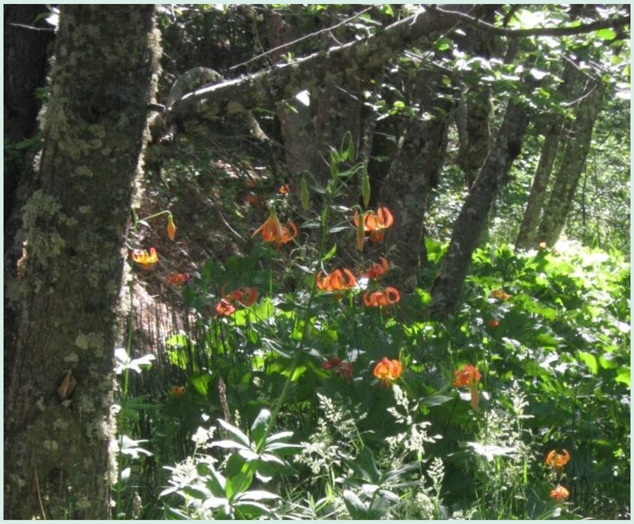
FINAL REPORT ◦ APRIL 2015

Cow Creek and Mill Creek Riparian Mapping and Conditions Assessment



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Cover photos: Photos taken during June 2012 reconnaissance tour of Mill and Cow Creek watersheds.

ABSTRACT

Cow Creek and Mill Creeks are east-side tributaries to the north Sacramento River that provide important habitat for native fish and other wildlife. To-date however, both watersheds have lacked detailed and spatially explicit information on the existing vegetation and ecological condition of the riparian corridors. To address this information gap and to help guide future restoration and enhancement efforts, this project was initiated with three primary goals: (1) map the riparian and adjacent vegetation; (2) assess conditions of the riparian corridors; and (3) develop recommendations in the form of an annotated list, on priority action areas for restoring or enhancing riparian vegetation. This project is funded through the Anadromous Fish Restoration Program administered by the US Fish and Wildlife Service. To map vegetation along the river corridors for Mill and Cow Creeks, we used a combination of remotely collected and field collected data. For three weeks in 2013, a field crew surveyed vegetation types at 244 points and performed more in-depth surveys of riparian conditions at 81 points in both watersheds. These field data provided ground truthing information for the draft vegetation map and information on riparian conditions. A draft vegetation map of the riparian corridors was created using aerial imagery from a variety of sources. Two attributes associated with riparian vegetation that are new or unusual components of vegetation maps were included in this effort: vegetation overhang along the stream channel and meadow type based on a hydrogeomorphic classification for the Sierra Nevada, published in 2011. Ground truthing demonstrated that the draft vegetation map had an overall accuracy of 89%. As a first step in the riparian conditions assessment, the riparian corridor within both watersheds was divided into reaches with consistent geology, hydrology and surrounding land use. Within these areas, information from the mapping effort, field surveys, technical documents and other spatially explicit data were used to assess riparian conditions. We used eight structural characteristics discernable using remote imagery or GIS data layers as indicators of riparian condition and then applied a consistent scoring scheme to develop advisory condition quantifications for each condition reach. These were used with other site-specific and less easily quantified information to develop final condition scores for each condition reach. Reaches with lower condition scores were more closely examined using remote imagery and other information sources to identify, in an annotated list, high priority areas for restoration and enhancement in Cow Creek and Mill Creek watersheds.

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1 PURPOSE

In September 2010, Stillwater Sciences and Aerial Information Systems were awarded a contract to map and assess conditions of the riparian vegetation in Cow Creek and Mill Creek watershed project areas (Figures 1-1 and 1-2), and to develop recommendations in the form of an annotated list, on priority action areas in each watershed. This project is funded through the Anadromous Fish Restoration Program which is administered by the US Fish and Wildlife Service. This document provides a brief background on watershed conditions and issues for Cow Creek and Mill Creek; a description of the methods used to map and assess the condition of vegetation in these areas; and a description of the methods used to identify priority action areas, as well as the annotated list of recommended priority areas for riparian restoration or altered management.

This project was performed as a series of steps which are the same and were essentially done together for each of the two watersheds. These steps are described following a review of the conditions in Cow Creek and Mill Creek watersheds. Briefly, these steps are:

- Stakeholder communication: meet with and communicate with watershed groups and other stakeholders or interested parties in Cow Creek and Mill Creek watersheds in order to learn about key issues, existing information, and private lands access.
- Reconnaissance field survey: Travel across both watersheds to learn about access to areas, survey the range of vegetation types in the watersheds, and gather ground photo-signatures of different vegetation types.
- Preliminary vegetation mapping: Develop draft vegetation maps of riparian vegetation and adjacent upland vegetation in the delineated project areas for both watersheds.
- Vegetation map accuracy assessment: Field check draft vegetation types and collect information on riparian conditions for condition assessment.
- Final vegetation mapping: Incorporate adjustments from accuracy assessment to refine vegetation types for final vegetation map.
- Riparian conditions assessment: Use field data, imagery, and other ancillary information to assign condition ratings to reaches in both watersheds and incorporate in a GIS shape file.
- Recommendations for priority action areas: Use all of the above information as well as reports, input from stakeholders, and other sources to develop an annotated list of recommendations for high priority restoration areas and actions in both watersheds.

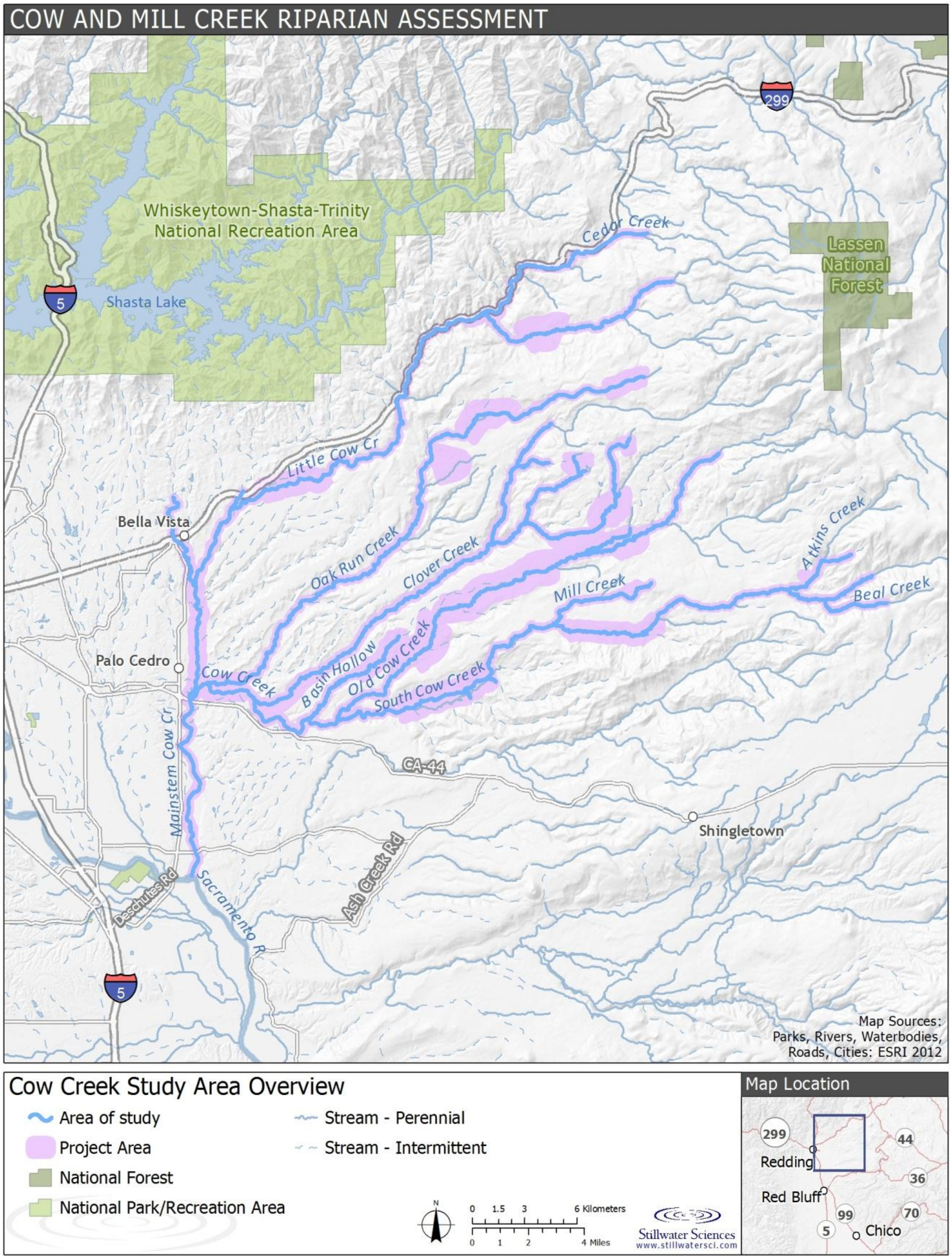

Figure 1-1. Cow Creek study area overview.

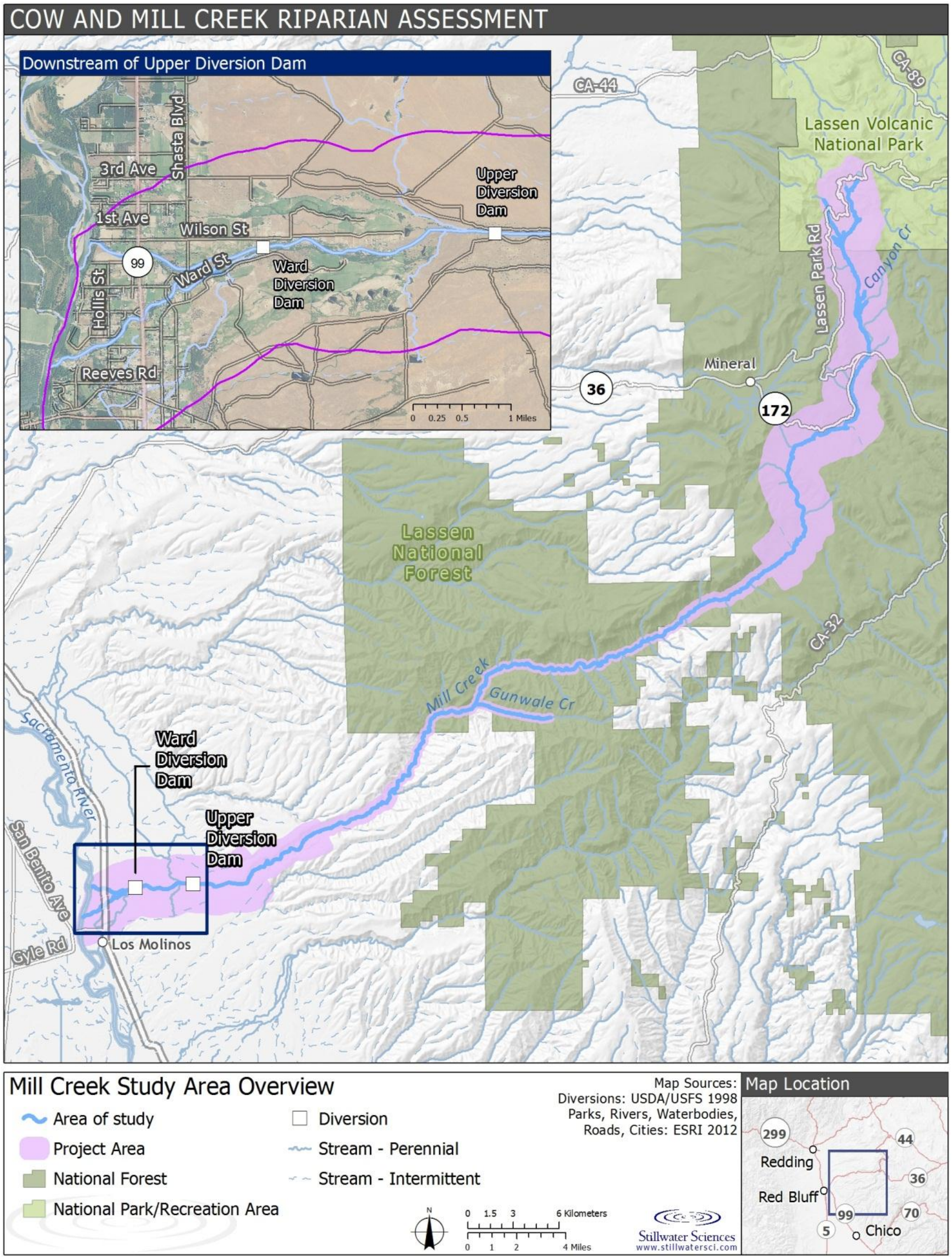

Figure 1-2. Mill Creek study area overview.

2 BACKGROUND

2.1 Cow Creek

Cow Creek is a tributary to the Sacramento River in Shasta County, California. Its watershed covers over 430 square miles (275,000 acres), and includes over 164 river miles along six major tributaries that span in elevation from 350 to 7,400 ft. The major tributaries to Cow Creek flow generally east in a palmate pattern off of lower elevation volcanic mountains in the southern Cascade Range between Mount Lassen and Mount Shasta. These tributaries join just south of Shasta reservoir along the Cow Creek mainstem. Water flows from Cow Creek are important for the Upper Sacramento River and account for approximately one-fifth of the peak discharge of the Sacramento between Shasta Dam and Red Bluff (SHN and Vestra 2001); the maximum annual peak flow reported in Cow Creek is 48,700 cfs in 1981 (USGS gage at Millville, 11374000). Mean monthly flows peak in the winter months at a 50-year monthly mean of about 1,600 cfs (generally November through March) and drop in the summer to a 50-year monthly mean of about 40 cfs (generally July through September; USGS gage 1137400 at Cow Creek; Figure 2-1). Water for this area was adjudicated by 1937 for Little Cow Creek, Oak Run Creek, and Clover Creek, and by 1969 for Old Cow and South Cow creeks (SHN and Vestra 2001). Riparian and adjudicated rights fully allocate summer stream flows; currently, none of these rights have associated instream flow requirements. Many diversions occur along Cow Creek mainstem and its tributaries; those known to divert over one cfs are listed from SHN and Vestra 2001:14 along Cow Creek mainstem ((includes 83% of total for the mainstem), 7 in Little Cow Creek (includes 64% of total for this tributary), 2 in Oak Run Creek (includes 80% of total for this tributary), 6 in Clover Creek (includes 76% of total for this tributary), 17 in Old Cow Creek (includes 95% of total for this tributary), and 18 along South Cow Creek (includes 76% of total for this tributary).

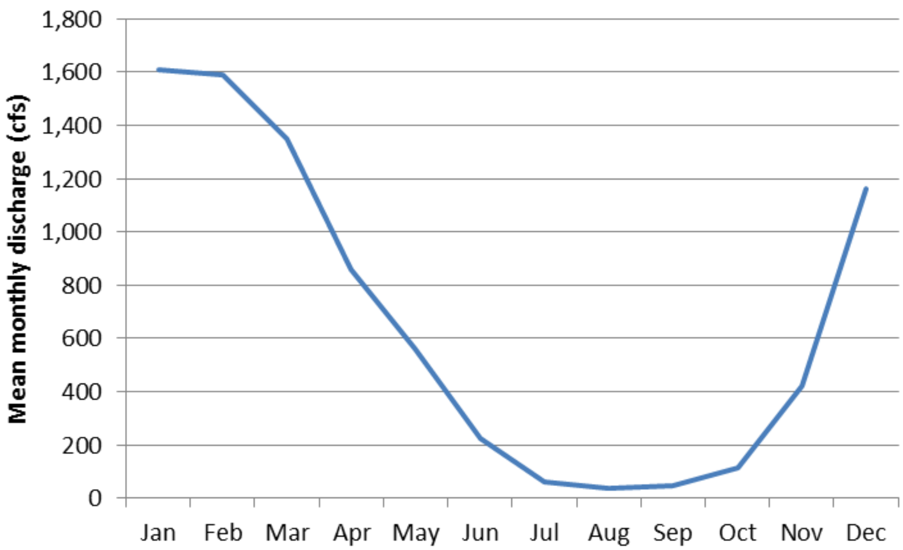

Figure 2-1. Mean monthly discharge recorded at USGS gage 11374000 on mainstem Cow Creek, roughly 2.3 miles upstream of the confluence with the Sacramento River. The 64 yr flow record extends from 1950 through 2013.

The bedrock under Cow Creek watershed is composed of several layers of volcanic rock on top of variously aged marine and non-marine deposits, river terraces and alluvium (Helley and Harwood 1985). Along with other broad scale differences in climate that co-occur with changes in elevation, five types of parent material, the Tuscan Formation, the hard Red Bluff pediment, the Bully Hill Rhyolite complex, the Chico Formation, and Tuscan-Tehama sediments dictate major variations in the type, distribution, and disturbance responses of riparian vegetation in Cow Creek watershed. The Tuscan Formation covers the greater extent of upper Cow Creek watershed and was created three to four million years before present by a series of volcanic mudflows referred to as 'lahars'; these are mixed with conglomerate, sandstone, siltstone and minor amounts of ash-flow in the Tuscan Formation (Helley and Harwood 1985). The Tuscan Formation is the oldest volcanic material in the Mount Lassen area and is a limited source of groundwater for the North Sacramento Valley (Turner et al. no date).

Some areas of the Tuscan formation are capped with the Red Bluff Pediment, seen as red gravels overlying the finer grained and more lightly colored sediments of the Tuscan Formation (Helley and Jaworowski 1985). The Red Bluff Pediment is made of recent and resistant volcanic material (0.45 to 1.08 million years before present) and forms hardpans which act as aquicludes that prevent surface water from percolating to the deeper subsurface groundwater (Helley and Jaworowski 1985). Farther north within Cow Creek watershed, the older Bully Hill Rhyolite complex covers mid-elevation portions of Little Cow Creek and patches of Oak Run and Clover Creek tributaries. This complex includes soft and hard materials that are subject to erosion and include sulfide ore which is rich in metals such as copper and mercury. The Afterthought Mine accessed these sulfide ore deposits and an ore transport tunnel from the mine that intersects with Little Cow Creek has been a source of acid discharge that affects downstream water quality (SHN and Vestra 2001). The mine is no longer operational but water quality concerns remain an issue. Most of the lower portions of Cow Creek cut through the Tuscan Formation to the Chico Formation in their mid-reaches. The Chico Formation is exposed in less than 10% of the watershed area and is composed of marine sandstone, shale and conglomerate laid down during the Cretaceous Period (66 to 145 million years before present). Land sliding and high rates of sediment input, as well as waterfalls, occur at these knickpoints, located at approximately 1,000 ft above MSL, where the creeks cut through the Tuscan Formation to the sedimentary material of the Chico Formation (SHN and Vestra 2001). Farther west, the rivers flow through the Quaternary sediments of the eastern Sacramento Valley.

Urban and suburban residential land use is prevalent along the mainstem and lower reaches of South Cow, Old Cow, and Oak Run creeks. Rangelands dominate the mid and lower portions of the watershed while private and public forests cover the watershed at higher elevations.

Cow Creek supports fall-run and late fall-run Chinook salmon, and steelhead, as well as resident rainbow trout (SHN and Vestra 2001, Entrix 2007). The Cow Creek Watershed Management Plan (Western Shasta RCD and CCWMG 2005) states that elevated water temperatures in the mid to lower reaches of the tributaries (vs. the mainstem) could be limiting fish populations, particularly for adult passage, spawning, and juvenile emigration. Findings from a water quality monitoring study from June 2004 through November 2005 indicate temperatures were above 20^{o}C (68^{o}F) from early June through early October in the lower tributary reaches and the mainstem; whereas stream temperatures were generally below that threshold throughout the monitoring year at locations above 2,000 ft elevation (Hannaford and Western Shasta RCD 2006).

The importance of a healthy and well-vegetated riparian corridor, which can help maintain cool water temperatures and provide juvenile salmonid rearing habitat , as well as habitat for other native fish, amphibians and native riparian birds, has been articulated in the Cow Creek Watershed Management Plan (Western Shasta RCD and CCWMG 2005); the plan also calls for riparian vegetation inventory, mapping and conditions assessment as part of establishing baseline conditions and for targeting conservation and enhancement actions in the watershed.

2.2 Mill Creek

Mill Creek is 65 miles long and flows from an elevation of 8,200 ft through meadows and forests off the western flank of Mount Lassen, then through a long, narrow canyon that includes part of the Ishi Wilderness Area. It emerges from the canyon and flows across the Sacramento Valley floor before joining the Sacramento River near the town of Los Molinos. The entire watershed is 134 square miles (85,760 acres). Mean monthly discharge ranges from about 475 cfs in the winter months (January through March) to 100 cfs in the summer (July through September) (Figure 2-2). Annual peak flows over the 85 year period of record range from 430 cfs to 91,400 cfs in December 2006 (this value is an estimate since flows were well above the gage height at the time) and average 7,252 cfs. The next highest annual peak flow occurred in December 1937 at 36,400 cfs as recorded at USGS gage 18020103, which is located a little over 5 miles east of the Sacramento confluence. The high upper elevations translate to snowmelt-dominated spring flows with occasional rain-on-snow events during the winter (USDA Forest Service 1998). Two geothermal hot springs contribute approximately 10–15% of the annual stream flow from above the Highway 36 crossing (USDA Forest Service 1998).

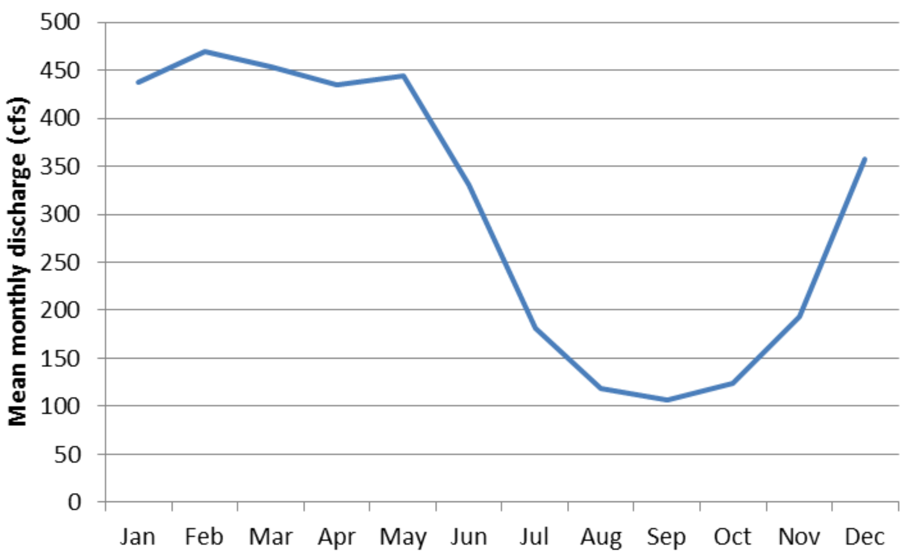

Figure 2-2. Mean monthly discharge recorded at USGS gage 11381500 on mainstem Mill Creek, roughly 5.1 miles upstream of the confluence with the Sacramento River. Flow record is 85 years, from 1929 through 2013.

Two diversion dams currently exist along Mill Creek, both of which are operated by the Los Molinos Mutual Water Company. A third diversion dam, operated by Clough and Owens ranches, was removed in 1997 (USDA Forest Service 1998).

The headwaters of Mill Creek cut through an ancient stratocone volcano, composed of andesitic lavas and pyroclastic deposits which partially convert to clay when exposed to hydrothermal activity associated with the volcano (USDA Forest Service 1998). These areas of higher clay content have relatively high erosion rates and are the source of fine sediment loading into upper Mill Creek (USDA Forest Service 1998). The upper portions of Mill Creek were shaped into a glacial valley over 10,000 years before present, where large mass-wasting processes, including landslides and debris flows in colluvial hollows, have occurred in the recent past and are associated with large precipitation events (NMFS 2014, USDA Forest Service 1998). These volcanically derived rocks in the upper Mill Creek watershed are part of the Tuscan Formation that covers most of upper Mill Creek watershed. Areas of Mill Creek watershed are also overlain with rhyolite deposits that form plateaus. Andesitic plugs form hard features in Mill Creek, including Black Rock and an intrusion of the Tuscan Formation that runs approximately parallel to the Creek (northeast trending; USDA Forest Service 1998).

Mill Creek cuts through the Tuscan Formation to the Chico Formation at the outlet of the canyon 6.7 miles east of the Sacramento River confluence. The Chico Formation, composed of marine sandstone, shale and conglomerate, is exposed in less than 10% of the area but these areas are a source of land sliding and high rates of sediment input to Mill Creek (USDA Forest Service 1998). Mill Creek flows over the Quaternary sediments of the eastern Sacramento Valley before joining the Sacramento River near the town of Los Molinos. Mill Creek cuts through a cemented alluvial fan just west of the canyon mouth for approximately 4 miles it runs along a fairly straight channel within an old inset floodplain constrained (and partially shaded) by old terrace gravels (Kondolf et al. 2001). For the 2.5 miles just upstream of the Sacramento confluence, Mill Creek flows through recently deposited and more erodible alluvium that has in recent time accommodated channel migration and the formation of distributary channels (Kondolf et al. 2001).

Mill Creek supports one of the most important runs of self-sustaining spring-run Chinook salmon in the Sacramento Valley. Fall-run Chinook, Central Valley steelhead, and Pacific lamprey also occur in Mill Creek (USFWS 2014, USDA Forest Service 1998). Spring flows range from 800 to 1,800 cfs and summer flows range from 60 to 120 cfs in this dominantly single-channel river. Protection and improvement of riparian habitat has been identified as a priority action to help protect and increase fish production in this watershed (NMFS 2014). Other special-status species associated with riparian areas also occur in this watershed, including the willow flycatcher and foothill yellow-legged frog (USDA Forest Service 1998). Cascade frogs were observed in Mill Creek watershed at elevations above 4600 ft up until the 1960s, but have not been reported there since (USDA Forest Service 1998). Since 1997, several studies to support restoration plans and sveral restoration projects have been implemented in the lower watershed (TNC 1999, Mill Creek Conservancy 2015); however a comprehensive view of Mill Creek's riparian systems is needed to ensure that future projects are as effective as possible.

3 STAKEHOLDER COMMUNICATION and PRIVATE LAND ACCESS

Prior to conducting any field reconnaissance, Stillwater personnel attended watershed group meetings for Mill and Cow Creeks to learn more about the issues in each watershed, gain information about potential access to private and public lands and determine if any existing data or reports were available that could inform the vegetation mapping and conditions assessment. Stillwater also gathered information on land ownership from Tehama and Shasta County and in the form of Excel datafiles and associated GIS shapefiles. Large maps (approximately 4 x 6 ft) of each watershed with public lands boundaries, roads, and towns were printed and brought to the watershed group meetings as a means of focusing stakeholders on spatially specific land and water use issues. We met with the Los Molinos Mutual Water Company in Los Molinos and had several follow-up calls with the Tehama County Resource Conservation District (RCD), and The Nature Conservancy (TNC) regarding Mill Creek watershed. Similarly, we made follow-up communications (phone and email) with representatives of the Cow Creek Watershed Management Group and the Western Shasta Resource Conservation District. One of the important outcomes of this process was much better understanding of the key issues in the watershed, a library of reports, maps, and other documentation, and increased understanding from the stakeholder groups on the goals, timeline, and overall methods of this project.

We also used the watershed group meetings as opportunities to gather suggestions on land access since 95% of Cow Creek watershed and 21% of Mill Creek watershed overall is privately owned. Within Mill Creek watershed these private lands are concentrated in the lower sections. The county-provided land ownership information was used in order to identify public and private entities and individuals with land along otherwise inaccessible areas of Cow Creek and Mill Creek watersheds. With input from U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (CDFW), and the watershed group stakeholders, Stillwater developed land access permission letters and mailed them to 187 landowners in Mill Creek watershed and 215 in Cow Creek watershed (example letter in Appendix A). Follow-up phone calls and emails were made with many of the landowners and ultimately we received permission to access 67 pieces of private property (36 in Cow Creek watershed and 31 in Mill Creek watershed) during the summer 2013 field assessment.

4 RIPARIAN VEGETATION MAPPING

4.1 Reconnaissance

A reconnaissance of the Cow Creek and Mill Creek project areas was conducted in June 2012 by three ecologists, two from AIS and one from Stillwater Sciences. The primary goals of the visit were to correlate vegetation communities with specific photo signatures, to better understand the relationship between vegetation type and environmental conditions in the project area, and to test and refine the accuracy assessment and conditions assessment field data collection forms. The field reconnaissance also provided an opportunity for sharing knowledge among the AIS vegetation mappers and Stillwater ecologists. With guidance from ecologists in the field, the photo interpreters become familiar with the flora, vegetation assemblages, and local ecology of the study area. At the same time, ecologists gained understanding from the photo interpreters' perspective about assessing vegetation through the framework of map creation.

Prior to the reconnaissance trip in June 2012, AIS photo interpreters reviewed imagery on-screen to identify and select potential reconnaissance sites in close proximity to roads. Sites were selected to represent different vegetation types and percent cover, as well as variations in geography, landform, and abiotic factors such as percent slope, aspect, shape of the slope, and elevation. AIS staff then reviewed these sites within the study area and selected the most appropriate sites to visit for observation. Hard copy maps were created for each of the sites; the potential site data were downloaded onto Google Earth KMZ files, and put onto a smartphone to assist in field navigation. Prior to the reconnaissance, field equipment was also gathered (e.g., a laser rangefinder, compass, high resolution Global Positioning System (GPS) handheld unit, binoculars, and camera).

During the reconnaissance, publicly accessible areas that crew members deemed important for study throughout the two watersheds were visited based on the list of potential observation sites compiled by AIS. Other areas of interest encountered in transit were visited in the field as additional observation points. Observation points were frequently taken at the transition between vegetation types with the intent of helping photo interpreters distinguish stand edges. A single observation point could contain information about more than one stand. It was also possible for a given stand to be assessed in multiple places. Some vegetation stands were remotely observed at a distance with the aid of binoculars. The location of these remote stands was determined using a compass and laser rangefinder. The field crewmembers from AIS recorded each location visited in a GPS unit and logged pertinent information on field sheets. Thus, at each location, the following information was recorded: (1) dominant canopy species (using binoculars if necessary), (2) GPS location, (3) distance, and (4), for remote stands, bearing to the dominant canopy species using a laser rangefinder and compass. At many observation points, the crew took digital color ground photos. The photo number, direction the photographer was facing, and other information about the photo was recorded on a field sheet and later input into computer files for easy reference. For the mapping effort, the field data (GPS waypoints and site descriptions) and linked ground photos were essential for correlating conditions seen on the aerial imagery to conditions on the ground. In addition, the draft data forms were tested to determine the practicality of gathering the information (time, clarity, repeatability), and to assess how well these metrics reflect on-the-ground interpretations of vegetation quality. Finally, photographs were taken and general observations on field conditions and methods were recorded.

Field notations, data, and hand-drawn field maps from the reconnaissance were transcribed, organized, and incorporated into a GIS database so that the exact location and attributes associated with each field-recorded vegetation type were included. In addition, the accuracy assessment and riparian conditions data form was finalized during the reconnaissance testing (see Appendix B).

4.2 Preliminary Mapping

AIS staff evaluated photo signatures and data from the initial field reconnaissance and acquired relevant existing data in order to create a preliminary field map. AIS used a heads-up digitizing technique, as opposed to image processing, for the most efficient and accurate results. Heads-up digitizing is the process of visually examining imagery on the computer screen and hand-digitizing (drawing with the mouse) vegetation and cover type boundaries based on interpretation of the images and other spatially explicit information. The existing Northern Sierra Nevada Foothills (NSNF) mapping, which was completed in 2010, overlaps the Mill and Cow Creek study areas and aided photo interpreters in their signature and biogeographical correlations to the riparian vegetation types.

4.2.1 Materials used for mapping

Several sets of imagery and ancillary data were used in the creation of the preliminary vegetation map. Since the project commenced prior to the release of the 2012 NAIP (National Agricultural Imagery Program) imagery, it was determined that the baseline imagery was to come from the 1-meter natural color 2010 NAIP for Shasta and Tehama County. All delineations and riparian conditions are referenced to the 2010 NAIP Imagery. NAIP 1-meter 2012 imagery was later added as a supplemental image dataset to aid in identification of the vegetation being observed. It should be noted that the 2012 NAIP does contain slight geospatial offsets from the 2010 base as well as physical changes to riparian conditions; therefore, the 2010 baseline imagery polygon delineations do not line up to the 2012 NAIP imagery in all cases.

Sometimes additional imagery was needed to help finalize vegetation-coding decisions. On these occasions, online imagery from Google Earth (GE) was used. In addition, the online imagery (Bing imagery) available through ArcGIS Online was also used when needed. The dates of the online imagery from ESRI were unknown and variable but the dates of the imagery used in conjunction with GE were acknowledged. Online imagery acquired through ESRI were georeferenced to the polygon delineations. GE imagery was used as a follow-on tool on an adjacent screen. The imagery type and characteristics are summarized in Table 4-1 below.

Table 4-1. Imagery data sources used to develop preliminary vegetation map for Cow Creek and Mill Creek riparian project areas.

Source name	Year	Spatial resolution	Color-type
NAIP (Base)	2010	1-meter	Natural Color
NAIP	2012	1-meter	Natural Color
ESRI - BING	Variable	Sub-meter	Natural Color
NAIP	2010	1-meter	Color infra-red
Google Earth	Variable	Variable	Variable

The following is a list of other datasets used by the photo interpreter in the mapping process.

- NSNF Existing Alliance Level Vegetation Map
- NSNF Accuracy Assessment Point Data
- NSNF AIS Field Reconnaissance Points
- ESRI online USA Topographic Maps
- USDA Forest Service CALVEG Vegetation Maps

Contour data derived from digital elevation models and supplementary information from the USGS topographic maps are important sources of data for the photo interpreter. For this project, the photo interpreters are the experienced team of AIS staff who translate aerial photographs or images of vegetation into vegetation type classes and, using GIS, draw boundaries around distinct areas of different vegetation types. Riparian plant communities that are defined to the Alliance have a wide range of image signature characteristics and overlapping signatures between Alliances can be extensive. Therefore it is necessary for the photo interpreter to have a thorough understanding of the ecological setting (slope steepness, direction of the slope, shape of the slope, position of the vegetation stand on the slope) in addition to modal elevation in which the vegetation communities occur. These features along with substrate characteristics, flooding frequency and severity are just a few of the characteristics that help in defining where a particular vegetation type is most likely to occur in the landscape.

4.2.2 Photo interpretation

Photo interpretation is the process of identifying map units based on their photo signature. All land cover features have a range of photo signatures. These signatures are defined by the color, texture, tone, size, and pattern exhibited on the aerial imagery. By observing the context and extent of the photo signatures associated with specific land cover types, the photo interpreter is able to identify and delineate the boundaries between plant communities or signature units on a digital image or map. It should be noted that vegetation stature as well as the scale and resolution of the aerial imagery determine the visibility of individual plants. Trees and shrubs are usually visible as individuals on high resolution digital imagery. However, grasses (other than bunch grass clumps) are rarely seen as individual plants.

Environmental factors such as elevation, slope, and aspect also play an important part in the photo interpretation decision-making process. Knowledge of these factors, and how plant communities respond to them, guides a photo interpreter in choosing from among the various vegetation types with similar photo signatures. Ultimately, such knowledge enables vegetation mappers to create biogeographical models of expected vegetation communities that can be applied when the vegetation types are indistinct on the imagery. This ecological approach produces a more accurate product than would be created by relying solely on extracting information from the imagery, which is subject to variations in clarity and ground conditions.

Vegetation types were mapped using the National Vegetation Classification System (NVCS) to the Alliance level, as depicted in the second edition of the Manual of California Vegetation, whenever possible (Sawyer et al. 2009). A separate classification system (USDA - Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Ranges in Weixelman et al. 2011) was incorporated into the effort for classifying higher elevation meadows above 4,500 ft in the upper reaches of Mill Creek watershed. This system was used for classifying herbaceous vegetation that could not reliably be assigned an Alliance-level floristic type using remotely sensed techniques. Meadow types were categorized into generalized moisture regimes, water sources and gradients.

The detailed descriptions of each vegetation type mapped in the study area, found in Appendix C, include examples of the types of information the photo interpreters incorporate into their understanding of the models. Some examples of these models include how one Alliance may favor broad floodplains, while another is found in the immediate fringe of narrow well-defined channels. Some Alliances may flourish on disturbed sites, while others cannot tolerate the lower temperatures at higher elevations. And, some Alliances are ubiquitous and found in a variety of settings. The descriptions also discuss the importance of various plant species in the Alliance. Frequently, complicated relationships exist between the relative covers of plants, such as in Alliances named for indicator species having lower percent cover than other species present. Thus, both environmental setting and rules regarding relative cover factor into the intelligent delineation of vegetation polygons.

During the photo interpretation process, it is common for photo interpreters to encounter areas that have questionable or confusing photo signatures. These polygons were flagged for ground observation (referred to as field checks) during the 2013 verification effort. Listed below are the consistently occurring difficulties photo interpreters encountered during the production mapping process:

- Mill Creek: Elevation break between white and mountain alder (*Alnus rhombifolia* and *A. incana ssp. tenuifolia*)
- Lower Elevations (Cow Creek and Mill Creek): Signature and/or further biogeographical distinctions between red, black and arroyo willow (*Salix laevigata*, *S. gooddingii* and *S. lasiolepis*).
- Further signature and biogeographical correlates for Oregon ash and box elder (*Fraxinus latifolia* and *Acer negundo*)
- Distinctions between Irrigated pasturelands and other agriculture

Upon completion of the preliminary mapping for both Cow Creek and Mill Creek, a 3-day field verification effort was undertaken. This field verification was designed to validate the overall accuracy of both the delineations and floristic assignments and to address the four issues outlined above.

4.2.3 Field verification

Findings from this 3-day field verification are presented below.

