one that would minimize additions so as to not dilute the rigor of the mathematical Marxan-generated network.

### Approach

The CLN 2.0 project team used network analysis to guide selection of a subset of analysis units (hexagons) that fill in gaps in the network in the most efficient locations. The project team used COST CONNECTIVITY in Esri ArcGIS. COST CONNECTIVITY finds the least-cost paths necessary to ensure connectivity between all regions/patches of a network.

### Methods

COST CONNECTIVITY requires two inputs: **Regions** and **Cost**. Regions are the patches of the network to connect. Cost is the impedance or cost to move planimetrically through each cell. In this application, the Regions are the "core" areas of the network. Cost is from the perspective of a species of animal or plant as it attempts to move across the landscape. Natural landscapes are assumed to be more passable or permeable than converted landscapes (urban, cultivated agriculture, etc.) for terrestrial species. Permeability is expressed as degree of resistance. Being terrestrial-focused, mapped water bodies (e.g., lakes, rivers, and estuaries) were assigned high resistance values along with converted landscapes.

### Data Used

For **Regions**, the Marxan-generated network with converted lands clipped out was used. The project team choose individual patches of the network of 300 acres or more (N=137; Figure 16). The Marxan-generated network is based on a grid of 250-acre hexagons (analysis units). Analysis units chosen 16-20 out of 20 Marxan runs were deemed "Essential" to achieving conservation target goals, while analysis units chosen 10-15 out of 20 Marxan runs are deemed "Important" to achieving conservation target goals.

*Note:* CLN 2.0 has modeled stream valleys added in (see section below and Figure 17). However, these were omitted for the network connectivity analysis. The CLN 2.0 project team determined that although the addition of stream valleys improves the connectivity of the network, they do not constitute the core areas of the network.

For **Cost**, the project team used a Resistance raster (Figure 4) developed for the California Omniscape Connectivity Map (TNC 2018). Resistance represents the degree to which human land uses or land modifications restrict movement of plants and animals. The data (Figure 18) were developed by

Conservation Science Partners for use in The Nature Conservancy California Chapter's Omniscape analysis and methods, which are generally described in Appendix A of McRae *et al.* 2016 and Theobald 2013. Human modification was estimated by combining several land use maps, including National Land Cover Datatset (NLCD 2016), TIGER roads and railroads, energy infrastructure, and census housing unit counts. The relative degree of resistance (or impedance) to wildlife of each land use or infrastructure type was weighted on a scale of 1 (low resistance, natural areas) to 1000 (maximum resistance, dense urban) and then normalized for use in the Omniscape analysis on a scale from 0 (lowest resistance) to 1 (highest resistance).
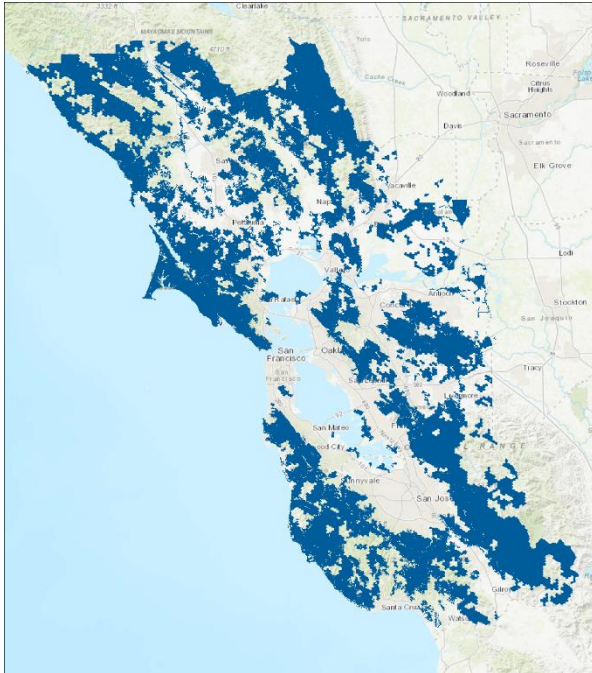


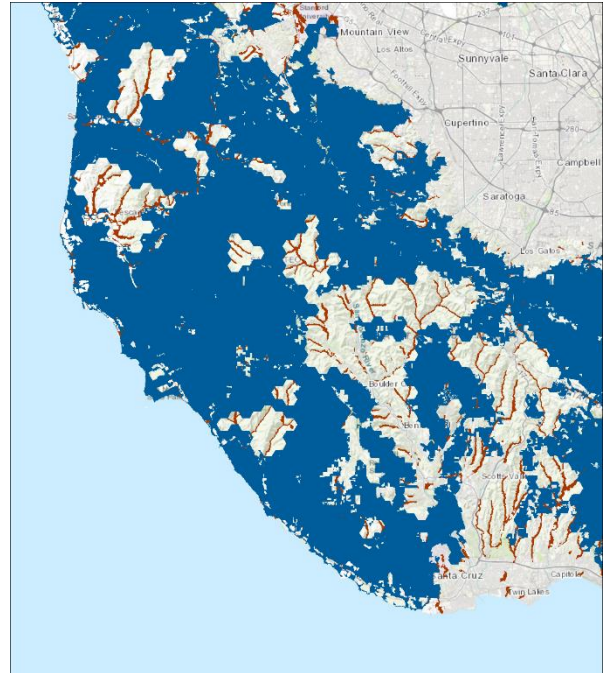*Figure 16.  CLN 2.0 Network patches of 300 acres or more.*



*Figure 17. Stream valleys (red) and CLN 2.0 (blue) in the Santa Cruz Mountains.*
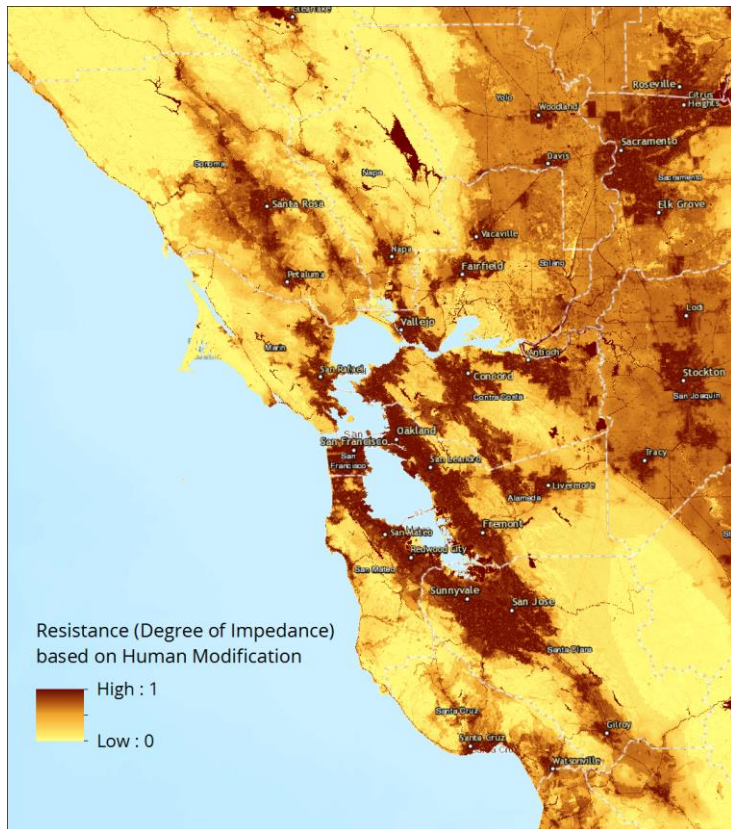
*Figure 18. Resistance Based on Human Modification. Red values correspond to the highest resistance to animal and plant movement. Yellow values correspond to the lowest resistance. Source: TNC 2018. Methods generally described in McRae et al. 2016 and Theobald 2013.*

