Mokelumne Amador Calaveras Forest Resilience Project (MAC) Monitoring Plan



USDA United States Department of Agriculture

Upper Mokelumne River Watershed Authority

Amador-Calaveras Consensus Group

Acknowledgements

The development of the MAC Monitoring Plan began in conjunction with the development of the MAC Forest Health and Resilience Project. The MAC Monitoring Plan will track outcomes associated with project implementation. The Monitoring Plan will focus on evaluating whether actions were implemented as intended and whether actions were effective in accomplishing the intended outcomes. The MAC Monitoring Plan was partially funded by the Sierra Nevada Conservancy (SNC) Regional Forest and Fire Capacity Program and through the expertise of numerous organizations represented in the Amador Calaveras Consensus Group (ACCG) Monitoring Workgroup, Upper Mokelumne River Watershed Authority (UMRWA), USDA Forest Service and many other contributing entities

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Cover photo: Photo taken by Stanislaus National Forest staff from an active managed fire burning at low intensity in a mixed conifer forest.

Table of Contents

Section 1: Monitoring Plan Background 6
1.1 Ecological and Socioeconomic Context of MAC Project 6
1.2 MAC Project Purpose and Background 7
1.3 Monitoring Plan Background and Purpose 8
1.4 Adaptative Management 11
1.4 Report Frequency ..... **Error! Bookmark not defined.**
1.5 Summary of the MAC Monitoring Plan ..... **Error! Bookmark not defined.**
Section 2. Monitoring Goals, Guiding Questions, Indicators, Rationale and Desired Conditions 13
2.1 Implementation Monitoring 13
Guiding Question 1: What percentage of the WUI surrounding at-risk communities have received wildfire mitigation treatments? 13
Guiding Question 2: How many miles of vegetation along ingress and egress routes have been maintained to provide safe escape? 14
Guiding Question 3: Are project design features and mitigations implemented correctly to protect target wildlife species and plant communities? 15
Guiding Question 4: Are project Best Management Practices (BMPs) designed to protect beneficial uses of water being implemented as planned? Are implemented BMPs effective in protecting beneficial uses of water? 17
Guiding Question 5: What acreage has been treated with prescribed fire or wildfire managed for resource benefit? 18
2.2 Social and Economic Monitoring 19
Guiding Question 6: How many local (Amador, Calaveras, Alpine, Tuolumne, El Dorado Counties) jobs (including contracts) have been created or maintained through restoration and management activities? 19
Guiding Question 7: What volume of forest products (e.g., timber, biomass) has been sustainably harvested from restoration areas in the last 12 months? 20
2.3 Effectiveness Monitoring 21
Guiding Question 8: Are shaded fuelbreaks being created and properly maintained to meet fire management objectives? 21
Guiding Question 9: Has there been a measurable reduction in the risks of wildfire to at-risk communities (WUI) following treatments? 23

DRAFT

Guiding Question 10: Has there been a measurable reduction in the risks of wildfire to vegetation community types in the general forest? 26
Guiding Question 11: Have treated areas seen a measurable reduction in fuel loading (e.g., tons per acre, tree density) that has facilitated the use of prescribed fire? 31
Guiding Question 12: Has the density, composition and structure of forest vegetation been maintained or improved to increase resilience to human and natural disturbances (e.g., wildfire, drought)? 34
Guiding Question 13: Have treated areas experienced fewer large-scale disturbances (e.g., wildfire, insect outbreaks) compared to untreated areas over the project implementation period? 44
Guiding Question 14: How do treatments affect terrestrial and aquatic wildlife species populations? 49
Guiding Question 15: How do treatments affect the habitat quality for terrestrial and aquatic wildlife species in treated areas? 50
Guiding Question 16: How did treatments affect the occurrence of Threatened and Endangered, Rare or other identified Forest Service Sensitive plants? 57
Guiding Question 17: How did treatments affect the occurrence of special terrestrial plant communities? 59
Guiding Question 18: Are project activities introducing and/or spreading invasive plants? 59
Guiding Question 19: Are we meeting treatment objectives for targeted invasive species infestations (i.e. eradication vs. control)? 61
Guiding Question 20: Are we making progress removing priority invasive infestations over the long term? 62
2.4 Cultural Monitoring 64
Section 3. Implementation & Field Monitoring Plan 66
3.1 Solution: Field-Based Geospatial Technology 66
Implementation Examples 67
Field Maps: Treatment Progress Tracking 67
Survey123: Long-Term Forest Trends Monitoring 67
Survey123: BMP Inspection Reports 68
3.2 MAC Monitoring Questions: Tool Summary 68
3.3 Custom HTML Dashboard 70
3.4 Monitoring Plan for Vegetation Data Collection 71
3.5 Monitoring Plot Selection Tool 72
3.6 Conclusion 75

DRAFT

Section 4. Funding 75
4.1 Background 75
4.2 Past Monitoring Funding Models 75
4.3 Proposed MAC Monitoring Funding Approach 76
4.4 MAC Monitoring Costs & Prioritization 76
4.5 MAC Monitoring Implementation Prioritization Strategy: Modules 76
Section 5. Literature Cited 85
Section 6. Additional Appendices 86

DRAFT

Section 1: Monitoring Plan Background

1.1 Ecological and Socioeconomic Context of MAC Project

The Mokelumne Amador Calaveras Forest Health and Resilience Project (MAC) is a collaborative project designed to support the creation of healthy forests and watersheds, fire-safe communities and sustainable local economies (USDA Forest Service 2026). The watersheds in the MAC project area has numerous forest and shrub vegetation types including unique habitats such as meadows and aspen. These forests provide habitat for state and federal threatened, endangered, candidate and sensitive wildlife, including the valley elderberry longhorn beetle, California red-legged frog, Sierra Nevada yellow-legged frog, foothill yellow-legged frog, Yosemite toad, California spotted owl, American marten and willow flycatcher among many more species. In addition, the watershed provides municipal water for more than 1.4 million East Bay area residents (Buckley et al. 2014, Elliot et al. 2016). The restoration of these watersheds would ensure the persistence of viable forests and water for the wildlife and residents within the project area.

In the MAC footprint, frequent fire was common prior to Euromerican settlement. According to the Fire Return Interval Departure database maintained by the US Forest Service Region 5, 65% of the area would have on average experienced fire every 11-20 years, 31% of the area would have experienced fire every 25-50 years, 2% of the area would experience fire every 51-100 years and less than 2% of the area would have experienced infrequent fire at a length of 150 years or longer (Safford and Van de Water 2014). Eighty-one percent of the area is characterized as extremely departed (>66%) from historic fire regimes with fires occurring less frequently than pre-Euromerican settlement. This departure coupled with past management has led to a shift in tree species composition, increase in tree density and a notable increase in high severity fire (Safford and Stevens 2017). These changes have necessitated critical restoration needs to ensure the resilience of these forested systems.

In addition to ecological needs, the watersheds are also critical to the cultural and socioeconomic success of the thousands of residents who reside in the Wildland Urban Interface (WUI) in the MAC project area. Many of these residents are tied to the local industries that arise from the management of natural resources. Consequently, the ACCG's guiding principles which overshadow the MAC project recognize that an All-Lands forest strategy must be grounded in locally based economic activity, local markets, and local jobs that can be sustained for years to come.

The development of the MAC Monitoring Plan began in conjunction with the development of the MAC Forest Health and Resilience Project. The MAC Monitoring Plan would track outcomes associated with project implementation. The Monitoring Plan would focus on evaluating

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whether actions were implemented as intended and whether actions were effective in accomplishing the intended outcomes. The MAC Monitoring Plan was partially funded by the Sierra Nevada Conservancy (SNC) Regional Forest and Fire Capacity Program and through the expertise of numerous organizations represented in the Amador Calaveras Consensus Group (ACCG) Monitoring Workgroup, Upper Mokelumne River Watershed Authority (UMRWA), USDA Forest Service and many other contributing entities.

1.2 MAC Project Purpose and Background

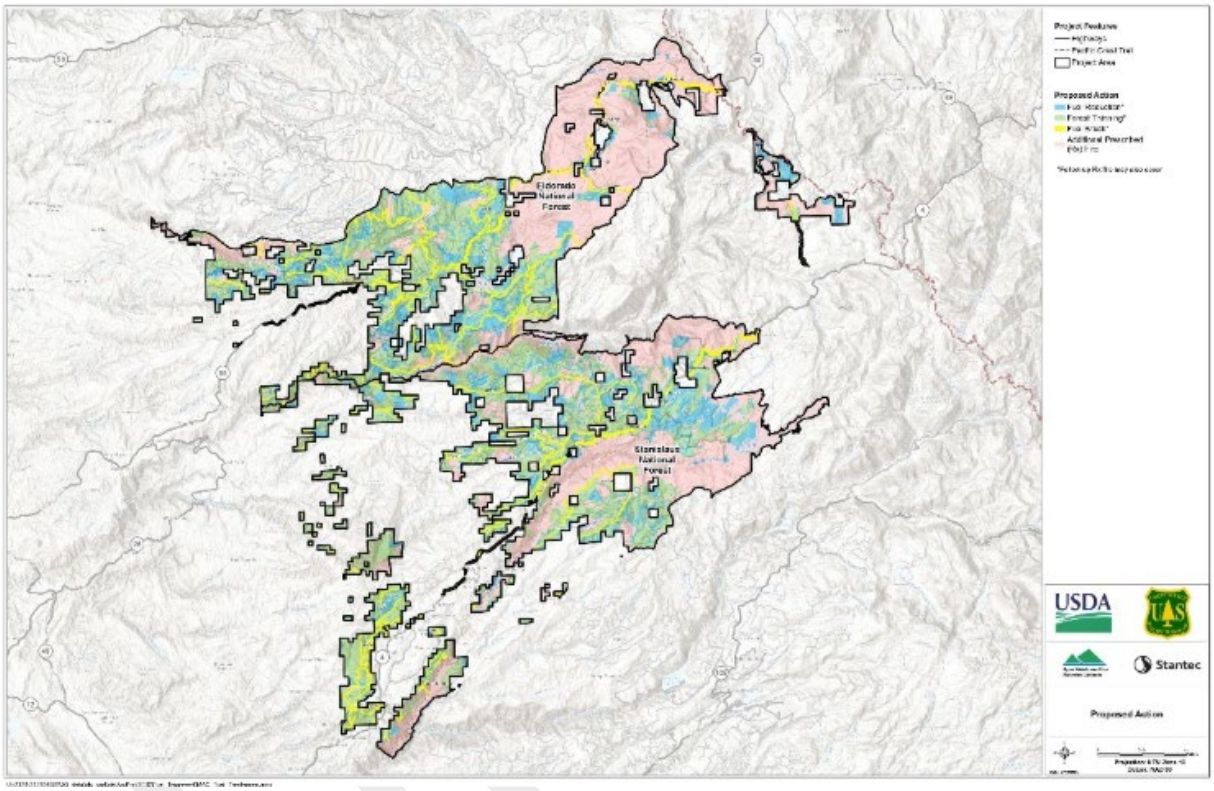


Figure 1. The MAC Project Area. The map shows different types of proposed treatments.

The Mokelumne Amador Calaveras (MAC) Forest Health and Resilience Project spans approximately 246,751 acres of National Forest System lands on the Eldorado and Stanislaus National Forests. UMRWA, a joint powers authority of six water agencies and three counties, serves as the primary non-federal partner under a master stewardship agreement with the USDA Forest Service (Figure 1).

The MAC Project is located entirely on National Forest System (NFS) lands managed by the Amador Ranger District of the Eldorado National Forest (ENF) and the Calaveras Ranger District of the Stanislaus National Forest (STF). The MAC Project area encompasses approximately 246,751 acres, comprising 120,577 acres on lands managed by the ENF and 126,175 acres on lands managed by the STF. The MAC Project area spans five counties: Alpine, Amador,

Calaveras, El Dorado, and Tuolumne. Major state highways that bisect the MAC Project area include California State Highway 88 and California State Highway 4. The MAC Project area spans elevations from 1,250 feet along the western portion and in river canyons to approximately 9,700 feet at the eastern portion in the high Sierra Nevada.

The MAC project aims to restore ecosystem health and resilience to wildfire, insects and disease, and drought through forest thinning, fuels reduction, fuelbreak construction and maintenance, prescribed fire, targeted grazing, and invasive plant control. With approximately 111,226 acres in the WUI, 21,987 acres proposed fuelbreak treatments, and 242,006 acres proposed for prescribed fire, the scale of implementation requires robust systems for tracking progress and verifying effectiveness.

1.3 Monitoring Plan Background and Purpose

The MAC Monitoring Plan was preceded by the Cornerstone Collaborative Forest Landscape (CFLR) project that covered a portion of this landscape and was awarded in February 2012 and concluded in February of 2022. One of the requirements under the CFLR was to conduct ecological, economic and social monitoring to document the implementation and effectiveness of restoration treatments. To create this monitoring strategy, the ACCG along with the ENF and STF created a ACCG Monitoring Workgroup (MWG) that developed the Cornerstone Collaborative Forest Landscape Restoration Project Monitoring Strategy (2016). The MWG has continued to be active in leading monitoring efforts across the landscape and has formed the basis for the team assembled to create the MAC Monitoring Plan. The development of the MAC Monitoring Plan will follow the USDA California Climate Hub Monitoring Workbook which was developed in partnership with SNC (Figure 2). This process details a step-by-step process to develop a Monitoring Plan that will provide a comprehensive approach to how monitoring will be conducted and summarized throughout the life of the project.

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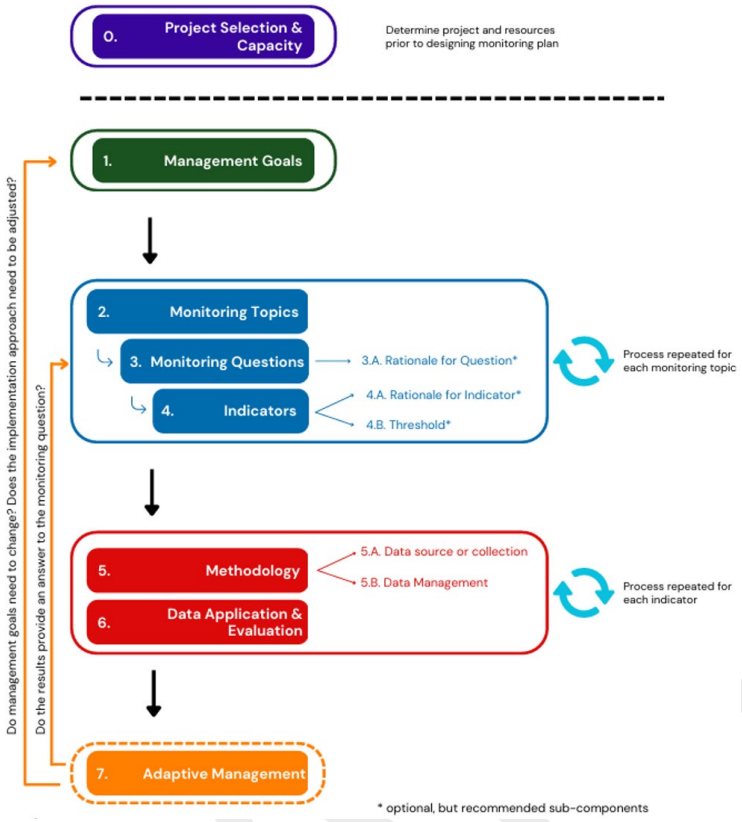


Figure 2. The process used to create the MAC monitoring plan (USDA CA Climate Hub Monitoring Workbook 2026).

