An Adaptation Plan for California's Forest Sector and Rangelands

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Introduction

With the increasing certainty found in recent climate change reports (IPCC, 2007; Cayan et al., 2006) it appears that even with reductions in greenhouse gases (GHG) emissions some level of climate change is likely and that adaptation strategies will be needed to maintain productive forest and rangelands. While climate model results differ, there are likely to be significant changes in the composition of forests throughout the state under all scenarios and models. In some cases, environmental effects from climate change have already been observed in California forest and rangelands. This includes shifts in species ranges, changes in the frequency of disturbance from wildfires and pests, and effects on forest productivity.

While mitigation measures for the forest sector have been proposed to reduce and offset GHG emissions, adaptation strategies will be needed to cope with impacts that are unavoidable. This report reviews many of the observed and forecasted impacts to California forests and rangelands as a result of climate change, proposes a framework for developing adaptation strategies and incorporating them into decision-making, and identifies an initial set of strategies for coping with climate change.

<u>What is adaptation and why is it needed?</u>

Adaptation to climate change is any activity that reduces the negative impacts of climate change and/or takes advantage of new opportunities that may be presented. Within the forest sector adaptation is defined as actions that are undertaken to increase the capacity of forests, ecosystems and society to function productively and cope with impacts from climate change (modified from Millar, 2007). This can include actions that are taken before impacts are observed (proactive) and after impacts have been felt

(reactive) (Easterling et al., 2004). The goal of adaptation planning is to reduce the vulnerability of forest and rangelands to climate changes and to increase the resiliency of lands to climate change. Resiliency is defined as the ability of a system, managed or natural, to withstand negative impacts without losing its basic functions. This does not imply that adaptation prevents impacts from occurring, but instead it reflects a desire to promote more resilient ecosystems.

Adaptation to climate change impacts will require making decisions with limited information and with uncertain outcomes. This underscores the need to make long term investments in monitoring and research, and to develop a robust set of management options.

Overview

California forest and rangelands provide a range of economic goods and environmental services that are vital to our well being. The forest sector is defined by tree dominated landscapes and includes: coniferous forests, woodlands, urban forests, riparian forests, and rangelands capable of supporting trees. Rangelands are wildlands with native or naturalized vegetation that are not dominated by trees. They include grasslands, shrublands, deserts and open canopied woodlands, and their primary economic use is grazing. This adaptation plan is focused primarily on the forest sector, as defined above, but also addresses some adaptation issues on rangelands. There are a broad range of stakeholders that include government agencies, private landowners, community groups and other non-governmental organizations. Within the forest sector the USFS manages roughly half of the forest land in California and thus play a critical role in developing a successful approach to adaptation.

The forest composition includes a broad range of tree species, tree sizes, and levels of canopy closure. Conifer forests and woodlands cover over 21 million acres and are most extensive in the Sierra, Modoc, and Klamath/North Coast bioregions of the State. Hardwood forests and woodlands cover nearly 10 million acres and extend along the perimeter of the Sacramento and San Joaquin Valleys and throughout the coastal ranges. The primary rangeland land covers includes 23.5 million acres of Desert Shrub, 14.6 million acres of shrub, 10.9 million acres of grassland, and 5.2 million acres of hardwoods.

California's conifer and woodland forests are extremely complex and dynamic ecosystems which have adapted to oscillations between wet/cold periods and warm/dry periods over the past several thousand years. Rapid climate change, however, may challenge the capacity of forest species and habitats to adapt. Temperature and precipitation changes can affect regeneration, tree growth and vigor, and forest health and productivity. In addition, temperature, drought and forest health can interact to enhance the level or occurrence of disturbances such as fire and pests. Human uses of the land (e.g. forest management and fire suppression), along with population growth and development, create additional stress that affects forest health and may increase vulnerability to impacts from climate change.

While forests will “adapt” in some fashion to climate change, management actions may increase the likelihood of achieving desired conditions by enhancing the resiliency of existing forests, establishment of future stands, and improving the ability to cope with disturbance and related impacts to climate change. In addition, land use decisions and management actions can also have adverse effects that create environmental stress and weaken the resiliency of ecosystems. Actions taken to reduce the current stress on forest and range ecosystems can also improve chances for successful adaptation (e.g. unintended adverse impacts on current forest health from fire suppression). Given the broad range of forest and hardwood/woodland species and environmental conditions, a toolbox of short and long term options, is needed for managers to address uncertain outcomes (Millar et al., 2007). In addition, while the individual actions that are needed to adapt to climate change are inherently unique to local conditions there is a need to develop adaptation measures and strategies at multiple government levels (Burton, 2006).

Climate change and environmental effects on forests and rangelands

Climate can greatly influence the dynamics of forest and range ecosystems. Climate influences the type, mix, and productivity of species. Future climate change scenarios predict expected increases in temperature, increases in atmospheric CO2 concentrations, and changes in the amount and distribution of precipitation (Cayan et al., 2006). Altering these fundamental drivers of climate can result in changes in tree growth, changes in the range and distribution of species, and alteration to disturbance regimes (e.g. wildfires, outbreaks of pests, invasive species).