## Analysis Steps

### 1. Run COST CONNECTIVITY Model

The ArcGIS COST CONNECTIVITY process was run with the inputs described above and resulted in 119 least-cost paths (Figure 20, shown in red).

### 2. Select analysis units in the vicinity of the least-cost paths

Analysis units were selected within 500 meters of each path, resulting in 631 selected analysis units. 500 meters was chosen as the search distance as that is half the diameter of an analysis unit. On average, this should result in two analysis units on either side of the least-cost path. Two analysis units (on average) was deemed an appropriate width for Connectors – wide enough to connect any one network analysis unit on two sides of the hexagon (~1,200-meter boundary), but not so wide that the resulting selection would grow too sizable and dilute the rigor of the Marxan-based network. The goal of a width of two analysis units per least-cost path aligns with Beier 2019, who recommends a minimum of 2000 meters for conservation corridors (Figure 19).

### 3. De-select analysis units already chosen for the Network

From the 631 selected analysis units, all analysis units chosen as "Essential" (chosen 16-20 out of 20 Marxan runs) or "Important" (chosen 10-15 out of 20 Marxan runs) were de-selected, removing 330 analysis units and leaving a final set of 301 analysis units (Figure 21).
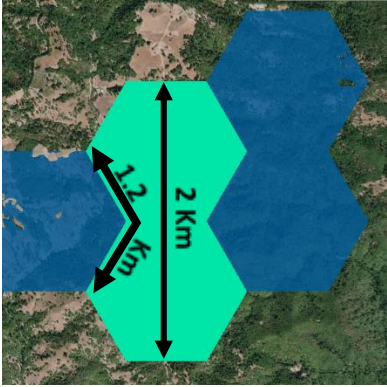
*Figure 19. Geometry of Connectors (teal). The width of two analysis units is 2000 meters. The boundary length between two Connectors and a Network analysis unit is 1200 meters.*
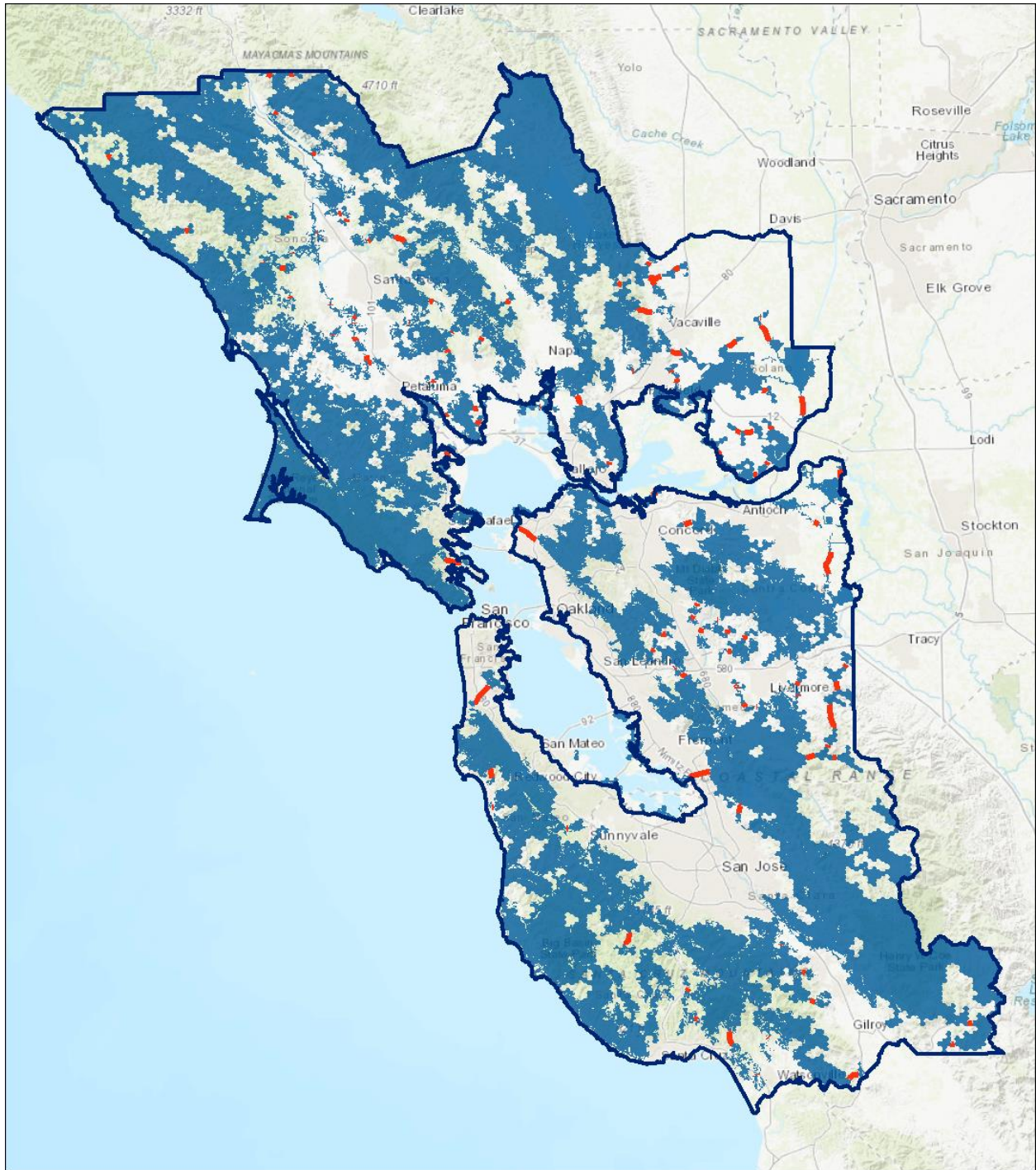
*Figure 20. Results of COST CONNECTIVITY. Red arcs represents the 119 least-cost paths necessary to connect each patch.*
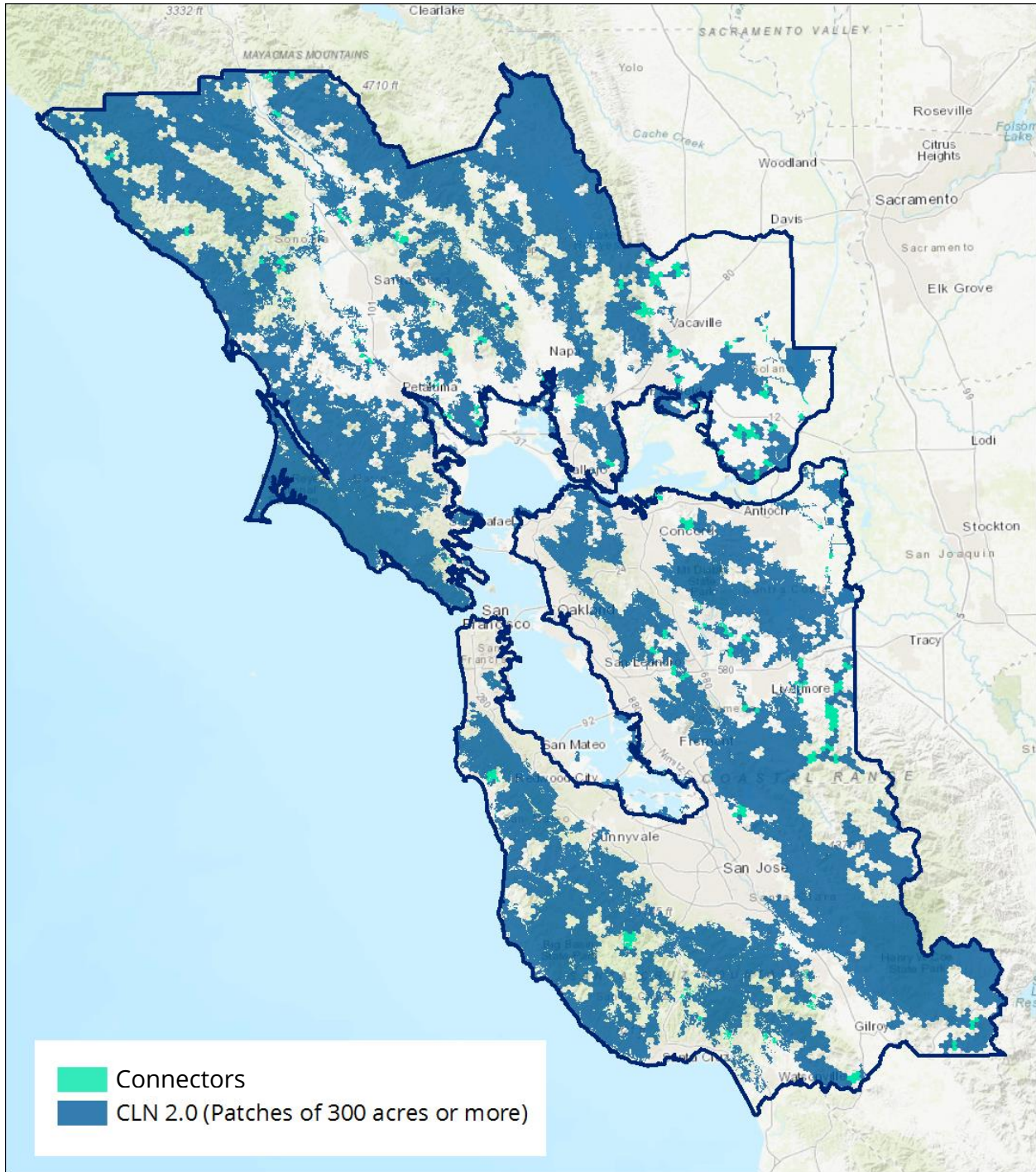
*Figure 21. Network Connectors (in teal).*

