CAMP FIRE

CAL FIRE Tree Inventory Sampling

This report presents the results of a tree inventory sampling procedure for dead and dying trees within the Camp Fire, Butte County.

Mission #5599 Task # 1817 CA-CDF-000586

October 18, 2019

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I. Introduction

The Camp Fire started on November 8, 2018 on Pulga Road and Camp Creek Road near Jarbo Gap and burned a total of 153,336 acres (about 240 square miles). A total of 13,983 single, multiple, and mixed commercial residences, 528 commercial and 4,293 other buildings were destroyed. To date, 86 civilian fatalities have been recorded. As a result, the Camp Fire has been designated the most destructive and deadliest California wildfire to date. Acting Governor Newsom issued a State of Emergency Proclamation for Butte County on November 8, 2018. A Presidential Major Disaster Declaration followed on November 12, 2018, and included the fires burning in Los Angeles and Ventura Counties. Local and state responsibility areas accounted for approximately 85 percent of the burn area, with the remaining 15 percent under federal responsibility area.

On October 8, 2019, Cal OES mission tasked CAL FIRE to complete a sampling survey of the Camp Fire tree mortality identifying the dead and dying trees threatening public infrastructure along a Cal OES provided GIS road layer. CAL FIRE started the survey Oct 14 and completed the field work on Oct 17. The field crews included 21 personnel; 17 Licensed Professional Foresters (RPFs), one Entomologist, two Forestry Assistants, and one Resource Data Specialists (GIS).

II. Hazard Tree Identification Criteria

Trees were considered to be hazards based on a decision matrix that was provided as a Survey123 application and in hard copy form as a dichotomous key. The Survey123 app did not record data but was designed to be a quick use training guide with conditional questions presented based on the response to the previous question. The matrix presented estimated Probability of Mortality (Pm) and cut/do not cut recommendations based on primary literature that evaluated the predictive strength of postfire burn characteristics. Characteristics included Percent Crown Length Killed (PCLK), Bole Char severity, Bark Condition (cracking, peeling, and/or sap flows) and Insect Damage. Cambium Damage, which is highly predictive, was not directly evaluated due to the time investment required and the fact it opens the tree up to attack by diseases and insects, which are especially acute when trees are stressed by factors including fire damage. Bole Char Severity, Bark Condition, and Insect Damage are highly correlated with cambium health (especially 12-16 months postfire), and can be assessed non-destructively and rapidly. When the Pm was within the 50-70% range Do Not Cut/Cut recommendations was presented with the caveat “at RPF discretion”. Feedback from the survey crews has led to the improvements in the matrix and Survey123 app including more rapid assessment of the relationship between tree height and distance to critical infrastructure and the inclusion of gray pine[1], which was not included in the draft version and is especially common below Paradise.

The following species were included based on preliminary surveys in Paradise and the availability of published analyses. Specific assessment guidelines were included for the following species.

- Conifers: Yellow pines[2], Douglas-fir[2], incense cedar[2], white fir[2], and coast redwood[3].
- Oaks: Black oak[4], interior live oak[4], and valley live oak[4].

Recommendations were provided for other conifers and hardwoods based on bark thickness and bole char, with final determinations left to the expertise of the RPF survey team lead.

Definitions of key terms and concepts were provided in the print matrix and in the Survey123 app. The definitions also included images, which could be viewed by selecting a thumbnail within the glossary in the Survey123 app. (see Appendix 1)

III. Tree Inventory Sampling - Summary of Procedures, Observations and Data

The objective of the survey was to develop an estimate of the total number of dead or dying trees 6 inches diameter at breast height (dbh) and above that have the potential to impact public infrastructure when they fall. The survey strategy produced an estimate of the total number of hazard trees with a confidence interval range using an inventory precision target of ±10% at a 68% confidence level. The design was based off a GIS road layer provided by OES and public parcel data from the County.

OSHA defines a hazard tree impact zone as two times the height of a subject tree. While it is true that a falling tree may cause a nearby tree to also fall and thereby impact public infrastructure beyond its own height (the domino effect), it is also true that any trees that may be toppled by the falling tree should themselves have been recorded as sample trees. Given the range of tree heights in the area, a distance of 260 feet from the road edge was examined for hazard trees.

The focus of the survey was public infrastructure only. This includes public roads but may also include schools and other public infrastructure. There are two sampling designs involved; roads and parcels. The two inventory estimates and standard errors are combined to provide a final total hazard tree estimate with confidence interval.