Given the long lifespan of trees in a forest stand, from decades to hundreds of years, the effects of climate change on disturbance regimes may become apparent prior to noticeable changes in forest and rangelands. These include changes in the timing, frequency, and magnitude of wildfires, pest infestations, and other agents of disturbance (Dale et al, 2001). While disturbances occur regularly in nature, large changes in the patterns of disturbance could make forests less resilient. Vegetation types with restricted ranges may be more vulnerable than others, as well as areas that are already under stress from land use (i.e. expanding Wildland Urban Interface) and management (Foster, 2003).

The influence that climate has on disturbance regimes may already be having an effect on forest and rangelands. In California, extended drought and earlier snowmelt are leading to longer and drier summers with more pronounced fire activity. Relatively small changes in temperature and precipitation can affect reforestation success, growth and forest productivity. The following section summarizes climate change effects that have already been detected and those that are expected under future climate scenarios (see Table 1).

Table 1 – Types of climate change impacts in the forest sector (modified from PEW Center, 2008)

- Changes in temperature, precipitation, and hydrologic processes (i.e. decreased snow pack, earlier spring runoff, lower summer base flows).
- Changes in the extent and frequency of disturbances from wildfires, pests, and disease outbreaks.
- Conditions may favor the spread of invasive species.
- Tree species expected to move northward or to higher altitudes.
- Changes in reforestation and regeneration success
- Changes in forest productivity affecting growth and carbon storage. The effect of additional CO2 on forest productivity is uncertain.
- Economic impacts from increased fire damage and fire suppression costs.

Temperature – Temperature in California and the western states have been increasing (Cayan et al., 2006). The 1990's was one of the warmest decades on record (i.e. since 1861). The nine warmest years during this century have occurred in the last 14 years. An increase in air temperature is one of the most certain climate effects. Climate models forecast increased temperatures that range from 1.7 C to 5.8C depending on the model and the assumed emissions scenario between 2000 and 2100 (Cayan et al. 2006). This single factor in itself can have broad reaching implications for the forest sector. In areas where water availability is not limiting, forests may expand under warming temperatures, while drier areas may see a loss of productivity. Temperature increases are expected to be more pronounced during summer months, but also show a trend towards warmer winters. Some studies have suggested that temperature increases will vary across the state, with higher increases in the Sierra Mountains (Snyder et al., 2002).

Precipitation – Precipitation variability has been a natural part of California's historic climate. Studies of tree ring data suggest that the last 200 years have been relatively wet and that the longer historic record has been comprised of periods of prolonged drought (Meko et al., 2001).

Although Global Climate Models (GCM) are fairly consistent in their predictions of increasing temperature, there is less agreement among models forecasting precipitation patterns. While models show variation in wetter or drier trends the seasonal distribution of rainfall is still typical of Mediterranean climate, with most precipitation occurring during the winter months. In general, the climate models show little or no change in annual precipitation, but they do show substantial inter-annual and decadal fluctuations in precipitation (Cayan et al., 2006).

Hydrology – Recent winters have been warmer and snow melt has begun sooner. Studies have documented declines in Snow Water Equivalence (SWE) from 1925 – 2000 that correlate with increases in temperature (Mote, 2005). The timing of snowmelt and spring runoff can lead to longer dry periods in the summer months and reduces the moisture availability for forest plants. With less snow, the peak in spring runoff occurs sooner.

Climate models forecast this trend to continue. Coupled with warmer temperatures climate models predict decreases in snow accumulation and a greater percentage of precipitation from rainfall (Knowles et al. 2006). This also leads towards an expectation of earlier snowmelt. Climate model simulations suggest that snow pack losses are likely to occur more quickly in milder climates and lower elevations. Slower losses are expected at higher elevations and particularly in the mountainous regions in the southern Sierra (Mote, 2005; Hayhoe, 2004).

Wildfire – The size, severity, duration, and frequency of fires are greatly influenced by climate. While fires are a natural part of the California landscape, the fire season in California seems to be starting sooner and lasting longer. The result has been an increase in the extent of forest fires across the state. The rolling five year average for acres burned by wildfires on all jurisdictions increased in the past two decades from 250,000 to 350,000 acres (1987-1996) to 400,000 to 600,000 acres (1997-2006) (2006 CA Wildfire Activity Statistics).

An increase in wildfires has been attributed in part to warmer spring and summer temperatures, reduced snowpack and earlier spring snowmelt (Westerling, 2006). All of these conditions lead to increased moisture stress that can result in an earlier and thus longer fire season. Fire regimes are also very sensitive to pathogens, insects and invasive plants that, which may increase with climate change.

The disturbance associated with predicted wildfire regime changes has been identified as one of the most potentially significant impacts to forested ecosystems from climate change. Increased wildfire frequencies may make forest more susceptible to vegetation type conversions where recurring fires kill regeneration and prevent stands from reestablishment.

Wildfire risk will continue to be highly variable across the state. Research suggests that large fires and burned acreage will increase throughout the century (Westerling and Bryant, 2006; Lenihan et al. 2006) with some declines after mid-century due to type conversions. Wetter scenarios may reduce rate of spread (Fried et al., 2006) but may increase fuels and thus wildfire hazard. An increase in wildfire frequency may mean an increase in GHG emissions and a corresponding increase in the number of bad air days.

