Monitoring and Assessment of California's Timberland Ecosystems Under Assembly Bill 1492 and the Timber Regulation and Forest Restoration Program

A Suggested Process for Selection of

Ecological Performance Measures

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1.0 Purpose

Assembly Bill 1492 directs the Timber Regulation and Forest Restoration Program to develop a statewide ecological performance measures (EPM) approach as an accountability measure for the multiple State programs that regulate timber management on nonfederal forestlands. Harnessing data from existing monitoring programs across State and Federal resource agencies, the intent is to establish a spatially explicit, consistent monitoring approach to track forest ecosystem condition over time at a regional scale. Results will be used to inform decision makers in their work to support adaptive management of timberlands and to help ensure the accountability of State-led forest management regulatory programs. Looking beyond the mandate of AB 1492, the EPM approach may also assist in the evaluation of State and Federal programs to invest in forest health and resilience. In the context of ever-increasing pressure and stress on these forested systems, including catastrophic wildfire and climate change, it is more important than ever to monitor changes in ecosystem conditions towards ensuring State regulations and programs are keeping pace with what is needed to sustain California timberlands into the future.

2.0 Executive Summary

Scientific consensus is that extensive areas of California's forested ecosystems are under extreme pressure and stress given current and projected climatic conditions, increased impacts associated with agents of forest mortality (pests, disease, fire), coupled with expanding human-caused disturbance and development within and around forested landscapes (Fire and Resource Assessment Program 2017, California's Fourth Climate Change Assessment 2018). The recently released California's Forests and Rangelands 2017 Assessment and the 2018 4th California Climate Assessment state that continued extreme weather events and ecological disturbances such as increasingly frequent and severe wildfires and pest infestations are expected to cause significant shifts in forest ecosystem dynamics. Examples include forest decline or stand replacement (type conversion) in some locations, and cascading degradation of aquatic and wildlife habitat throughout the State including species' range shifts (Fig. 1). In California alone, Federal, State and private expenditures associated with wildland fire emergency response, rebuilding, and the economic fallout associated with recovery efforts amount to billions of dollars annually (Federal

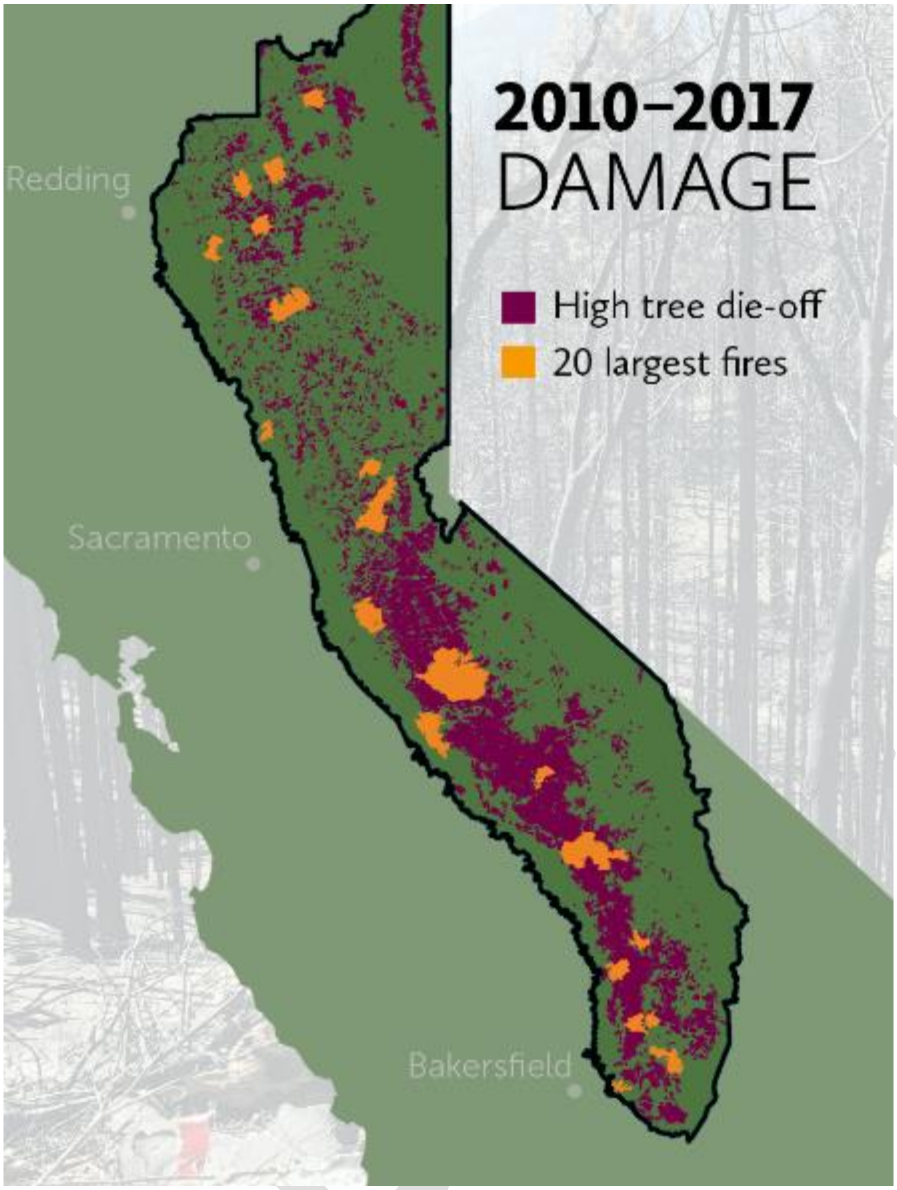

Fig. 1. Example showing Sierra Nevada tree mortality and forest fires (2010-2017). Figure from J. Branham, Sierra Nevada Conservancy.

Emergency Management Agency 2015; Kousky et al. 2018; Sierra Nevada Conservancy 2017; USDA Forest Service 2015); currently at the expense of forest management programs, in some cases. Tens to hundreds of millions of dollars are expended by the State annually towards management of California's forested landscapes (in part from Timber Regulation and Forest Restoration Program funds and programs). With expanded financial commitments made by Governor Jerry Brown and the State Legislature in fiscal year 2018-19 through budget and legislation (e.g., Senate Bill 901, Dodd, Chapter 626, Statutes of 2018), increased funding for forest fire resilience, restoration, and regulatory programs to protect and restore forests, water quality, and wildlife populations will deliver an influx of new resources to support forest management.

Given mounting evidence of unprecedented pressure and change occurring in California forest ecosystems, significant new forest management investment, and limited understanding as to how forest systems may be differentially impacted statewide, a long-term forest ecosystem monitoring and assessment program is needed to keep decision makers apprised of significant changes to enable management response and adaptation. The establishment of an assessment framework includes determining performance measures of interest, as well as establishing a data collection schema and timeframe for answering the question: Are forest management activities, mitigation measures, and associated State regulatory programs providing intended outcomes in forest ecosystem condition within the monitoring period? Consistent, locally relevant, spatially scalable monitoring methods to support assessment of forest resource conditions across California's forested ecoregions can help link the outcomes of on-the-ground projects and management activities to the efficacy of state funded programs, including those for restoration and regulatory compliance. To achieve this, stakeholders (forest managers, policy makers, and the public) need long-term and continuous data collection of ecological indicators across biophysical categories. There is presently no coordinated statewide approach with sufficient resolution to yield a detailed evaluation of ecological performance of forest management regulatory systems in California at the ecoregional scale.

Ecological monitoring program across California's coniferous & mixed coniferous forested ecosystems at a ***regional scale***

While California forest systems are vast, comprising approximately 33 million acres, timberlands which are the subject of AB 1492 Program funds constitute about 17 million acres (USDA Forest

> *Forest is considered **timberland** if it is growing on ground capable of significant annual conifer tree growth and considered available for timber management. This is land potentially available for production of wood products and does not include acreages locally withdrawn from timber harvest or other active management (Forest Inventory Assessment 2016).*

Service, Forest Inventory and Analysis Program 2016). The monitoring and assessment program under development here will focus principally on approximately 8 million acres of timberland (generally **conifer** and **mixed conifer** forest ecosystems), across non-federal ownership types (e.g., private and State-owned land). However, given how interspersed federal timberlands are throughout California, and the ecosystem basis of the subject monitoring and assessment program, federal forestlands may play a role in the present study. Timberland ecosystems are central to the pest and fire management challenges the State now faces and key to the premise of AB 1492, which is to sustain timber and other forest resources into the future. Conifer and mixed conifer forest ecosystems and their associated terrestrial and aquatic habitat are integral to the process of EPM evaluation.

> ***Coniferous forests** consist mostly of conifers, trees that grow needles instead of leaves, and cones instead of flowers. Conifers tend to be evergreen, that is, they bear needles all year long. These adaptations help conifers survive in areas that are very cold or dry. Some of the more common conifers are spruces, pines, and firs. (NASA Earth Observatory).*
>
> *The **mixed-conifer** forest group may be composed of several western conifers including Douglas-fir, ponderosa pine, sugar pine, Jeffrey pine, incense cedar, white fir, red fir, and other true fir species (USDA Forest Inventory and Analysis 2016). May also include hardwoods such as oak trees as a component.*

Under AB 1492, development of EPMs and an associated monitoring and assessment program will enable interagency collaboration to quantitatively assess the effectiveness of statewide regulatory programs aimed at timberlands across California. The monitoring and assessment program will use EPMs to approximate forest ecosystem conditions at the regional scale based upon target ecosystem services and related indicators (e.g., specific metrics used to evaluate status of ecosystem conditions such as water quality, habitat condition). Working with partner agencies and departments, the EPM Program will build upon existing monitoring and assessment programs and datasets statewide, identify the minimum monitoring program elements required to provide a quantitative basis for evaluating program and regulatory efficacy, and identify data gaps. The program will compile existing data and assessments from statewide programs, identify data needs, and work to standardize reporting of monitoring results across biophysical categories. The end-product is envisioned as a searchable database and information dashboard, accessible to the public through an interactive webmap, where monitoring results and scientific assessment of monitoring data can be accessed in support of ongoing forest management, program evaluation, and policy making.

Guiding the development of the EPM program will be a core interagency EPM Working Group (e.g., State and Regional Water Boards, Department of Fish and Wildlife, CAL FIRE, California Geological Survey, etc.) as well as close involvement and consultations with private landowners, federal agencies, non-governmental organizations, and academic institutions. Throughout the development process, the EPM Working Group will actively seek the input of stakeholders to ensure the widest possible spectrum of participation to inform key decisions for EPM Program development and ensure relevance and utility for stakeholders.

To establish a framework upon which to build this newly defined ecological monitoring program, this document brings together a range of methodologies and considerations involved in landscape-scale monitoring efforts, referencing approaches used within California, throughout the USA, and abroad. Definitions and key concepts are presented for consideration of stakeholders, to help frame future discussion for the selection of methods to be employed to monitor and assess California's forested ecosystems at a regional scale.

3.0 Introduction

Historically, California forests possessed fine-scale heterogeneity and a range of conditions that contributed to high resilience to disturbances like fire and drought, and the ability to respond and adapt to changing climate. The past two centuries of settlement patterns and land use management in the United States transformed the landscape and largely replaced heterogeneity with relatively homogenous (in terms of stand density, age and horizontal structure) forest conditions. This recent history of human interference with natural forest ecosystem regimes (e.g., through forest management activities and fire suppression policies) has led to intermountain, western US forests' increased vulnerability to intense and large-scale disturbances such as catastrophic wildfire, leaving forests with low resilience and inhibited adaptive capacity; all compounded by climate change (Safford and Van de Water 2014). Today, the same types of disturbances that enhanced forest heterogeneity and resilience in the past – fire, drought, insects, and disease – are now threatening the ecological and social benefits that forests provide.

Currently, scientists, forest managers, and policy makers are working to return California's forested ecosystems to more natural forest regimes, with the intent of reducing the extent and severity of disturbance. However, due to limited **monitoring** and **assessment**, it is unclear how timber and ecosystem management regulations, combined with forest restoration projects, are impacting forest ecosystem function across California's landscapes, and whether existing regulations, policies, and programs are achieving their intended goals. Given the multi-year, multimillion-dollar efforts in place to improve forest ecosystem management, a long-term, spatially explicit statewide ecological monitoring and assessment program is needed, with sufficient resolution to track forest ecosystem conditions over time. Further, the ability to disentangle forest conditions (effects) from management (one of several causes) is important to enable forest managers and policy makers to refine regulations and improve management activities on the ground.

KEY DEFINITIONS

Ecological or environmental **monitoring** is the repeated, systematic, consistent collection of measurements at one or more locations to determine the current state and trends of abiotic and/or biotic indicators in the environment. It is generally a neutral reporting system stating results only.

Assessment is the use of monitoring data to evaluate or appraise a resource of concern and/or to determine the condition and provision of ecosystem services and support decision-making and planning processes.

The goal of the TRFRP (AB 1492) is to promote and encourage sustainable forest management and restoration practices consistent with existing legislation (e.g., California Environmental Quality Act, Z'Berg-Nejedley Forest Practice Act, Timberland Productivity Act, Fish and Game Code, Porter-Cologne Water Quality Control Act, etc.), and therefore also improve forest

resilience to stress factors such as fire, pests, drought, disease, cannabis cultivation/ fragmentation/urbanization, and climate change; to protect biodiversity; and to reduce threats to human well-being. AB 1492 directs the development of **Ecological Performance Measures** (EPMs) to inform scientists, land managers, and policy makers of long-term trends in forest ecosystem function and state across California, and to provide analysis of those trends. Information gleaned from this process will help the public and decision makers determine whether programs, policies, and regulations are supporting the retention of desired **ecosystem services**, such as carbon sequestration, water quality and quantity, biodiversity (diverse flora and fauna species), and timber yield, and to help gauge the extent of forest ecosystem resilience to current and future disturbance.

The TRFRP seeks to develop a long-term, collaborative, systematic, and consistent monitoring program across California's coniferous and mixed coniferous forest ecosystems, and to assess management effects, using **indicators** linked to the ecosystem services that forest ecosystems provide. The aims of this effort are to be scaleable, yield spatially and temporally explicit results that can best identify the management practices and regulatory programs promoting ecosystem service performance, and identify underperforming or deficient programs.

KEY DEFINITIONS

Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks that would naturally occur (Walker et al. 2004).

Ecological Performance Measures are used to evaluate ecosystem services against a suite of indicators and associated metrics to help determine an ecosystem's state and level of function and represent a method of ecological monitoring.

Ecosystem Services, also called "desired landscape outcomes", "criteria", or "values", are the direct and indirect contributions of ecosystems to human well-being. They include neutral identification of 1) processes, such as carbon sequestration, water quantity regulation, etc.; 2) physical entities such as timber, wildlife, etc.; and 3) forest condition such as biodiversity, soil bulk density, etc. Socioeconomic factors may also be incorporated.

