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Forest Stewardship Series 26: Mapping Forest Features

RICKY SATOMI, UC Cooperative Extension (UCCE) Forestry Advisor for Sutter-Yuba, Butte, and Nevada counties;

CHRISTIAN EGGLETON, California Registered Professional Forester and Vice President of Forest Research Solutions and Technologies Corp, in Grass Valley, CA;

VAN BUTSIC, UCCE Land Systems Specialist, Department of Environmental Science, Policy, and Management at UC Berkeley

Surveying and documenting forest features is a core component of forest stewardship in California. When preparing a forest management plan, landowners and managers are required by state and federal laws to evaluate sensitive areas and forest resources. Clearly locating these features is critical for assessing potential issues, developing mitigation measures, and determining management potential. Foresters and operators also rely on mapped forest features to ensure that treatments comply with landowner intent and regulatory requirements.

The services of a consulting Registered Professional Forester are typically recommended to assist landowners with the evaluation and mapping process. In addition to ensuring regulatory compliance, a professional can help align individual management goals with site potential. However, not every step of plan preparation will require specialist knowledge. Using publicly available information, field collection, and background history of a property, a landowner can independently prepare many of the required maps to reduce planning costs or articulate management goals when professional services are required (for example, from a licensed surveyor, forester, or archaeologist).

To aid in this process, the California Cooperative Forest Management Plan (CCFMP) template is available to guide forest landowners through preparation of a forest management plan. Completion of a CCFMP and its mapping requirements ensures eligibility for several grants and landowner support programs from the California Department of Forestry and Fire Protection (CAL FIRE), the U.S. Forest Service, the American Forest Foundation's American Tree Farm System, and the Natural Resources Conservation Service.

Objective: Understand how to identify and capture the critical landscape features necessary to develop a forest management plan.

Competencies

- Become familiar with three basic types of spatial data: point, line, and polygon.
- Become familiar with collecting and maintaining location information for critical forest features.

Related publications in the Stewardship Series

- Forest History, UC ANR Publication 8234
- Forest Vegetation Management, UC ANR Publication 8326
- Forest Streams, ANR Publication UC ANR Publication 8239
- Forest Roads, ANR Publication UC ANR Publication 8247

Defining mapping goals

All maps are imperfect representations of reality. Rather than capturing every physical detail, maps should highlight key information to help readers interpret the features in a landscape. It is also important that maps only contain information relevant to the purpose of each map (table 1). Including extraneous details not only adds to planning costs but may confuse map readers or distract them from key information. To focus field collection efforts and locate key feature details, it is therefore important to first determine which maps will be produced.

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Forest planning maps are generally designed to perform one of three general functions:

Topographical: A detailed map with elevation information to aid in identification of landmarks and surface features. Often uses contour lines to allow detailed study of landscape and drainage features.

Thematic: A subject-based map highlighting geographical distribution of a particular topic. Includes qualitative and quantitative information which may require the map user to have specialist knowledge.

Cadastral: A map of individual properties that shows parcel boundary, land use type, ownership, and infrastructure features. Most county governments maintain a registry of property titles for taxation and land use planning purposes.

The CCFMP template identifies nine specific maps (see table 1) commonly required by CAL FIRE, U.S. Forest Service, Natural Resources Conservation Service, and American Tree Farm System landowner assistance programs. Combined, these maps fulfill most logistical and legal planning requirements, though additional maps may be required for specific funding programs or types of management activity (Forest Stewardship Series 19, Forest Stewardship Series 20).