- White and mountain alder were seen in close proximity to each other at approximately 4,200 ft in Mill Creek watershed. Several large polygons in the region depicted mountain alder in its characteristic shrubby stature. Adjacent stands of white alder were in tree stature form only slightly smaller than stands at lower elevations.
- Distinctions between black and red willow remain extremely difficult with geographical settings overlapping considerably. Black willow was observed to prefer stream courses with a gentler gradient on broader floodplains. Arroyo willow always tended to occur as a tall shrub with a consistent height across the canopy.
- Box elder tended to have a brighter green signature than other hardwoods; stands were observed in limited settings and were always very small. This species was noted most of the time to occur as a component to other hardwood Riparian Alliances. Oregon ash was also observed as a component to other Riparian Alliances but occasionally was noted in small stands in extensive riparian ecosystems in Cow Creek watershed.
- Nearly all herbaceous irrigated agriculture tended to be pasturelands.

4.2.4 Mapping process

Just as the use of biogeographical models by experienced photo interpreters contributed to the production of a high-quality vegetation map, the use of reliable mapping procedures allowed for the map to be produced in a highly efficient manner. For example, the study area was divided into seven modules. This expedited project work flow by enabling several staff members to work on the mapping effort simultaneously.

Using an on-screen heads-up digitizing method, the photo interpreters had at their disposal a suite of standard and custom ArcMap tools to facilitate the creation of polygons. The photo interpreters generally viewed the imagery at scales ranging from 1:1000 to 1:4000. They used variations in the color, texture, shape and shade patterns in the images (‘image signature’) to draft boundaries separating areas of different vegetation types and/or distinct categories of percent cover of several stature levels. To assist in boundary placement and coding decisions, photo interpreters also referenced supplemental imagery, field reconnaissance data, and other ancillary data. These sources were displayed in the ArcMap session as needed.

The Vegetation Mapping Classification is located in Appendix D. A custom menu enabled code values for different vegetation attributes to be assigned efficiently, minimizing the possibilities for entry errors. The vegetation codes were entered as numeric values, which are easier to input and manipulate than alphanumeric codes. Numeric code values also allow for the hierarchical grouping of like vegetation communities, assisting the mapper to know at a glance which Alliances are found in a particular hierarchical grouping. Once the geodatabase neared completion, the numeric code values were correlated with the actual vegetation type names. Ditches were added to the linear features after the initial vegetation polygons were complete.

The modules were edge-matched and checked for invalid codes and topology errors. Once finished, the seven completed modules were joined into two seamless geodatabases (one for each watershed). The geodatabases were subject to further processing, edge-match checks, and review by a senior staff member before being delivered to the client. Quality control procedures implemented during the mapping effort and before final delivery of the data improved the consistency and accuracy of the overall geodatabase.

4.2.4.1 Mapping criteria

As discussed above, appropriate tools and reference sources, photo interpretation training, and knowledge of vegetation communities are all essential in creating a quality vegetation map. However, without the establishment and refinement of mapping criteria, a given vegetation map could be riddled with discrepancies, as different photo interpreters approach the task with different assumptions and styles. Guidelines and rules regarding exceptions, special situations, and minimum feature size are discussed and disseminated to all staff members before and during the mapping effort. This creates a clear and consistent product. Establishing criteria also makes the mapping process more efficient, as individual photo interpreters do not have to pause too long to consider how best to capture the more commonly occurring ambiguous situations that are confronted.

4.2.4.2 Mapping attributes

The following section describes each of the attributes mapped for the all of the vegetation within the defined study area.

PI
This is the 4 digit code that corresponds to a vegetation type (mapping unit, Alliance or Group level) or miscellaneous class (e.g., urban disturbance, water) in the Vegetation Mapping Classification. The PI attribute is assigned to all the vegetation polygons in the geodatabase.

Each vegetation type is described in Appendix C and the Vegetation Mapping Classification is presented in Appendix D.

Vegetation mapping considerations
When the photo interpreter could not confidently classify a polygon at the Alliance level, or the vegetation was a mix that didn’t fit into an Alliance level or mapping unit, the polygon was assigned a broader Group level code. This did not happen frequently, but in certain instances, unknown vegetation stands were assigned to a group level in the NVCS hierarchy.

For vegetation mapping, a minimum polygon size is an important consideration when creating and viewing a vegetation geodatabase. A minimum mapping unit (MMU) is established to ensure the map contains polygons of a workable, meaningful size. The choice of an MMU is influenced by the clarity of the imagery, the detail of the mapping classification, the purpose of the data, and time and budget constraints. MMU can vary for different categories of features being mapped. The Statewide mapping criteria have established different MMUs depending on the area being mapped (e.g., Desert mapping MMUs are different than Sierra Foothills MMUs).

For this project, there were two established MMUs: 1 acre for uplands and 0.5 acre for special and wetland features. Based on discussions during field reconnaissance and specific project-client needs, AIS opted to map below these limitations in wetland and riparian settings where structural, floristic and or ecological characteristics were significantly different from the adjacent vegetation. Some examples of mapping below the MMU include:

- Riparian vegetation exhibiting distinct boundaries that occurred in different groups within the hierarchy, such as a break between a stand of Oregon ash and Fremont cottonwood.
- Most riparian, wetland and water features bounded by upland types

The establishment of an MMU requires the need for making rules for aggregating stands that cover areas smaller than the MMU. In general, similar life forms are aggregated together: tree-dominated types are aggregated with other tree-dominated types, shrub types with other shrub types, and herbaceous types with other herbaceous vegetation types. However, if possible, wetland vegetation types are not aggregated with upland types, even if they are in the same life form. Another guideline used is when a vegetation unit below the MMU in size is aggregated with the vegetation type that completely surrounds it. Finally, if a vegetation unit that is below MMU is the same life form as two adjacent larger stands, and the adjacent stand types are very dissimilar in environment, the unit may be aggregated with the more similar adjacent type.

In addition to establishing MMU size, guidelines were established for the minimum width (MW) of a map polygon. The rule of thumb was to make the MW roughly half the width of an MMU square. For the .5-acre MMU, the MW is approximately 70 feet and for the 1-acre MMU, the MW is approximately 135 feet. The appropriate MMUs were still observed. This guideline didn't preclude the creation of polygons where a small section fell below the minimum width, as long as the greater portion of the polygon met the stated criteria. This is most common when a narrow stream or riparian polygon was mapped and areas below the MMU or MW thresholds were also mapped in order to keep the continuity of the stream or riparian vegetation. As mentioned above regarding overall MMU, AIS opted to map below these limitations where structural, floristic and or ecological characteristics were significantly different from the adjacent vegetation.

Another type of mapping consideration pertains to sparsely vegetated or nonvegetated areas. Polygons assigned to a floristic type in the NVCS often contain small areas of unvegetated surface that are too small to delineate. These sparsely vegetated to nonvegetated areas were not coded in the database unless they met the minimum mapping resolution and could be mapped as separate polygons. The most common examples are the small riverine flats and point bars occurring along the channels throughout the Mill and Cow Creek watersheds.

Percent cover attributes

The percent cover attributes include the following:

- DensityConifer
- DensityHardwood
- DensityShrub
- DensityHerbaceous

Percent cover, also referred to as density, is a quantitative estimate of the aerial extent of the living plants for each vegetation layer mapped within a stand. Percent cover, based on a birds-eye (what a photo interpreter can see from the sky looking down) view, is the primary metric used to quantify the importance or abundance of a life form and/or species.

The percent cover was estimated separately for conifer, hardwood, shrub and herbaceous cover. To determine the vegetative density, photo interpreters assigned percentages to the different life forms visible on the imagery, including non-vegetated areas. The cover percentages were then converted into the appropriate cover category for each of the life forms being mapped. For example, if a conifer density was 5%, then it was assigned the range of 2–9%. These values are listed in Appendix E.

Photo interpreters formed separate polygons when there were changes from one cover class to another within a vegetation mapping type. A given vegetation polygon would have been subdivided due to cover differences regardless of which strata the cover difference occurred in. For example, two adjacent polygons in the geodatabase may have had the same shrub vegetation type assigned but different cover categories for conifers (for example, 2–9% versus <2%).

Most standardized vegetation mapping efforts have a set of criteria regarding percent cover. The Mill Creek-Cow Creek project follows the same criteria as the CA Statewide criteria, where a life form generally needs to account for at least 8 to 10 percent cover in order for an Alliance of that life form to be mapped.

Percent cover mapping considerations

It is important to note that the photo interpreters could only accurately quantify the vegetation that is visible on the aerial imagery. Therefore in this project, only "bird's eye" total cover was mapped. Thus, the cover of understory layers which were obscured by overstory layers was not included in this analysis. For this reason, the total percent cover of understory vegetation in a stand may be underestimated if its extent was hidden under the crowns of trees, and the mapped percent cover attribute value may differ from assessments done on the ground.

Stands of riparian vegetation, adjacent conifer and higher elevation hardwood or mixed forests often have dense overstory cover, exceeding 60%. Where the overstory cover exceeded 40%, it was considered too dense to give a reliable estimate of lower tier canopy or understory percent cover. In these situations the code assigned for percent cover for the understory life forms would be given a value of "Not applicable/Not assigned". This same criterion was used in the Statewide mapping effort. For example, if the conifer tier cover exceeded 40%, then the other tiers below (hardwood and shrub) were not evaluated for cover. If the conifer tier cover was <40% but together with the hardwood tier the combined cover was > 40%, then the shrub cover was not estimated. Appendix E includes tables that present the ranges of percent cover used for each of these categories, along with any relevant notes.

The date that the aerial photography mission is flown influences the percent cover assigned to vegetation types. Subsequent field reconnaissance and field verification efforts must take into consideration the following factors that can cause apparent discrepancies between the percent cover evident on the imagery and percent cover seen in the field:

- Seasonality—The percent cover of most plants is variable due to their annual growth cycle. Depending on whether the aerial imagery was taken during the wet season or the dry season, a mapped unit could show a different percent cover on the aerial imagery than is observed during an on-site visit at a different time of the year. Differences in leafiness (cold deciduous, drought deciduous) can affect plant cover determination. Leaf-on conditions obscure the understory. Imagery of leaf-off conditions would allow photo interpretation of the understory, but make it difficult to identify the overstory species since there is no foliage present.
- Annual variability—The environmental conditions at the time of the imagery (wet vs. drought years, flooding, etc.) may affect the percent cover seen during the on-site field visits.

Field check

The field check attribute was used to indicate a polygon that could not be assigned a vegetation type by photo interpreters using imagery alone. These polygons required a ground site assessment of the vegetation stand in question. The polygons were flagged as a question for the subsequent verification effort.

Comment

This field is considered a catch-all for significant information regarding a polygon and generally contains "value added" information that cannot be statistically quantified by the photo interpreter.

An example of this "value added" information is the photo interpreter noting predominant species present in the stand other than the characteristic species of the vegetation type being mapped. Many of the upland conifer stands in the Lassen Park contain comment information which can be used to define the polygon to an association within the specified Alliance. The most common examples being the presence of pinemat manzanita (*Arctostaphylos nevadensis*) under a canopy of red fir and/or western white pine which would allow the users of the map to define these stands to higher (association) level within the NVCS hierarchy.

Modal height

This is the only field in the database that was partially modeled based on other attributes of the vegetation. Height category values were initially assigned based on the floristic (Alliance) assignments to the vegetation polygons. For example, the white alder Alliance was assigned a value in the database as a category 4 (2–5 meters). It was determined upfront (based on field reconnaissance and initial mapping effort) that most of the white alder stands in the study fell within this height category.

Modal height assignments were assigned subsequent to the initial interpretation of the vegetation polygons. After the initial height values were assigned, photointerpreters systematically reviewed the polygons for trends toward taller or shorter stature stands. Very small stands of white alder in areas of higher fluvial disturbances tended to be reassigned to lower height categories, while those in more mature settings often adjacent to valley oak or Oregon ash were frequently assigned to a height category of 5 (5–10 meters).

Canopy overhang

It was determined early on in the mapping effort that photo interpreters could, with consistent reliability, attribute the canopy shade cover of all the major tributaries and main channels in the study area. It was also agreed upon between photo interpreters and riparian ecologists that this would provide a valuable tool in the quality assessment of the riparian conditions of the channel. Resolution from ancillary sub-meter imagery provided a view of overhanging vegetation in relation to the edge of the active stream channel and how far beyond the channel edge the canopy extended. The resultant value was a function of the canopy density and degree of overhang into the channel from the main stem of the plant. The output values are categorized into five broad classes, including a value to indicate when the streambed is completely obscured by the overhanging vegetation. Due to the dynamic nature of riparian vegetation and resolution of the imagery, it is not possible to distinguish these categories into finer levels in this remote sensing effort. Examples of canopy overhang delineations are provided in Appendix F.

4.2.5 Mapping meadows

With guidance from Stillwater Sciences ecologists, photo interpreters used components from the USDA Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Ranges field key to produce a simplified meadow classification scheme to use in the field for the higher elevation meadows in the upper Mill Creek watershed (Weixelman et al. 2011). This classification was also used in the verification effort to help classify the meadows while in the field. After the verification effort, corrections were made to the map, high elevation meadows were defined and the final database was checked for GIS related errors and topology.

4.2.6 Quality control and delivery of the final draft product

Quality control steps were used throughout the duration of the project in order to make sure the map followed set guidelines and consistency among the photo interpreters. Once the initial photo interpretation phase was completed, a comprehensive quality control was performed by a different photo interpreter. Checks were then run for invalid vegetation codes, invalid densities for each life form, and topology-related problems. Quality control checks for illogical coding combinations were also run on polygons. After the final changes from the field checks were implemented into the geodatabase, one last round of quality control checks were run on the geodatabase before it was delivered to the client.

4.2.7 Draft vegetation map

Small ditches, which are too narrow to depict as polygonal units, were identified as linear features; these indicate water diversion from existing natural channels in the mapping area. The draft vegetation map, with an additional layer of mapped irrigation ditches, was subsequently delivered by AIS to Stillwater Sciences for the final Accuracy assessment. Results from the accuracy assessment were used to update the vegetation map. Final corrections and refinements were made to any remaining incorrect trends not noted previously in the verification effort.

4.3 Vegetation Map Accuracy Assessment

After completing the reconnaissance and preliminary vegetation map, a two-week field survey was performed according to CDFW protocols to improve the accuracy of the final vegetation map and to gather information on riparian condition, including occurrence and distribution of invasive non-native plant species (CDFW 2008, Meidinger 2003). In this section, we describe the field and data analysis methods used to perform the accuracy assessment for the draft vegetation map for the Mill and Cow Creek project areas. We also present the results of the accuracy assessment. As discussed previously, the degree of match between the 2013 field assessment points and the draft vegetation map reflects the accuracy of these maps in relation to the current vegetation.

4.3.1 Field survey methods

Assessment points were pre-selected from the preliminary vegetation map using a stratified random sampling design. The project areas within the two watersheds were stratified into accessible and non-accessible lands based on where landowners granted access for the survey and publicly accessible areas (see Section 3.0 Stakeholder Communication and Private Lands Access). Accessible areas were then stratified by vegetation type. Although we attempted to target at least five assessment points per major vegetation type within each watershed; this was not possible for all major vegetation types within the accessible areas. Agricultural fields, urban areas, and open water areas were excluded from the random sampling process because these land use types are readily identifiable during aerial imagery interpretation and it was not considered necessary to verify them in the field. This process resulted in the selection of 200 and 54 vegetation polygons for the field assessment in Mill and Cow Creeks respectively. The accessible polygons included representation of all of the vegetation types mapped in 1% or more of the polygons in Cow Creek except Canyon Live Oak (*Quercus chrysolepis*), and all but buckbrush (*Ceanothus cuneatus*), black oak (*Quercus kelloggii*), Ponderosa pine – Douglas-fir (*Pinus ponderosa - Pseudotsuga menziesii*) and several meadow types in Mill Creek. Not all 254 polygons could be sampled during the field survey, but all selected polygons were retained to provide survey crews the flexibility to select alternate assessment points, as needed, based on field conditions.

Prior to the field assessment survey, field equipment was gathered (e.g., laser rangefinder, compass, GPS unit loaded with pre-selected assessment points, binoculars, tablet with roadmaps and accessible areas outlined, and GPS-enabled camera) and field base maps and data forms were prepared. The field assessment polygons were printed on field base maps with 2012 NAIP aerial imagery background to help guide field crews. Although field base maps showed preliminary vegetation polygon boundaries, they were not labeled with the preliminary vegetation type to preclude bias during the field assessment survey (Meidinger 2003, CDFW 2008).

The field team consisted of two experienced plant ecologists. They used field base maps, and a tablet with roadmaps to navigate to pre-selected assessment polygons, with the goal of sampling as many of the pre-selected assessment polygons as possible during the two-week survey. If an assessment polygon was considered to contain more than one vegetation type with a minimum size of 0.5 acre, the field crew divided the polygon as appropriate and collected data for the polygon that appeared to best represent the original assessment polygon.

A stand of vegetation most representative of the pre-selected assessment polygon was located and sampled using a stream-lined version of the CNPS and CDFW rapid assessment protocol (see Appendix B; CNPS/CDFW 2011). At each point, the dominant plant species by strata were recorded, along with the species age code and percent cover. Other information collected, as summarized in the data form provided in Appendix B, included: landscape characteristics (longitudinal connectivity and adjacent land use); stream shade characteristics (vegetation over hang, percent of channel shaded, dominant canopy height); floodplain connectivity (channel gradient, flood frequency and extent, structures that impede flooding); and evidence of disturbance and special features (human disturbance categories, micro-topography, soil texture, fluival surface type, presence of emergent wetlands, gravel bars, oxbows, snags, and eroding cliffs) and a field assessment of stand 'health'. A photograph was taken at each field assessment point to document site conditions, and the vegetation type, to the Alliance level, was determined using MCV-2 membership rules and recorded on the data form (Sawyer et al. 2009). Finally, the boundary of the assessment polygon and surrounding polygons were revised on the field base maps where appropriate based on field observations. The vegetation type of any observable surrounding polygons was determined using Sawyer et al. (2009) and recorded on the field base maps and/or data forms.

In addition to the stratified random sample of points pre-selected for the field assessment, dominant vegetation types of other polygons were also noted as encountered in the field. These notations were recorded on the field maps, and then transcribed into a separate data column titled 'map notes' in the geospatial database.

Back in the office, data forms were checked for completeness, entered into a Microsoft Access database, and a thorough quality assessment/quality control (QA/QC) was performed on the data prior to analysis by a third party to ensure that all of the data were correctly entered into the database. Any vegetation polygon boundary revisions were scanned and digitized into a revised version of the draft vegetation map. Assessment locations were downloaded from the GPS units into a GIS database. Digital photographs were archived into folders labeled by date. For each AA polygon, the draft final call on vegetation type was reviewed by Stillwater senior riparian ecologist and any changes from initial "field call" were recorded in the database.

4.3.2 Field survey results

During the field assessment survey, 80 polygons were sampled using the modified CNPS and CDFW rapid assessment protocol (38 and 42 for Cow Creek and Mill Creek, respectively; see Table 4-2 and Figures 4-1 and 4-2). In addition, map notes for 104 and 66 polygons were also recorded in Cow Creek and Mill Creek, respectively. Thus, dominant vegetation types on a total of 250 vegetation polygons were ground-truthed for the accuracy assessment. This amounts to 1.6 and 2.7% of the total number of polygons mapped in Cow Creek and Mill Creek project areas, respectively.

Table 4-2. Number and type of data points collected in the field assessment survey for the accuracy assessment in Cow Creek and Mill Creek project areas.

Data type	Cow Creek	Mill Creek	All
Field accuracy assessment point	38	42	80
Map note	104	66	170
Total	**142**	**108**	**250**

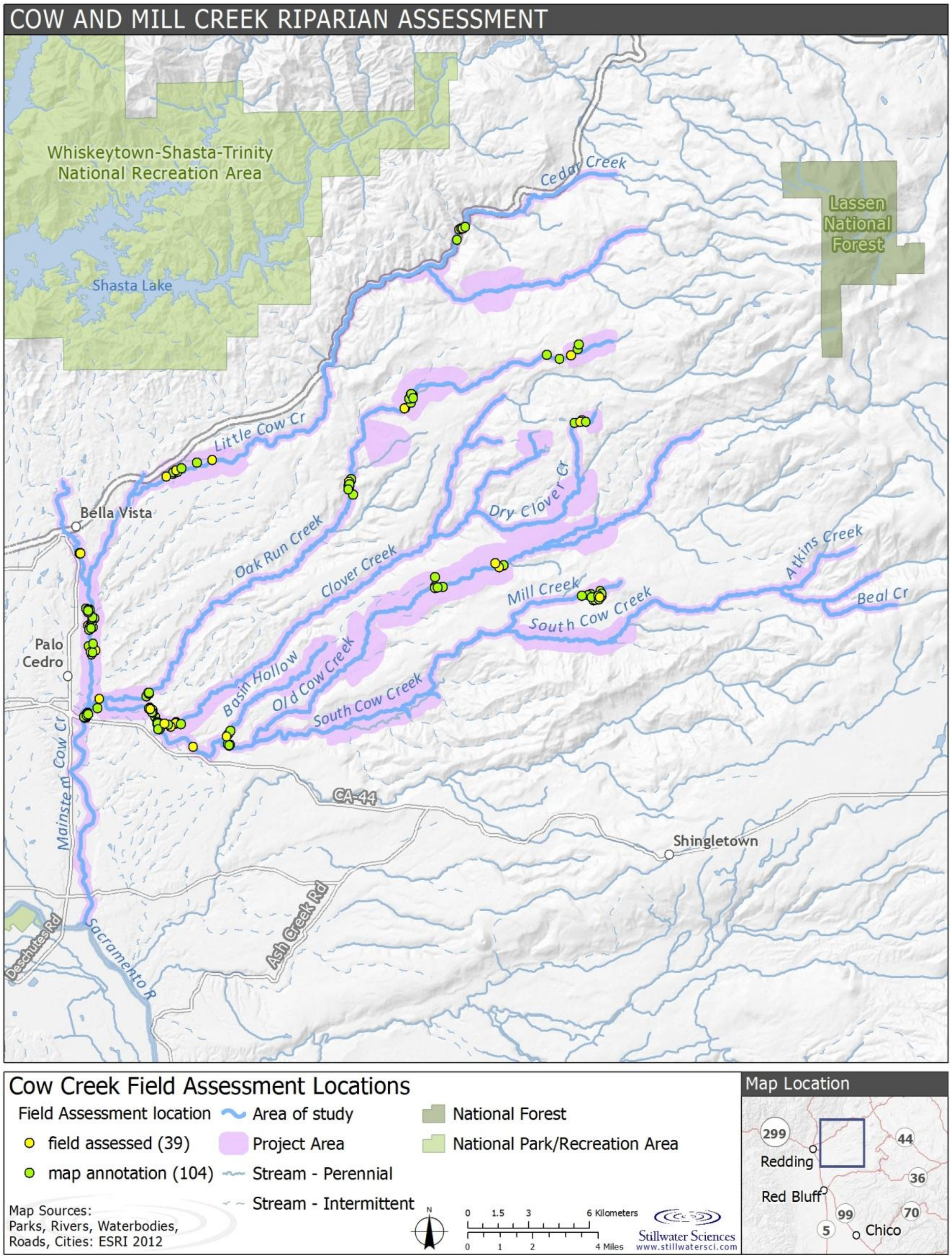

Figure 4-1. Cow Creek field assessment locations.

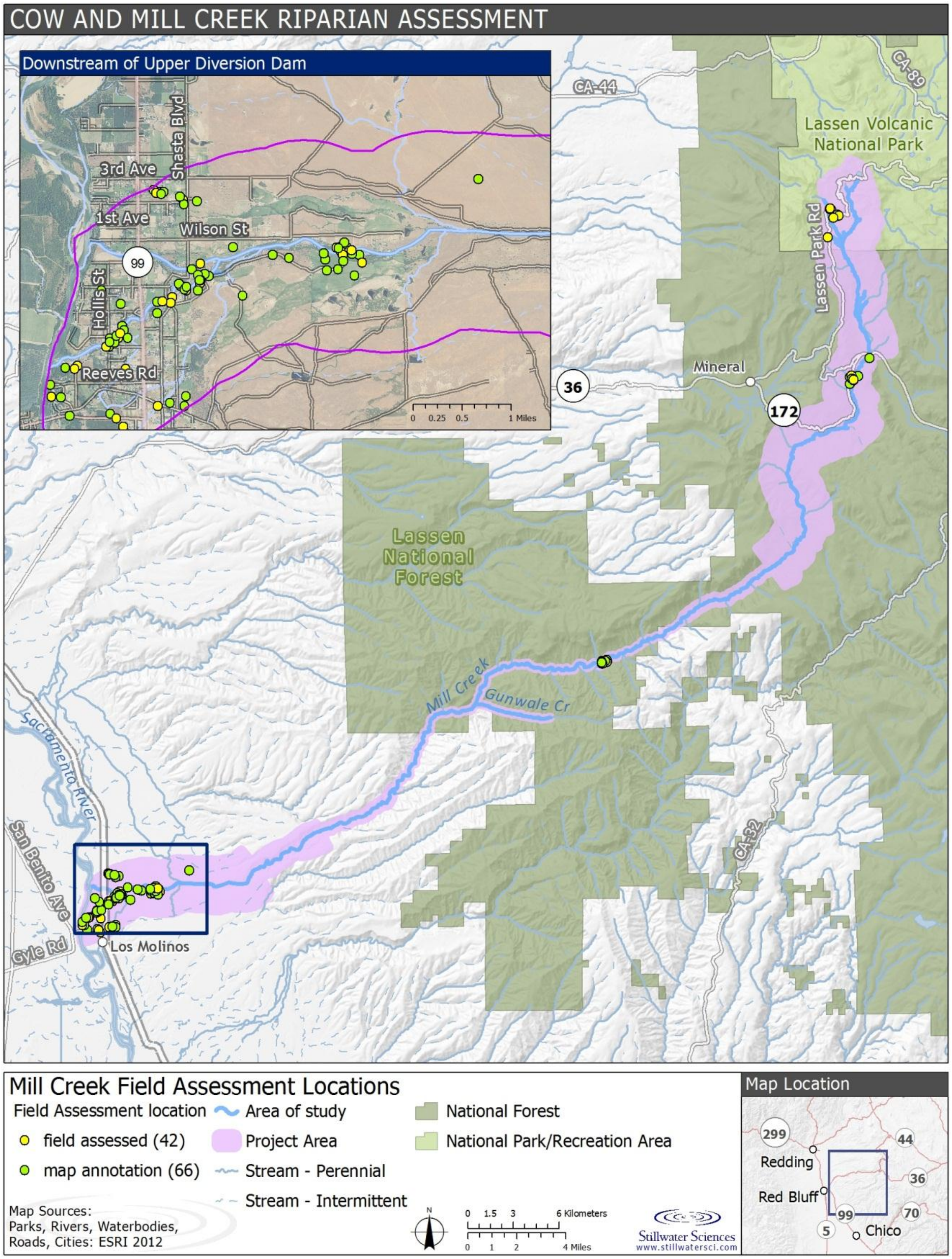

Figure 4-2. Mill Creek field assessment locations.

4.3.3 Accuracy assessment scoring

The final vegetation types assigned to the field accuracy assessment and map note polygons were lined up with the draft vegetation map classes to compare the draft classifications to the field observed classifications. Stillwater applied the "fuzzy logic" (Gopal and Woodcock 1994, Woodcock and Gopal 2000) framework used by the CDFW Vegetation and Mapping Program with guidance from program leads, Todd Keeler-Wolf and Diana Hickson, in order to score the accuracy of each vegetation type classification in the draft vegetation map. Scores are assigned based on the degree of similarity between the field-call and the draft map vegetation type assignments. Accuracy scores range from 0 (no relationship between field and draft map classes) to 5 (draft map completely matches field call class). The rank scoring and rationales for each are detailed in Table 4-3 below.

Table 4-3. Fuzzy logic scoring rules for accuracy assessment on Mill and Cow creeks.

Reason for score	Score
Photo-interpreter (PI) completely correct	5
Correct Group OR next level up in hierarchy	4
Threshold/transition between PI call and Final call	4
Correct Macro Group OR next level up in hierarchy	3
Based on close ecological similarity	3
Correct Division	2
Some floristic/hydrologic similarity	2
Correct only at Life Form	1
No similarity above Formation and incorrect Life Form	0

4.3.4 Accuracy assessment results

Map notes and field accuracy assessment points were reviewed and seven were thrown out due to uncertainty in field calls. Thus, fuzzy logic scoring was applied to 108 polygons in Mill Creek watershed and to 136 polygons in Cow Creek watershed for a total of 244 AA polygons; these include both the map notes and the more detailed field accuracy assessment points. Those vegetation types for which there were at least three AA polygons were included in the assessment. There were 24 such types, as listed in Table 4-4. Average AA scores for these draft vegetation types range from 3.33 to 5.00 and altogether average a score of 4.48 out of 5.0, or 89%. The accuracy varied among vegetation types; with perfect accuracy for irrigated pasture, urban areas, ponderosa and canyon live oak forests, nearly perfect mapping for valley oak, white alder, and narrowleaf willow, and more uncertainty in mapping red vs. arroyo vs. mixed willow thickets, and areas dominated by invasive Himalayan blackberry. Other riparian vegetation types observed only in one or two field polygons scored either a 4 or 5, including *Arundo donax*, wet and dry meadows, Goodding's willow, Lemmon's willow, cattail wetlands, and black cottonwood.

Table 4-4. Vegetation types with 3 or more field observations and associated accuracy assessment scores for Mill and Cow Creek riparian vegetation mapping.

Vegetation Type	Number of field observations*	Average accuracy score**	Score as percent
Irrigated Pasture Lands	16	5.0	100%
Built up & Urban Disturbance	6	5.0	100%
Pinus ponderosa - Calocedrus decurrens	3	5.0	100%
Quercus chrysolepis (Canyon Live Oak)	3	5.0	100%
Small Earthen Dam Ponds and Natural Lakes	3	5.0	100%
Mediterranean California Naturalized Annual & Perennial Grasslands & Meadow Macrogroup (weedy)	13	4.8	97%
Quercus lobata (Valley Oak)	37	4.8	96%
Agriculture (Without fallow annual grasses dominating)	5	4.8	96%
Salix exigua (Narrowleaf willow)	16	4.8	95%
Alnus rhombifolia (White Alder)	21	4.7	94%
Cliffs & Rock Outcroppings	3	4.7	93%
Populus fremontii (Freemont Cottonwood)	12	4.6	93%
Platanus racemosa (California Sycamore)	9	4.4	89%
River & Lacustrine Flats & Streambeds	12	4.4	88%
Fraxinus latifolia (Oregon Ash)	5	4.4	88%
Quercus douglasii (Blue Oak)	9	4.3	87%
Quercus wislizeni (Interior Live Oak Tree)	4	4.3	85%
Alnus incana (Mountain Alder)	5	4.2	84%
Vancouverian Riparian Deciduous Forests	5	4.0	80%
Salix laevigata (Red Willow)	6	3.7	73%
Salix laseolepis (Arroyo Willow)	5	3.4	68%
Rubus discolor (Himalayan Blackberry)	3	3.3	67%
(Red/Black Willow) Thicket - Young Sapling Stands	9	3.1	62%
Southwestern Riparian Evergn. & Decid. Woodlands	8	3.0	60%
OVERALL	**218**	**4.5**	**89%**

* Field observations include sites where field data were collected using a modified CNPS rapid assessment protocol and map notes, as described in the text above.

** See Table 4-3 for explanation of accuracy scoring structure.

4.4 Final Riparian Vegetation Map

After completion of the accuracy assessment, Stillwater Sciences delivered the preliminary results to the AIS photo interpreters. Each point was reviewed and two spreadsheets (one for each watershed) were generated with comments on each of the AA points. AA points were noted by photo interpreters as to whether or not they were in agreement with the final call made by the Stillwater field ecologists. If the call was in question or dispute, it was noted in the database along with the reason for its question. Stillwater Sciences performed the final review and delivered the results of the AA back to AIS photo interpreters. AIS photo interpreters corrected all of the remaining polygons which were scored with different floristic assignments. Photo interpreters used these points to evaluate trends and make additional corrections to the map. Although the final product is more accurate than the final accuracy assessment process, it cannot be determined how much more accurate the vegetation map is without additional field evaluation.

The 2014 riparian vegetation map is provided in digital form as part of this project. Overall, 85 different vegetation types were mapped in both watersheds. Table 4-5 lists all of the vegetation types listed in the final map as alliances and semi-natural stands (Sawyer et al. 2009) and their corresponding acreages for each watershed.

4.4.1 Mapped vegetation distribution

Native uplands and annual grasslands make up most of the mapped lands in the Mill Creek and Cow Creek project areas (Figure 4-3). Native riparian forest and shrubs make up 19% and 6% of Cow Creek and Mill Creek project areas, respectively. Meadows make up 5% of the area in Mill Creek and herbaceous wetlands were mapped in 2% of the area in Cow Creek watershed. A more detailed list of the distribution of vegetation types in the Cow Creek and Mill Creek project areas is provided in Table 4-5.

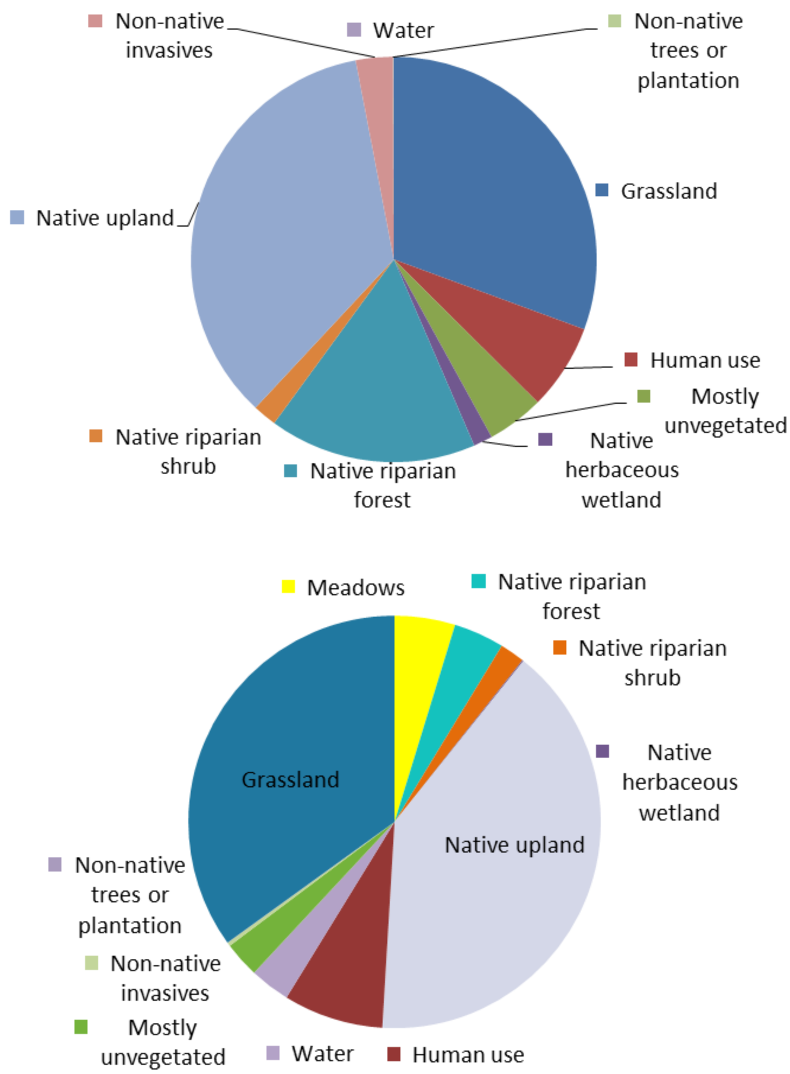

Figure 4-3. Distribution of generalized vegetation groups mapped in the Cow (top) and Mill (bottom) Creek project areas.

Table 4-5. Acreage and percent area of vegetation types mapped in the Cow Creek and Mill Creek project areas.

