Introduction to the Bear Creek Watershed Assessment

and

Solicitation for Stakeholder Input

1 December 2008

Acknowledgments

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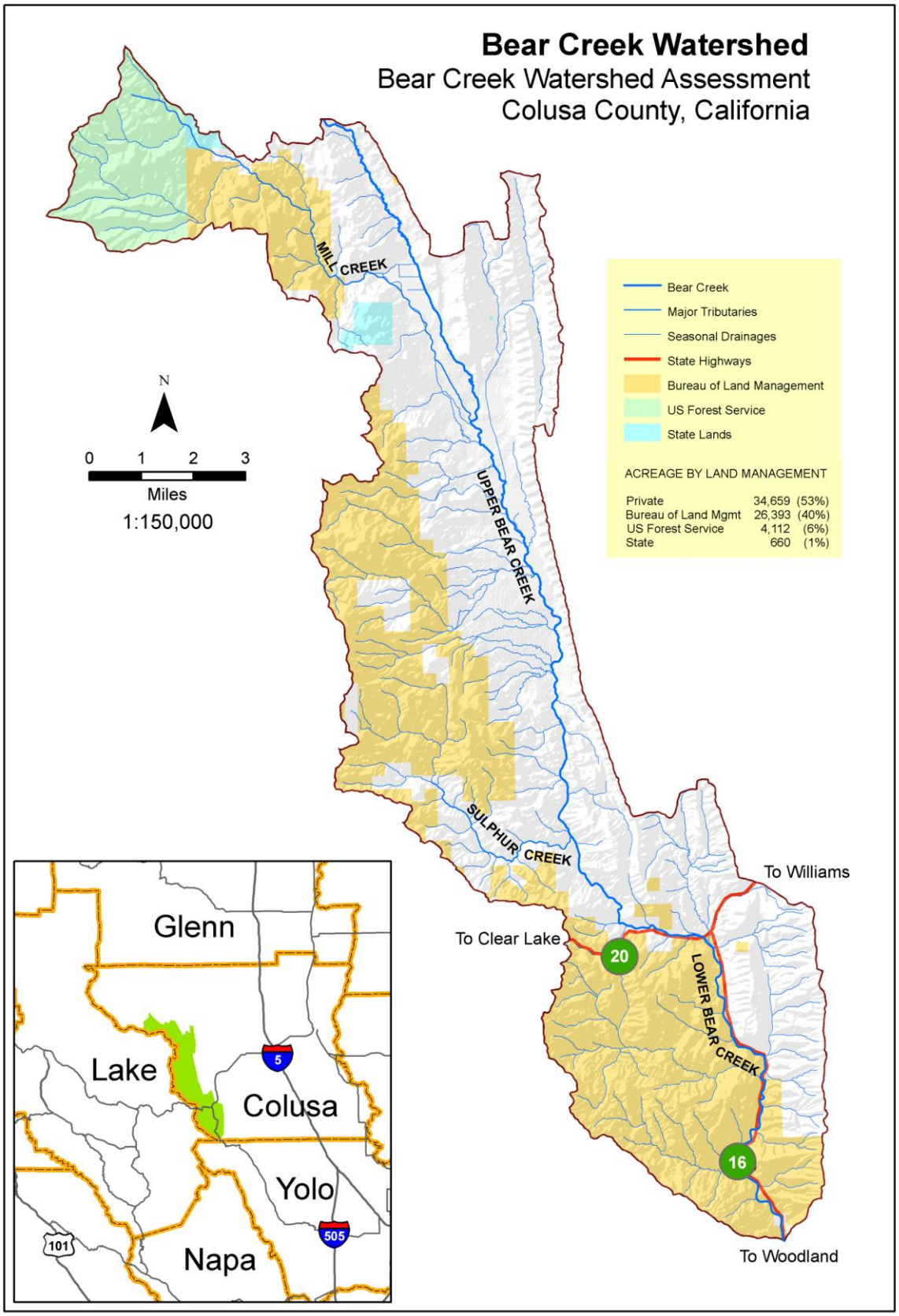