Prefield planning: Locating existing records

Field collection of data often requires considerable labor and time. However, this step can be made more efficient by leveraging existing information and resources. Records from past management plans, property assessments, and oral tradition can offer a wealth of information about forest features. Some features, such as elevation, soil type, or cultural site location, rarely change and may be reused. Others

Table 1. Commonly required management planning maps from the California Cooperative Forest Management Plan

Map name	Purpose
Property location map (topographical)	Shows general orientation to assist in navigation to a particular property. Contains property boundary and road information to show accessibility from nearby towns or landmarks. Topographical information illustrates the area's general landform, including aspect, slope, elevation, and drainage patterns
Parcel map (cadastral)	Shows property boundaries, project boundaries, and road network locations. Often contains assessor parcel numbers (APNs), public land survey system description (township, range, and section), or recorded surveyor information
Soil type map (thematic)	Identifies soil types in order to inform management strategies and decisions. Shows name and location of soil types present in project area. Data are available from the National Resources Conservation Service Soil Survey database
Site class map (thematic)	Identifies forest site class in order to provide information about a particular area's capacity for growth. Typically requires a professional forester to complete site assessment and evaluation
Water resources map (thematic)	Identifies drainage patterns (watercourses) and other surface water features to inform management decisions that prevent downstream impacts on water resources. Shows name, location, and classification of watercourses; springs; drafting locations; wells; and other water resources
Road assessment map (thematic)	Identifies road conditions and accessibility during management activity. Includes all watercourse crossings on roads and skids, including type of crossing. Indicates locations where road projects such as surface repair and culvert replacement are planned
Vegetation unit map (thematic)	Indicates baseline condition of the forest and informs how activity will modify or improve overall forest condition. Includes past management areas, distinct forest types, and areas without trees or vegetation
Special areas map (thematic)	Identifies sensitive resources and informs planning for adequate protection measures. Shows mitigation plan for sensitive resources including threatened and endangered species, unstable areas, or archeological sites
Project area map (thematic)	Activity map showing location of proposed management activities. Covers planned activities over a period of at least 5 years

are more dynamic, such as cultural resources or vegetation types. Locating past records of these features can indicate where to focus field collection efforts or provide insight about the current forest condition.

Public agencies are also valuable sources of forest feature information:

- Information on soil type and erosion hazard is maintained by the Natural Resources Conservation Service Web Soil Survey, websoilsurvey.nrcs.usda.gov. The local field office may have additional records if past management work was completed with their assistance.
- General stream and watershed information is available from the California Department of Fish and Wildlife's Biogeographic Information and Observation System, wildlife.ca.gov/Data/BIOS.
- Property boundary locations are available from your local county assessor's office or county geographic information systems department, as well as commercial vendors. Digital parcel records are generally accurate, but a written legal description is required for official documents.
- Localized information may also be found in past environmental impact reports or CAL FIRE forest management plans, caltreesplans.resources.ca.gov/caltrees/. The resource evaluation and map requirements of these environmental review documents contain useful topographic, hydrological, and road feature information.
- Information on elevation, hydrography (bodies of water), watersheds, geographic names, governmental units/boundaries, transportation, and land cover type, as well as distortion-corrected images (orthorectified), are available from the United States Geological Survey's National Geospatial Program, apps.nationalmap.gov/viewer/.

Prefield planning: Selecting a collection tool

Various tools are available for field collection of forest features, each with its own advantages and disadvantages. Stand-alone geopositioning devices, smartphones with geopositioning capability, and printed maps (fig. 1) are among the most common.