## Results

301 analysis units in 109 distinct areas were selected for a total of approximately 50,000 acres. A comparison with CLN 1.0 AFCs is shown in Figure 22.

*Figure 22. Comparison between proposed CLN 2.0 Connectors and CLN 1.0 Areas for Further Consideration.*

|  | Total Acres | # of Analysis Units Selected | Distinct Areas/Patches |
|---|---|---|---|
| Connectors (CLN 2.0) | 50,000 | 301 | 109 |
| Areas for Further Consideration (CLN 1.0) | 160,000 | 700 | 34 |

This analysis found that 114 distinct patches totaling 75,000 acres are necessary to connect patches within the network. Considering the size of the Marxan study area (4.8M acres), and the fragmentation of the network from human land uses, this suggests that the draft Marxan network was already fairly well-connected.

The CLN 2.0 project team believes the least-cost paths method is an improvement over manual techniques. Although the AFCs added focus on network integrity and are well-documented in the CLN 1.0 report, the modeled Connectors are produced using an objective, repeatable method that requires a single explanation as opposed to explanations for each individual patch.

The least-cost paths method located areas that are theoretically the most efficient for maintaining network integrity. The results are parsimonious and do not dilute the rigor of the Marxan network itself.

## Addition of Stream Valleys

### Background

Riparian areas are important for biodiversity and ecosystem function. In CLN 1.0, since riparian vegetation is under-represented in medium-resolution vegetation mapping and thus under-represented in the Network, all riparian vegetation polygons were added to the Network as 'Essential' after Marxan was run. New perspectives on "riparian" call for a broader spatial definition, one that includes the many landforms that make up the stream valley, such as channels, floodplains, terraces, and upland fringe. This perspective recognizes that while the presence of riparian obligate vegetation is an important facet of stream health, it is also ephemeral and not the only indicator of stream health. Equally important to stream health is an intact system of interacting hydrologic and ecological processes that take place across the stream valley.

### Approach

For CLN 2.0, we added to the network modeled intact (undeveloped) stream valleys. The Stream Valleys data created for CLN 2.0 are geomorphically-derived estimates of the zone that influences or is influenced by the stream, following methods by Smith *et al.* 2008.

### Methods

### Data Used

USGS 10m DEMs for terrain raster, CA Dept. of Conservation FMMP data for urban and cultivated agriculture, and Sonoma Veg Map and County of Napa data for vineyards.