Vegetation types	Cow ac	% Cow	Mill ac	% Mill	Total ac	% Total
(Red/Black willow) Thicket	149.81	0.7%	15.55	0.1%	165.36	0.4%
Abies concolor - Pinus lambertiana (white fir - sugar pine)	35.29	0.2%			35.29	0.1%
Abies concolor (White fir)			320.96	1.5%	320.96	0.7%
Abies concolor and *Pinus lambertiana* (White fir and Sugar Pine)			92.31	0.4%	92.31	0.2%
Abies magnifica (Red fir)			1148.49	5.5%	1148.49	2.7%
Abies magnifica and *Abies concolor* (Red fir and White fir)			153.09	0.7%	153.09	0.4%
Acer macrophyllum (Bigleaf maple)	0.08	0.0%	15.84	0.1%	15.92	0.0%
Acer negundo (Box elder)		0.0%	15.74	0.1%	15.74	0.0%
*Aesculus californic*a (California buckeye)	75.61	0.3%	8.76	0.0%	84.37	0.2%
Agriculture (Without fallow annual grasses dominating)	526.63	2.4%	689.58	3.3%	1216.21	2.8%
Alnus incana (Mountain alder)			301.42	1.4%	301.42	0.7%
Alnus rhombifolia (White alder)	617.04	2.8%	261.16	1.2%	878.20	2.0%
Arctostaphylos nevadensis (Pinemat manzanita)			56.96	0.3%	56.96	0.1%
Arctostaphylos patula (Greenleaf manzanita)			0.96	0.0%	0.96	0.0%
*Arctostaphylos viscid*a (Sticky whiteleaf manzanita)	41.35	0.2%	9.33	0.0%	50.67	0.1%
Arundo donax (Giant reed)			5.93	0.0%	5.93	0.0%
Built up and Urban Disturbance	988.74	4.5%	948.83	4.5%	1937.57	4.5%
California and Western Cordilleran Montane Chaparral MG's		0.0%	18.19	0.1%	18.19	0.0%
California Mixed Perennial and Annual Grassland and Meadow Macrogroup	1196.47	5.4%	5573.86	26.6%	6770.33	15.7%
California Montane Conifer Forests (use for plantation)	9.43	0.0%	5.76	0.0%	15.19	0.0%
California Xeric Chaparral	18.79	0.1%			18.79	0.0%
Ceanothus cordulates (Mountain whitethorn)			9.53	0.0%	9.53	0.0%
Ceanothus cuneatus (Buckbrush)	106.39	0.5%	199.16	1.0%	305.56	0.7%
Chrysolepis sempervirens (Pinemat manzanita)			3.38	0.0%	3.38	0.0%
Cliffs and Rock Outcroppings	53.18	0.2%	581.77	2.8%	634.94	1.5%
Discharge Slope Meadows - Mesic Trending			70.22	0.3%	70.22	0.2%
Discharge Slope Meadows - Wet			90.23	0.4%	90.23	0.2%
Dry Meadows			436.49	2.1%	436.49	1.0%
Eleocharis macrostachya, Downingia, Trifolium variegatum, Eryngium (Vernal Pools >MMU)	1.94	0.0%	0.78	0.0%	2.72	0.0%
Eucalyptus	0.13	0.0%	1.59	0.0%	1.72	0.0%
Exotic Trees	1.17	0.0%	2.61	0.0%	3.78	0.0%
Fraxinus latifolia (Oregon ash)	91.11	0.4%			91.11	0.2%
Lacustrine Fringe Meadows			0.67	0.0%	0.67	0.0%

Vegetation types	Cow ac	% Cow	Mill ac	% Mill	Total ac	% Total
Mediterranean California Grassland and Forb Meadow Division (Vernal Pool Matrix)	269.57	1.2%		0.0%	269.57	0.6%
Mediterranean California Naturalized Annual and Perennial Grasslands and Meadow Macrogroup (weedy)	2836.56	12.8%	963.98	4.6%	3800.54	8.8%
Mediterranean Scrub	6.08	0.0%			6.08	0.0%
Naturalized non-native perennial grassland and Meadow Macrogroup (Irrigated Pasture Lands)	2743.11	12.4%	774.31	3.7%	3517.42	8.2%
North American Arid West Freshwater Marsh (Marsh Vegetation)	16.67	0.1%	10.73	0.1%	27.41	0.1%
Perennial Stream Channel	700.99	3.2%	440.10	2.1%	1141.09	2.6%
Pinus albicaulis (Whitebark pine)			27.33	0.1%	27.33	0.1%
Pinus jeffreyi (Jeffrey pine)			477.97	2.3%	477.97	1.1%
Pinus monticola (Western white pine)			119.08	0.6%	119.08	0.3%
Pinus ponderosa (Ponderosa pine)	88.99	0.4%	12.37	0.1%	101.36	0.2%
Pinus ponderosa - Pseudotsuga menziesii	311.26	1.4%	395.76	1.9%	707.02	1.6%
Pinus ponderosa (Ponderosa pine)		0.0%	2.62	0.0%	2.62	0.0%
Pinus ponderosa and *Calocedrus decurrens*	345.71	1.6%	236.37	1.1%	582.08	1.4%
Pinus ponderosa and *Pseudotsuga menziesii* (Ponderosa pine and Douglas-fir)			1295.03	6.2%	1295.03	3.0%
Pinus sabiniana (Foothill pine)	125.27	0.6%	2.95	0.0%	128.22	0.3%
Plantation	4.04	0.0%			4.04	0.0%
Platanus racemosa (California sycamore)			60.33	0.3%	60.33	0.1%
Populus fremontii (Fremont cottonwood)	206.18	0.9%	115.26	0.6%	321.44	0.7%
Populus tremuloides (Quaking aspen)			7.37	0.0%	7.37	0.0%
Populus trichocarpa (Black cottonwood)			45.16	0.2%	45.16	0.1%
Pseudotsuga menziesii (Douglas-fir)	62.27	0.3%			62.27	0.1%
Quercus chrysolepis (Canyon live oak)	408.92	1.8%	441.88	2.1%	850.80	2.0%
Quercus douglasii (Blue oak)	4507.26	20.4%	2520.51	12.0%	7027.77	16.3%
Quercus kelloggii (Black oak)	870.06	3.9%	324.34	1.6%	1194.40	2.8%
Quercus lobata (Valley oak)	2143.57	9.7%	217.99	1.0%	2361.56	5.5%
Quercus wislizeni (Interior live oak tree)	820.08	3.7%	230.65	1.1%	1050.72	2.4%
Quercus wislizeni shrub			33.05	0.2%	33.05	0.1%
Riparian Related Meadows - Mesic low gradient			233.76	1.1%	233.76	0.5%
Riparian Related Meadows Mesic high gradient			19.08	0.1%	19.08	0.0%
Riparian Related Meadows Mesic medium gradient			6.72	0.0%	6.72	0.0%
Riparian Related Meadows Wet high gradient			10.52	0.1%	10.52	0.0%
Riparian Related Meadows- Wet low gradient			100.56	0.5%	100.56	0.2%

Vegetation types	Cow ac	% Cow	Mill ac	% Mill	Total ac	% Total
Riparian Related Meadows-Wet medium gradient			13.75	0.1%	13.75	0.0%
River and Lacustrine Flats and Streambeds	172.46	0.8%	187.13	0.9%	359.59	0.8%
Rubus discolor (Himalayan blackberry)	656.70	3.0%	53.27	0.3%	709.97	1.6%
Salix exigua (Narrowleaf willow)	250.93	1.1%	35.03	0.2%	285.96	0.7%
Salix gooddingii (Black willow)	9.23	0.0%	2.15	0.0%	11.37	0.0%
Salix laevigata (Red willow)	186.92	0.8%	21.72	0.1%	208.64	0.5%
Salix lasiolepis (Arroyo willow)	168.83	0.8%	16.67	0.1%	185.50	0.4%
Salix lemmonii (Lemmon's willow)			14.45	0.1%	14.45	0.0%
Schoenoplectus spp. (Bulrush)	2.55	0.0%	17.24	0.1%	19.79	0.0%
Small Earthen Dam Ponds and Natural Lakes	61.98	0.3%	32.53	0.2%	94.51	0.2%
Southwestern Riparian Evergreen and Deciduous Woodlands	161.34	0.7%	37.30	0.2%	198.64	0.5%
Temperate Flooded Forests			4.80	0.0%	4.80	0.0%
Toxicodendron diversilobum (Poison oak)	0.74	0.0%			0.74	0.0%
Tsuga mertensiana (Mountain hemlock)			273.51	1.3%	273.51	0.6%
Typha spp. (Cattail)	3.06	0.0%			3.06	0.0%
Umbellularia californica (California bay)	1.57	0.0%	14.33	0.1%	15.90	0.0%
Undefined areas with little or no vegetation	17.68	0.1%	2.42	0.0%	20.10	0.0%
Undefined areas with little or no vegetation (Human disturbance)			2.53	0.0%	2.53	0.0%
Vancouverian Riparian Deciduous Forests	19.27	0.1%			19.27	0.0%
W. N. American Montane-S-Alpine Riparian Scrub			23.91	0.1%	23.91	0.1%
Warm Temperate Forests and Woodlands			1.19	0.0%	1.19	0.0%
Water	6.83	0.0%	0.17	0.0%	7.00	0.0%
Western North American Temperate Marsh and Wet Meadow Macro Group (Meadow Vegetation)	42.38	0.2%	1.88	0.0%	44.26	0.1%
Grand Total	**22,142**	**100%**	**20,920**	**100%**	**43,063**	**100%**

5 CONDITIONS ASSESSMENT

5.1 Purpose

The purpose of this task is to map out differences in riparian vegetation conditions within the Mill and Cow Creek project areas. The final product of this conditions assessment is a GIS shape file and associated attribute table, with the riparian condition ratings for both of the watersheds. This document is meant to accompany the shapefile and attribute table. In this section, we describe the methods used and summarize our findings. Methods were developed specifically for this project.

5.2 Methods

Working with the Technical Advisory Team, we started with a set of criteria for assessing riparian condition based on important functions that riparian systems can provide and on linkages between these functions and observable structural conditions. We then stratified the project area into 'condition reaches', or stretches of river in which the riparian corridor is subject to a consistent set of landscape controls, including surrounding parent material, land use, channel size and flow (accounting for effects of confluences and diversions). Once these condition reaches were designated, we used existing GIS data and aerial imagery, along with information from the field reconnaissance, field surveys, and the vegetation mapping effort to develop condition rankings for each condition reach. The methods applied in each of these steps are detailed in the sections below.

5.2.1 Articulate linkages between structure and condition

The Stillwater team summarized essential landscape and reach scale features that support healthy riparian areas and the benefits they provide in Figure 5-1. This flow diagram illustrates the linkages between landscape scale features such as the physical landscape, climate, and stream flow regime, and the reach-specific features they affect, such as floodplain connectivity, topographic shade, and riparian vegetation structure and composition. As described below, we used the first two rows of characteristics (broad scale) in Figure 5-1 to identify "condition reaches," and then looked for indicators of characteristics listed in the third and fourth rows of Figure 5-1 to assess riparian conditions. Finally, the bottom row in Figure 5-1 summarizes benefits provided by healthy riparian corridors, and these were used to help target the priority recommended action areas as described in Section 6.

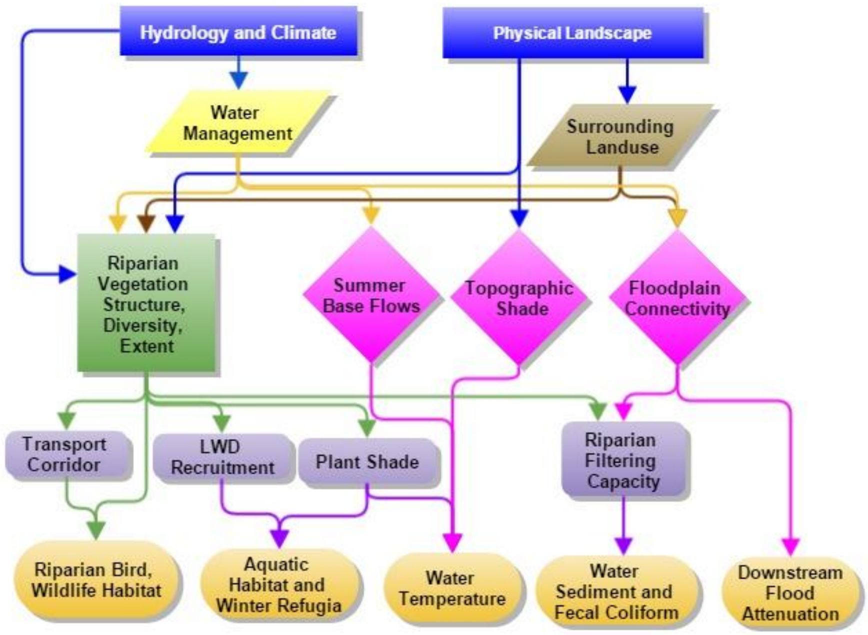

Figure 5-1. Linkages between landscape and reach-scale features that support provision of riparian benefits.

5.2.2 Designate condition reaches

We broke the 250 river miles in the Mill and Cow Creek project areas into shorter river reaches in which a consistent set of landscape scale factors affect riparian structure and processes, as illustrated in Figure 5-1. These landscape scale factors include differences in: physical landscape, hydrology, and climate, along with important changes in water management and surrounding land use. In application, we translated these factors into the following criteria for delineating the condition reaches:

1. Elevation (surrogate for climate)
2. Change in parent material (geology)
3. Presence of a confluence (hydrology)
4. Presence of a (large) diversion (hydrology)
5. Major change in land use (e.g., rangeland to urban)

Since there were sufficient breaks created by applying criteria 2–5, we did not need to create additional breaks associated with changes in elevation (climate). This approach resulted in 81 condition reaches along the seven major tributaries and the mainstem of Cow Creek, and 20 condition reaches along Mill Creek. The number of condition reaches designated along Cow Creek is greater due to the more complex structure of its river network (e.g., it has more major tributaries). The number of these condition reaches and their associated river miles are summarized by tributary within Cow Creek in Table 5-1, including the average length and standard deviation for the reaches within a single tributary. The number of condition reaches and their associated river miles are summarized in Table 5-2 for Mill Creek. Since Mill Creek includes few tributaries and fewer condition reaches than Cow Creek, lengths of all the Mill Creek condition reaches are presented and there is no need for summary statistics for reaches within tributaries.

Table 5-1. The number and length (in miles) of condition reaches identified along the mainstem and tributaries to Cow Creek.

Cow Creek tributaries	Number of condition reaches	River miles				
		Total	Avg	Std dev	Max	Min
Atkins Creek (trib to South Cow)	3	3.06	1.02	0.38	1.45	0.73
Basin Hollow (trib to South Cow)	2	5.58	2.79	0.37	3.05	2.53
Beal Creek (trib to South Cow)	1	2.64	2.64	N/A	2.64	2.64
Cedar Creek (trib to Little Cow)	2	8.09	4.04	0.22	4.20	3.89
Clover Creek	6	17.33	2.89	1.56	5.72	1.55
Coal Creek (trib to Clover)	1	1.38	1.38	N/A	1.38	1.38
Dry Clover (trib to Clover)	5	9.59	1.92	1.15	3.73	0.65
Little Cow Creek	7	26.62	3.80	1.84	6.84	1.43
Mainstem Cow Creek	16	19.25	1.20	0.61	3.16	0.55
Mainstem Cow Creek	3	2.96	0.99	0.02	1.00	0.96
Mill Creek (trib to South Cow)	4	4.55	1.14	0.75	2.25	0.66
Oak Run Creek	11	24.06	2.19	1.34	4.73	0.46
Old Cow Creek (trib to South Cow)	6	22.32	3.72	1.21	5.14	2.08
Rosebrier Creek (trib to Clover)	2	4.43	2.21	2.25	3.80	0.62
South Cow Creek	11	26.72	2.43	1.84	5.71	0.23
Unnamed trib to Little Cow Creek	1	0.83	0.83	N/A	0.83	0.83
Grand Total	**81**	**179.39**	**2.21**	**1.52**	**6.84**	**0.23**

Table 5-2. River mile length of the riparian condition reaches delineated along Mill Creek. Lengths of all the Mill Creek condition reaches are presented and there is no need for summary statistics for reaches within tributaries.

Mill Creek condition reach code	River miles
1a	1.05
1b	1.38
1c	0.47
2	2.52
3	2.97
4	3.55
5	3.84
6	6.19
7	11.16
8	4.59
9	5.03
10	5.80
11	1.79
12	1.00
13	4.73
14	2.27
15	2.02
16	3.77
Gunwale Creek	3.18
North Mill Distributary	1.47
Total	**68.80**
Average	**3.44**
Standard deviation	**2.45**

5.2.3 GIS analysis

We examined several attributes in the vegetation type shape file developed by AIS as part of this project (Section 4. Vegetation Mapping) to screen the Cow Creek and Mill Creek watershed project areas for condition reaches likely to be in poor shape. For all condition reaches, we applied this screening to mapped areas extending 30 and 100 feet from the river bank; for condition reaches along higher order channels, we also examined vegetation attributes within the 500 ft buffer. The attributes summarized from the vegetation map (shapefile) for the buffer areas are listed below:

- Percent of area mapped as woody vegetation
- Percent of area mapped as native riparian vegetation
- Percent of area mapped as invasive non-native vegetation
- Average canopy density for woody dominated vegetation
- Average estimated canopy height
- Average channel canopy overhang

For each watershed, we looked at the frequency distribution of values for each of these attributes within the buffer areas and used these to develop approximate thresholds for identifying reaches likely to be in notably worse shape than others, as exemplified in Figure 5-2. Thus, for each watershed, condition reaches with one or more of these attribute values exceeding the identified threshold were flagged for closer examination.

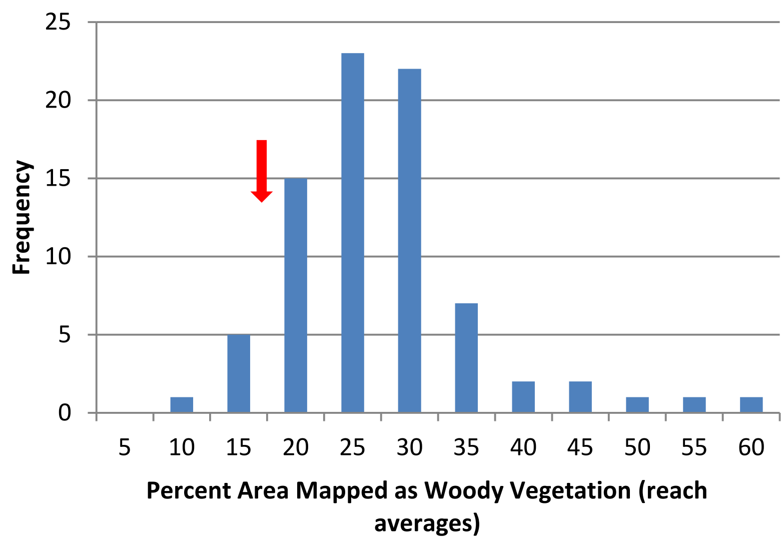

Figure 5-2. Frequency distribution of percent area of woody vegetation mapped within a 30 ft buffer (30 ft to either side of the channel) along condition reaches in Cow Creek and Mill Creek. Cut off for flagging reach as in 'potentially poor condition' was set at <15% area (red arrow).

Results from the GIS analysis provided less insight on riparian conditions than expected. Through aerial imagery, we could see that some unflagged condition reaches were in poor condition and other flagged condition reaches appeared to be in very good condition. In retrospect, it is likely that the GIS analysis did not provide a reliable screening of good vs. poor condition reaches because the attributes examined (above bullet points) varied with the landscape scale factors used to designate the condition reaches. For example, the maximum potential lateral extent of buffer area dominated by riparian vegetation could be small due to steep narrow valleys characteristic of upper reaches in Cow Creek watershed, or because only a thin and intermittent set of valley oaks were left alongside a channel in the lower reaches of Cow Creek. Both reaches might have the same percent area within the 30 ft buffer occupied by native riparian vegetation, but the first reach could be in poor condition while the second could be in excellent condition. Since this GIS screening did not reliably narrow the set of condition reaches to be more closely examined, we decided to move ahead with applying the visual assessment to all of the condition reaches in both watersheds. Therefore, we did not use the GIS analysis results as an initial screening to identify areas likely to be in poor condition, and instead examined all of the condition reaches using the visual assessment described below.

5.2.4 Visual Assessment using Remote Imagery

Visible potential sources of disturbance or poor riparian conditions were identified with the intent of developing a tractable basis for determining riparian conditions, and for identifying specific areas in these condition reaches where actions might be recommended (see Section 6. Recommendations for Priority Management Areas). Each condition reach was visually assessed for the following condition indicators, which are mostly represented by the first, third and fourth rows in Figure 5-1:

Flood connectivity: This was assigned based upon the difference between the scores for potential floodplain width and the actual floodplain width. The rank was calculated as (5 – (potential – actual)) because 5 is the maximum difference between the actual and potential, yielding a '0' (minimum) score for flood connectivity in those cases and a '5' where the potential appears to be fully realized. The potential floodplain width is defined as the lateral extent to which frequent and moderately frequent river flows could extend in undisturbed conditions and is estimated based primarily upon topography and reach location in the watershed, where topography is estimated from a visual assessment of aerial imagery. Thus, apparently incised channels in depositional reaches with indications of historical wide floodplains would be assigned a 'wide' or 'very wide' rank. The actual floodplain width is defined as the lateral extent to which frequent and moderately frequent river flows could extend under existing conditions, estimated in the same way as potential width, but focused on visual cues of recent flooding. Thus, apparently incised channels in depositional reaches would be assigned a 'low' (30-100 ft) or 'narrow' (<30 ft wide) rank under actual floodplain. Ranks are assigned as the following: >1000ft = very wide (rank =5); 500-1000 ft= wide (rank =4); 250-500ft =moderate (rank =3); 100-250= moderate-low (rank =2); 30-100 ft = low (rank =1); <30 ft = narrow (rank =0).

Channel complexity: This was assigned based on evidence of an actively meandering channel that is appropriate for the reach, including sinuosity, instream sediment bars, and back channels ("Floodplain connectivity" in Figure 5-1). Channel complexity was assigned a low (0), low to moderate (1), moderate (2), moderate to high (3), or high (4) rank.

Urban encroachment: This is a reflection of landuse and hardened landscapes that can limit channel meander, increase sediment input, and constrain natural flooding ("Surrounding landuse" in Figure 5-1). Scores were assigned according to these categories: undeveloped (0), open range and/or plantation (1), agricultural fields (not pasture) (2), large lots (aka, low density suburban) (3), moderate density suburban (4), high density suburban (5).

Eroding banks: This is based on evidence of steep and deeply cut banks in many areas (3), a few to moderate number of locations (2), one or a few locations (1), or no eroding banks seen (0). ("Floodplain connectivity" in Figure 5-1)

Elevated sediment input: Indicators of potentially elevated surface erosion due to high density of dirt trails and roads, existence of gullies connected to channel, presence of cattle trails near stream bank ("Surrounding landuse" in Figure 5-1). These are recorded as none observed (0), small (1), moderate (2), or high (3) amount of indicators.

Longitudinal continuity: This is recorded as the degree to which the reach has continuous woody vegetation along both sides of the channel ("Riparian vegetation extent", Figure 5-1). These are recorded as none to very low or roughly <25% (1), moderate or roughly 25 to 75% (2), or high to nearly continuous at over 75% (3) of reach banks supporting continuous woody vegetation.

Lateral extent of woody vegetation: This is recorded as the width of continuous woody vegetation on both sides of the channel (e.g., from roughly one to three to many tree-canopy widths; "Riparian vegetation extent", Figure 5-1). These are recorded as none to very low (1), moderate such as 2 to 4 canopy widths most of the length (2), or high, such as over four canopy widths most or all of the reach length (3).

Non-native vegetation: As an approximate metric, we used percent of area in a 30 ft buffer that is mapped as dominated by non-native vegetation ("Riparian vegetation diversity" in Figure 5-1). These are recorded as less than 5% (4), 5 to 10% (3), 10 to 20% (2), and over 20% (1).

Rank scores for these eight attributes were normalized to the percent of potential for each attribute (e.g., a '2' rank for non-native vegetation would be converted to a 2/5 or 40% score). All attribute scores were then converted so that 100% reflected excellent condition (e.g., urban encroachment scores were converted by subtracting score from 100% to reflect degree to which urban encroachment was *not* observed along the condition reach). These scores were then averaged for each reach, giving equal weight to each of the eight condition indicators. The average for each condition reach is reported as the 'Condition Quantification' score. Because this scoring system does not include the many idiosyncratic factors that can affect conditions observed in the riparian corridor, such as existence of in-line ponds, variation in likely background sediment loading, potential riparian vegetation cover, observed but not mapped instances of *Arundo* within the reach, etc., and because the scoring is based on simple equal weighting of these eight attributes when in reality the importance of these attributes can vary along the riparian corridor, these scores were then used as advisory information, rather than the final condition scores.

Final condition scores were made based on the condition quantification scores described above, as well as other factors. These other factors include **Geology -** parent material underlying and directly adjacent to the riparian corridor (informs potential natural vegetation, erosion, channel form); **Fish Accessibility -** whether an area is above or below a partial or complete barrier to fish passage (e.g., natural falls); and **Notes** – information on other important, sometimes idiosyncratic characteristics about a condition reach. Once all of these factors were taken into consideration, final condition score were assigned. Condition reaches were assigned one out of seven ratings, ranging from poor (1) to excellent (4) condition. Once all of the condition reaches had been reviewed and draft condition scores assigned, all of the reach condition ratings and specific notations were finalized by a senior riparian ecologist with targeted input from a senior geomorphologist. The riparian condition rating system developed for this project is described in Table 5-3 below.

Table 5-3. Condition rating scores applied to Mill and Cow Creek project areas with example descriptions of reaches assigned each rating.

Rating	Rating name	Example Reach Descriptions for each Condition Rating
1	Poor	Lots of erosion, sparsely vegetated banks with apparent lateral connectivity mostly limited at low and moderate flows, Google Earth imagery for 8/27/2013 shows no water in channel; weeds prevalent (HBB)
1.5	Poor to Fair	Some riparian vegetation along banks but often just 1 tree-canopy wide; signs of surface, gully, or bank erosion; indications that channel is incised in some areas; invasive weeds mapped on 5–10% of area.
2	Fair	Large suburban homes with surface erosion on south bank; some homes and pasture north bank; 1 tree width riparian corridors link river bends with a few riparian forest/shrublands established on the inside of bends; few signs of meander and lateral connection
2.5	Fair to Good	Several areas of well-developed riparian forest; but river left and parts of river right are constrained by land use. Several large sections with little to no riparian vegetation and a few points with bank erosion visible.
3	Good	Approximately 1/3 of riparian corridor is sparsely vegetated patches of riparian forest observed; irrigated pasture with cow trails could increase sediment inputs, creek appears to flood most potential lateral extent, includes complex channel structure and movement.
3.5	Good to Excellent	Riparian corridor mostly lined with alders and adjacent upland support native [undeveloped] vegetation; Some additional sediment sources from power line crossing, dirt roads with gullies visible from Google Earth imagery.
4	Excellent	Mostly continuous and wide streamside vegetation with channel movement and riparian forest development in bends and over three canopy widths in between. No non-natives mapped or visible within corridor, adjacent uplands are undeveloped. A few patches with sparsely vegetated banks observed.

5.3 Condition Assessment Findings

Careful review of imagery in conjunction with the GIS summary data revealed that the most informative GIS-derived information on reach condition was percent of buffer area dominated by non-native vegetation. As mentioned above in section 5.2.3. GIS analysis, other summary data on the riparian vegetation map attributes were not consistently indicative of observed riparian vegetation conditions. For example, percent of buffered area mapped as woody vegetation could be low in healthy reaches that naturally had very low vegetation cover, such as low density oak woodland areas in the mid-elevation reaches of Basin Hollow (Figure 5-3). Similarly, vegetation height was not indicative of riparian conditions since some areas were surrounded by native shrublands while others supported (native or non-native) forests (Figure 5-4).

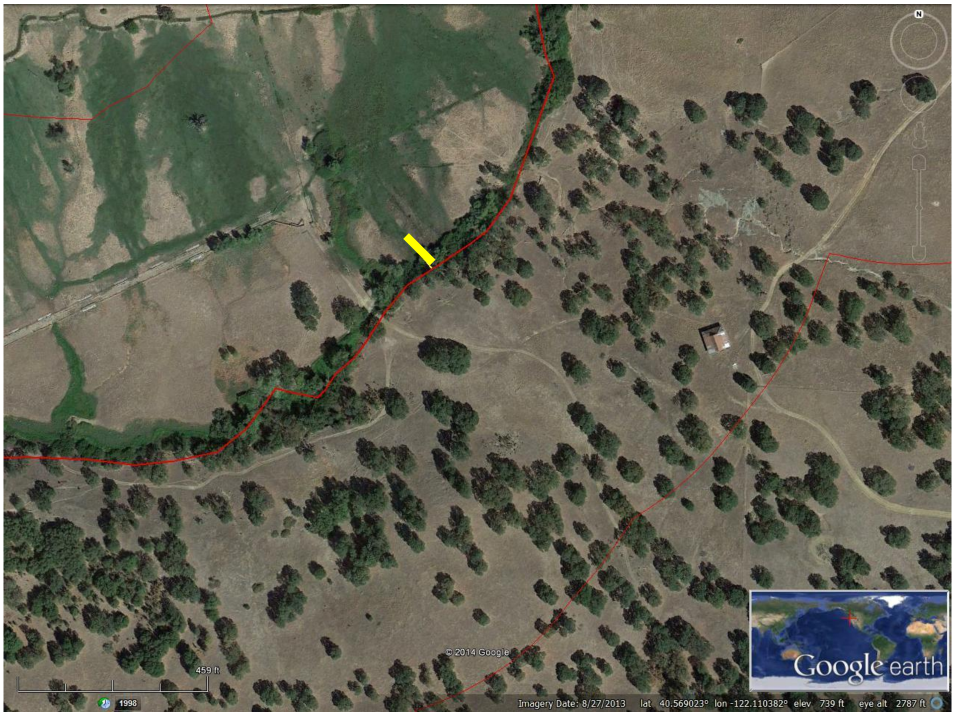

Figure 5-3. Low density oak woodlands in landscape surrounding Basin Hollow riparian area in Cow Creek watershed have naturally low woody vegetation cover within the 100-ft buffer (yellow line).

Figure 5-4. Low density oak woodlands with narrow strip of riparian shrubs in landscape surrounding upper Clover Creek riparian area in Cow Creek watershed have naturally low woody vegetation cover low and stature shrubs within the 30 ft buffer (yellow line).

The reach condition scores are summarized in Table 5-4 below and illustrated in Figures 5-5 and 5-6 for Cow Creek and Mill Creeks, respectively. The full list and description of the condition ratings for each condition reach is provided in Appendix G for Cow Creek and Appendix H for Mill Creek. These condition ratings and rationales are also included as attributes in the Riparian Condition shapefile and Excel data file provided with this report.

Table 5-4. Summary of riparian condition ratings in Cow Creek and Mill Creek watershed project areas.

Score	Condition rating	Cow Creek		Mill Creek	
		River miles	Percent total	River miles	Percent total
1	Poor	7.29	4%	5.04	7%
1.5	Poor to Fair	9.95	6%	1.38	2%
2	Fair	30.83	17%	3.44	5%
2.5	Fair to Good	38.14	21%	1	1%
3	Good	26.95	15%	7	10%
3.5	Good to Excellent	8.72	5%	12.62	18%
4	Excellent	57.52	32%	38.3	56%
Total		**179.39**	**100%**	**68.78**	**100%**

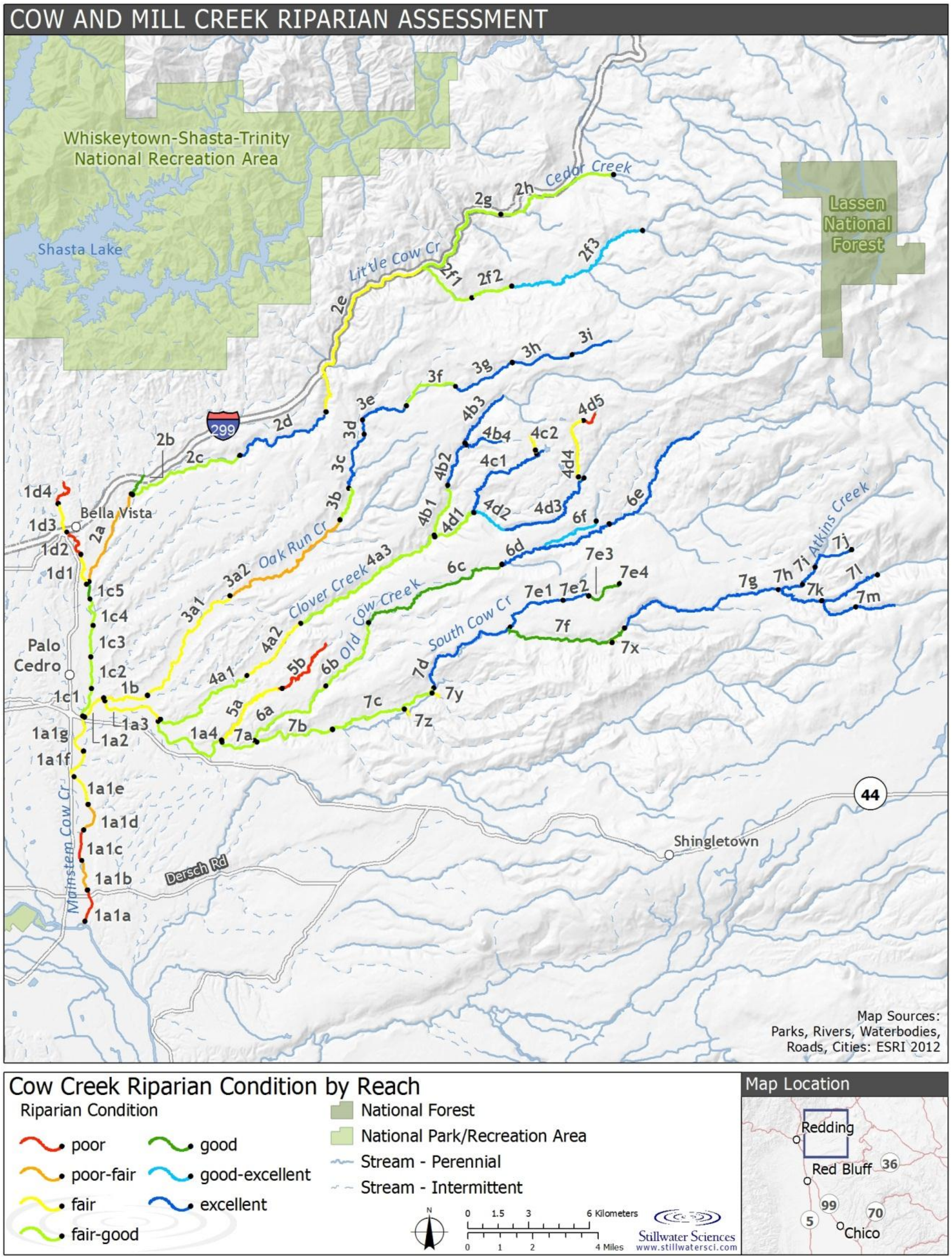

Figure 5-5. Cow Creek riparian condition by reach.

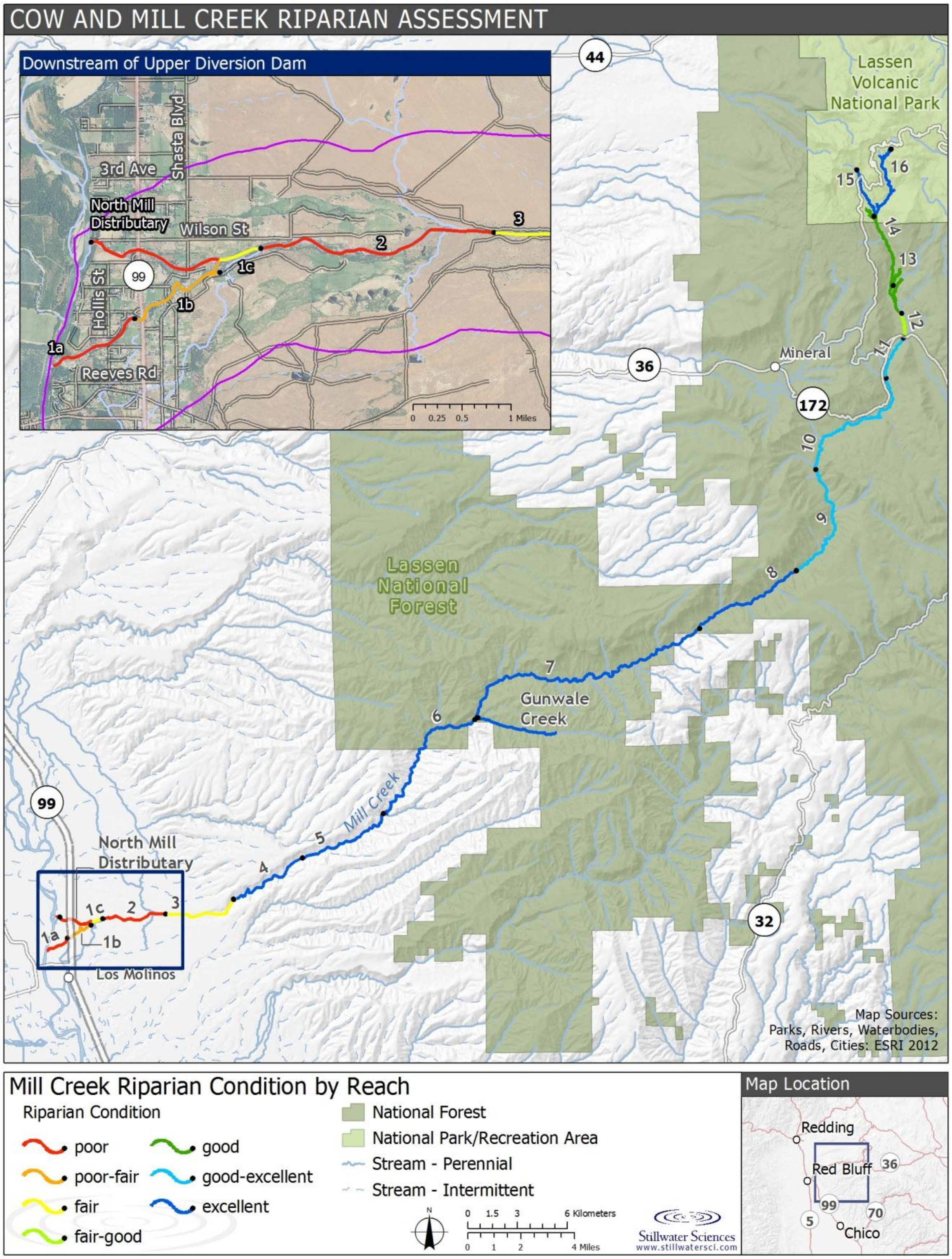

Figure 5-6. Mill Creek riparian condition by reach.

6 RECOMMENDATIONS FOR PRIORITY MANAGEMENT AREAS

Priority management areas were identified by combining the condition ratings described above with knowledge of the critical management issues in each watershed, as described below. To identify critical management issues, we reviewed existing information on natural resources and management in the watersheds as recorded in reports and websites, and as communicated by the Technical Advisory Team and stakeholders during the watershed meetings. We then identified those management issues within Cow Creek and Mill Creek watersheds in which changes in riparian vegetation could improve the aquatic and riparian habitat. We used an approach which is idealized in the following steps:

1. Identify priority issues for each watershed;
2. Locate reaches within each watershed where priority issues are most limiting;
3. Assess degree of potential benefits for bird and wildlife habitat and to aquatic habitat provided under existing riparian conditions in limiting reaches;
4. Determine potential for riparian vegetation enhancement to provide increased environmental benefit in those reaches;
5. Highlight those areas with the greatest difference between 3 and 4.
6. Make restoration and management recommendations for those highlighted areas identified in step 5.