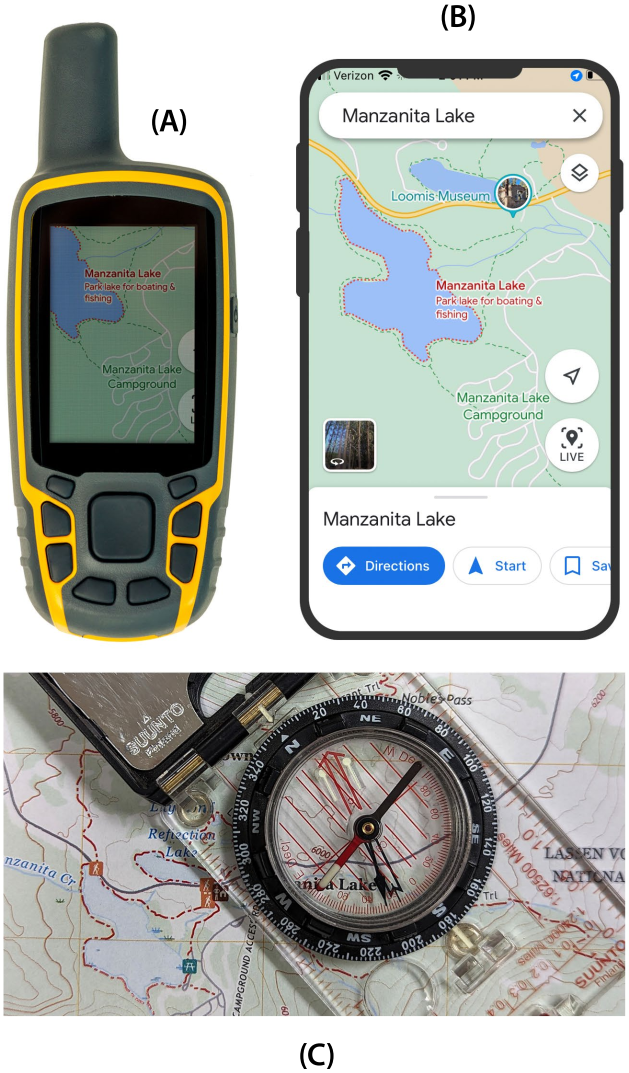

Figure 1. Handheld GPS device (A), Android smartphone device (B), and printed map with compass (C).

Digital systems with geopositioning capabilities use one of several satellite constellation systems orbiting the Earth to provide receivers with location data. The main satellite systems in use are maintained by governments and private companies, and include

- Global Positioning System (GPS)—United States
- Global Navigation Satellite System (GLONASS)—Russia
- Galileo—European Union
- Quasi-Zenith Satellite System (QZSS)—Japan
- BeiDou (BDS)—China

Sidebar

What is a legal description?

Legal description refers to a written description of parcel location using the United States Public Land Survey System. Originally designed to facilitate the transfer of public domain lands into private ownership, the Public Land Survey System is a composite of several surveys forming an invisible grid across the Western United States. The Bureau of Land Management maintains the Public Land Survey System and provides it to the public.

Each survey is based on an *initial point* where the *principal meridian* and *base line* intersect (fig. S-1). The principal meridian is represented by an axis running north to south. The base line is a perpendicular axis running east to west. In California, there are three initial points from which surveys are anchored: *Humboldt*, *Mt. Diablo*, and *San Bernadino*.

When identifying the legal DESCRIPTION of an area, begin with the initial point. The Public Land Survey System divides land into a grid of parcels (fig. S-2). The largest grouping is a **Township**, or square parcel of land measuring 6 miles on each side. Each township is further subdivided into a grid of square-mile **Sections** numbered 1 through 36, beginning in the northeast corner and ending in the southeast corner. Each section consists of one square-mile area (640 acres) but may be further divided into half-sections, quarter-sections, or "quarter-quarter" sections. Permanent monuments are placed at each section corner.

The location of a township is identified by its distance from the initial point along the *principal meridian* and *base line* (for example, Mt. Diablo, Township 2 South, Range 3 East).

Initial point: The township refers to the Mt. Diablo survey.

Township: T.3S refers to the distance north or south (of the baseline) from the initial point in units of 6 miles.

Range: R.2W refers to the distance east or west (of the principal meridian) from the initial point in units of 6 miles.

The full description should be written out from the smallest unit to largest unit. Sections are typically divided into quarters based on their orientation. The descriptions are read from the smallest division to the largest and are usually written in shorthand.

SW ¼	SE ¼	Sec. 17	T2S	R3E	Mt. Diablo
¼-section	¼-section	section	town-ship	range	meridian

Of note, accidental and intentional errors exist within the original Public Land Survey System grid. However, physically monumented corners are considered authoritative, and any new surveys must be tied to the existing corners and survey lines, even if they are known to have errors.

Figure S-1. Location of principal meridians, base lines, and initial points for the three U.S. Public Land Survey System surveys in California.