Bear Creek Watershed
Bear Creek Watershed Assessment
Colusa County, California
MILL CREEK
UPPER BEAR CREEK
SULPHUR CREEK
LOWER BEAR CREEK
Bear Creek
Major Tributaries
Seasonal Drainages
State Highways
Bureau of Land Management
US Forest Service
State Lands
ACREAGE BY LAND MANAGEMENT
Private 34,659 (53%)
Bureau of Land Mgmt 26,393 (40%)
US Forest Service 4,112 (6%)
State 660 (1%)
N
0 1 2 3
Miles
1:150,000
To Williams
To Clear Lake
To Woodland
20
16
Glenn
Lake
Colusa
Yolo
Napa
5
505
101

BEAR CREEK WATERSHED ASSESSMENT
STEWARDSHIP GOALS and ISSUES

Purpose

The Bear Creek watershed assessment is designed to:

- Gather information from stakeholders, technical literature, documents, and data sets that describe past and current conditions in the watershed
- Determine stakeholder goals and stewardship issues
- Conduct natural resource inventories and identify data gaps
- Assess water quality, hydrologic function, soil and site stability, and biotic integrity
- Identify locations, stewardship practices, and opportunities appropriate for addressing resource issues in the watershed

Goals

Thus far, stakeholders have identified eight broad goals for the watershed:

- Improve water quality
- Restore hydrologic function
- Conserve topsoil and stabilize erosion-prone areas
- Protect and enhance biological diversity
- Enhance recreation
- Develop energy resources
- Maintain economic livelihoods and create jobs
- Reduce the likelihood and impacts of catastrophic events

Issues

Stakeholder issues that must be addressed to achieve goals include:

- Toxic chemicals
- Sediment delivery to watercourses
- Creek channel alterations
- Creek and tributary headcuts
- Roads, trails, and fire suppression lines
- Fire
- Stressors to oak woodlands
- Disturbances to ultramafic soils*
- Non-native invasive species
- Low recruitment of native woody riparian plants
- Impacts from certain livestock grazing practices and browsing and gnawing animals
- Growing demand for recreation and tourism
- Potential environmental impacts of energy developments
- Fiscal and policy obstacles for landowners to meet regulatory targets
- Climate change
- Information gaps

* soils with a high ratio of magnesium to calcium, including serpentinite, commonly known as “serpentine”

The eight sections that follow highlight key information about Bear Creek watershed issues, organized under the watershed goals.

GOAL 1: IMPROVE WATER QUALITY

The Central Valley Water Board has established total maximum daily load (TMDL) targets for Bear Creek and its tributary Sulphur Creek. The TMDLs limit the amount of total mercury and methylmercury, the biological form that accumulates in animals. Large quantities of sediment enter Bear Creek watershed drainages annually during storm events, discharging biological, chemical, and physical pollutants to the waterways. Analysis of aerial photographs (above Highway 20) by Pacific Watershed Associates (PWA 2008) indicated that approximately 205,000 cubic yards of sediment was delivered into the Bear Creek watershed between 1937 and 2005, a conservative figure reflecting only sediment delivery observable at a 1:20,000 map resolution.

Rathburn-Petray Mine Complex is the largest abandoned mercury mine in the watershed.

- Toxic chemicals – mercury and methylmercury
  - ✓ Sources of mercury in the watershed include: waste ore and tailings from abandoned mercury mines, geothermal and cold springs, soil erosion, and atmospheric deposition (Stanish and Cooke 2007; Slowey and Rytuba 2008)
  - ✓ Bear Creek has had the highest concentrations of methylmercury in California streams where recreational fishing occurs, prompting the California Environmental Protection Agency in 2005 to issue a health advisory that no one should eat fish or shellfish from Bear Creek.
  - ✓ Bear Creek is the second largest source, after Clear Lake, of methylmercury for the Upper Cache Creek Basin, about 17 percent of methylmercury produced in the entire Basin (Cooke et al. 2004).
  - ✓ The Rathburn-Petray mine complex generates 1.2 - 24.3 kg/yr of total mercury; an as yet unknown amount of mercury reaches Bear Creek (Churchill and Clinkenbeard 2003).
  - ✓ Total mercury in creeks spike between January and March, coinciding with storm events that release

mercury-laden sediments into waterways (Domagalski et al. 2004), especially Sulphur Creek (Cooke and Morris 2005).