An **Indicator** (or suite of indicators) is a measurable variable relating directly to one or more ecosystem services and refers to a site-specific condition at a given moment. Using multiple indicators taken together (especially when measured over time) can approximate a process, physical entity, or condition. Measuring an indicator implies identifying an appropriate unit of measurement (a "metric" be it biological, physical or chemical), and then creating or utilizing a corresponding data set. Indicators are used to measure the degree to which ecosystem services are being delivered.

Looking specifically to AB 1492 regarding EPMs, there is direction that:

- "The Legislature further finds that the state's forest practice regulatory program needs to develop adequate performance measures to provide transparency for both the regulated community and other stakeholders." Public Resources Code (PRC) § 4629.1

- "On or before January 10, 2013, and on each January 10 thereafter in conjunction with the 2014–15 Governor's Budget and Governors' Budgets thereafter, the Secretary of the Natural Resources Agency, in consultation with the Secretary for Environmental Protection, shall submit to the Joint Legislative Budget Committee a report on the activities of all state departments, agencies, and boards relating to forest and timberland regulation. This report shall include, at a minimum, all of the following:…

  (8) In order to assess efficiencies in the program and the effectiveness of spending, a set of measures for, and a plan for collection of data on, the program, including, but not limited to:...

    (F) Evaluating ecological performance." PRC § 4629.9(a)

The latter section of the PRC provides AB 1492's most specific and direct language regarding EPMs. Based on this direction, the primary focus of EPMs will be to support the various forest-related regulatory programs and restoration programs that are addressed by the AB 1492 agencies/departments/boards. In particular, this scope includes providing information that will be useful to the regulatory entities, the Legislature, regulated parties, and the public for evaluating the effectiveness and efficiency of these programs in reaching their environmental goals. The EPM information developed could suggest areas where regulations need to be adjusted (e.g., need more stringency or able to be more precisely focused or relaxed), areas where forest resilience or restoration programs need to be modified, or areas where incentive or educational programs need to be better targeted.

The EPMs need to support consideration of not just standard commercial timber harvest, but also other forest management activities, such as restoration, biomass removal, fuels management (including prescribed fire), and carbon offset projects. In addition to supporting backwardlooking program evaluation, the ecological performance measures also will be useful in forward-looking project planning.

A <u>secondary focus</u> for the ecological performance measures will be on broader purposes, such as creating linkages with other governmental planning or assessment activities; for example, the State Wildlife Action Plan, Forest and Rangeland Resource Assessment, California Biodiversity Council indicators project, State Water Plan, Healthy Watersheds Partnership, Freshwater Conservation Blueprint, and National Forest Plans, the Board of Forestry and Fire Protection's Effectiveness Monitoring Committee, and the Forest Management Task Force.

Figure 2 attempts to weave together in a mostly conceptual, spatially hierarchical fashion the range programs and assessment efforts that comprise the above primary and secondary focuses

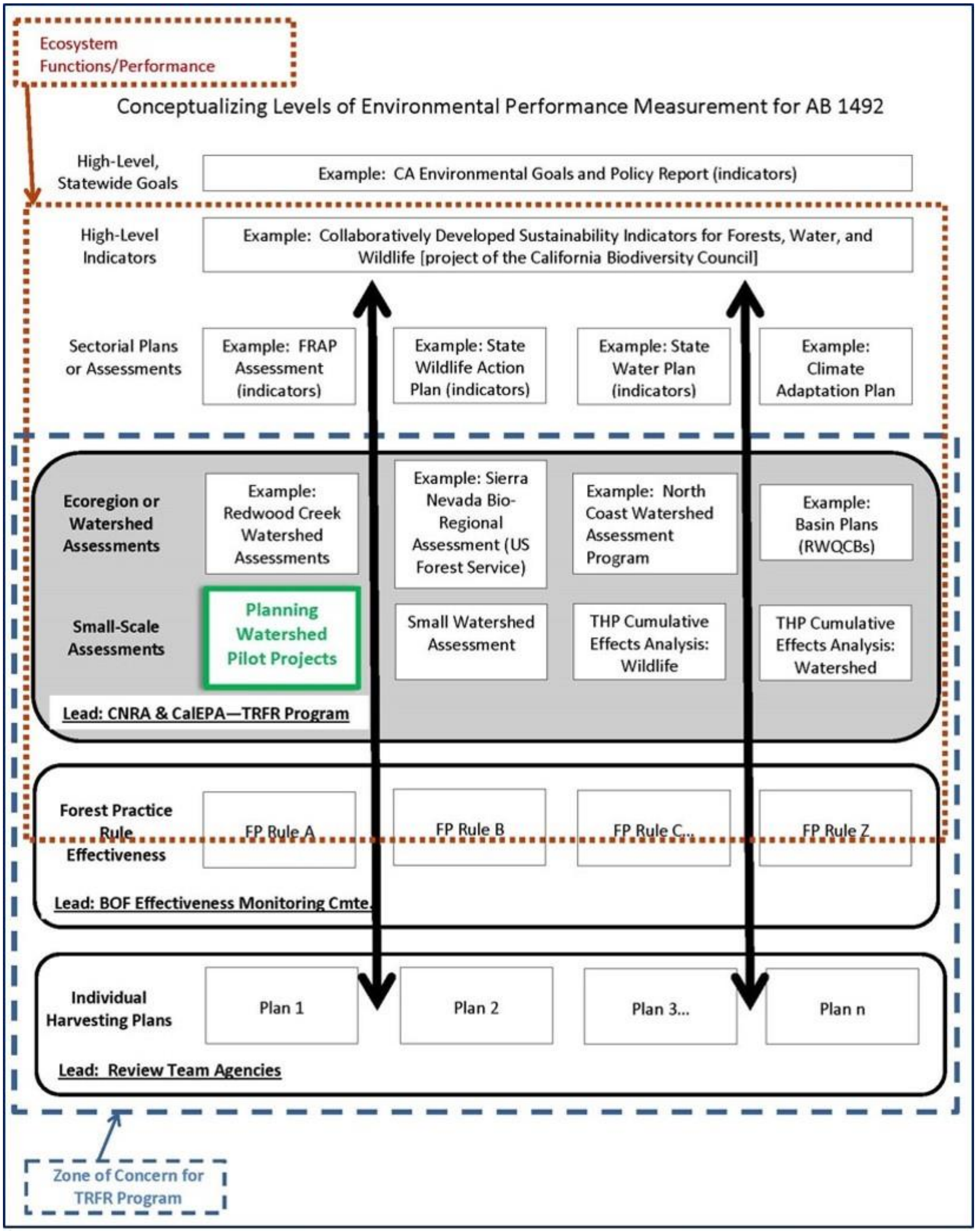

Fig. 2. The TRFR Program has a large "zone of concern" regarding site-specific forest management activities and impacts as well as how these effects interact across the landscape through ecosystem processes. The intersection between the "zone of concern" and the area of "ecosystem functions/performance" defines the direct area of interest of the TRFR Program for ecological performance measures. The TRFR Program also is interested in the potential to develop indicators that can be aggregated or disaggregated across ecosystem landscape scales to allow assessment of ecosystem function/performance at multiple scales.

of the AB 1492 EPM approach. It identifies a "zone of concern" for the TRFRP that spans from the level of individual timber harvesting plans to ecoregion or watershed assessments. The heavy, vertical arrows are intended to represent the nested nature of the levels of assessment and to stress the value of being able to link monitoring data and assessments in a process-based fashion across spatial scales.

Programs that similarly monitor the condition and state of California's natural resources include:

- Surface Water Ambient Monitoring Program (SWAMP) is statewide program managed by the State Water Resources Control Board which maintains regional and state datasets and uses indicators and metrics to monitor water quality and aquatic systems (macroinvertebrates, algae, fish);
- Forest Inventory Assessment (FIA) is a nationwide dataset collected by the US Forest Service to systematically compile information based on a broadly deployed set of indicators to assess forest condition, status and trends, assist in forest health assessments, and project how forests are likely to appear decades into the future, among other studies;
- Fire and Resource Assessment Program (FRAP) operated by CAL FIRE, focuses on analyzing the conditions of California's forests and rangelands at the state level, monitoring their extent, and identifying alternative management and policy guidelines. The program produces periodic assessments of the forests and rangelands of California;
- U.S. Historical Climatology Network (USHCN) data are collected by the National Centers for Environmental Information from a nationwide network of weather stations and are used to quantify national- and regional-scale temperature changes in the contiguous United States; and
- California Natural Diversity Database (CNDDB), maintained by the California Department of Fish and Wildlife, is an inventory of the status and locations of rare plants and animals in California which can be used to infer biodiversity/species richness for further assessment.
- Vegetation Classification and Mapping Program (VegCAMP) operated by the California Department of Fish and Wildlife develops and maintains California's version of the National Vegetation Classification System through assessment and mapping projects in high-priority conservation and management areas, and through working continuously on

best management practices for field assessment, classification of vegetation data, fine-scale vegetation mapping, and archiving of vegetation data.

- California Air Resources Board Natural and Working Lands Inventory is a statewide program that quantifies the carbon within all terrestrial vegetative biomass spatially and temporally, based on ground-based inventories, remote sensing data and allometric equations.

Utilizing and building upon information collected by existing monitoring programs, such as those listed above, the TRFR Program aims to develop a statewide timberland ecosystem EPM monitoring and assessment program to understand resource-management linkages within and across regional units such as watersheds to better understand the ecosystem outcomes of forest management activities and programs (Fig. 2). Ecological monitoring data are collected by private landowners, nongovernmental organizations, and government agencies to meet requirements for a variety of regulatory programs and to manage particular ecological resources. This EPM program proposes to bring these data together, and supplement or complement them with other datasets, as needed. Next, program implementers will apply an assessment method or methods, and report findings in a format affording insight into the efficacy of forest management activities and regulatory programs at the regional scale. A well-defined monitoring and assessment program with a statistically rigorous sample design will help decision makers and the public prioritize management activities and investments (Fig. 3).

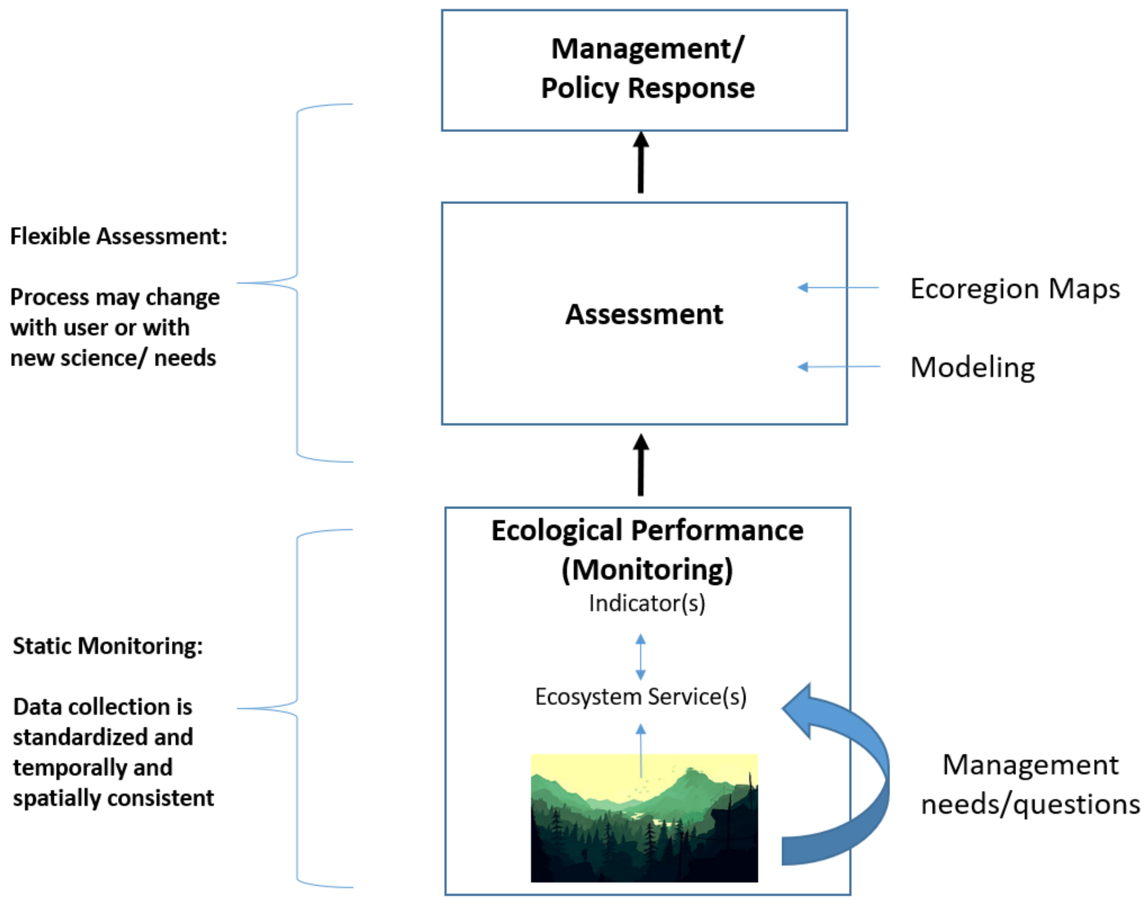

Fig. 3. Conceptual diagram of the California forest ecosystem EPM Monitoring and Assessment Program. At its foundation, EPM program development is led by fundamental resource management needs and questions that will drive program monitoring activities. This in turn yields key ecosystem services and associated indicators best suited to addressing these needs/questions. The aim of monitoring is to develop a standardized, consistent approach to monitoring indicators, statewide. Additional monitoring schema could be integrated, or new ecosystem services evaluated over time, but monitoring should remain consistent through change. The assessment portion of the EPM program is nimble and can incorporate new scientific approaches and models to support analysis of indicator data. The monitoring and assessment outcomes are then reported to decision makers and land managers to inform management and policy response on a continual basis.

The remainder of this document lays out additional definitions, considerations, and a methodological approach that we propose be used as guidance for stakeholders and agency personnel to inform discussions on the development of a California Ecological Performance Measure Program under AB 1492.

The methodology is presented in two parts:

- **(1) Monitoring**
- **(2) Assessment**

This initial methodological proposal is expected to evolve with ongoing agency and stakeholder input.

4.0 Ecological Monitoring

4.1 Definition of Ecological Monitoring

Ecological or environmental monitoring is defined here as the repeated, systematic, consistent collection of measurements at one or more locations to provide data used to assess the current state and trends of abiotic and/or biotic conditions in the environment. Effective monitoring programs start with posing good questions, including problem definition and objective setting, that result in quantifiable objectives that offer clear signposts for measuring progress (Lindenmayer and Likens 2010; MacDonald et al.,1991).