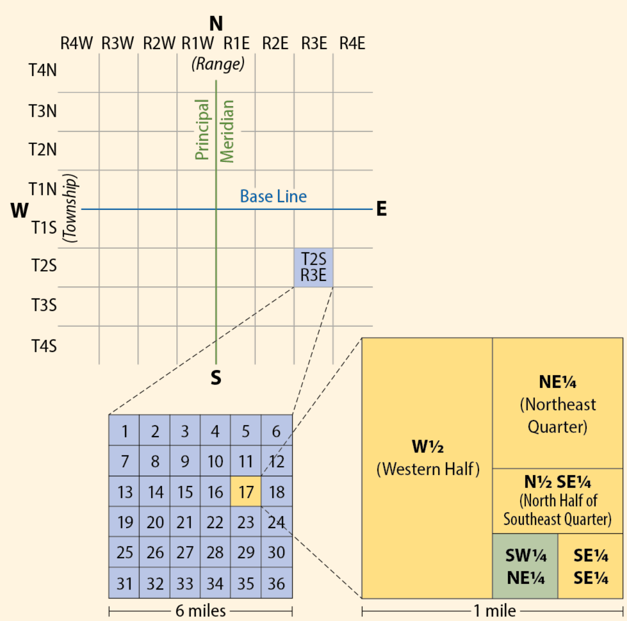

Figure S-2. Township (blue), section (yellow), and subsections in a U.S. Public Land Survey System grid system. This parcel (green) may be read as: Southwest quarter of the southeast quarter of Section 17, Township 2 South, Range 3 East, Mount Diablo Meridian.

Each satellite in a constellation sends out radio signals that can be captured by a handheld geoposition-enabled device. A device uses information about the time between the initiation of a satellite's transmission and its reception to identify its distance from the satellite. By identifying the distance from multiple satellites, a device's location can be derived (fig. 2). Geopositioning systems can rapidly determine location but require power to operate and may lose accuracy in areas with dense tree canopy or deep valleys.

Dedicated GPS devices vary in cost from a few hundred dollars to several thousand dollars for high-precision devices. These devices are often designed for field collection, incorporating rugged designs and field-navigation software. In contrast, modern smartphone devices have less accuracy than high-end GPS devices but are readily available and sufficient for most mapping purposes.[1] Default applications on most smartphone devices can also perform basic field collection functions, but they often require internet connectivity. When using a smartphone as a GPS data collector, it is recommended that you install a dedicated mapping application through the Android or iOS app store. Avenza Maps is one such application, but there are many trail, hunting, hiking, and navigation apps that are designed with offline cartography capacity.

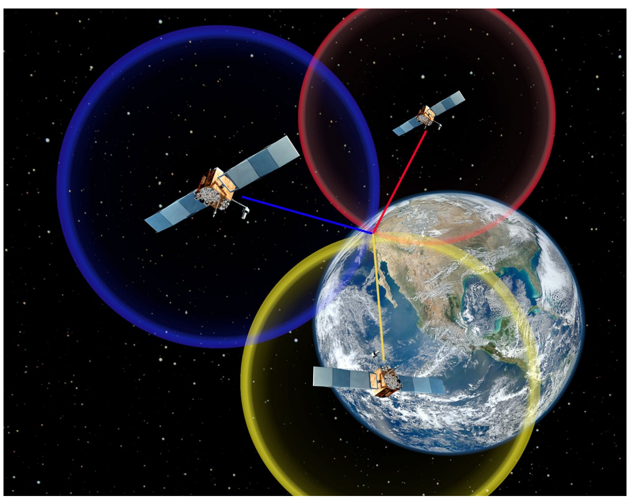

Figure 2. Satellite trilateration.

Features may also be recorded directly on paper maps using references from existing roads or other visible landmarks. While analog feature collection does not require specialized equipment, some expertise is needed to accurately record feature locations.