Monitoring Plan Purpose

As MAC moves forward with project implementation, a Monitoring Plan is essential to tracks change over time to measure treatment effectiveness and tracking of socioeconomic and cultural benefits. This helps assess whether the project is meeting the MAC goals to restore ecosystem health and resilience to wildfire, insect and disease, and drought through forest thinning, fuels reduction and related watershed improvement actions, and socioeconomic and cultural objectives of the project. The MAC Monitoring Plan has a strong relationship with Forest Service Strategic and state monitoring programs and guidance (Figure 3). These programs provide a critical foundation for the MAC Monitoring Plan.

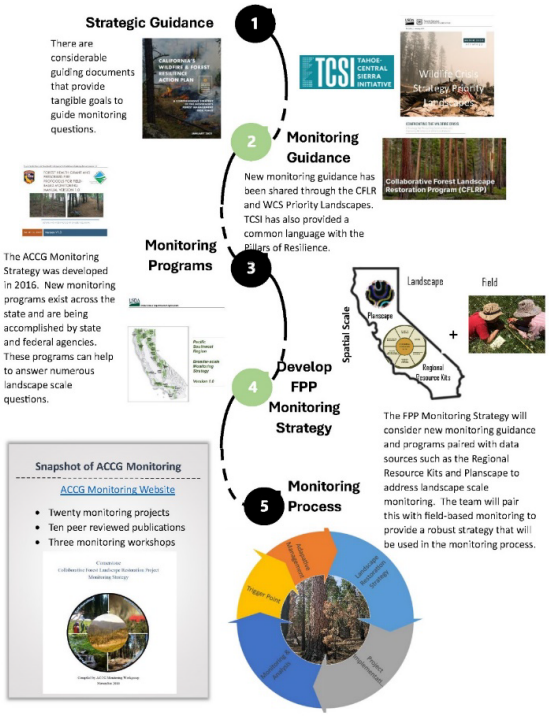


Figure 3. Interaction between the MAC Monitoring Plan and strategic guidance, state monitoring programs and guidance.

The MAC Monitoring Plan also ties to the Cornerstone Collaborative Forest Landscape Restoration Project Monitoring Strategy (2016) but will improve in several ways: 1) The MAC Monitoring Plan provides long-term landscape scale monitoring that capitalizes on an existing long term monitoring network. 2)The MAC Monitoring Plan is adding value and providing different and new innovative techniques for summarizing data as compared to other programs. 3) The MAC Monitoring Plan utilizes new and innovative technologies to effectively monitor large landscapes such as remotely sensed data and drone imagery that can expand upon the sampled plot data (Figure 4). One important characteristic of the MAC Monitoring Plan is its dynamic nature. The plan will need to evolve and adapt as the environment changes and monitoring improves.

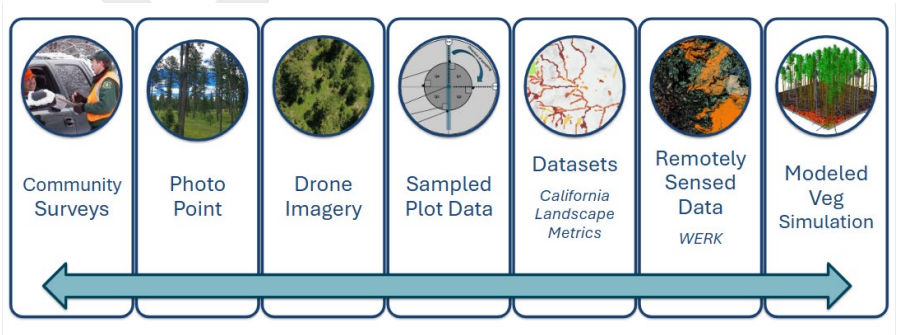


Figure 4. Options for data collection (USDA CA Climate Hub Monitoring Workbook 2026).

1.4 Adaptative Management

Adaptive management is a structured and iterative process with clearly defined outcomes that allow us to refine and improve our management using the outputs from our implementation and effectiveness monitoring, new information, knowledge, or technologies. The adaptive management cycle is illustrated in Figure 5. Goals and objectives are developed to drive management actions that transition the resource towards a desired condition. The result of management actions is monitored to evaluate achievement towards the desired condition, to establish changes in a system and to alleviate uncertainty (Thompson et al. 2013). If the management action is not achieving the project's objectives, then management is adapted or changed, and monitoring continues. The adaptative management process provides a holistic management system to offer a flexible, iterative process that allows learning from outcomes to help support resilient socioecological systems (USDA California Climate Hub 2026).

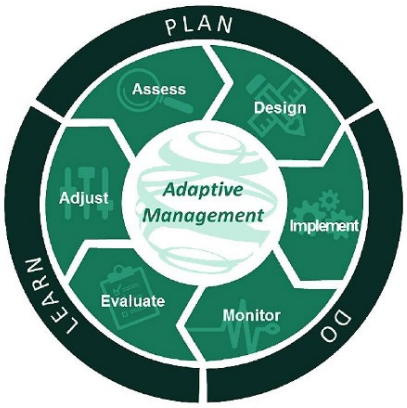


Figure 5. Adaptive management process (USDA CA Climate Hub Monitoring Workbook 2026).

1.5 Report Frequency

The recommended reporting frequency varies depending on questions and indicators, but a report would be generated every five years. The intent is to create a framework where monitoring data can be viewed on a more frequent basis (e.g., annual) but would only be analyzed and summarized over a longer time interval (e.g., 5 years). The expected duration of the MAC Monitoring Plan would be a minimum of 20 years, in which the plan may be updated throughout its life.

1.6 Monitoring Plan Organization

The MAC Monitoring Plan is composed of three main sections that summarize the plan development and structure with additional details located in the Appendices.

1. Monitoring Goals, Guiding Questions, Indicators, Rationale and Desired Conditions Plan
2. Implementation and Field Monitoring Plan
3. Funding Plan
4. Metadata for Monitoring Questions

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Section 2. Monitoring Goals, Guiding Questions, Indicators, Rationale and Desired Conditions Plan

2.1 Implementation Monitoring

Guiding Question 1: What percentage of the Wildland Urban Interface (WUI) surrounding at-risk communities have received wildfire mitigation treatments?

Question Rationale: This question is designed to track the success of completing wildfire mitigation treatments around at-risk communities. Communities can benefit from direct treatments to WUI which would reduce wildfire risk and from indirect creation and maintenance of fuel breaks that would assist in fire management activities.

Scale: The scale to summarize data for this question would occur at the landscape scale (MAC scale) within the designated WUI zones and fuelbreak network as defined by the Amador and Calaveras Ranger Districts.

Frequency: Annually.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Threshold
1.1 Acres by treatment type in the WUI (initial or maintenance)	This indicator is intended to track any changes in treatment in WUI.	FACTS and AGOL Implementation Interface	See Implementation monitoring description in Appendix A.	Success would be measured as an increase in acres treated or maintained in WUI. A decrease in acres of treatment in WUI might indicate a threshold but it would be necessary to evaluate the contributing factors. For example, if all areas in WUI have already been treated then the reported acreage might lower in subsequent years until maintenance needs to occur.

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1.2 Acres or miles of fuelbreaks by treatment type (initial or maintenance)	This indicator is intended to track any changes in treatment in WUI.	FACTS and AGOL Implementation Interface	See Implementation monitoring description in Appendix A.	The acreage of initial or maintenance treatments in fuelbreaks on an annual basis is sufficient to maintain the network.

Guiding Question 2: How many miles of vegetation along ingress and egress routes have been maintained to provide safe escape routes?

Question Rationale: This question is designed to track the success of completing wildfire mitigation treatments around at-risk communities. Communities can benefit from direct treatments to WUI which would reduce wildfire risk and from indirect creation and maintenance of fuel breaks that would assist in fire management activities. This includes the maintenance of vegetation along ingress and egress routes.

Scale: The scale to summarize remote sensing data for this question would occur at the landscape scale (MAC scale) adjacent to ingress/egress routes classified as Level 3 to 5 roads.

Frequency: Annually.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
2.1 Miles of vegetation treated along ingress and egress routes (Level 3 ,4 and 5 roads).	This indicator is intended to track any treatment of vegetation along ingress and egress	FACTS and AGOL Implementation Interface.	See Implementation monitoring description in Appendix A.	The desired condition would be to reduce surface and ladder fuels along roads to maintain safe ingress and egress routes. Horizontal clearance would be a reduction of all flammable materials of at least 10 feet on either side of the

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	routes to document progress.			road and 15 feet of vertical clearance above the roadway.

Guiding Question 3: Are project design features and mitigations implemented correctly to protect target wildlife species and plant communities?

Question Rationale: Indicators for this question would be selected based on specialists' concerns on project implementation. The indicators listed below are a representative example of design features and mitigations currently identified as priority for implementation monitoring.

Scale: Project scale

Frequency: Pre and post treatment

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
3.1 Acres of sensitive terrestrial wildlife areas (e.g., CSO PACs) identified and treated or avoided following the standards assigned in the MAC decision	This indicator will help track the avoidance of all identified sensitive areas.	AGOL Implementation Interface	See Implementation monitoring description in Appendix A.	Desired conditions and thresholds are captured in the MAC EIS management requirements and design features. A desired condition would be the avoidance of all sensitive terrestrial wildlife areas and the protection of important habitat.
3.2 Acres and size of rare plant and sensitive habitat	This indicator will help track the avoidance of all	AGOL Implementation Interface	See Implementation	Complete avoidance of all rare plant and sensitive habitat buffers and more than 80 percent avoidance in other mechanical treatment buffers.

areas and mechanical treatment buffers identified and avoided	identified sensitive areas buffers.		monitoring Appendix A.	
3.3 Acres of sensitive aquatic wildlife areas (e.g., Riparian Conservation Areas (RCAs)) identified and treated or avoided following the standards assigned in the MAC decision	This indicator will help track the avoidance of all identified sensitive areas.	AGOL Implementation Interface	See Implementation monitoring Appendix A.	The avoidance of all aquatic wildlife sensitive areas and the protection of important habitat. Avoidance of all RCAs buffers. Complete adherence (100%) in areas of T&E species and adequate (80%) adherence in general RCAs.
3.4 Acres of avoided non-native species	Avoidance of non-native species is important to track through the implementation process.	AGOL Implementation Interface	See Implementation monitoring Appendix A.	Avoiding non-native species introduction or spread.
3.5 Number of Limited Operating Periods (LOPs) implemented as prescribed	LOPs are important to track through the implementation process.	AGOL Implementation Interface	See Implementation monitoring Appendix A.	Avoidance and adherence to LOPs.

Guiding Question 4: Are project Best Management Practices (BMPs) designed to protect beneficial uses of water being implemented as planned? Are implemented BMPs effective in protecting beneficial uses of water?

Question Rationale: The MAC Project is consistent with the National Best Management Practices for Water Quality Management on National Forest Lands–Volume 1: National Core BMP Technical Guide (USDA Forest Service 2012a).

USDA Forest Service policy directs compliance with the Clean Water Act (CWA) and state water quality programs and requires the use of BMPs to control non-point source pollution to meet applicable water quality stands and other CWA requirements. The MAC Project is designed to restore ecosystem health and resilience and maintain or improve water quality on NFS lands. This includes management requirements and BMPs designed to avoid non-point source pollution and meeting CWA requirements.

Scale: Watershed and MAC Scale.

Frequency: Reporting on a baseline and annual timeframe and summarizing every 5 years depending on the pace and scale of treatment occurrence.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
4.1 BMP implementation and effectiveness rates	The MAC Project is consistent with the National Best Management Practices for Water Quality Management on National Forest Lands–Volume 1: National Core BMP Technical Guide (USDA Forest Service 2012a). USDA Forest Service policy directs compliance with the Clean Water Act (CWA) and state water quality programs and requires the use of BMPs to control	AGOL Implementation Interface and BMP reporting	Summarize BMP reporting by watershed within projects and MAC landscape.	Meet state water quality objectives to maintain and improve watershed conditions.

	non-point source pollution to meet applicable water quality stands and other CWA requirements. The MAC Project is designed to restore ecosystem health and resilience and maintain or improve water quality on NFS lands. This includes management requirements and BMPs designed to avoid non-point source pollution and meeting CWA requirements.			

Guiding Question 5: What acreage has been treated with prescribed fire or wildfire managed for resource benefit?

Question Rationale: This question would help inform progress towards promoting a fire-resilient landscape and reflect overall forest and fire maintenance activities for prescribed fire. Tracking the acres of treatment with beneficial fire would help us understand whether we are successfully reestablishing fire processes.

Scale: MAC Scale.

Frequency: Annual reporting and summarized every 5 years.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
5.1 Area of prescribed fire	This indicator would track the number of acres treated with beneficial prescribed fire across the MAC project. This coupled	FACTS and AGOL Implementation Interface	Track area that has been prescribed	Increased use of prescribed fire to remove understory fuels and promote changes in structure.

	with vegetation indicators in Q#13 and 14 would help to establish whether we are moving towards a more natural fire regime.		burned (e.g., pile burning, broadcast burning)	A desired condition would be the increased use of prescribed fire to remove understory fuels and promote changes in structure. A threshold would be if the percentage of the landscape with completed mechanical treatment increases but the use of prescribed fire does not increase after the first 10 years of the project. This would likely include an analysis of other conditions since there could be other contributing factors (e.g., climate).
5.2 Area of wildfire managed for resource benefit	This indicator would track the number of acres treated with beneficial wildfire across the MAC project. This coupled with vegetation indicators in Q#13, 14 and 15 would help to establish whether we are moving towards a more natural fire regime.	FACTS and FRAP	Track area where wildfire has been managed for resource benefit.	Increase the use of wildfire from natural ignitions that occur within the MAC project area to mimic natural or desired fire regimes, and to remove understory fuels and promote changes in vertical structure. A threshold would be if the percentage of the landscape with complete mechanical treatment increases but the use of wildfire managed for resources benefit doesn't increase. This would likely include an analysis of other conditions since there could be other contributing factors (e.g., climate).