## Analysis Steps

**1. Prepare DEM and Stream Grid**

Multiple 1/3 arc-second (~10-meter) digital elevation model (DEM) tiles were stitched together to create one DEM that covered all watersheds that drain to the 10-county study area (minus Sacramento River and San Joaquin River mainstems). Esri ArcGIS ArcHydro tools (FILL, FLOW DIRECTION, FLOW ACCUMULATION) were run on the DEM. MAP ALGEBRA was run on Flow Accumulation multiple times to find an appropriate raster of streams. STREAM LINK was run on Flow Direction to generate a hydrologically networked Stream Grid. STREAM ORDER (Strahler) was run to create a Stream Grid with stream orders. Using Stream Order and stream link size (number of pixels), the Stream Grid was winnowed to streams that were at least 100 pixels long and a stream order higher than 1.

**2. Create Slope Classes for Cost Input**

The SLOPE (degrees) and RECLASSIFY Esri ArcGIS tools were used to generate 9 equal interval slope classes.

**3. Create PATH DISTANCE Raster**

PATH DISTANCE was run on the winnowed Stream Grid (slope classes as Input Cost; Fill as surface raster). The project team visually inspected known sites around the region to determine an appropriate break point for the Path Distance raster. A value of 300 was determined to best approximate the stream valley in the sampled sites. Using MAP ALGEBRA, a Stream Valleys polygon was created (Path Distance <=300).

**4. Post-analysis Processing Steps**

The following processing steps were conducted:

- Masked out water bodies where Size >= 0.1 sqkm (Source: National Hydrography Dataset)
- Masked out bay and baylands (Source: California Aquatic Resource Inventory)
- Masked out valleys (VALUES 1 and 2 of USGS Land Surface Forms, first removed USGS valleys where acres <= 900)
- Added Eveg riparian and wetlands polygons (dissolved)
- Added FEMA floodplains (dissolved)

**5. Classify Stream Valleys**

The Stream Valleys polygon was merged with urban and cultivated polygons (CLN 2.0 Converted; see below) to create three classes of Stream Valleys: Natural/semi natural, Converted – urbanized, or Converted – cultivated.

## Results

Figure 22 lists acreage of the three Stream Valley classes by county. An example of the Stream Valley analysis results in southern Marin County is shown in Figure 23.

*Figure 22. Stream Valley class acreages by county. San Francisco was excluded from the analysis given the extent of landscape modification.*

| COUNTY | NATURAL/SEMI-NATURAL | CONVERTED - CULTIVATED | CONVERTED - URBANIZED | TOTAL |
|---|---|---|---|---|
| **ALAMEDA** | 35,005 | 851 | 11,958 | 47,814 |
| **CONTRA COSTA** | 30,861 | 280 | 23,778 | 54,918 |
| **MARIN** | 34,127 | 2,338 | 11,862 | 48,327 |
| **NAPA** | 51,444 | 13,832 | 2,593 | 67,870 |
| **SAN FRANCISCO** | * | * | * | * |
| **SAN MATEO** | 23,800 | 2,873 | 8,988 | 35,661 |
| **SANTA CLARA** | 63,973 | 2,989 | 11,380 | 78,343 |
| **SANTA CRUZ** | 26,126 | 3,634 | 11,980 | 41,740 |
| **SOLANO** | 21,708 | 3,002 | 10,277 | 34,987 |
| **SONOMA** | 98,902 | 26,171 | 4,393 | 129,465 |
| | | | GRAND TOTAL | 539,125 |
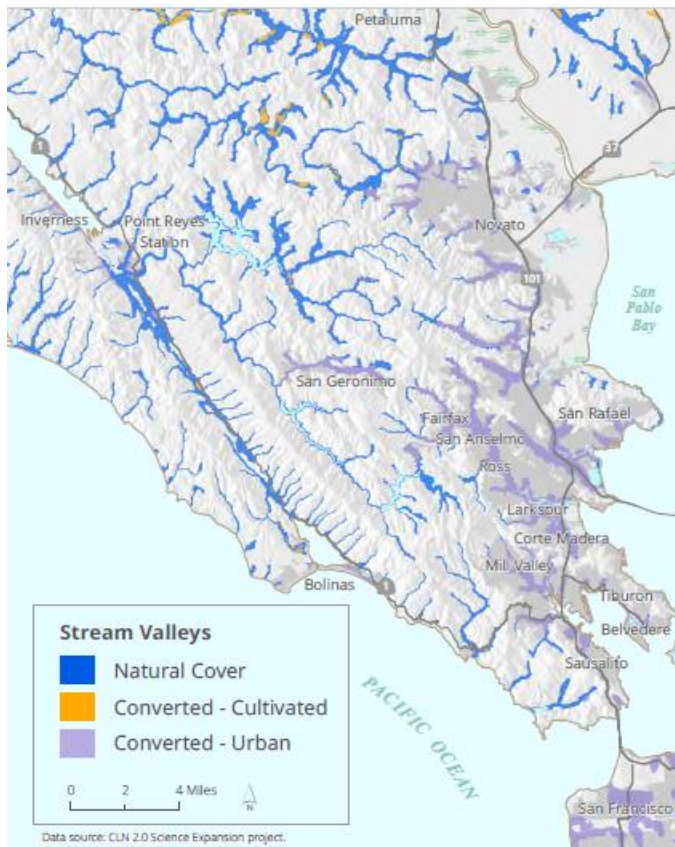