- ✓ Annual amounts of mercury and methylmercury in creeks range widely depending on rainfall patterns. Data collected by scientists indicates the watershed budget for mercury and methylmercury as follows:

Sources	All Bear Creek Watershed		Only Sulphur Creek Sub-watershed	
	Total Mercury	Methylmercury	Total Mercury	Methylmercury
Natural Sources	kg per year	kg per year from all sources	kg per year	kg per year from all sources
Soil Erosion	4.9 – 75.9		1.2	
Geothermal Springs	1.4	0.021	1.4	0.080
Abandoned Mines	9.9 – 32.7		9.2	
Grazing Erosion	?		?	
Road Erosion	?		?	
Mixed Sources	kg per year		kg per year	
Atmospheric Deposition	4.6		0.03	
Volatilization to Atmosphere	1.9 – 43.6		1.9 – 12.3	

Sources: Churchill and Clinkenbeard (2003), Gustin (2003), Cooke and Stanish (2007)

- ✓ Low summer flows (often < two cfs) and warm, shallow pools in lower Bear Creek create ideal conditions for a spike in methylmercury production (Schwarzbach et al. 2001).

- ✓ Recently discovered mercury-rich cold springs on the Bear Valley floor flow directly into Bear Creek (Slowey and Rytuba 2008).

- Toxic chemicals – other than mercury
  - ✓ Arsenic and antimony: One of the mines within the Sulphur Creek sub-watershed has high concentrations of arsenic (813 µg/liter) and antimony (728 µg/liter) (TetraTech 2003).

  - ✓ BLM law enforcement staff closed two illicit marijuana growing operations in 2007/2008 that used unauthorized pesticides, fertilizers, and fossil fuels left on site.

- Sediment delivery to watercourses
  - ✓ The California Department of Transportation estimates that 12 tons of sediment are delivered to Bear Creek annually from Highways 16 and 20, due to hillslope, roadfill, and hillslide-derived material.

  - ✓ Although the precise quantity of sediment that actually reaches Sulphur Creek is not known, up to 72,800 tons/yr of sediment are estimated to erode from the Sulphur Creek sub-watershed (Tetra Tech 2003).

  - ✓ Mine waste sediments capable of erosion in the Sulphur Creek sub-watershed total 51,400 tons (Churchill and Clinkenbeard 2003).

  - ✓ In Sulphur Creek sub-watershed, 67 percent of surface sediment volume (16,158 cubic yards) comes from cutbank surfaces adjacent to roads (PWA 2008).

  - ✓ Of the eight largest landslides in the watershed (all >20,000 cubic yards), none of these slides was related to land uses. Six of the landslides involved ultramafic soils on steep (>30 percent) slopes (PWA 2008, Weigand GIS analysis).

  - ✓ The Central Valley Water Board cited the California Department of Transportation in August 2008 for dumping sediment next to Bear Creek.

  - ✓ To clear roads following major storm events, road crews routinely place sloughed roadcut material

onto fill slopes along Bear and Sulphur creeks.

- Fire
  - ✓ When fires remove vegetation cover and expose mercury-rich soils and sediments to storm flows, cumulative sediment flow and total mercury input to streams are apt to markedly increase (Caldwell et al. 2000).

  - ✓ The frequency of large wildfires has not increased in the watershed since 1950.

- Information gaps
  - ✓ Locations for upland and drainage channel improvements to reduce sediment movement at the base of landslides have not yet been analyzed.

  - ✓ Dissolved organic matter from animal waste in streams may promote mercury methlyation (Suess et al. 2007, Slowey and Rytuba 2008).

GOAL 2: RESTORE HYDROLOGIC FUNCTION

A watershed has three primary water-related functions: capturing water, storing it in the soil, and releasing it beneficially (Bedell and Buckhouse 1994). Throughout the Bear Creek watershed, modifications in the uplands and riparian zones have altered hydrologic flows and watershed function. Excessive amounts of bare soil from land uses, poorly designed road networks, stream channel alterations and floodplain loss have created unstable hydrologic conditions in the watershed.