Public Parcel Plots:

All publicly owned parcels were selected within the incorporated town of Paradise and the unincorporated area of Magalia. The unincorporated area of Magalia extends well beyond the residential part of the town, so all parcels that were clearly not part of the town infrastructure, such as the State Land Conservancy, Paradise Irrigation District near Magalia reservoir, and some Federally owned parcels were removed from the selection. 173 parcels were included in the analysis. A 200 meter “fishnet” grid was applied across all the public parcels, generating 46 plots. The public parcel plots were number 501-546.

Road Plots:

A geospatial roads layer of Butte County was supplied by Cal OES.

All roads within the final Camp Fire perimeter were identified based on the Cal OES road dataset and were included in the plot selection. This includes State, County, Town of Paradise and privately maintained roads.

The distance between plots was roughly based on the desired number of road plots to equal approximately 400. According to the GIS Dataset, the total length of roads in the fire perimeter = 475 miles. The public parcels plus a 200 foot buffer where removed from the road plot layout to eliminate redundant tree counting between the parcels and the roads. Due to the complexity of the road layers with its many nodes and short neighborhood streets, many plots are closer than 1.3 miles apart. This road complexity is also the reason why the interval distance of plots is not a direct function of "total road length"/"desired number of plots". A Generate Points Along Lines process was run at a distance of 1.3 miles apart, generating 417 plots. The road series of plots was number 1-417.

The total tree estimate is calculated as the total number of sampled hazard trees multiplied by the plot expansion factor. The plot expansion factor is the total road length divided by the sampled road length. For example, if there is 100 miles of road and 5 miles of road was sampled then the plot expansion factor is 100/5 = 20. If 1,000 hazard trees were sampled then estimated the total number of hazard trees is 1,000 X 20 = 20,000 hazard trees.

The confidence interval is calculated as the t-value multiplied by the standard error to create the error bound. The error bound is then subtracted from the total tree estimate to get the lower value, and added to get the upper value. The bound is calculated in excel using the CONFIDENCE.T function, where the inputs are the sample standard deviation and confidence level.

These calculations have been set up in an excel workbook so that only the plot number and tree count on the plot is needed. There is a separate calculation for the road plots and the parcel plots. These estimates are then combined by totaling the total hazard tree estimates and combining the variances for the confidence interval.

Although the original plot design designated survey locations along the Cal OES provided road layers, not all plots within the fire area could be evaluated, this includes remote areas where road conditions were not passable or areas located behind locked gates. However, we anticipated this possibility and built in additional plots to maintain the confidence interval as described.

Summary:

- Total number public parcel plots: 40
- Total number road plots: 349
- Total number of plots: 389

See Appendix II for plot layout design locations.

IX. Summary of Findings

The following summary includes as estimate of the total trees located within the Camp Fire perimeter and along the Cal OES provided GIS road layer.

- **Estimate of Total Trees:** **280,779 Trees**
- Lower Confidence Interval: 258,084 Trees
- High Confidence Interval: 303,473 Trees
- Percentage Error: 8.1%

- **Estimate of Road Trees:** **273,951 Trees**
- Lower Confidence Interval: 249,991 Trees
- High Confidence Interval: 297,910 Trees
- Percentage Error: 8.7%

- **Estimate of Parcel Trees:** **6,828 Trees**
- Lower Confidence Interval: 5,537 Trees
- High Confidence Interval: 8,119 Trees
- Percentage Error: 18.9%

Active hazard tree felling was occurring during the sampling effort and it is expected the felling will continue for the foreseeable future. The estimate supplied reflects an estimate at a snapshot in time. No adjustments were made to the number to reflect expected additional tree felling activities nor any expected hazard trees which may fall by themselves this winter.

References

[1] Borchert, M. & D. Schreiner et al. (2002). Predicting postfire survival in Coulter pine (*Pinus coulteri*) and gray pine (*Pinus sabiniana*) after wildfire in Central California. Western Journal of Applied Forestry 17(3).

[2] Smith, S.L. and D.R. Cluck (2011) Marking Guidelines for Fire-Injured Trees in California. US Forest Service, Region 5, Forest Health Protection, Report #RO-11-01

[3] Douglas,R.B. & T. Bendure (2011). In: Standiford, R. B. T.J. Weller.; D.D. Piirto, and J.D.,Stuart, tech. coords. Proceedings of coast redwood forests in a changing California: A symposium for scientists and managers. Gen. Tech. Rep. PSW-GTR-238. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. pp. 363-371.

[4] Plumb, T.R. & A.P.Gomez (1983). Five Southern California Oaks: identification and postfire management. Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-71.

Appendix I: Definitions

Threat to Critical Infrastructure: ANY overlap with the following.
Buildings
Ground level exposed water, or gas valves, pipes, etc.,
Buried waterlines or gas lines,
Hydrants,
Road or Curb,
Sidewalk, and
Rock Walls.