Prefield planning: Selecting a basemap

Basemaps are reference maps that visualize terrain and landmark features to aid collection of new feature data. While there is no standard convention for what may be used as a basemap, topographical maps, satellite images, and online navigation maps are the most common (fig. 3).

Depending on the intended mapping goals (see table 1), the type of basemap can obfuscate or highlight relevant information for the user. Dense tree canopy on a satellite image may obscure roads and streams that would otherwise be visible on a U.S. Geological Survey quadrangle. However, a satellite image may also help confirm historic information—for example, by aligning a major highway between the basemap and an older map record (to define past treatment boundaries).

When collecting features by hand on a printed map, the basemap should have a scale bar and graticules (lines that indicate geographic coordinates) to assist in identifying cardinal directions and distances. Light colors on a printed map are also important to improve visibility when adding new features and

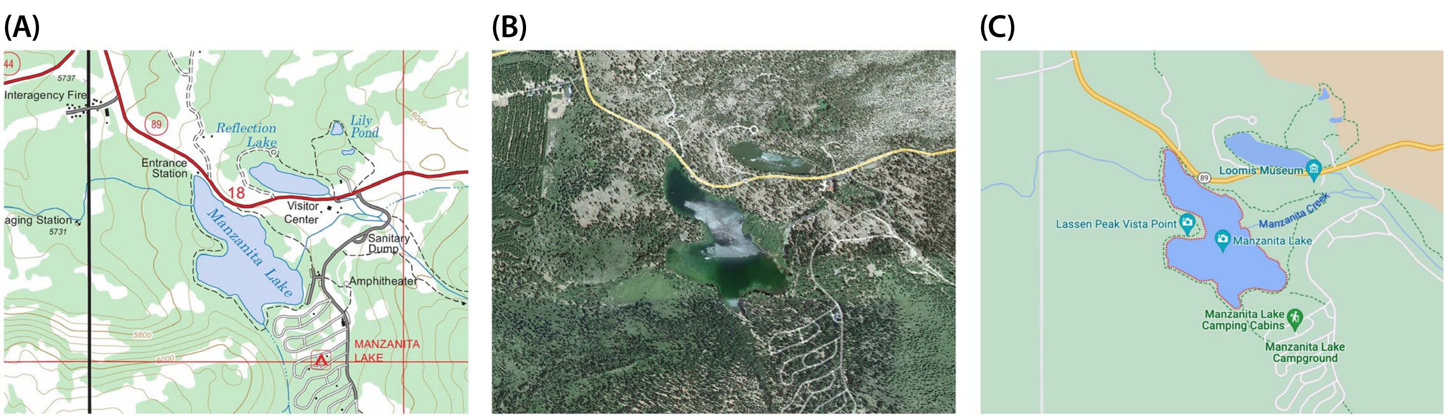

Figure 3. U.S. Geological Survey quadrangle topographical map (A), satellite image (B), and Google navigation basemap (C).

notations. For digital feature collection, a basemap should be saved to a handheld device before arriving at the collection site in order to ensure the basemap is accessible at the desired extent and scale without a cellular signal.

Topographical. Topographical maps display elevation as contour lines, or imaginary lines connecting points that have the same elevation. Contours form patterns to symbolize the shape of Earth's surface and are used to identify key geographic features including ridgelines, peaks, slope severity, and valleys. Topographic maps also often show key landmark features including roads, railroads, rivers, lakes, and ownership boundaries. The US Geological Service EarthExplorer, earthexplorer.usgs.gov, provides these maps for public use. *Useful for*: identifying geophysical terrain, elevation, aspect, roads, hydrologic features, and other infrastructure.

Satellite/aerial imagery. Satellite and aircraft-based systems display images of the Earth's surface features. Publicly run systems such as Landsat, earthexplorer.usgs.gov; Sentinel, sentinel-hub.com; or the *National Agriculture Imagery Program*, naip-usdaonline.hub.arcgis.com provide digital orthophotography to governmental agencies and the public. Privately run systems can offer higher resolutions and different sensor bands, but at a cost. Data aggregation services (CalTopo, Google, Bing, Mapquest, Esri, Mapbox, OpenStreetMap, and others) provide this information through user-friendly websites. Please note that these services may change by time of publication and their listing does not constitute an endorsement by the University of California. *Useful for*: classifying vegetation types and health based on the density of trees or coloration of visible trees. Landscape-scale alterations such as roads or past management may be visible.