During their visit to the watershed in 2001, the National Riparian Service Team (BLM/US Forest Service) found excessive channel width-to-depth ratios in Bear Valley, Sulphur Creek valley, and the BLM's Bear Creek Ranch. Channel incisement, lowered water table, creek channels disconnected from historic floodplains, headcuts, gullies, and sparse riparian vegetation were noted as symptoms of instability. These conditions accelerate the exit of water from the watershed during storm events and reduce the "sponge" capacity of floodplains to retain water longer for longer release through dry periods.

Road networks alter water movement across the landscape and belowground. Compacted road surfaces decrease infiltration and increase the rate of runoff, and road cuts intercept and bring groundwater to the surface. Ditches and culvert systems divert surface and subsurface flows and concentrate storm runoff, reducing the upland capture of water and speeding its exit from the watershed. Roads built on steep or unstable slopes frequently trigger landslides (Weaver and Hagens 1994; Zeedyk 2006).

- Creek channel alterations
  - ✓ In the late 1890's channel engineering at the north end of Bear Valley fundamentally altered Bear Creek (Keegan, pers. comm.).

  - ✓ During the late 1880's, miners moved the lower main stem of Sulphur Creek from the west side to its current location on the east**,** adjacent to the Manzanita Mine.

  - ✓ Invasive saltcedar (*Tamarix parviflora*) thrives along Bear and lower Sulphur creeks, traps sediments and develops stable hummocks that alter creek flow and flooding patterns (Birkland 1996).

Along Sulphur Creek

Compacted road surface draining water to ditch

Resulting sediment plume from ditch water

- Creek and tributary headcuts
  - ✓ Headcuts on Bear Creek, Sulphur Creek, upstream from Leesville Gap, and tributaries throughout the watershed are creating extensive corridors of topsoil loss, often coinciding with poor culvert placement and certain livestock grazing practices. Alderson (2001) has mapped 37 headcuts thus far in Bear Valley tributaries.

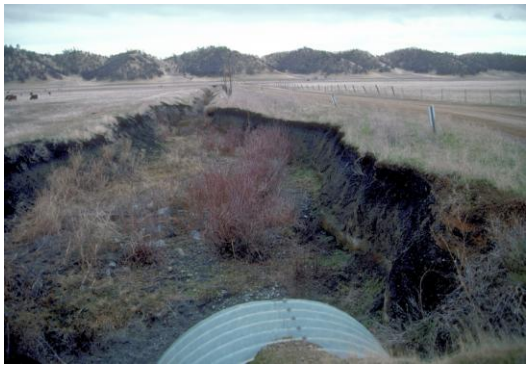
  - ✓ The entire wetland complex in the Sulphur Creek valley is now threatened from active headcuts (PWA 2008; Thomsen, pers. comm.).

  - ✓ Additional headcuts exist on tributaries within BLM's Bear Creek Ranch; a complete inventory is needed.

- Roads, trails, and fire suppression lines
  - ✓ More than 200 miles of paved and unpaved roads, trails, and fire suppression lines traverse the watershed. Many are poorly designed and are not functioning properly (PWA 2008).

  - ✓ 100 miles of OHV trails on BLM lands in the Sulphur Creek sub-watershed and elsewhere on Walker Ridge will be designated as either open or closed to motorized use (Weigand, GIS calculation). Currently, all trails within the 2008 Walker Ridge fire area to are temporarily closed to vehicles to prevent excess damage to soils.

  - ✓ Culverts, placed under roads to divert water flow, are contributing to soil erosion and sedimentation into creeks.



Gulley created by culvert in Bear Valley

Gulley created by culvert near Leesville

- Non-native invasive species
  - ✓ Yellow starthistle depletes large quantities of soil moisture, sometimes equivalent to as much as nine inches of rainfall from infested soils (Gerlach 2004).

- Impacts from certain grazing practices, and browsing and gnawing animals
  - ✓ Annual reports from BLM and California Department of Fish and Game from the 1970's to the 1990's describe degraded riparian conditions along Bear Creek from excessive livestock grazing on the Bear Creek Ranch prior to BLM acquisition.

  - ✓ Uplands, meadow complexes, and drainages west of Cowboy Camp are characterized by steep, exposed ultramafic slopes, lower than recommended levels of residual dry matter (RDM), massive headcuts, and degraded channel networks (Field evaluations 2008).