Hazardous Tree
A tree of any species located with in the burn area perimeter of the Camp Fire (Nov 8, 2019) that has the following characteristics:

1. Location
a. Within the defined Operational Area and the public road right of way "buffer zone." The buffer zone is where all hazardous tree assessment and removal work will commence.
b. In a position that poses a hazard to a target, and likely to result in injury or damage to the public road infrastructure, or a traveler on the public road infrastructure, if the tree were to fall and strike a target.

2. Target
a. Any part of the public road infrastructure, including pavement, curb, drainage system, bridge, abutment, sidewalk, bike path, maintenance building, traffic signals, signage, guard rail.

3. Characteristics
a. Minimum dimensions of 6" or > in diameter and 60" (5') or > in height
b. Damage from wildfire, which can be easily identified by visual inspection of trunk or limbs or foliage-bearing crown.
c. Assessment by a Registered Professional Forester (RPF), or authorized designee, provides documentation and best professional judgement that the tree is dead or dying, and likely to die within five years.

Percent Crown Length Killed (PCLK): Visually estimate the percent crown length killed (PCLK) for **white fir, red fir, incense cedar and sugar pine** to the nearest 5 percent, by standing far enough back from the tree so that the entire crown is visible. Optimum viewing of the crown is against a blue sky away from the sun.

First, determine the original crown base height. Pre-fire crown base height can be estimated by looking at the fine branch structure and needles. Branches lacking fine twigs were likely dead before the fire. Trees often have asymmetrical crown bases so, if necessary, visually "move" some of the lower branches to the other side of the crown to even out the base.
Next, determine the crown kill height by establishing a "line of best fit" (Figure 1). Crown killed areas include any brown needles, as well as any areas that have blackened fine branches. If large gaps occur

in the crown (> 4 feet in length), visually "move" lower branches up to fill in these areas. Be sure to evaluate the backside of the tree if its condition cannot be determined from the original vantage point.

Visually estimate the percent crown length killed (PCLK) for **yellow pine** *post-bud break*, to the nearest 5 percent, by looking for completely dead branches (both scorched and/or blackened). Count an entire scorched branch as part of the live crown if green needles are extending from any of its lateral shoots.

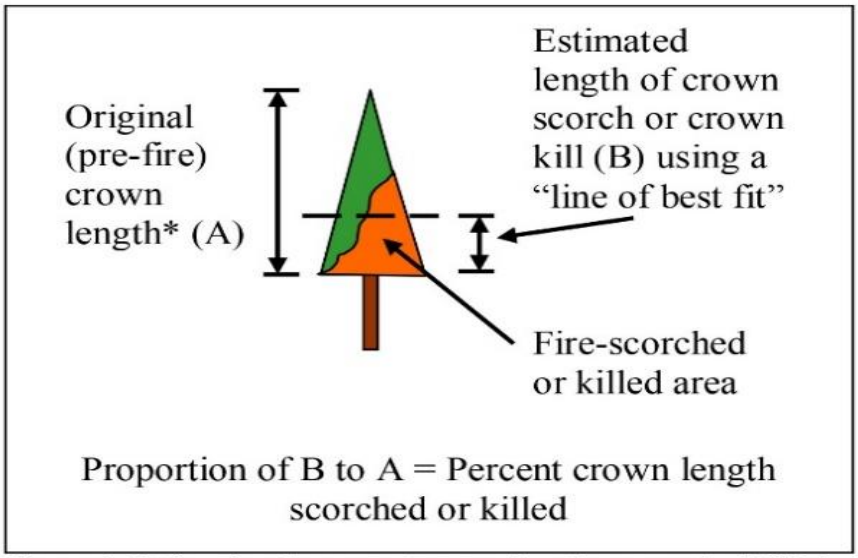


Figure 1. Estimating the percent crown length or scorched killed.

Bark Charring: (For Pines, Firs, and Cedars). When salvage marking includes cambium sampling, additional time is required to assess each tree. Direct cambium sampling can be reduced by using unburned, light, moderate, and deep bark char classes as a substitute (Hood et al 2008). Divide the tree bole into four quadrants and assess the bark from 2" to 1 foot of ground line. Use the bark char class that best represents the majority of the area. Please refer to the following bark char descriptions when substituting bark char classes for direct cambium sampling.

Light charring – light charring has some blackened areas on the bark but unburned portions remain. These unburned portions are generally found in the bark fissures. (*Assume cambium is alive*).

Moderate charring – all bark is blackened but the bark characteristics remain.