2.2 Social and Economic Monitoring

Guiding Question 6: How many local (Amador, Calaveras, Alpine, Tuolumne, El Dorado Counties) jobs (including contracts) have been created or maintained through restoration and management activities?

Question Rationale: Human communities in the vicinity of the MAC project are a critical part of land management. Social and economic conditions in the broader landscape can influence the sustainability of resources and ecosystems within the MAC project.

Data on social and economic conditions can provide insight into the resilience of local communities and their sensitivity to changes in forest management and resource conditions.

Scale: County Scale and MAC Scale.

Frequency: Baseline and every 5 years depending on the pace and scale of treatment occurrence.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
6.1 Number of forest-related local jobs or contracts	The total number of jobs and contracts related to work in the MAC project area could provide key information on economic benefit to the local communities.	Treatments for Restoration Economic Analysis Tool (TREAT) model and implementation reporting.	Summary of forest-related local jobs and contracts.	Increase local job opportunities. Increase local job opportunities. A decrease in job opportunities doesn't imply that there is a negative benefit and other contributing factors must be considered.

Guiding Question 7: What volume of forest products (e.g., timber, biomass) has been sustainably harvested from restoration areas in the last 12 months?

Question Rationale: Human communities in the vicinity of the MAC project are a critical part of land management. Social and economic conditions in the broader landscape can influence the sustainability of resources and ecosystems within the MAC project. Data on social and economic conditions can provide insight into the resilience of local communities and their sensitivity to changes in forest management and resource conditions.

Scale: County Scale and MAC Scale.

Frequency: Annual or depending on the pace and scale of treatment occurrence.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
7.1 Estimated/ actual volume (biomass, sawlog-tons per acre)	Tracking the volume of forest products will provide information on economic streams from restoration treatments.	Implementation reporting	TREAT model. Summary of actual volume (biomass, sawlog-tons per acre).	Increase the actual volume.

2.3 Effectiveness Monitoring

Guiding Question 8: Are shaded fuelbreaks being created and properly maintained to meet fire management objectives?

Question Rationale: Fuelbreak creation and maintenance (implementation) is being tracked in Indicator 1.2. This question tracks the vegetation composition structure following fuelbreak creation and tracks the need for ongoing maintenance. This question does not track whether the fuelbreaks are effective for fire management or fire behavior modification which will be addressed on a landscape scale in Q#15.

Scale: The scale to summarize remote sensing data for this question would occur at the landscape scale (MAC scale) within the shaded fuelbreak network. The scale to summarize field-based data collection would occur at the shaded fuelbreak scale.

Frequency: Baseline and post-treatment and every 5 years depending on the pace and scale of treatments and maintenance.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
8.1 Canopy cover of overstory, shrubs by size class (low, medium, high) and forbs (including invasives)	Fuelbreak creation and maintenance (implementation) is being tracked in Indicator 1.2. This question tracks the vegetation composition structure following fuelbreak creation and tracks the need for ongoing maintenance. This question does not track whether the fuelbreaks are effective for fire management or fire behavior modification which will be addressed on a landscape scale in Q#15.	Remote sensing that summarizes overstory, shrub and forb (invasives) cover Photo points and field data at random locations to quantify overstory and understory cover using Common Stand Exam protocols (subjective assessments of covers by functional group).	Summarize changes in tree and shrub canopy cover within the fuelbreak network.	Outside PACs: Retention of some overstory trees in dominant and codominant size class creating an average crown spacing of 0.5 to 1.5 crown widths. Overstory canopy cover should be 30% on average outside PACs and shrub cover would be initially 0% and would not exceed 30% and occur in scattered patches of low growing native shrub species with an adequate cover of forbs excluding invasives. Inside PACs: Retention of some overstory trees in dominant and codominant size class trees creating an average crown spacing of 0.5 to 1.5 crown widths. Overstory canopy cover should be 50% on average or in certain circumstances in WUI defense zones 40% canopy cover. Shrub cover would be initially maintained as 10%, wherever behavior objectives can be met with this level of vegetation retention and would not exceed 30% and occur in scattered patches of low growing native shrub species with an adequate cover of forbs excluding invasives.

8.2 Height to Live Crown for trees, maximum fuel height for understory fuels	Height to live crown base (HTLCB) is an indicator of connectivity of surface fuels to canopy fuels and is an indication of ladder fuels.	Remote sensing data will be taken from the most current LiDAR acquisition evaluating tree heights and understory fuel heights.	Summarize tree height to live crown and maximum fuel height for the understory.	Outside PACs: Lower branches would be pruned to create a distance of three times the height of the surface vegetation to the height to live crown. Inside PACs: Lower branches would be pruned to create three times the height of the surface vegetation to the height to live crown.

Guiding Question 9: Has there been a measurable reduction in the risks of wildfire to at-risk communities (WUI) following treatments?

Question Rationale: Reduction in the general forest risk to wildfire is a desired outcome for the MAC project. There are approximately 111,000 acres of the project near communities. Based on current conditions, these communities are at an elevated risk from high severity wildfire and need treatments to reduce this risk. This question will assess whether there is progress toward reducing wildfire risk using the probability of fire severity (low, moderate and high) and the conditional burn probability that evaluates the likelihood of wildfire occurrence. This analysis will compare pre-treatment and post-treatment wildfire risk across the MAC landscape in at-risk communities (e.g., WUI). Changes in cumulative risk to communities would be assessed both in the year following implementation and every 5 years during the maintenance phase.

Scale: The scale to summarize remote sensing data for this question would occur at the landscape scale (MAC scale) within the WUI and fuelbreak network as defined by the project.

Frequency: Baseline and post-treatment and every 5 years depending on the pace and scale of treatments and the availability of new fire behavior modelling.

Summary of Indicators:

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Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
9.1 Conditional Flame Length	Conditional flame length (CFL) was selected as a key indicator of potential fire behavior because it directly relates to intensity, suppression difficulty, and ecological impact. In fire behavior science, flame length is a function of surface fuel load, fuel moisture, wind, and slope, and it serves as a practical measure of how aggressively a fire will burn under modeled conditions. Shorter flame lengths generally indicate lower fireline intensity, reduced crown fire potential, and improved opportunities for safe and effective suppression. Conversely, longer flame lengths signal higher-intensity fire behavior, greater spotting potential, and increased risk of habitat loss and resource damage. These assumptions mean that flame length values	Conditional flame length (CFL) is calculated using GridFire https://github.com/pyregence/gridfire) (see MAC EIS for specifics). CFL is a key indicator of fire behavior and is related to intensity, suppression difficulty and ecological impact. Could also be derived from Pyrologix or the Rocky Mountain Research Station Western Fire protocols.	Summarize the probability of each severity class within the mapped WUI and fuelbreak layers based on predicted C**onditional Flame Length** (p. 109 of MAC EIS). Low severity = predicted flame length of < 4 feet, moderate severity = predicted flame length of 4-8 feet, high severity = predicted flame length of >8 feet. Completed treatment would be overlaid with the severity metric and proportion in each class would be calculated.	Reduced fire risk and safety hazards in communities within the WUI. Flame lengths are gradually trending towards low severity in WUI.

	should be interpreted as relative indicators of treatment effectiveness, not as predictions of actual flame lengths during any specific wildfire event. Lower flame length values in treated areas reflect reductions in surface fuel continuity and load, which treatments achieve through forest thinning, fuel reduction, fuelbreak construction and cultural or prescribed burning.			
9.2 Conditional Burn Probability	This indicator provides a measure of the probability of burning and can be used to estimate fire risk (Parisien et al. 2019). This indicator is particularly useful for comparing pre and post treatment landscapes because it reflects how changes in fuel structure and continuity influence the probability that a simulated ignition will reach a given point on the landscape. Lower conditional burn probability (CBP) indicate a lower likelihood that a	Conditional Burn Probability (CBP) was calculated using GridFire (https://github.com/pyregence/gridfire). See p. 108 of MAC EIS for specifics. CBP is calculated as the ratio of times burned to fires initiated during a time period as provides information on changes in fuel structure and continuity. CBP could also be derived from Pyrologix or the Rocky Mountain Research Station or using FVS modeling.	Conditional Burn Probability represents the likelihood of a wildfire of any intensity occurring at a given location (pixel) in a single fire season (p. 109 of MAC EIS). This probability would be summarized for the WUI and fuelbreak network. Completed	Reduced fire risk and safety hazards in communities within the WUI. Shift the percentage of conditional burn probabilities in the highest category (>0.2%) to the lowest category (<0.1%) (Table 29 in MAC EIS). A threshold or trigger would exist if conditional burn

	simulated ignition will reach a location. Treatments reduce the CBP by breaking fuel continuity in surface and canopy layers, reducing reaction intensity and flame length, and weakening spotting potential. Logical expectations associated with outputs include that treatments targeting canopy structure such as forest thinning, will reduce crown fire initiation potential and slow spread, while prescribed fire will further reduce CBP by eliminating fine surface fuels that drive rapid fire growth and spotting. Together, these treatments create conditions that lower modeled exposure risk and help protect the general forest.		treatment would be overlaid with the burn probability metric and proportion in each class would be calculated.	probability remained stationary or increased.

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Guiding Question 10: Has there been a measurable reduction in the risks of wildfire to vegetation community types in the general forest?

Question Rationale: Reduction in the general forest risk to wildfire is a desired outcome for the MAC project. This question will assess whether there is progress toward reducing wildfire risk using the probability of severity and the conditional burn probability

that evaluates the likelihood and severity of wildfire occurrence. This analysis will compare pre-treatment and post-treatment wildfire risk across the MAC landscape. Changes in cumulative risk would be assessed both in the year following treatment implementation and every 5 years.

Scale: The scale to summarize remote sensing data for this question would occur at the landscape scale (MAC scale) and at the watershed scale (e.g., HUC 12).

Frequency: Baseline, post-treatment and every 5 years depending on the pace and scale of treatments and the availability of new fire behavior modelling.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
10.1 Conditional Flame Length	Conditional flame length (CFL) was selected as a key indicator of potential fire behavior because it directly relates to intensity, suppression difficulty, and ecological impact. In fire behavior science, flame length is a function of surface fuel load, fuel moisture, wind, and slope, and it serves as a practical measure of	Conditional flame length (CFL) is calculated using GridFire (see MAC EIS for specifics). CFL is a key indicator of fire behavior and is related to intensity, suppression difficulty and ecological impact. Could also be derived from Pyrologix or the Rocky Mountain Research Station Western Fire products.	Summarize the probability of each severity class within the general forest based on predicted C**onditional Flame Length**. Low severity = predicted flame length of < 4 feet, moderate severity = predicted	Landscape-scale objectives for probability of moderate and high fire severity outside of WUI would show a decreasing trend away from high severity to low and moderate severity following treatment. No change in the proportion of the probability of low, moderate and high severity fire particularly in treated areas.

	how aggressively a fire will burn under modeled conditions. Shorter flame lengths generally indicate lower fireline intensity, reduced crown fire potential, and improved opportunities for safe and effective suppression. Conversely, longer flame lengths signal higher-intensity fire behavior, greater spotting potential, and increased risk of habitat loss and resource damage. These assumptions mean that flame length values should be interpreted as relative indicators of treatment effectiveness, not as predictions of actual flame lengths during any specific wildfire		flame length of 4-8 feet, high severity = predicted flame length of >8 feet. Completed treatment would be overlaid with the severity metric.	

	event. Lower flame length values in treated areas reflect reductions in surface fuel continuity and load, which treatments achieve through forest thinning, fuel reduction, fuelbreak construction and cultural or prescribed burning.			
10.2 Conditional Burn Probability	This indicator provides a measure of the probability of burning and can be used to estimate fire risk (Parisien et al. 2019). This indicator is particularly useful for comparing pre and post treatment landscapes because it reflects how changes in fuel structure and continuity influence the probability that a simulated ignition will	Conditional Burn Probability (CBP) was calculated using GridFire (https://github.com/pyregence/gridfire). See p. 108 of MAC EIS for specifics. CBP is calculated as the ratio of times burned to fires initiated during a time period as provides information on changes in fuel structure and continuity. CBP could also be derived from Pyrologix or the Rocky Mountain Research Station or using FVS modeling.	Conditional Burn Probability represents the likelihood of a wildfire of any intensity occurring at a given location (pixel) in a single fire season. This probability would be summarized for	Shift the percentage of conditional burn probabilities in the highest category (>0.2%) to the lowest category (<0.1%). (Table 29 in the MAC EIS)). A threshold or trigger would exist if conditional burn probability remained stationary or increased.

	reach a given point on the landscape. Lower conditional burn probability (CBP) values indicate a lower likelihood that a simulated ignition will reach a location. Treatments reduce the CBP by breaking fuel continuity in surface and canopy layers, reducing reaction intensity and flame length, and weakening spotting potential. Logical expectations associated with outputs include that treatments targeting canopy structure such as forest thinning, will reduce crown fire initiation potential and slow spread, while cultural or prescribed fire will further reduce CBP by eliminating fine surface fuels that drive rapid fire growth and		the general forest. Completed treatment would be overlaid with the burn probability metric and proportion in each class would be calculated.	

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	spotting. Together, these treatments create conditions that lower modeled exposure risk and help protect the general forest.			

Guiding Question 11: Have treated areas seen a measurable reduction in fuel loading (e.g., tons per acre, tree density) that has facilitated the use of cultural or prescribed fire?

Question Rationale: After nearly a century-long over-emphasis on fire suppression, Sierra Nevada forests are now uncharacteristically dense, with understory ladder fuels often coupled with suppressed to codominant sized trees and a thick layer of dead and down woody material, litter, and duff. Altered fuel conditions have disrupted fire regimes of forests historically characterized by high-frequency and low-to-moderate-severity fire. Managers use fuel treatments to alter undesirable fire behavior and effects. Mechanical treatments are effective at reducing fuel loading (surface and ladder fuels and tree density) and increasing canopy base height in the short term however the long-term goal would be to reintroduce cultural or prescribed fire. The USDA Forest Service recognizes the need to increase the pace and scale of fuels reduction across NFS lands, specifically via the use of cultural or prescribed fire within fire-adapted ecosystems (USDA Forest Service 2023b). It will take a full suite of management actions, including forest thinning, mastication, machine piling and burning, and cultural or prescribed fire or managed wildfire to promote a fire-resilient landscape. Due to currently unsafe conditions and risk of extreme fire behavior, most of the MAC Project area needs management action prior to cultural or prescribed fire being implemented at the scale needed to reach and maintain the desired condition. This monitoring question will help to provide quantitative information that could be used to facilitate the use of cultural or prescribed fire.