In reality, information guiding us through some of these steps was incomplete, so the process was less linear than outlined above. Our findings from this information review are summarized in the following two sections.

6.1 Cow Creek: Priority Issues

Cow Creek supports anadromous fish populations, including fall-run and late fall-run Chinook salmon and steelhead. Stream temperatures and flows could be limiting anadromous fish migration during summer and fall low-flow periods. Also, several reaches of Cow Creek are out of compliance with the Clean Water Act for pathogens (fecal coliform) and one reach is out of compliance for metals (a section of Little Cow Creek is listed for cadmium, copper and zinc) (California Water Boards 2010). In addition, invasive non-native plant species, particularly Himalayan blackberry and *Arundo*, threaten the structural diversity and species diversity of the riparian corridor.

6.1.1 Fisheries

Cow Creek supports fall-run and late fall-run Chinook salmon as well as steelhead populations (NMFS 2014, SHN and Vestra 2001, Entrix 2007). In the Recovery Plan for Central Valley spring-run and winter-run Chinook salmon and steelhead (NMFS 2014), key stressors to anadromous fish populations in Cow Creek can be summarized as the following: (1) low spring, summer and fall flows; (2) high summer water temperatures and resulting thermal barriers associated with low flows; (3) unscreened diversions; (4) competition and hybridization among different salmonid populations; (5) predation affecting juvenile rearing and outmigration; and (6) low availability of natural floodplains for juvenile rearing and outmigration. Many of these stressors are interlinked. For example, low flows reduce the thermal inertia so that a stream gains or loses heat more rapidly under low flow than under high flow conditions (Poole and Berman 2001). High stream temperatures could also increase predation mortality if out-migrating juveniles are forced to move through such reaches under conditions that approach their thermal tolerance, particularly for extended periods or distances (Coutant 1973, Marine and Cech 2004).

Waterfalls create natural impediments to upstream fish passage in most of the tributaries (Figure 6-1) and unscreened diversions can entrain juvenile fish, resulting in mortality. Unscreened agricultural water diversions have been cited as a potential limit on the production of salmon and steelhead in Cow Creek watershed (Reynolds et al. 1993, USFWS 1995, Western Shasta RCD and CCWMG 2001). Figure 6-1 illustrates the extent of river miles used by anadromous species. By reducing streamflow during the April–October diversion period, diversions also increase summer water temperatures and reduce available rearing habitat.

A partial fish barrier occurs at Diddy Wells Falls on **Little Cow Creek**; these falls were determined to be a partial barrier to steelhead, but in practice, could require more energy than the anadromous fish have after swimming upstream through the Delta and Sacramento River for approximately 420 miles before reaching Cow Creek (HT Harvey 2014).

The lower reaches of **Oak Run Creek** and **Basin Hollow** appear dewatered or discontinuously watered during the summer months in nearly all of the 2007- 2013 Google Earth imagery (2011 is the exception). Oak Run Falls acts as an additional partial barrier upstream of these lower reaches. We found no reports of anadromous fish occurrences in Oak Run Creek or Basin Hollow.

The lower reaches of **Clover Creek** are watered but likely very warm since most of this tributary is unshaded and flows are relatively low. A partial barrier created by a siphon and diversion dam impedes access to potential habitat approximately 10 miles downstream of a Clover Creek Falls (T. Bratcher, CDFW, pers. comm.). Farther upstream, Clover Creek Falls acts as a fish barrier (Figure 6-1). We found no reports of anadromous fish occurrences in Clover Creek, but more than 700 rainbow trout were reported in Clover Creek during a fall 1981 survey (SHN and Vestra 2001).

Whitmore Falls on **Old Cow Creek** were also reported to be a partial barrier for adult steelhead and Chinook salmon but passable under certain flow conditions. Farther upstream are two un-named falls which could limit anadromy for the remaining upstream river miles along Old Cow Creek (HT Harvey 2014).

Diversion dam structures in **South Cow Creek** reportedly do not impede anadromous fish access to the upper reaches of this sub-watershed; although a naturally steep section of the channel at Wagoner Canyon could impede upstream access at very low flows (SHN and VESTRA 2001; M. Berry and P. Bratcher, CDFW, pers. comm.).

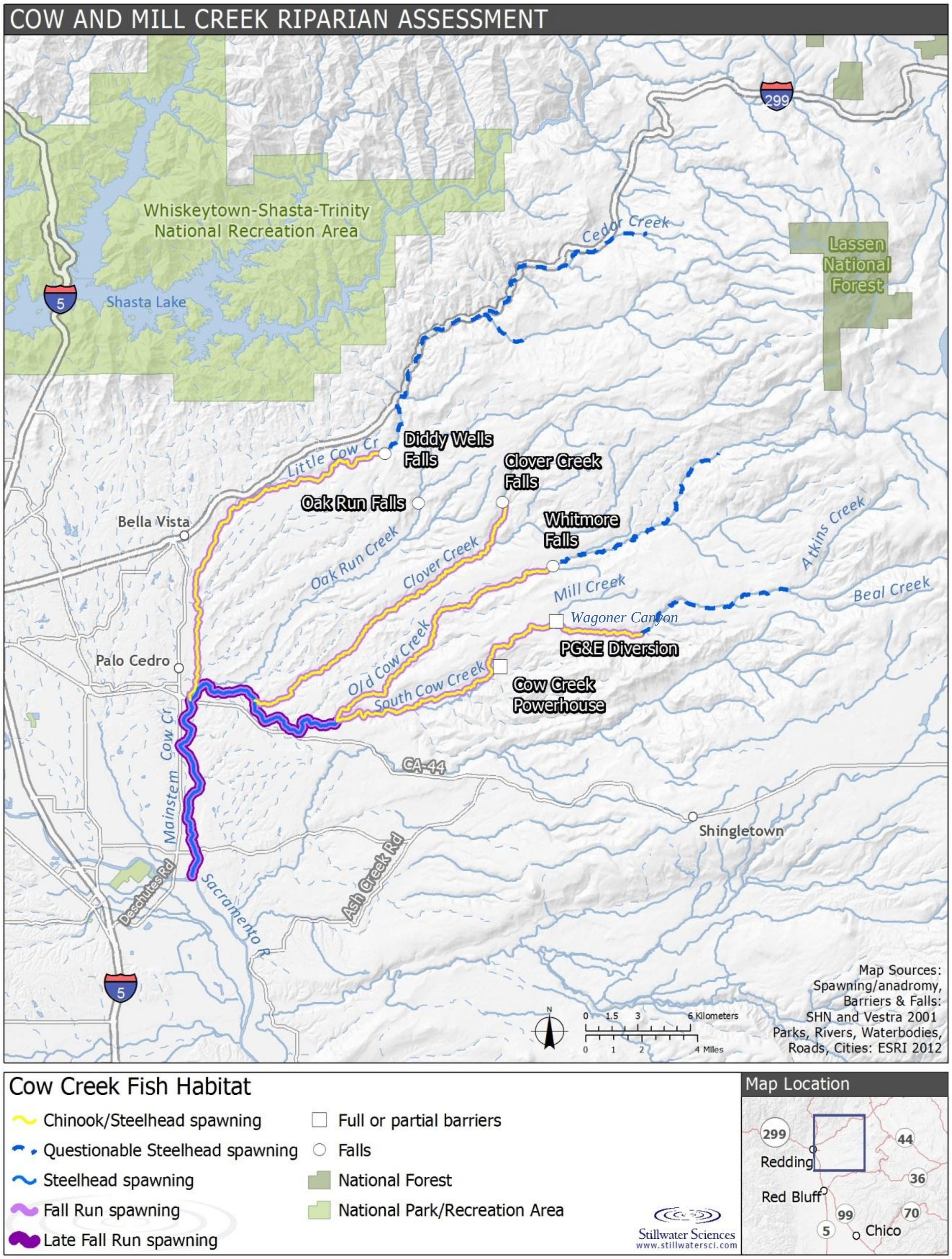

Figure 6-1. Anadromous fish habitat in Cow Creek study area.

Spring-run Chinook: The NMFS recovery plan lists Cow Creek as supporting a spring-run Chinook population, based on sightings of what are assumed to be stray individual spring-run Chinook along Old Cow Creek (NFMS 2014, Entrix 2007). Cow Creek watershed is not believed to have supported substantial numbers of spring-run Chinook salmon historically due to the lack of deep holding pools downstream of the partial passage barriers in each tributary and the lack of access to the cooler headwater reaches (Yoshiyama et al. 2001, Lindley et al. 2004). Surveys for adult spring-run Chinook salmon in Cow Creek in 1989 and 1991 apparently documented "few or no salmon" (Pipal 2005), although no data appear to be available from these surveys. Reynolds et al. (1993) cited an undated report of spring-run Chinook salmon occurring in South Cow Creek, and NMFS (2005) includes mainstem Cow Creek upstream to the confluence with South Cow Creek in its critical habitat designation for spring-run Chinook salmon. However, Reynolds et al. (1993) reported that high summer water temperatures in the lower mainstem and tributary reaches, below the barriers, render Cow Creek watershed unsuitable for spring-run Chinook salmon.

Fall-run Chinook: Video surveys on Cow Creek mainstem below Highway 44 conducted during fall and early winter from 2006–2011 documented 4,209 adult fall-run Chinook entering Cow Creek in 2006, 2,044 in 2007, 478 in 2008, 265 in 2009, 536 in 2010, and 1,617 in 2011 (Killam and Merrick 2012). Fall-run Chinook use the mainstem and lower reaches of several tributaries for spawning and rearing but do not use the mid-reaches due to low stream flows during the fall (Figure 6-1). According to the Cow Creek Watershed Assessment, some fall-run Chinook access areas up to the base of Wagoner canyon on South Cow Creek, but do not use Wagoner Canyon itself (condition reach 7f). Low flows and high stream temperatures during late spring and early fall could constrain the time-period for fall-run Chinook juvenile outmigration and adult up-migration, respectively. Fall-run Chinook that out migrate during periods of high stream temperature could suffer mortality due directly to high temperatures and/or indirectly due to increased vulnerability to disease and /or predation mortality associated with heat stress (Coutant 1973, Marine and Cech 2004).

Late fall-run Chinook: use of Cow Creek by late fall-run Chinook salmon is not well documented. One report states that late fall-run were observed no higher than the confluence of Old Cow and South Cow Creek (SHN and Vestra 2001).

Winter-run Chinook: There is no evidence that Cow Creek watershed historically supported winter-run Chinook salmon (Lindley et al. 2004), and no current data to indicate use of the watershed by winter-run Chinook.

Steelhead pass through the lower reaches to the mid-reaches of some Cow Creek tributaries since they migrate during higher flow periods than fall-run Chinook (SHN and Vestra 2001, Entrix 2007). High quality spawning habitat exists along condition reaches 7d and 7f on South Cow Creek, below and above the PG&E diversion dam (SHN and Vestra 2001) (Figure 6-1). Steelhead sightings have been reported for areas farther upstream than condition reach 7f, extending all the way up to condition reach 7h (Atkins Creek). Thus, maintaining access to the mid and upper reaches of South Cow Creek by providing cool running waters along lower South Cow Creek is important for supporting the steelhead population in Cow Creek. Steelhead have also been sighted at Diddy Wells Falls on North Cow Creek (condition reach 2d).

The mainstem of Cow Creek is used as a migration corridor to and from higher reaches by steelhead and is an important spawning area for fall-run Chinook (Killam and Merrick 2012, SHN and Vestra 2001). Overall, the "primary limiting factors for salmonids are low fall and summer flows, which block or delay adult immigration, and [diversions which] entrain juveniles" (NMFS 2014).

Moreover, recent studies indicate that reducing stream temperatures during the critical spring and summer months will help maintain the anadromous life history component of the Cow Creek steelhead population. Populations of *Oncorhynchus mykiss* in Cow Creek watershed include both resident (rainbow trout) and anadromous (steelhead) life history forms (SHN and VESTRA 2001, Moore 2003, Moore 2004a, Moore 2004b, Thompson et al. 2006). With many former anadromous steelhead populations in California's Central Valley fragmented by dams and reduced by habitat degradation, the importance of conserving the migratory (anadromous) life history phenotype is a top priority for recovering and maintaining viable populations (Satterthwaite et al. 2010, Kendall et al. 2014, NMFS 2014). Recent research indicates that the expression of a migratory life history strategy in *O. mykiss* has a strong heritable genetic component (Pearse et al. 2014, Phillis et al. 2014), and can be lost when selective pressures such as poor downstream and ocean survival select against anadromy (Satterthwaite et al. 2010, Phillis 2014). Restoration actions designed to improve environmental conditions conducive to downstream survival of rearing and outmigrating juveniles (e.g., cool water temperatures and floodplain habitat during spring) will increase the likelihood that outmigrants will return to spawn as adults, thus helping to maintain an anadromous life history expression through natural selection. In Cow Creek, high spring and summer water temperatures have been identified as a primary factor limiting the *O. mykiss* population (Reynolds et al. 1993, USFWS 1995, USFWS 2001, Thompson et al. 2006). Restoration actions that help maintain or reduce water temperatures along the migratory corridor of Cow Creek during the critical spring and summer months will similarly help maintain the anadromous life history component of the Cow Creek *O. mykiss* population.

Based on this general assessment from the Recovery Plan (NMFS 2014) and our analysis of the watershed, we propose that the most important areas for steelhead and fall-run Chinook habitat are: (1) mainstem Cow Creek downstream of the South Cow Creek confluence; (2) South Cow Creek up to the PG&E Diversion Dam (and Wagoner Canyon just upstream); (3) Old Cow Creek up to Whitmore Falls; and (4) Little Cow Creek up to Diddy Wells Falls.

6.1.2 Water quality concerns

Elevated Temperatures: The Cow Creek Watershed Management Plan (Western Shasta RCD and CCWMG 2005) states that elevated temperatures in the mid to lower reaches of the Cow Creek tributaries occur during the summer and early fall. High fall and spring temperatures have been specifically identified as limiting for Chinook salmon along Clover Creek downstream of Whitmore Falls, Little Cow Creek downstream of Diddy Wells Falls, and along the lower reaches of these tributaries as well as the mainstem (Western Shasta RCD and CCWMG 2005). The Recovery Plan (NMFS 2014) states that "water temperatures appear to be suitable for salmonids year-round in the upper reaches of Old Cow and South Cow Creeks… [but that] stressful and lethal water temperatures were observed in the lower reaches" of these tributaries between June and October. As described in the previous section, low water flows have also been identified in the Recovery Plan (NMFS 2014) as a key stressor for steelhead adult immigration; since areas with summer low water flows are more susceptible to solar heating, warm summer temperatures and poor water quality are also listed as key stressors to steelhead population in Cow Creek, including adult immigration and holding, spawning, incubating and juvenile rearing and outmigration (NMFS 2014).

Improved riparian condition can address stream temperatures by increasing thermal insulation with shade and increasing thermal buffering by increasing hyporheic interactions through greater floodplain connectivity (Poole and Berman 2001). Increased vegetation shade is most effective along southern channel banks since this blocks the greatest amount of solar input, and in areas that are not already protected by topographic shade, such as occurs in narrow canyons. Stream reaches with reduced flows, such as those below diversions, are particularly vulnerable to elevated stream temperatures and should be targeted for actions to increase shade and hyporheic exchange (increased floodplain extent). Similarly, maintaining cool temperatures in waters entering reaches with diversions is also important for ensuring that cool downstream water temperatures can be maintained through shade and/or increased hyporheic exchange. Creation of 'thermal refugia' through increased channel shade and in-channel habitat heterogeneity (pools, large woody debris jams) can support successful migration through reaches that are otherwise elevated above the assumed thermal threshold (Poole and Berman 2001).

Pathogens: At this time, three of the six major Cow Creek tributaries are 303(d) listed for not meeting water quality standards for pathogens (fecal coliform): Oak Run Creek, Clover Creek, and South Cow Creek (Table 6-1). Little Cow Creek is 303(d) listed for not meeting water quality standards for heavy metals (status 5A; Table 6-1). Cow Creek and its tributaries are typically at very low flow levels during the summer due to multiple upstream uses and diversions (Western Shasta RCD and CCWMG 2005). There is a need for more information on water flows, water temperature, and water bacteria levels in order to assess current conditions and long-term trend responses to altered management.

As with water temperature (discussed above), other water quality concerns can be addressed through increased riparian vegetation cover and floodplain connectivity (Naiman et al. 2005). Pathogens, such as fecal coliform, are most effectively reduced in stream waters by excluding cattle from the channels (fencing) and by increasing extent and percent cover of perennial herbaceous plants within the floodplain and channel banks so that surface and near subsurface runoff carrying pathogens and sediment is physically filtered by plant stems and through the rooting zone before reaching the channel (Lowrance et al. 1984, Daniels and Giliam 1996, Micheli and Kirchner 2002, Tate et al. 2006).

Table 6-1. Cow creek tributaries that are listed as impaired under the Clean Water Act section 303(d) (California Water Board 2010).

Reach or tributary	303(d) listing
Mainstem Cow Creek	Not listed
Little Cow Creek	1 mile reach below Afterthought Mine listed for Cadmium, Copper and Zinc
Oak Run Creek	6 mile reach listed for pathogens (fecal coliform)
Clover Creek	11 mile reach listed for pathogens (fecal coliform)
Old Cow Creek	Not listed
South Cow Creek	8 mile reach listed for pathogens (fecal coliform)

6.1.3 Wildlife

Northwestern pond turtle (*Clemmys marmorata marmorata*), osprey (*Pandion haliaetus*), and Shasta salamander (*Hydromantes shastae*) are state and/or federally listed species that are at least partially or fully dependent upon riparian zones and have been reported in Cow Creek watershed (SHN and Vestra 2001). Several listed or special-status species occur in the watershed but are not riparian dependents (e.g., northern spotted owl [*Strix occidentalis caurian*], American peregrine falcon [*Falco peregrinus Americana*], and ringtail [*Bassariscus astutus*]) (SHN and Vestra 2001).

Improved riparian vegetation and floodplain access support these listed riparian dependent species and improve habitat and support populations of non-listed species including riparian songbirds and wildlife that use the riparian corridor to move and interbreed throughout the broader landscape (RHJV 2004, Naiman et al. 2005).

6.1.4 Invasive non-native plants found in riparian areas

Large areas of the mid and lower Cow Creek watershed have been converted to rangeland, and invasive non-native plants (aka, weeds) are likely to be prevalent in many of these areas. In the upper reaches, forest harvesting and fire suppression have affected vegetation type and vegetation structure; on the other hand, invasive plant species are likely to be less prevalent in these forested areas. One recommendation from the Cow Creek Watershed Management Plan is to conduct inventories to document existing conditions, including detrimental non-native invasive plants and native and non-native riparian vegetation in the whole contributing area (Western Shasta RCD and CCWMG 2005). Upland species, such as French and scotch broom (*Cytisus scoparius* and *Genista monspessulana*), cheat grass (*Bromus tectorum*), and pampass grass (*Cortaderia selloana*), are found in the uplands adjacent to the riparian corridor (SHN and Vestra 2001).

Through our riparian vegetation mapping and brief field survey of Cow Creek, we found many invasive non-native plants in the riparian corridors of Cow Creek watershed, particularly below 5,000 ft elevation. The most common invasive plant found in riparian areas and particularly along irrigation canals is Himalayan blackberry. Monocultures of Himalayan blackberry were observed growing along many miles of irrigation ditches mapped as line features for this project (see Section 4. Vegetation Mapping). Many other invasive plants occur, but are less frequent. Yellow star thistle (*Centaurea solstitialis*) was common in the uplands and several of the riparian field sites (Table 6-2). Invasive plants introduced from gardens or other residential plantings, such as common fig (*Ficus carica*) and tree of heaven (*Ailanthus altissima*), are more common in the residential areas of Cow Creek mainstem and lower tributaries. *Arundo* has also been observed from aerial imagery and by others on the ground (e.g. Tricia Bratcher, pers. comm.), but was not encountered at any of the field sites during the Cow Creek field surveys.

Removal and replanting with native plant species is an important means of controlling the spread of these invasive species and managing for a diverse and healthy riparian corridor. By nature, invasive non-native plants will continue to appear (brought in from tires, shoes, gardens, water, wind, etc.) in the riparian corridor and contributing area; these are best addressed through constant monitoring and early removal.

Table 6-2. Invasive non-native plants found in Cow Creek watershed, along with their invasive status per the California Invasive Plants Council (http://www.cal-ipc.org/) and the number of observations of these species recorded during the 2013 field effort.

Scientific name	Common name	CalIPC rank	Number of observations in Cow Creek
Ailanthus altissima	Tree of heaven	Moderate	1
Arundo donax	Giant reed	High	*
Centaurea solstitialis	Yellow star thistle	High	3
Cynosurus echinatus	Annual dogtail	Moderate	2
Ficus carica	Fig	Moderate	1
Hirschfeldia incana	Mediterranean mustard	Moderate	1
Mentha pulegium	Pennyroyal	Moderate	4
Phalaris canariensis	Canary grass	Moderate	1

Rubus armeniacus	Himalayan blackberry	High	35
Rumex crispus	Curly dock	Limited	1
Torilis arvensis	Hedgeparsley	Moderate	1
Tragopogon dubius	Western salsify	Not listed	1

*This species was not observed during Stillwater field surveys; however Tricia Bratcher of CDFW and others have reported multiple observations of this species in Cow Creek watershed.

6.2 Priority Management Areas, Cow Creek

The preceding review of priority issues in Cow Creek watershed led us to recommend focusing restoration and/or protection of riparian vegetation in the lower reaches where observations of steelhead and Chinook have been made, including:

- Little Cow Creek
- Old Cow Creek
- South Cow Creek
- Mainstem below the South Cow Creek confluence

High summer water temperatures, low water quality, and low flows have all been listed as stressors to steelhead and fall-run Chinook in Cow Creek (NMFS 2014, SHN and Vestra 2001). Therefore recommended management actions focus on restoring or protecting existing riparian corridors to increase channel shade, floodplain connectivity, and channel structural diversity (hyporheic exchange). These vegetation-related actions will have a greater chance of improving aquatic habitat if done in concert with efforts to increase in-stream flows. More detailed descriptions of recommended actions are provided in the text below and summarized in Table 6-3 in section 6.2.5 Annotated List; locations of each recommended action are provided in a Google Earth kmz file (Cow Creek Action Reaches.kmz) and GIS shapefile that accompany this report.

6.2.1 Little Cow Creek

Chinook and steelhead have been reported up to Diddy Wells Falls along Little Cow Creek; however high stream temperatures are believed to limit both fall-run Chinook and steelhead there (SHN and Vestra 2001). Much of the channel just below Diddy Wells Falls (reach 2d in Figure 5-5) appears constrained by bedrock and offers little opportunity for development of a rich riparian corridor. However, areas below this reach could be restored to improve stream temperatures (reduce solar heating and increase hyporheic exchange) and address areas with high bank erosion. Cattle trails and low ground cover are visible along mid and lower Little Cow Creek, and we recommend working with landowners to erect fencing to exclude cattle from within 100 ft of the channel in several areas along condition reaches 2a, 2b, and 2b (Figures 6-2, 6-3 and 6-4). The floodplain and banks above and below the Dura road crossing along lower condition reach 2c also has a lower amount of riparian woody vegetation than areas upstream and downstream and increased protection and potentially planting in this area should be explored to increase channel shade and protect the existing floodplain from further suburban encroachment (Figures 6-2 through 6-4).

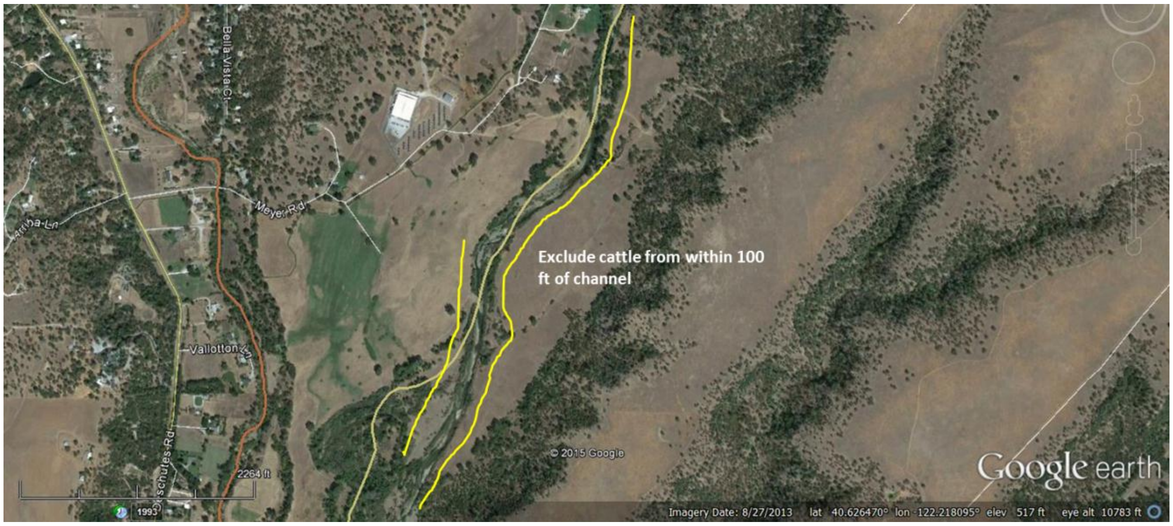

Figure 6-2. Condition reach 2a along Little Cow Creek. Recommended action is to exclude cattle from 100 ft buffer of channel.

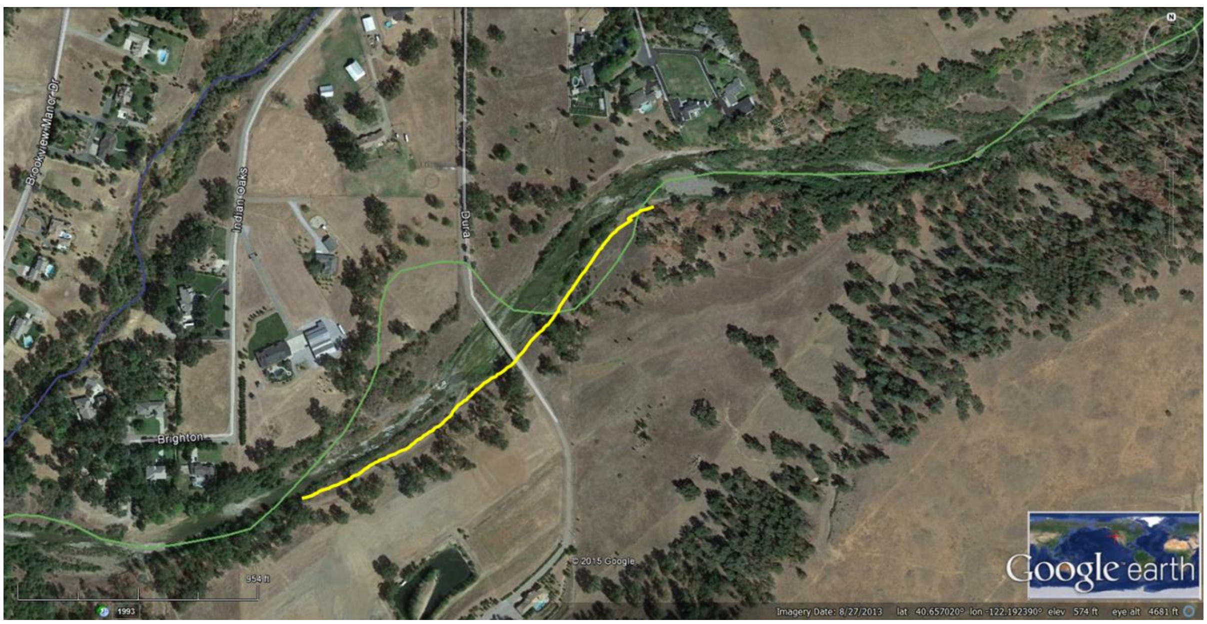

Figure 6-3. Condition reach 2c, site 1 along Little Cow Creek. Recommendation is to protect floodplain and banks and explore options to increase woody riparian cover along the south bank.

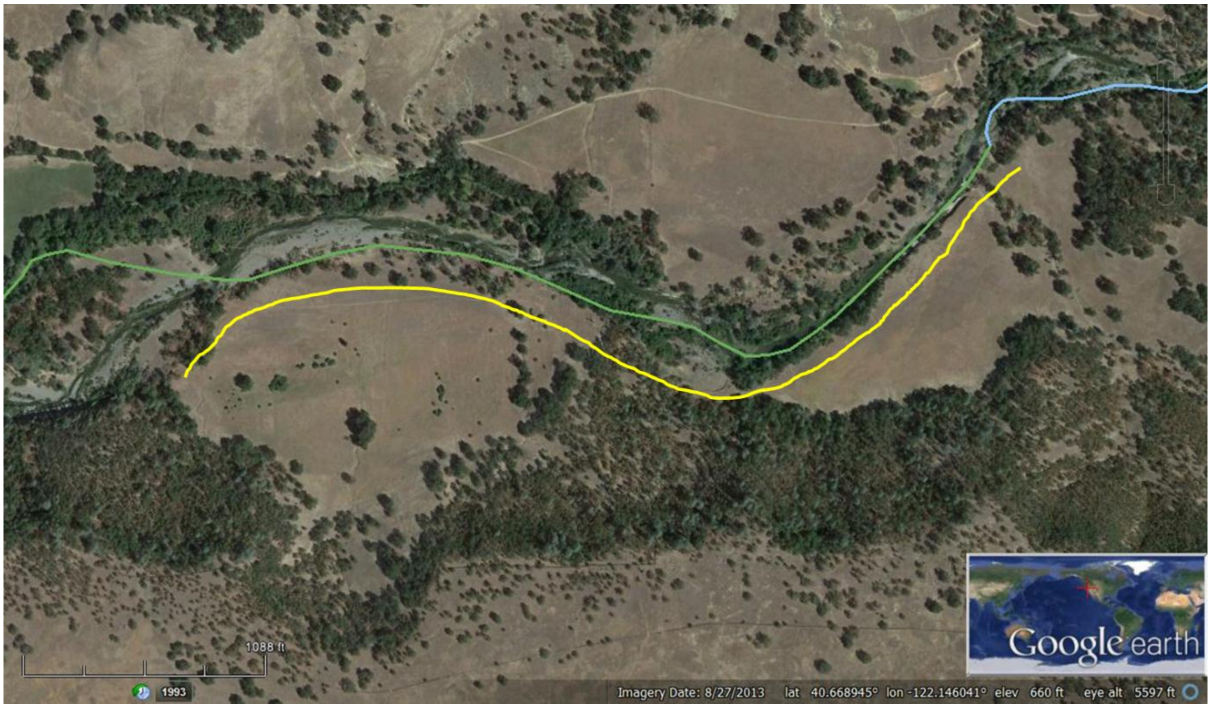

Figure 6-4. Condition reach 2c, site 2 along Little Cow Creek. Recommendation is to work with landowners to exclude cattle from within 100 ft of channel along south bank.

6.2.2 Old Cow Creek

Water temperatures are sufficiently cool for anadromous fish throughout the year in upper Old Cow Creek (NMFS 2014). Adult steelhead have been reported in Old Cow Creek below Whitmore Falls (NMFS 2014 and SHN and Vestra 2001). Areas below Whitmore Falls have much less existing riparian cover than potential; part of this low riparian vegetation cover could be recovered by cattle fencing while other areas could be more actively restored to increase floodplain connection (e.g. along reach 6b; Figures 6-5 through 6-7).

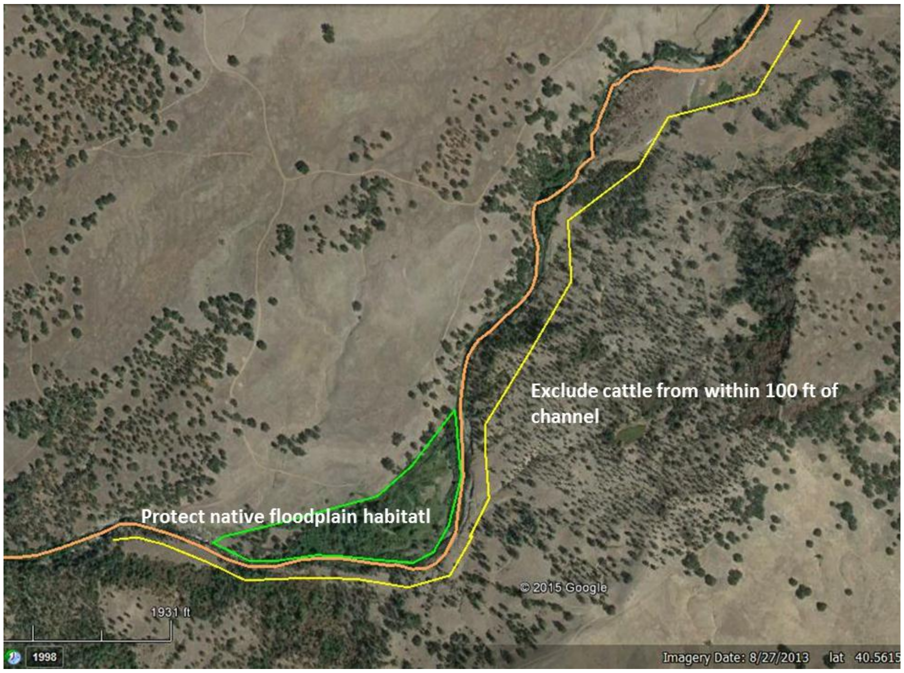

Figure 6-5. Condition reach 6a along lower Old Cow Creek. Recommendation is to exclude cattle from within 100 ft of channel on the river left (south side of channel) and to protect existing excellent floodplain habitat on a section of the river right.

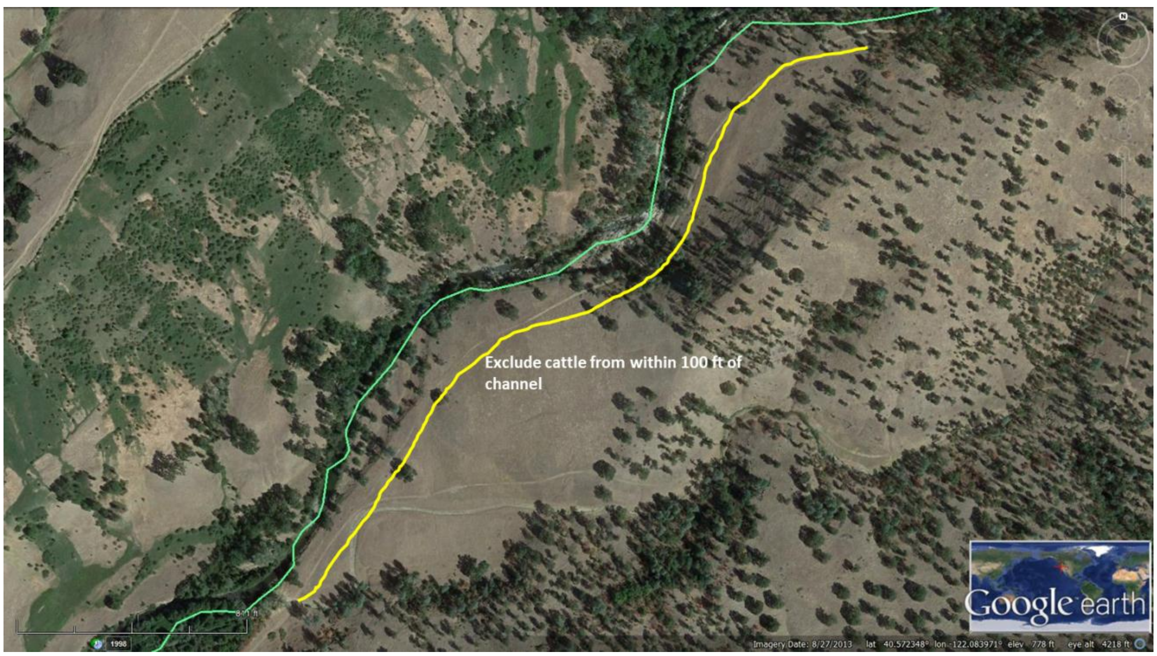

Figure 6-6. Condition reach 6b, site 1 along Old Cow Creek. Recommended action is to exclude cattle from 100 ft buffer of channel.

Figure 6-7. Condition reach 6b, sites 2 and 3 along lower Old Cow Creek. Management recommendations include excluding cattle from within 100 ft of the channel, replanting the banks with native riparian willows and oaks, and exploring options to increase floodplain connectivity along the river left.

6.2.3 South Cow Creek

Adult steelhead have been reported in South Cow Creek along a 5-mile reach located approximately 1.5 miles below the South Cow Creek Diversion Dam to about 3.5 miles above the dam (Healy 1997 as cited in NMFS 2014). Steelhead spawning has also been observed farther upstream including along Atkins Creek (SHN and Vestra 2001). Fish habitat conditions in South Cow Creek at and above Waggoner Canyon have been noted as suitable for spawning adult and rearing juvenile steelhead, and that water temperatures are sufficiently cool for anadromous fish throughout the year in upper South Cow Creek (NMFS 2014). Active diversions for agriculture and for PG&E hydropower reduce flows along the mid reaches of South Cow Creek and could importantly affect juvenile steelhead rearing in these areas (NMFS 2014; USFWS 1995). In the lower reaches farther downstream, water temperatures rise to stressful and even lethal levels between June and October, possibly constraining the period of adult up-migration (NMFS 2014).