Deep charring – all the bark is blackened, bark often cracked and peeling, and bark characteristics highly reduced or no longer discernable. (*Assume cambium is dead*)

Insect Damage: If bark is obviously charred but not cracked or separated, use insect damage to assess condition of underlying cambium. Look at the base of the tree and in bark fissures.

1) ***Small, light cream to reddish, smooth, Pitch Tubes*: Note: the bark beetles that produce these tubes nearly always transmit blue stain fungi, which can cause mortality even when infestation is light.** Western Pine Beetle (ponderosa pine), Jeffery Pine Beetle (Jeffery Pine), and Mountain Pine Beetle (Sugar Pine), create distinctive, light colored,

pitch tubes. A few tubes scattered around the bole MAY not indicate extensive cambium death. Numerous tubes indicate cambium death.

2) Exit Holes: Penetrates to cambium: Indicates damage and probable localized cambium death. Numerous exit hole often adjacent to pitch tubes.

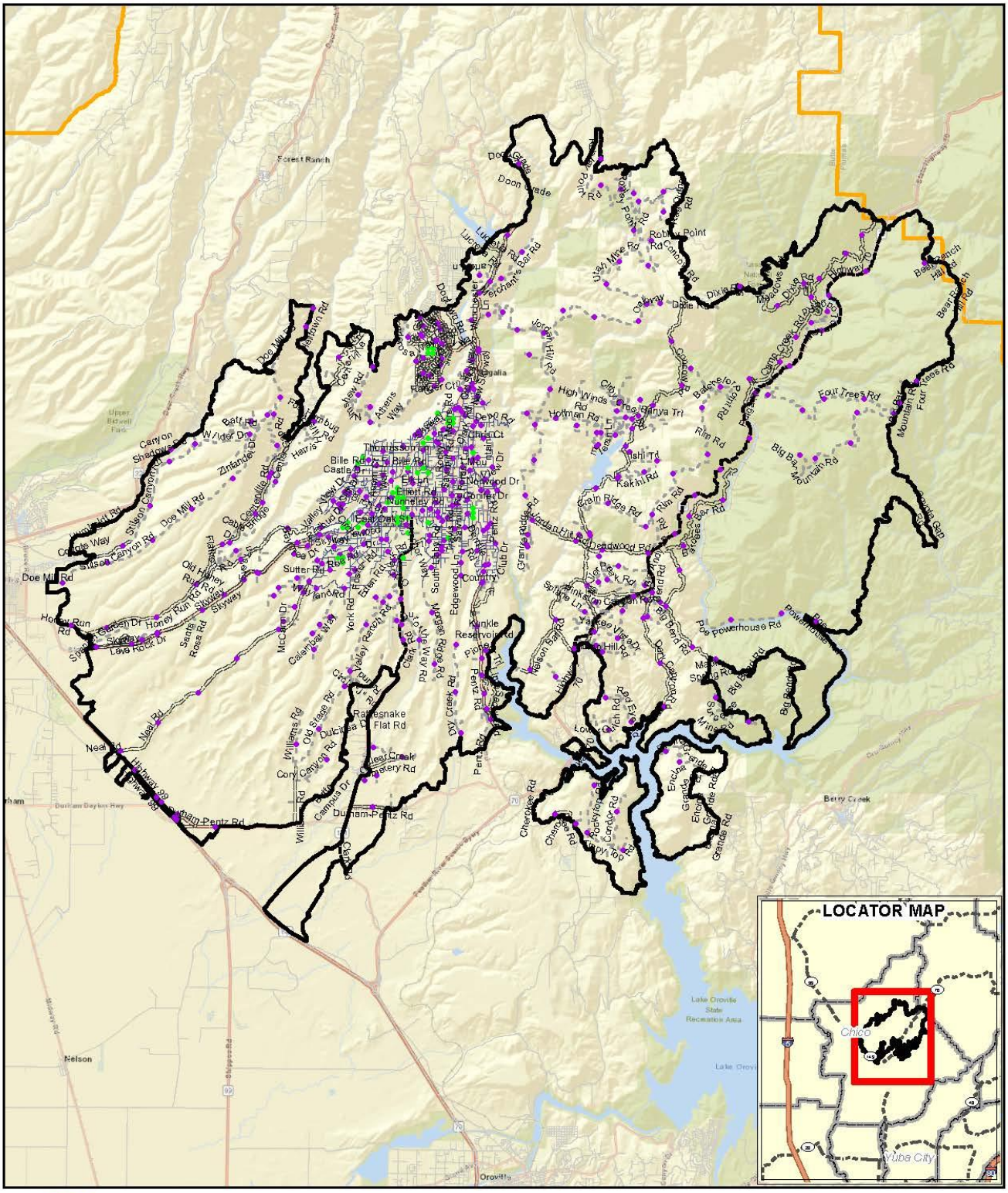
3) *Large, dark red to brown, rough, Pitch Tubes and/or very coarse reddish frass*: <u>Red Turpentine Beetles</u> in living cambium. When infesting a tree often do not kill the tree if limited to a few tubes around the root color. Pitch Tubes encircling the root color or higher up the bole (to 20 feet or more), indicate a severely weakened tree which is not likely to survive.