Monitoring is generally carried out over the long term, such as at least 10 years; though limitations in duration exist depending on mission, objectives and funding (Vos et al. 2000; Lindenmayer and Likens 2010). Scale of monitoring can range from a project-specific, localized area (e.g. an individual Timber Harvesting Plan or a restoration project within a recent burn area) to ecoregional (e.g., Gulf of Mexico oil spill restoration) to statewide or nationwide (e.g., Forest Inventory and Analysis, FIA). Typically, ecological monitoring is based on some type of indicator and associated metric that approximates an ecosystem service/ecological process or biophysical element of interest (examples are provided in Section 5.1.2). Empirical measurements of indicators can be field-based (e.g., direct collection of water quality samples) or derived using technology in an office environment (such as by using remotely sensed satellite data). Measurements collected for any given indicator to assess biological conditions are then analyzed against a known range of variation (or historical condition) for the indicator to compare the observed to an expected or desired outcome. Often, a relative “score” is used to report back to scientists and decision makers on whether the indicator is performing within an accepted, scientifically credible “normal range” (see Section 7.2), or if perturbations exist that may be stressing the indicator of interest to a point outside its normal or target range. Resultant information is then used to inform management planning, and in ideal cases is used to improve management action.

4.2 How Ecological Monitoring Is Used

Ecological information gained through monitoring can provide valuable insight into changes in ecosystem structure, ecological process, and ecosystem function, especially in response to land management activities (Lindenmayer and Likens, 2010b). Importantly, monitoring efforts are used to track efficacy of projects and programs such as restoration activities or meeting legislative requirements (e.g. Fish and Game Code, Forest Practice Act and Rules, etc.). Also, data gathered can serve various other functions including providing empirical information for testing ecological theory and developing computer simulation models, guiding evidence-based environmental legislation, and evaluating ecosystem responses to disturbances (Biber, 2013; Lindenmayer and Likens, 2010). Further, ecological monitoring data can be used to inform decision makers and support adaptive management, adjusting forest management regulations in response to changes in indicator performance (Fig. 4).

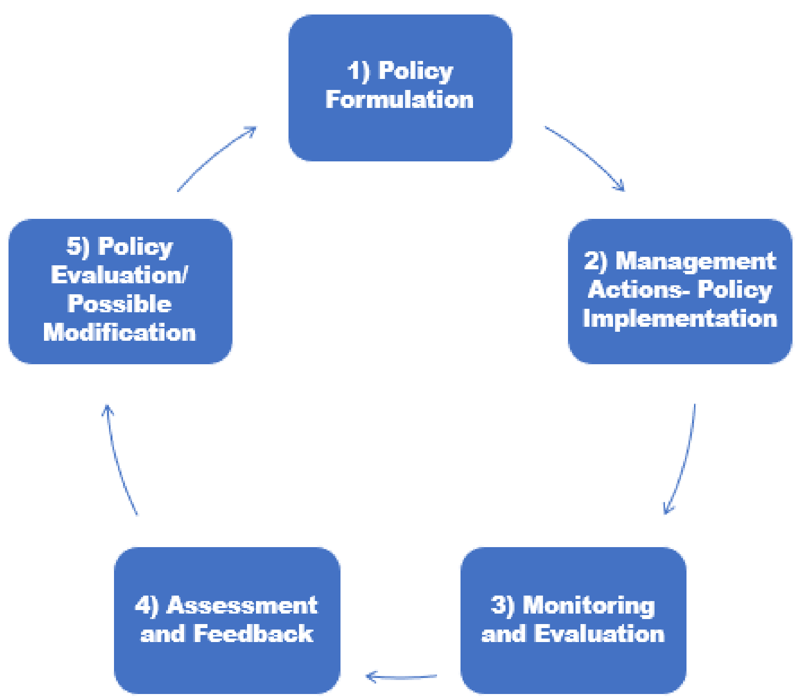

Fig. 4. Iterative cycle of policy development and implementation used in adaptive management, allowing monitoring data to inform management and regulation.

4.3 Types of Ecological Monitoring Programs

Ecological monitoring programs, take different forms: (1) trend, (2) implementation, (3) effectiveness, (4) baseline, (5) compliance, and (6) validation; all of which answer different questions and achieve differing goals (MacDonald et al. 1991). The monitoring framework to be undertaken by the present EPM program will likely include a subset of monitoring types discussed below.

Even though there can be overlap between monitoring programs (e.g., compliance and implementation), it is important to briefly understand the purpose and function of different types of monitoring discussed below (Table 1). MacDonald et al. (1991) provides detailed monitoring guidelines to evaluate the effects of forestry activities on streams and water quality, including descriptions of the types of monitoring used in forestry applications.

Table 1. Types of monitoring applicable to forestry activities.

Type of Monitoring	**Definition**
Baseline Monitoring	Characterizes current conditions as a baseline, or a reference point to compare against future monitoring results. Baseline monitoring is often used as a first step in determining the effectiveness of project implementation.
Implementation Monitoring	Consists of monitoring project areas or design features to ensure project elements and best management practices were implemented in accordance with the project language and all applicable permits and laws. Its purpose is to ensure that proposed work was successfully completed as designed.
Trend Monitoring	Conducted to determine the condition of physical, chemical, or biological attributes across a given area and evaluate their change over time.
Effectiveness Monitoring	An in-depth analysis focused on evaluating whether specified activities had the desired effect. Effectiveness monitoring is designed to determine if the project is effective at meeting its physical, biological, and ecological objectives.

Type of Monitoring	Definition
Validation Monitoring	Assesses the soundness of assumptions, models, methods, and proposals through research.
Compliance Monitoring	Verifies that environmental regulations have been correctly followed.

Baseline Monitoring

A baseline is a set of conditions observed at a specified time and spatial scale. A baseline monitoring program, by extension, tracks deviations from the baseline over time. When monitoring managed lands, baselines may be different for every property. After the baseline conditions are determined, indicators are established that show environmental shifts over time. Typically, these shifts are a result of or are correlated with changes in human activities or exogenous environmental factors (e.g., climate change). Indicators are sImple variables that provide insight into larger ecosystem trends. They are used in other forms of monitoring efforts further discussed. If indicators are chosen correctly, noticeable changes in the indicators could provide an early warning of environmental change or show improvement/deterioration of ecological conditions.

Implementation Monitoring

Implementation monitoring evaluates compliance with agreed upon standards associated with management practices and mitigation strategies associated with projects and programs on the ground (Gardner, 2010). Implementation refers to translating a study design into field activities that aim to achieve the initial monitoring objectives and goals. Implementation efforts are often costly and dependent on the available budget. Implementation measures are related to the systematic monitoring and data collection operations prior to the completion of the initial study design framework.

Trend Monitoring

Status and trend monitoring are conducted to determine the condition of physical, chemical, or biological attributes across a given area and evaluate their change over time (OWEB Monitoring & Reporting). Trend analysis can reveal if conditions are moving in a direction that may be similar to a desirable, undisturbed state, or in another direction altogether.

Effectiveness Monitoring

Effectiveness monitoring focuses on demonstrating the success of management actions by evaluating whether specified activities had the desired effect. This monitoring approach assesses changes in management actions, and uses the information gathered as an indicator of overall project performance (Gardner, 2010). It also assesses whether the overall biological and ecological objectives of the project have been met (OWEB Monitoring & Reporting). A practical effectiveness monitoring program should analyze the trends in frequency distributions of ecosystem conditions, rather than expect that all ecosystems are in good condition, or that they stay in that condition indefinitely (Reeves et al., 2004). Effectiveness monitoring can be used to guide adaptive management. In the case of assessing the effectiveness of natural preserves, for example, monitoring programs must document the conditions of both natural areas and adjacent human-altered landscapes to be able to evaluate the success of conservation measures (Kremen, 1994).

Validation Monitoring

Validation monitoring is equivalent to long-term applied research activities (Gardner, 2010). Validation approaches often incorporate testable hypotheses and meticulously designed sampling regimes (Gardner, 2010). Some validation monitoring approaches are designed to validate assumptions, ecological models, study methods, and proposals (OWEB Monitoring & Reporting). Validation methods compare the results of hypothetical model runs to the data collected in the field. After ecological models are fit, assessing the validity of these models is an essential step in developing relevant inferences and conclusions (Gitzen et al., 2012). Validation monitoring also helps identify the relationship between changes in management and subsequent changes in the attributes studied (Gardner, 2010).

Compliance Monitoring

Compliance monitoring verifies that environmental rules and regulations have been followed. Often, compliance monitoring is implemented following the development of a project. Compliance mechanisms often aim at assuring that the project underway follows ecological standards or best management practices and in accordance with specific regulatory requirements. For instance, protection of water quality, aquatic habitat, and general watershed health are among the intents of the California Forest Practice Act and Rules (FPRs). The goals of this regulatory construct are multifaceted. While it provides field personnel with specific rules or “best management practices” for field operations, it also entails achieving the overarching environmental goals of the Forest Practice Act, including: achieve a balance between growth and harvest; maintain functional wildlife habitat; ensure functional connectivity between habitats; protect water quality.

Approaches to monitoring programs can be structured in different ways including (1) passive monitoring which may or may not be conducted with specific questions or underlying study design (e.g., FIA datasets); (2) mandated monitoring as per legislative requirement or administrative directive (e.g., the Forest and Rangeland Resource Assessment); and (3) question-driven monitoring with a conceptual model and rigorous design with *a priori* questions that can be tested (e.g., status of water quality in Bay Delta); or a combination thereof (Lindenmayer and Likens 2010). Mandated monitoring tends to produce coarse level summaries of temporal changes in a target population or resource condition, similar to “status updates”, but provides limited understanding of ecological mechanisms behind changes observed (Lindenmayer and Likens 2010). Question-driven monitoring typically is finer scaled and process based, uncovering linkages between cause and effect with a given ecological question, but is difficult to extrapolate to larger scales.

While monitoring often focuses on a single habitat type or species in isolation, integrated monitoring is also possible where efforts are conducted with awareness of other related but independently conducted monitoring (Royal Academy of Sciences 2017). In this context, monitoring instead involves a number of scientists, each focused on monitoring different ecosystems or species, possibly across differing scales and resolutions, working in a compatible manner to assess overall management/restoration progress in a complementary manner.

In the present effort to monitor California's statewide timberland ecosystems, we are likely to assimilate diverse datasets and underlying methodological approaches using a combination of the above-mentioned monitoring approaches; specifically baseline, trend, and effectiveness monitoring types.

4.4 Reasons why Monitoring Programs Fail

Despite the paramount importance of monitoring conservation or restoration projects/programs to assess efficacy, many projects and programs are ill-equipped or entirely fail to monitor pre- and/or post implementation (Reid 1999, Lindenmayer and Likens 2010). In these instances, researchers and decision makers are limited in their capacity to implement adaptive management to respond to changing forest conditions, such as recalibrating management activities to improve indicator performance (Royal Academy of Sciences 2017). Some reasons for the lack of, or inadequate, monitoring programs include:

- Lack of political will and/or public awareness/support;
- Lack of understanding of costs associated with monitoring in evaluating program funding needs;
- Unclear, infeasible or non-existent vision and program goals;
- Unclear, untestable or unbounded project objectives;
- Metrics that are not tied to objectives or use of inappropriate performance criteria;
- Insufficient baseline data or shifting baselines;
- Unsuitable site selection and lack of reference sites;
- Inadequate statistical sampling design;

- Inaccurate understanding of scaling inconsistencies and regional differences; (National Academies of Sciences 2017);
- Inability to secure access to private lands;
- Tendency for monitoring to be the first area to have funding reduced or eliminated when agencies face budget reductions;
- Program was not designed to answer the specific questions posed;
- Monitoring plan was not adequately reviewed prior to implementation; and
- Data analysis began after the monitoring ended.

While far from simple or easy to design, initiate implementation, and maintain over time, thoughtful monitoring programs can yield important insights from ecosystems that can be used to more effectively deploy limited resource management funds. Projects and programs that are not systematically monitored pre- and post-implementation run the risk of losing valuable information on their performance and the factors that have led to success or failure of natural resource management initiatives. Adaptive management cannot function effectively without a robust monitoring and assessment system in place that can isolate the factors contributing to indicator outcomes.

5.0 Role of Ecological Performance Measures

A method of monitoring, Ecological Performance Measures are the use of one or more indicators and associated metrics to approximate the provision of one or more ecosystem services and assess overall forest ecosystem state and function (Fig. 5). They provide information to assess whether a project or set of projects/programs have achieved their stated objectives in terms of desired biological or broader ecosystem structure, composition and/or ecosystem service(s) provided. This monitoring informs the public and funding agencies of benefits realized from investments and provides accountability (National Academy of Sciences 2017).

Ecosystem services, also commonly referred to as "desired landscape outcomes", "criteria", or "values", are things for which we deem a forest to be important. They include (1) processes, such as carbon sequestration, water supply, etc.; (2) physical entities such as timber supply, biomass supply, wildlife species abundance, etc.; and (3) forest condition such as biodiversity, etc. Cultural values and recreation are also often referenced when considering ecosystem services.

Indicators refer to a site-specific condition at a given moment (or reflecting a process measured over time). Multiple indicators taken together over time can approximate an ecosystem service. Indicators can be biotic (e.g., species abundance, number of trees per acre) or abiotic (e.g., water pH or temperature). Measuring an indicator implies identifying an appropriate unit of measurement/s (i.e., "metric"; such as cubic feet of water flowing in creek at a given time), and then creating or using a corresponding data set. In some cases, an indicator and metric may be identical (e.g., trees per acre), and in some cases, complex indicators may combine multiple metrics (e.g. fire severity).