Scale: All Field Monitoring would be summarized at stand scales, and remote sensing would be summarized at the stand or MAC scale.

Frequency: Baseline, post-treatment and every 5 years depending on the pace and scale of treatments.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
11.1 Surface fuel loading (1-, 10-, 100-, 1,000-hour fuels) and litter, duff and fuel bed depth	This indicator will provide quantitative information on the distribution and amount of fuel loading across projects that will help to guide cultural or prescribed burning.	Photo points with fuel model assessments. Common Stand Exam (CSE) plots within stands using the Browns Handbook for Inventorying Dead and Downed Woody Material.	Collect surface fuels and fuel bed depth within Common Stand Exams and summarize at tons per acre at the plot and stand scale – mean and ranges.	Reduce surface and ladder fuels to enable cultural or prescribed burning and reduce the risk of high severity fire. Reduce surface fuel loading and fuelbed depth to a low to moderate risk to allow for the implementation of broadcast burning (see Table 1 in Q11 Metadata).
11.2 Height to Live Crown for trees, maximum fuel height for understory fuels	Height to live crown base (HTLCB) is an indicator of connectivity of surface fuels to canopy fuels and is an indication of ladder fuels. It is often the critical flame height that allows for a crown fire. This indicator can be compared to the crown height in the photo series.	Remote sensing data will be taken from the most current LiDAR acquisition evaluating tree heights and understory fuel heights. Common Stand Exams can also be used at the field scale to collect the height to live crowns and the height for understory fuels.	Summarize tree height to live crown and maximum fuel height for the understory.	Reduce surface and ladder fuels to enable cultural or prescribed burning and reduce the risk of high severity fire. Thresholds would be a notable increase in fuel loading following treatments. These areas would need to be reevaluated for follow up treatments to facilitate cultural or prescribed fire.

11.3 Density: Trees per unit area (e.g., acres) by quadratic mean diameter, vegetation type and status	Trees per acre (TPA) is an indicator of resilience of upland forests to fire, insects, disease, drought and climate change. In general, as forests become denser (e.g., more TPA), they are less resilient to various disturbances. The acceptable resilient condition for the TPA indicator came from the published literature sources for historic and contemporary reference conditions.	Quadratic Mean Diameter (QMD) ranges: Derived for each Tree Approximate Object (TAO) using a remote sensing product (e.g., LiDAR or Treemap). QMD ranges are found in Table A3. Vegetation type: FVEG - WHR Type (Table A2). Status: Live or dead trees. This variable likely will only apply to forest types. Trees per unit area: Use a remote sensing product that designates TAOs. Options could be LiDAR or Treemap or other remote sensing tool that allows individual tree canopies to be	Summarize data at the stand scale to evaluate the amount of ladder fuels and maximum height of fuels/understory	Ladder fuels: remove live trees < or = 10” DBH. Reduction in the tree density in the smallest size classes. Snags: retain 4 of the largest snags per acre in mixed conifer forest type; 6 of the largest per acre in the red fir forest type.

		obtained to express a tree density per unit area.		
11.4 Area of forest thinning by treatment type (e.g., forest thinning, fuel reduction)	To facilitate the use of fire across the landscape mechanical treatments must be utilized to create conditions where risk and hazard will be reduced.	FACTS and AGOL	Summarize acreage of forest fuel reduction treatments.	Increased forest thinning treatments to facilitate the use of cultural or prescribed fire.

Guiding Question 12: Has the density, composition and structure of forest vegetation been maintained or improved to increase resilience to human and natural disturbances (e.g., wildfire, drought)?

Question Rationale: The MAC landscape has indicated a need to monitor ecosystem resilience to drought, insects and disease and fire. One approach to measuring resilience is to assess whether treatments are successfully moving conifer forest stand structure closer to targets that can be approximated using tools such as the Natural Range of Variation (NRV) at the treatment and project level (e.g., Safford and Stevens 2017; Meyers and North 2019). The ACCG Monitoring Workgroup will work as a team to determine the relevant NRV souces for each relevant metric.

Type of monitoring: Remote Sensing – stand scale to landscape scale. Field Monitoring – This is used when appropriate to the Indicator (Composition: Vegetation Type, Density: Trees per unit area, and Density: Stand Density Index).

Scale: The scale to summarize remote sensing data for this question would occur at multiple scales. All Field Monitoring would be summarized at stand and mid scales.

1) Minium mapping unit for remote sensing – Smallest remote sensing unit of measure (e.g., 1 meter to 30 meter)
2) Minimum summary unit for remote sensing - Eight-acre hexagon which represents a consistent stand scale.
3) Stand scale – Mapped stand scales that are developed for implementation.

4) Wildlife scale (PACs, territories)
5) Mid-scale – Watershed or climate classes. Also, could consider PODs as a mid-scale unit
6) Large scale/maximum scale– Project area – MAC project area

Frequency: Pre or baseline would represent the pre-treatment landscape. Post treatment (this could vary depending on timing of implementation but ideally it would be within a year of any treatment (e.g., mechanical, fire). Following treatment, the frequency would be at five-year intervals unless the treatment requires a more frequent monitoring period.

Type of monitoring: Field Monitoring– plot scale to stand scale to mid-scale

Scale: The scale to summarize Field Monitoring data would occur at multiple scales.

1) Stand scale – Multiple plots for each stand of interest
2) Mid-scale – Sub-watershed or climate classes
3) Implementation scale – Sub MAC project scale

Frequency: Pre or baseline would represent the pre-treatment landscape. Post treatment (this could vary depending on timing of implementation but ideally it would be within a year of any treatment (e.g., mechanical, fire). Following treatment, the frequency would be at five-year intervals unless the treatment requires a more frequent monitoring period

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
12.1 Composition: Vegetation types	Composition is an important indicator to understand shifts in vegetation type. It is critical to document as it guides structural indicators.	Remote Sensing - Vegetation type: FVEG - WHR Type (see Table 2 in Q12 Metadata).	Summarize percent of the MAC landscape (acres) in each vegetation type (vegetation type composition proportion). This	Increase the relative abundance of fire-tolerant and shade-intolerant tree species.

			indicator can be summarized at all scales.	Maintain or increase the relative abundance of hardwood (e.g., aspen, oaky).
12.2 Density: Trees per unit area (e.g., acres) by quadratic mean diameter, vegetation type and status	Trees per acre (TPA) is an indicator of resilience of upland forests to fire, insects, disease, drought and climate change. In general, as forests become denser (e.g., more TPA), they are less resilient to various disturbances. The acceptable resilient condition for the TPA indicator came from the published literature sources for historic and contemporary reference conditions.	Quadratic Mean Diameter (QMD) ranges: Derived for each Tree Approximate Object (TAO) using a remote sensing product (e.g., LiDAR or Treemap). QMD ranges are found in (see Table 3 in Q12 Metadata). Vegetation type: FVEG - WHR Type (see Table 2 in Q12 Metadata). Status: Live or dead trees. This variable likely will only apply to forest types. Trees per unit area: Use a remote sensing product that designates TAOs. Options could be LiDAR or Treemap or other remote sensing tool that allows individual tree canopies	Summarize trees per unit area by QMD size class (see Table 3 in Q12 Metadata)., vegetation type and status by appropriate scales described above reporting both means and ranges of tree density.	Reduce stand densities and increase the large tree component on the landscape.

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		to be obtained to express a tree density per unit area.		
12.3 Density: Stand Density Index (SDI) by vegetation type	Stand density index (SDI) helps vegetation managers to identify levels of site utilization and competition to determine management scenarios to meet objectives and is often used for forest health-oriented treatments. SDI was also proposed by North et al., (2022) as an operational resilience metric for western fire adapted forests.	Stand Density Index: LiDAR or other remote sensing product that calculates SDI Mesic/Xeric Gradient Stand density index (SDI) helps vegetation managers to identify levels of site utilization and competition to determine management scenarios to meet objectives and is often used for forest health-oriented treatments. SDI was also proposed by North et al., (2022) as an operational resilience metric for western fire adapted forests. This metric is a	Summarized the raw SDI values or the proportion of maximum SDI by vegetation class or mesic/xeric gradient.	SDI Ranges derived from North et al. 2022 SDI: Pine MC – 58-109, Xeric MC – 49-95, Mesic MC – 80-157 Proportion of Max SDI: Pine MC 14-305, Xeric MC – 16-33%, Mesic MC – 18-36% MAC SDI Project: Pine: 50-150 Dry mixed conifer: 100-200 Moist mixed conifer: 150-250 Also, this is different at the At the stand level, treatments will generally create more open canopy conditions on upper slope positions (ridges) and south-facing aspects, while denser canopy conditions will be retained on lower

		quantitative measure that relates the current stand density to the size class distribution of the stand. Reineke uses quadratic mean diameter, a weighted mean, to estimate the stand size class, whereas the Zeide method (also known as the summation method) uses Dr (Reineke's diameter). Stand density index: Number of trees per acre expressed as an equivalent density in a stand with a quadratic mean diameter of 10 inches. Proportion of Maximum SDI: The maximum forest stand density represents an		slope positions (drainages) and on north-facing aspects . Topography e could be used to further refine Ridges & S facing on lower ends of SDI ranges (Pine 50-100; Dry mixed conifer 100-150, Moist mixed conifer150-200) and in Canyons and N facing slopes on higher ends Pine 100-150; Dry mixed conifer 150-200; Moist mixed conifer 200-250.

		approximate upper limit to the SDI of a site, and tree growth may be limited by competition as SDI approaches maximum SDI. This approximate upper limit on potential site SDI has is consdiered species- and site-specific by several authors using different variables to characterize the stand.		
12.4 Structure: Seral stage by vegetation type	Seral stage can be an indicator of overall forest complexity and resilience. The seral stages are categories that represent the developmental progression of forest ecosystems from initial establishment or following a stand replacing event (e.g., high severity fire) to a forest dominated by trees in the upper age classes for a given forest type. Percent of seral	Quadratic Mean Diameter (QMD) ranges: Derived for each Tree Approximate Object (TAO) using a remote sensing product (e.g., LiDAR or Treemap). QMD ranges are found in (see Table 3 in Q12 Metadata)..	Seral stage refers to overstory tree DBH (inches). Early development (ED): ≥6"; Mid development (MD): 6-11”; Late development (LD): >24”. Once Seral stage has been classified then acres of seral stage by vegetation type should be summarized across	Over-represented seral stages are reduced, under-represented seral stages are increased, and the landscape is set on a positive trajectory.

	stage across the landscape is an indicator of resilience of upland forest and in some cases meadow/riparian ecosystem to fire, insects, disease, drought and climate change. Seral stage was developed based on tree size classes and canopy cover, both of which can affect competition, fire behavior, susceptibility to pest infestations, etc. Seral conditions across landscapes were highly variable prior to major European settlement in the western US. These patterns were highly attuned to dominant disturbance regimes and the multi-scaled variability in environmental conditions across topographic and climatic gradients. These patterns helped to reinforce fire regimes dominated by	Vegetation type: FVEG - WHR Type (see Table 2 in Q12 Metadata).	the entire landscape.	

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	low- to moderate-severity fire across much of the region and provided for multiple habitat requirements for a wide variety of species.			
12.5 Structure: Individual trees, forest clumps (patches) and openings (ICO)	Forest management in MAC aims to restore structural heterogeneity by creating forested patches and canopy openings (ICO). This indicator will provide spatial resolution and temporal frequency to assess fine-scale structural outcomes.	Planet or LiDAR data Other LiDAR products might be considered such as from the UCD FOCAL group or from the UW Spatial Lab.	Comparison of forest patch area and forest opening area by size class (0–0.25, 0.25–0.5, 0.5–1, 1–3, 3–5, and 5+ acres). Alternatively, structure classes can be classified by closed canopy, dense ICO, Intermediate ICO, and Open ICO (Chamberlain et al. 2023).	Openings will be located near mature conifers and oaks and range in size from 0.25 - 2.5 acres with openings having less than 10% overstory canopy cover. Openings will be no more than 30% of the treatment areas in a project. In CSO PACs, openings will be <0.25 acres and less than 5% of a stand. In CSO Territories, openings will not exceed 1.25 acres in size but generally 0.5 acres and not more than 30% of total territory. Forest patches (tree clumps) would consist of large trees (>30 inches) in notable habitat. The forest patches and openings can be compared to the Historic Range of Variability to determine trends.

				Desired distributions of ICO structures could align with reference conditions that are dominated by open and intermediate ICO classes with lower proportions of dense ICO structure classes (see Figure 1 and 2 in Q12 Metadata).
12.6 Structure: Fine scale heterogeneity	A key component of forest structure descriptions is the spatial heterogeneity (i.e., tree clumps and gaps), which influences vegetation growth, competition, and succession, disturbance processes, and wildlife habitat. Developing spatial heterogeneity through mechanical and cultural or prescribed fire treatments is often a goal of restoration projects and targets for the distribution of individual trees, clumps and gaps are often derived from historical estimates of stand structure. This	LiDAR Other LiDAR products might be considered such as from the UCD FOCAL group or from the UW Spatial Lab.	The metric is derived from 3m resolution PhoDAR estimates of spring 2020 canopy height produced by Salo Sciences. Pixels with height greater than 2m were classified as canopy; pixels with height less than or equal to 2m were classified as canopy gaps. Fractal dimension index was calculated within a 90m (900-pixel) moving window using the following	Increase fine scale heterogeneity across the MAC landscape (see Figure 3 in Q12 Metadata).

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	fractal dimension index is intended to be used in combination with the percent canopy cover as a measure of fine-scale heterogeneity. Fine-scale heterogeneity in forest structures may interrupt fuel continuity and reduce mortality of overstory trees. Fractal dimension is a measure of the complexity of shapes and ranges from 1, for simple shapes (fewer canopy interruptions), to 2, for complex shapes (more canopy interruptions). Fractal dimension is typically applied to single-part shapes, here we apply it to forest canopy within a 90m x 90m moving window.		expression, applicable to shapes represented by rectilinear pixels (McGarigal and Marks 1995). The following diagram illustrates how fractal dimension index values correspond with spatial patterns of forest canopy coverage. Green areas denote canopy coverage and brown areas denote low-growing vegetation or bare areas. Areas where the shape of canopy coverage is more complex or patchy thereby have higher fractal area index..	