Periods of access to South Cow Creek by salmonids could be limited due to low flows and concomitant high stream temperatures in the fall. This could be particularly true in the lowest reaches, including condition reaches 1a3, 1a4, 7a, 7b, and 7c (Figure 5-5 and Figures 6-8 through 6-17). We recommend exploring options to protect or restore active floodplains along Reaches 1a3, 1a4, and 7a, particularly where there appears to be potential for increasing juvenile rearing habitat (e.g., Figure 6-17). Other priority areas for action include the south-side banks along these reaches to increase shade and LWD recruitment into the channel (e.g. priority areas 3 and 4 along South Cow Creek condition reach 1a4 (Figure 6-10). Reaches 7b and 7c both appear to have lower vegetation cover than these areas could potentially support and we recommend working with the NRCS or RCD to develop programs that encourage ranchers to exclude cattle from a 100-ft buffer of the channel. Added riparian shade and hyporheic exchange in these areas could also reduce downstream temperatures. Reach 7c, over a mile above the Old Cow Creek confluence, appears to have the potential to provide high quality salmonid habitat that could be expanded and improved (Figures 6-12 and 6-13). We recommend building on the habitat quality in the areas downstream of the high quality habitat in Wagoner Canyon to create a core of excellent steelhead habitat along South Cow Creek (NMFS 2014; Figures 6-10 through 6-17). Other wildlife species could also benefit from such actions.

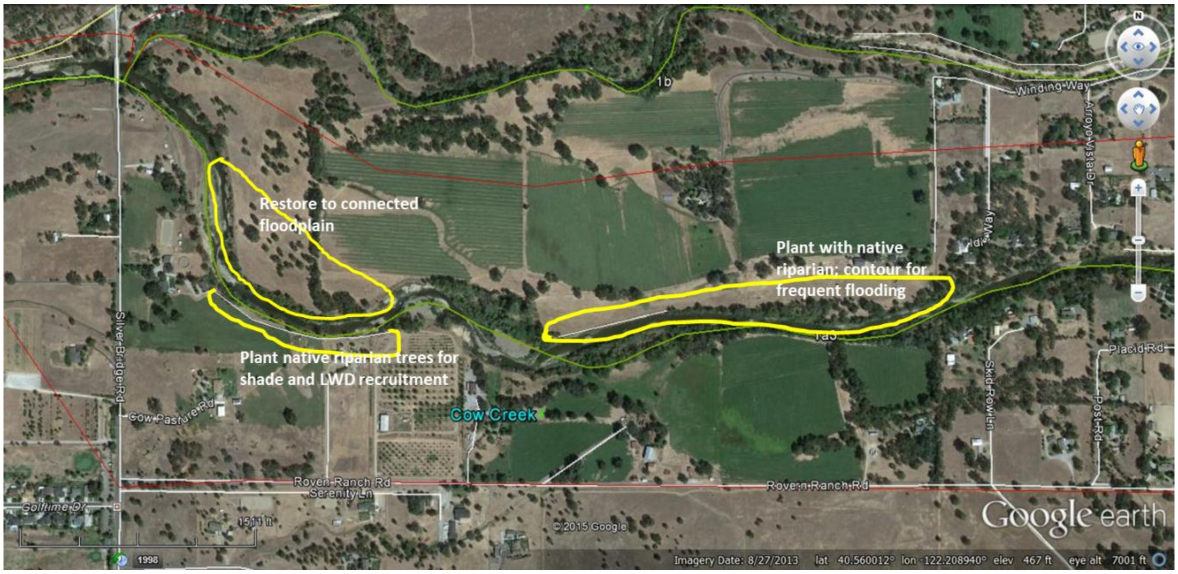

Figure 6-8. Condition reach 1a3 on South Cow Creek below Clover Creek confluence, recommended priority area sites 1, 2 and 3 (upper left, lower left, and right, respectively).

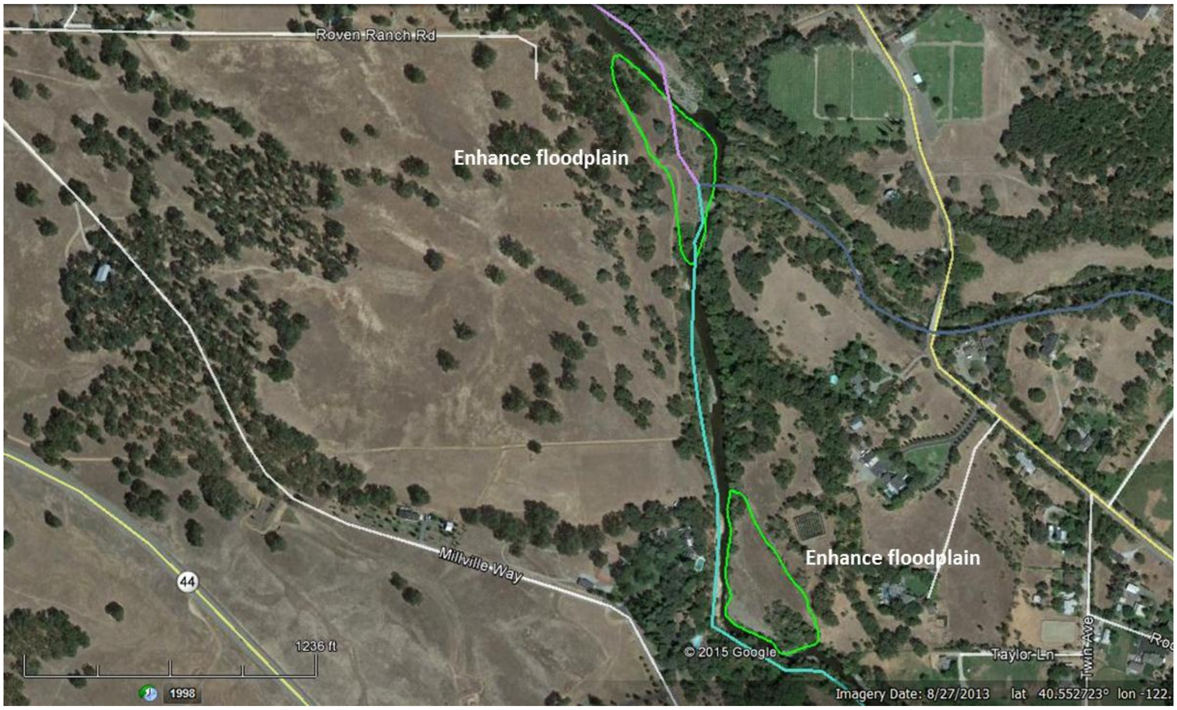

Figure 6-9. Recommended priority sites at South Cow Creek - Clover Creek confluence along condition reach 1a3 site 4 (upper site) and at Reach 1a4 site 1 (lower site).

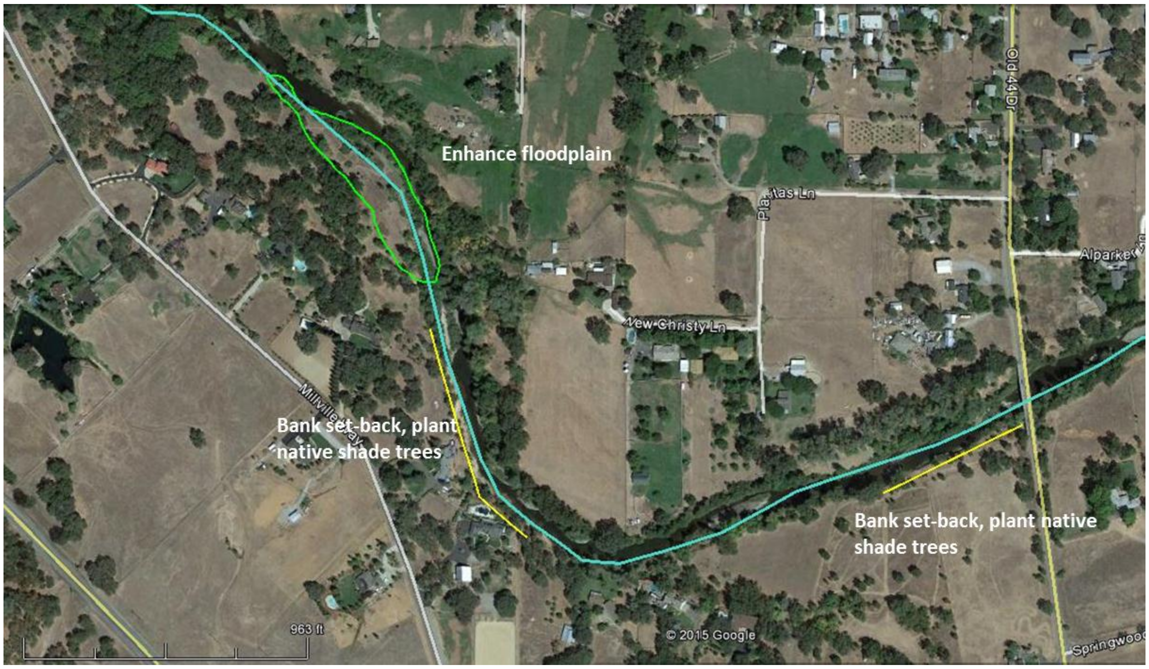

Figure 6-10. Condition reach 1a4 on South Cow Creek sites 2, 3, and 4 (left to right) recommended priority areas.

Figure 6-11. Condition reach 1a4 on South Cow Creek sites 5, 6, and 7 (left to right) recommended priority areas.

Figure 6-12. Condition reach 1a4 on South Cow Creek sites 8 and 9 (left to right) recommended priority areas.

Figure 6-13. Condition reach 7a. Recommended priority management area along South Cow Creek below Old Cow Creek confluence.

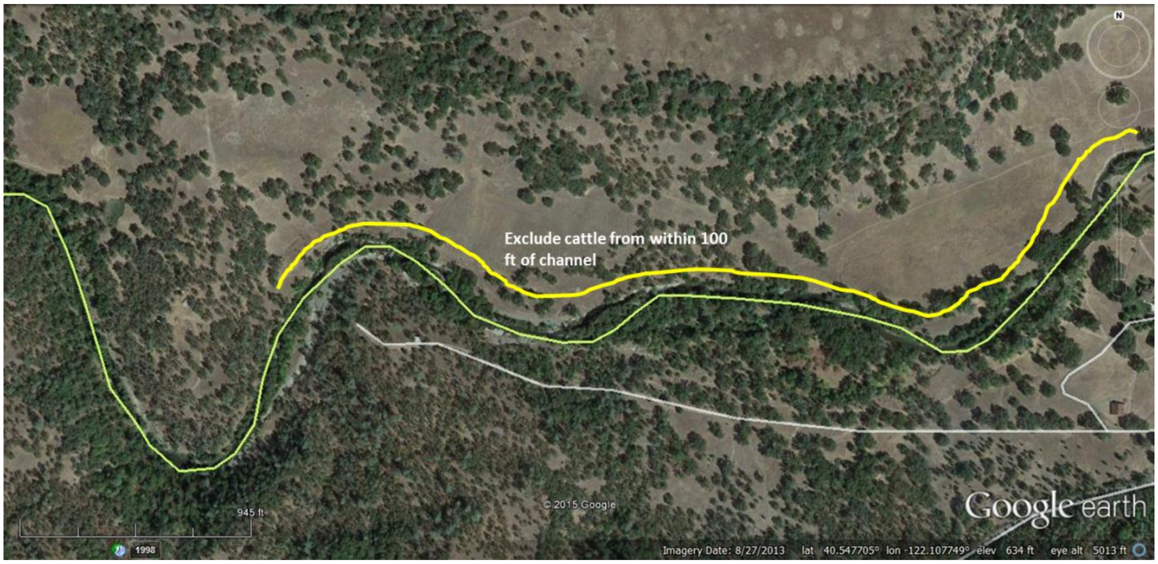

Figure 6-14. Condition reach 7b, site 1. Recommended priority management area along South Cow Creek: erect fencing to exclude cattle from within 100 ft of low flow channel on the north side of the channel to promote natural recruitment and growth of riparian trees (oaks).

Figure 6-15. Condition reach 7b, site 2 along South Cow Creek upstream of Old Cow Creek Confluence. Recommended priority management actions include excluding cattle from within 100 ft of channel and exploring options to increase river left floodplain connectivity.

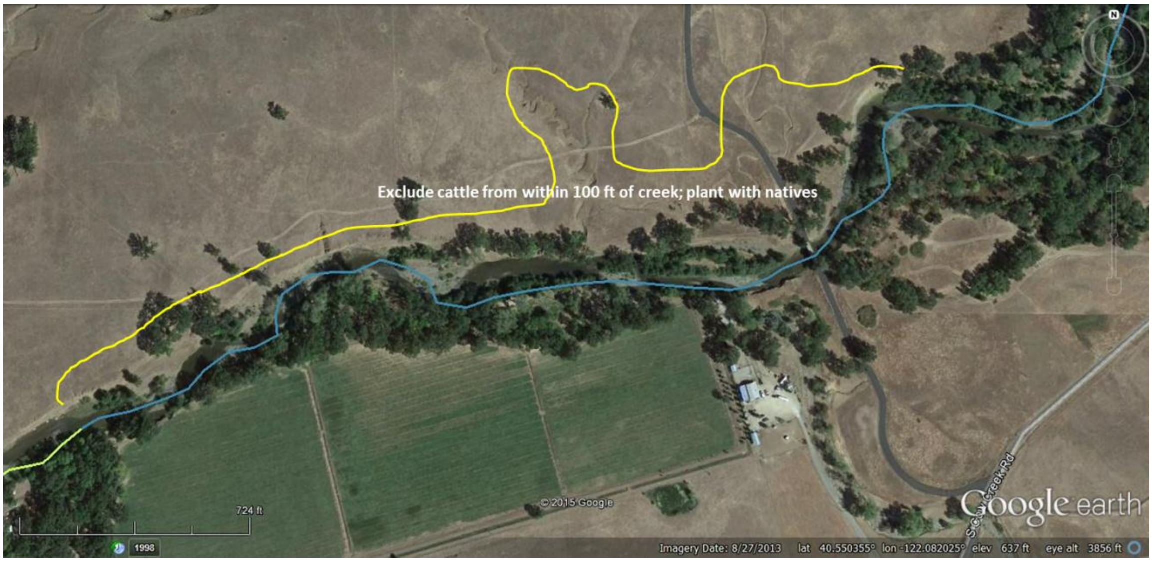

Figure 6-16. Condition reach 7c, site 1 along South Cow Creek above Old Cow Creek confluence. Recommended action is to exclude cattle from within 100 ft of channel on river right.

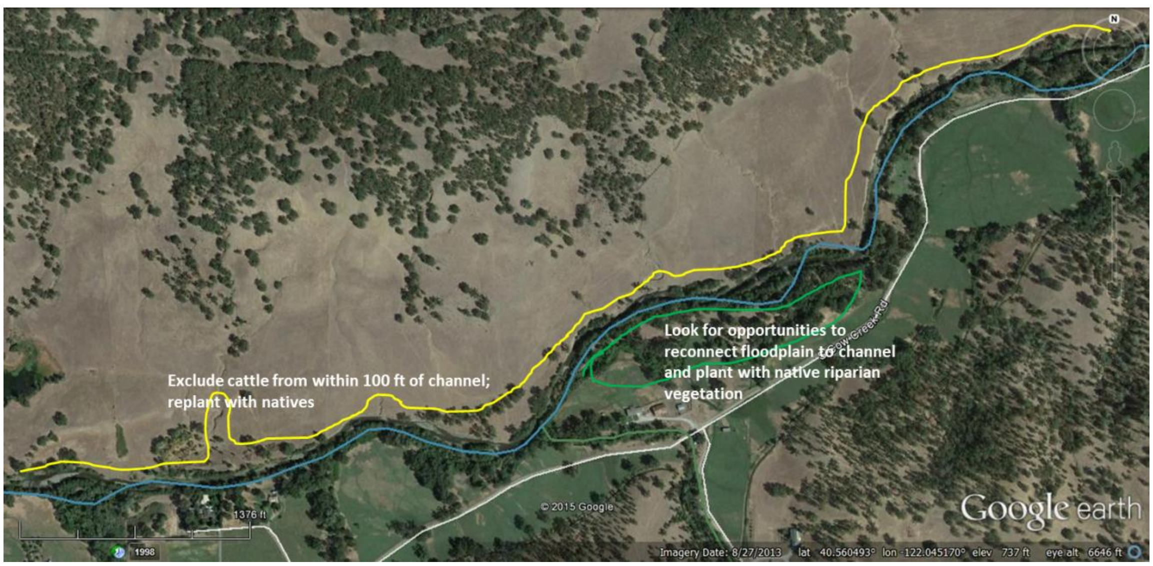

Figure 6-17. Upper condition reach 7c, site 2 along South Cow Creek above Old Cow Creek confluence. Recommended action is to exclude cattle from within 100 ft of channel on river right and explore opportunities to increase floodplain connectivity along river left.

6.2.4 Cow Creek mainstem

The high temperatures reported for mainstem Cow Creek and the lower tributaries (e.g. below ~1,000 ft elevation) are a significant limiting factor for anadromous salmonids (Reynolds et al. 1993, Thompson et al. 2006), likely constraining the steelhead and Chinook outmigration period to fall through late spring (perhaps early spring in warm, drought years). Steelhead and, if present, spring-run Chinook would benefit from restoration and protection of the mainstem because improved conditions could extend the period when spring-run Chinook immigrate into Cow Creek and the period when both species emigrate out to the ocean (to include early summer months, currently precluded by temperature). Currently, individuals hatched in the mainstem or lower tributary reaches must either move farther upstream past the partial fish barriers to cooler waters, out-migrate as 'young of the year', or risk mortality associated with excess heat in the lower reaches over the summer months. Those juveniles that emigrate at age 0+ (in their first year of life) are at a disadvantage since the likelihood of their survival to adulthood and their return as spawners is substantially lower than juveniles that emigrate at an older age and larger body size (Kabel and German 1967, Hume and Parkinson 1988, Ward et al. 1989). Therefore, to increase the self-sustaining population of fall-run Chinook and steelhead in Cow Creek, spawning and rearing conditions and the migratory corridor to and from these areas need to be restored. Such an approach should combine increased in-stream summer flows, increased thermal insulation and buffering, and protects and/or increases aquatic habitat diversity in focal fall-run Chinook spawning areas and rearing areas for fall-run Chinook, spring-run Chinook, and steelhead and an associated migratory corridor. Improved riparian and aquatic habitat conditions along the mainstem, South Cow Creek and Little Cow Creek would help meet this objective.

Mainstem Cow Creek downstream of the South Cow Creek confluence (7.4 river miles, primarily south of the Highway 44 bridge) includes condition reaches 1a1a through 1a1g (Figure 5-5) and provides important spawning habitat for fall-run Chinook salmon and potentially late fall-run Chinook salmon, as well as a passage corridor for steelhead and potentially spring-run Chinook salmon, but is in relatively poor condition (SHN and Vestra 2001). Because it provides ingress and egress to ht rest of Cow Creek, improving conditions of mainstem below the South Cow Creek confluence would support all of the anadromous fish populations using Cow Creek watershed.

More information on anadromous fish use of Cow Creek above Highway 44 is needed (Pipal 2005, NMFS 2014); however based on existing information, mainstem Cow Creek above Highway 44 to the Little Cow Creek confluence (4.5 river miles) is used as a migration corridor for steelhead using Little Cow Creek and as spawning habitat for fall-run Chinook (Reynolds et al. 1993, SHN and VESTRA 2001). Protecting and restoring aquatic and riparian habitat in these reaches would therefore support those steelhead and fall-run Chinook that use the upper mainstem and Little Cow Creek for spawning and/or rearing. Current information on anadromous fish use of Cow Creek mainstem above the South Cow Creek confluence and of Little Cow Creek would be extremely useful for establishing restoration priorities in these reaches.

Mainstem Cow Creek below the Little Cow Creek confluence is currently in moderate to poor condition, and under the current trajectory, likely to continue to degrade in the coming decades as urban and suburban development continues. Mainstem Cow Creek south of Highway 44 in particular has segments with relatively broad floodplain inundation, dynamic fluvial processes, and the potential for natural riparian recruitment; all characteristics that are of high value to salmonid populations in the watershed. These areas are being impacted by watershed disturbances (e.g., increased runoff and increased sediment supply from fire and encroaching development). Many areas of the mainstem flow over sedimentary bedrock, which resists downward incision and forces channel widening by bank erosion. This has led some land owners to accelerate hardening of the channel margins through riprap and other means to protect developed agricultural and residential lands. Many areas could be protected or restored to create patches of higher quality habitat; a few examples of such locations are presented in Figure 6-18. However, without a broader plan, increasing development along the mainstem near Palo Cedro and Bella Vista could continue to constrain and degrade the existing riparian and aquatic habitat and isolated patches of restored habitat would provide diminishing benefit. A plan that incorporates natural fluvial and vegetation dynamics and fish habitat requirements into land use planning and restoration is needed to develop a viable strategy for protecting and improving upon the important habitat along the Cow Creek mainstem while also accommodating the surrounding human communities.

Figure 6-18. Condition reach 1a sites 3 and 4 (left), and 7 and 8 (right) along lower Mainstem Cow Creek. These are examples of areas where existing floodplains could be protected and enhanced, and eroding channel banks set back and or planted, according to findings on local processes and needs.

Since the area around Cow Creek mainstem is under development pressure and ongoing land use change, we recommend working with county and city governments to develop zoning protections for existing and potentially restored riparian habitat. We also recommend an assessment of the Cow Creek mainstem to develop the information base necessary for prioritizing more specific areas and actions for aquatic and riparian habitat protection through easements, fencing, or active restoration. Information needed for targeting priority parcels and actions includes clear articulation of the river meander belt, rates of incision and channel bank erosion, distribution and diversity of in-stream and floodplain habitat. This study would provide a baseline for moving forward in developing an effective integrated strategy for the Lower Cow Creek area.

6.2.5 Annotated List of Recommended Action Areas along Cow Creek

The annotated list of priority reaches and potential management target outcomes for Cow Creek is provided in Table 6-3 below. This table is a summary of particular areas described within each reach where actions are recommended. The specific reach locations and action areas within these reaches are included in a Google Earth (kmz) and a GIS layer that accompany this report. The same spatial data set submitted with this report includes a layer with parcel ownership information obtained from the County.

Table 6-3. Recommended priority riparian vegetation management areas for Cow Creek watershed project area, organized by Condition Reach (see Figure 5-5 for reach locations). 1 = Poor, 2 = Fair, 3 = Good, 4 = Excellent.

Reach code	Condition score	Recommendation
1a	1 to 1.5	Lower Mainstem Many areas could be protected or restored to create patches of high quality aquatic habitat; however this area should be studied to better understand the geomorphic processes controlling the overall structure and dynamics of the river corridor in response to upstream and downstream changes (see text). The locations specified below are examples of where actions might be appropriate. Land use planning, including efforts to protect existing functional floodplains and policies to limit development (buildings) within 100 ft of the channel, is recommended. • **Site 1a1-site 1:** Just below Highway 44 crossing. Protect and increase floodplain connectivity to help maintain cooler waters and diverse aquatic habitat structure (LWD inputs) and to reduce channel bank erosion. • **Site 1a2-site 2:** Address steeply eroding banks and lack of bank shade cover and LWD recruitment potential by setting back banks where appropriate and feasible and planting native riparian vegetation. • **Site 1a1-site 3:** Assess existing floodplain connectivity and scour processes to determine site needs to restore native riparian vegetation, where appropriate. • **Site 1a2-site 4:** Address steeply eroding banks and lack of bank shade cover and LWD recruitment potential by setting back banks where appropriate and feasible and planting native riparian vegetation. • **Site 1a2-site 5:** Protect and increase floodplain connectivity where feasible and appropriate; plant upper banks for shade, terrestrial habitat and LWD recruitment • **Site 1a1-site 6:** Address steeply eroding banks and lack of bank shade cover and LWD recruitment potential by setting back banks where appropriate and feasible and planting native riparian vegetation. • **Site 1a1-site 7:** Protect and increase floodplain connectivity where feasible and appropriate; plant upper banks for shade, terrestrial habitat and LWD recruitment. • **Site 1a1-site 8:** Address steeply eroding banks and lack of bank shade cover and LWD recruitment potential by setting back banks where appropriate and feasible and planting native riparian vegetation.
1a3	2	Lower South Cow Most of this reach would benefit from fencing to preclude cattle from grazing within 100 ft of the low flow channel. • **Site 1a3-1:** Reconnect larger portion of floodplain to increase extent of frequently flooded area, replant with natives where necessary. • **Site 1a3-2:** Address steeply eroding banks and lack of bank shade cover and LWD recruitment potential by setting back banks where appropriate and feasible and planting native riparian vegetation. • **Site 1a3-3:** Reconnect larger portion of floodplain to increase extent of frequently flooded area, replant with natives where necessary. • **Site 1a3-4:** At confluence with Clover Creek; reconnect floodplain, replant with natives where necessary.

Reach code	Condition score	Recommendation
1a4	2	Lower South Cow Most of this reach would benefit from fencing to preclude cattle from grazing within 100 ft of the low flow channel and from local planning policies to limit development (buildings) within 100 ft of the channel. • **Site 1a4-1:** Reconnect larger portion of floodplain to increase extent of frequently flooded area, replant with natives where necessary. Plant upper banks with natives to create wider corridor, habitat, and LWD recruitment. • **Site 1a4-2:** Protect and reconnect larger portion of floodplain to increase extent of frequently flooded area, replant with natives where necessary. Plant upper banks with natives to create wider corridor, habitat, and LWD recruitment. • **Site 1a4-3:** Address steeply eroding banks and lack of bank shade cover and LWD recruitment potential by setting back banks where appropriate and feasible and planting native riparian vegetation. • **Site 1a4-4:** Address steeply eroding banks and discontinuous bank shade cover and LWD recruitment potential by setting back banks where appropriate and feasible and planting native riparian vegetation. Limitation of cattle and OHV access might also be considered. • **Site 1a4-5:** Address steeply eroding banks and lack of bank shade cover and LWD recruitment potential by setting back banks where appropriate and feasible and planting native riparian vegetation. • **Site 1a4-6:** Protect and reconnect floodplain to increase extent of frequently flooded area, replant with natives where necessary, plant upper banks with native vegetation. • **Site 1a4-7:** Protect and reconnect floodplain to increase extent of frequently flooded area, replant with natives where necessary, plant upper banks with native vegetation. • **Site 1a4-8:** Protect and reconnect floodplain to increase extent of frequently flooded area, replant with natives where necessary, plant upper banks with native vegetation.
7a	2.5	South Cow Creek This reach provides access to high quality habitat upstream and is currently degraded below potential likely due to long-term grazing activity up to the channel edge. Bank and surface erosion were also observed. We recommend exclusion fencing and water and salt resources be placed in uplands to keep cattle outside of 100-ft buffer of channel. This will allow natural regeneration of riparian vegetation, thereby increasing shading (cool waters), reducing fine sediment inputs, and increasing aquatic habitat complexity (LWD). • **Site 7a-1:** Protect and reconnect floodplain to increase extent of frequently flooded area, replant with natives where necessary, plant upper banks with native vegetation, work with landowners to exclude cattle from within 100 ft of channel.
7b	2.5	South Cow Creek This reach also provides access to high quality habitat in reach 7c and is currently degraded below potential likely due to long-term grazing activity up to the channel edge. Bank and surface erosion also were observed. Exclusion fencing and water and salt resources placed in uplands is recommended to keep cattle outside of 100-ft buffer of channel to allow for natural regeneration of riparian vegetation. This would provide shading (cool waters), reduced fine sediment inputs, and increased aquatic habitat complexity (LWD). • **Site 7b-1:** Work with landowners to exclude cattle from within 100 ft of channel, assess reach to consider planting and other actions to reduce

Reach code	Condition score	Recommendation
		erosion into channel and increase channel shade. • **Site 7b-2:** Work with landowners to exclude cattle from within 100 ft of channel, assess reach to consider planting and other actions to reduce erosion into channel and increase channel shade.
7c	2.5	<u>South Cow Creek</u> Build upon existing high quality habitat to create very rich reach to support larger salmonid population(s). Roughly half of potential riparian vegetation is present; we recommend supporting development of riparian vegetation, as well as addressing severe bank erosion on river right. Methods to address these concerns could include exclusion fencing for 100+ ft buffer, with possible active planting along some of banks. This reach could be elevated to focal area for conservation easements because it provides good habitat and passage to additional habitat in reach 7d and 7e (Wagoner canyon). • **Site 7c-1:** Work with landowners to exclude cattle from within 100 ft of channel, assess reach to consider planting and other actions to reduce erosion into channel and increase channel shade. • **Site 7c-2:** Work with landowners to exclude cattle from within 100 ft of channel, assess reach to consider planting and other actions to reduce erosion into channel and increase channel shade. • **Site 7c-3:** Work with landowners to exclude cattle from within 100 ft of channel, assess reach to consider if actions needed to increase floodplain connectivity and/or to enhance native riparian vegetation.
6a	2.5	<u>Lower Old Cow Creek</u> Downstream half of this reach appears to have higher potential condition than currently observed. Himalayan blackberry control needed in areas. • **Site 6a-1:** Riparian enhancement might be achieved with exclusion fencing and possible active planting along southern and eastern banks to maintain cool stream temperatures later in season. Steep cut banks could be set back and planted. • **Site 6a-2:** Existing floodplain forest appears in good shape and we recommend protection from any future changes as well as exploration of this area as possible reference site for other floodplain restoration efforts.
6b	2.5	<u>Lower Old Cow Creek</u> Downstream half of this reach appears to have higher potential condition than currently observed. Himalayan blackberry control is needed in areas. Riparian enhancement might be achieved with exclusion fencing and possible active planting along southern and eastern banks to maintain cool stream temperatures later in season. Increased floodplain connection and exclusion fencing could also reduce fine sediment input. Steep cut banks could be set back and planted. Similar recommendations apply for the upper extent of reach 6a. • **Site 6b-1:** Riparian enhancement might be achieved with exclusion fencing and possible active planting along southern and eastern banks to maintain cool stream temperatures later in season. • **Site 6b-2:** Work with landowners to exclude cattle from within 100 ft of channel, assess reach to consider if actions needed to increase floodplain connectivity and/or to enhance native riparian vegetation. • **Site 6b-3:** Riparian enhancement might be achieved with exclusion fencing and possible active planting along southern and eastern banks to maintain cool stream temperatures later in season.
2a	1.5	<u>Lower Little Cow Creek</u> Bank erosion is visible along many areas of this reach, and cattle trails leading up to and along the channel bank suggests that grazing impacts could limit

Reach code	Condition score	Recommendation
		growth and survival of naturally recruited riparian trees and shrubs. Increasing the frequency of lateral flooding could also help to buffer stream temperatures; this appears physically feasible in the lower portions of reach. • **Site 2a-1:** Recommend increasing shade and decreasing bank erosion through exclusion fencing, some replanting, setting back and planting cut banks. • **Site 2a-2:** Recommend increasing shade and decreasing bank erosion through exclusion fencing, some replanting, setting back and planting cut banks.
2c	2.5	Little Cow Creek Reach has wide potential meander belt and offers opportunity to build upon the existing habitat to develop a productive reach with a rich riparian forest. Increased hyporheic exchange and channel shade in this area could help to maintain cool water temperatures. • Site 2a-1: Recommend increasing shade and decreasing bank erosion through exclusion fencing, some replanting, setting back and planting cut banks. • Site 2a-2: Recommend increasing shade and decreasing bank erosion through exclusion fencing, some replanting, setting back and planting cut banks.

6.3 Mill Creek: Priority Issues

Mill Creek supports anadromous fish and California foothill yellow-legged frog as aquatic and riparian dependent species. NMFS has identified three key stressors for Central Valley spring-run and Central Valley steelhead in Mill Creek (NMFS 2014): (1) elevated water temperatures that affect adult immigration and holding; (2) low flows that affect attraction and migratory cues of immigrating adults, and (3) possible catastrophic events such as wildfire in the contributing area.

6.3.1 Fisheries

Spring-run and fall-run Chinook, steelhead, and Pacific lamprey occur in Mill Creek, which has no major water impoundments along its length. Aquatic habitat in Mill Creek, along with Deer and Butte Creeks, is considered essential for recovery of wild stocks of spring-run Chinook salmon (NMFS 2014, Reynolds et al. 1993; McEwan and Jackson 1996, as cited in USDA Forest Service 1998). High quality holding and spawning habitat for spring-run Chinook occurs in high elevations along Mill Creek, which are isolated from fall-run Chinook salmon by low flows during late summer and fall (NMFS 2014). Spring-run Chinook and steelhead are able to use nearly the entire length of the river, 58 miles, for one or more life-history stage (USDA Forest Service 1998). However, spring-run Chinook escapement estimates have dropped precipitously since the mid-1970's, except for a temporary increase in the reported population between 2001 and 2005, and declines in the past three years are of concern (NMFS 2014, Appendix A, pg. 106). Spring-run Chinook migrate upstream in the spring to reaches as high as 5,000 ft above sea level (USDA Forest Service 1998 and NMFS 2014), where they remain through the summer months until they spawn in late summer/early fall (late August through mid-October). Juveniles out-migrate six to 18 months after hatching. Mill Creek hosts the highest elevation spawning population of spring-run Chinook reported in California (USDA Forest Service 1998). Fall-run Chinook migrate upstream to spawn in the fall, but do not swim as far upstream as the spring-run Chinook (USDA Forest Service 1998). Superimposition of spring-run and fall-run Chinook redds is minimized in Mill Creek by thermal barriers that prevent fall-run Chinook from accessing the higher reaches occupied by spawning spring-run Chinook (NMFS 2014).

All life-history stages of steelhead are also supported along the lower 25 mi of Mill Creek (NMFS 2014). Extensive spawning and rearing habitat for steelhead is available in this watershed.

Stream reaches below the Upper Diversion and Ward Dam, including condition reaches 1a, 1b, and 1c, are most critical for maintaining healthy salmonid fish populations in Mill Creek because these three miles of river need to offer spring, summer and fall flows that support spring-run and fall-run Chinook and steelhead life history stages (NMFS 2014, Harvey-Arrison 2009). According to the NMFS recovery plan (NMFS 2014), the primary restoration focus in Mill Creek for spring-run Chinook should be on "maintaining flow conditions for upstream migrating adults so they can access important holding and spawning habitat (Mills and Ward 1996) and for out-migrating fry." Moreover, expected temperature increases due to climate change could make these accessible upper (cooler) reaches even more important than they already are for the continued survival of the species (Lindley et al. 2007).

6.3.2 Water flow and water quality concerns

Flows and temperature: Below the canyon mouth, Mill Creek has two existing diversion dams since a third, Clough diversion dam, was removed in 1997 (Figure 1-2; NMFS 2014). However these lower creek diversions are not considered 'major impediments for fish passage' since they have fish ladders. Nevertheless, late spring and early summer diversions can result in in-stream flows low enough to block access for late-migrating adult spring-run Chinook salmon. Low flows also prevent downstream migrating smolts from reaching the Sacramento River (CDFW 1996). Earlier evaluations of Sacramento Valley anadromous fishery resources (CDFW 1993, USFWS 1996, CDFW 1996) consistently identified low flows as one factor potentially limiting anadromous fish production in the watershed.

High summer water temperatures below approximately 1,000-ft elevation, due in part to low summer flows, are also a factor blocking fall-run Chinook from migrating into the mid and upper reaches of Mill Creek during and after the spring-run Chinook spawning period. This thermal barrier is believed to minimize redd superimposition between the two populations (NMFS 2014, USDA Forest Service 1998). Higher stream temperatures below the Upper Diversion could occur with reduced flows due to withdrawals and /or due to lower precipitation in the contributing area associated with with climate change; higher stream temperatures could also occur because of higher air temperatures associated with climate change (NMFS 2014).

Increased upstream shading and hyporheic exchange with connected floodplains could insulate cool waters entering these lower reaches, and thereby could help mitigate effects of increased stream water temperatures associated with lower flows.

Sediment: Rhyolitic soils in the mid and lower portions of this creek have high erosion rates which can be a significant source of sediment input to streams (USDA Forest Service 1998). Surface erosion is reported to have increased 'substantially' in this watershed (USDA Forest Service 1998) and roads on rhyolitic soils have been identified as important sediment sources (Meadowbrook 1997). However, many of the Forest Service roads have been decommissioned in recent years (NMFS 2014). Increases in fine sediment inputs to the channel have been "minor" (USDA Forest Service 1998). However, fine sediment in gravels has been observed along the lower three miles of Mill Creek and was identified as a problem for salmon spawning there (CH2M HILL 1997, Kondolf et al. 2001). Kondolf et al. (2001) identified the north bank downstream of Highway 99 as being particularly vulnerable to flooding and bank erosion. Additional surface erosion due to roads, intensive grazing, and other human land uses has increased and thereby added to the overall sediment input rates to the channel (USDA Forest Service 1998). Importantly, catastrophic wildfires, or even relatively small wildfires located near or along the stream channel could result in large amounts of sediment input through mass wasting. As stated in the recovery plan for Central Valley Chinook and Steelhead (NMFS 2014), this kind of event "could potentially devastate the fishery." Although this document is directed towards management within the riparian corridor, the importance of managing upland forests to minimize risk of large wildfire and its potential effects on the stream ecology seems worth repeating.

6.3.3 Wildlife

Wildlife in Mill Creek includes peregrine falcons, bald eagles, California spotted owls and willow flycatchers (USDA Forest Service 1998). Within the riparian corridor, Cascades and foothill yellow-legged frogs (*Rana cascadae* and *R. boylii*) forage and bask along the mainstem and could use tributaries and backwaters for reproduction (USDA Forest Service 1998). The western pond turtle (*Emys marmorata*) could also occur in areas of Mill Creek watershed (USDA Forest Service 1998). Improved riparian vegetation could increase cover and create quiet back waters that would provide high quality habitat for the California yellow-legged frog. Bank swallow (*Riparia riparia*), a state threatened species, is known to nest in the lower mile of Mill Creek (Tricia Bratcher, CDFW, Pers comm).