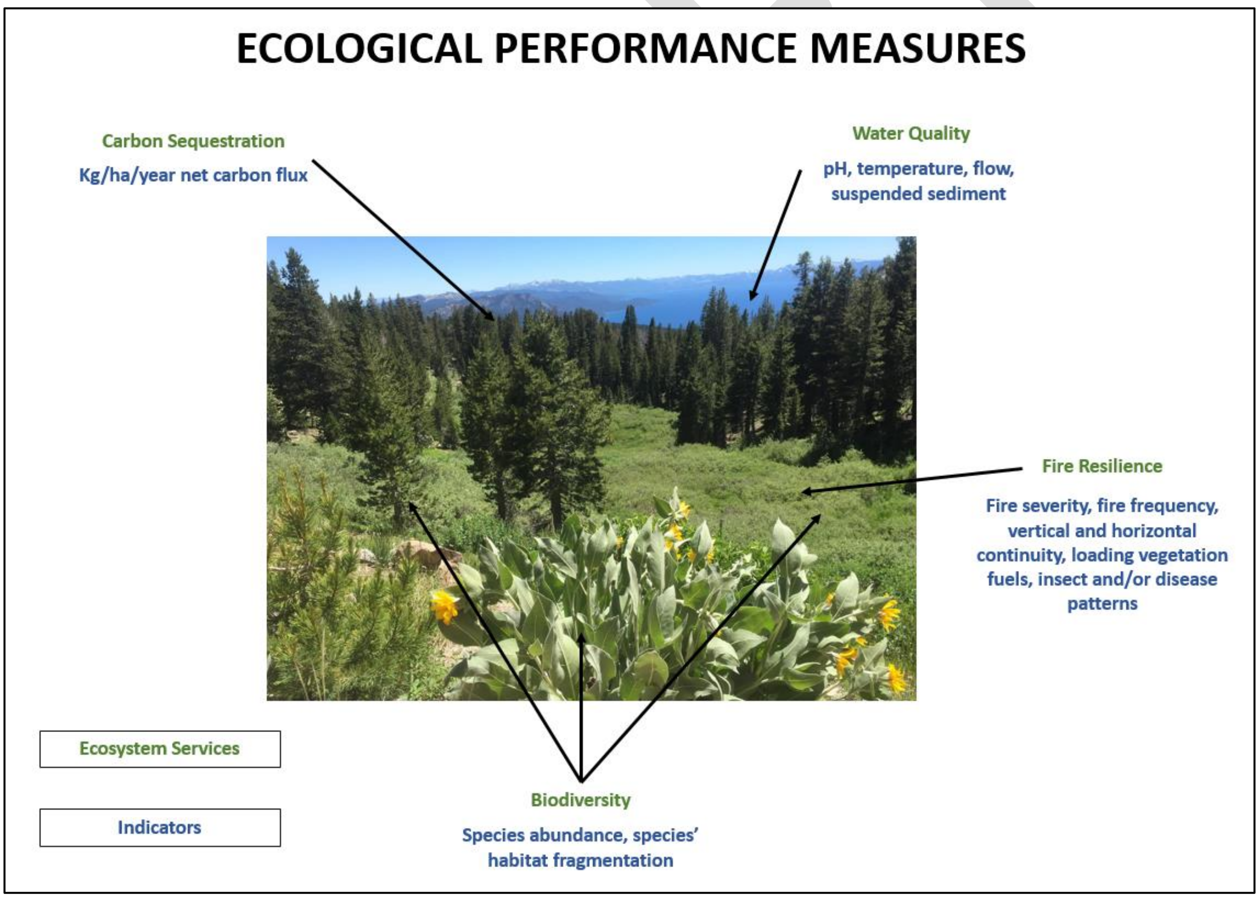

Fig. 5. Ecological Performance Measures can include one or more ecosystem services (green text above) to understand forest ecosystem function and state for localized or large-scale assessment of forested ecosystems. An indicator (blue text above) can be linked to multiple ecosystem services. Figure depicts examples of ecosystem services and related examples of indicators.

While more detailed discussion of ecosystem services and indicators and the process for their selection appears in the Methodology section below, we describe some basic parameters here. In general, indicators should be real, measurable, objective and scalable. Further, measurements of indicators must be repeatable through time. Indicators are real when they are objectively quantifiable (e.g., "scenic beauty" would not qualify well as "real"). Indicators should be directly linked to corresponding metrics, with the use of commonly accepted units of measure (i.e., there should be the ability to apply metrics to indicator, rather than "good" or "bad" qualitative measures). Lastly indicators and their corresponding metrics should be scalable—it should be possible to collect and aggregate indicator data across an entire spatial extent to allow the evaluation of the indicator at different resolutions.

Ecosystem service and indicator nomenclature and level of specificity importantly influence the utility and collective understanding of what is being measured (Duinker 2001). Depending on level of specificity, ecosystem services and indicators can be interpreted very differently by stakeholders. As Duinker (2001) explains with an example, "conservation of biodiversity" to describe an ecosytem service/criterion may lead to the use of very different indicators. This is because 'biodiversity' could be interpreted as ecosystem diversity, species diversity, or genetic diversity. Being very clear about the ecosystem service of interest is a key first step. Going a step further, terminology used to describe an indicator must be very clear. As Duinker (2001) suggests, there are two main tests for determining if something is an indicator: (1) it is void of any specification of the desired level of the entity being measured (if the level is there, then the entity statement includes more than an indicator); and (2) it is possible to specify directly the appropriate units of measure (if not then further specification of the entity is required). For example, "level of fragmentation and connectedness of forest ecosystem components" is not a valid indicator because no clear metrics are readily apparent. However, forest fragmentation could be refined to say (1) proportion of forest area designated as 'core' habitat; and (2) contrast-weighted edge density, to more specifically pinpoint an indicator and identify metrics for measurement.

Towards assessment of ecological performance of forested ecosystems, a directional statement or goal should be established early-on for each ecosystem service (criteria, value, desired landscape outcome), such as: (1) forests are long-term net sinks of atmospheric carbon; (2) forests produce a continuous non-declining flow of quality wood to meet mill needs; (3) forests will maintain current levels of species biodiversity. Indicators also require directional statements or objectives to track progress such as (1) more than zero kg/ha/yr (positive value) for net carbon uptake; and (2) at least 10% increase in species X abundance. There are strict relationships among ecosystem services and goals, and indicators and objectives, as depicted in Figure 6.

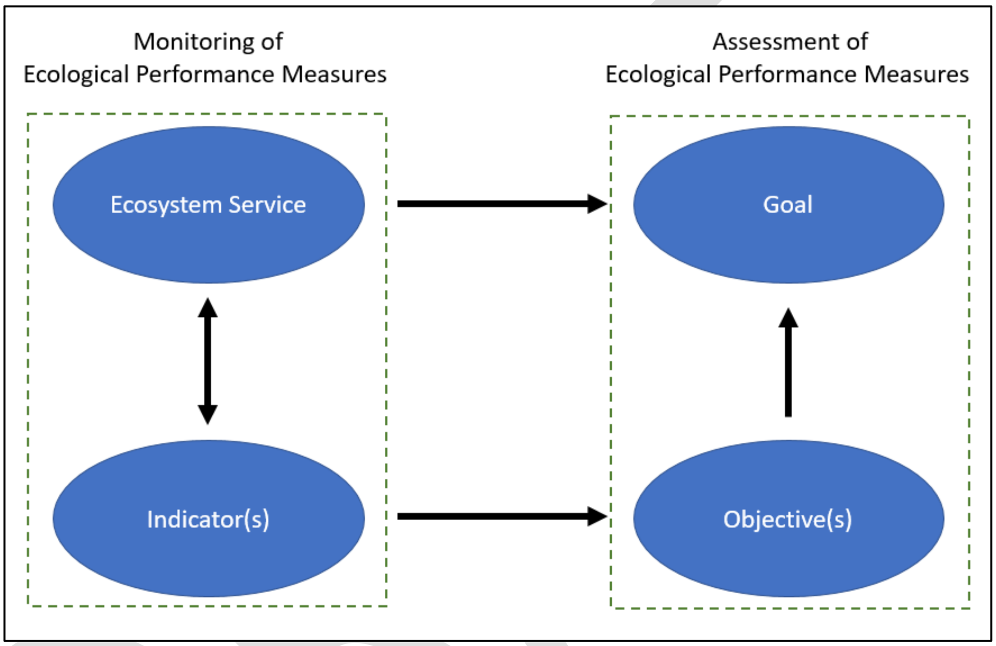

Fig. 6. For each ecosystem service, there is a goal statement and one or more indicators. For each indicator, there is one objective statement. The Ecosystem Service is 'satisfied' if the goal is reached. The goal is reached if all the objectives are reached. Goals and objectives should be agreed upon by stakeholders as a part of an evaluation of management questions and desired outcomes on the landscape. Adapted from Duinker 2001.

5.1 Example Approaches

There are numerous approaches for evaluating ecological performance with countless monitoring programs already in place or under development around the globe. We briefly summarize a few of them here, providing California-based examples, to give the reader a sense of various programs and their chosen indicators to monitor ecosystems. Reflecting on the previous section, the reader can see there is great variation in how indicators are named.

5.1.1 Tahoe-Central Sierra Initiative

The Tahoe-Central Sierra Initiative (TCSI) is currently carrying out its own Landscape Resilience Assessment, which is expected to ultimately lead to monitoring of over 2 million acres of public and private land to assess efficacy of management activities in the Tahoe ecoregion. As a part of their stepwise approach to establishing a monitoring program, they along with invited stakeholders, assembled a "Values-Disturbances-Indicators" table to keep track of fundamental relationships between disturbance types and the landscape values and services of most importance to the working group. They list disturbances such as fire, flooding, drought, insects/disease, and climate change, and they break down how these interface with the landscape values and services most important to stakeholders in the region (e.g., meadows/marshes, aspen forests, streams/lakes, life/property, water quality/supply, air quality, recreation, etc.). Given the intersection of disturbances/stressors and the landscape values/services of most importance to the ecoregion, TCSI in consultation with stakeholders put together a list of tentative indicators (Table 2) which will undergo further consideration and screening in the near future.

Table 2. Excerpt from draft Values-Disturbances-Indicators table generated by TCSI for initial indicator selection. Landscape values and services (e.g., aquatic ecosystems, upland ecosystems, etc.) were categorized and considered against each disturbance type category (e.g., fire, flood, drought, etc.) to obtain a listing of candidate indicators (shown in bold) to measure resilience (metrics listed below indicators).

Candidate Indicators and Potential Metrics- Measure of Resilience to Disturbance					
Resilience to Fire: Mean condition class; Fire Severity; Trees per acre; Fire risk index; Roads & trails linked to water channels; Human access; Water quality; Seral stage (P); Vertical Heterogeneity (P); Horizontal heterogeneity (P)	**Resilience to Flood:** Roads & trails linked to water channels; Water quality; Floodplain condition	**Resilience to Drought:** Trees per acre; Meadow refugia; Meadow connectivity; Climatic water deficit; Snowpack; Aquatic organism passage; Floodplain condition; Bark beetle predators; Native fish diversity; Seral stage	**Resilience to Insects and Disease:** Trees per acre; Climatic water deficit; Bark beetle predators; Seral stage (P)	**Resilience to Insects and Disease:** Trees per acre; Climatic water deficit; Bark beetle predators; Seral stage (P)	**Resilience to Climate Change:** Fire severity; Trees per acre; Meadow refugia; Meadow connectivity; Thermal tolerance; Climatic water deficit; Snowpack; Human access; Floodplain condition; Bark beetle predators; Native fish diversity; Seral stage
Resilience to Erosion: Roads & trails linked to watercourses; Human access; Water quality; Floodplain condition	**Resilience to Air Pollution:** TBD	**Resilience to Human Presence:** Roads & trails linked to water channels; Human access; Floodplain condition			

5.1.2 One Tam: Mount Tamalpais

A smaller-scale monitoring approach, One Tam is an ecological monitoring program developed by stakeholders that make up the Tamalpais Lands Collaborative which encompasses over 46,000 acres of coastal and mountain open space. Seeking to track efficacy of land management projects and programs, One Tam employed methodology used by the National Parks Service (Natural Resource Condition Assessments) to evaluate the condition of its natural resources. They identified a broad set of biophysical indicators to monitor changes on the landscape over time. Its first report in 2016 provides a "report card" based upon an aggregation of indicators' metrics comparing past and current monitoring findings, and ranking indicators (sample listing provided in Table 3) with a scoring system ranging from "good", "caution", "significant concern," to "unknown" (moderating the scores are quantitative values that yielded the qualitative values found in table below). Going a step further, One Tam reports on the level of confidence in the data quality and availability that supports assessment of each indicator.

Table 3. Excerpt from One Tam summary table showing conditions and trends of select "ecological health indicators" based upon the report titled 'Measuring the Health of a Mountain: A Report on Mt. Tamalpais' Natural Resources. Each indicator was given an overall condition of good, fair, poor, or unknown, and a trend of improving, no change, declining, or unknown. The last column indicates the level of confidence in each assessment.

HEALTH INDICATOR	CONDITION & TREND	CONFIDENCE
Overall Health of Mt. Tam	FAIR ↔	Moderate
PLANT COMMUNITIES		
Old-growth Coast Redwood Forests	GOOD ↑	High
Second-growth Coast Redwood Forests	FAIR ↓	Moderate
Sargent Cypress	GOOD ↔	Moderate
Open-canopy Oak Woodlands	FAIR ↓	Moderate
Shrublands: Coastal Scrub and Chaparral (Including Serpentine Chaparral)	GOOD ↔	Moderate
Maritime Chaparral	POOR ↓	High
Grasslands	FAIR ↓	Low
Serpentine Barren Community Endemics	FAIR ↓	Moderate
WILDLIFE		
Lagunitas Creek Coho Salmon	POOR ↔	Moderate
Redwood Creek Coho Salmon	POOR ↓	Moderate
Steelhead Trout	POOR ↔	Moderate
Three-spine Stickleback	GOOD ↔	Low
California Red-legged Frog	GOOD ↔	Moderate

5.1.3 Fire Resource and Assessment Program (FRAP)

CAL FIRE's Fire and Resource Assessment Program (FRAP) produces a periodic assessment of the forest and rangelands in the state, looking broadly across all ownerships. In the 2017 FRAP Assessment, a new indicator approach was used. FRAP used a process of indicator selection that involved significant stakeholder interaction, including what might best be described as an on-line crowdsourcing process. The result of the process was the compilation of numerous indicators, including those determined to be most relevant to California forests and timberlands (Fig. 7).

Fig. 7. FRAP listing of indicators, selectively listed for indicators focused on forest ecosystems. Excerpt from the 2017 FRAP report.

Chapter 1: Sustainable Working Forests Indicators
1.1: Net Growth of Growing Stock on Timberland
1.2 Timberland in Need of Restoration Treatment to Reduce or Increase Stocking
1.3: Timberland Harvested by Silvicultural Method
1.4: Timber Harvest from Private and Public Lands
1.5: Timberland Managed Under Forest Certification, or Other Sustainable Forestry Standards
1.6: Acres of Forestland Being Managed as Carbon Offset Projects

Chapter 4: Wildfire Threat Indicators
4.1: Fire Regime Interval Departure (FRID)
4.2: Fire threat
4.3: Wildfire activity by fuel type/bioregion
4.4: Vegetation burn severity
4.5: Amount of fuel treatment acres by treatment type and fuel type.