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Guiding Question 13: Have treated areas experienced fewer large-scale disturbances (e.g., wildfire, insect outbreaks) compared to untreated areas over the project implementation period?

Question Rationale: Fire is an important ecological process in Sierra Nevada forests. Prior to the twentieth century, fires were a common occurrence in the Sierra Nevada and foothills. Much of the forests burned at regular intervals on a 15- to 30-year cycle due to natural causes like lightning or intentional ignitions and vegetation management by Indigenous people. This historical, regular pattern of fire, known as a fire regime, created a mosaic of vegetation patterns including varying degrees of canopy cover and forest openings. After nearly a century-long over-emphasis on fire suppression, Sierra Nevada forests are now uncharacteristically dense, with understory ladder fuels often coupled with suppressed to codominant sized trees and a thick layer of dead and down woody material, litter, and duff. Now, when fires ignite, forests erupt into infernos that generate their own weather, burning large expanses of forested lands at much higher intensities and severity than historical levels, consuming or killing most of the live vegetation and leaving, in some areas, sterilized soils and long-lasting fire scars on huge expanses of our public lands.

The USDA Forest Service recognizes the need to increase the pace and scale of fuels reduction across NFS lands, specifically via the use of cultural or prescribed fire within fire-adapted ecosystems (USDA Forest Service 2023b). It will take a full suite of management actions, including forest thinning, mastication, machine piling and burning, and cultural or prescribed fire or managed wildfire to promote a fire-resilient landscape. Due to currently unsafe conditions and risk of extreme fire behavior, most of the MAC Project area needs management action prior to cultural or prescribed fire being implemented at the scale needed to reach and maintain the desired condition.

Scale: Remote sensing will be summarized at the scale of MAC with a focus on the disturbance event.

Frequency: Baseline and every 5 years depending on the pace and scale of treatments and new disturbance perimeters.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds

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13.1 Mean condition class (mean fire return interval departure condition class)	This indicator uses the mean percent FRID to measure the extent to which contemporary fires (i.e., since 1908) are burning at frequencies like the frequencies that occurred prior to Euro-American settlement summarized across known literature, with the mean reference FRI binned into another basis for comparison. Mean PFRID is a metric of fire return interval departure (FRID) and measures the departure of current FRI from reference mean FRI in percent.	The Fire Return Interval Departure Analysis (FRID) is a remote sensed product generated by the Forest Service in Region 5. The FRID is updated every year to reflect changes in fire perimeters that are provided from the Cal Fire Fire and Resource Assessment Program (FRAP).	Use Fire Return Interval Departure Analysis (FRID) - Condition Class (CC) departure - Low (CC1), Moderate (CC2), or High (CC3) departure.	The Fire Return Interval (FRI) is moving towards natural variability with more acres moving towards desired CC 1; less (and eventually no) acres in CC 3. From the MAC EIS: A fire return interval departure (FRID) analysis quantifies the difference between current and pre-settlement fire frequencies and provides a basis to identify areas for targeted management (Safford and Van de Water 2014). Based on FRID analysis of the MAC Project area, approximately 56 percent is highly departed, 27 percent is moderately departed, and 4 percent is within the historical range of variability. See example in Figure 4 in Q13 Metadata).

13.2 Area burned by fire summarized by the vegetative fire severity and min, mean, and max patch size by high severity	This wildfire severity indicator would look at wildfire trends within and across the MAC landscape to report how many acres of wildfires burned and at what severity, and where there were patches of high severity fire that exceeded 250 acres (representing the upper end of the natural range of variation) in montane and upper montane ecological zones. Wildfire trends will be evaluated spatially in the context of treatment locations. Vegetation burn severity can	Use Rapid Assessment of Vegetation Condition after Wildfire (RAVG) data. There is also a new viewer through Cal Fire – the California Vegetation Burn Severity Data Online Viewer.	Summarize areas of high, moderate, and low vegetation and soil burn severity in fires that have burned in the MAC landscape using the Basal Area loss and the BARC products Define high severity patches suing the PatchMorph tool. This is described in Appendix in GTR 270 located here. Summarize the mean and maximum of high severity patches.	Fires burn primarily at low to moderate severity with limited high severity fires in patches less than 10 acres in size. Reduce the Probability of Low, Moderate and High Severity closer to a natural range of variability (L – 10-30% , M – 30-55% H – 5-10%), extrapolated from Meyers et al. 2015). These values are realized so might only be a target for a modelling exercise. See example in Figure 5 and 6 in Q13 Metadata).

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	provide insight into the degree of post-fire ecological change, including changes in post-fire stand structure (e.g., canopy cover or basal area loss). Stable or increasing trends of high severity, large-scale wildfire with high severity patch sizes greater than 250 acres, especially those overlapping treated areas, would trigger a re-evaluation of treatment pace, scale, and intensity. Other factors to consider along with the fire regime are climate, site history, fuel loading, vegetation structure.			

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13.3 Trends in acres of tree mortality, number of dead trees, and damage causing agents (conifer and oak)	Trends in tree mortality (both conifer and oak) would be assessed using Aerial Detection Surveys, with consideration of future products in development by the California Natural Resources Agency (CNRA).	Aerial Detection Surveys (ADS) Alternate Source: CNRA/CARB/NASA eDART	Data for tree mortality would come from Aerial Detection Survey (ADS) primarily accessed via the new Aerial Detection Survey dashboard for Region 5. Alternative and supplemental data sources may include Existing Vegetation Data (eVeg) and a change detection system like eDaRT. ADS products include: (1) acres affected by tree mortality and (2) estimates of the number of trees that have died. See WCS methodology for summarizing this metric.	Treatments areas are showing a decreasing trend in mortality of trees (acres) as categorized by damage causing agents following an episodic and epidemic disturbance event. Any increase would trigger further evaluation. Management may need to be evaluated to determine whether treatments were effective similar to protocol in (Young et al. 2023).

Guiding Question 14: How do treatments affect terrestrial and aquatic wildlife species populations?

Question Rationale: This question is designed to evaluate the trend in occupancy of terrestrial and aquatic wildlife species as influenced by management action designed to increase resilience to disturbances. This question will also evaluate the impacts from any unforseen disturbance events. Results from this question will help prioritize treatments, adapt our management approaches and to suggest whether additional or different management actions may be necessary to improve habitat resilience while maintaining habitat quality.

Scale: MAC Scale.

Frequency: Annually

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
14.1 California Spotted Owl (CSO), Goshawk, Great Gray Owl occupancy (location and detection)	Occupancy and reproductive status for the California Spotted Owl (CSO) in both Protected Activity Centers (PAC) and territories is important to track as they will be altered by both treatments and disturbance events. CSO habitat has been increasingly	Level 1: Protocol field surveys long term (occupancy and reproduction) (6 visits over 2 years) Level 2: Regional ARU data (occupancy) Level 3: Regional ARU data supplemented with project level	Summarize occupancy data to explore the changes in trends.	Short term DC: Adjust management to maintain CSO and Goshawk populations Long term DC: Maintain or increase number of CSO detections in PACs Desired conditions include a Short term and Long-term DC. Short Term DC: Adjust management to maintain CSO and Goshawk populations Long term DC: Maintain or increase number of CSO detections in PACs. Thresholds can be adapted for the relevant species.

	affected by large scale disturbance events (Ng et al. 2026).	passive ARU data (occupancy)		Conservation Strategy: Occupancy of CSO or Goshawk declines significantly over space or time. The number of CSO territories occupied by singles versus pairs increases significantly. Adaptive management would include updating and modifying management and monitoring as information and conditions change over time.
14.2 Foothill yellow-legged frog, Sierra Nevada yellow-legged frog, Yosemite toad occupancy	Occupancy of critical aquatic species is important for documenting effects from treatments.	Basking field surveys in identified habitat	Summarize basking field surveys by treatment type	Maintain or improve occupancy of amphibians.

Guiding Question 15: How do treatments affect the habitat quality for terrestrial and aquatic wildlife species in treated areas?

Question Rationale: This question is designed to evaluate the trend in habitat of terrestrial and aquatic wildlife species as influenced by management action designed to increase habitat resilience to disturbances. Results from this question will help prioritize treatments, adapt our management approaches and to suggest whether additional or different management actions may be necessary to improve habitat resilience while maintaining habitat quality.

Scale: MAC Scale. PAC and territory scale. Stream zones.

Frequency: Baseline and every 5 years depending on the pace and scale of treatment occurrence.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds

15.1 Canopy cover in CSO and Goshawk PACs, Territories and Riparian Zones	Canopy cover is an important indicator for terrestrial and aquatic wildlife. For example, CSO occupancy is greater in large/tall tree-dominated habitat with moderate to dense canopy cover (Jones et al. 2017, North et al. 2017a). Likewise, continuous corridors of riparian vegetation are highly desirable for the protection of fish and wildlife. Maintaining adequate canopy cover in riparian areas is important to prevent increasing stream temperatures and sediment or nutrient pulses that	See Indicator 14.5 for canopy cover. Remote sensing such as LiDAR would be used to quantify canopy cover. Dry/Moist gradient Stream Layer	Summarize canopy cover at the PAC and territory scale by the dry/moist gradient. Summarize canopy cover in riparian zones.	Maintain CSO PAC canopy cover above 50 percent and CSO territory for canopy cover for dry suitable habitat at 40% and moist habitat at 50%. Maintain adequate canopy cover in riparian areas to prevent increasing stream temperatures and sediment or nutrient pulses that could degrade aquatic habitat.

	could degrade aquatic habitat. Tracking canopy cover following treatments will be important to determine shifts and influence on wildlife populations.			
15.2 Late seral habitat	The highest quality nesting and roosting habitat for the CSO consists of areas with large/tall tree (more than 24 inches, but preferably more than 30 in QMD1) and moderate to high canopy cover (more than 40 percent cover) which is largely connected to the late seral habitat indicator (Tempel et al. 2016).	Canopy cover: This will be derived from LiDAR or other remote sensing product (e.g., Treemap). See 14.5. and supplemented or validated with field based data. Quadratic Mean Diameter (QMD) ranges: Derived for each Tree Approximate Object (TAO) using a remote sensing	Late seral habitat (Highest Quality Nesting and Roosting Conditions (HQNR)- 5M/D, 6-5D – tree size >24 inches and 40-100% canopy cover ; Suitable Habitat (SH) - 4M, 4D, 6-4D – tree size 11-24 inches and 40-100% canopy cover) by vegetation type (yellow pine, mixed conifer, red fir)	Maintain or increase acres of HQNR in PACs and territories and facilitate the recruitment of large, tall trees in nesting and roosting habitat outside of PACs and territories to enable creation of additional HQNR. Desired condition would be to maintain or increase acres of HQNR in PACs or territories. Thresholds can be adapted for the relevant species from the CSO Conservation Strategy: The amount of HQNR in PACs and territories decreases. Adaptive management would include updating and modifying management and

		product (e.g., LiDAR or Treemap). QMD ranges are found in (see Table 3 in Q12 Metadata). and supplemented or validated with field based data. Vegetation type: FVEG - WHR Type (see Table 2 in Q12 Metadata). and supplemented or validated with field based data. Dry/Moist gradient		monitoring as information and conditions change over time.
15.3 Canopy height	The indicator canopy height represents distance between the ground and the top of the canopy. Certain wildlife species CSOs select for tall tree cover	LiDAR Other LiDAR products such as from the UCD FOCAL group.	Cover of tall trees > 50 feet in relevant size classes. This would have to be combined with the canopy cover indicator.	Within PACs and Territories, retain patches of large/tall trees (more than 48 meters [approximately 160 feet]) with high canopy cover (more than 70 percent), both inside and outside of PACs, for developing future nesting sites.

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	(more than 160 feet) and against short tree cover (less than 53 feet). North et al. (2017a) suggest density of large/tall trees is likely the most important attribute for suitable owl nesting habitat, rather than the amount of canopy cover. The canopy height indicator will track the distribution of canopy height across the project area.			
15.4 Riparian vegetation openings	Riparian zones are biodiversity hotspots that play a fundamental role in the functioning of aquatic habitats. This indicator will track the	Planet or LiDAR data. Could also implement a drone strategy to quantify openings. Stream layer	Summarize openings in the riparian buffers.	Increase openings within riparian buffers and along streams.

	heterogeneity of riparian zones.			
15.5 Sediment deposition in amphibian habitat	Sediment deposition is an important indicator to track.	Field surveys in pools downstream from treatments	Summarize sediment deposition before and after treatment.	Reduction of sediment input into habitat.
15.6 CWHR Type (combination of canopy cover and QMD size class and vegetation type)	CWHR can be used to define forest composition and structure for a number of MIS species. The MAC Project is consistent with Forest Service Manual 2630– Management Indicator Species (MIS). MIS are animal species identified in the Sierra Nevada Forests MIS Amendment Record of Decision (ROD) signed December 14, 2007. Guidance regarding MIS	Canopy cover: This will be derived from LiDAR or other remote sensing product (e.g., Treemap). See 14.5. Quadratic Mean Diameter (QMD) ranges: Derived for each Tree Approximate Object (TAO) using a remote sensing product (e.g., LiDAR or Treemap). QMD ranges are found in Table A3.	Summarize CWHR for all combinations.	Maintain CWHR habitat for select target species (see Table 2 in Q15 Metadata).

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	directs Forest Service resource managers to (1) at Project scale, analyze the effects of proposed projects on the habitat of each MIS affected by such projects, and (2) at the bioregional scale, monitor populations and/or habitat trends of MIS. The MIS analyzes the effects of the proposed action on the habitat of selected Project-level MIS, no long-term impacts to MIS species were identified. Supporting Documentation: MIS Report	Vegetation type: FVEG - WHR Type (see Table 4 in Q12 Metadata).		

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Guiding Question 16: How did treatments affect the occurrence of Threatened and Endangered, Rare or other identified Forest Service Sensitive plants?

Question Rationale: The MAC project area provides habitat for diverse plant species including Threatened and Endangered, Rare or other Sensitive plants. Monitoring how treatments will affect plants is important to prevent a decline in the populations.

Scale: Plant population/habitat scale; variable buffer sizes might be used, and the rare plant habitat might exceed those buffers so it would be good to monitor inside or outside stated buffers to document expansion or contraction.