Insects and Pathogens – Mortality from insect and pathogens is also an important disturbance agent (Logan et al., 2003). Climate change can increase adverse impacts from pests and pathogens by enhancing their survival and spread and by reducing forest stand vigor and thus increasing susceptibility to insects and pathogens. For example, a 2 degree increase in annual average temperature allows mountain pine beetle to complete its life cycle in one year versus two (Logan and Powell, 2001). Climate change has also allowed it to expand northward and eastward into new habitats. In southern California on-going drought conditions have been implicated in the increased success of bark beetle attacks and the resulting widespread forest mortality.

Recent statewide aerial surveys reported nearly 800,000 acres of forest mortality, following consecutive years of below normal precipitation, almost half of which was caused by bark beetles and other biotic agents (USFS, 2007).

Invasive Species – Native species are thought to have adapted to environmental conditions and disturbance regimes that developed slowly over long periods of time. The alteration of those conditions over a relatively short period of time directly through climate change or indirectly through increased disturbances caused by climate change may favor invasion by exotic species. Invasive plant species exhibit characteristics that make them aggressive competitors and which facilitate their establishment and dispersal. These include large numbers of easily dispersed seed, ability to reproduce by both seed and vegetative growth, and relatively better ability to persist under variable environmental conditions such as dry or wet soil conditions. Climate change may enhance the spread of invasives through alteration of disturbance regimes. For example, invasive grass species in native grass or shrubland can increase fine fuels, resulting in greater fuel continuity, fire frequency and rate of fire spread. The shortening of fire return interval exacerbates the invasion of non-natives and produces a vegetation type conversion (see Klinger et al. 2006; Harrison et al. 2003).

Tree Species Migrations and Ecosystem Shifts - With warmer temperatures, tree species in California are likely to respond by migrating both northward and to higher altitudes (Shugart, 2003). As the rate of climate change increases some tree species may not be able to adapt to changed conditions. It is expected that species with currently restricted ranges will be most vulnerable, while species with broader climate tolerances may be able to adapt more easily. Alpine forests and related plant species are particularly vulnerable. With projected temperature increases, their habitat range is likely to be compressed with little room to expand. Forest adaptations from paleoclimate studies have documented the advancing and retreating tree line for sub-alpine conifers, as well as other species, in the Sierra (Stine, 1996). In another study, Thorne et al. concluded that a 500 m upward elevation shift of Westside Ponderosa Pine in Amador/ El Dorado County area was due to drought stress impacts to regeneration.

The simulated effect of climate on the distribution of vegetation types has been analyzed for several different climate change scenarios (Lenihan et al, 2006). Under all three scenarios, Alpine/Sub-alpine forest cover declined with increased growing season and warming temperatures. Conifer forests were displaced by mixed evergreen forest, and, declines in the extent of woodlands and shrubland was due to encroachment by forest types and grassland. These models are relatively new and have certain limitations. They are mostly representative of natural vegetation, as they do not simulate impacts from human activities on the environment.

Impacts on Rangeland Ecosystems - Due to the significant level of rangeland changes induced by human activities, including livestock grazing, it may be difficult to isolate climate effects on rangeland ecosystems from other factors that have and will continue to affect the system (McCarthy et al. 2001). The majority of California's native perennial grasslands have already been converted to annual grass species as a result of livestock

introduced by the Spanish. Annual grasses increase “flashy” fuels and can result in more frequent, intense fires. In eastside habitats this has also reduced important brush forage species. Higher temperatures from climate change may further impact brush species (Archer and Predick 2008), while other research indicates increases in CO2 may favor expansion of red brome and yellow star thistle (Joyce et al. 2008), further increasing fire risk and degrading range productivity for livestock and wildlife.

At the landscape scale, grassland acreage may increase as forest and woodlands contract; however brushland and oak woodland rangeland area is predicted to decrease (Lenihan 2006). Competition for water for livestock with other uses will likely increase; development and possibly agriculture will likely continue to encroach upon rangelands as higher economic uses (McCarthy et al. 2001). Additional research is needed on carbon cycling, management options for increasing vegetation with higher sequestration potential (phytoliths), markets and other incentives for lower carbon beef production (grass-fed), rangeland biofuel opportunities and other climate effects, mitigation and adaptation options (Bartolome, personal communication).

Terrestrial and Aquatic Habitat Impacts - Impacts to terrestrial and aquatic habitats may result from climate changes at the vegetation stand and also at landscape scales. Decreases in the size and contiguity of small or unique habitats, such as serpentine outcrops or vernal pools in California rangelands, may make species migration impossible (Wilkinson 2002). Increases in stream and lake water temperature on forests and rangelands may result in competitive displacement of cold-water fish species by more temperature tolerant or competitively successful non-native species. Climate change may also favor the expansion of native species or increase their abundance such that other native species are negatively affected (Rahel and Olden 2008).

Productivity Changes - Climate change effects on forest productivity are uncertain, due largely to uncertainties about precipitation and water availability and also by a limited understanding of the effects that increased CO2 could have on plant growth (Stugart, 2003). For example, Lenihan et al. (2006) showed increased woody biomass over the next century using a wetter climate scenario model, but showed biomass decreases when using the drier climate scenario model. In a related study, Battles et al. (2006) predicted reduced conifer tree growth of up to 18% in mature stands and up to 31% for pine plantations that would result under a warmer climate scenario. However, preliminary results in more recent studies have shown an increase in pine yield with corresponding increases in temperature (T. Robards, personal communication, December 10, 2008). Changes in rangeland productivity will depend on climate effects and management response. Increased droughts will reduce biomass and forage for livestock and wildlife. Increases in CO2 may promote more invasive species that are less useful to wildlife and livestock. If these adverse impacts increase and livestock management systems are not adjusted quickly enough, grazing could further reduce cover, impact soils and watershed health, and affect nutrient cycling.