Chapter 5: Forest Pests and Disease Indicators
5.2: Area of tree mortality from insects, diseases, and other damaging agents on forest lands in California
5.3: Number of native and exotic pests that occur on forest lands in California*

Chapter 6: Population Growth and Development Impacts
6.1: Recent and projected population trends
6.2: Area of conversions from forest and rangeland to development
6.3: Percent of private forest and rangeland currently under Williamson Act contracts or Timber Production Zone restrictions
6.4: Percent of private forest and rangeland currently under conservation easements

Chapter 7: Climate Change Indicators
7.1: Annual average temperature departure from long term average by ecosystem units.
7.2: Annual average precipitation departure from long term average by ecosystem units
7.3: Total forest ecosystem carbon pools and changes
7.4: Total forest product carbon pools and changes

Chapter 9: Water Indicators
9.1: Water quality
9.2: Snow pack
9.3: Spring runoff
9.4: Cumulative water deficit

Chapter 10: Wildlife Indicators
10.1 Number of Threatened and Endangered Species Listed under the State and Federal and Endangered Species Acts.
10.2 Forestland Structure (Stand Age Class) by Ownership
10.3 Terrestrial Intactness of CWHR Types based on Human Impact
10.4 Impact of Climate Change on the Extent of Habitat Types
10.5 Vegetation Types Protected from Conversion

6.0 Methodology- Monitoring for Ecological Performance

The California Natural Resources Agency (CNRA) and the California Environmental Protection Agency (CalEPA), through the timber harvest review team agencies [Department of Conservation- California Geological Survey, Fish and Wildlife, and Forestry and Fire Protection (CAL FIRE) at CNRA; State and Regional Water Boards at CalEPA] will take coordinated actions through the Ecological Performance Measures Working Group and AB 1492 Leadership Team, to develop the EPM program. All work and decisions throughout the process will solicit the input of stakeholders in the form of workshops and other similar opportunities for engagement.

In the following sections, we lay out a general approach and proposed methodology to establish a statewide ecoregional monitoring program for conifer and mixed conifer forest ecosystems in California. We highlight key "decision points" that denote when stakeholder input is needed to support the process moving forward. We seek to stimulate discussion on next steps for the program with a suggested methodology based upon review of similar monitoring programs around the globe.

KEY DEFINITION

Forest Management is the process of planning and implementing practices for the stewardship and use of forests and other wooded land to meet specific environmental, economic, social and cultural objectives (Food and Agricultural Organization, United Nations). Forest management may include (but not be limited to) such activities as standard commercial timber harvest, biomass removal, fuels management, carbon offset projects, restoration and conservation projects, and the like.

The EPM Program suggests a monitoring approach that: (1) identifies key monitoring objectives and questions; (2) develops conceptual models that help support selection of Ecological Performance Measures (EPMs); (3) screens to narrow down and identify the most relevant and potentially successful EPMs; and (4) evaluates existing EPM datasets to determine their quality and availability, statewide.

6.1 Identifying Key Monitoring Objectives and Questions

> ***Decision Point***
>
> What are desired ecosystem services?
>
> What are key disturbance factors impacting the landscape?
>
> What management is being done presently to impact (positively or negatively) these ecosystem services?

At the outset of an ecological monitoring program, an evaluation of management challenges associated with California's forested ecosystems (related to fire regime, wildlife populations, water quality, etc.), as reported in published literature and given expert opinion, should steer the monitoring program in a direction that will most directly support decision making and adaptive management. Direct and indirect human stressors, further exacerbated by nonstationary stressors (which in many cases are an indirect result of human activities; e.g., climate change), are contributing factors that influence ecosystem condition. Management questions need to be translated into specific, testable hypotheses or measurable questions that can be addressed in a quantitative manner through a data collection process (Fig. 8; National Academy of Sciences 2017). For example, if "resilience" of ecosystem services is deemed important to the TRFR program, the question posed, e.g., "What do we want forest ecosystems to be resilient to," will yield many answers that lead us to different indicators and metrics to track in subsequent monitoring. Correspondingly, if "biodiversity" is an ecosystem service deemed important to stakeholders, more information is needed to understand exactly what attributes of biodiversity are sought: biodiversity among all forest species, native species, or targeting a select few species, etc. The EPM Program must clearly pose questions as to what we want to know about the forest ecosystems we are managing and detail the endpoints that are desired from the monitoring program (Failing and Gregory 2003).

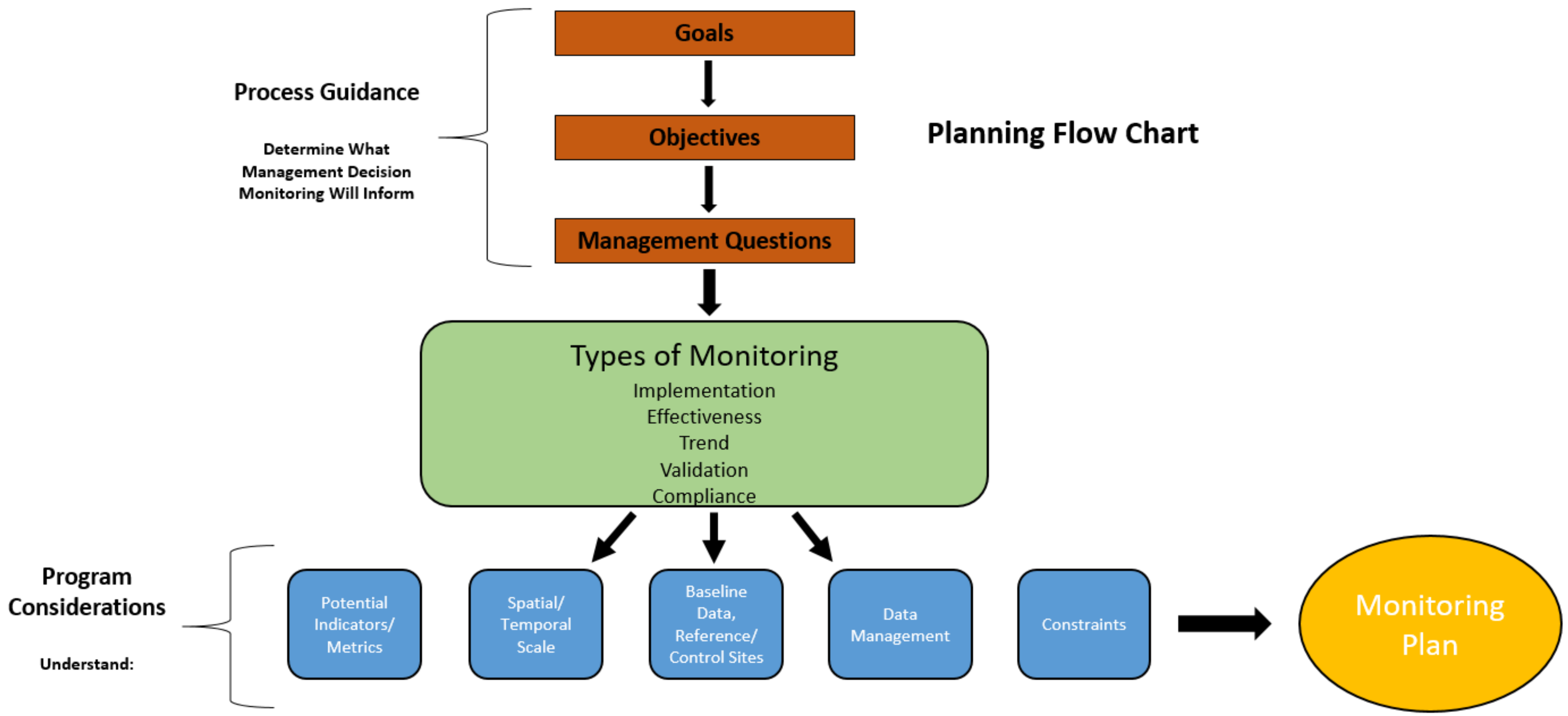

Fig. 8. Basic conceptual model of EPM program planning. Adapted from Royal Academy of Sciences 2017.

6.1.1 Develop Supporting Conceptual Models

Development of conceptual models (i.e., diagrammatic representation how key ecological processes of a target ecosystem or population interact/influence one another and are affected by system stressors such as drought, pests, human activities), can help identify elements that need to be understood (measured) in order to address the management questions (Lindenmayer and Likens 2010). Given that landscapes are heterogeneous mosaics of patches, the conceptual models describing them require the identification of pattern. According to Jensen and Bourgeron (1994), pattern recognition is the description of variation at a given scale. Once ecological patterns are characterized, the agents of pattern formation must be identified. The agents of pattern formation are grouped into three categories: biotic processes (e.g., migration and extinction), disturbances (e.g., fires and floods), and environmental constraints (e.g., landforms and soils). Ecological relations are defined by matching ecological patterns with their relevant agents of formation. A conceptual model (Fig. 9) can provide a clearer vision of how an ecosystem service and all relevant components (inputs and outputs) interact, which can deliver a clearer vision of the key mechanisms behind ecosystem function and change, posit what responses might occur following management interventions, and yield indicators to track changes in an ecosystem.

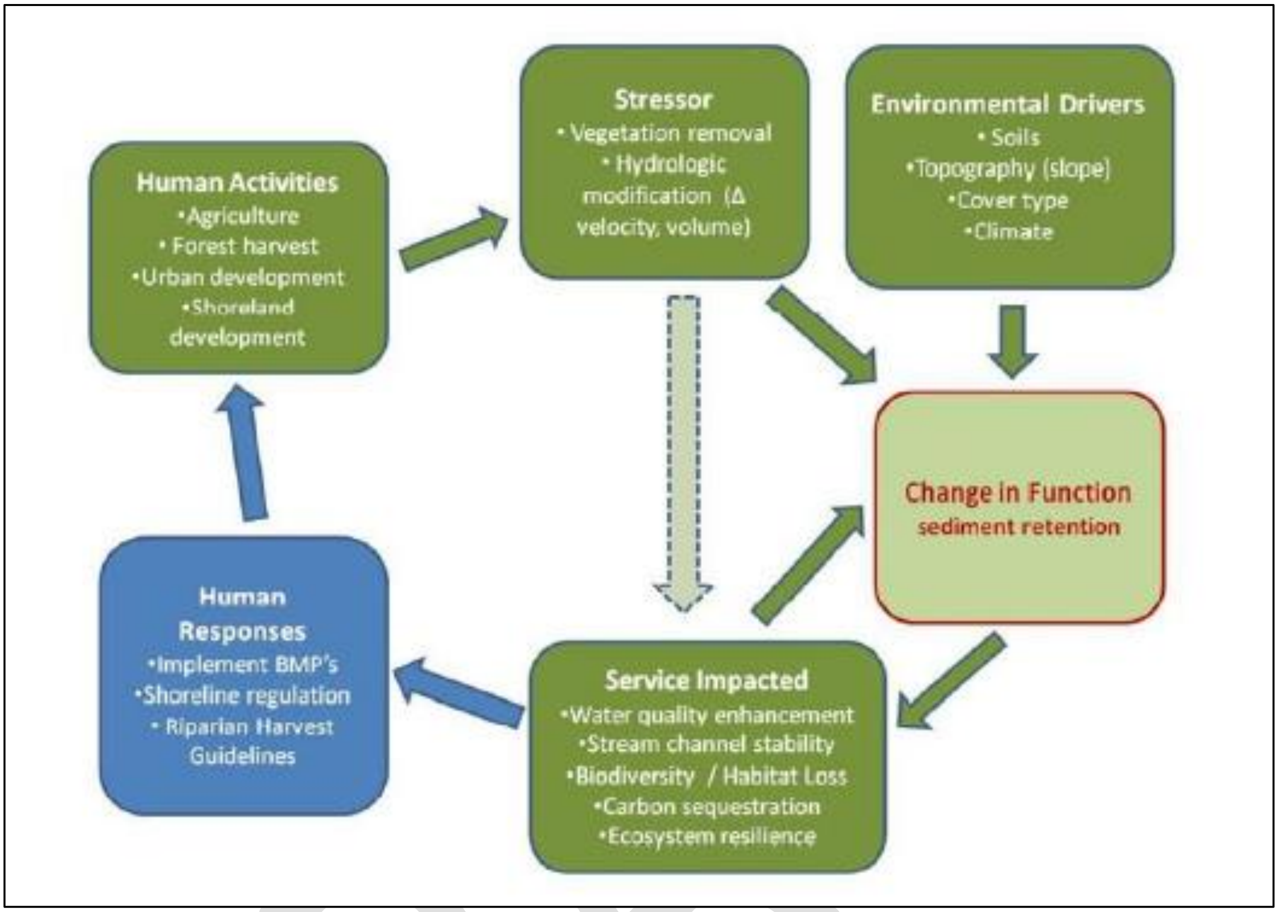

Fig. 9. Sediment retention stressor-function-service-response diagram (Wright and Johnson 2011).

Following the delineation of the key questions and endpoints which may evolve during a long-term monitoring program, the process for selection of indicators linked to ecosystem services may begin.

6.2 Considerations for Screening and Selection of Ecosystem Services and Indicators to Evaluate Ecological Performance

6.2.1 Proposed EPM Screening Process

We referenced published literature on ecological monitoring, ecological indicators, and lessons learned from other large-scale ecosystem monitoring programs, including a recent approach proposed to support monitoring of multi-billion-dollar restoration projects and programs in the Gulf of Mexico after the BP Deepwater Horizon oil spill (Baldera et al. 2018; Royal Academy of

Sciences 2017). Based upon this, we have assembled a proposed methodology for the selection of ecosystem services and indicators/metrics to monitor the state and function of California's forested ecosystems (Fig. 10) to meet AB 1492 directives. Each of the steps, in Figure 10, is described in detail below.

This is a general proposed approach intended to guide future discussions. It should not be considered exhaustive of all considerations and decisions that will need to be made along the way in stakeholder workshops and/or in Ecological Performance Measure Working Group and AB 1492 Leadership Team discussions. Through consultation with scientific experts and the broader stakeholder community, we expect to modify and add more detail to the proposed approach.