  - ✓ Other areas in the watershed show similar problems, with low levels of RDM, terracettes, streambank and channel degradation, and active headcutting, in part, associated with a long history of livestock grazing.

GOAL 3: CONSERVE TOPSOIL and STABILIZE EROSION-PRONE AREAS

Site instability and resulting soil erosion are tightly linked to degraded *hydrologic conditions*, with both identifiable from many of the same "rangeland health indicators" on the landscape (Pellant et. al 2005). To avoid repetition, the following section is short because most of the same issues highlighted under hydrologic function apply to this section. Additionally, many water quality issues, such as sediment delivery to watercourses, also apply here.

Three headcuts on ultramafic soils moving to hillslopes

Main headcut channel from the previous photograph in a landscape that will deliver sediment to Bear Creek during winter storms

- Disturbances to ultramafic soils
  - ✓ A 10.6-acre block of exposed ultramafic rock and soils along Highway 20 is in need of stabilization to halt sediment delivery to Bear Creek (O'Dell and Claassen 2006a, b).

- Roads, trails, and fire suppression lines
  - ✓ Design and planning for restoration of closed OHV trails on public lands to natural contours and vegetation cover has yet to begin on federal public lands in the watershed.

  - ✓ Sufficient funding to address deferred maintenance on paved roads is an ongoing challenge for County of Colusa government (Colusa County General Plan 1989).

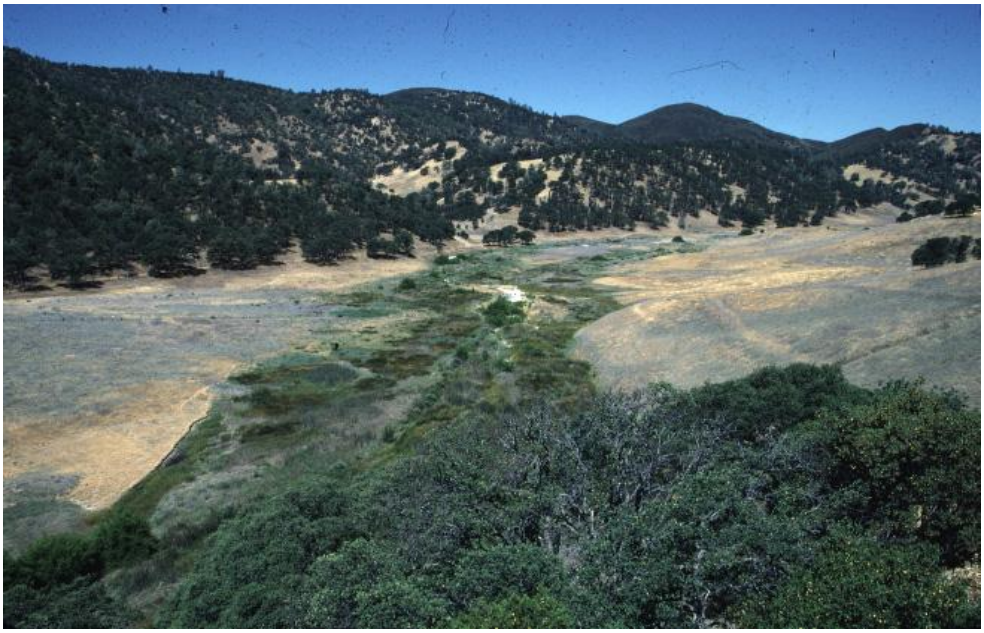
- Information gaps
  - ✓ 21 miles of fire lines were created in 2008 to halt the spread of the Walker Ridge fire, although the potential on-site soil loss from these areas has not been evaluated.

  - ✓ Vehicles stir up dust that becomes airborne in amounts that have not been calculated to date.

GOAL 4: PROTECT AND ENHANCE BIOLOGICAL DIVERSITY

Scientists, agencies, and the public recognize the significant ecological values of Bear Creek watershed. Highlights include: spectacular wildflower fields; alkali wetlands, ultramafic soils and associated seep, riparian, grassland, and chaparral communities; extensive blue oak savanna, the Bear Creek Botanical Management Area, and many rare plants associated with ultramafic soils. Dean et al. (2008) has documented 315 native species from the Bear Creek Ranch alone, including 25 serpentine endemics and an undescribed *Atriplex*, a species that is probably new to science. The California Native Plant Society (2005) has proposed designation of all of Walker Ridge as an Area of Critical Environmental Concern (ACEC). This would significantly expand the existing ACEC.