Socio-Economic Impacts - Economic impacts are not all well defined or understood, but are clearly substantial. Economic loss from wildfire and insect outbreaks are the most

severe. Impacts on water supply from runoff may also be significant. The cost of fire damage and fire suppression can be expected to increase with increasing fire frequency. A few studies have also suggested that declines in forest productivity for pine plantations and other common tree species could lead to substantial losses (Battles et al, 2006).

The Imperative to Act: Mitigating *and* Adapting to Climate Change

Adaptation and mitigation are complementary approaches to addressing impacts from climate change. Mitigation measures can reduce the rate and severity of climate change impacts over the long term, while adaptation can help us cope with short and mid-term impacts that have already been set in motion.

The forest sector mitigations measures developed for the AB32 scoping plan are designed to reduce GHG emissions from wildfires, enhance carbon sequestration through adjustments in forest management, reforestation, and urban tree planting, and provide alternative energy from forest biomass. These actions should lessen the severity of climate change that might have occurred without intervention.

To support the AB32 scoping plan and previous work by the Climate Action Team (CAT), CALFIRE has developed five strategies for reducing and offsetting GHG emissions. These strategies are primarily developed as a form of mitigation, but many of the actions in these strategies have benefits for adaptation (Table 2).

Table 2 – Summary of existing CAT / AB32 Strategies for the forest sector.

CAT / AB32 STRATEGIES	**MITIGATION DESCRIPTION**	**ADAPTATION BENEFITS**
Reforestation / Afforestation	Replant lands that were previously forested to sequester more CO2	Can provide a broader mix of tree species and increase forest resilience.
Forest Conservation	Purchase forest land to prevent CO2 emissions and lost sequestration potential from land use conversion.	Forest reserves could provide valuable refugia for tree species with contracting ranges.
Fuels / Biomass	Reducing fuel loads on forest lands to avoid wildfire GHG emissions and to substitute renewable biomass energy for fossil fuels	Can help restore natural fire regimes and reduce severity of increased environmental and public safety impacts from increasing wildfire
Urban Forestry	Increasing tree planting in urban areas to sequester more carbon, reduce energy consumption through increased shade, and use wood waste as fossil fuel substitute.	Urban forests can help maintain habitat continuity, mitigate public health impacts from heat events through shading, filter increased runoff, and absorb increasing air pollutants.
Forest Management	Forest stand management to increase carbon storage and growth.	Forest management will assist in promoting forest health and increasing forest resilience.

Developing an Adaptation Framework to Manage Forests, Rangelands, and Watershed Health

Adaptation will help us deal with those changes that will still unavoidably occur, despite current mitigation measures. Adaptation planning involves making decisions about the best strategy to take while acknowledging the high degree of uncertainty about future climate change or the responses of systems to adaptation strategies. This requires a flexible approach to develop and implement management strategies that are designed to reduce the degree of uncertainty in forest and range management (Ohlson et al., 2005). The development of an adaptation plan requires identifying locations and species that are most vulnerable to the impacts from climate change. Vulnerability is considered to be a function of exposure and sensitivity to climate change impacts, and the adaptive capacity of the forest ecosystem to respond to climate change. Systems that are highly exposed, sensitive and less able to adapt are more vulnerable. There are no standard methods for assessing vulnerability from climate change, but there is some guidance emerging through a developing body of research (Luers and Moser, 2006; Burton, 2006; Snover, et al., 2007). The following planning framework is proposed as a guide for supporting adaptation planning on forest and rangelands (modified from Spittlehouse and Stewart, 2003):

Step 1 – Define Issues of Concern and Raise Public Awareness
There are a broad range of environmental and social systems that are potentially affected by climate change. Primary issues of concern in the forest sector from climate change include: increasing fire risk, forest health, forest productivity, and lack of adequate financial and other resources to respond to these factors. It is important to work with stakeholders and other sectors when identifying issues of concern.

Step 2 – Conduct an Assessment of Vulnerability and Climate Risks
A vulnerability assessment is a process of identifying and quantifying the degree that a system is susceptible to climate related impacts, as well as evaluating the capacity of a system to adapt to changing conditions (UK CLIP, 2003). Knowledge of relative uncertainties is an important part of a vulnerability assessment that can be used to evaluate the probability of a specific climate related event (i.e. wildfire, insect or disease outbreak, flooding, drought) occurring. Vulnerability assessments must consider inherent ecosystem roles and functions. Methods for assessing vulnerability assessments should consider magnitude of effect (size, frequency, and timing), certainty of effect, and resiliency (potential for system to recover) to eco processes and values.

One approach is to construct an assessment matrix that considers different spatial scales, temporal scales and ownership. For example, impacts and vulnerability at statewide, regional or ecosystem, and local levels will be needed to develop effective adaptation strategies and to garner support. Temporal assessments should consider climate change effects and implementation options, e.g. when impacts are expected, when actions could be implemented or completed, and when actions would produce results.