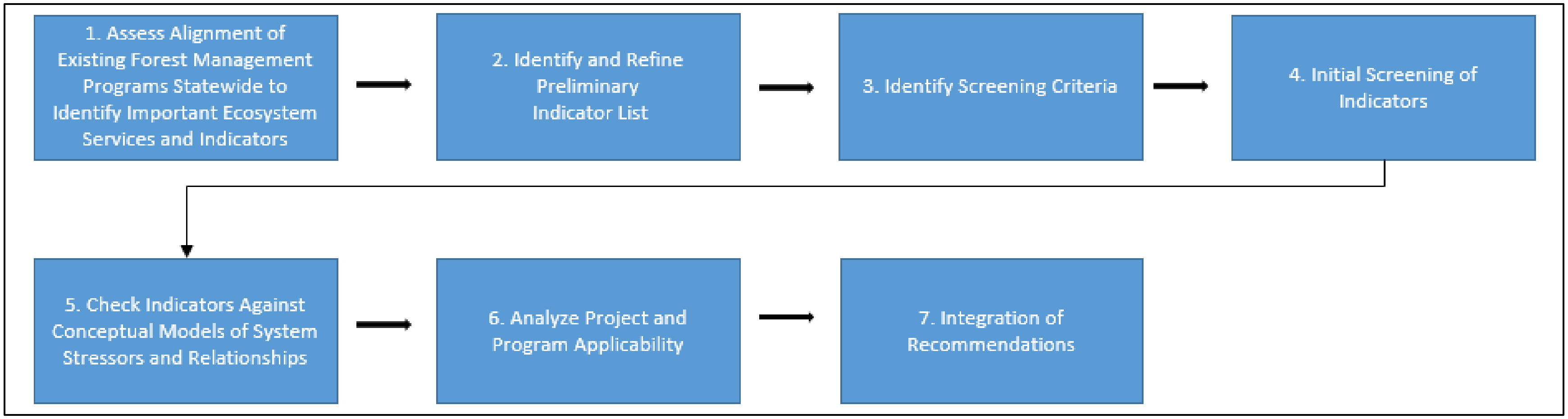

Fig. 10: Summary of suggested seven-step approach to selecting ecological performance measures. Adaptation of Baldera et al. 2018.

6.2.1.1 Assess alignment of ecosystem-based forest management regulatory and program goals, objectives, and approaches throughout California (Step 1)

As a basis for evaluating efficacy and the collective ecosystem impacts of forest management and related regulatory programs on nonfederal forest lands, a first step involves tracking existing statewide forest management activities and regulatory program goals and objectives (e.g., restore and conserve habitat; restore/maintain water quality and quantity; restore/revitalize timber/non-timber forest product economy).

> ***Decision Point***
>
> Evaluate existing forest management statutes, regulations, and programs in California and based on areas of overlap, divergence and alignment of goals and objectives, determine final list of Ecosystem Services to guide EPM development and acquire initial set of indicators.

First, a statewide survey of major forest management and ecosystem restoration related statutes, regulations, program goals, and objectives could be used to help determine areas of alignment, overlap and divergence, thereby identifying ecosystem services of most importance across the state (Baldera et al, 2018; Doren et al, 2009).

Next, identify areas of alignment, overlap or divergence for forest management resource types (specific species or taxonomic groups, habitat types such as wetlands and meadows, issues such as nutrient loading or wildfire, and matters linked to socioeconomic importance) that are connected to the abovementioned goals and objectives. This information should help target areas of focus for the monitoring program.

The last piece to this step is to evaluate alignment, overlap, or divergence in forest management approaches by determining how combined programs, regulations and statutes have been targeting the management goals, objectives, and resource types above. The resulting alignment can then be used to help identify various system stressors to further build upon conceptual models for monitoring forest ecosystem resources and screening for ecological performance measures or indicators (see Section 6.2.1.4).

6.2.1.2 Identify and refine preliminary indicator list (Step 2)

> ***Decision Point***
>
> Compile an initial list of indicators that are used to evaluate ecosystem condition, referencing statewide forest management and restoration statues, regulations and programs (see Step 1), building upon conceptual models and ecological questions.

Referencing existing California forest ecosystem management and monitoring programs (e.g. FRAP, FIA, SWAMP, State Water Plan, and smaller scale assessments and projects), we will compile an initial list of indicators that are used to evaluate ecosystem function and state. However, as Lindenmayer and Likens (2010) caution, "laundry list" approaches are not advised for many reasons including (1) diverting those responsible for establishing a monitoring program from posing well-crafted and tractable questions; (2) there are limited funds for monitoring; and (3) there is a risk of monitoring many things badly. Further they suggest that generic frameworks (e.g., Montreal Process Criteria and Indicators) are not recommended to be used exclusively, as they likely will fail to target issues of most relevance for the program goals and the region of study. It is best to simply use initial indicator lists as a starting point for discussion with stakeholders about what to monitor. Screening thereafter should target the most relevant indicators and a tight nexus should exist between the ecological services of importance and those indicators that are monitored (see 6.1.1).

According to Baldera et al. (2018), an initial indicator list can be shortened by combining similar indicators. Indicators can be further eliminated when they are highly unique and narrowly define objectives and are not indicative of overall program success from a scientific or public perception. That is not to say that the indicators that are eliminated in the latter case are unimportant in a project-specific case, but rather they lack relevance for evaluating collective performance at the programmatic level. In the case of the Gulf of Mexico study (Baldera et al., 2018), the initial indicator list of 196 potential indicators was brought down to 34 after this step.

Examples of indicators that were selected among the 34 include:

- Status of imperiled flora and fauna (e.g., threatened or endangered species) or habitat condition;
- Sediment and nutrient loading (natural versus anthropogenic);
- Elevation;
- Invasive species;
- Patch size/structure;
- Vegetation cover;
- Connectivity to nearby habitats/habitat fragmentation;
- Fire frequency/intensity;
- Species abundance; and
- Nutrient concentrations.

Recall that the CAL FIRE FRAP, noted in Figure 7, underwent a similar approach. In that process, the CAL FIRE FRAP yielded a candidate indicator list for 13 different categories, which was used in screening process for the 2017 FRAP assessment, available for viewing at: http://frap.fire.ca.gov/assessment2017/index.

6.2.1.3 Identify Screening Criteria and Apply Initial Screening Process to Indicators (Steps 3 and 4)

> ***Decision Point***
>
> Determine screening criteria for candidate indicator selection.

After a preliminary indicator list has been compiled to prepare for agency and stakeholder engagement on indicator selection, it is important to establish a transparent listing of criteria that will be used to judge indicator inclusion or exclusion for the process moving forward. Once a public process is underway, new indicators will likely be suggested for use and there must be a process that all can follow to understand what indicators will be selected and the rationale for those decisions. There is a deep body of literature on what makes a good indicator and lessons learned from review of other large-scale monitoring efforts (Baldera et al 2018; Doren et al., 2009; Duinker 2001; Failing and Gregory 2003; Lindenmayer and Likens 2010; Royal Academy of Sciences 2017). Screening criteria, listed below (Table 4), are derived from the literature review and are among those that will be considered for use in the present EPM Monitoring and Assessment Program.

Table 4. Sample listing of screening criteria for indicators. Note: This list is meant for illustrative purposes and does not imply all criteria would be used by the present EPM approach. (Baldera et al, 2018; Duinker 2001; Doren et al., 2009).

Criterion- Indicator Selection	Definition
Sensitive	Indicator must be sensitive and responsive to change so that management actions can readily influence its behavior (responsive to human disturbance gradients)
Predictable	Future indicator levels must be predictable (metric range is clear)
Practical/Feasible to implement	Monitoring techniques readily available and are not cost-restrictive to encourage its continued use and improve the rigor of the indicator as longer time series are collected
Relevant	Relevant to stated goals, objectives, priorities of program, ecosystem of interest
Scientifically valid	An accepted relationship exists between the indicator and its purpose, with scientific consensus that change in the indicator signifies a response to a management action (directly or indirectly) and that the data used are reliable and verifiable
Measurable	It is possible to measure the indicator (i.e., technology exists to measure the indicator) and objective empirical measurements are possible to capture over time. Changes in indicator are readily detectable.
Clear targets	Clear measurable targets can be established for indicator to allow for assessments of success
Specificity	Indicator is specific so that corrective, measured action can be taken to adjust management
Easily understood and communicated	Conceptual relationships between management purpose and action are clear and easily articulated, and understood by the public and decision maker
Applicable (across state)	The indicator is important for documenting changes for two or more management categories (e.g. meadows, wetlands)
Responsive to scale	Responsive to variability at a scale that makes it applicable to entire system

An initial list of indicators can be refined by using a tiered, prioritized filter (Baldera et al. 2018). After ensuring that the most relevant and applicable indicators are under consideration (see Sec. 6.2.1.2), referencing Table 4, indicators can be given relative scores based upon frequency/performance in meeting these criteria. Baldera et al. (2018) used a 4-point scale to assign values and respective definitions (ranging from: “doesn’t meet criterion” to “strongly meets criterion”) to weigh the extent to which candidate indicators closely matched the criteria. Indicators can also be categorized into functional groups (Duinker 2001) to ensure they cover the breadth of major management goals and categories.

At this stage of the indicator screening process, it is important to start exploring the availability of statewide datasets for candidate indicators. Elimination of a candidate indicator just because data do not exist should not be assumed, but consideration of feasibility and practicality come into play. While not all indicators will have sufficient statewide coverage, they may still be appropriate and useful. This will be determined in consultation with the EPM Working Group and with stakeholders. Examples of data sources the EPM program will reference when evaluating indicators include:

a. CAL FIRE Fire and Resource Assessment Program (FRAP);
b. State Water Resources Control Board California Environmental Data Exchange Network (CEDEN; including Surface Water Ambient Monitoring Program [SWAMP] program);
d. Department of Water Resources Open and Transparent Water Data Act (Assembly Bill 1755, Chapter 506, Statues of 2016) data portal;
e. USDA Forest Service Forest Inventory and Analysis Program (FIA);
f. CAL FIRE Watershed Mapper;
g. Department of Fish and Wildlife California Natural Diversity Database (CNDDB);
h. Department of Fish and Wildlife Vegetation Classification and Mapping Program (VegCAMP), Areas of Conservation Emphasis (ACE), and other aquatic and terrestrial data located in Biogeographic Information and Observation System (BIOS);
j. Department of Water Resources State Water Plan (SWP, updated every 5 years).
k. Geospatial landscape-scale indicators for change detection/trend analysis (Landsat data, LiDAR (e.g., GEDI (Global Ecosystem Dynamics Investigation) high

resolution laser ranging of forests), LEMMA (Landscape Ecology, Modeling, Mapping, and Analysis), National Agriculture Imagery Program aerial photos, etc.).

6.2.1.4 Identify Relationships Between Stressors, Target Resources, and Forest Management Programs (Step 5)

As discussed in Section 6.1.2, conceptual models can help provide insights into how forest management activities, restoration and conservation projects, and regulatory programs interact with stressors (biophysical and anthropogenic disturbance factors) and forest resource types. A conceptual model based upon review of existing project and program evaluations of threats to ecosystems can yield a comprehensive/ systemwide model that captures the most common stressors influencing conifer and mixed conifer forest ecosystems in California. Candidate indicators should be evaluated against this model to verify transparently whether and how indicators directly apply to assessment of timberland ecosystems of interest across the state. Commencing a monitoring program with a tight nexus between the disturbances of most concern and landscape features/services of high value to stakeholders will help to ensure limited monitoring and assessment funds focus on priority topics affecting California's timberland ecosystems.

> ***Decision Point***
>
> Consult conceptual model(s) per Section 5.1 to ensure linkages between Ecological Performance Measures (forest ecosystem services and indicators), system stressors, and management activities

6.2.1.5 Evaluate Candidate Indicators Within and Across Forest Management Resource Types and Programs to Determine Most Robust Indicators for Statewide Application (Step 6)

The extent to which indicators apply broadly across biophysical categories throughout the state is important to ensure relevance and applicability of candidate indicators to a program-wide monitoring approach (Baldera et al., 2018). This step involves taking all candidate indicators and evaluating them across programs in California, to determine how often a candidate indicator is applied to conservation, restoration and management activities. Further, the degree to which the indicator is prioritized within programs is also assessed to determine level of relevance.

6.2.1.6 Integration and Recommendations for Final Candidate Indicators (Step 7)

A final step in the indicator screening process is to transparently map out how final candidate indicators align with the programmatic (statewide) conceptual model, demonstrating a robust relationship across biophysical categories and ecosystem services, and in relation to system stressors.

The goal of this process, outlined above, is to gather together a robust suite of highly relevant indicators linked to forest ecosystem services to track efficacy of forest management statutes, regulations, and regulatory programs across the State's coniferous and mixed coniferous forest ecosystems.

6.3 Data Availability and Quality

Once a core group of candidate indicators are identified that best align with EPM Monitoring Program goals and objectives, we will research existing long-term datasets collected by other state agencies and research institutions covering the state to confirm availability of data and quality of the data that best support the indicators of interest. To determine indicator feasibility and find data (either one dataset or several datasets) that can be harmonized across the state through time, we will ask the following types of questions:

1) Is the indicator being monitored throughout the forested watersheds of California?
2) What are the objectives of the monitoring activities?
3) Are the monitoring objectives being achieved and are data being utilized for management/ regulatory purposes?
4) What is the statewide distribution of these monitoring activities? Do various datasets need to be cobbled together across ecoregions in the state?
5) How similar or dissimilar are data collection methods and metrics to indicators of interest? Can discrepancies be overcome?
6) Are monitoring data accessible (e.g., available for analysis) on an ongoing basis?

7) How frequently is this indicator monitored and is this frequency consistent throughout California?

It is not anticipated that new sampling efforts will be developed around an indicator, if the data have not already been collected. However, existing datasets could be modified in the future to better fit/conform to related statewide datasets. It may be possible that in the beginning we utilize data with varying methods/metrics but encourage that work be undertaken to ensure future data collection is consistent statewide.

This brings up an important issue regarding the impacts of possible data bias or monitoring inconsistencies. Given what we already know about inconsistencies across existing datasets in the state (Mazor et al. 2016; Dr. Rich Walker, CAL FIRE FRAP, Santa Rosa, pers. comm.), we are likely to encounter differences in how indicator datasets were collected, such as regional differences in sampling design, scale, etc. (e.g., stand density or basal area can vary greatly depending on if an inventory plot was measured using a fixed area plot or angle-count sampling; Moreno et al. 2016). Such inconsistencies may impact the ability of a given dataset to be used within the statewide program, or will require modifications (statistical or otherwise) to resolve the issue. Whether sufficient samples were collected to support the resolution of analysis (see Sec. 4.1) and the resulting level of confidence we have in the data to quantify changes in metrics will influence our ability to use a dataset (Moreno et al. 2016). Statistical confidence in the data presented for each metric may be impacted by a variety of sources of uncertainty including: measurement error, uncertain or inappropriate use of the sampling frame, sampling error, and process error (Shilling et al. 2014). Descriptions of these types of error are provided below.

- Measurement error — Random or systematic errors introduced during the measurement process, sample handling, recording, sample preparation, sample analysis, data reduction, transmission and storage (Thompson 2002)

- Uncertain/inappropriate interpretation of sampling frame — Errors in inference resulting from opportunistically mining the available data without knowledge of the sampling frame. For example, macroinvertebrate data may have been collected by several different studies with different objectives and target populations (e.g. they could have focused on different stream orders or used differing methodologies; see Danehy and Arismendi 2018). Without this knowledge, we must make assumptions about the probability of selecting each site and the appropriate weighting of the observation.

- Sampling error — The error resulting from only examining a portion of the total population (Thompson 2002), if a census of the population is taken (e.g., school lunch enrollment) then there is no sampling error.