Frequency: Baseline and at a frequency that captures implementation.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
16.1 Rare Plant Population Trends	The MAC project area provides habitat for diverse plant species including Threatened and Endangered, Rare or other Sensitive plants. Monitoring how treatments will affect plants is important to prevent a decline in the populations.	FS Rare Plant Protocol	Summarize TES, rare and sensitive plant populations occurrences and habitat. Rare plants that occur in stands where forest thinning or fuels reduction treatments occur would be avoided (See Implementation Question #3). Additional monitoring	Maintain or improve the populations or habitat of TES, rare or sensitive plants. The desired condition would be to maintain or improve the populations or habitat of TES, rare or sensitive plants. The threshold would be any decline in these populations. Adaptive management would involve consulting a botanist for recommendation to adjust the treatments.

			might be required to track rare plants in surrounding exclusion zones. Rare plants not within forest thinning or fuels reduction treatments would fall within three potential categories: 1) Rare plants that benefit from low or moderate intensity fires 2) Rare plants that do not benefit from any fire 3) Rare plants that do not respond to fire.	

Guiding Question 17: How did treatments affect the occurrence of special terrestrial plant communities?

Question Rationale: Forest restoration treatments in mixed conifer forests are often done with objectives to move current forest structure toward historical conditions and, in turn, increase the system's resilience to future wildfires. Enhancing the heterogeneity of the horizontal canopy structure also increases the diversity of the understory light environment which may have implications for biodiversity of understory plant communities. This question will help track trends in plant populations in special terrestrial plant communities. There are also specific treatments such as mastication that may have direct impacts on terrestrial plant communities that can be tracked uisng appropriate monitoring indicators.

Scale: Terrestrial plant community scale. MAC Scale.

Frequency: Baseline and every 5 years depending on the pace and scale of treatment occurrence.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
17.1 Plant population trends in special terrestrial plant communities (see Table 5 in Q17 Metadata).)	Plant population trends are an important indicator used to track changes in special terrestrial plant communities.	Photo and field monitoring	Aspen/Meadow and Conifer Removal Protocol, CSE or other appropriate methodology	Maintain or improve special terrestrial plant communities

Guiding Question 18: Are project activities introducing and/or spreading invasive plants?

Question Rationale: Invasive species in any ecosystem can cause harm to the economy, environment, or human health. If left unchecked, invasive species can threaten native species, biodiversity, ecosystem services, recreation, water resources, agricultural and forest production, cultural resources, economies and property value, public safety, and infrastructure. Invasive species can

cause massive disruptions in ecosystem function by reducing biodiversity and degrading ecosystem health. Currently, there are approximately 1,085 acres of mapped known occurrences of 32 invasive plant species, within the MAC Project area. This question will help track whether invasives are being introduced in project areas or if known populations are spreading.

Scale: MAC and project scale.

Frequency: Baseline and every 5 years depending on the pace and scale of treatment occurrence.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
18.1 Non-native invasive cover	Non-native invasive cover is a suitable indicator for tracking the extent and cover of invasive species.	Remote sensing or plot level assessments.	Summarize cover of non-native invasives within project areas.	Decrease the cover of non-native invasives. The desired condition would be a decrease in the cover of non-native invasives and a threshold would be an increase which would trigger a change in management.
18.2 Acres of non-native species	This indicator will help identify the extent of non-native species across the MAC landscape.	FACTS and AGOL	See Implementation monitoring description in metadata.	Decrease the acres of non-native species. The desired condition would be to decrease the acres of non-native species. An increase might indicate a threshold which would lead to a change in management.

Guiding Question 19: Are we meeting treatment objectives for targeted invasive species infestations (i.e. eradication vs. control)?

Question Rationale: Invasive species in any ecosystem can cause harm to the economy, environment, or human health. If left unchecked, invasive species can threaten native species, biodiversity, ecosystem services, recreation, water resources, agricultural and forest production, cultural resources, economies and property value, public safety, and infrastructure. Invasive species can cause massive disruptions in ecosystem function by reducing biodiversity and degrading ecosystem health.

Scale: Non-native plant infestations.

Frequency: Baseline and annually depending on the pace and scale of treatment occurrence.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
19.1 Post-treatment efficacy in FACTS	This indicator tracks whether we are meeting our annual objectives to decrease non-native species.	AGOL and FACTS USDA Forest Service's *Data Recording Protocols and Requirements for Invasive Species Survey, Inventory and Treatment* (2014).	See Implementation monitoring description in metadata.	Treatment objective for targeted infestation is being met with current treatment strategy (i.e. eradication vs control).
19.2 Reduction in non-native infestation (acres/cover)	This indicator is intended to track reduction in invasive plant cover in a treated	Remote sensing or plot level assessments.	Data summary should be a percent reduction in cover in treated infestations.	Improve and protect plant and wildlife habitat and biodiversity. Decrease the cover of non-native invasives.

	infestation (not at the project scale).	USDA Forest Service's *Data Recording Protocols and Requirements for Invasive Species Survey, Inventory and Treatment* (2014).		

Guiding Question 20: Are we making progress removing priority invasive infestations over the long term?

Question Rationale: Invasive species in any ecosystem can cause harm to the economy, environment, or human health. If left unchecked, invasive species can threaten native species, biodiversity, ecosystem services, recreation, water resources, agricultural and forest production, cultural resources, economies and property value, public safety, and infrastructure. Invasive species can cause massive disruptions in ecosystem function by reducing biodiversity and degrading ecosystem health.

Scale: Non-native plant infestations.

Frequency: Baseline and every 5 years depending on the pace and scale of treatment occurrence.

Summary of Indicators:

Indicator	Rationale	Data Source	Data Gathering Process and Synthesis	Desired Conditions and Thresholds
20.1 Percentage of priority	This indicator is important to understand	AGOL and FACTS	See Implementation monitoring	Increase acres treated of priority infestations.

invasive acres annually treated	progress on treatment of priority invasive infestation areas.	USDA Forest Service's *Data Recording Protocols and Requirements for Invasive Species Survey, Inventory and Treatment* (2014).	description in metadata.	The desired condition would be to increase acres treated of priority infestations and the threshold would be a decrease in acres treated of priority infestations. Consider setting a SMART goal for a minimum of 50% of priority infestations treated annually. Adaptive management is detailed in several documents. Invasive species management guidance can be found in Forest Service Manual 2900 Invasive Species Management. The National Strategy and Implementation Plan for Invasive Species Management provides additional management options, identifying key management strategies such as (1) prevention, (2) early detection and rapid response, (3) control and management, and (4) rehabilitation and reforestation.
20.2 Percentage of priority acres successfully restored after 5 years	This indicator is important to track long term success of treating priority invasive areas.	AGOL and FACTS USDA Forest Service's *Data Recording Protocols and Requirements for Invasive Species Survey, Inventory and Treatment* (2014).	See Implementation monitoring description in metadata.	Decrease priority infestations. A SMART goal of at least 50% of targeted (eradication) infestations successfully restored after 5 years. The desired condition would be a decrease in priority infestations, and a threshold would be no change in priority infestations. Adaptive management is detailed in several documents. Invasive species management guidance can be found in Forest Service Manual 2900 Invasive Species Management. The National Strategy and Implementation Plan for Invasive

				Species Management provides additional management options, identifying key management strategies such as (1) prevention, (2) early detection and rapid response, (3) control and management, and (4) rehabilitation and reforestation.

2.4 Cultural Monitoring

The MAC Project is within ancestral lands of numerous California Native American Tribes, and who are the first and continued stewards of these lands. Therefore, the final component of the MAC Monitoring Plan is to address cultural and Traditional Ecological Knowledge (TEK) related objectives. These may range from monitoring the level of tribal participation in implementation of management activities, to assessing benefits of treatments to culturally significant species, applying adaptive management to better protect culturally significant resources, or assessing benefits of TEK practices implemented in the project. However, these objectives cannot be developed, planned or implemented without collaboration and participation by Tribes.

The first milestone in the development of the cultural and TEK objectives will be to develop a Tribal Monitoring Advisory Committee. The charge and goals of this committee will align with UMRWA's Tribal Engagement Plan (2026) and will inform cultural monitoring questions and will also explore potential pathways for Tribes to participate or lead implementation of cultural-related monitoring. The following are example cultural and TEK-related monitoring questions that may be explored:

- How many management activities have incorporated Traditional Ecological Knowledge in the planning or execution phases in the past year? E.g., cultural burning and collaborative creation of burn plans for specific areas that would benefit ecologically from fire.
- How many California Native American Tribes participated in the implementation of acreage treatment? How many Acres per each Tribe?
- How many acres of prescribed fire was listed as including cultural objectives directly proposed by Tribes, or was informed prior to implementation by Tribal Consultation, how do the long-term effects of a cultural burn differ from those of a prescribed fire?

- How many monitoring related meetings have California Native American Tribes participated annually?

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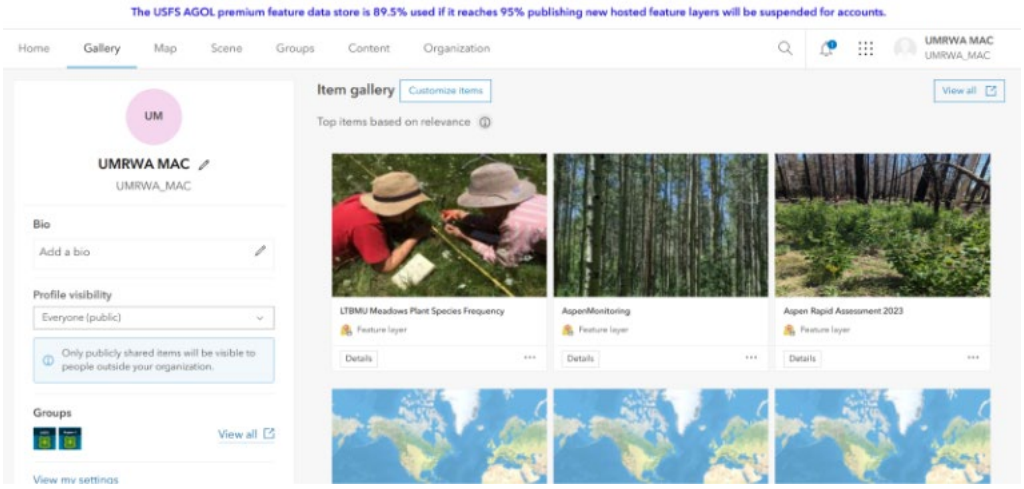
Section 3. Implementation and Field Monitoring Plan

3.1 Solution: Field-Based Geospatial Technology

Esri's platform takes a map-based form and form-based map approach to data collection. UMRWA will deploy four integrated tools:

- **ArcGIS Field Maps:** map-centric data collection for capturing treatment polygons, plot locations, and field observations with GPS precision.
- **Survey123:** form-centric data collection for structured monitoring protocols, BMP inspections, and reports with photo attachments and branching logic.
- **Custom HTML Dashboard:** a publicly accessible web application modeled after the Placer County Fuels Reduction Projects dashboard (https://rfh-dashboard-v2-0-6.netlify.app/), displaying real-time implementation and monitoring data without requiring an Esri account.
- **MAC Monitoring Plot Selection Tool:** a web-based interactive application, developed with Becky Estes (Central Sierra Province Ecologist, Eldorado NF), for spatially distributing and finalizing monitoring plots. Modeled after the Santa Cruz Mountains Forest Monitoring plot designer (https://scmforests.org/plot-designer.html).

All maps, surveys, and data are stored in the UMRWA_MAC ArcGIS Online (AGOL) account, a headless, project-owned account created by Lukas Wilkinson (USDA Forest Service). This ensures all content persists under a single project account regardless of staff changes and can be shared with Forest Service partners and ACCG members without requiring individual Esri licenses.



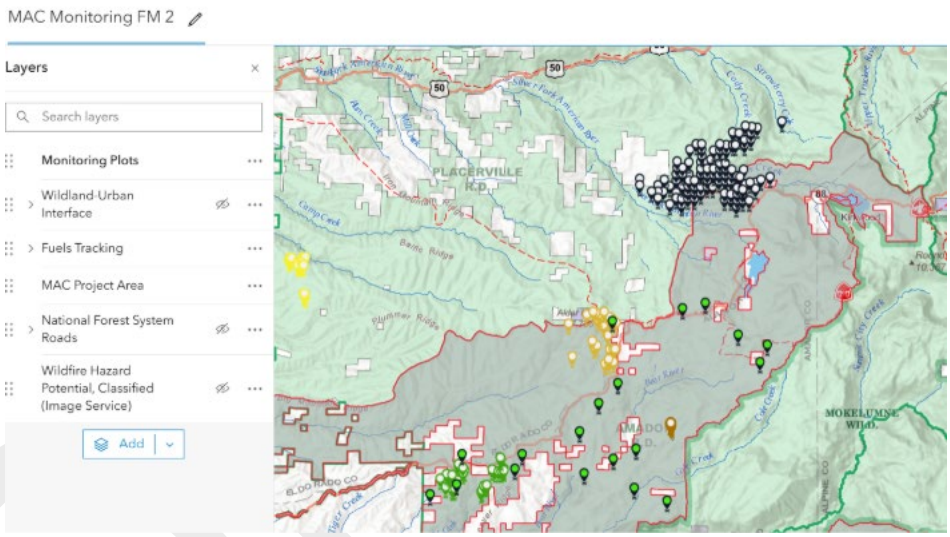
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> **Key Advantage:** *UMRWA_MAC is not tied to any individual. Data belongs to the project, not a person, so nothing is lost with staff turnover.*

Implementation Examples

Field Maps: Treatment Progress Tracking

UMRWA will use a Treatment Progress Layer, a polygon feature class in AGOL, to track treatment unit status in real time. As work is completed, the crew updates status (In Progress, Mechanically Complete, Cultrual or Prescribed Fire Applied), records the date and contractor, and attaches geotagged photos. The project manager sees updates immediately. The same layer feeds the HTML dashboard for partner reporting.



Map 2. The draft UMRWA_MAC Field Map for Tracking Implementation.

> **Example:** *Crew arrives at Unit 14A after mechanical thinning. On an iPad, they open Field Maps, tap the polygon, update status to 'Mechanical Complete,' and attach three photos. The project manager sees the update within seconds. The dashboard reflects the new acreage automatically.*

Survey123: Long-Term Forest Trends Monitoring

Survey123 guides a two- to three-person crew through the monitoring protocol, modeled on the Santa Cruz Mountains Long Term Forest Stewardship Monitoring Program (SCMLTFSMP) protocol, capturing:

- **Plot ID and GPS coordinates (auto-populated).**
- **Vegetation type and seral stage (dropdown menus).**
- **Tree-by-tree tally: species, DBH size class, crown class, live/dead (repeating section).**
- **TPA and SDI (auto-calculated from entered data).**

- **Canopy cover and shrub cover by functional group along N-S and W-E transects.**
- **Down and dead surface fuels by size class.**
- **Directional photo points (N, S, E, W) for longitudinal comparison.**
- **Invasive species presence, cover class, and photos.**

Permanent plot GPS coordinates are stored in Field Maps so crews navigate directly to the same location each visit, essential for detecting trends over time. All data syncs to the UMRWA_MAC AGOL account when the device reaches cell coverage.