*Figure 23. Stream Valleys in southern Marin County.*

*Adding to the CLN*

Only Stream Valleys with natural or semi-natural cover were added to the CLN. Where Stream Valleys crossed Important, Connecting, or Contributing CLN land classes, the Stream Valleys took precedence (Figure 24).
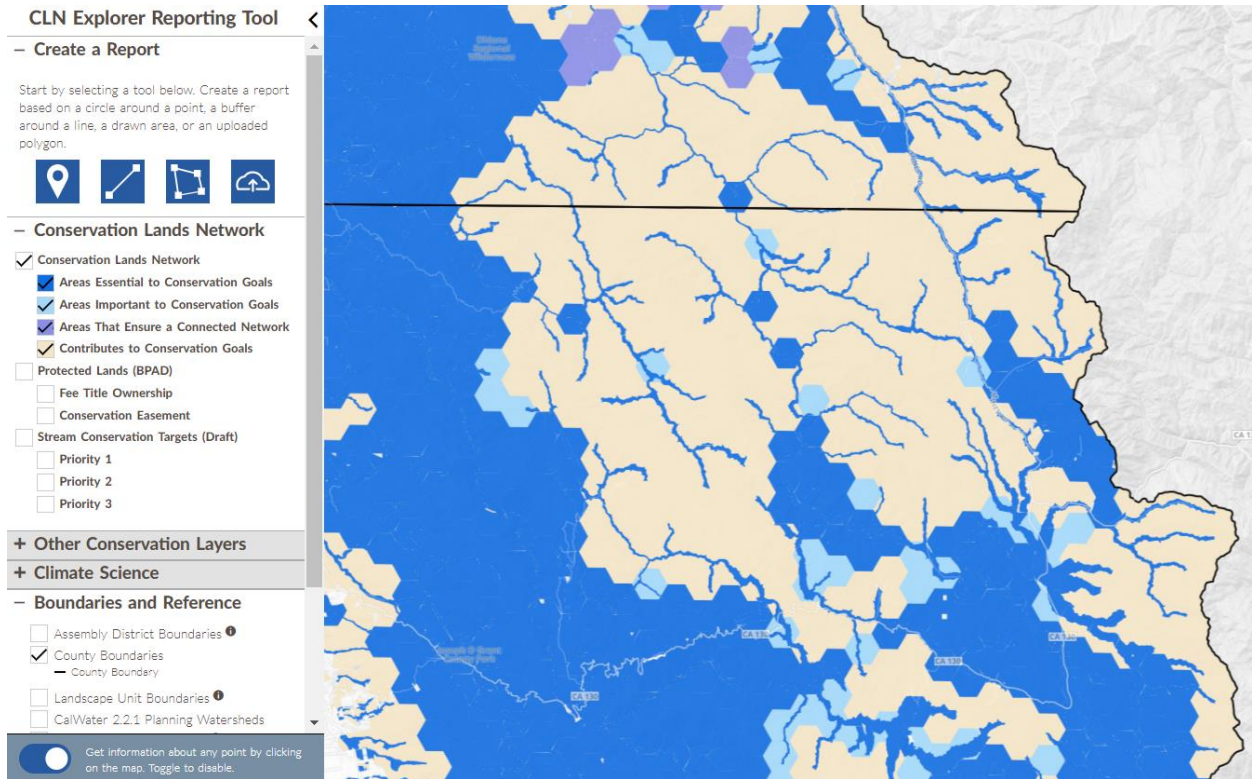


*Figure 24. Stream Valleys as 'Essential'. (Screenshot of the CLN 2.0 Explorer at www.bayarealands.org)*

## Removal of Converted Lands

Marxan selects whole planning unit hexagons. Portions of planning units may consist of urban, cultivated agriculture, or rural residential land covers – collectively called Converted Lands. While these lands have less conservation value, target occurrences within these planning units, if accurate, may be important for conserving even amongst Converted Land. To address the problem, Converted Lands were erased from hexagons, leaving the fragments of the selected planning units that contain the records of CLN target occurrences.

## Final Network Land Classes

The final network land classes changed in CLN 2.0. These changes are discussed in Chapter 3 of the CLN report (p. 37). A summary of the final land classes follows:

| | | | |
|---|---|---|---|
| | Areas Essential to the CLN Goals | Planning units in this category were selected 16 or more times during 20 Marxan runs (80-100%) because they support high value conservation targets and/or are adjacent to existing protected lands. Included in the category are Stream Valleys added in after Marxan. | Conservation of these areas should be pursued since they serve vital functions in any potential network configuration and conservation goals will be difficult to meet without them. |
| | Areas Important to CLN Goals | Planning units in this category were selected between 11 and 15 times during 20 Marxan runs (55-79%). | Conservation opportunities in these areas should also be pursued as they represent areas of high conservation suitability and are generally adjacent to Areas Essential to Conservation Goals and protected lands. |
| | Areas that Ensure a Connected Network | Planning units in this category were selected because they connect the major patches of the CLN Network in the most efficient pattern. | Conservation opportunities in these areas should also be pursued as they important to the integrity of the Network as a functional unit. |
| | Areas that Contribute to CLN Goals | Planning units that were not selected as part of the Network, but consist of natural land and thus still contribute to conservation goals. | Although conserving the CLN 2.0 Network is ostensibly the most efficient path to achieving the habitat goals, other lands contain goals and thus can contribute to achievement of those goals. As new land is conserved, future CLN networks will incorporate these lands. |

# Supplemental Datasets

## Stream Conservation Targets

Methods to produce the CLN 2.0 Stream Conservation Targets are discussed in detail in the CLN 2.0 report (p. 98).

## Headwater Source Areas

Headwater source areas are discussed in the CLN 2.0 report (p. 95) and represent an estimate of the zones of primary water, sediment, and nutrient contribution to Bay Area streams. The purpose is to help identify areas to which to target conservation for maintaining, restoring, or enhancing watershed

function in headwaters where minimizing impervious surfaces and draws on groundwater are key strategies.

## Data Used

USGS 10m DEM (accessed August 2018), CalWater 2.2.1 watersheds.

## Analysis Steps

Using SLICE tool in ArcGIS, 10 equal interval elevation classes were generated for each of the 54 Hydrologic Units (HUs) in the study area. The resulting rasters were mosaicked into one raster (excluding bay and delta HUs [IDs = 3, 4, 12, 35, 40, 43, 49]). Headwater Source Area were defined by the third elevation class and up (Value >= 3). The result was converted to polygon; polygons less than 50 acres were removed. Esri ModelBuilder was used to automate the SLICE functions (Figu 25).
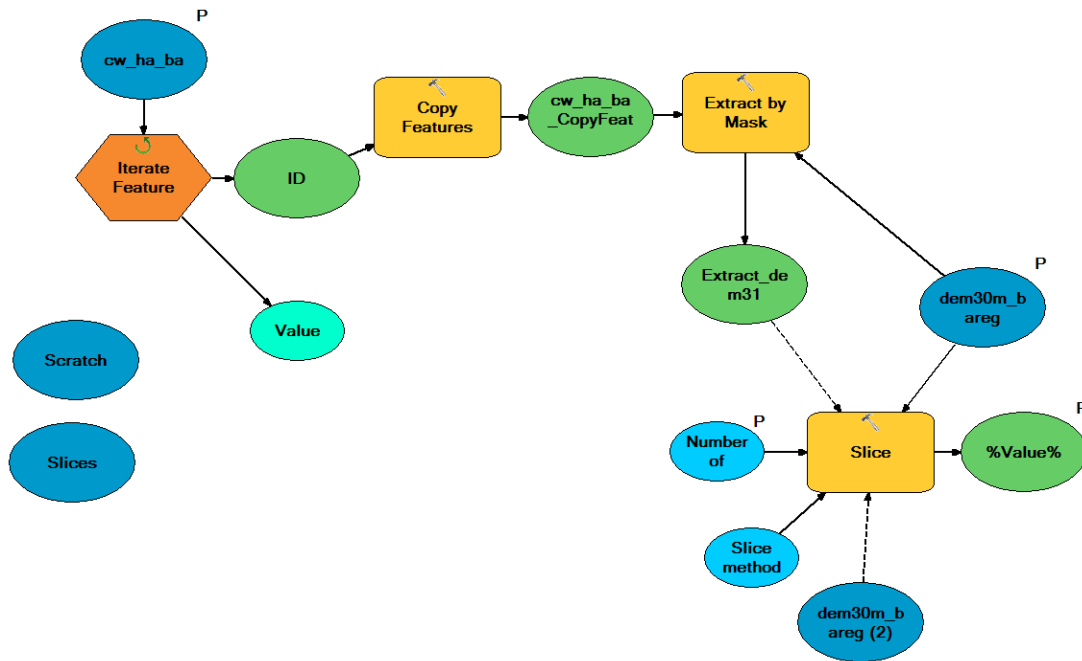