Moyle (pers. comm.) considers Bear Creek a rare aquatic ecosystem, harboring native fishes, yellow-legged frogs, western pond turtle, beaver, and river otter. Bear Creek is one of six known hot-spots in California for damsel- and dragonflies (K. Biggs, pers. comm.). It is a major corridor for neo-tropical migratory birds (Hoffman, pers. comm.) and an important wintering area for bald eagles. Shapiro (2002) listed 85 butterflies (80 confirmed and 5 expected) in the watershed. Three rare insects are known from the Wilbur Springs area. Tule elk, once nearly extinct in California, were re-introduced to the watershed in the 1920's and are thriving.



Alkali wetlands in the watershed are a rare habitat, identified by the California Department of Fish and Game as uniquely important for natural diversity. See headcut photos below (page 9).

- Non-native invasive species
  - ✓ Invasive plants have infested most of the watershed's grasslands; three noxious weeds, medusahead, barbed goatgrass, and yellow starthistle are widespread.

  - ✓ Invasive plants are also abundant along the Bear Creek riparian zone, especially tamarisk, perennial pepperweed, tall wheatgrass, and tall fescue, leading to major losses of native riparian plants.

Weed-dominated riparian zone along Bear Creek

- Low recruitment of native woody riparian plants

  - ✓ Beavers, tule elk, rabbits, gophers, invasive plants, floods, drought, herbicide residues, and poor site selection were obstacles to revegetation efforts for many woody riparian species along Bear Creek (LaClergue 2004, Thomsen 2007, Mangan pers. obs.).

- ✓ Downcutting has lowered water tables, reducing site potential and passive revegetation for many wetland-floodplain species.

Headcut migration: stream channel cutting, sediment release to stream, and loss of wetland floodplain

- Fire
  - ✓ Many rare plant species do not germinate without periodic fires; their current status may be due to unnatural fire frequencies for chaparral vegetation (Safford and Harrison 2004).
  - ✓ With fire suppression, foothill pines become more common and compete against oaks, thus reducing stand health and setting the stage for more intense wildfire and potential oak mortality. (Thomsen, pers. obs., McCreary, pers. comm.)
  - ✓ With lack of periodic fire, scattered stands of decadent chamise chaparral become monotypic and greatly reduce plant and animal diversity within this habitat.
- Stressors to oak woodlands
  - ✓ Large-scale loss of oaks for firewood and forage enhancement has occurred in the watershed in the past.
  - ✓ Loss of canopy cover reduces rainfall interception and compromises long- term soil fertility (Dahlgren et al. 1997).
  - ✓ A ranch study just north of Bear Creek watershed found that livestock compacted soil around blue oak saplings; blue oak saplings in grazed plots had smaller diameters and heights than saplings in ungrazed plots (Jansen et al. 1997).
  - ✓ Young valley oaks along Bear Creek are not regenerating to replace old trees. Seedlings are abundant in some locations, but saplings are rare and appear to only be surviving in one location where tule elk have less access and where the saplings are given somewhat greater protection (Thomsen 2007).
- Roads, trails, and fire suppression lines
  - ✓ Unmanaged mine roads and OHV trails are fragmenting ultramafic chaparral (BLM and USFS OHV route inventory data) that furnishes habitats for rare plants and birds.
- Potential environmental impacts of energy developments
  - ✓ BLM and USFS sensitive animal species with ranges inside the energy lease areas include foothill yellow-legged frog, western pond turtle, and Townsend's big-eared bat (California Natural Diversity

Database 2008).

- ✓ Eight BLM sensitive plant species have been documented from the energy lease areas (BLM 2007) according to the California Natural Diversity Database (2008).

- ✓ Raptors may be impacted but no detailed information is available on raptor presence on Walker Ridge.

- ✓ Ground disturbance will encourage the spread of noxious weeds such as barbed goatgrass and yellow starthistle.