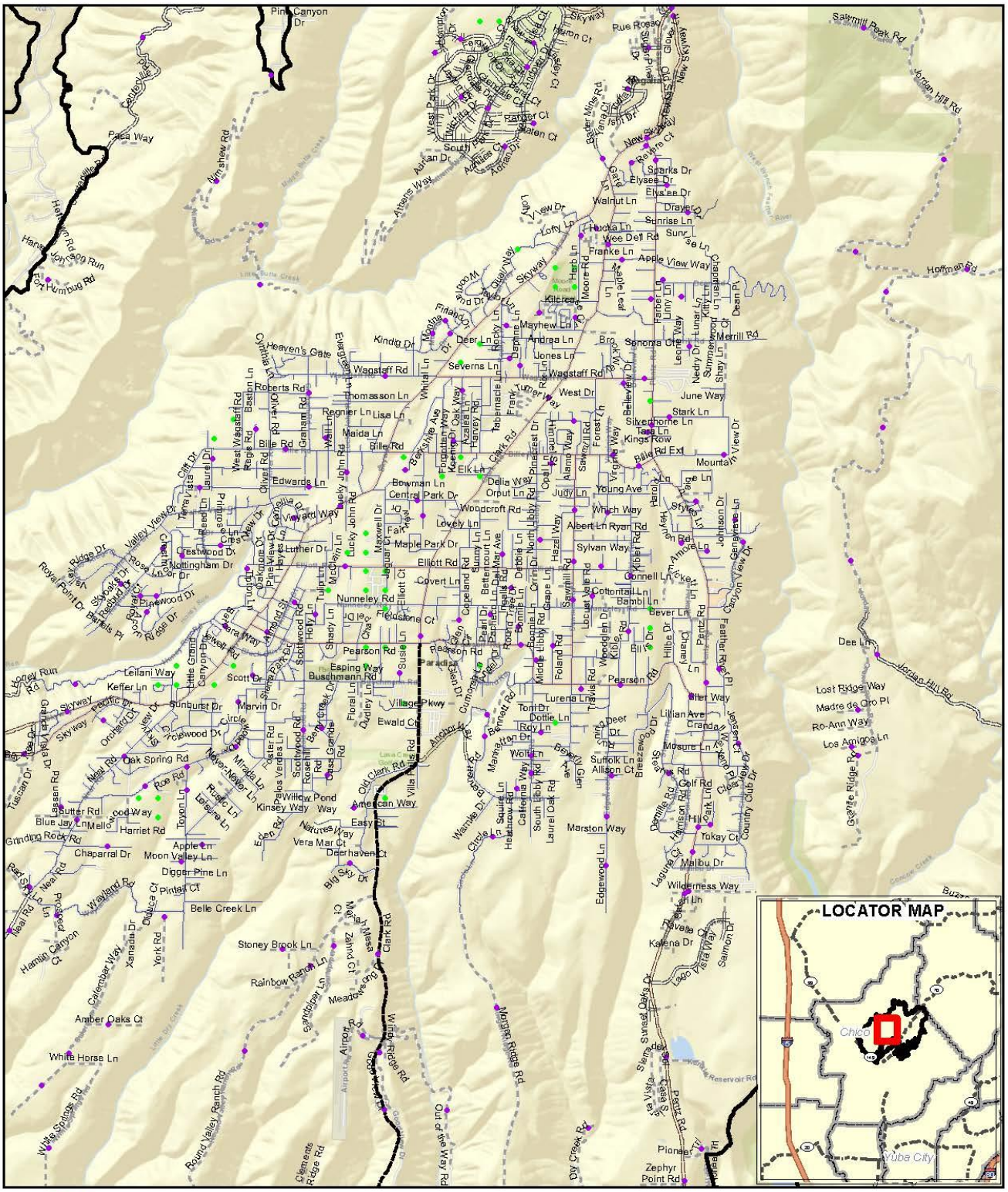
4) *Frass: Dry, dark reddish to brown in color*: Red Turpentine Beetles and other bark beetles in dead cambium. If the frass is coarse (sometimes fine), dry, and light to dark reddish brown it is usually the product of bark beetle activity in dead cambium/phloem.