*Figure 25. Esri ModelBuilder model for calculating elevation classes per watershed.*

## Results

Members of the Steering Committee visually inspected the results of the headwaters analysis (Figure 26) and determined that it approximated headwaters areas well. It was important that the elevation classes were generated per watershed, ensuring that the upper elevation values were relevant locally (Figure 27).
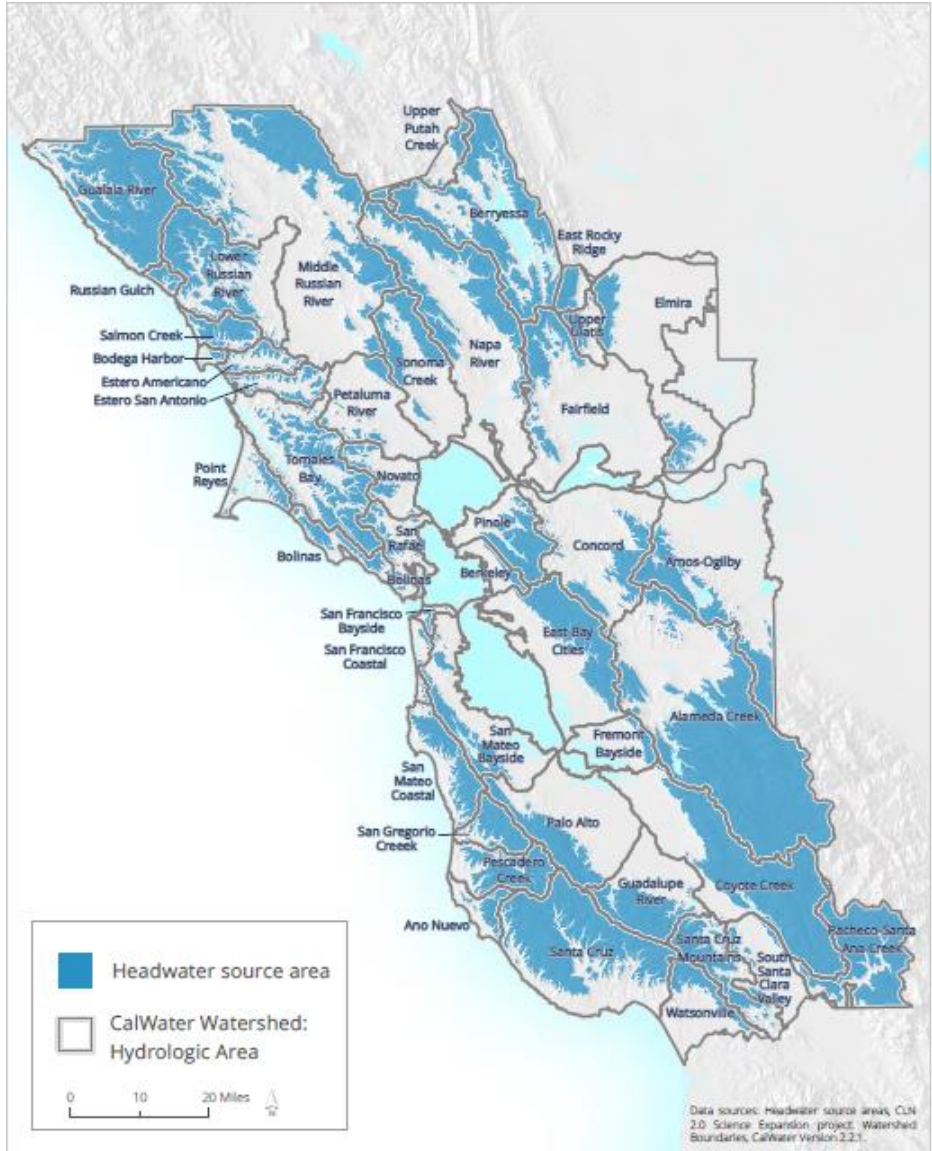
*Figure 26. Headwater Source Areas. (From Figure 5.6 in the CLN 2.0 report)*
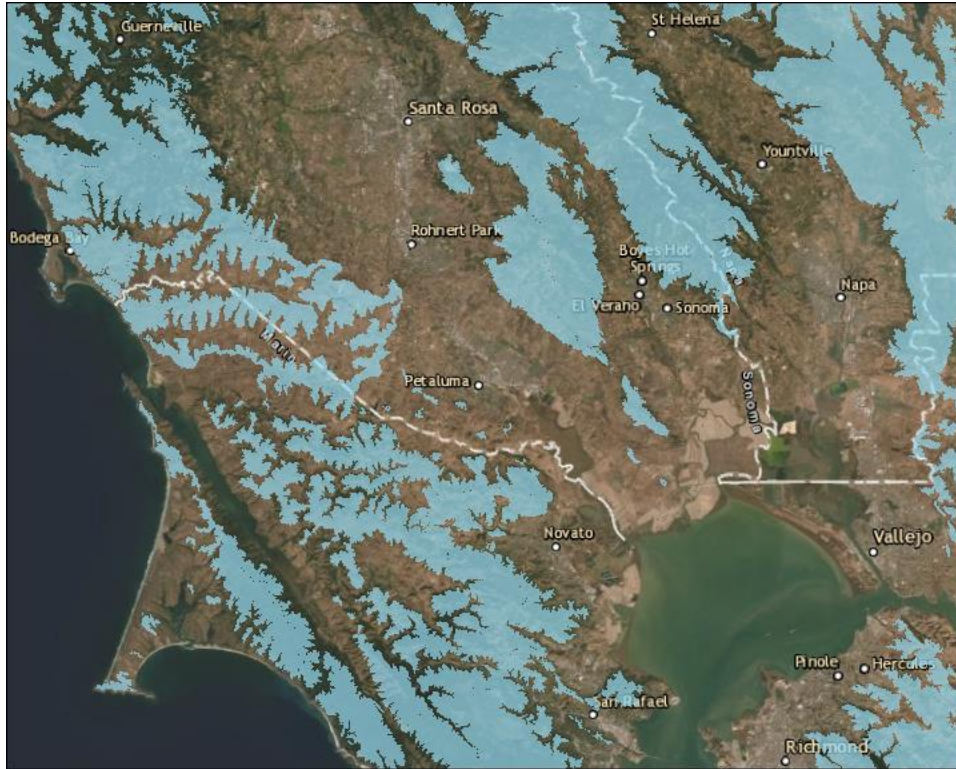
*Figure 27. Results of Headwater Source Area analysis in the North Bay.*

## Visibility from Populated Places and Major Roads

Bay Area residents value the aesthetics of the natural lands surrounding their communities. Visibility was calculated for the study area using a 30m digital elevation model (resampled from 10m) and a set of observation points. The observation points were derived from points spaced 0.5 miles apart along all state highways throughout the Bay Area and within census block groups within incorporated cities (1 point per 1000 people).