Navigation map. Web and print navigation services provide maps with simplified road information. Although potentially less reliable in remote areas and on private land, many of these resources are available for public noncommercial use. The aforementioned data aggregators are reliable sources for acquiring this information. *Useful for*: navigation.

Table 2. Example of common information collected and used to inform required California Cooperative Forest Management Plan maps

			Relevant maps								
Forest feature	**Data type**	**Information to collect (other than location)**	**Property location**	**Parcel**	**Soil type**	**Site class**	**Water resources**	**Road assessment**	**Vegetation unit**	**Sensitive areas**	**Project area**
Parcel boundaries	polygon	legal description of property, owner name, adjacent landowners (if multiple), and condition of boundary line	X	X	X	X	X	X	X	X	X
Property infrastructure	line, point	power and gas lines, building locations, and well locations	X	X				X		X	X
Project location	polygon	legal description of property size, slope elevation range, and road accessibility from public roads	X	X	X	X	X	X	X	X	X
Road	line	road surface type, length of road segment, and condition of road	X	X	X	X	X	X	X	X	X
Stream	line	size class, presence of flowing water, and presence of wildlife				X	X	X		X	X
Stream crossing	point	condition of crossing, culvert type, culvert size, and outlet condition				X	X	X		X	X
Cultural resource	point, line, polygon	type of visible features and condition of artifacts						X		X	X
Wildlife	point	nest/habitat type and invasive or endangered species					X	X		X	X
Skid trails and landings	line, point	Condition repair requirements			X		X	X		X	X
Vegetation type	polygon	stand age, vegetation type, site index, average diameter at breast height, and tree species			X	X	X		X	X	X

Recording forest features

When documenting forest features, it is valuable to collect both location data and descriptive attributes (table 2). Detailed attribute information such as watercourse width or classification (per the California Forest Practice Rules) can inform road crossing and riparian buffer designs when preparing road-assessment, water-resource, and project-area maps. Detailed information also helps prioritize management needs such as identifying areas without equipment access or in need of repair.

Determining what features and which of their attribute information to collect will depend on the map being prepared (see table 2). A collection plan should be developed prior to implementing field collection to ensure that relevant information is collected, and that the level of detail collected aligns with time and cost constraints. By collecting features used by multiple planning maps, the surveyor can optimize the time available to meet several mapping goals. Similarly, if insufficient time is available, focusing efforts on one or two planning maps may net a better outcome.

To get started, identify the forest features to be represented by the map and the spatial data type that best fits their representation. For a two-dimensional map, forest features (for example, a nest tree, watercourse, road, spring, or forest-stand type) can be classified as one of three data types.

Point: A feature that occupies a single location on the ground. Examples include springs, nest trees, and watercourse crossings. *Collecting point features*: Most digital applications will use an icon to indicate the current position of the device. When collecting point-features data, most applications will record the information at the current position of the device, though some allow for manual adjustment in the event of a signal error.

Line: A feature that is linear. Examples include roads, streams, trails, and power lines. *Collecting line features*: Most digital applications collect line features by recording a series of points at a designated time or distance interval, which are then converted into a line. These are often called GPS tracks. Recording GPS tracks is often suitable for features that can be traversed, such as a road or trail. Linear features may also be manually drawn by the user, which is useful when a feature, such as the centerline of a wide watercourse, cannot be followed on the ground.

Polygon: A feature that represents the boundary of an area sharing a common characteristic. This feature can represent either the area within or the perimeter of the polygon. Erosive soils, meadows, forest stands, or past management activity may all be represented by polygon features. *Collect polygon features*: Polygon features are recorded similarly to line features in the field. From a collection standpoint, a polygon is simply a line feature that is connected to its starting point. It is up to the user whether the interior or exterior of the shape is of relevance. While some digital applications allow creation of polygons in the field, points or lines may also be collected and post-processed into polygons on a computer.