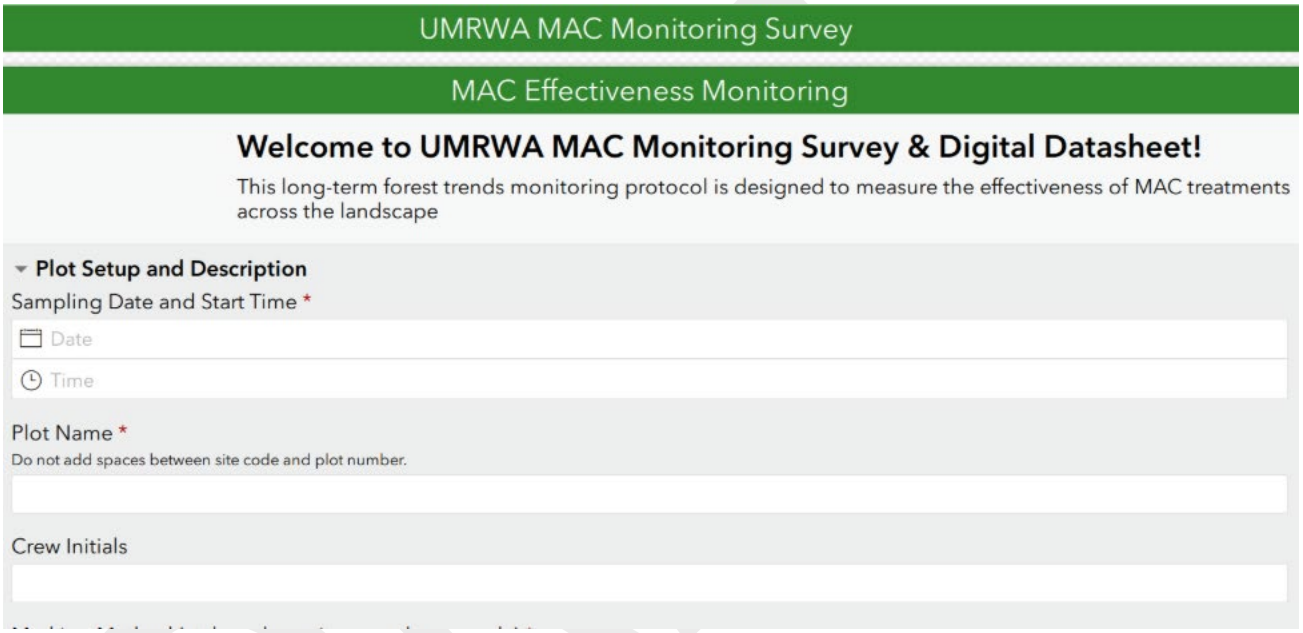


Figure 2. Example Survey123 MAC Effectiveness Monitoring Form.

> **Example:** *A* two- to three-person crew *establishes a 1/10-acre circular plot in a recently thinned stand. One calls measurements; the other enters data in Survey123. The form prevents submission until required fields are complete. Upon sync, the project coordinator reviews submissions in AGOL and flags any outliers for follow-up.*

Survey123: BMP Inspection Reports

UMRWA will use a Survey123 inspection form to track BMP compliance (Guiding Question 4). The form captures location, weather, contractor representative, a BMP checklist, narrative observations, and required photos. Completed reports can be auto converted to a formatted PDF or Word document for Forest Service submission, eliminating manual report writing.

3.2 MAC Monitoring Questions: Tool Summary

The table below maps key MAC Monitoring Workgroup guiding questions to specific mobile GIS tools and workflows.

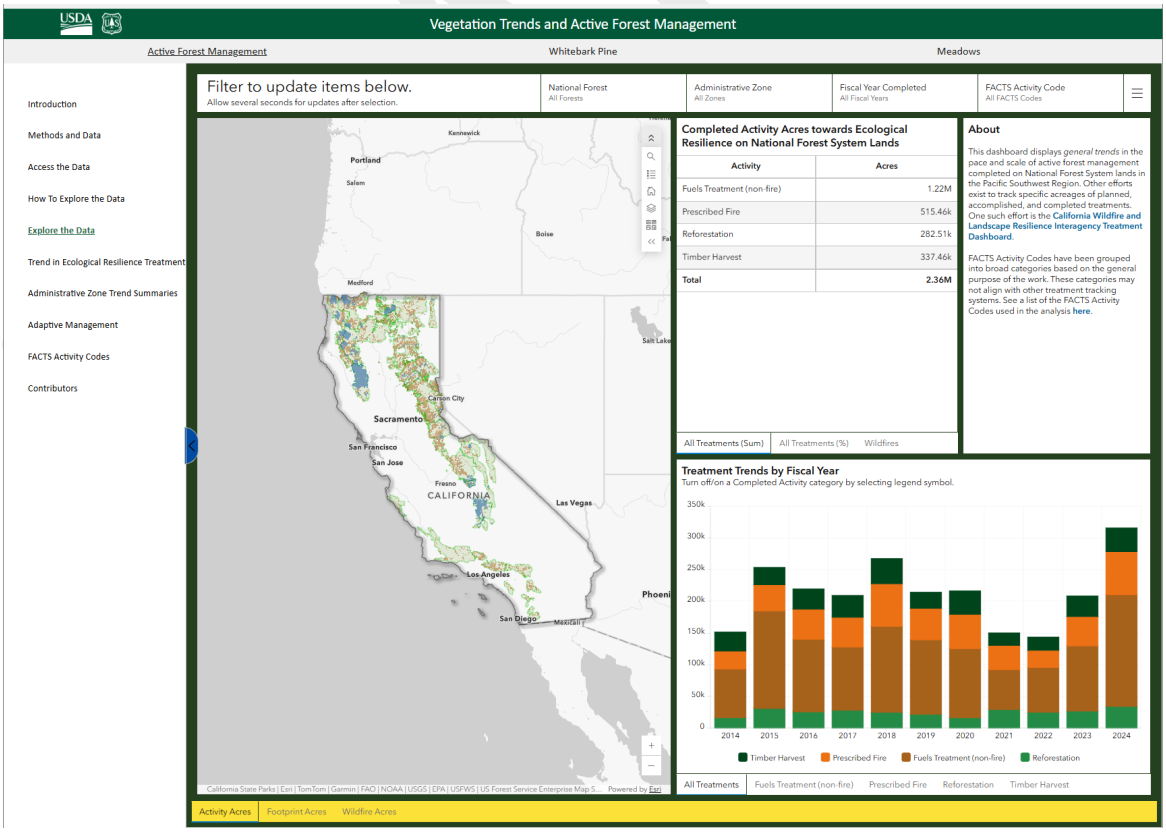
MAC Guiding Question	Tool	How it Answers the Question	Example Indicator
Q1: What percentage of the WUI surrounding at-risk communities have received wildfire mitigation treatments?	Field Maps	Crew maps completed treatment polygons with type, date, and status. Acreage auto-calculates in AGOL.	1.1: Acres by treatment type in WUI. Polygon digitized on-device; dropdown records treatment type and status.
Q2: How many miles of vegetation along ingress and egress routes have been maintained to provide safe escape routes?	Field Maps	Crew traces route segments by GPS, flags start/end points, records treatment width and method.	2.1: Miles of vegetation treated along Level 3 to 5 roads. Line feature captures route; form records date and method.
Q4: Are project Best Management Practices (BMPs) designed to protect beneficial uses of water being implemented as planned?	Survey123	Structured BMP checklist form completed at each site visit. Photos attached. Auto-generates inspection report for Forest Service.	4.1: BMP implementation rates. Required/completed BMP fields, photos, and narrative linked to treatment polygon.
Q8: Are shaded fuelbreaks being created and properly maintained to meet fire management objectives?	Survey123 + Field Maps	Crew locates plot in Field Maps, then completes a CSE-based Survey123 recording canopy cover, shrub class, and invasives.	10.1: Canopy cover by overstory and shrub size class. Photo points and transect data linked to fuelbreak polygon.
Q12: Has the density, composition and structure of forest vegetation been maintained or improved to increase resilience to human and natural disturbances (e.g., wildfire, drought)?	Survey123 + Field Maps	Plot-based crew records TPA, basal area, species composition, and size class per CSE protocol at GPS-locked permanent plots.	14.2: Trees per acre (TPA). GPS coordinates locked in Field Maps; Survey123 captures DBH, species, and crown class.
Q13: Have treated areas experienced fewer large-scale disturbances (e.g., wildfire, insect outbreaks) compared to untreated areas over the project implementation period?	Field Maps + Dashboard	Crew maps post-disturbance observations. Dashboard overlays disturbance polygons against treatment history for comparison.	15.1: Area burned at high/moderate severity in treated vs. untreated stands. Features auto-summarized in dashboard.
Q18: Are project activities introducing and/or spreading invasive plants?	Survey123 + Field Maps	Crew records invasive species as georeferenced points with species, percent cover, and photos.	20.1: Non-native invasive cover. Point feature with species from dropdown, cover class, and photo attachment.

3.3 Custom HTML Dashboard

UMRWA will build a custom HTML-based dashboard hosted independently (e.g., Netlify or GitHub Pages) and connect to the UMRWA_MAC AGOL account via Esri's REST API. Data collected in the field flows automatically into the dashboard with no manual export required. Any user with a web browser can access it; no Esri account is needed.

The dashboard will include two views:

- **Implementation Tracker:** interactive map of treatment unit status, with summary panels for acres treated by type, miles of fuelbreaks, and annual progress toward targets (addresses Q1, Q2, Q4, Q5).
- **Long-Term Monitoring Trends:** charts for TPA, SDI, canopy cover, shrub cover, and invasive species detections over time; plot locations clickable on the map to show full monitoring history (addresses Q10, Q14, Q20).



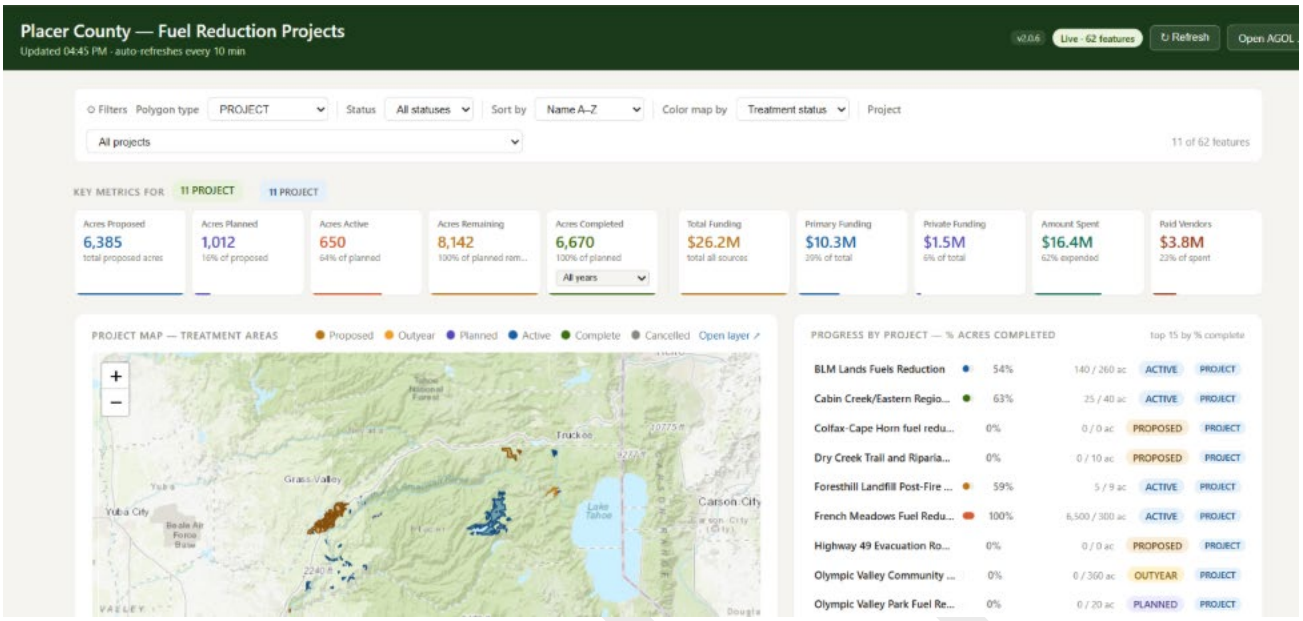


Figure 3. Examples of a live Implementation Tracker dashboard (R5 Broader Scale and Placer County – Fuels Reduction Projects).

> **Example:** *At an ACCG quarterly meeting, UMRWA displays the live Implementation Tracker. Stakeholders follow along on their phones at the same URL. The Monitoring Trends view shows TPA declining toward the target range in post-treatment plots, with no report preparation required.*

3.4 Monitoring Plan for Vegetation Data Collection

This section lays out a comprehensive monitoring plan for vegetation field data collection in the MAC monitoring project. This monitoring plan will provide the framework for where and how to install field monitoring plots. A field monitoring component will be identified in the MAC Monitoring Plan and above in the tool summary section above associated with each question and indicator. This plan outlines where and how the field monitoring will be applied. Some field monitoring will be associated with specific questions and indicators (e.g., terrestrial wildlife) whereas this plan covers how to establish broad scale vegetation field monitoring in projects.

There are a few background data sources that should be considered when designing vegetation monitoring plots. ACCG Monitoring Plots were established in the Cornerstone CFLR project. These monitoring plots were established in prior mechanical treatment projects that have been partially treated. Although it is unlikely that these plots will be treated under MAC there are opportunities for broadcast burning and follow up monitoring to happen over the life of the MAC project. FACTS Completed Units will provide context for treatment plots and a complete understanding of prior treatment.