- Process error — Actual variability between spatial or temporal units in the population. This source of variability exists even if a census is taken with no measurement error. This is often referred to as natural variability.

Any of the above sources of uncertainty affect confidence in the metric (indicator) estimates and may reduce the ability to detect trends over time. For some indicators, quantification of different sources of uncertainty in the data may be possible, but in many cases, there are limitations to providing a qualitative description of the likely sources of error and associated magnitude. Reporting confidence, certainty, and/or variance is important to building trust in the use of indicators by stakeholders.

These types of considerations are highly complex, and the discussion here has only provided a limited indication of the issues that the California Natural Resources Agency and collaborators will need to address.

It is possible to use advanced technologies to generate new datasets using (for example) a remote sensing component, with limited field data collection (Slesak et al. 2018). Creative solutions when data do not exist or if data do not adequately support the study design, include such products as the Oregon State University Landscape Ecology, Modelling, Mapping and Analysis (LEMMA) group’s Forest Biomass Mapping product to monitor forest carbon and biomass dynamics (CMONster project) in California and western Oregon. Their system leverages USDA Forest Service Forest Inventory and Analysis (FIA) data and Landsat imagery. Specifically, this project incorporates satellite imagery from multiple Landsat missions (Landsat 5, 7, and 8) and 16 years of FIA plot data to understand the patterns, causes, and consequences of biomass stock status and change, especially as it relates to forest disturbances (e.g., drought-induced mortality, wildfire, etc.). Additionally, this work studies uncertainties in resulting forest biomass maps to inform their use by land managers, policy makers, and scientists. Another approach employed to monitor forested ecosystems at the watershed scale in Minnesota, relied heavily on the use of timber harvesting BMP (best management practices) implementation data and remotely sensed watershed characteristics and forest disturbance metrics to uncover forest management impacts on watersheds (Slesak et al. 2018). Technological approaches such as these may support questions (or fill in the gaps) in areas where FIA or other types of data were not collected, particularly an issue on private land in California where significant timberland acreage is located.

7.0 Methodology- Assessment

7.1 Data Harmonization- Spatial and Temporal Scale in Monitoring

The scope of the statewide EPM Program lies above project-level timberland monitoring efforts (e.g., Timber Harvesting Plan, THP), and is planned to be reported on a regional basis, preferably nested below broader statewide-level assessments such as provided by the FRAP assessment produced approximately every five years (see Fig. 2). To uncover spatially-based information that allows us to understand the status and trends of ecological conditions in timberlands, we believe monitoring at the regional scale may yield sufficiently detailed information to support our study of the efficacy of statewide programs and regulatory requirements. Commonly used scales for statewide monitoring programs lie between the hydrologic unit code (HUC) scales of 8-10 (Slesak et al 2018). A HUC is a representation of part or all of a surface drainage basin (watershed). The HUC 8 scale averages approximately 800,000 acres per unit (Fig. 11) and a HUC 10 scale averages approximately 100,000 acres per unit (Fig. 11). However, settling on spatial scale and corresponding resolution of datasets are not foregone conclusions, as there is much to consider when determining spatial scale in a large-scale monitoring program when bringing together statewide datasets. Here, we cover just a few of the numerous considerations on this topic that the EPM Working Group and stakeholders will need to discuss in forthcoming meetings.

The scale at which indicators are reported, or at which data are collected, depends on the type of understanding needed. For example, abundance of a species might naturally vary widely over an entire region, but may be homogeneous over smaller areas. In the latter case, the indicator's importance is diluted and less useful. The present EPM Monitoring Program across California's timberlands requires spatially-explicit gridded data (rasterized, evenly spaced cells where data are presented) that can describe the characteristics and conditions of these forest ecosystems at scale. Such data require integrating terrestrial and remotely sensed data which must be derived using one level of resolution to make the data set consistent (Moreno et al. 2016). Therefore, optimal grouping across indicators is needed to link datasets from throughout the state to support a regionalized approach to a statewide analysis of timberland management and forest ecosystem conditions. A challenge is that indicator data applied at the state level are intended to be broad and cover differing conditions (e.g., coastal and inland areas; mountains and valleys; differing latitudes), while indicator data applied at a watershed level yield metrics aligned to a specific area. In both cases we confront spatial and temporal scales which may or may not be the same, and may not directly translate to the statewide study we are undertaking. Some indicators may have to be eliminated if they cannot scale up to fit a statewide analysis.

Methods will need to be developed through the EPM development process to harmonize all relevant indicator datasets to a common temporal and spatial scale in order to allow data aggregation within and between indicators. For common reporting on the state of forest ecosystems in California, a challenge will be to find a common, correct resolution to aggregate indicator data to, without over smoothing of the data (Moreno et al. 2016). A risk is that assessments that have been optimized at the state and regional level may hide substantial variability that is present in the datasets when viewed at finer resolutions. A possible way to overcome this issue, while still achieving a statewide analysis, is to consider breaking up the analysis at the regional level, and/or breaking up the study areas based on larger ecoregional areas (e.g., Sierra Nevada Range, Northern California Coast) to help preserve the integrity of the datasets but ensure statewide, consistent monitoring. An approach suggested by the USDA in partnership with The Nature Conservancy within their Landscape Toolbox, Tools and Methods for Effective Land Health Monitoring, is to use stratified groupings to resolve data issues across large, diverse landscapes. They suggest that accuracy and precision of a monitoring program can be improved by dividing study areas into uniform units for monitoring, called strata, based on similarities such as vegetation, soil type, management units, land use, etc. Given a set of common classifications, indicators are expected to respond similarly to changes in management and to catastrophic disturbances, such as a combination of drought and fire, thereby making them better points of comparison in a highly variable landscape.

Regarding matters more specific to temporal scale, frequency of monitoring of an indicator may vary through time (e.g., stream gauge data collected during rainy season versus during dry season). This can be true within one indicator metric or across indicator metrics. Setting a common temporal resolution within and across indicators will be challenged by the importance of reporting these differences and settling on a scale that is most representative of realities on the ground. Another matter to consider is that depending on the temporal resolution that was selected for a given indicator, and the varying forest management practices or system stressors that may have been introduced during the monitoring interval, important effects of management may be masked or diluted by a metric that is based on averages over a long period of time (Safford and Van der Water 2014). Alternatively, given slow changes that may occur after a treatment such as restoration, or the onset of drought, the ecosystem may take considerable time to respond and more frequent observations may not readily reveal the implications of management in ecosystem response; i.e., there is a latency to the indicator response (Royal Academy of Sciences 2017). This may confound our ability to link change to a policy or management action that has occurred on the landscape and is a matter to track as indicator metrics are analyzed to ascertain trends and signals for a given ecosystem service.

The most limiting, or “coarsest,” indicator based on its spatial or temporal resolution (the largest spatial resolution among the indicators, or the least frequently collected dataset among the indicators, respectively) will likely determine the scale that all indicator metrics must aggregate towards for a full statewide assessment of California forests that considers all indicators for analysis. This limitation impacts the collective resolution of analysis, what indicators are ultimately included, and the frequency with which assessments and reporting may be accomplished. More frequent reporting of indicator metrics may be possible for subsets of indicators using a finer resolution, as needed or desired by stakeholders.

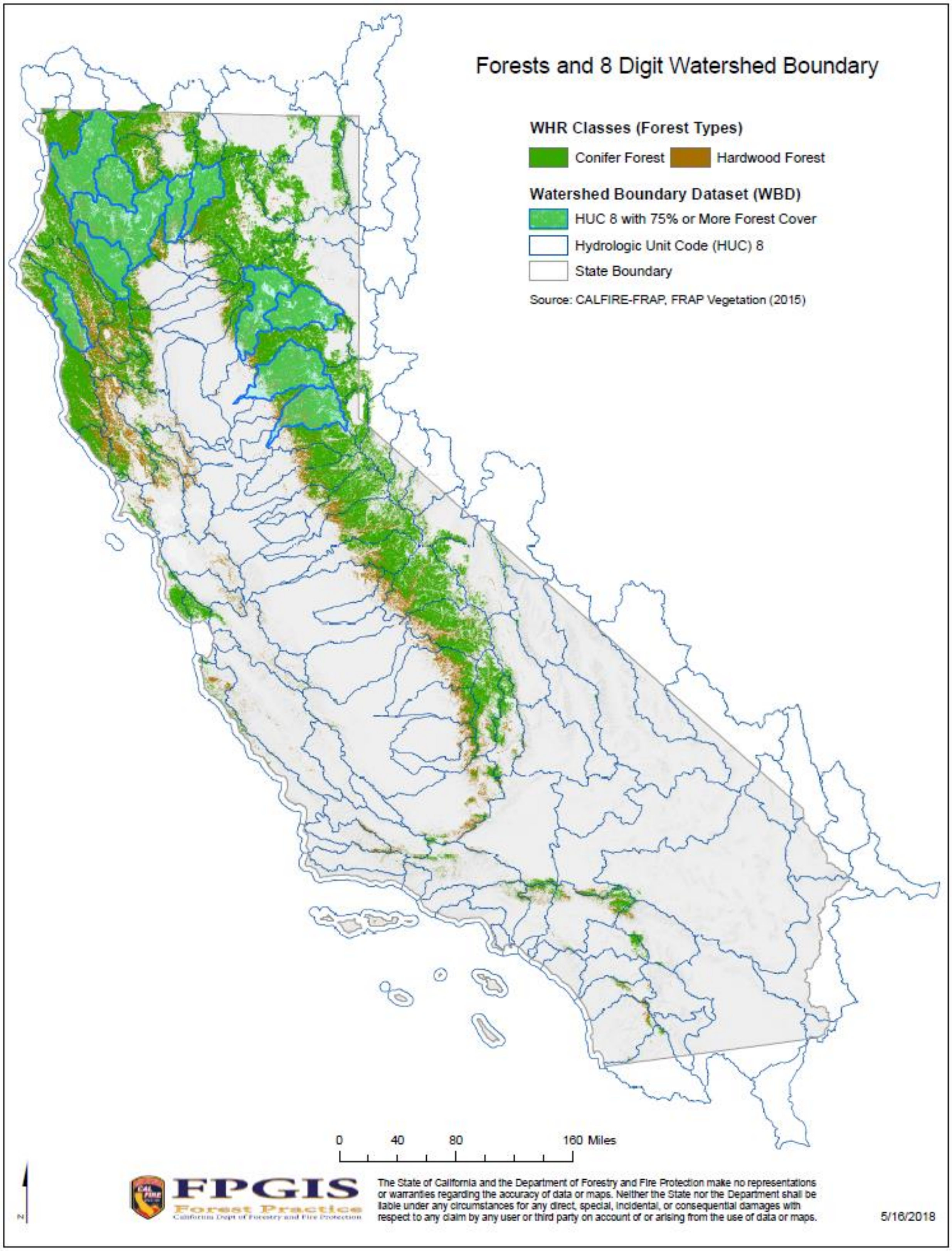

Fig. 11. HUC 8 watersheds with at least 75% or more forest cover in California. There are 142 HUC 8 watersheds in the state, with an average size of 877,752 acres or 1,300 square miles (36 mi x 36 mi; CAL FIRE).

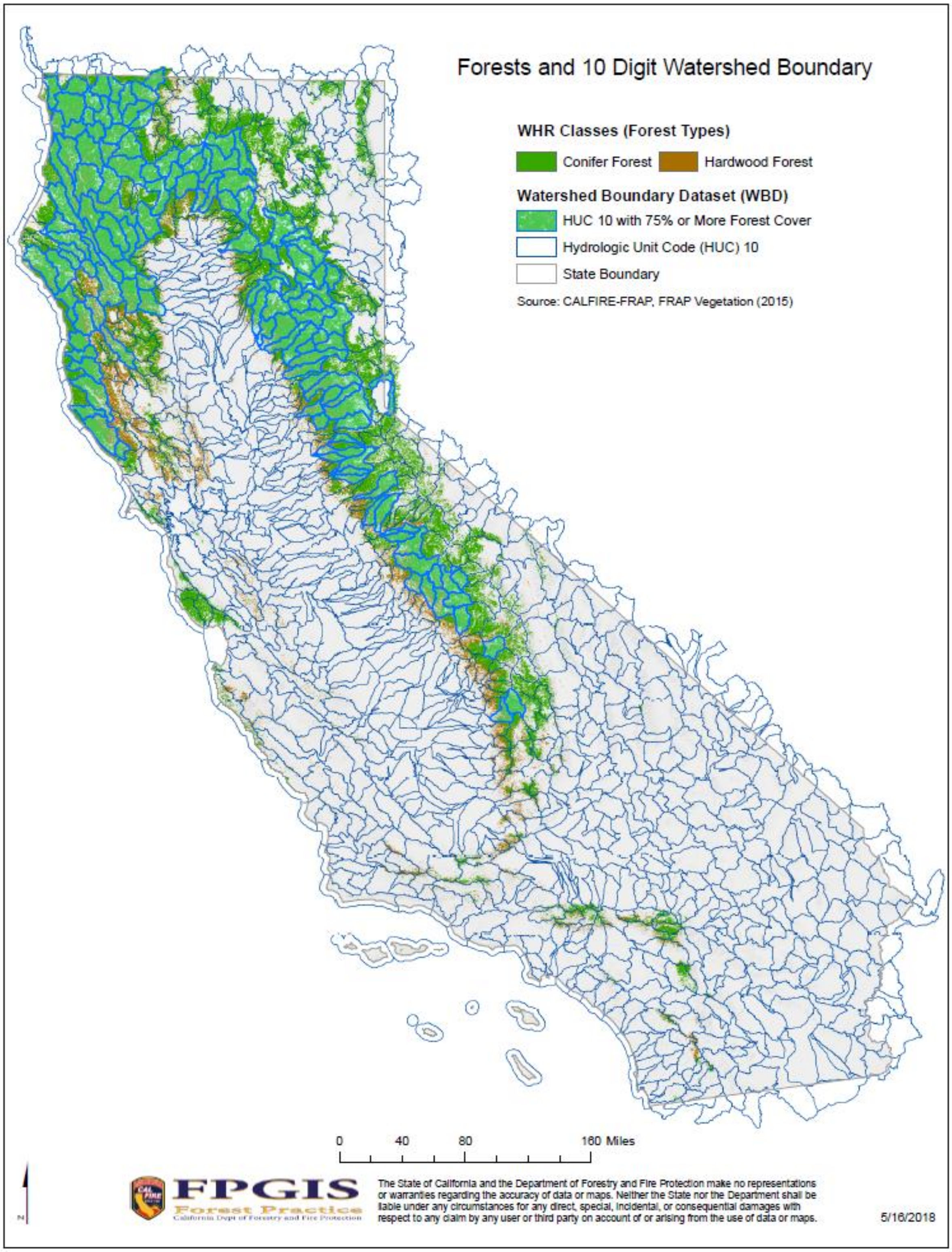

Fig. 12. HUC 10 watersheds with at least 75% or more forest cover in California There are 1,038 HUC 10 watersheds in the state, with an average size of 108,653 acres or 169 square miles (13 mi x 13 mi; CAL FIRE).