Note that when making maps, it is common to represent forest features using more than one data type. For example, using line features for a watercourse channel location and point features for road crossings results in a detailed representation of a stream. Similarly, sensitive wildlife habitat may be delineated using a single point in the case of a nest tree, or polygons that represent the extent of a sensitive nesting area. For more detail on the relevant attributes to collect for forest features, review the related publications in the UC ANR Forest Stewardship Series.

Table 3. Common file types used to store geospatial data

Name	File suffix	Data structure
Comma separated value	.csv	simple table format that can be viewed as a spreadsheet
Keyhole markup language	.kml, .kmz	tag-based structure with nested elements and attributes; can be opened with a text editor but requires cartographic software to interpret spatially
Shapefile	.cpg, .dbf, .prj, .sbn, .sbx, .shp, .shx, .txt	proprietary file format developed by Esri; requires cartographic software to view/edit
GPS exchange format	.gpx	tag-based structure with nested elements and attributes; can be opened with a text editor but requires cartographic software to interpret spatially

Transferring map data

Once field collection is complete, data can be stored or further processed with a computer. Digital spatial data use specific file formats to store location and attribute descriptions of collected point, line, and polygon data. These unique file formats (table 3) ensure that spatial information is correctly formatted and easily shared across different devices. To export spatial data, save collected data as one of these standard formats and share the file using email, physical transfer with a CD or flash drive, or a cloud-based file-sharing service. Data collected on paper maps can be photocopied and shared or manually digitized with a computer.

Building your map

When preparing maps for management plans, several free and commercial software options are available to review and organize collected data. Desktop applications such as Google Earth Pro, ArcGIS, or Quantum GIS (fig. 4) allow the user to work on a local computer, whereas browser-based applications such as CalTopo or ArcGIS Online require an internet connection to view and modify the data.

Collected feature data should be added to your map based on the intended map purpose (see table 2). Once added, feature data can be further modified to correct collection errors, stylized to highlight information, or analyzed to create new information. For example, watercourses are often colored blue with varying thickness to indicate the rate of flow. Patterns and shading intensity can also be used to indicate relative differences between map features.

Adjusting the order, transparency, and fill of features can also help make features distinct, particularly in data-rich maps. Overlapping features often cover important information and should be adjusted so that all collected feature data are visible (fig. 5).

In addition to feature data, including the following map elements can help ensure that the map is interpreted correctly:

- **Scale:** A graphical or textual description showing the ratio between a distance on the map and its corresponding distance on the ground. Because digital maps can be printed at various sizes, it is preferable to use a graphical scale bar.
- **Title:** A brief description of the map, including the map type and project name.
- **Author:** The person who prepared the map. This can help a map user locate additional information if necessary.
- **North arrow:** A graphic indicating the map orientation. Make sure the north arrow is easy to read and does not distract from the data represented on your map. A simple arrow design is quickly recognizable and unambiguous in its orientation to the reader.