5) *Frass: Dry, light white to yellow in color*: Frass is usually very fine and will collect in bark fissures near the gallery entrance hole and in bark fissures below. In extreme cases will pile up at base of tree. Ambrosia beetles attacking the boles of trees in California almost universally are an indicator of dead cambium and xylem.

6) ***Exit Holes*****:** ***Superficial, do not penetrate into cambium*****:** Do not consider in assessment. Carefully flake off outer bark to assess.

Appendix II: Plot Layout Design Locations





CAMP FIRE DYING AND DEAD TREE INVENTORY PLOTS CITY OF PARADISE DETAIL

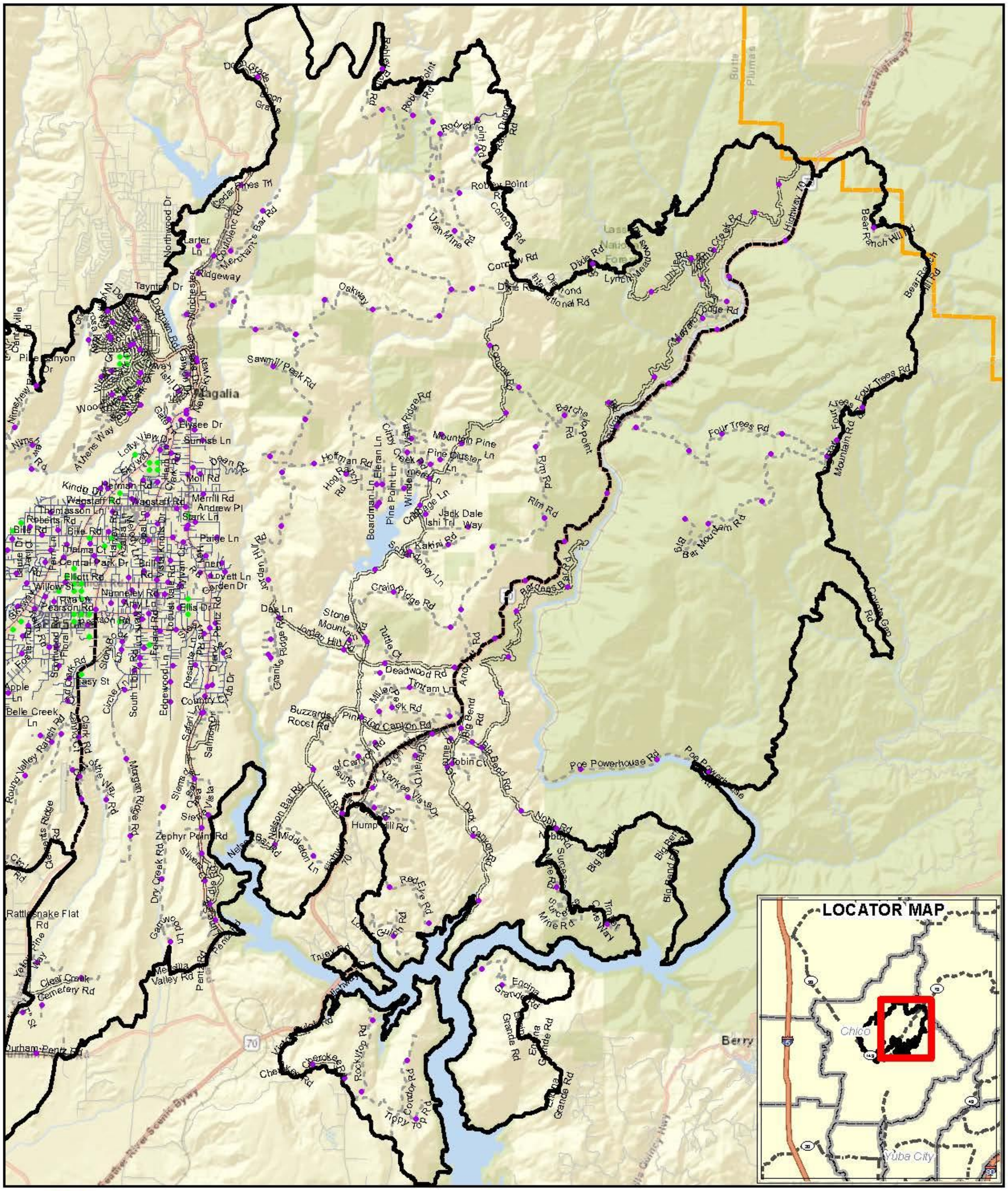
October 18th, 2019

- Public Parcel Plots
- Road Segment Plots
- Camp Fire Perimeter 2018

ROAD JURISDICTION

- PRIVATE
- PARADISE
- COUNTY
- STATE

0 0.35 0.7 1.05 Miles



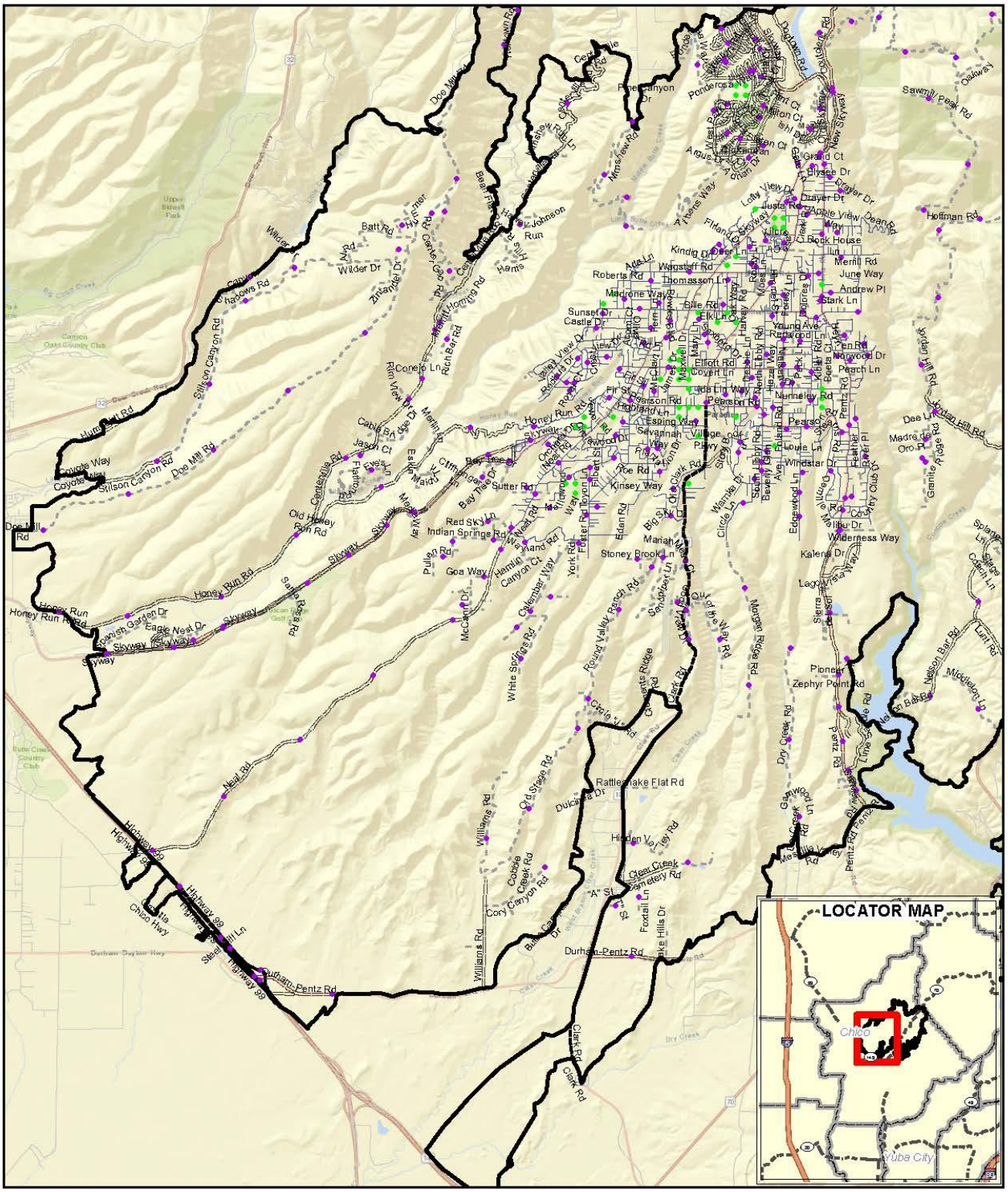
CAMP FIRE DYING AND DEAD TREE INVENTORY PLOTS EAST DETAIL

October 18th, 2019

0 0.9 1.8 2.7 Miles

● Public Parcel Plots
● Road Segment Plots
▭ Camp Fire Perimeter 2018

ROAD JURISDICTION
- - - - PRIVATE
—— PARADISE