Populations of willow flycatchers (*Empidonax traillii*) have been recently documented in adjacent watersheds (Spencer Meadows and Gurnsey Creek) (USDA Forest Service 1998), and Mill Creek is within the historical range of this species. Willow thickets and stringers in mountain meadows provide habitat for this listed species. Cowbirds, associated with rangelands, negatively impact willow flycatchers (USDA Forest Service 1998). Healthy meadow riparian areas with water tables near the surface through June can be managed or restored within Mill Creek. Range allotments could be managed to ensure that grazing does not occur during the willow flycatcher breeding season and to ensure that willow thickets are protected from browsing, since dense canopies below four feet are an important part of the species' habitat.

6.3.4 Invasive non-native plants found in riparian areas

Descriptions of weed species in Mill Creek were not found in any of the existing materials; however we observed a number of invasive non-native plants during the 2013 field surveys, and these are listed in Table 6-4 below. Himalayan blackberry was by far the most prevalent.

Table 6-4. Invasive weeds observed in Mill Creek project area.

Scientific name	Common name	Cal IPC rank	Number of observations in Mill Creek
Arundo donax	Giant reed or *Arundo*	High	2
Centaurea solstitialis	Yellow star thistle	High	4
Cynodon dactylon	Bermuda grass	Moderate	1
Ficus carica	Fig	Moderate	2
Robinia pseudoacacia	Black locust	Limited	1
Rubus armeniacus	Himalayan blackberry	High	20
Torilis arvensis	Hedge parsley	Moderate	2

6.4 Priority Management Areas, Mill Creek

Primary actions suggested in the Recovery Plan for Mill Creek include actions to improve conditions in the reaches below the Upper Diversion Dam near where the creek emerges from the canyon to where it flows into the Sacramento River (NMFS 2014). Stream temperatures and in-stream flows below the mouth of the canyon (500 ft above MSL) could limit spring-run Chinook salmon during late spring migration and the summer holding period (NMFS 2014, Reynolds et. al. 1993; McEwan and Jackson 1996; Harvey-Arrison 2009). Cooperative programs to develop alternative irrigation water sources (e.g., wells) or to obtain alternative water rights to reduce withdrawals during the spring and fall have been implemented with local landowners in Mill Creek, the Los Molinos Irrigation District, the Mill Creek Conservancy, DWR and CDFW (NMFS 2014). Also, we recommend eradicating or controlling invasive non-native plant species, particularly Himalayan blackberry and *Arundo*, that threaten the structural and species diversity of the riparian corridor in the lower reaches. Finally, we recommend increased attention towards some of the meadows and areas experiencing high sediment input rates in some of the upper reaches of the watershed. Specific recommendations for actions to protect, enhance or increase riparian vegetation and habitat quality are described in the text below and summarized in Table 6-5 at the end of this section. Locations of recommended action areas in Mill Creek are provided in the Google Earth kmz file (Mill Creek Action Reaches.kmz) and GIS shape file that accompany this report.

6.4.1 Lower Reaches of Mill Creek

Low flows and associated high water temperatures have been identified as limiting salmonid migration between the Upper Diversion and the Sacramento River confluence and efforts to maintain or increase flows during critical periods are recommended in the Recovery Plan (NMFS 2014). The riparian corridor in these lower reaches can also be restored to improve conditions for migrating salmonids through improvements in the structure and composition of riparian vegetation and floodplain that would insulate the channel from solar heating and provide thermal buffering. For example, the period when stream water temperatures are cool enough for spring-run Chinook to migrate up Mill Creek could be extended (or maintained in the face of on-going climate change) with more shade that blocks solar energy from entering the channel (thermal insulation), particularly along the southern river banks. Buffers store heat in the continuous groundwater-surface water system and 'level' the heat load over time and space (Poole and Berman 2001). In many rivers the hyporheic zone, the saturated alluvium around the channel bed, is the most important thermal buffer (Naiman et al. 2005). Restoring floodplain connectivity, sinuosity, and in-stream structural diversity can increase hyporheic exchange and improve thermal buffering (Poole and Berman 2001). For example, surface water enters and exits the hyporheic zone at riffle heads and tails and above and below log jams. Increased hyporheic thermal buffering also occurs with increased stream sinuosity where surface waters enter and exit the hyporheic zone at the top and bottom of meander bends, through abandoned side channels, and preferential flowpaths along old channels and active floodplains (Naiman et al. 2005). Increased channel complexity and sinuosity through floodplain restoration projects would increase thermal buffering in the reaches downstream of the Upper Diversion. Increased floodplain area would also provide additional habitat for juvenile rearing in these reaches. Finally, restored riparian vegetation and increased floodplain connectivity in the reaches below the canyon mouth can reduce bank and surface erosion that result in elevated fine sediment inputs.

Recommended priority areas to protect, enhance, and /or restore along condition reach 1a, between Highway 99 and the Sacramento River are pictured in Figures 6-19 and 6-20.

Figure 6-19. Mill Creek condition reach 1a sites 1 and 2 (lower and upper, respectively). (Google imagery date 8/27/2013)

Figure 6-20. Mill Creek condition reach 1a sites 3 and 4 (lower and upper, respectively). (Google imagery date 8/27/2013)

Recommended priority areas to protect, enhance, and /or restore along condition reach 1b, upstream of Highway 99 to where the northern distributary diverges from the mainstem (near Billberry Street), are pictured in the Figures 6-21 and 6-23.

Figure 6-21. Mill Creek condition reach 1b site 1. *Arundo* eradication and enhancement of existing native riparian vegetation is recommended. (Google imagery date 8/27/2013)

Figure 6-22. Mill Creek condition reach 1b site 2, with recommendations to enhance existing vegetation and to eradicate invasive weeds (A*rundo* locations shown with red pins). (Google imagery date 8/27/2013)

Figure 6-23. Mill Creek condition reach 1b sites 3 and 4 (left and right polygons, respectively). Planting native trees for shade recommended at site 3, and enhancement of existing native riparian vegetation recommended for site 4, including weed eradication (*Arundo* locations shown with red pins). (Google imagery date 8/27/2013)

Above the North Mill Creek Distributary along condition reach 1c, there is a large area with intact riparian vegetation just below the lower diversion that we recommend be protected and enhanced as found appropriate following closer study. This area is pictured in Figure 6-24 below.

Figure 6-24. Mill Creek condition reach 1c site 1, with recommendations to enhance existing vegetation and to eradicate invasive weeds (*Arundo* locations shown with red pins). (Google imagery date 8/27/2013)

Farther upstream in condition reach 2, natural streamside vegetation becomes increasingly sparse. However we suggest considering planting native oaks or similarly appropriate native trees along the south stream banks to provide channel shade. This will help keep the water entering the most temperature-impacted portions of the creek as cool as possible and the trees will provide recruitment material for instream LWD. These recommended locations are pictured in Figures 6-25, 6-26, and 6-27.

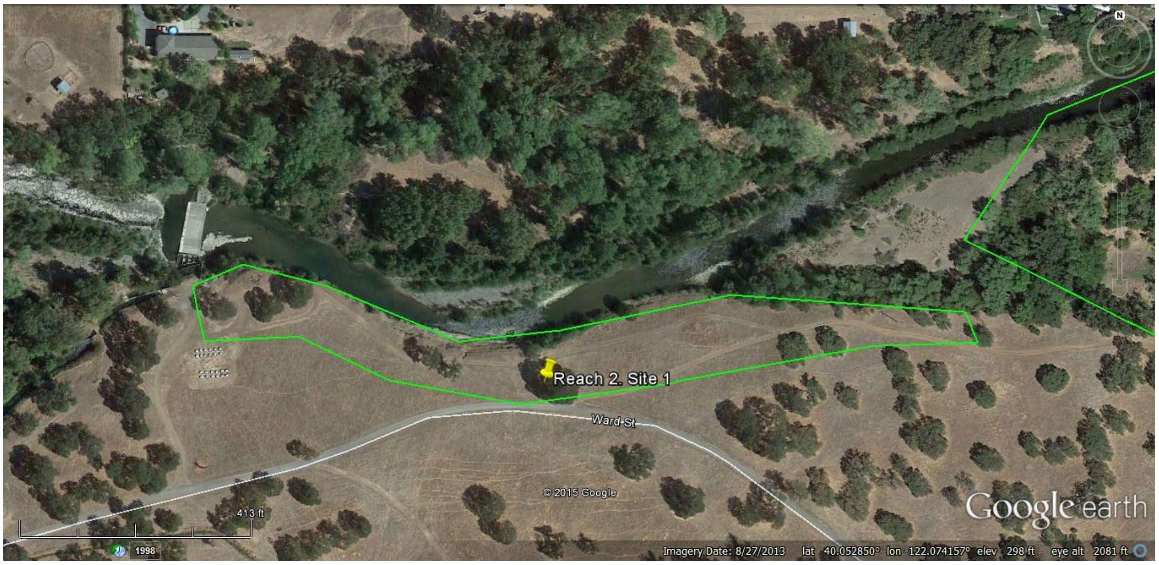

Figure 6-25. Mill Creek condition reach 2 site 1, with recommendations to enhance existing vegetation, work with the landowner to exclude grazing from within 100 ft of the channel edge, and to plant shade trees along the southern channel bank. (Google imagery date 8/27/2013)

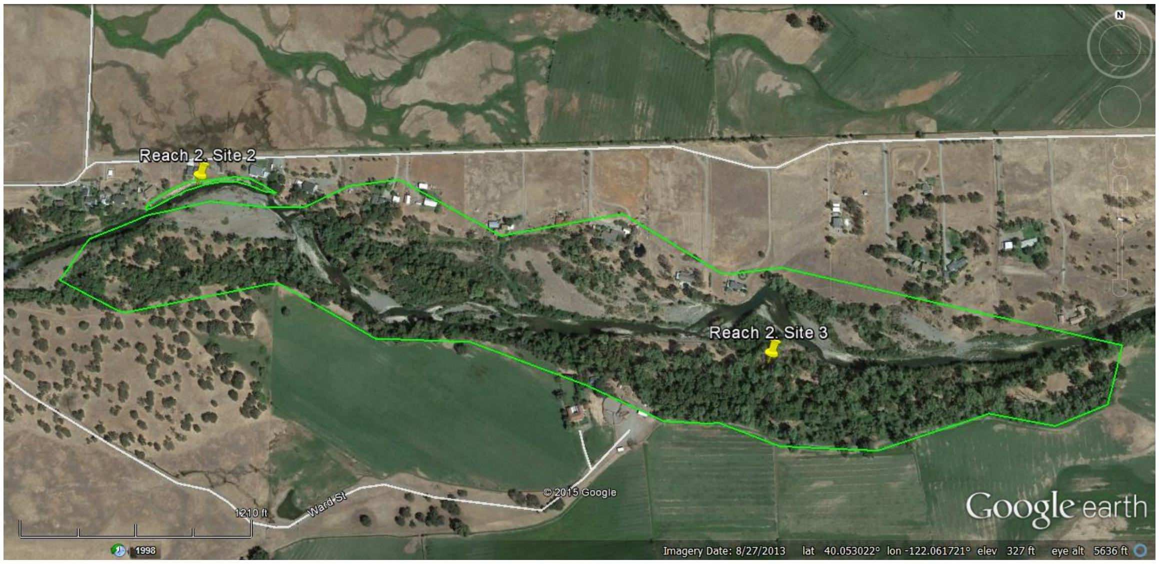

Figure 6-26. Mill Creek condition reach 2 sites 2 and 3 with recommendations to enhance existing vegetation. (Google imagery date 8/27/2013)

Figure 6-27. Mill Creek condition reach 2 sites 4 and 5, with recommendations to enhance existing vegetation, work with the landowner to exclude grazing from within 100 ft of the channel edge, and to consider planting shade trees along the southern channel bank. (Google imagery date 8/27/2013)

Invasive weeds were found in the lower reaches during field surveys and, in some cases, were visible from aerial imagery. Weeds such as *Arundo* and Himalayan blackberry can quickly come to dominate other (native) plant species, resulting in a monoculture with drastically simplified plant composition and habitat structure. This reduces the habitat quality for riparian dependent species such as riparian songbirds and invertebrates (RHJV 2004). Some invasive weed species, such as *Arundo* and tamarisk, can alter the local hydrology and fire regime of a riparian corridor, further reducing the ability of native species to thrive in the altered conditions (Coffman 2007, Coffman et al. 2010, Brooks et al. 2008). Therefore, we recommend focusing restoration efforts on the most pernicious non-native invasive weeds observed in lower Mill Creek (few were observed in the reaches above the canyon mouth). These target weeds include *Arundo*, Himalayan blackberry, and tamarisk. For each target weed species, eradication should start at the upper reaches where it occurs and then work its way downstream to avoid natural recruitment into recently cleared locations (e.g., Stillwater Sciences 2008). These species are persistent and eradication could require several seasons of physical removal which could be accompanied by herbicide applications where appropriate (DiTomaso et al. 2013). A more in-depth weed survey and management plan should be developed for each of the target weed species; however *Arundo* was particularly visible and prevalent along the channel in these lower reaches. Removing this weed will become increasingly difficult as it spreads. The extent and frequency observed in this study increases downstream (see Figure 6-28 and the attached kmz file, Arundo.kmz), with large areas of *Arundo* occurring in the Mill Creek delta at the confluence with the Sacramento. Removal of this weed will allow for growth of structurally diverse native riparian vegetation.

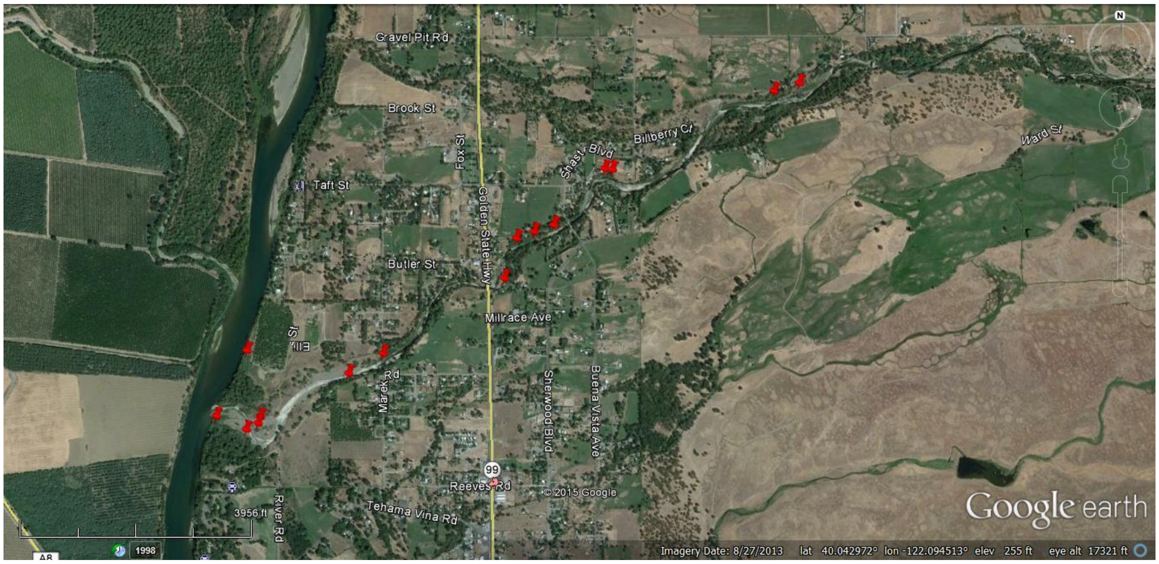

Figure 6-28. Observations of *Arundo* along Mill Creek from the upper end of condition reach 1c (where North Mill Creek distributary divereges from the mainstem) to the confluence and banks of the Sacramento River. (Google imagery date 8/27/2013)

6.4.2 Upper Reaches of Mill Creek

Alluvial reaches in the upper watershed above and below Highway 36 support modest floodplains with meadows and riparian forests. The riparian corridor above and below the Highway 36 crossing includes areas that receive significant and event-related sediment loading from sparsely vegetated south-facing slopes of Mount Lassen. The channel has moved laterally within the alluvial area over the past 20 years (Google Earth historical imagery 1993 to 2015) and includes grazed areas. The Recovery Plan lists meadow restoration as a second level action priority for salmonids (USFWS 2014). These high elevation areas with cool waters could be protected to ensure that they continue to provide spawning and juvenile rearing habitat into the future. Mountain meadows with willows, sedges and diverse herbaceous groundcover also occupy parts of the upper riparian corridor – these areas should be protected and enhanced where appropriate to ensure they provide healthy habitat for meadow dependent species such as the willow fly catcher. We recommend an initial review of the meadows in this reach to identify potential improvements, either with grazing management or actions with the channel, in order to identify the best approach for improving conditions for native meadow vegetation, and dependent wildlife and aquatic species (Figure 6-29). For example, the meadows can be managed to protect growth of willow thickets that provide habitat for willow flycatcher and to discourage occupation of the area by predatory non-native birds, such as cowbirds, which predate willow fly catcher and other native bird species (USDA Forest Service 1998). Range allotments could be managed to ensure that grazing does not occur during the willow flycatcher breeding season and to ensure that willow thickets are protected from browsing, since dense canopies below four feet are an important part of the species' habitat.

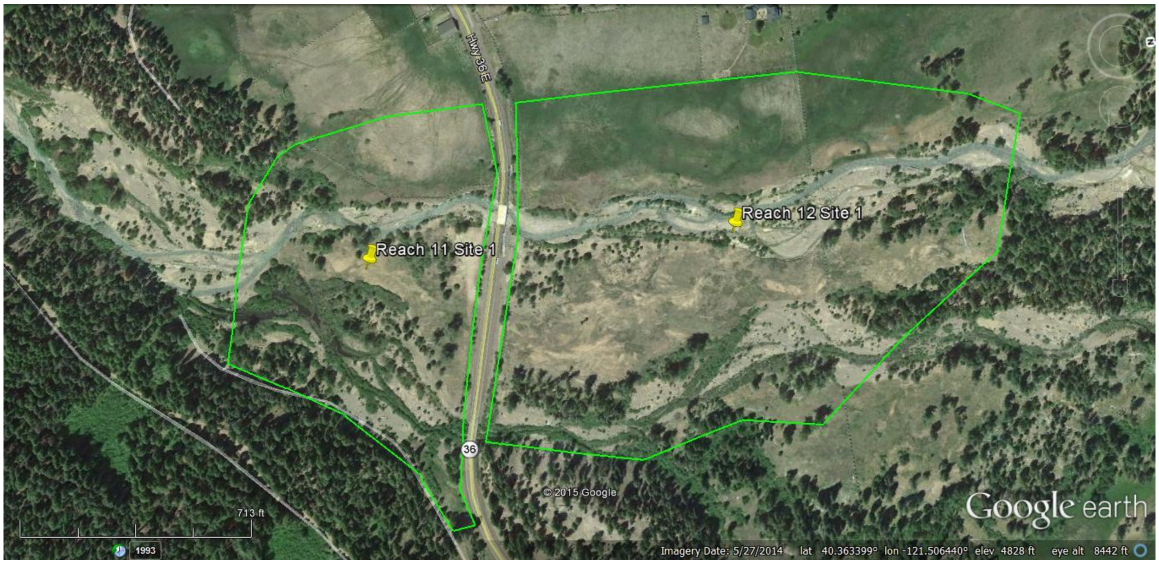

Figure 6-29. We recommend a closer review of the geomorphic, hydrologic and vegetation conditions along the stream channel and meadows above and below highway 36; part of condition reach 11 (below 36 to the left) and 12 (above 36 to the right).

6.4.3 Annotated List of Priority Action Areas along Mill Creek

The annotated list of priority reaches and potential management activities for Mill Creek is provided in Table 6-5 below.

Table 6-5. Priority riparian vegetation management action areas for Mill Creek watershed project area (see Figure 5-6 for reach locations).

Reach code	Condition score	Recommendations
1c-1a	N/A	***Arundo* eradication:** Eradicate *Arundo* and tamarisk from these areas, starting at the upper most sites where it is observed and moving downstream. Occurrences of *Arundo* observed in field and via imagery provided with this report should be augmented with a complete field survey (walk up the creek) to document tamarisk and other occurrences of *Arundo* and to ensure all upstream occurrences are documented and removed. Follow-up monitoring to remove weeds if/when they reoccur also is needed. Ideally, a weed management and monitoring plan should be developed and followed.
1a	1	Restore riparian trees to increase shade especially on south banks of channel while supporting channel lateral meander; repair and manage trails near channel to reduce surface erosion into channel; remove and replace non-natives with riparian natives. **Site 1a-1.** This area could be considered for riparian revegetation to increase shade and increase quality of juvenile rearing habitat. Planting to be balanced with ensuring channel mobility. **Site 1a-2.** Consider restoring riparian forest and shrub matrix to this area to expand upon existing riparian forest/shrubs near river mouth; do not constrain natural channel migration. **Site 1a-3.** Protect and enhance existing riparian forest on the river left. **Site 1a-4.** Just downstream of Hwy 99 bridge plant shade trees along south bank.
1b	1.5	Build upon existing riparian vegetation to create more shade cover and to increase connectivity with flood plain, particularly in areas 0 to 1 mile upstream of the

		Shasta Blvd bridge. Protect and enhance existing riparian forests. **Site 1b-1.** Remove/control invasive weeds and consider enhancing native riparian vegetation to increase shade and aquatic and riparian habitat quality without constraining channel (e.g., use willows or other flexible species). **Site 1b-2.** Protect and enhance existing riparian forest on both sides of channel. Remove invasive species (*Arundo*) and replant with natives. **Site 1b-3.** Shade trees such as valley oak could be planted along this bank to increase shade and LWD recruitment potential in this small area. **Site 1b-4.** This area along the river right bank should be managed to eradicate invasive weeds, address local erosion and runoff from adjacent uplands and to plant native riparian shrubs.
1c	1.5	This short reach supports a relatively large native riparian stand which we recommend be protected and enhanced, as described below. **Site 1c-1.** - Protect and enhance this large existing riparian complex; eradicate and manage invasive weeds. Specifically, remove *Arundo*, observed from Google Earth imagery and located at 40° 3.118'N, 122° 4.877' W. This is the upper most location observed and so is critical for controlling all downstream occurrences. Protect and enhance large area of existing riparian forest and shrub.
2	1	Increase channel shade by planting dense canopy of oak or other appropriate native trees, particularly along southern channel banks; some incised banks could be laid back and replanted; consider developing riparian forests/shrub communities in channel meanders, such as just upstream from Wilson Street. Work with landowners to fence off cattle from within100 ft of channel edge and work with the municipal planning department to encourage planting native riparian trees and shrubs along banks of creek-side homes. **Site 2-1.** Work with landowner to exclude grazing from within 100 ft. of creek bank and to plant oaks or other native riparian trees along bank to increase shade and LWD recruitment. **Site 2-2.** Work residential landowners to plant native riparian shrubs along channel banks and consider potential actions to address rapid bank erosion observed in this area. **Site 2-3.** Protect and enhance this large existing riparian complex; eradicate and manage invasive weeds. **Site 2-4.** Use the vegetation banks downstream of this area as a potential reference for replanting banks and excluding cattle from creek buffer to support increased shade and LWD input to improve aquatic and riparian habitat. **Site 2-5.** Explore feasibility of establishing oak or other native tree along the southern banks to increase shade. Work with landowner to exclude grazing from within 100 ft of creek banks.
11	3.5	**Site 11-1.** Study geomorphology of this reach to assess whether or not it is in a state of recovery from recent sediment influx and is naturally recovering and re-vegetating or if channel incision is increasing downstream of Hwy 36 crossing.
12	2.5	**Site 12-1.** Study geomorphology of this reach to assess whether or not it is in a state of recovery from recent sediment influx and is naturally recovering and re-vegetating or if channel incision is increasing, particularly, along the river left roughly 1,000 ft upstream of Hwy 36 crossing.

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Appendices

Appendix A

Letter to Landowners

Stillwater Sciences

2855 Telegraph Avenue, Suite 400, Berkeley, CA 94705
phone 510.848.8098 fax 510.848.8398

June 5, 2012

Dear Landowner:

Under contract with the U.S. Fish and Wildlife Service, Stillwater Sciences and Aerial Information Systems (AIS) will be mapping stream-side (riparian) habitat distribution and quality to support watershed management and to recommend areas for restoration, preservation, and enhancement. The results of our survey are intended to support watershed-level efforts to improve habitat conditions for the Sacramento River salmon and steelhead fisheries. **The purpose of this letter is to request your assistance in this effort by providing access to your property between June 25 and June 28, 2012 so that we can conduct these vegetation surveys.** We sincerely appreciate your willingness to participate in this worthwhile study.

The first phase of this riparian vegetation survey will be in the summer of 2012, and the second phase will occur in summer of 2013. The survey itself will entail a two-to-three person crew of botanists recording information on riparian vegetation along the stream channel, adjacent floodplain, and adjacent uplands. Field equipment will include a global positioning device (GPS to record locations), and a hand level (to measure percent slope). Our survey crew will enter and exit the creek only from locations where landowner access has been provided and we will coordinate with the landowner regarding the date and timing of our field visit. This June 2012, we anticipate spending no more than a few hours on any single piece of property in the watershed; during the second field phase in 2013 we anticipate spending no more than one day in any single location. No agency staff will be present during any of our field surveys.

Your assistance in granting Stillwater Sciences and AIS access to survey on your land is voluntary. Surveys will not be conducted through your property if you do not authorize us to do so. However, your support will help us provide the best information possible to the FWS as well as your local watershed group to serve as a basis for decisions for riparian restoration, enhancement and preservation in the watershed.

In exchange for your consent, Stillwater Sciences and AIS agree that:

- The sole purpose of our activity will be to characterize and map the vegetation along the channel, in the floodplain, and adjacent uplands. This includes a crew of two to three botanists recording the dominant vegetation and substrate. This survey is not targeting the occurrence or location of rare and endangered species.

- All reasonable steps will be taken to preserve your privacy and only pertinent vegetation information will be collected.

- Landowner and/or lessee in possession will be held harmless against any loss or liability arising from this agreement or our survey effort, including damage to property or injuries to or deaths of agents, contractors, or employees of Stillwater Sciences and AIS by reason of the exercise of privileges conferred herein.

- Permission to survey may be revoked at any time and this agreement does not create an easement or right-of-way over the property.

Please check the appropriate box on the Stillwater Sciences copy of the enclosed "Permission to Survey Vegetation in 2012 and 2013" form, sign, and return it in the enclosed self-addressed, stamped envelope **by June 15, 2011**. Please retain this letter and the landowner copy of the “Permission to Survey Vegetation in 2012 and 2013” form for your records. *If you agree to let us survey on your property, we will contact you by phone or email the week of June 18-22 to confirm an agreeable access location and time for our survey.*

Feel free to call Amy Merrill (510) 848-8098 x154 or contact her via e-mail at amy@stillwatersci.com if you have any questions or comments regarding our survey effort.

Thank you for your time and consideration of this important matter.

Sincerely,

Amy Merrill

Senior Riparian Ecologist
Stillwater Sciences
Berkeley, California
510/848-8098 x154
Cell 510/506-3321
http://www.stillwatersci.com

PERMISSION TO SURVEY RIPARIAN AND ADJACENT UPLAND VEGETATION IN 2012 AND 2013

(Landowner Copy)

Please check one of the two boxes below and sign at the bottom of this sheet. Please use the enclosed self-addressed, stamped envelope to return this form as soon as possible. Thank you.

☐ Permission to access areas along river channels, irrigation ditches and adjacent uplands in order to record information on riparian (stream-side) and adjacent upland vegetation on my property is hereby granted to Stillwater Sciences and Aerial Information Services, during mutually agreed-upon dates within the period June 2012 through October 2013, subject to the conditions contained in the October 13, 2011 letter from Stillwater Sciences.

My permission is granted with the following additional conditions (Please check all that apply):
( ) Permission is subject to my presence during survey activities or the presence of my authorized agent;
( ) Other (please specify):

____

____

☐ I **DO NOT** grant permission to Stillwater Sciences and Aerial Information Services to survey vegetation on my property during the summers of 2012 and 2013.

Landowner/Lessee in Possession

Sign Here: ____

Date: ____________________

Print Name: ____

Address: ____

Phone Number: ____

The best time to reach me is: ______________________________

( ) I would like to know more about this survey effort; please contact me.
( ) Please contact me so that I can arrange to observe the survey effort or to participate.

(Please keep this copy for your records)

PERMISSION TO SURVEY RIPARIAN AND ADJACENT UPLAND VEGETATION IN 2012 AND 2013

(Stillwater Sciences Copy)

Please check one of the two boxes below and sign at the bottom of this sheet. Please use the enclosed self-addressed, stamped envelope to return this form as soon as possible. Thank you.

☐ Permission to access areas along river channels, irrigation ditches and adjacent uplands in order to record information on riparian (stream-side) and adjacent upland vegetation on my property is hereby granted to Stillwater Sciences and Aerial Information Services, during mutually agreed-upon dates within the period June 2012 through October 2013, subject to the conditions contained in the October 13, 2011 letter from Stillwater Sciences.

My permission is granted with the following additional conditions (Please check all that apply):
( ) Permission is subject to my presence during survey activities or the presence of my authorized agent;
( ) Other (please specify):

____

____

☐ I **DO NOT** grant permission to Stillwater Sciences and Aerial Information Services to survey vegetation on my property during the summers of 2012 and 2013.

Landowner/Lessee in Possession

Sign Here: ____

Date: ____

Print Name: ____

Address: ____

Phone Number: ____

The best time to reach me is: ____

( ) I would like to know more about this survey effort; please contact me.
( ) Please contact me so that I can arrange to observe the survey effort or to participate.

(Please return this copy of the permit in the self-addressed stamped envelope provided)

Appendix B

Field Data Form

Name: ______________________________________ Date: ______________________

GENERAL SITE DESCRIPTION

1. Polygon # ____________________
2. Field tile#_________
3. Camera/GPS: ***Pentax WG-2,#2440/WGS 84*** Photo #: ________________________________
4. Assessment Area Size (acres): <0.5, 0.5, 1, 1-5, >5
5. How much of the polygon can you see? (<20%, >20%)

LANDSCAPE CHARACTERISTICS (Habitat Quality)

6. Longitudinal Connectivity
   - _____ Polygon above/below fish passage barrier (circle one)
   - _____ Intact riparian areas > 25 continuous acres within ~1.5 mile radius of polygon (y/n)
   - _____ % intact riparian area within ~0.5 mile up and downstream of polygon and within 100 ft. of channel
7. Upland Continuity, Adjacent land use is (%):
   - _____ Natural lands (non-agricultural) _____ Levee
   - _____ Unmanaged pasture (lightly or not grazed) _____ Urban, paved, residential land uses
   - _____ Row crops, vineyard or orchards _____ Dense dairy or grainery (corvids)
   - _____ Channel (open water) _____ Other (specify ___________________________)

STREAM SHADE

8. Stream Channel Width (at bankfull; circle one): 0-5 ft, 5-10 ft, 10-15 ft, 15-20 ft, 20-30 ft, 30-50ft, >50 ft.
9. Is polygon directly adjacent to channel bank? Y/N
10. How much of the reach length associated with the polygon* receives shade from vegetation overhang? ____%
11. How far does the vegetation hang out over summer flow the channel? _____ ft
12. Channel bank aspect: ______________ (degrees) (use magnetic north)

Channel Shade	% reach length w\ veg	Dominant Ht	Canopy Density (%)
Vegetation 0-30 ft from bank			
Vegetation 30-100 ft from bank			
Topographic 0-30 ft from bank			100

*Answer questions for the channel reach associated with target polygon, even if polygon itself does not support vegetation providing the shade.

FLOODPLAIN CONNECTIVITY

13. Stream Gradient (circle one): 0-2%, 2-4%, 4-8%, >8%
14. Estimated last time surface flooded (circle years since present) <1, 1, 2-4, 5-10, >10
15. Valley Bottom Width (circle one): 10-20 ft, 20-40 ft, 50-75 ft, 75-100 ft, 100-150 ft, 150-250 ft, 250-500 ft, >500 ft; (direct estimate ____ feet)
16. Percent of polygon subject to frequent flooding (~2yRI): ______________
17. Percent of polygon subject to infrequent flooding (~10yRI): ___________
18. Are there structures or other elements impeding channel connectivity with the floodplain? Y/N
19. If yes, what? (circle what applies): levees, incised channel, re-enforced banks (rip rap), debris piles, road(s), natural formations such as cliffs, steep bank slopes, other (describe___________________________________)

DISTURBANCE AND SPECIAL FEATURES

20. Disturbance codes[4] inside polygon/disturbance level (High, Medium, Low) _______________ ____________________
21. Adjacent disturbances (within 100 m on same side of river) CODES/ (L/M/H): _________________________________
22. No. Large Trees ((>8" DBH and >10 ft tall)within 100 feet of bank full edge) ________ _________
23. No. Large Snags ((>8" DBH and >10 ft tall) within 100 feet of bank full edge): ________ _________
24. Cliffs or eroding banks present (at least 3 ft tall and 20 ft long)? Y/N
25. Off-channel oxbows present? Y/N ;
26. Fresh gravel/cobble bars (unvegetated or sparsely vegetated) present? Y/N
27. Emergent herbaceous wetlands present? Y/N
28. Stand Fluvial Surface[1] code: _________;
29. Stand Microtopography: convex flat concave undulating
30. Soil Texture code[2]: _____________
31. % Surface cover: H20:_______ BA Stems:________ Litter: ______ Bedrock :______ Boulder (25-60cm):_____ Cobble (6.4 -25 cm):______ Gravel (0.2 -6.4cm):______ Fines (<0.2cm):______ =100%

Name: ____ Date: __________________________

RIPARIAN VEGETATION DESCRIPTION

1. Polygon #: ___________________ 2. Avg. Lateral Extent*: ______________________

**Record closest and farthest distance from water's edge for community type. E.g. if alder dominated community begins at water's edge and extends 30 ft inland, record 0 to 30. If Valley oak type begins 20 ft from edge and extends 100 ft inland, record 20 to 100.*

Initial Draft Vegetation Type Classification

3. Field Vegetation Type Classification: ______________________________________
4. Confidence in Field Classification (L/M/H) __________________________________
5. Is polygon >1 Vegetation Type? Yes/No (if yes, were others types sampled separately? Yes/No
6. Adjacent Vegetation types/polygon numbers: _____________________________________

7. Dominant Species.

Layer Classes: Trees T1 (seedling: 0-1 yrs), T2 (sapling to mature: 2+ yrs),T3 (decadent:>20% Dead), Shrubs S1 (seedling: <1 yr), S2 (mature >1 yr), S3 (decadent >20% dead), Herbaceous H1 (<1 ft), H2 (> 1 ft) NV (Non-vascular)

Veg Layer	Avg. Ht (ft)	% Cover	Latin Name	Common name/Code	Regenerating? (H/M/L)	C^5
ALL	**Total veg % cover**					
ALL	**Total % Invasive**					
8.	**Upper canopy Density (>10′) %**					
9.	**Mid canopy Density (2′-10′) %**					
10.	**Lower canopy Density (<2′) %**					

11. Stand health and regeneration assessment (Excellent/Good/Fair/Poor), explain:

12. Site History

13.*DRAW A BOUNDARY AROUND STAND ON FIELD MAP AND LABEL STAND NUMBER. **DONE? (Y / N)**
14. Did you change the polygon boundary? (Y/N)

14. Final vegetation type name:	**Alliance** ____ **Association**

[1] **Fluvial surface codes**

1. Active Floodplain
2. Other Floodplain
3. Channel Bank (Low Flow)
4. Outer Bank (High Flow)
5. Terrace (Retired FP)
6. Isolated Wetland or Oxbow

[2] **Soil texture codes**

1. Gravel (G)
2. Silt (Si)
3. Loam (L)
4. Clay (C)
5. Sand (S)

[3] **BA** = Basal Area

[5] **C** = Collected specimen for office ID

[6] **Age Codes**

Tree Age Code
T1= Seedling (0-1 yrs)
T2= Sapling to Mature (2+ yrs)
T3= Decadent (≥20% canopy dead)
Shrub Age Codes
S1= Seedling (≤1 yr old)
S2= Mature (>1 yr old)
S3= Decadent (≥20% dead)
Herbaceous Age Codes
H1 < 12" ht
H2 > 12" ht

[7] **Canopy Overhang Categories**

0 = Negligible: <5% of stream segment
1 = Low: 5-25% of stream segment
2 = Medium: 25-50% of stream segment
3 = High: Greater than 50% of stream segment
4 = Obscured: Significant portions of stream channel hidden and the locations are approximated
9 = Not Applicable to polygon

[4] **Disturbance codes:**

01 Development (buildings, pavement)
02 Landfill
03 ORV activity
04 Agriculture
05 Grazing
06 Competition from exotics
07 Logging
08 Wood cutting
09 Mining/Tailings
10 Road/trail construction/maintenance
11 Agricultural return flows (pipe)
12 Altered flow regime
13 Groundwater pumping
14 Surface water diversion
15 Dam/inundation
16 Off-channel ponds and wetlands, impoundments
17 Improper burning regime
18 Erosion/runoff (record source)
19 Rip-rap, bank protection

- Low 10-30% of banks
- Medium 30-60 % of banks
- High >60% of banks

20 Actively eroding banks

- Low 10-30% of banks
- Medium 30-60 % of banks
- High >60% of banks

21 Channel incision

- Low (0-2 feet)
- Medium (2-4 feet)
- High (> 4 feet)

22 Recreational trails/compaction and trampling
23 Recreational use (non ORV)
24 Vandalism/dumping/litter
25 Feral animals
26 Plantations/Cultured Exotics
27 Other (describe in Site History)

Appendix C

Descriptions of Mill Creek-Cow Creek Riparian Study—Vegetation Mapping Types

EXPLANATION OF THE DESCRIPTIONS

This section of the report contains descriptions for each of the vegetation types (Alliances and Map Units) represented in the final geodatabase for this project.