Step 3 – Develop and Implement Adaptation Strategies

Once the vulnerability from climate change is better understood, an adaptation response can be developed. Based on an assessment of vulnerability to different levels of risk a proposed set of short and long term actions can be developed as part of a management strategy. The individual actions identified contribute to a larger strategy for adaptation and include: reducing risks through preventative actions (example fuels hazard treatments), offsetting losses by spreading risks, building adaptive capacity, and looking for new opportunities that may arise as climatic conditions change. Some additional considerations for selecting management strategies include:

1) Reducing risk of impact; 2) reducing the impact itself (eg size and extent, intensity, frequency and duration) to forests and to institutions (ie human communities); 3) increasing ability to recover from impacts.

Some actions may combine one or more of these strategies.

Given that management decisions need to made with high levels of uncertainty an overall approach is to implement strategies that have “no regrets” or “low regrets” first that take few resources and have little cost rather than take actions that may be extremely costly, or greatly restrict future management options. However, “no regrets” options should not be chosen exclusively at the expense of long term investments that may also be needed for successful adaptation.

Even with limited information on risks and vulnerabilities an initial set of strategies and supporting actions need to be chosen and implemented. Working within the constraints of available resources and based on criteria discussed above strategies need to be prioritized and actions implemented.

Step 4 – Improve Planning and Implementation by Building Adaptive Capacity and Supporting Necessary Research

Landowners and agencies can increase their capacity to adapt to a changing environment. This will require additional information, development of analytical tools, management guidance and incentives and supportive policies and programs to promote the necessary actions to implement adaptation strategies. In addition, research is needed to address are knowledge gaps and uncertainty about the affects of climate change on forest ecology and forest health (see strategy 6).

Step 5 – Monitor Effectiveness of Strategies

Strategies must be evaluated in terms of effects on environmental, social, and economic values. Therefore, it is essential to develop a monitoring program with indicators that evaluate forest and range conditions and the effectiveness of management actions. Through monitoring, a baseline of environmental conditions is established that can be used to track changes in forest condition. This information can then be used to develop an iterative process of adaptive management.

Step 6 - Evaluate Cost Effectiveness of Strategies

Implementation of an adaptation plan requires an assessment of cost and benefits of proposed actions. The valuation of benefits from actions that preserve or enhance existing environmental services from forest and rangelands can be difficult to quantify. However, ideally, the benefits should exceed costs for a preferred strategy. As many of the actions in the forest and range sectors have multiple co-benefits an emphasis should be place on identifying opportunities for cost-sharing. Once actions are initiated information is needed over time to compare the effectiveness of management tools. Information on cost effectiveness can be used further to revise actions (see step 3) and to identify no regrets or low regrets strategies.

Potential Strategies to Adapt to Climate Change

Strategies are used to define the range of options that decision-makers have for addressing climate change impacts. Given the high level of uncertainty under which decisions must be made a broad range of options are needed. Ideally, the information from a risk based assessment of vulnerability supports the development of specific adaptation strategies. Due to the nature of forests with many long-lived species, flexible or adaptive management options should be an integral part of the adaptation strategy to be implemented.

In addition, strategies for the forest sector need to be developed and refined over time with broad consultation from landowners, government agencies, and other stakeholders. To be successful the adaptation plan for the forest sector needs input and support from state, federal, and local government. The CA Resources Agency will assume leadership through convening a multi-agency group to foster broad agency and stakeholder support. Essential elements for crafting a set of strategies include:

- Clarify the scope and intent of the adaptation plan.
- Frame approaches that account for risk and uncertainty
- Promote public awareness
- Engagement of cross-sector partners (i.e. water, wildlife, infrastructure)
- Consider and clearly formulate tradeoffs
- Identify and consider value judgments and risk preferences

Additional elements for consideration include:

- Approaches need to be regional, spatial, temporal, issue specific.
- Define scope of the plan; which lands are covered (i.e. jurisdictions and ownerships). Give consideration to communities, demographics, and infrastructure.
- Recognize resource limitations and fiscal constraints.
- Identify early actions (i.e. existing programs that have climate benefits)

The following strategies should be viewed as a preliminary set of options that can be revised over time as risk assessments (see step 2) related to climate change are conducted and the results become integrated into the planning process. Given limited

resources, further work is needed to identify appropriate criteria to prioritize strategies (see Snover et al., 2007). A more detailed description of the strategies with specific actions is provided in appendix 1.

Strategy 1: Define and assess key forest sector and rangeland uncertainties and vulnerabilities and incorporate existing climate information into policy development and program planning.

Strategy 2: Improve institutional capacity by improving information and analytical tools for assessment, strategic planning and tactical planning.

Strategy 3: Actions to Address Climate Vulnerabilities (Sector Preparedness Action Plan)

A. Manage Forest and Range Lands for Resilience, Restoration, and Recovery

B. Promote Adaptation in Land Use, Public Safety and Economic Infrastructure

C. Identify Private and Public Investment Options and Other Strategies to Address Adaptation

Strategy 4: Define and implement priority research agenda, including experimentation and feedback.

Strategy 5: Implement Forest Health Monitoring in an Adaptive Management Context.

Cross Sector Issues and Opportunities

Actions that are needed to adapt to effects on forest and rangelands will require cooperation and collaboration with agencies that have authority over environmental protection, land use, energy and public health, and with the private sector that owns land and can invest in adaptation management. It is therefore extremely important to identify mutual goals, co-benefits and synergies of adaptation strategies.