7.2 Range of Variation of Indicators and Consideration of Baseline, Historical and Reference Conditions

Ecological Performance Measures (EPMs) are useful for evaluating the distance from and progress toward a desired condition for a given ecosystem service and associated indicators to answer the question: Are ecosystem services being delivered acceptably in the eyes of the public and based upon scientifically credible evidence? In a state as large and geomorphically diverse as California (CGS 2002), we know and expect monitoring data for a given indicator will vary widely across the state, as ecological conditions vary significantly. In an example provided by Safford and Van de Water (2014), the Sierra Nevada span approximately 435 miles (700 km) north to south and there is significant variation in precipitation and temperature, forest structure and composition, tree densities and canopy cover, etc. Such gradients can have major effects on indicator performance, like fire return interval departure. In order to analyze an indicator's performance in the face of such landscape variability when carrying out statewide assessments, it is necessary to have a grasp of an indicator's expected performance (metrics) if consideration is given to what conditions would occur without human management interventions and activities (factoring in environmental constraints such as soil, altitudinal gradient, etc.) in a location. In this way, it is more likely to reduce the "noise" in the data and tease out the signals in the data that are most likely linked to a management actions or regulatory programs affecting timberlands.

KEY DEFINITIONS

Range of Variation refers to the range of conditions a given indicator (metric) may experience under naturally occurring circumstances, usually defined based upon known "historical conditions" that have been observed in the past, and not typically registered under extreme events such as catastrophic fire or the like which would significantly skew indicator metric response.

Historical conditions reference the range of variation associated with an ecological process or feature given change over time and space for (an) associated ecological variable(s), based upon past information collected for the variable(s) in all the locations it (they) occur(s). For example, known range of conditions for water temperature and quality, vegetation, latitude, etc. associated with steelhead habitat may collectively help us understand likelihood of species presence /absence and population distribution.

Initial Conditions refer to a measurement taken at or immediately before the commencement of a monitoring program, against which, trends and signals from indicator metrics are evaluated (not all indicators can benefit from this; such as measuring Net Primary Productivity which varies as a forest ages).

Reference Conditions, much like a control site in an experiment, refer to sites or areas that are physically and biologically similar to an area that has undergone management, but that is not receiving or subject to the same management.

The concept of "**range of variation**" is widely debated as scientists seek to understand what conditions are expected when evaluating indicators versus what is actually observed. In order to define range of variation for a given indicator we often look at **historical conditions** for ecological processes. Once an indicator's **initial condition** is registered at the start of a monitoring program, it is considered against its historic conditions or a given range of variation. Yet, there are many issues with using historic conditions to evaluate whether an indicator is within its range of variation. One of the biggest problems is that in order to have a range that accurately reflects the system, long-term datasets are needed. While there may be long-term data available for some indicators (such as the Forest Inventory and Analysis (FIA) data), for many indicators of interest there is insufficient temporal and spatial information for this approach to be useful. Historical information may be assembled in some cases using data that have been collected in past decades or centuries for a given ecological variable (e.g. satellite data, or using land survey data where forest structure data were incidentally collected in the past century). Alternatively, if historical information is limited or unavailable, targets can be set for desired conditions working closely with subject matter experts and by using **reference condition** information collected in least-managed forested ecosystems as a point of comparison.

Relying on historical conditions to inform our understanding of the range of variation as the bases of Ecological Performance Measures may assume that past and future conditions are similar. In the case of increased climate uncertainty, it is unlikely that this is the case. For instance, climatic variability in some parts of the state may increase, in other areas they may decrease, while in other parts of the state departure from historic conditions may be relatively low. In addition, the rates and magnitude of change likely will vary among different locations and forest types. Predicted climate change effects for different forest types should be considered when using the concept of range of variation (Thorne et al. 2016). For areas with changing climate, comparing initial conditions to historical conditions, or to a range of variation based on a past climate, may not be useful unless those effects can be readily addressed. It may be the case that despite appropriate management practices, historical conditions cannot be attained. Similarly, landscapes that have been heavily modified for human use are unlikely to return to their historical condition. Given this confounding uncertainty, in the case of some indicators, it may be necessary to rely on expert opinion of scientists to assemble a scientific case for the range of variation we will use to compare indicator conditions against, so that we can make better informed decisions on resource condition and trends.

Because of changing environmental baselines, historical conditions against which indicators can be evaluated may no longer be a sustainable long-term management goal (Safford and Van de Water 2014). We will need to cautiously evaluate how such factors as climate change will affect our assessment of indicator data going forward. Finally, it is noted that we may not be able to meaningfully define a range of variation or historical conditions for all indicators. In some cases, we may only be able to evaluate whether the trend of an indicator is moving in a desirable or undesirable direction.

In any case, a transparent discussion of uncertainty underlying assessment of the data must be disclosed as a part of this process so that stakeholders and decision makers are able to understand the state of the evidence when considering management action or further study that may be needed to support management and decisions.

7.3 Data Aggregation and Interpretation Within and Across Indicators

To assess timberland ecosystem condition and evaluate forest management, the task of aggregating indicator datasets and aggregating datasets across indicators on a regional basis is not trivial. Many considerations will need to be discussed in the EPM Working Group to address factors such as sampling bias, disparities in sample size, confidence in datasets, and confounding factors that may also be influencing monitoring results (e.g., large fire event, climate change, etc.), to name a few. Ultimately all indicator data will need to be aggregated into a multi-metric index that brings all indicators/metrics into a single measure of biological or abiotic condition for any given ecosystem service.

A common system of indicator scoring is needed to resolve issues of individual metrics having different scales and different responses to stress, with variation across regions. Given differing levels of human activity, or differing latitudinal or altitudinal factors, some metrics decrease while others increase (Mazor et al. 2016; Safford and Van der Water 2014). As an example, if for a given indicator, marginal site conditions exist (due to inherently natural conditions such as slopes, soil conditions, etc.), we would not expect an indicator to score very well, but that does not necessarily imply poor management is occurring. Some indicators will perform poorly in locations hampered by naturally occurring, limiting biotic or abiotic factors, while in other locations indicators may be performing well under ideal biotic and abiotic circumstances (refer to Sec. 7.2, natural range of variation). To mediate this situation, a scoring system can help transform metrics to a standard scale range, also referred to as normalization. For example, assigning a range from 0 (i.e., indicator in worst state) to 1 (i.e., indicator in best possible state), within which context can be better integrated into individual indicator results.

To put EPM monitoring results into context, environmental data are needed from multiple sources to characterize natural and anthropogenic factors known to affect indicator conditions such as climate, elevation, geology, land cover, road density, hydrologic alteration, and known management types/units (e.g., timber conversion, conservation, restoration, etc. using satellite imagery and data from programs such as CAL FIRE's Forest Practice Watershed Mapper). Reflecting on the observed versus expected range of variation for a given indicator (see section 7.2), and using the previously mentioned environmental data as context, we will attempt to deconstruct the driving factors that may be leading to indicator results in a region, and help inform adaptive management decision making. The aim is to work to understand how forest management may be impacting trajectories/trends of EPMs. There are many confounding factors that may influence indicator monitoring results (e.g., climate change or other stressors), which underscores the need to know the underlying land use and management activities. This information will allow us to compare those factors with indicator response in reference forests, where presumably similar climactic and environmental stressors influence the landscape.

As all indicator metrics are evaluated and aggregated for a given ecosystem service, we can begin to assess the status of an ecosystem service of interest (e.g. water quality or supply, wildlife habitat). Considering all ecosystem services together, we can develop a causal assessment of timberlands across California, on a regional basis, to link condition with causal stressors to evaluate regulatory program performance. In areas where indicators are outside their natural range of variation or where indicator data is suboptimal, it may be advisable to add additional monitoring activities such as increased remote sensing inquiries or field studies to try to isolate the factors (land use or otherwise) that are contributing to abnormal or unexpected results. Focused LiDAR surveys may be called for to support this analysis.

In terms of conveying results, it is important to provide detailed reporting of monitoring results rather than generalizing datasets and ensure the ability to spatially display monitoring results across the state. Indicator data are best conveyed using numerical/continuous data reporting, rather than exclusively categorical (green-yellow-red, “thumbs up” or “thumbs down”) reporting (Safford and Van der Water 2014). Doing so allows analysis of environmental conditions within and between HUCs and the ability to compare spatially variable results. For example, many management questions will require spatial information to better understand questions like edge effects, habitat connectivity, hydrologic change, fire resistance, timber value, etc.

7.4 Reporting Assessment Results

Timely reporting of monitoring information will be of utmost importance. Depending on the temporal scale that is selected for a statewide, consistent EPM monitoring program (Section 6.1), it may be possible to release assessment results on an approximately five to ten year basis. This is because the most limiting indicator (the coarsest temporal scale) will limit the entire grouping of indicators and collective analysis; which is a consideration when selecting the most appropriate indicators to meet the needs of this study. That said, more frequent reporting on monitoring results for other indicators may be possible to achieve and will be discussed with the broader EPM working group and stakeholders during the indicator screening and early assessment process. Landscape-level changes and the results of monitoring are not likely to be realized during one-year periods, as trends are usually discernible only after several years. The EPM program may elect to carry out variable reporting intervals to accommodate more urgent assessment needs (as data support) and only present a full assessment after the 5 or 10-year period concludes (from the start of monitoring for the collective grouping of indicators until the most limiting indicator data has been collected). The important theme is that we will need sufficient detection of trend data accumulated to be able to inform adaptive management decisions.

Irrespective of the monitoring and assessment intervals that are adopted, analyzed information, with recommendations for management action, will be reported regularly. The assessment report will present content including:

- Management questions being addressed;
- Monitoring report summaries;
- Spatially explicit maps with monitoring results and scores displayed;
- Assessment of management context and implications within and across indicators to track efficacy of forest management strategies; and
- Suggestions for adaptive management policy, changes to biological or habitat goals, or updates to monitoring activities.

These reports may also describe actions that are about to be undertaken by California agencies (CNRA and others) in the upcoming reporting period.

The Timber Regulation and Forest Restoration Program will report on its EPM monitoring processes and results in its annual report to the Legislature. Further, the program will provide reports to the Board of Forestry and Fire Protection. Special project reports that stand alone as individual studies or technical papers may also be available, and monitoring program updates and project descriptions will be available on the California Natural Resources Agency website. As the monitoring program develops, reporting mechanisms will be refined and improved.

7.5 Coordination with other Programs

Given increased monitoring activities occurring within state, federal, and nongovernmental organizations in California, coordinated efforts are critical to the success of the EPM Program. Aforementioned monitoring programs including the State Water Plan (Department of Water Resources), the Fire Resource and Assessment Program (CAL FIRE, Water Quality Control Plans and related Surface Water Ambient Monitoring Program (SWAMP; State Water Resources Control Board), National Forest Management Plans (USDA Forest Service), and regional groups such as the Tahoe-Central Sierra Initiative (TCSI), will be consulted during development of the present program. Further, there may be potential for the EPM program to support the work of the Forest Management Task Force (Governor's Office of Planning and Research) towards developing a common set of indicators to track the efficacy of statewide forest management and restoration programs.

The Timber Regulation and Forest Restoration Program also will look for opportunities to connect its EPM work with (1) existing monitoring occurring on private land; (2) the efforts of the Board of Forestry and Fire Protection's Effectiveness Monitoring Committee to evaluate the Forest Practice Rules and related timber harvesting regulations, and (3) other interagency efforts to monitor the implementation and effectiveness of the Forest Practice Rules at the level of individual THPs and Exemption and Emergency Notices.

Cooperation and exchange of information among programs will allow for a more extensive exploration of the effects of the landscape management objectives and generation of recommendations for adapting management or monitoring activities. Other forms of anticipated coordination include participation in multi-agency monitoring committees; contact, planning, and coordination with watershed councils; review, application, or modification of existing protocols; joint development of protocols with landowners, stakeholders, and other agencies; and data sharing.

7.6 Opportunities for Public Involvement

The purpose of public involvement in the development and implementation of the EPMs is to improve the quality and effectiveness of the implementation process by providing stakeholders with a variety of opportunities to provide input into decisions about EPMs, and to seek informed consent among stakeholders. Specifically, for the EPM program, we will provide the public the opportunity to comment on this White Paper, the planning and prioritization of research and monitoring activities, including weighing in on the suggested methodology and the adjustment or refinement of the methodological steps that were covered in this document. The EPM program's plan for public involvement provides opportunities for ongoing and regular review and comment through the process of developing EPMs. The EPM program will also provide information to the public about the EPM program and the activities associated with implementation of the monitoring program, including through the reporting processes described in the above section.

7.7 Staffing and Preliminary Schedule for Ecological Performance Measures Monitoring and Assessment Program

Currently there is only one dedicated staff person from the Timber Regulation and Forest Restoration Program, located at CNRA, assigned to developing the EPM program. As needed and available, other staff (most likely supported by AB 1492 funds) will be brought into the process at the appropriate time. Further staffing needs, as identified by the EPM Working Group, will be determined and additional funding may be sought through the usual State budget processes to support the ongoing work of the EPM program. While the program timetable has yet to be fully developed, foreseeable next steps through December of 2019 have been approximated below in Table 5.

Table 5. AB 1492 EPM Program Phases: October 2018-December 2019.

October 2018 – January 2019 Develop EPM Methods	White Paper review by WG and stakeholders (workshop). Assemble all input and finalize methodology for EPM development process.
January 2019 - April 2019 Working Group and Public Screening of EPMs	Commence EPM selection screening in consultation with EPM WG. Stakeholder workshop to solicit input on EPM screening results (candidate indicators). By April select final candidate EPMs for further analysis.
April – June 2019 EPM Data Availability Evaluation	Work through EPM data availability and technical challenges in consultation with WG. Develop recommended final eligible (feasible) EPMs for monitoring and assessment.
June 2019 Final EPM Selection	Present draft final EPMs to stakeholders (workshop)
June- December 2019 Next Steps of Data Gathering, Processing, etc.	Commence technical steps of accessing and processing data, etc. Begin to refine plan for Assessment stage of EPM program.

8.0 Conclusion

The task to develop an EPM monitoring and assessment program to meet the needs of AB 1492 is far from simple, and next steps in elaborating on the proposed methodology will necessarily be iterative and require flexibility. This White Paper presents a proposed path forward, meant to stimulate discussion on the opportunities and challenges of effectuating the program given the complexity of the questions that need to be answered, and the great diversity presented by California's timberland ecosystems.

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