### Data Used

USGS 1/3rd arc-second digital elevation model resampled to 30 meters (accessed Fall 2018); CalTrans highways; TIGER Census population by block group (2016).

### Analysis Steps

- Removed double highway lines (deleted "Left" and "Left Split Align" from 'AlignCode')

- Generated points along highway lines at 0.5 miles using GENERATE POINTS ALONG LINES python script in Esri ArcGIS

- Generated 1 point per 1000 people within census (2016) block groups from 'Summary File 1' using the CREATE RANDOM POINTS tool in Esri ArcGIS

- Removed census points outside incorporated city boundaries

- Resampled 10m DEM to 30m for faster processing

- Used VISIBILITY (Esri ArcGIS Spatial Analyst). Parameters: Analysis Type: FREQUENCY; Observer offset: 1.5 meters. Analysis Elapsed Time: 64 hours 12 minutes 49 seconds

- Set four classes (Low - Very High) based on quantiles (Natural Breaks): Low visibility = 0 observers, Medium = 1-14 observers, High = 15-102 observers, Very High = 103-4,787 observers.

### Results

The visibility analysis results (Figure 28) help identify where landscapes are particularly prominent and are provided as a metric in user-generated Conservation Portfolio Reports via the CLN 2.0 Explorer at www.bayarealands.org.
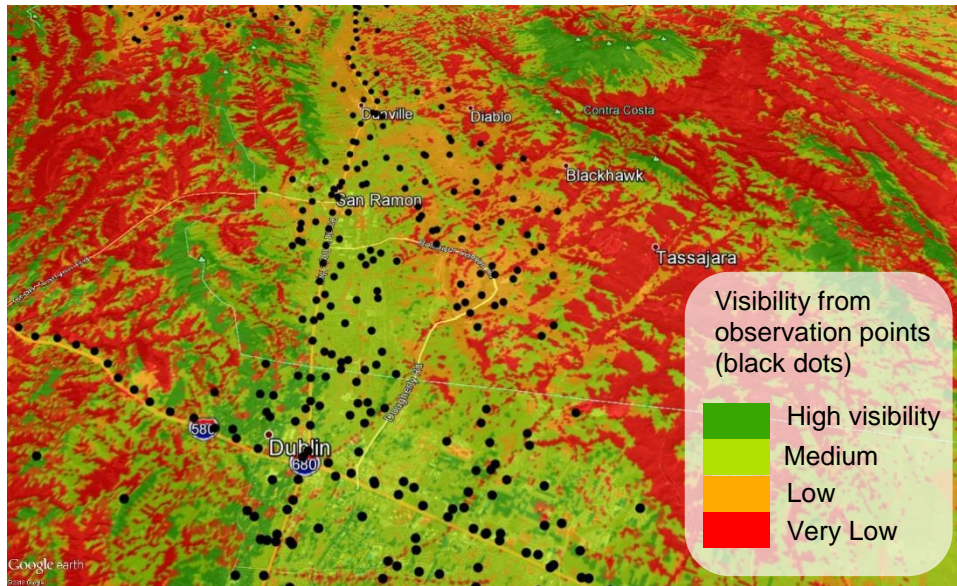


*Figure 28. Visibility Analysis results in the San Ramon Valley.*

## Vegetation Vulnerability to Drought

Vegetation Vulnerability to Drought is an estimate for any given stand of natural vegetation in the study area of the proximity to the edge of their climatic "comfort zone" using the climate variable Climatic Water Deficit (CWD), a proxy for drought stress to vegetation. The 95th percentile of CWD values for each vegetation type was used as a proxy for a given stand's upper tolerance limit for CWD. Stands with CWD values beyond the 95th percentile are assumed to be at very high risk of drought. Stands with CWD values approaching the 95th percentile are assumed to be at high risk. The 95th percentile CWD value was determined via Cumulative Distribution Function for each natural vegetation type in the 10-county Bay Area (Figure 29).

### Data Used

Vegetation: Eveg (USFS); 1981-2010 average CWD: USGS California Basin Characterization Model (Flint and Flint 2014)

### Analysis Steps

- Rasterized Eveg vegetation vector dataset to 5m pixels.

- Assigned CWD percentiles for each vegetation type from Cumulative Distribution Function 'Limits Summary' (Figure 29) and created a grid of CDW 95th percentiles.

- Subtracted CWD 95th percentile grid from 1981-2010 CWD to create grid of the difference (in mm) from the 95th percentile limit.

- Used mid-century scenario (CAN 45) to scale the distance to limit and assign pixels to vulnerability classes. The class breaks for difference grid are: Very High <=0, High >0 and <=50, Medium >50 and <=150, Low >150.

*Figure 29. Climatic water deficit cumulative distribution function values for Bay Area vegetation.*