- Information gaps
  - ✓ Large portions of the watershed have no biological inventories (Mill Creek sub-watershed) or incomplete inventories (Walker Ridge).

  - ✓ Data are needed to better determine distributions of USFS and BLM sensitive species, and California Department of Fish and Game species of special concern in the Bear Creek watershed.

  - ✓ Optimal fire frequencies and seasonal timing to sustain and enhance the diverse natural communities are unknown.

  - ✓ Townsend's big-eared bats may be impacted depending on the tower design and height and length of blades; no other information is available about other bat species in the areas (Brown, pers. comm.).

  - ✓ Consequences of climate change for native species in the Bear Creek watershed are unknown.

GOAL 5: ENHANCE RECREATION

Recreational opportunities abound in the watershed. Each year thousands of people from around the world visit Wilbur Hot Springs, lodge in an historic hotel, and hike on trails in the Sulphur Creek sub-watershed. An estimated 32,000 people visit the federal public lands in the watershed annually within the Cache Creek Natural Area for hiking, hunting, equestrian riding, camping, and nature exploration (RMIS data 2008) Some OHV activity is available in the Walker Ridge area The wildflower displays in Bear Valley and scenic vistas from Walker Ridge draw people to the watershed. A current proposal for the Berryessa-Snow Mountain National Conservation Area would include all federally and state-managed lands within Bear Creek watershed.

- Growing demand for recreation and tourism
  - ✓ Populations of the three counties surrounding Bear Creek watershed (Colusa, Lake, and Yolo) are projected to grow by an additional 92 percent over the next forty years (California Department of Finance 2007).

  - ✓ Demand for recreation on public lands will grow and create associated conflicts that inevitably arise from public carelessness and overuse.

- Potential environmental impacts of energy developments
  - ✓ Energy developments will affect scenic values that draw visitors to Wilbur Hot Springs, Walker Ridge, and Bear Valley.

- Roads, trails, and fire suppression lines
  - ✓ Traffic on unauthorized OHV trails creates noise and dust that affect recreation opportunities for other users.

- ✓ Unauthorized OHV trails remaining open provide entry points for criminal production of marijuana. Armed growers pose risks to recreational users who unknowingly enter illegal marijuana gardens.

GOAL 6: DEVELOP ENERGY RESOURCES

Walker Ridge is a unique area of Bear Creek watershed because it has the potential to supply energy from four sources: oil, gas, geothermal, and wind. Few other parts of California have as many potential energy resources so close together. Proposals to lease public lands to install wind turbines and geothermal infrastructure are now under consideration. The items under this goal pertain to environmental considerations and eventual effects on multiple, concurrent land uses and ecological services in the area.

- Disturbances to ultramafic soils
  - ✓ Ultramafic soils, which cover 76 percent of the oil and gas lease area, 55 percent of the wind lease area , and 41 percent of the geothermal lease area (Colusa County Soil Survey 2006, BLM lease boundaries), often have high content of arsenic, nickel, and mercury (Morrison et al. 2008).
  - ✓ Access roads and pads would fragment ultramafic soils, vegetation, and wildlife habitat.
- Sediment delivery to watercourses
  - ✓ The NRCS rates most of the wind lease and geothermal areas as having very high erosion hazard (Colusa County Soil Survey 2006).
  - ✓ Large amounts of earth moving for project development might further impair water quality and undermine hydrologic function.
- Creek channel alterations
  - ✓ The geothermal lease area in the watershed encompasses 36 percent of the remaining 188 acres of rare hydric soils, critical in Sulphur Creek sub-watershed for hydrologic function and the Walker Ridge ecosystem values (Colusa County Soil Survey 2006).
- Growing demand for recreation and tourism
  - ✓ Right-of-ways and leases for energy production on public land could be detrimental to recreation by affecting views and habitat, and increasing noise from vehicles and industrial activity.

GOAL 7: MAINTAIN ECONOMIC LIVELIHOODS AND CREATE JOBS

Activities in the watershed that generate employment include: livestock production, crop production, resort management, revegetation, mine remediation, road and culvert re-design, invasive plant removal, repairing stream banks and headcuts, diverse recreational opportunities, and tourism.