Water Resources (issues: flooding and water storage) – With the expectation of decreasing snowfall and a greater amount precipitation occurring as rain, the risk of flooding could increase. Examples of cross sector strategies include restoration of riparian corridors and woodlands to mediate flooding, restoration of alpine meadows for improving the storage, timing, and delivery of water, and fuel reduction in upland forests to minimize wildfire impacts to watersheds.

Public Health (issues: increasing summer heat waves) – With increasing temperatures cities across the state are likely to experience a greater number of heat waves and higher fire risk and heat stress to communities. Expansion and improvement of urban forests can be used as part of an adaptation response to reduce the heat island effect (Menne and Ebi, 2006). Strategic fuels management can decrease wildfire smoke

impacts. The use of prescribed fire for this purpose will require cooperation with air quality districts and stakeholder groups to ensure net health benefits.

Biodiversity and Habitat (issues: shifting habitats, invasive species) – Increasing temperatures and changes in precipitation patterns are likely to result in shifts in the extent and distribution of forests and range lands across the state. This will have a direct impact on wildlife that utilizes these habitats and the sustainability of reserves to protect them. Collaboration on vulnerability assessments, adaptation of forest and woodland management, regeneration and restoration methods, development of stewardship incentives, and monitoring will be needed to maximize co-benefits.

Barriers and Constraints

Constraints to implementing an adaptation plan for forestry include the following:

- A limited understanding of the climate risks and vulnerability in the forest sector.
- Implementing consistent policies on private and federal forest lands.
- Contrasting and divided views on the environmental effects of forest management.
- Prohibitive costs and existing budgets limit the capacity to implement proposed actions.
- Institutional capacity to implement adaptation planning into an existing business process.
- Limited capacity to provide information on climate change impacts and risk assessments to forest landowners.
- Laws and policies that forbid or do not facilitate the “triage” approaches that may be necessary in the face of climate change impacts.

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Glossary (modified from PEW Center, 2008; www.pewclimate.org)

Adaptation: Actions by individuals or systems to avoid, withstand, or take advantage of current and projected climate changes and impacts. Adaptation decreases a system's vulnerability, or increases its resilience to impacts.

*Adaptability**:*** refers to the degree to which adjustments are possible in practices, processes, or structures of systems to projected or actual changes.

Adaptive Capacity: A system's inherent ability to adapt in a way that makes in better equipped to deal with climate change impacts.

Autonomous adaptation: Refers to adaptations that occur naturally to changing conditions.

Impact: An effect of climate change on the structure or function of a system.

Mitigation: Actions taken to offset or reduce greenhouse gas emissions.

Planned Adaptation: Consists of proactive actions that are taken to reduce the vulnerability to impacts from climate change.

Resilience: The ability of a system, managed or natural, to withstand negative impacts without losing its basic functions.

Sensitivity: Reflects the degree to which a system will respond to changes in conditions; due to climatic influences.

System: A population or ecosystem; or a grouping of natural resources, species, infrastructure, or other assets.

Vulnerability: The potential for a system to be harmed by climate change; considering the impacts of climate change on the system as well as its capacity to adapt.

Appendix 1
CAL FIRE Draft Strategies

Strategy 1: Incorporate existing climate information into policy development and program planning.

CAL FIRE is working with the Climate Action Team, UC, the PIER climate research program, WESTCARB, the USFS and others looking at climate effects and climate management options. While information and data are still being developed, we can now begin to incorporate forest related information on trends and effects into program planning.

- *Incorporate climate information into CAL-FIRE programs* – The information developed on assessing climate related risks needs to be integrated into the planning and implementation of existing CAL-FIRE programs.

- *Define Key Forest Sector and Rangelands Adaptation Considerations* - Program managers and stakeholders will identify key climate effects or uncertainties that may affect implementation of a broad range of programs including: Forestry Assistance programs, State Forests, Forest Practices regulation, Fire Protection, Fire Prevention, Unit Fire Plans, Capital Outlay

- *Identify Stakeholders* - Fully engage Forest Sector and cross-sector stakeholders (e.g. USFS, BLM, National Park Service, other state agencies, local government, private landowners, community groups and non-government organizations.)

- *Clarify Adaptation Policy* - Department will identify implications for policy actions by BOF
    - State Fire Plan
    - BOF Policy Statement
    - Forest Practices Review
    - Research and Science Committee
    - Forest and Range Assessment

Strategy 2: Improve institutional capacity for data development and analysis, assess climate effects and forest vulnerabilities, and recommend strategic and tactical responses.