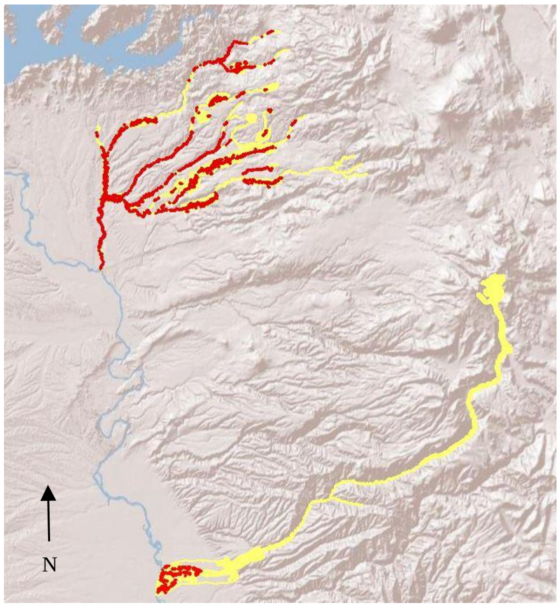
Detailed descriptions are for riparian and wetland vegetation types and have the following components:

- **Screenshots:** These are digital images (in most cases from higher sub-meter resolution imagery) showing aerial views of the vegetation stands. The screenshots give the reader a sense of the overall photo signature.
- **Ground photos:** These are digital pictures taken during the reconnaissance effort. They are a snapshot in time showing the plants in their landscape. They usually represent only a portion of the actual mapped stand.
- **Descriptions:** The descriptions discuss the expected locations, cover characteristics, species composition and other pertinent information. The species cover characteristics and relative abundance conform to the second edition of *The Manual of California Vegetation* (MCV), but are specifically tailored to the Mill Creek-Cow Creek Study. For example, where *Quercus kelloggii* is described in the MCV as occurring on all aspects and topographic settings, the descriptions in this document are more restrictive due to the fact that within the mapping area, they are more likely to be found on mid to upper slopes and ridgelines.
- **Photo Interpretation Signature:** These descriptions help the reader identify the vegetation from an aerial perspective. Since most of the Alliance-level assignments come from the improved color balancing of the 2012 NAIP imagery, signature descriptions come from this dataset, unless otherwise noted.
- **Distribution Maps:** The distribution maps show the mapped polygons of the vegetation types within the overall study area and give the user an overall range of the species distribution in the study. Depictions of infrequently mapped types are enhanced to help the reader see the locations. Enhanced locations are noted on the map.

Some vegetation types have a very limited presence in the study area at sizes above the MMU. For these types, it was not possible to formulate the standard in-depth descriptions. Instead, they are represented only with a short description of their location within the study area. These are at the end of the descriptions within this Appendix.

Upland vegetation types, outside the main focus riparian study (but still within the mapping area boundaries) are described primarily in relation to their riparian neighbors with a brief description of their location and setting.

1313—Quercus lobata Alliance



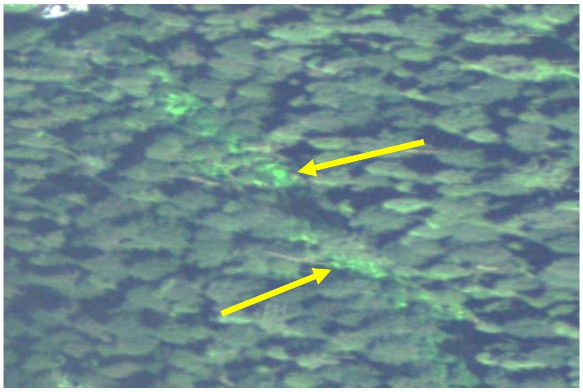
Description:

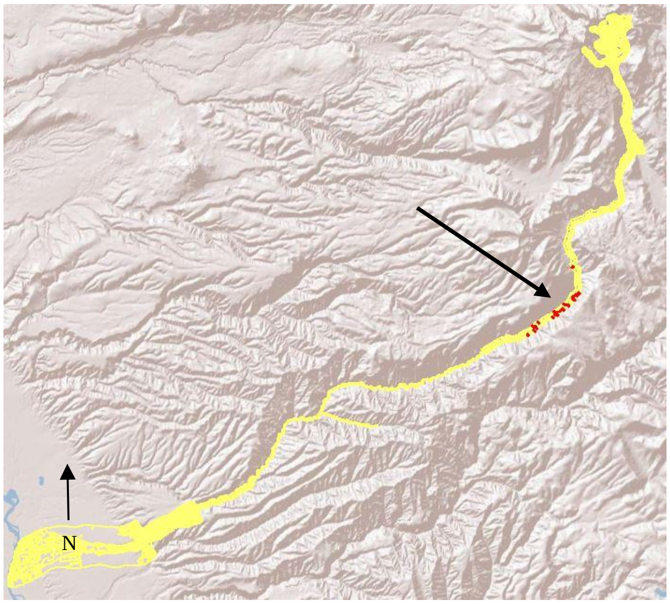
The *Quercus lobata* Alliance occurs throughout Cow Creek Watershed and only in the lower most elevations of Mill Creek. The Alliance is mapped where *Q. lobata* dominates or co-dominates the stand, generally with *Populus fremontii* and/or *Alnus rhombifolia.* Stand cover ranges from open savannah like settings to dense woodlands where it occurs with *A. rhombifolia* in rather narrow bands. Stands occur in both riparian and upland settings.

Photo interpretation signature:

Q. lobata tends to have a large crown with low- to mid-stem multiple branching throughout. Crowns are more open and irregularly shaped than interior live oak and are generally lighter green. Sites occur on fairly deep soils, especially where *Q. lobata* dominates.

2111—Acer macrophyllum Alliance





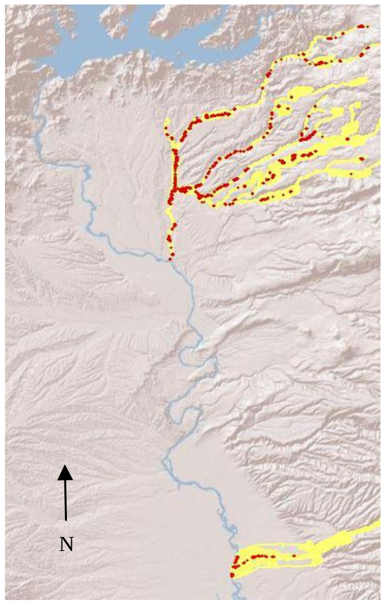
Description:

This Alliance occurs on narrow steep north trending canyons adjacent to a 5-mile segment of Mill Creek from the 3200’ level up to where Mill Creek bends due north around 3800’. Only 16 acres of this type were mapped in the study area. This Riparian Alliance occurs adjacent to stands of *P. ponderosa* and *P. menziesii* on both sides of the watershed.

Photo interpretation signature:

Acer macrophyllum occurs in distinct settings forming narrow polygons of varying length. Crowns are typically in new leaf phase with a variety of colors and hues, from green with a yellow-green tint to darker blue green. Crown color varies considerably within the stand. Crowns are large and irregularly shaped with poorly defined margins. Other hardwood species tend not to influence the overall signature, and stand margins are distinct, rarely extending beyond the lowest portion of the canyon. Adjacent mixed conifer forests are a clue to the setting.

3101—Mixed Willow Thickets – Young Saplings Mapping Unit (Southwestern Riparian Woodlands Group)



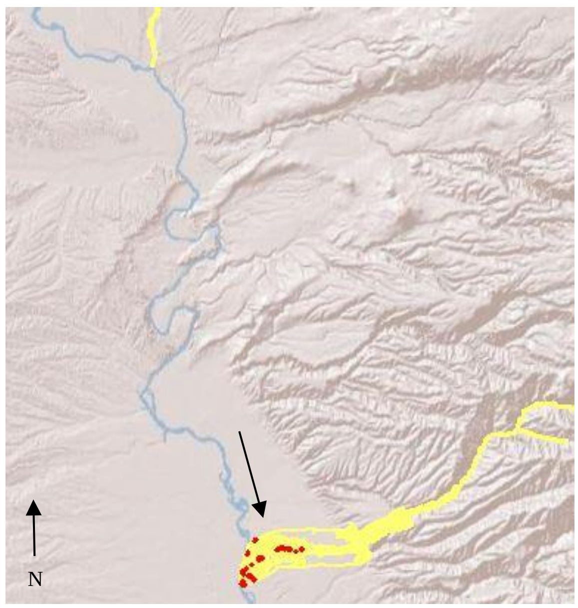
Description:

Mapped where photointerpreters are unable to distinguish any characteristic features (either signature or setting related) which would enable an informed decision to a specific Alliance. Stands may contain one or more of the following species; *Salix laevigata*, *S. gooddingii*, *Populus fremontii*, all occurring in sapling to young tree growth stature. *Salix lasiolepis* may also be present in the thicket canopy.

Photo interpretation signature:

Canopy texture characteristics are fairly uniform across the stand (generally smooth), accounting for the even age and young stature which make species identification extremely difficult. Colors range from light to dark green, often mixing across the stand.

3310—Platanus racemosa Alliance



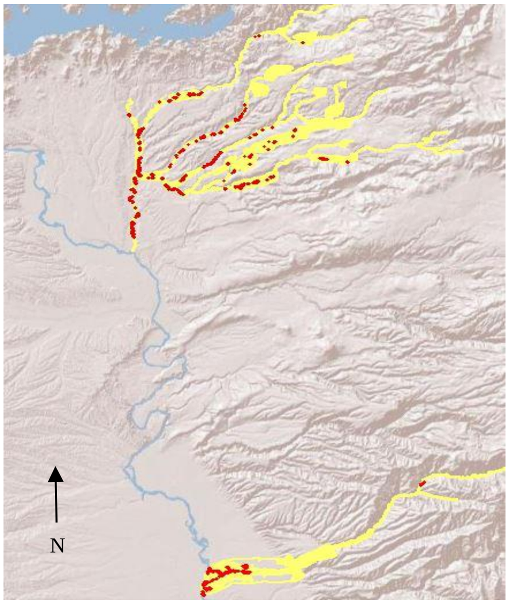
Description:

Platanus racemosa dominates the hardwood canopy in this Alliance in moderate to dense cover. Other species such as *Q. lobata*, *Populus fremontii* and *Acer negundo* are generally present in the hardwood canopy. Although *P. racemosa* is a component to riparian woodlands and forests throughout the lower portions of both watersheds, it is mapped to the Alliance only in the lowest reaches of Mill Creek watershed near the town of Los Molinos.

Photo interpretation signature:

Platanus racemosa has a fairly consistent light green signature color with a faint yellow tint to the hue. Crowns are smaller than other riparian trees such as *Q lobata and P. fremontii*. Crowns are irregularly shaped and poorly defined. Signature recognition is difficult as this species often shares dominance with other trees which make cover estimates tricky.

3110—Populus fremontii Alliance



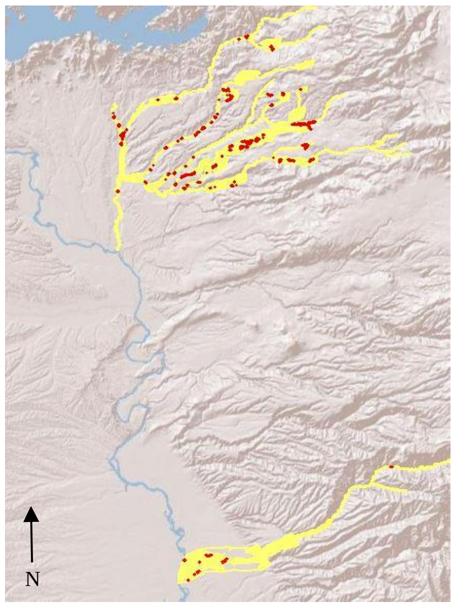
Description:

Populus fremontii dominates or co-dominates the hardwood canopy in this Alliance in moderate to dense cover. *Salix* spp. is characteristically present as in the example above. *Q. lobata* can be present in the canopy, but only in small numbers.

Photo interpretation signature:

Populus fremontii has a somewhat variable signature depending on the age of the stand. More mature stands have a grayish green hue and are not as brightly colored as other riparian species commonly comingling such as *Platanus racemosa* or *Acer negundo*. When *Salix spp.* are present in the stand, they can be separated out from *P. fremontii* by the individual crown density (mature willows having the denser crown).

3111—*Salix laevigata* Alliance



Description:

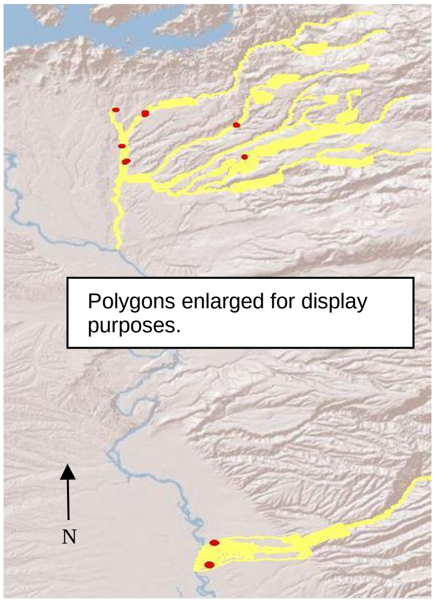
Salix laevigata dominates the hardwood canopy in this Alliance in moderate to dense cover. *Salix lasiolepis* can co-dominate in the stand; generally in a lower stature understory. *Populus fremontii* can be present in the canopy but does not co-dominate. Stands were mapped in generally more dynamic settings than *P. fremontii*, usually in slightly more flooded moisture regimes.

Photo interpretation signature:

Salix laevigata has a fairly consistent signature, varying little across the stand; more mature trees are somewhat darker green and have a more irregular texture. The Alliance generally trends toward a greener signature with a less gray hue than *Populus fremontii.* Mixed stands contain the brighter greens when *A. negundo* and/or *P. racemosa* are a component. Stand age and disturbance are the main factors in signature variability in this Alliance.

3111—Salix gooddingii Alliance

No Ground Photos taken for *Salix gooddingii* Alliance



Description:

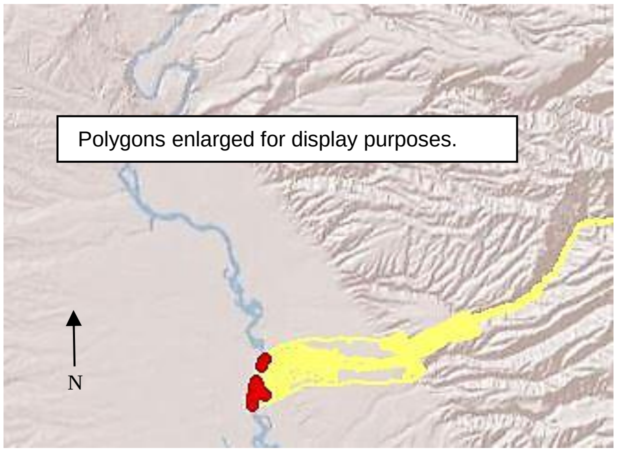
Salix gooddingii dominates the hardwood canopy in this Alliance in moderate to dense cover. Only 8 polygons totaling approximately 12 acres have been mapped to the Alliance level. This type could be more common in the mapping area but was observed infrequently during field reconnaissance. Noted as a component to the *Salix laevigata* and *Populus fremontii* Alliance throughout their range along the lower most reaches of both watersheds.

Photo interpretation signature:

Salix gooddingii is difficult to distinguish from other willow species. It is also difficult to predict its distribution due to fact that it rarely forms stands in the study area. This Alliance is more frequently found along the Sacramento River connecting the two watersheds in the study area.

3114—*Acer Negundo* Alliance

No Ground Photos taken for *Acer negundo* Alliance



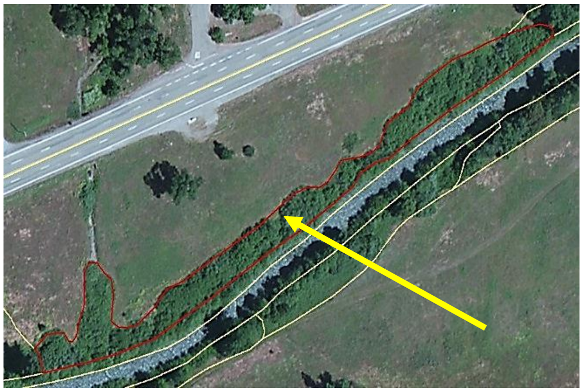
Description:

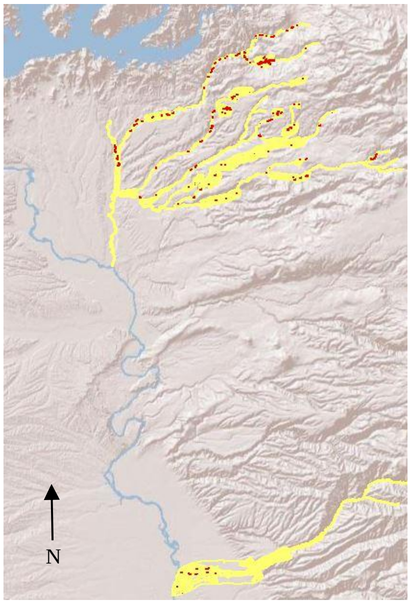
Acer negundo rarely forms stands in the watersheds but is frequently a fairly common component to lower elevation well developed riparian forests and woodlands. Several polygons in the lower reaches of Mill Creek watershed have been pulled out from existing larger stands of *Populus fremontii.* In these small stands, *A. negundo* strongly dominates the riparian canopy.

Photo interpretation signature:

Acer negundo generally yields one of the brighter green signatures of the Riparian Alliances but can easily be confused with other types that occasionally form stands such as *Fraxinus latifolia.* Stands in the mapping area generally occur at lower elevations than stands defined to the *Fraxinus latifolia* alliance.

3115—Salix lasiolepis Alliance





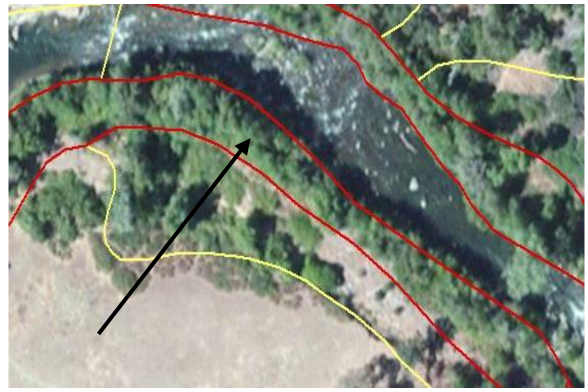
Description:

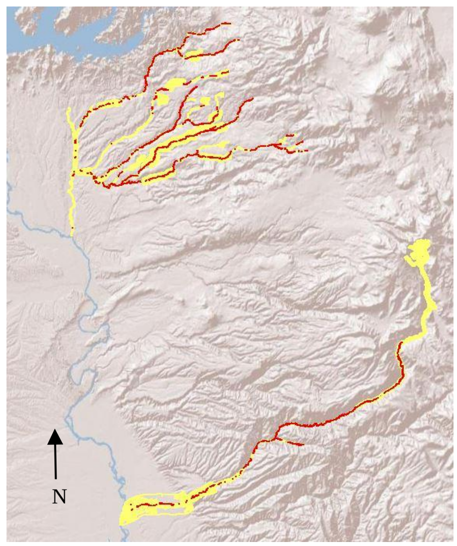
Salix lasiolepis occurs in dense cover as a tall shrub mainly in all but the lowest reaches of Cow Creek watershed. *Salix lasiolepis* strongly dominates the canopy; emergent tree willows can be present as an inconsistent cover. *Salix exigua* occasionally co-dominates the stand. This Alliance tends to form along the outer margins of forested riparian types.

Photo interpretation signature:

Signature generally remains fairly even across the stand in dense settings; color and texture tends to vary more in open disturbed settings. The sample picture above depicts a dense even-age stand almost entirely populated with *Salix lasiolepis.*

3210—Alnus rhombifolia Alliance





Description:

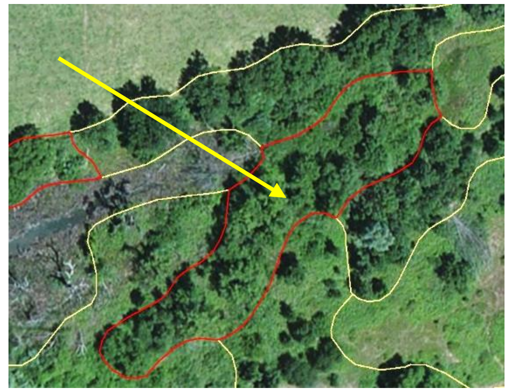
The *Alnus rhombifolia* Alliance is frequently mapped along the margins of the perennial stream channels where it occurs in very narrow bands, often as the sole riparian tree in the stand. Cover is characteristically dense, but can be lower in disturbance settings. Distribution of this Alliance is widespread, occurring in all regions except the lower most reaches of Cow Creek watershed and the upper third of Mill Creek watershed. It is uncharacteristically absent from most of the Oak run, possibly due to the low gradient along the waterway and/or the high amount of disturbance along this tributary.

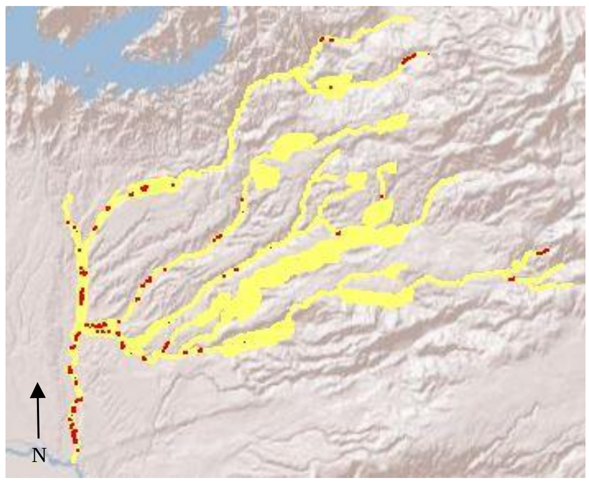
Photo interpretation signature:

Recognition of this Alliance is most frequently attributed to the setting and shape of the stand. Mature stands form consistent patterning along the length of the mapped polygon. Signature color is similar to *Salix* types but tends to have a slight trend towards blue in the overall hue. Unlike the shrubby *Alnus incana,* this Alliance nearly always forms a tree canopy.

3211—Fraxinus latifolia Alliance

No Ground Photos taken for *Fraxinus latifolia* Alliance





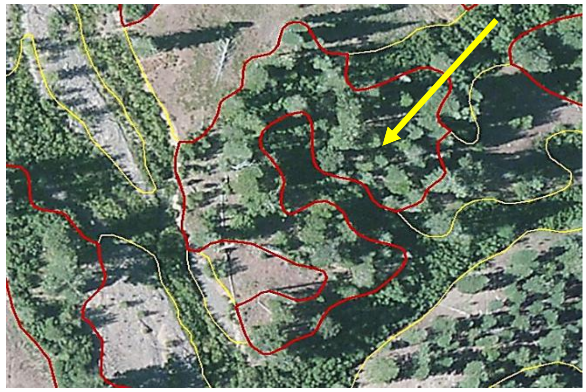
Description:

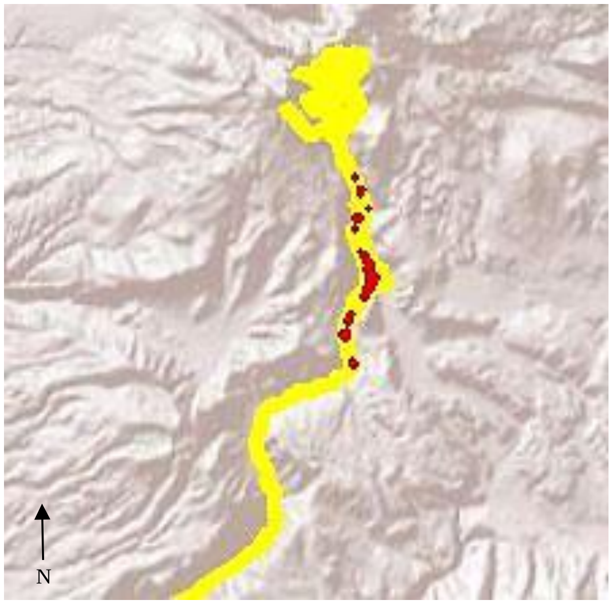
The *Fraxinus latifolia* Alliance is limited to Cow Creek watershed; mainly in the middle and lower reaches of Cow creek proper and most of its tributaries. In the mapping area, it is often a component to larger stands of riparian forests on fairly broad but deeper soil floodplains. Small stands were mapped where *Fraxinus latifolia* dominates or co-dominates with other riparian trees.

Photo interpretation signature:

This is a difficult type to recognize in that it forms stands infrequently in the mapping area and the stands are limited in extent. *Fraxinus latifolia* shares similar signature characteristics to *Acer negundo, Juglans* spp. *Platanus racemosa* and in certain settings, tree willow types. Overlap of the species range is considerable to the abovementioned types. Stands which trend greener than *Populus fremontii* that are in similar settings to *Q. lobata* riparian types may be a *Fraxinus latifolia* Alliance.

3312—Populus trichocarpa Alliance





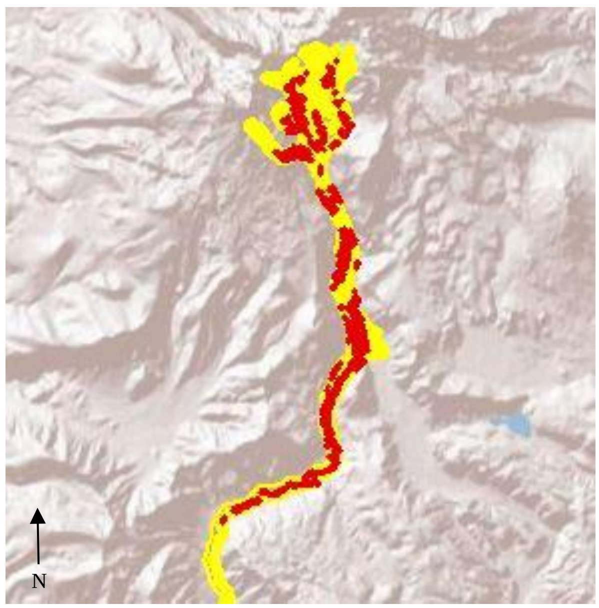
Description:

Populus trichocarpa is found in the upper Mill Creek watershed in the vicinity of Childs Meadows to the south of Lassen National Park. Stands are dominated by *Populus trichocarpa* in open to moderately dense cover and at times have a minor component of *Pinus jeffreyi* in the canopy as depicted in the above image. Stands often are adjacent to mesic low gradient riparian meadows and may form boundaries along the drier margins of *Alnus incana* thickets. Polygons appear to be mapped in well drained settings. About 45 acres of this uncommon type were mapped in the study.

Photo interpretation signature:

Signature is fairly distinct in that it is the only large riparian tree in its elevation range. Adjacent conifer stands tend to have a more rounded or conical crown; *Alnus incana* in most cases has a lower stature. Dead branching on the tree or immediately adjacent to the plant is frequent within larger stands due to recent flooding events.

3320—*Alnus incana* Alliance



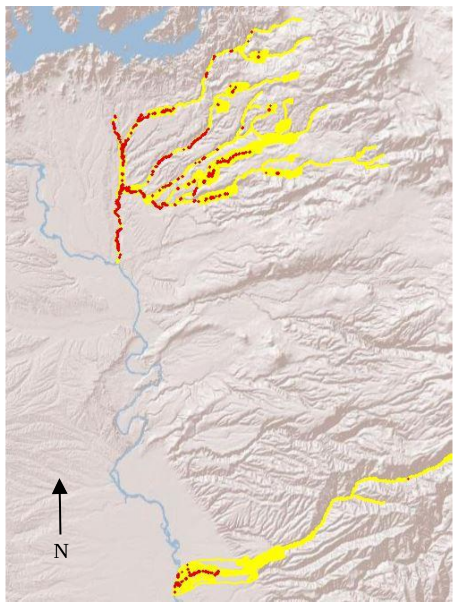
Description:

Alnus incana is found in the upper Mill Creek watershed from approximately 4200' upwards to nearly the highest elevations in the mapping area at over 7500'. Mapped where *A. incana* forms dense stands; generally as a sole species in the shrubby canopy layer. Found in riparian and meadow discharge settings alike on a variety of slopes. When adjacent to meadows, it is generally mapped on somewhat steeper slopes.

Photo interpretation signature:

Uniformity of crown height is a characteristic feature of this high elevation Riparian Alliance; it appears similar to willow thickets at lower elevations but its presence at high altitudes makes identification of this type fairly easy. High elevation willow stands tend have lower cover and are more associated with larger meadows.

6211—*Salix exigua* Alliance



Description:

Salix exigua ranges extensively along all tributaries and the main stem of Cow Creek at the mid and lower elevations; within Mill Creek watershed, it is found only in the lowest reaches of that region. This Alliance is mapped where *S. exigua* dominates the shrub layer, generally in dense cover. Young sapling willows other than *S. exigua* may be a component and at times can co-dominate the thicket. Generally found close to the active channel.

Photo interpretation signature:

Salix exigua in most circumstances is one of the easiest willows to recognize due to its characteristically glaucous leaf color that readily translates into a distinct photo signature. Stands consistently are a uniform height and give off a smooth texture even on lower resolution 1-meter NAIP imagery. This type can be difficult only when there is a mixing of young sapling willows other than *S. exigua,* or when it co-dominates with *S. lasiolepis* which does not happen frequently.

UPLAND VEGETATION TYPES MAPPED IN THE STUDY

1110—Umbellularia californica Alliance

Several polygons totaling about 16 acres were mapped in the middle and lower portions of Mill Creek watershed; generally on steep northerly trending slopes in shady protected settings. Generally mapped above portions of the stream in narrow canyons. *Alnus rhombifolia* is a common down slope riparian community.

1111—*Quercus wislizeni* Alliance

Frequently mapped (over 1850 acres) in the both the middle portions of Cow Creek and Mill Creek Watersheds, generally on relatively steep north trending slopes. *Alnus rhombifolia* and *Quercus lobata* are common riparian species downslope in settings where the two species often share dominance.

1210—*Pinus sabiniana* Alliance

Approximately 120 acres mapped; widely distributed mostly in the tributaries to Cow Creek. Mapped in a variety of settings, at times as a component to the drier margins of riparian stands of valley oak, but most frequently in association with *Quercus douglasii* woodlands.

1310—*Aesculus californica* Alliance

Mapped infrequently in riparian settings; generally localized to the middle portions of the Clover Creek tributary where nearly half of the approximately 60 acres mapped in the study occur along a 4-mile stretch of the creek. Often occurs on the drier margins of the riparian zone and adjacent northerly trending steep slopes in rocky settings.

1311—*Quercus douglasii* Alliance

This alliance is one of the most commonly mapped upland types in the study with over 7000 acres mapped. It was mapped throughout Cow Creek watershed and the middle and lower portions of Mill Creek watershed below Black Rock.

1312—*Quercus kelloggii* Alliance

Mapped in the upper portions of Cow Creek watershed and middle portions of Mill Creek. Mapped in settings where *Pinus ponderosa* usually co-dominates in dense mixed conifer-hardwood forests. At times mixes with the drier margins of higher elevation riparian stands of *Q. lobata*. Over 1100 acres mapped in the two watersheds.

1410—*Quercus chrysolepis* Alliance

Mapped primarily in the middle portions of Mill Creek watershed and along the upper portions of the Cow Creek tributaries, especially along Little Cow Creek and the south fork of Cow Creek. Occurs on steeper settings but often in close proximity to *Q. kelloggii*. Frequently occurs adjacent to narrow bands of *Alnus rhombifolia*; mixing of the two species occurs however over a narrow range of the two Alliances. Approximately 850 acres mapped in the two watersheds.

2110—*Pseudotsuga menziesii* Alliance

Mapped exclusively in Cow Creek watershed along a 5 ½ mile stretch of Little Cow Creek. Occurs on lower protected slopes on both sides of the watershed; generally upslope from narrow bands of *A. rhombifolia* or occasionally from mixed riparian stands where *Q. lobata and A. rhombifolia* co-dominate. Occurs in steeper more protected settings but often in close elevation proximity to *Pinus ponderosa.* Mixing of the two conifer species occurs often.

2112—*Pinus ponderosa—Pseudotsuga menziesii* Alliance

Mapped in both the Mill and Cow Creek watersheds on mid to middle-upper elevations, generally in narrow canyons upslope from riparian stands of *Alnus rhombifolia*. Over 2000 acres were mapped representing one of the more extensive mix of conifer types in the upland portions of the mapping area. The two conifer species generally co-dominate in the study area, often with a component of either *Q. kelloggii* or *Q. chrysolepis.*

2210—*Pinus ponderosa* Alliance

Less frequently mapped than other lower to mid elevation conifer and mixed types, this Alliance is mapped on gentler slopes than stands containing *P. menziesii*. Lower elevation stands tend to occur on drier portions of the floodplain, occasionally with a component of *Q. lobata* and/or *A. rhombifolia.* Stands further upslope are strongly dominated by *P. ponderosa*; usually with some *Quercus kelloggii.* Higher elevation stands along Mill Creek transition upwards to *P. jeffreyi.* Only slightly more than 100 acres were mapped in the study. This Alliance is limited in extent; upper elevations rapidly gain a component of either *P. menziesii* or *C. decurrens* while lower elevations become a mixed stand with *Q. kelloggii* where it is defined to the hardwood type.

2212—*Pinus ponderosa—Calocedrus decurrens* Alliance

Found in the upper most portions of the Cow Creek tributaries and also in mid to upper elevations along Mill Creek. Over 500 acres of this type were mapped where the two conifers co-dominate the stand, often with a component of *Q. kelloggii.* Stands are immediately adjacent to the riparian *A. rhombifolia* Alliance where *C. decurrens* frequently is a component. Mapped where the two conifers co-dominate and at times either may be a sub-dominant.

2214—*Abies concolor—Pinus lambertiana* Alliance

This is the lowest of the mid to higher conifer Alliances and with the exception of a few narrow stands occurring on the upper most portions of the South Cow Creek tributary, is exclusively found on steeper slopes adjacent to Mill Creek above Childs Meadows. Stands follow the outer upland margins of the study and rapidly become a pure or mixed fir Alliance upslope. Riparian meadow complexes occur along Mill Creek immediately adjacent downslope, sometimes with small patches of *Alnus incana* where the conifer forest boarders the meadow fringe. Mapped where *Pinus lambertiana* co- dominates or occasionally is a sub dominant to *A. concolor*.

2215—*Abies concolor* Alliance

Found exclusively in Mill Creek watershed where *Abies concolor* dominates the conifer layer in dense stands; often on moderately steep to steep slopes. Riparian meadow complexes and *A. incana* patches are both common riparian and wetland communities downslope. This Alliance is mapped where *A. concolor* dominates the stand; in the study area, *C. decurrens* was found to be a minor component to the conifer layer.

2216—*Abies magnifica—Abies concolor* Alliance.

This mixed fir forest was mapped in dense stands to the north of the *A. concolor* Alliance and adjacent to but upslope from that type. It dominates the upland community along a small 2-mile stretch and transitions to higher elevation conifer types where the three branches of Sulphur Creek split apart from the main stem of Mill Creek. This type was mapped where the two fir species co-dominate the stand, frequently with a small component of *Pinus jeffreyi.*

2217—*Pinus jeffreyi* Alliance

Mapped in cold air basins at lower elevations than would be expected. *C. decurrens* and a small amount of *A. concolor* are frequent in the canopy. Frequently mapped as small upland islands in the meadow complex and on slopes immediately adjacent in setting less steep than conifers dominated by *A. concolor*. Commonly mapped in the vicinity of the Childs Meadows.

2218—*Abies magnifica* Alliance

Within the study, this Alliance is exclusively found in Lassen National Park upslope from a variety of higher elevation meadows in open woodland to dense forest settings. *A. magnifica* strongly dominates the canopy and is often a sole dominant. More open stands generally have a small component of *P. monticola*. Several associations within this Alliance may be defined based on the comments field which often denote a presence of *Wyethia mollis* or *Arctostaphylos nevadensis*. Over 1150 acres of this type were mapped in the study area.

2310—*Populus tremuloides* Alliance

Only eight polygons were defined (none verified) in the study area totaling just over 7 acres on rocky steep talus slopes just upslope from the main stem of Mill Creek.

2311—*Pinus albicaulis* Alliance

Six polygons mapped at the upper most elevations along the margins of the study area just downslope from Lake Helen around 8000' elevation.

2410—*Pinus monticola* Alliance

Mapped in open woodland settings on ridgelines and upper slopes just below the highest elevation conifer stands containing *P. albicaulis*. Mapped where *P. monticola* dominates the conifer layer; often with a minor component of either *Tsuga mertensiana* or *A. magnifica*. The comments field denotes the understory presence of *A. nevadensis* where it is visible in open stands. Small dry meadows, often containing *Wyethia mollis* occur within and adjacent to these small conifer stands.

2411—*Tsuga mertensiana* Alliance

Mapped in fairly large areas where *Tsuga mertensiana* dominates the conifer layer. Stands are often divided into unique cover categories. Often mapped near or adjacent to mesic or wet steep sloped discharge type meadows. Nearly 275 acres were mapped to this Alliance, exclusively in Lassen National Park.

6213—*Rubus discolor* Alliance

Mapped in disturbance settings, especially in irrigated pasture settings along the tributaries of Cow creek. Polygons mapped as 7102 (Irrigated Pasture) often have a shrub component noted in the cover estimates; this is often *R. discolor*. Over 700 acres mapped in both watersheds.

6301—*Toxicodendron diversilobum* Alliance

Two polygons mapped on steep slopes in post disturbance settings in Cow Creek Watershed. More commonly mapped in other parts of the NSNF project; noted in small patches on field reconnaissance in both watersheds within this study effort.

6401—*Rosa californica* Alliance

Observed on field reconnaissance but not mapped in the study area. Mapped infrequently in the NSFN project.

4112—*Arctostaphylos viscida* Alliance

Small polygons mapped in middle elevations in Mill Creek watershed; mapped in middle to upper elevation tributaries in Cow Creek watershed. Approximately 50 acres mapped in small stands; often in post burn settings adjacent to open stands *Pinus sabiana* or *P. ponderosa*. Riparian areas downslope from these post burn stands of *A. viscida* do not appear in most cases to have burned.