| Cumulative Distribution Function of Climatic Water Deficit | | | | | | | |
|---|---|---|---|---|---|---|---|
| Veg Code | Vegetation Type | Count BCM | 90th | 95th | 99th | 1.0 | Count Vegetation Polygons | Total Acres |
| CA | Chamise | 5325 | 933 | 943 | 953 | 973 | 4504 | 96052 |
| CC | Ceanothus Chaparral | 282 | 868 | 881 | 915 | 922 | 51 | 5075 |
| CK | Coyote_Brush | 3314 | 831 | 854 | 906 | 936 | 2817 | 61843 |
| CQ | Lower_Montane_Chaparral | 7963 | 909 | 917 | 933 | 969 | 5402 | 144757 |
| CS | Scrub_Oak | 526 | 894 | 926 | 959 | 973 | 763 | 9252 |
| DF | Pacific_Douglas_Fir | 9102 | 796 | 813 | 842 | 914 | 2983 | 163489 |
| DP | Douglas-fir_Ponderosa | 526 | 791 | 816 | 857 | 871 | 361 | 9565 |
| EX | Coastal_Hardwoods | 3288 | 882 | 904 | 936 | 964 | 2516 | 59608 |
| KP | Knobcone_Pine | 733 | 848 | 857 | 869 | 874 | 417 | 13157 |
| MN | McNab_Cypress | 539 | 905 | 913 | 919 | 941 | 54 | 9715 |
| MP | Mixed_Coniifer | 165 | 854 | 857 | 869 | 874 | 61 | 445 |
| MS | Sargent_Cypress | 526 | 791 | 816 | 857 | 871 | 36 | 2971 |
| NX | Interior_Hardwoods | 15241 | 877 | 901 | 947 | 980 | 7854 | 276455 |
| PD | Gray_Pine | 1805 | 921 | 941 | 959 | 996 | 2096 | 32409 |
| PM | Bishop_Pine | 369 | 772 | 778 | 787 | 799 | 136 | 6947 |
| PP | Ponderosa_Pine | 178 | 829 | 848 | 889 | 908 | 136 | 3197 |
| PR | Monterey_Pine | 98 | 837 | 846 | 861 | 916 | 72 | 2571 |
| QA | Coast_Live Oak | 12631 | 916 | 938 | 963 | 989 | 9660 | 228439 |
| QB | California_Bay | 2648 | 831 | 853 | 898 | 956 | 2307 | 47553 |
| QC | Canyon_Live_Oak | 390 | 796 | 809 | 848 | 853 | 460 | 7180 |
| QD | Blue_Oak | 10474 | 926 | 945 | 975 | 1011 | 4606 | 189215 |
| QG | Oregon_Oak | 2064 | 793 | 813 | 857 | 922 | 1847 | 37605 |
| QH | Madrone | 89 | 768 | 774 | 803 | 807 | 118 | 1549 |
| QK | Black_Oak | 215 | 794 | 814 | 862 | 929 | 183 | 4278 |
| QL | Valley_Oak | 393 | 921 | 939 | 975 | 1009 | 799 | 6467 |
| QT | Tanoak__Madrone | 1435 | 742 | 766 | 807 | 827 | 767 | 25343 |
| QW | Interior_Live_Oak | 480 | 912 | 928 | 944 | 963 | 405 | 9030 |
| RD | Redwood DF | 9585 | 778 | 802 | 849 | 906 | 1340 | 173832 |
| RW | Redwood | 6607 | 836 | 848 | 879 | 914 | 601 | 119738 |
| SCH | Serpentine_Chaparral | 2242 | 919 | 923 | 939 | 957 | 1539 | 40022 |
| SRC | Serpentine_Conifer | 421 | 901 | 913 | 923 | 940 | 1625 | 7862 |
| SRG | Serpentine_Grassland | 921 | 932 | 940 | 952 | 964 | 2824 | 16561 |
| SRH | Serpentine_Hardwoods | 834 | 908 | 921 | 950 | 961 | 3954 | 14868 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SRS | Serpentine_Scrub | 36 | 934 | 941 | 947 | 948 | 216 | 614 |
| SS | California_Sagebrush | 1964 | 801 | 834 | 897 | 933 | 1216 | 37418 |
| TX | Montane _Hardwoods | 2131 | 793 | 815 | 875 | 919 | 1433 | 38177 |
| ZC | Cool_Grassland | 3106 | 766 | 786 | 833 | 857 | 1709 | 59634 |
| ZH | Hot_Grassland | 15629 | 994 | 1002 | 1018 | 1039 | 6280 | 282772 |
| ZM | Moderate_Grassland | 5561 | 833 | 850 | 884 | 985 | 3611 | 100931 |
| ZW | Warm_Grassland | 27387 | 920 | 940 | 972 | 987 | 10968 | 493588 |

## Results

The results of the vegetation vulnerability to drought analysis illustrate the possible variation in vegetation response to future drought associated with climate change (Figure 30).
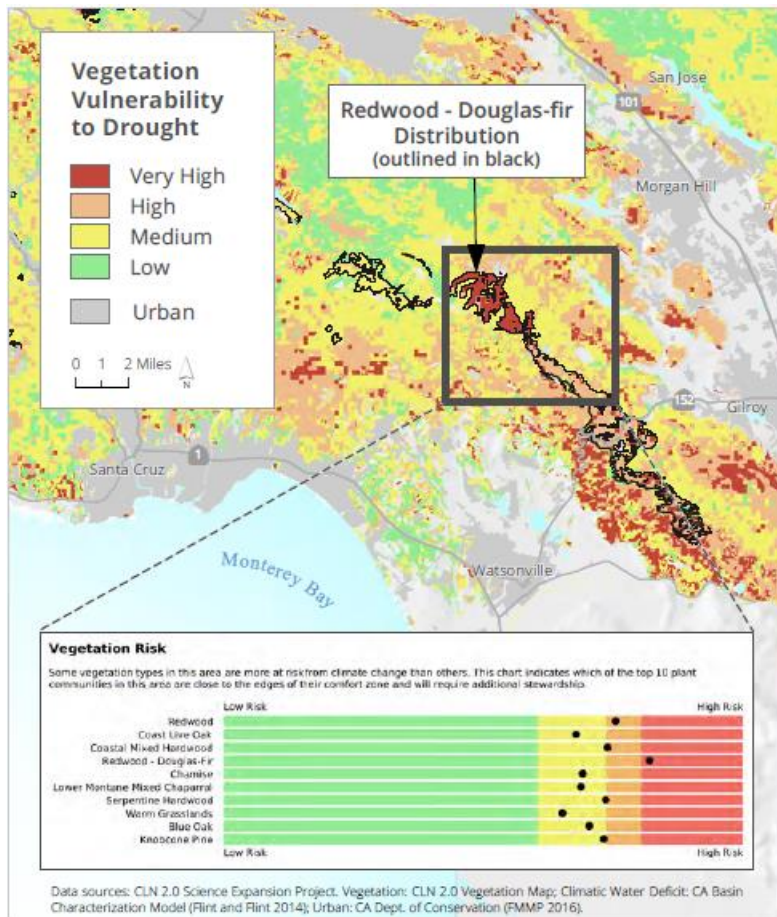


*Figure 30. Sample Portion of Conservation Portfolio Report Showing Vegetation Vulnerability to Drought. Vegetation vulnerabililty to drought is a function of the distance to vegetation-specific climatic water deficit (drought stress) limits sampled across the study area. This sample shows Redwood-Douglas-Fir forests on the eastern slope of Sierra Azul, where the vegetation vulnerability to drought ranges from low to very high risk. (From Figure 3.8 in the CLN 2.0 report)*

Future improvements to the vegetation vulnerability to drought analysis could include incorporation of local-scale (below 270m) modifications: insolation (heat-load index) and Topographic Moisture Index.

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