Livestock production has been a major economic enterprise for many generations in the watershed. These "working landscapes" generate income, provide food, maintain wildflower fields, promote conservation programs, and protect these large landscapes from commercial development and residential subdivisions.

Three conservation easements have been placed on lands within the watershed, providing external funding for economic enterprises and land protection.

The stewardship activity plan that will follow this assessment will provide estimates of jobs created for watershed projects for the period 2009-2013. Stakeholder issues generate possibilities for employment as they are addressed to attain watershed goals. Past stewardship projects have already generated employment,

through project funding amounting to more than $1.5 million. The following list of economic enterprises and issues could help generate new employment, while improving the landscape and waters of the Bear Creek watershed.

- Growing demand for recreation and tourism
  - ✓ Establishment of the proposed Berryessa-Snow Mountain National Conservation Area (NCA) would increase travel and tourism jobs in watershed gateway communities in Colusa, Lake, and Yolo counties and add tourism- and recreation-based jobs in Bear Creek watershed.
  - ✓ If the proposed Berryessa-Snow Mountain NCA is established, funding for stewardship projects on federal lands within the watershed could become available using a wide range of existing and new public/private partnerships.
- Toxic chemicals
  - ✓ Abandoned mine and waste ore remediation requires an interdisciplinary team of engineers, hydrologists, soils scientists, machine operators, and revegetation specialists to remove wastes, restore landscape integrity, rehabilitate soils, and restore native plant cover (Tetra Tech 2004; Central Valley Water Board 2005, 2007; Ecology and Environment 2008).
- Sediment delivery / Creek channel alterations / Creek and tributary headcuts
  - ✓ Remediation of sediment-producing sites has already started in the watershed by O'Dell and Claassen (2006), Pacific Watershed Associates (2008), and Alderson and Thomsen (2007).
- Roads, trails, and fire suppression lines
  - ✓ Road engineers, geomorphologists, and machine operators can redesign unpaved road and trail networks and culverts to greatly reduce accelerated water flows, soil erosion, sediment delivery to watercourses, and future maintenance costs.
  - ✓ Closing and rehabilitating unauthorized off-highway trails, many of which are on ultramafic sites, requires expertise from scientists familiar with these soils and associated plants.
  - ✓ Restoration ecologists and their crews could also assist with closing and restoring to natural conditions trails that are redundant or no longer of service as part of habitat improvements and reductions to sediment flows.
- Stressors to oak woodlands
  - ✓ Foresters familiar with oak woodlands and their silviculture are needed to manage woodlands on public lands to enhance ecological services and traditional foods from these woodlands.
- Non-native invasive species
  - ✓ Landowners, land managers, and their contractors have considerable work ahead in developing strategic, effective, and low-cost plans to control existing populations and prevent spread of new species.

GOAL 8: REDUCE THE LIKELIHOOD AND IMPACTS OF CATASTROPHIC EVENTS

Five categories of catastrophic events are: toxic chemicals and sediments that threaten water quality; adverse outcomes from large-scale and intense fires; floods; drought; and climate change.

- Toxic chemicals
  - ✓ A coordinated toxic materials response plan for Bear Creek watershed is needed.

- Sediment delivery to watercourses
  - ✓ Natural landslides are mostly in the steeper western half and at the south end of the watershed (PWA 2008, CALFIRE Fire and Resource Assessment Program 2004).

  - ✓ Development for specific land uses is constrained on sites prone to catastrophic mass wasting and avalanches.

- Fire
  - ✓ In 2008, two human ignitions burned the most watershed acreage in any one year since 1950; otherwise, few wildland fires have burned in the watershed, resulting in high fuel loads and extreme fire hazards, especially within chaparral habitat.

  - ✓ A schedule for prescribed burns across the watershed landscape to alleviate fire hazards and potential mass wasting subsequently is needed.

- Drought
  - ✓ Long-term drought would severely limit the capacity of Bear Creek watershed to produce water, forage, and other ecosystem services.

- Climate change / Stream channel alterations
  - ✓ Projections of coming water shortages with climate change for California's growing population foretell water shortages under future climate change projections. Summer flows are probably much lower than in the past because of hydrologic changes induced by land uses.

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