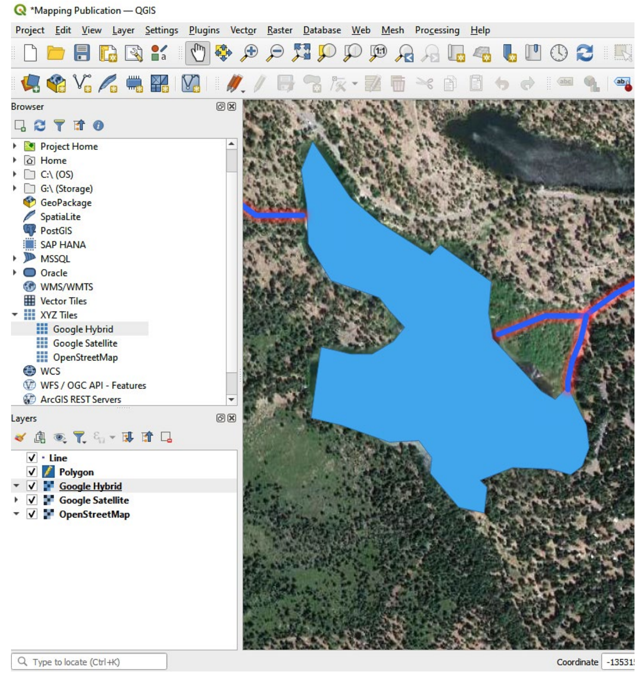

Figure 4. Quantum Geographic Information System desktop application with polygon and line data.

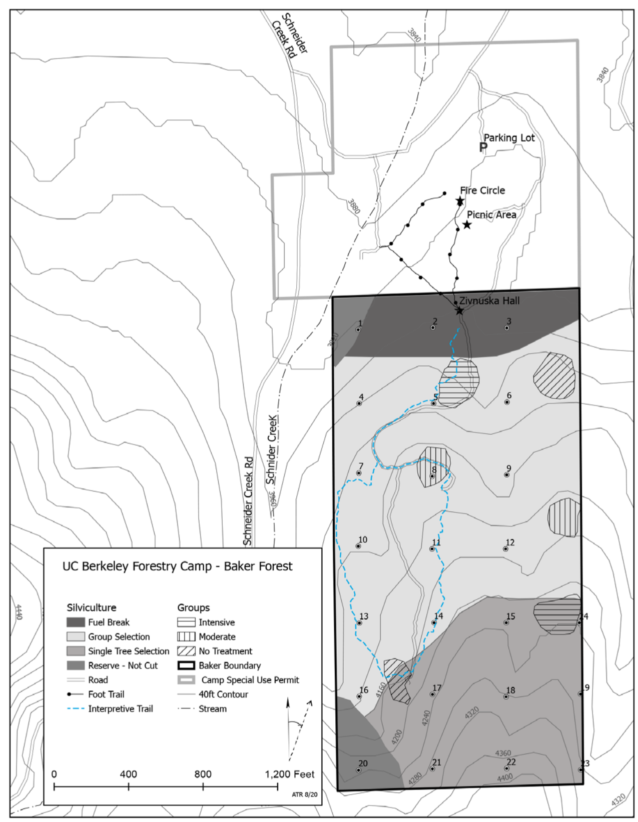

Figure 5. Sample map of Baker Forest in Plumas County with detailed legend and map elements. Map aligns with California Cooperative Forest Management Plan recommendations for property location, parcel, vegetation unit, and project- area maps. *Source:* Ariel Roughton, Forest Manager, Berkeley Forests.

- **Date:** The date of map preparation will identify the relevance of the information contained within.
- **Legend:** A legend will help the map user interpret the symbols found on the map.

Next steps

When complete, maps may be saved and shared using a geo-enabled format. Georeferenced Portable Document Format (or GeoPDF) files are accessible on most computers or GPS devices and can be accessible even when there is no internet connectivity. This format is similar to plain PDF files but with added mapping functions (such as turning map layers on and off, obtaining XY coordinates for a location, measuring length, and more). Custom maps may also be used as a basemap layer during the collection process.

Maps play an important role in the stewardship planning process. A spatial inventory of forest resources allows landowners to improve their understanding of the ecological resources that must be addressed in a management plan. Landowners can also assist resource professionals by collecting pertinent information ahead of time, which may help the landowners better articulate their expectations about the management process. While many aspects of the forest management process require a paid professional to meet legal standards, forest stewards with a good grasp of the resources on their land can help inform proper management by conveying this knowledge through the use of effective maps.

Notes

[1]The National Technology and Development Program of the U.S. Forest Service regularly tests GPS systems and provides accuracy reports to support, among others, field users of Forest Service Global Navigation Satellite Systems/GPS with a convenient source of information related to global navigation satellite systems supported by mobile devices and hardware, fs.usda.gov/database/gps/index.htm.

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