Information on the environmental conditions of forest and range lands provides decision support guidance that is needed to help government agencies and land owners prepare for climate change and to make informed decisions. Specific actions that are needed to implement this strategy include:

- *Improve Data and Modeling Capabilities* - Fill major data gaps for strategic planning and assessment by CAL FIRE and other programs:

- FRAP should resume Vegetation mapping and change detection for forest health assessment and for fuels mapping to support Fire Suppression and Fire Prevention planning
- Expand post-fire assessment and monitoring by and in support of Burned Area Emergency Response and State Emergency Assessment Teams
- Explore collaborative efforts to expand information on land use and development to support Fire Prevention and Timberland Conversion programs

- *Improve Scientific Knowledge Base* - Work with SCRIPPS, UC, USFS, CEC and others to refine climate models for CAL FIRE Fire Protection and Resource Management needs.
  - Identify opportunities for improving Predictive Services for Fire Protection tactical response
  - Consider long-term climate implications for strategic Fire Protection planning for capital outlay (fire stations) and other fire fighting resources
  - Consider implications of long-term climate change for fire prevention and land use programs (such as commenting on general plans and projects and public education)

- *Conduct strategic risk analyses and vulnerability assessments in order to identify and prioritize planning and tactical actions to address adaptation needs:* Department will develop and implement a risk assessment through the Forest and Rangeland Resource Assessment and the Fire Plan.
  - Establish assessment framework and criteria -
    - magnitude and timing of impact x certainty x adaptive capacity;
    - short vs long-term likelihood for success (eg capital outlay, reforestation);
    - co-benefits (eg mitigation benefits, energy generation, air quality improvement, water supply and quality, habitat)
    - cost and cost-effectiveness
  - Identify geographic "hot spots" and develop contingencies to monitor, assess and react to abrupt climate change
  - Conduct cross-sector assessments with other agencies, including input in other state plans where possible (eg Wildlife Action Plan, Water Plan), and identify actions with cross-sector benefits

- *Develop policy, management and funding recommendations for actions by BOF, CAL FIRE, other agencies (including USFS) and private sector on policies and programs related to increase resilience of forest lands and resources.*

- *Support Implementation Actions* - Determine and implement key monitoring needs (forest health, development and land use pressure, effectiveness of actions)
  - Develop or work with other agencies to develop indicators of forest and range health that are sensitive to climate change (FRAP as lead)
  - Continue to track development and land use pressure on forest and rangeland

- State Forests will continue to work with UC, USFS and others to establish trans-elevation and latitudinal transects to monitor vegetation response and change to climate change
- Develop or work with reporting agencies to establish standardized reporting procedures and formats

Strategy 3: Actions to Address Climate Vulnerabilities (Sector Preparedness Action Plan)

A. Managing Forest and Range Lands for Resilience

CAL FIRE Management actions in cooperation with federal, state and local agencies, can help reduce the vulnerability of forests to disturbance from climate change impacts. Specific actions that are needed to implement this strategy include:

- *Reduce Fire Risk, Hazards and Emissions* – Fire Prevention and Resource Management programs will work together in cooperation with landowners, local entities such as RCDs, state agencies such as Sierra Nevada Conservancy, USFS and others to increase fuels management in high value and high risk areas
  - Explore and demonstrate the value of fuels reduction for mitigation and adaptation benefits
  - Promote increased use of woody biomass for energy or other products
  - Develop more effective partnerships with agencies, utilities, and private entities to improve infrastructure and business climate for the use of woody biomass.
  - Develop a strong post-fire analysis and planning program to develop restoration actions that will reduce the risk of re-occurrence of intense wildfires in the same area.

- *Support Restoration Activities* - CFIP and Nurseries will work with state agencies such as DFG and DPR, USFS, landowners, and others to develop guidance for:
  - regeneration and other silvicultural practices (eg increase species diversity, use of drought tolerant species, thinning existing stands, afforestation on leading edges of forest habitats) and seed zone changes
  - Post-fire vegetation management recovery to minimize timberland and habitat fragmentation and reduce invasion of exotic species

- *Provide Nursery Support*
  - State Nursery Program will work to increase seed banks and develop appropriate vegetative propagation technologies to ensure adequate supplies of genetically diverse stock
  - CAL FIRE will work with other state, federal and local agencies and stakeholders to develop and implement a program to identify genetic stocks at risk of loss and take appropriate steps to preserve key genetic legacies represented by rare or isolated subpopulations.

- *Expand Landowner Assistance and Technology Transfer* - Forest Improvement will work with USFS, UC Extension, RCDs and others to prevent, minimize and assist with recovery from:
    - increased forest pathogen and insect impacts, including working with Fire Prevention to reduce wildfire risk, eg southern California
    - Post wildfire recovery to improve resilience and reduce invasion of exotic annual species

- *Review Regulatory Framework* – The Board of Forestry, Forest Practices, Fire Protection and State Fire Marshal programs will consider regulatory and related improvements, e.g.
    - Restocking standards, watershed protection, fuel treatment (FPA)
    - Mitigation for conversions and guidance for determining "bona fide" intent for ag conversions in the face of climate change (Timberland Conversion)
    - Building standards (SFM) and related interpretive documents
    - Increased use of long-term planning documents for Forest Practices that can better incorporate climate change analysis and planning (eg SYPs, PTEIRs)
    - Changes to CEQA and the development of mitigation options that are consistent with adaptation

- *Support Urban forestry* - Urban Forestry will work with local entities to protect and expand urban forests as a buffer to impacts to local wildland forests, thus providing sequestration, watershed, water quality and habitat co-benefits

- *Support efforts to identify and address rangeland adaptation needs* - Support University and private sector exploration of managing for carbon cycling benefits and species that maximize carbon sequestration in phytoliths.