==== COUNTY
▬▬▬ STATE



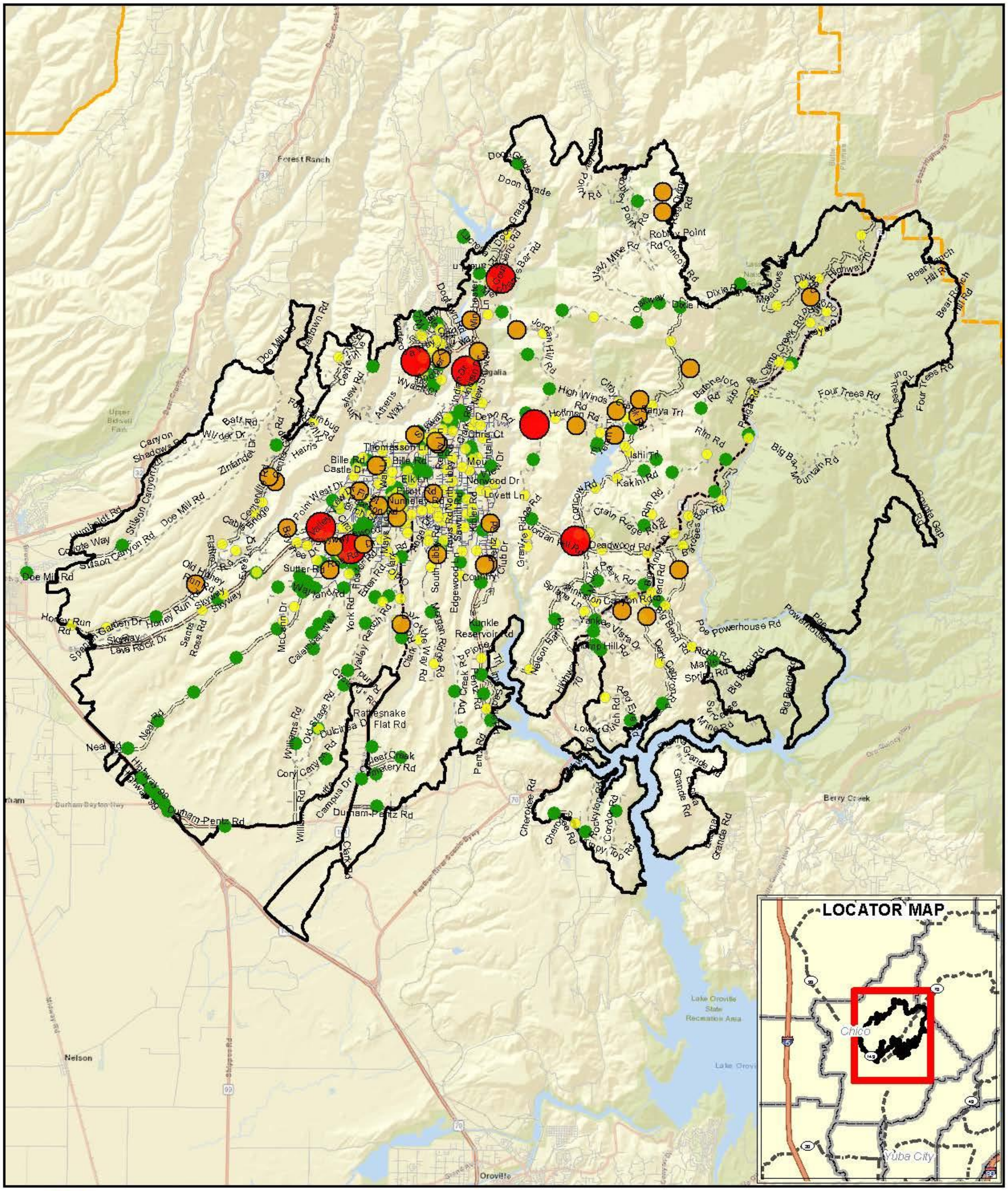
CAMP FIRE DYING AND DEAD TREE INVENTORY PLOTS WEST DETAIL

October 18th, 2019

Public Parcel Plots
Road Segment Plots
Camp Fire Perimeter 2018

ROAD JURISDICTION
PRIVATE
PARADISE
COUNTY
STATE

0 0.75 1.5 2.25 Miles



CAMP FIRE DEAD AND DYING TREE
INVENTORY PLOTS
DEAD AND DYING TREE DENSITY

October 18th, 2019

Range of Hazard Trees
- 1 - 10
- 11 - 30
- 31 - 78
- No Hazard Trees

ROAD JURISDICTION
- PRIVATE
- PARADISE
- COUNTY
- STATE

Camp Fire Perimeter 2018

0 1 2 3 Miles