4113—*Ceanothus cuneatus* Alliance

Over a hundred polygons mapped in both watersheds; generally in association with or adjacent to open stands of *Quercus douglasii* woodlands. Tends to prefer the rockier openings in the blue oak woodlands. Approximately 300 acres mapped to this shrub type.

4410—*Quercus wislizeni* Shrub Alliance

34 polygons mapped in the lower mid elevations of Mill Creek watershed; occurring in slightly higher elevations in more mesic settings than *C. cuneatus* and *A. viscida.* 33 total acres mapped.

4510—*Arctostaphylos patula* Alliance

One polygon mapped in a mixed conifer opening along Mill Creek watershed. Frequently mapped in similar settings in the NSNF project.

4511—*Arctostaphylos nevadensis* Alliance

Mapped in high-elevation conifer openings as small polygons in the highest elevations in Mill Creek watershed. Noted in the comments field (and noted as a shrub component in the shrub cover field) to red fir and western white pine stands which can be used to define these high elevation open woodlands to an association level. 57 total acres mapped. Often mapped in close proximity to discharge and high elevation dry meadows containing *Wyethia mollis.*

4512—*Chrysolepis sempervirens* Alliance

Seven polygons mapped totaling just 3 acres of shrublands in the highest elevations of Mill Creek watershed.

4513—*Ceanothus cordulates* Alliance

Five polygons mapped totaling slightly under 10 acres of shrublands in the highest elevations of Mill Creek watershed.

7100—California Mixed Perennial and Annual Grasslands Macrogroup

This group is used to designate dry mostly nonnative California annual grasslands. Stands can have a small native forb and/or native grasslands component. Mapped on dry hillsides and in between open blue oak woodlands in the lower half of Mill Creek watershed and along most of the Cow Creek tributaries. Over 6500 acres mapped making it one of the most extensive upland communities that fringe the focus riparian areas.

7101—Mediterranean California Naturalized Annual and perennial Grasslands and Meadow Macrogroup

Over 4000 acres mapped; almost exclusively throughout Cow Creek Watershed and the lowest reaches of Mill Creek watershed. Stands of these weedy grasslands occupy very disturbed sites, often on old agricultural fields, vacant lots, or heavily used areas.

7102—Naturalized non-native perennial grassland and meadow Macrogroup (Irrigated Pasturelands)

Nearly 3000 acres mapped (See description on page 7 on the Irrigated Pasturelands of Cow Creek watershed) on most tributaries of Cow Creek watershed and lower most reaches of Mill Creek watershed.

Note the comparisons between the three herbaceous groups and annual agricultural lands below:

7102—Irrigated pasture—green during the dry season without consistent rows

7101—Weedy—note late season greening and mottling to the signature

9200 – Agriculture – note consistent "rows" across the picture

7100—California Annual Grasses—less mottling across the stand

Infrequently Mapped Riparian Types:

Note: Signature and/or environmental correlations have not for the most part been developed for these types, and therefore cannot be always be reliably mapped from existing digital imagery. Polygons are mapped based in part on field reconnaissance and/or verification efforts by Stillwater Science ecologists.

3330—*Salix lemmonii* (Lemmon's willow): 20 polygons mapped from the Childs Meadows north into Lassen National Park. Mapped within riparian meadow complexes, usually adjacent to small rivulets within the meadow. Approximately 15 acres mapped.

6210—*Baccharis salicifolia* (Mulefat Scrub): This is a rather common component to stands of young willow thickets; it was never observed in the study area as mappable stands.

6214—*Cephalanthus occidentalis* (Buttonwillow): Individual plants and small patches noted in rocky portions of Cow Creek Watershed; mapped in the NSNF project but not in this effort.

6216—*Sambucus nigra* (Blue elderberry): 9 polygons mapped; mainly along the main stem of Cow Creek in small patches along the drier margins of the riparian fringe in grassy settings. Stands are open cover.

6212—*Tamarix* spp. (Tamarisk): Small patches noted at lower elevations in both watersheds, none were observed on existing imagery and therefore not mapped.

6215—*Arundo donax* (Giant Cane): 15 polygons mapped, all with the lower reaches of Mill Creek and along the margins of the Sacramento River. Mapped stands are extremely small; cover is a uniform dense thatch of giant cane. Removal of patches were noted from previous image datasets.

7310—*Typha* spp. (cattail) Mapping Unit: 4 polygons mapped to the Alliance level in the study. *Note: Most marshes have been mapped to the generic group level 7300 (See Appendix A—Mill Creek-Cow Creek Classification).

7320—*Schoenoplectus* spp. (bulrush) Mapping Unit: 19 polygons mapped to the Alliance level in the study. *Note: Most marshes have been mapped to the generic group level 7300 (See Appendix A—Mill Creek-Cow Creek Classification).

Meadow Vegetation

*Note—Lower elevation meadows have been mapped to the more generalized group level in the NVCS hierarchy (Class 7200). (See Appendix A—Mill Creek-Cow Creek Classification).

High Elevation Meadow Types

*Note—Mapping classification for this type was taken from the USDA Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Range Key

7210—Dry Meadows: Mapped where vegetation reflects senescenced conditions on NAIP imagery. If conditions still appear green on NAIP imagery, then historic Google Earth imagery in early fall conditions is viewed.

7220—Discharge Slope Meadows

> **7221—Mesic Trending Discharge Slope Meadows:** Mapped away from stream channels or rivulets; often along the margins of conifer forests where the water appears to be originating from the adjacent stand or at the break in slope between the nearly level surface and adjacent steeper slope. Signature is a light to medium green; little or no senescing of the vegetation in the stand and no standing water is visible.
>
> **7222—Wet Trending Discharge Slope Meadows:** Mapped in in similar slope settings to mesic trending discharge meadows but in conditions where signature on the 2012

NAIP is dark green to dark brown. Surface water in portions of the meadow may be visible in areas.

7230—Riparian Related Meadows

7231—Mesic Low Gradient Meadows: Mapped in proximity to stream channels and small rivulets that flow into the more defined channels. Meadows are away from defined slope breaks and have minimal slope across the mapped meadow. Elevation maps depict slope <2%. Signature is a light to medium green; little or no senescing of the vegetation in the stand and no standing water is visible.

7232—Mesic Medium Gradient Meadows: Mapped in similar settings to type 7231 and yielding similar image signature characteristics, but on slopes that are noted on elevation maps in the 2-4% range.

7233—Mesic High Gradient Meadows: Mapped in similar settings to type 7231 and 7232 and yielding similar image signature characteristics, but on slopes that are noted on elevation maps over 4%.

7234—Wet Low Gradient Meadows: Mapped in similar settings to mesic low gradient meadows but with signature characteristics defining wetter conditions (darker greens and dark brown colors)

7235—Wet Medium Gradient Meadows: Mapped in similar settings to mesic medium gradient meadows but with signature characteristics defining wetter conditions (darker greens and dark brown colors)

7236—Wet High Gradient Meadows: Mapped in similar settings to mesic high gradient meadows but with signature characteristics defining wetter conditions (darker greens and dark brown colors)

7240—Subsurface Meadows: Higher elevation meadows were mapped to this category, away from small rivulets and streams. Herbaceous vegetation in most cases appear partially to mostly senesced yielding a light tan with varying hues. On higher resolution imagery, *Wyethia mollis* is visible and Stillwater Science ecologists instructed photo interpreters to map these meadows into this subsurface type.

7250—Lacustrine Fringe Meadows: Only one polygon mapped to this type along the northern margins of Upper Ridge Lake at the 8000' level.

Miscellaneous Classes

9200—Agriculture: *Note comparison on p.52 between agriculture and irrigated pasture. Mapped where grain crops are used for animal or human consumption where visible rows are present. Fallow fields are mapped if agriculture was present after 2005. Orchards and vineyards mapped to this category in the study. Most crops are either grain or fruit.

9300—Built up and urban disturbance: This type is mapped when the native vegetation surrounding the urban disturbance is <10% and the area is impacted by structures, irrigated landscaping and/or impervious surfaces. . Note that areas that are built up for agricultural related uses (stables) are coded as this category.

9401—Cliffs and rock outcroppings, talus and scree: Mapped where there is less than 10% vegetation on rocky substrates. Follows almost the entire length of the lower-middle portions of the Mill Creek, often on both sides of the channel. Also noted in the highest elevations in Lassen National Park as outcroppings, talus and scree where it often is adjacent to mesic to wet discharge meadows and dry meadows containing *Wyethia mollis*. Continuous bands of rocky side slopes were also mapped along a five-mile stretch of Little Cow Creek near Little Round Mountain.

9402—River and lacustrine flats and streambeds: Over 350 acres mapped throughout the entirety of the two watersheds in a variety of flooding regimes. Riverine flats are mapped where vegetation falls below 7-8% cover. Stands approaching that density often contain very young sapling willow species and wetland forbs. Streambeds are mapped where no water is visible on the 2010 NAIP imagery and the rocky or sandy streambed can be seen. At times the streambed is mapped under a closed canopy of vegetation for connectivity. The canopy overhang field is useful in these circumstances.

9403—Anthropogenic areas of little or no vegetation: These are areas that have been recently cleared and don't have enough vegetation present to classify as a vegetation type. These areas are usually around homes, agriculture, roads or artificial embankments along river channels.

9500—Exotic Trees: This category was used for exotic trees that were not identifiable on the imagery, and therefore could not be classified into a specific mapping type. Only 5 stands mapped, all on the lower reaches of Mill Creek.

9501—Eucalyptus: Three polygons mapped in the study area.

9800—Water: Polygons mapped to this category did not fit into types 9802 or 9803 and were not part of the perennial stream channel. Most polygons were cut off meanders along the main perennial channel of Little Cow Creek.

9801—Perennial Stream Channel: 1141 acres mapped where water is visible in the channel on the 2010 NAIP imagery. At times the perennial streambed is mapped under a closed canopy of vegetation for connectivity. The canopy overhang field is useful in these circumstances. Note below the canopy cover values and examples of canopy overhang.

9802—Reservoirs: No reservoirs were mapped in the watershed study effort.

9803—Semi-natural Ponds: 130 of these small water bodies have been mapped in the study area. Most of these water features have small earthen dams with the water follow the contouring of the natural landscape. Many have very small emergent wetland marshes; usually where the drainage empties into the pond which contain some cattail and/or bulrush.

Appendix D

Vegetation Classes and Codes

1000—Warm Temperate Forests and Woodlands
1100—California Evergreen Sclerophyll Forests and Woodlands
1110—*Umbellularia californica* (California Bay)
1111—*Quercus wislizeni* (Interior Live Oak Tree)
1200—California Evergreen Coniferous Forests and Woodlands
1210—*Pinus sabiniana* (Foothill Pine)
1300—California Upland Deciduous Forests and Woodlands
1310—*Aesculus californica* (California Buckeye)
1311—*Quercus douglasii* (Blue Oak)
1312—*Quercus kelloggi*i (Black Oak)
1313—*Quercus lobata* (Valley Oak)
1400—Vancouverian Evergreen Forests and Woodlands
1410—*Quercus chrysolepis* (Canyon Live Oak)
2000—Cool Temperate Forests and Woodlands
2100—Upland Vancouverian Mixed Forests
2110—*Pseudotsuga menziesii* (Douglas-fir)
2111—*Acer macrophyllum* (Bigleaf Maple)
2112—*Pinus ponderosa-Pseudotsuga menziesii* (Ponderosa-Doug-fir)
2200—California Montane Conifer Forests (use for plantation)
2210—*Pinus ponderosa* (Ponderosa Pine)
2212—*Pinus ponderosa-Calocedrus decurrens*
2213—*Calocedrus decurrens* (Incense Cedar)
2214—*Abies concolor-Pinus lambertiana* (White Fir-Sugar Pine)
2215—*Abies concolo*r (White Fir)
2216—*Abies magnifica-Abies concolor* (Red Fir-White Fir)
2217—*Pinus jeffreyi* (Jeffrey Pine)
2218—*Abies magnifica* (Red Fir)
2300—Rocky mountain mesic subalpine forest and woodland MG
2310—P*opulus tremuloides* (Quaking Aspen)
2311—*Pinus albicaulis* (Whitebark Pine)
2400—Vancouverian Subalpine forest MG
2410—*Pinus monticola* (Western White Pine)
2411—*Tsuga mertensiana* (Mountain Hemlock)
3000—Temperate Flooded Forests
3100—Southwestern Riparian Evergreen and Deciduous Woodlands
3101—(Red/Black Willow) Thicket-Young Sapling Stands
3110—*Populus fremontii* (Fremont Cottonwood)
3111—*Salix laevigata* (Red Willow)
3112—*Salix gooddingii* (Black Willow)
3113—*Juglans hindsii* (Walnut)
3114—*Acer negundo* (Box Elder)
3115—*Salix lasiolepis* (Arroyo Willow)
3310—*Platanus racemosa* (California Sycamore)
3200—Vancouverian Riparian Deciduous Forests
3210—*Alnus rhombifolia* (White Alder)
3211—*Fraxinus latifolia* (Oregon Ash)
3212—*Populus trichocarpa* (Black Cottonwood)
3300—W. N. American Montane-S-Alpine Riparian Scrub
3320—*Alnus incana* (Mountain Alder)
3330—*Salix lemmonii* (Lemmon's Willow)
6200—Southwestern Riparian Wash Scrub

6210—*Baccharis salicifolia* (Mulefat)
6211—*Salix exigua* (Narrowleaf Willow)
6214—*Cephalanthus occidentalis* (Buttonwillow)
6216—*Sambucus nigr*a (Blue Elderberry)

Southwestern Introduced Riparian Scrub
6212—*Tamarix* spp. (Tamarisk)
6215—*Arundo donax* (Giant Cane)

Temperate and Boreal Scrub and Herb Coastal Veg.
6213—*Rubus discolor* (Himalayan Blackberry)
6300—Vancouverian Coastal Deciduous Shrubs
6301—*Toxicodendron diversilobum* (Poison Oak)
6400—California Warm-Temperate Riparian Scrub
6401—*Rosa californica* (California Wild-rose)
4000—Mediterranean Scrub
4100—California Xeric Chaparral
4112—*Arctostaphylos viscida* (Sticky Whiteleaf Manzanita)
4113—*Ceanothus cuneatus* (Buckbrush)
4400—California Evergreen Coastal Scrub Macrogroup
4410—*Quercus wislizeni* shrub (Interior live oak)
4500—California and Western Cordilleran Montane Chaparral MG's
4510—*Arctostaphylos patula* (Greenleaf Manzanita)
4511—*Arctostaphylos nevadensis* (Pinemat Manzanita)
4512—*Chrysolepis sempervirens* (Pinemat Manzanita)
4513—*Ceanothus cordulates* (Mountain Whitethorn)

6000—Temperate and Boreal Shrubland
6100—Southern Vancouverian Montane Deciduous Shrubs
6110—*Ceanothus integerrimus* (Deerbush)
6111—*Quercus garryana* var. *breweri* (Brewer oak)

Herbaceous Vegetation
7101—Mediterranean California Naturalized Annual and Perennial Grasslands and Meadow Macrogroup (weedy)
7103—Centaurea (Star Thistle)
7102—Naturalized non-native perennial grassland and Meadow Macrogroup (Irrigated Pasture Lands)

Temperate and Boreal Freshwater Marsh
7200—Western N. American Temperate Marsh and Wet Meadow Macro Group (Meadows)
7201—Forest-Riparian Fringe and Forest Openings
7210—Dry Meadows
7220—Discharge Slope Meadows
    7221—Mesic Trending
    7222—Wet
7230—Riparian Related Meadows
    7231—Mesic low gradient
    7232—Mesic medium gradient
    7233—Mesic high gradient
    7234—Wet low gradient

7235—Wet medium gradient
7236—Wet high gradient
7240—Subsurface Meadows
7250—Lacustrine Fringe Meadows
7300—North American Arid West Freshwater Marsh (Marsh Vegetation)
7310—*Typha* spp. (Cattail)
7320—*Schoenoplectus* spp. (Bulrush)

Mediterranean California Grassland and Forb
7100—California Mixed Perennial and Annual Grassland and Meadow Macrogroup (Native Component)
7401—Mediterranean California Grassland and Forb Meadow Division - (Vernal Pool Matrix)
7600—Western NA Vernal Pools and Other Seasonally flooded Macrogroup
7601—*Eleocharis macrostachya*, *Downingia*, *Trifolium variegatum*, *Eryngium* (Vernal Pools)
9200—Agriculture (Without fallow annual grasses dominating)
9300—Built up and Urban Disturbance
9310—Urban Window
9400—Areas of Little or No Vegetation
9401—Cliffs and Rock Outcroppings
9402—River and Lacustrine Flats and Streambeds
9403—Undefined areas with little or no vegetation (Human Disturbance)
9500—Exotic Trees
9501—*Eucalyptus*
9502—Plantation
9800—Water
9801—Perennial Stream Channel
9802—Reservoirs
9803—Small Earthen Dam Ponds and Natural Lakes

Appendix E

Attributes in Cow Creek and Mill Creek Riparian Vegetation Map

MAPPING RULES FOR RIPARIAN VEGETATION CHARACTERISTICS

Density (Hardwood, Conifer, Shrub)
5 = 60+ %
4 = 40-59%
3 = 25-39%
2 = 10-24%
1 = 2-9%
9 = Not Applicable

Density, Herbaceous
1 =<20%
2 =20-40%
3 = 40-60%
9—Not Applicable

Model Height Classes—(From CNPS RA Form)
1 = < ½ Meter
2 = ½–1 Meter
3 = 1–2 Meters
4 = 2–5 Meters
5 = 5–10 Meters
6 = 10–15 Meters
7 = 15–20 Meters
8 = 20–35 Meters
9 = Not Applicable

Canopy Overhang Categories
0 = Negligible Canopy Overhang: Less than 5% of the stream segment
1 = Low: 5–25% of the stream segment
2 = Medium: 25–50% of the stream segment
3 = High: Greater than 50% of the stream segment
4 = Obscured: Significant portions of the stream channel hidden and the locations are approximated
9 = Not Applicable to polygon

Appendix F:
Delineating Canopy Overhang

Figure F-1. Example showing a portion of Mill Creek delineated to the tree canopy edge. Although the lines depict canopy overhang, it is not quantifiable.

Figure F-2. Same area with delineations to the perceived channel boundary—depicts accurate delineation of the stream course but there is no visual representation of canopy overhang

Figure F-3. Side by side comparison showing canopy delineations (in red) and channel edges delineated (in blue). *Note—actual delineations on the map are to the channel edge

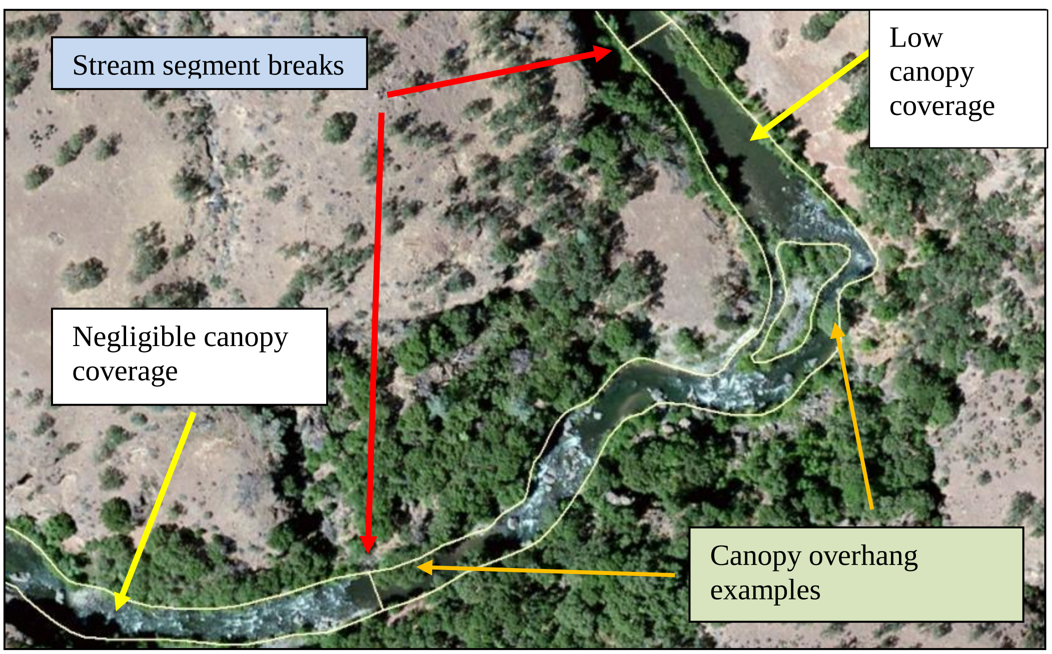


Figure F-4. By segmenting stream courses into high, medium, low and negligible canopy overhang, analysts can quantify what percentage a stream segment is shaded by adjacent tree canopies in addition to depicting the most accurate representation of the stream channel location (See Appendix E for description of overhang categories).

Appendix G: Condition Ratings for Cow Creek

Reach	Condition	Tributary	Notes
1a1a	1	Mainstem Cow Creek	Nearly unvegetated banks close to confluence with Sacramento; eroding banks, shallow rip tree strip on west side (1 tree deep); recruitment needs; vegetated riparian corridor width generally < 50 ft.
1a1b	1.5	Mainstem Cow Creek	Many unvegetated or sparsely vegetated banks on both sides, erosion common with steeply cut banks on east side; bedrock channel bottom vertical controls exposed in many areas; creek meanders with small patches of riparian forest
1a1c	1	Mainstem Cow Creek	Many unvegetated or sparsely vegetated banks on both sides, erosion common
1a1d	1.5	Mainstem Cow Creek	Many unvegetated or sparsely vegetated banks on both sides, erosion common
1a1e	2	Mainstem Cow Creek	Slightly more vegetation along banks but mostly only one to two trees wide
1a1f	2	Mainstem Cow Creek	Many unvegetated or sparsely vegetated banks on both sides, erosion common; land use constraining river movement on both sides
1a1g	2	Mainstem Cow Creek	Many unvegetated or sparsely vegetated banks on both sides, erosion common, room to create riparian forest on east side
1a2	2	Mainstem Cow Creek	Many unvegetated or sparsely vegetated banks on both sides, single tree width riparian canopy, riparian veg width much smaller than potential
1a3	2	Mainstem Cow Creek	Areas with bank erosion and no/few trees but also more areas with wider (2–4 canopy width) vegetated riparian corridors, patches of riparian forest/shrub allowed to connect with channel but channel along most (~75%) of reach is constrained and riparian vegetation is narrow strip. Bedrock control, steep bank incision.
1a4	2.5	Mainstem Cow Creek	Large suburban homes/pools/yards with surface erosion on south bank; some homes and pasture north bank; 1 tree width riparian corridors link river bends with small riparian forest/shrublands established on the inside of bends; some meander and lateral connection
1b	2	Oak Run Creek	Wider and denser riparian veg on downstream end of reach; upstream end has stretch with little bank vegetation; some bank erosion and surface erosion from trails on adjacent uplands (and no water in channel during image capture- August 2013; Google imagery)
1c1	2.5	Mainstep Cow Creek	Modestly dense residential; many banks with 1 tree width or less deep riparian corridor; less area without any trees than those rated '2
1c2	2.5	Mainstep Cow Creek	Over 2 tree width riparian forest on both sides common; residential development constraining river left and invasive species; some connected floodplains along with small riparian forests
1c3	2.5	Mainstep Cow Creek	Several areas of well-developed riparian forest; but river left and parts of river right constrained by land use with some patches of little to no veg and bank erosion visible

Reach	Condition	Tributary	Notes
1c4	2.5	Mainstem Cow Creek	Although meandering within floodplain, adjacent riparian vegetation is diminished (land use, bank failures); potential issues from homes and bank erosion on river left; riparian vegetation is sparse along most of banks—channel almost completely exposed.
1c5	3	Mainstem Cow Creek	Potential issues from homes on river left, some erosion spots; channel lateral connectivity fairly high
1d1	2	Mainstem Cow Creek	Landuse constraining lateral connectivity and width of riparian corridor (1-2 trees); also indications of surface erosion and eroding banks; some weed issues (HBB)
1d2	1	Mainstem Cow Creek	Lots of erosion, sparsely vegetated banks with apparent lateral connectivity mostly limited (?) by low flows (GE imagery for 8/27/2013 shows no water in channel); some weeds (HBB)
1d3	2	Mainstem Cow Creek	Very low flows, bare banks, signs of erosion from adjacent lands; residential encroachment hight on river left, or single-tree thick riparian corridor; heavy weeds likely (HBB)
1d4	1	Mainstem Cow Creek	Very low flows, bare banks with no cover most of length, few single-tree thick riparian strips; weeds,
2a	1.5	Little Cow Creek	Lots of unvegetated and thinly vegetated banks, eroding cut banks visible; lateral connectivity okay, esp. river right but likely that land use has reduced existing riparian vegetation to current very low levels. Creek fully exposed (unshaded)
2b	3	Unnamed trib to Little Cow Creek	Small trib to Little Cow Creek; fairly well vegetated below 299 more degraded above, some residential development constraining lateral flooding and riparian vegetation development
2c	2.5	Little Cow Creek	Mostly wide well vegetated active riparian corridor; adjacent terraces show surface erosion (grazing) and on then soils of Red Bluff formation; two small sections on downstream and upstream ends with few trees and dirt trails and downcutting unvegetated banks (river left). Suburban encroachment on ds end
2d	4	Little Cow Creek	Undeveloped; mostly open bedrock constrained channel with sparse veg; conifer and shrubs
2e	2	Little Cow Creek	Runs along hwy 299 entire length (within 100 ft); otherwise mostly undeveloped and bedrock constrained.
2f1	2.5	Little Cow Creek	Some farm lots with grazing, bare soil along ~20% of length otherwise riparian trees at least 1-2 wide along about 90% of length
2f2	2.5	Little Cow Creek	Cattle paths and dirt roads indicate local surface erosion leading to channel and some areas with steeply cut banks, otherwise riparian trees at least 1-2 wide along about 90% of length; evidence of active meandering and riparian vegetation development in bars on inside of meander bends;
2f3	3.5	Little Cow Creek	Mostly lined with alders, and adjacent native uplands; Some additional sediment sources from power line crossing, dirt roads with visible gullies from GE
2g	2.5	Cedar Cr (trib to Little Cow)	Some farm lots with grazing, bare soil, dirt roads along ~10% of length otherwise riparian trees at least 1-2 wide along about 90% of length; evidence of active meandering

Reach	Condition	Tributary	Notes
2h	2.5	Cedar Cr (trib to Little Cow)	Some farm lots with grazing, bare soil, dirt roads along ~10% of length otherwise riparian trees at least 1-2 wide along about 90% of length; evidence of active meandering
3a1	2	Oak Run Creek	Riparian corridor fairly continuous but very narrow (mostly 1 tree wide); constrained by residential development along lower reach; ag lands otherwise; surface erosion from adjacent lands appears common; some cut banks along upper of high flow channel.
3a2	1.5	Oak Run Creek	Vegetated riparian corridor discontinuous and very thinly vegetated; surface and bank erosion visible; cattle trails and two tracks adjacent to channel likely sources of erosion input
3b	2.5	Oak Run Creek	Riparian corridor fairly continuous but very narrow (mostly 1 tree wide); some dirt trails and a lot of steep bank erosion—reach looks incised. Reach ends at culvert under Oak Run Road
3c	4	Oak Run Creek	Undeveloped; steep walls with upland vegetation (native)
3d	4	Oak Run Creek	Undeveloped; steep walls with upland vegetation (native)
3e	4	Oak Run Creek	Undeveloped; steep walls with upland vegetation (native)
3f	2.5	Oak Run Creek	Reservoir in middle of lower section; corridor above ~ continuous and >1 tree wide; frequent dirt trails within 100 ft.
3g	4	Oak Run Creek	Mostly undeveloped and forested along sides
3h	4	Oak Run Creek	Mostly undeveloped and forested along sides
3i	4	Oak Run Creek	Creek appears intermittent here; Mostly undeveloped and forested along sides (transmission line swath cut in small fraction)
4a1	2.5	Clover Creek	Potential floodable width appears currently limited by lower flows; riparian vegetated corridor is 1 to 4 trees thick and nearly continuous; irrigated pasture common on landside of trees; few areas with little to no veg
4a2	2	Clover Creek	Corridor is narrow (~1 tree wide) and discontinuous; adjacent is pasture or otherewise annual grasslands, cut banks common; need for more vegetation b/c channel ~90% exposed
4a3	2.5	Clover Creek	South side continuous and wide; north side discontinuous and often narrow; likely in part naturally so
4b1	2.5	Clover Creek	Upstream section appears incised and has very little riparian shade along east and west banks
4b2	4	Clover Creek	Steep canyon walls; naturally with low density upland vegetation
4b3	4	Clover Creek	Steep canyon walls; densely forested on east side; south facing canyon wall more open upland forest
4b4	4	Coal Creek (trib to Clover)	all natural land use; no apparent grazing or forestry; moderately vegetated shrublands with narrow intermittent riparian corridor
4c1	4	Rosebrier Creek (trib to Clover)	all natural land use; no apparent grazing or forestry; moderately vegetated shrublands with narrow intermittent riparian corridor; natural meander apparent

Reach	Condition	Tributary	Notes
4c2	2	Rosebrier Creek (trib to Clover)	200 x 600 ft cow pond placed in-line with tributary; lots of algae. Otherwise natural with riparian corridor in upland sparse grassland/woodland matrix
4d1	2.5	Dry Clover (trib to Clover)	HBB along edges (?), trails and some surface erosion along north side, otherwise ~natural lands and RZ
4d2	3.5	Dry Clover (trib to Clover)	Narrow riparian corridor in upland grazed matrix of grass oak woodland; surface erosion, some banks with no/little riparian vegetation
4d3	4	Dry Clover (trib to Clover)	Narrow riparian corridor in upland matrix of grass oak woodland; some surface erosion, corridor nearly continuous
4d4	2	Dry Clover (trib to Clover)	Runs parallel to power lines (bare soils), has pond in line with channel, narrow strip of shrubby rip veg in dry grassland oak matrix. Surface erosion.
4d5	1	Dry Clover (trib to Clover)	~seasonal in upper parts but on ranch with narrow non-continuous strip of rip veg cover through apparent pastures with multiple active eroding surface and gullies from adjacent lands, weeds (HBB).
5a	2	Basin Hollow (trib to S. Cow)	Invasive weeds (check field data); riparian corridor continuous and >1 tree wide up to power line crossing; weeds at crossing and above (HBB and possibly *Arundo*); upstream of that riparian corridor condition diminishes substantially
5b	1	Basin Hollow (trib to S. Cow)	Lots of invasive weeds (HBB, possibly *Arundo*); narrow corridor of native riparian vegetation' irrigated pasture drains into creek; likely too small cfs for fish
6a	2.5	Old Cow (trib to S. Cow)	Over 1/3 of riparian corridor is sparsely vegetated on SE banks -- could be natural for area or legacy of land use (grazing)
6b	2.5	Old Cow (trib to S. Cow)	Approximately 1/3 of riparian corridor is sparsely vegetated; irrigated pasture with cow trails could increase sediment inputs, creek appears to flood most potential lateral extent, includes complex channel structure and movement
6c	3	Old Cow (trib to S. Cow)	Riparian corridor nearly all continuous and >1 tree wide; dirt trails, irrigated pasture and likely HBB in adjacent lands keep from being in excellent condition
6d	4	Old Cow (trib to S. Cow)	Mostly excellent with channel movement and riparian forest development in bends, but a few stretches with sparsely vegetated banks
6e	4	Old Cow (trib to S. Cow)	Some roads and residential but appears in excellent shape
6f	3.5	Old Cow (trib to S. Cow)	Reservoir in middle of upper section; corridor below ~ continuous and >1 tree wide
7a	2.5	South Cow	Mostly in okay shape; Some floodplains not accessed often possibly due to on-going low flows; surface erosion from trials along adjacent uplands; some single-tree strips of riparian veg could be expanded

Reach	Condition	Tributary	Notes
7b	2.5	South Cow	Most with okay riparian corridor but patches with little to no riparian vegetation, bank and surface erosion into channel at upper end of reach need attention
7c	2.5	South Cow	Over half has wide riparian vegetation development but half has little to no riparian vegetation; a lot of bank erosion on river right; S. Cow Creek road and residential development constrains river left
7d	4	South Cow	Corridor continuous and >1 tree wide; no visible erosion or land use except a dam (Cow Creek forebay)
7e1	4	Mill Creek (trib to South Cow)	Corridor continuous and >1 tree wide; no visible erosion or land use except a dam (Cow Creek forebay)
7e2	4	Mill Creek (trib to South Cow)	Corridor continuous and >1 tree wide; no visible erosion or land use
7e3	3	Mill Creek (trib to South Cow)	Corridor continuous but in places ~1 tree wide or bare on each bank likely associated with grazing; some visible erosion from adjacent uplands
7e4	3	Mill Creek (trib to South Cow)	50 to 150 ft wide (varies) buffer (from edge to edge) within ~3 yr old clear cut. Rip veg continuous in area. Not sure this stream runs all year.
7f	3	South Cow	Continuous rip veg; about half length with wide riparian forest development Other half 2-4 tree wide per side; irrigated pasture on both sides
7g	4	South Cow	Corridor continuous and >1 tree wide; no visible erosion or land use effects
7h	4	Atkins Creek (trib to South Cow)	Corridor continuous and >1 tree wide; no visible erosion or land use effects
7i	4	Atkins Creek (trib to South Cow)	Corridor continuous and >1 tree wide; no visible erosion or land use effects
7j	4	Atkins Creek (trib to South Cow)	Corridor continuous and >1 tree wide; no visible erosion or land use effects
7k	4	South Cow	Corridor continuous and >1 tree wide; no visible erosion or land use effects
7l	4	South Cow	Corridor continuous and >1 tree wide; no visible erosion or land use effects
7m	4	Beal Creek (trib to South Cow)	Corridor continuous and >1 tree wide; no visible erosion or land use effects
7x	2	South Cow	Intermittent channel with weeds likely (HBB?), intermittent veg cover over channel
7y	2	South Cow	70% of channel length has not veg over it. Appears seasonal however. Could be important small trib for fish
7z	2	South Cow	50% of channel length has not veg over it. Appears seasonal however. Could be important small trib for fish

Appendix H: Condition Ratings for Mill Creek

Reach	Condition	Notes
1a	1	Priority site; very little shade especially on south banks of channel; some roads and trails near channel could increase surface erosion into channel; flows lowest since downstream of diversions; non-natives mapped in 16% 30 ft buffer area; low LWD recruitment potential.
1b	1.5	Residential areas constrain channel meander and lateral connectivity; shade low here, especially on south side, surface erosion from roads and trails likely. Another diversion reduces flow, non-native vegetation recorded in 21% of 30 ft buffer area; high cover non-native vegetation.
1c	2	Diversion at top of 1c decreases downstream active channel width; riparian forest development on floodplain occurring but includes barren or low density areas as well, surface erosion from high road density near channel likely; non-native vegetation occurs in 18% of 30ft buffer area.
2	1	Channel flows out of constraining Red Bluff formation hills to either side onto flatter alluvial fan and sinuosity increases with increasing width of floodplain; riparian forest development on some inside bends; some residential land uses constraining channel and show some bank erosion. Shade could be increased along upper stretch of reach; agricultural landuse directly adjacent uplands could increase sediment inputs (already high from volcanic contributing area).
3	2	Channel emerges from canyon but still very confined by Red Bluff formation to either side (thin soils, low veg cover); 20-60 ft ledge along channel edge supports narrow and intermittent riparian vegetation. Valley walls do not shade; no veg to shade from adjacent uplands (apparently naturally so).
4	4	Naturally barren landscape, nearly barren uplands and almost only rock along very constrained channel; valley walls very steep; small and narrow pockets of riparian vegetation within 15 ft of channel.
5	4	Naturally barren landscape, nearly barren uplands and almost only rock along very constrained channel; valley walls very steep; small and narrow pockets of riparian vegetation within 15 ft of channel.
6	4	Naturally barren landscape
7	4	More confined river valley, sediment load not as high as reaches above, great shape
8	4	More confined river valley, sediment load not as high as reaches above
9	3.5	Large sediment load moving downstream; actively meandering channel suggests revegetation not advisable in floodplain
10	3.5	Large sediment load moving downstream; actively meandering channel suggests revegetation not advisable in floodplain
11	3.5	Large sediment load moving downstream; actively meandering channel suggests revegetation not advisable in floodplain; restored meadow gully along river right to be protected

Reach	Condition	Notes
12	2.5	Large sediment load moving downstream; actively meandering channel suggests revegetation not advisable in floodplain; is this level of sediment load and channel movement within 'natural range of variability'? Steeply cut banks ~1,000 ft upstream of Hwy 89 crossing on western channel indicate potential problem.
13	3	Appears in recovery from large event-related sediment inputs—upland sediments sources analysis to determine if actions could reduce future event related inputs, or if within natural range of variability. Braided channel; recovering riparian vegetation (?) on adjacent floodplains
14	3	Appears in recovery from large event-related sediment inputs—upland sediments sources analysis to determine if actions could reduce future event related inputs, or if within natural range of variability. Appears to simply receive high sediment pulse loads from above barren recent volcanic area.
15	4	Top of Lassen, naturally low vegetation cover (recovery from early 20th C eruption and lava flows)
16	4	Top of Lassen, naturally low vegetation cover (recovery from early 20th C eruption and lava flows)
Gunwale Creek	4	Tributary to lower part of canyon (top of reach 6); narrow at top, widens to alluvial fan with dense native riparian forest at confluence. Nearly entire tributary is contained within clearly and geologically defined boundaries with ~barren volcanic Tuscan formation in surrounding lands
Mill north distributary	1	Not an active channel, non-native vegetation mapped in 25% of 30 ft buffer area.