B. Promoting Adaptation in Land Use, Public Safety and Economic Infrastructure

Promote an active response by communities and other institutions to prevent or decrease the impacts of climate change disturbance, and assist with recovery. This should include improving land use planning and implementation to reduce conversion and wildfire risks. Specific actions that are needed to implement this strategy include:

- *Determine regional readiness to respond to disasters* - Fire Protection will work with governmental agencies and others to examine the impact of more frequent extreme natural events such as floods and wildfire on the demand for and ability of regional or statewide resources to respond

- *Improve Local Land Use Planning Support* - Fire Protection and State Fire Marshall (SFM) will work with local agencies and groups to decrease risk and hazards and increase public safety options, eg
    - Landscape architects, builders and others to increase use of fire and drought resistant landscaping and design

    - Fire Safe Councils and local government to improve escape routes and other strategic options for communities at increased risk
    - Increased long-term vegetation management for fuel reduction

- *Factor Climate Change into Planning for Fire Protection Services* - Fire Protection will encourage local fire management plans to explicitly evaluate climate change impacts as part of planning process. Fire management plans should identify risks, vulnerabilities, and preventative measures to cope with climate change affects.

- *Minimize impacts of Development* - Work with other agencies to incorporate adaptation concerns into permitting programs (RM - conversions, forest practice) County General Plans, subdivision map act and individual development projects)

- *Improve Utilization of forest Carbon Stocks* - CAL FIRE and BOF will work with state agencies, industry, the Legislature and others to ensure adequate infrastructure for biomass utilization and traditional wood products

- *Improve opportunities for rangeland management adaptation* - Support private sector efforts to identify economic opportunities for low carbon footprint beef production, biofuel production, riparian forest restoration, etc.

C. Identify Investment Options and Other Strategies to Address Adaptation

The State, CAL FIRE and Board of Forestry must build public support for long term investments in public and private forestlands and a robust set of options to address adaptation needs for protecting forest and range land resources.

- *Promote local capacity* - Work with local communities to clarify their concerns and to inform them about actions and options to address climate change
- *Adequately Fund Programs* - Consider development and allocation of potential funding sources such as carbon fees, Carbon Trust, bonds, etc) to support above actions
- *Encourage Market Development* - Encourage Investment in biomass-related industries, esp. infrastructure for conversion to electricity or biofuels).
- *Explore Cross Agency and Sector Synergies* - Collaborate with other state planning processes, grant and assistance programs, and management activities on actions with high co-benefits (eg ARB for cap and trade market revenue investments and actions with mitigation co-benefits; WCB on Prop 84 forest conservation; DWR for upper watershed protection and riparian reforestation through IRWMP, Water Plan, proposed climate Public Goods Charge; DFG on habitat conservation; RPS implementation; OPR on land use planning; Sierra Nevada Conservancy Prop 84 programs)
- *Maintain Current Wood Product Utilization Capacity*-Encourage policies and strategies that maintain current utilization infrastructure (sawmills, pulpmills, veneer

plants, etc.) and as supply permits encourages modernization of existing facilities or development of new facilities.

- *Provide Regulatory Certainty* - Address need for additional incentives or removal of disincentives to ensure that landowners can manage forestlands to support adaptation needs (cap and trade markets and protocols; RPS implementation)

Strategy 4: Implement priority research agenda

There is substantial uncertainty in the response of forests to climate change and in the effectiveness of proposed management actions. CAL FIRE will work with CEC PIER Program (Climate Action Team Scenarios), ARB, UC et. al to identify and fill knowledge gaps related to adaptation and to evaluate which strategies are most effective. Potential priorities are:

1) Urban Forests and Climate Change: Comprehensive Cost and Benefit Analysis
2) Predictive Tree Biomass Model Evaluation and Improvement
3) Wildfire GHG Emission Analysis: Standardized Estimation Methodologies
4) Life-Cycle Characterization of Forest Carbon Pools and Wood Products in California
5) Forest Landowner Profile Development: Current and Projected Forest Conditions and Landowner Participation in Programs and Markets
6) Improved Forest Research and Management Tools: Climate Smart Forest Projections and Risk Assessments for Pests and Fire
7) Forest Bioenergy and Biofuel GHG Profile Characterization
8) Climate Change and Forests Research and Monitoring Infrastructure Development: Joint Strategic Planning
9) Quantification of managed fire versus wild fire GHG emissions in California forests.
10) Risk and prevention analysis of catastrophic tree mortality in California forests from exotic insects and disease.
11) A comprehensive monitoring and adaptive management program to quantify the effects on climate change and the effectiveness of adaptation strategies.
12) Improved analysis of timberland conversion trends and effects.

Strategy 5: Implement Forest Health Monitoring in an Adaptive Management Context.

A monitoring program is needed both to detect affects on vegetation from climate change and to evaluate the effectiveness of management actions. Specific actions that are needed to implement this strategy include:

- *Define Indicators* - Development of ecosystem and other climate related indicators that show or measure trends.
- *Establish Monitoring Criteria* - Establish a network of long term monitoring plots that are implemented across both longitudinal and elevation gradients to detect climate change impacts.

- *Continue and Expand Pest Detection* - Support existing programs that can provide early detection of insects, disease, and drought in forest and range lands.
- *Establish Adaptive Management Criteria* - Identify feedback process to inform and, as necessary, adjust policy, strategies, and regulatory approaches
- *Monitor changes in land-*use ; Acres of growth and loss of forest cover as well as resulting carbon stock effects.
- *Interagency cooperation to leverage limited monitoring resources.*