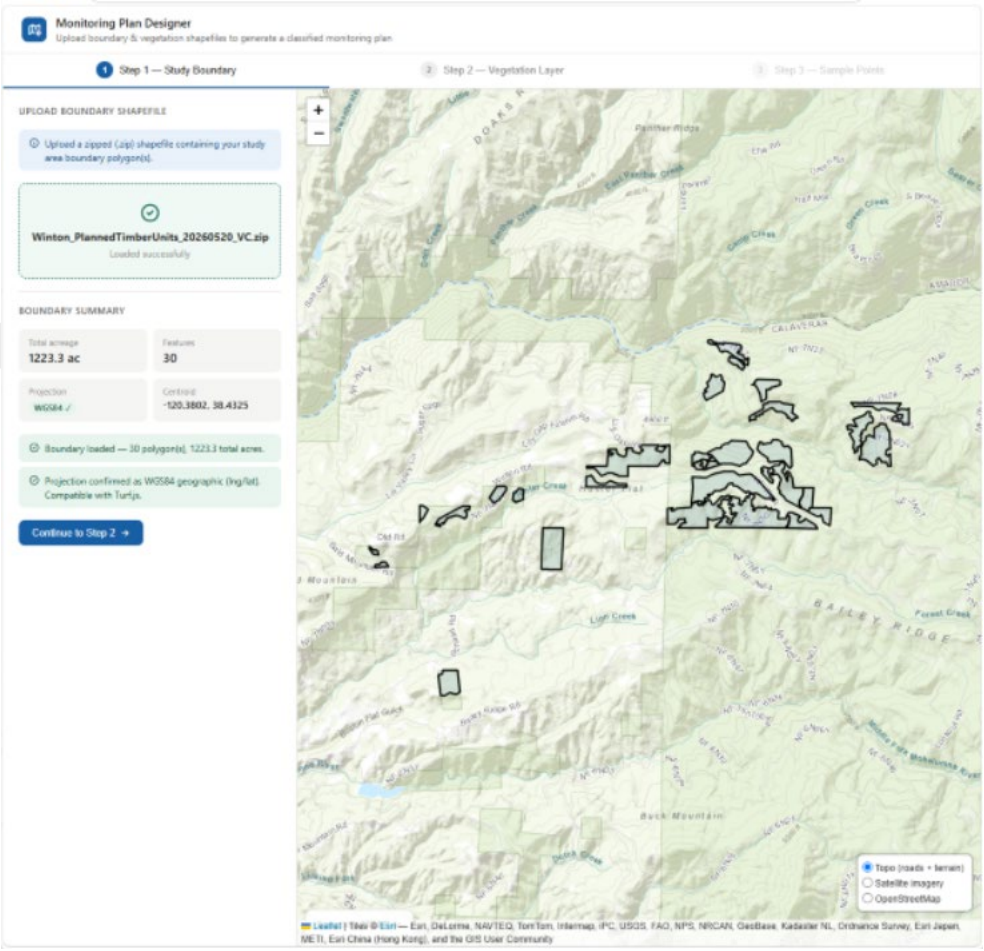
3.5 Monitoring Plot Selection Tool

UMRWA and the USDA Forest Service (Becky Estes, Central Sierra Province Ecologist) are developing a web-based plot selection tool for the MAC project, modeled after the Santa Cruz Mountains Forest Monitoring plot designer. The tool allows project coordinators to:

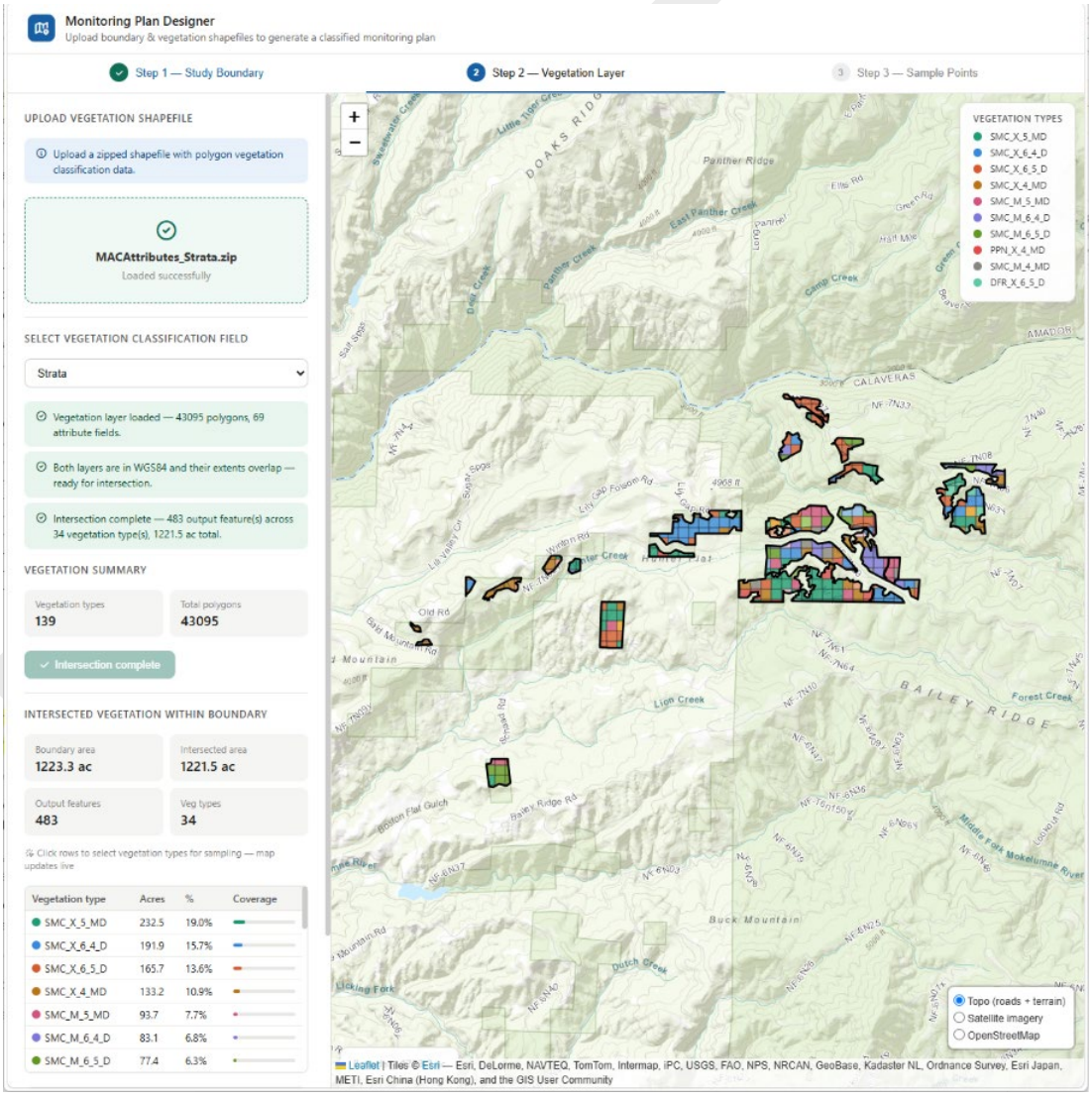
- Load MAC treatment unit polygons from the UMRWA_MAC AGOL account.
- Filter by vegetation type, treatment type, or other important overlays such as CSO PACs
- Set sampling parameters and generate randomized or stratified-random plot distributions.
- Review and manually adjust candidate plot locations.
- Export finalized plots directly to UMRWA_MAC AGOL as a permanent navigation layer in Field Maps to be then used in the field

The process for selecting plots is as followed:

Step 1: Project Boundary: Load the proposed project boundary from AGOL or from USDA Forest Service Silviculturists.



Step 2: Vegetation Classification: Begin with the raw MAC_AllAttributes dataset. This dataset has numerous attributes that can be used to stratify the project area to target different types of monitoring. For example, in order to establish vegetation monitoring plots that capture the variability of forest types, the user might choose to develop strata that represent WHR forest type, tree size, canopy cover, and mesic/xeric gradient. This can be summarized within a new field in the MAC_AllAttributes dataset. This would result in unique classifications. For example, Sierra Mixed Conifer in a xeric gradient in Size Class 4 with open canopy conditions. The strata can then be identified across the project area.



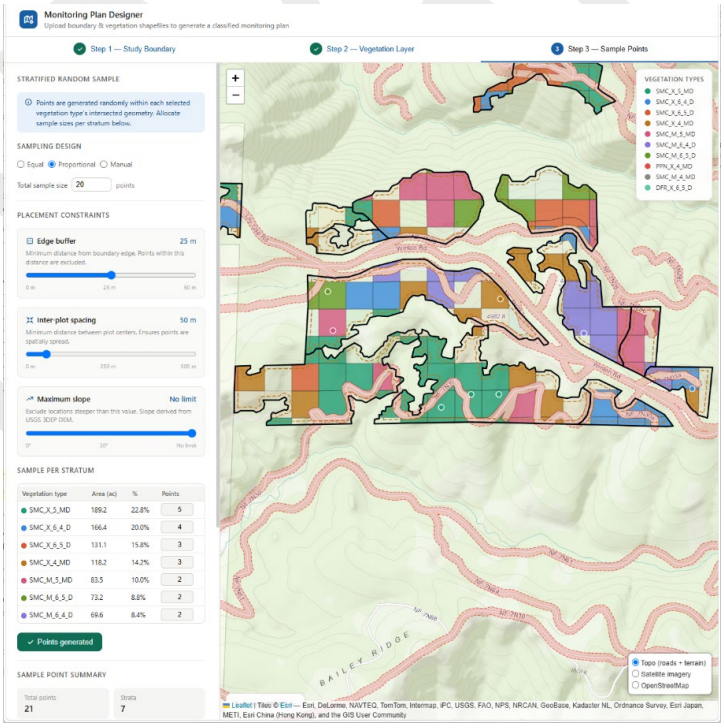
Step 3: A number of overlays can also be used to further refine monitoring plots. For example, we might be interested in monitoring habitat of CSO PACs in late seral forests.

The user can use the CSO PACs as an overlap to further refine where plots would be placed.

Step 4: A number of exclusion buffers might also be of interest. Most users might want to buffer around roads so that monitoring plots are not put close to roads.

Step 5: The final step would be to create the monitoring plots. The user might choose to set an appropriate number of plots to provide a statistically meaningful depending on the indicator chosen to answer a question. A rule of thumb would be to determine the number of plots to represent a 500x500 meter grid in the project area (61 acres). For a 250x250 grid the area would be roughly 15 acres. For example, if the project area is 2,368 acres, then you would roughly need 38 plots in the project area.

- Monitoring plots can be assigned randomly or strategically (based on priorities).
- Identify edge buffer, inter plot spacing and maximum slope.
- Identifying Controls (optional): identify the areas adjacent to the project area that could function as controls. You can use the monitoring combos in Step 4 as guidance. The most common combos would be the focus of control areas. Make sure to clip out FACTS data and any proposed or future projects that would lead to a control plot being treated.



Key Advantage: *Plot locations are permanently documented with a record of why and how they were selected, essential for the long-term scientific integrity of the monitoring program.*

3.6 Conclusion

Forest collaboratives are challenged with pace and scale, and human capital is limited. Field-based geospatial technology multiplies the effectiveness of a small crew, enabling real-time tracking, rigorous long-term monitoring, and transparent reporting to partners without adding headcount.

UMRWA's deployment of Field Maps, Survey123, a custom HTML dashboard, and the MAC plot selection tool, all anchored in the UMRWA_MAC AGOL account, positions the MAC project to meet its monitoring obligations, support adaptive management, and demonstrate progress to the Forest Service, ACCG, water agencies, and the public.

The Yosemite Rivers Alliance (formerly known as Tuolumne River Trust) demonstrated that these tools could support treatment of 6,000+ acres of fuel reduction and 2,400 acres of reforestation for the SERAL project with a limited team. UMRWA is positioned to build on that model at the scale of the MAC project.

Section 4. Funding Plan

4.1 Background

Funding and capacity are anticipated to be the primary drivers determining future implementation of the MAC Project Monitoring Plan. Future funding for monitoring, and USDA FS staffing capacity to perform the monitoring, is unclear at this time. Therefore, this plan is intended to identify 1) potential future funding sources and 2) strategies to implement all, or portions of, the MAC Monitoring Plan, to adapt to uncertainty in future funding and resource availability. This plan is meant to serve as a guide and to be a living document, updated as needed.

4.2 Past Monitoring Funding Models

The Amador-Calaveras Consensus Group (ACCG) collaborative's Cornerstone Monitoring Strategy (2016) was developed and implemented as part of ACCG's Collaborative Forest Landscape Restoration (CFLR) project (2012-2022). This was a collaborative monitoring effort, with numerous partners implementing various components of the strategy, with most of the funding to implement this monitoring effort coming from federal dollars and internal USDA FS staff capacity. The Cornerstone monitoring implementation framework and funding model is not anticipated to be a reliable model for implementing the MAC Monitoring Plan, at least not

in its entirety as funding tied specifically to monitoring is unavailable and other sources will need to evaluated to make the program whole.

4.3 Proposed MAC Monitoring Funding Approach

Potential Funding Sources

Assuming implementation of the MAC Monitoring Plan by the USDA FS staff will be limited in the future, the expectation is that implementation of this plan will likely be funded predominately through state grant programs. This funding will most likely come from implementation, capacity building, or monitoring-specific grant programs. However, since grant programs specific to funding research and monitoring are highly competitive, funding for implementation of the MAC Monitoring Plan will likely come through a small portion of state-funded implementation grants (e.g., 5-10% of total implementation grant amount). It is important to note that this funding plan assumes that availability of state funding will not diminish into the future.

4.4 MAC Monitoring Costs & Prioritization

MAC Monitoring Costs

The estimated total cost to implement the MAC Monitoring Plan on an annual basis is $514,072- $620,540, assuming all questions and indicators are addressed using a combination of desktop- and field-based methods. Assuming funding for this monitoring program will predominantly come from a small portion of state-funded implementation grants, only a subset of the monitoring plan could be implemented annually (e.g., 5-10% of a $5M total grant would be $250K-$500K total for monitoring, or $62.5K-$125K annually for a 4-year grant term).

4.5 MAC Monitoring Implementation Prioritization Strategy: Modules

Assuming resource availability will be limited into the future, the monitoring plan questions and indicators were stratified into modules (Table 1). The module framework, adapted from Butte County RCD's Concow Resilience Monitoring Plan (2020), is utilized here in this plan to help UMRWA and other partners tailor their monitoring efforts based on potential funding availability and project-specific goals at the time of applying for grants.

Under this module framework there are Core and Additional Modules. Core Modules are those that are essential questions and indicators that should be prioritized in order to address key project outcomes, assuming limited resource availability. These modules can be addressed at a relatively low cost, due to ease of data collection and processing, and relatively low staffing needs. Additional, non-core modules are those that address other important components of the monitoring plan, that with additional funding, capacity and expertise, could be implemented to complement or bolster information gleaned from the Core Modules.

The MAC Project Monitoring Plan Module framework includes three themes that address ACCG collaborative's triple bottom line mission and also aligns with the MAC Project Environmental Impact Statement's (EIS) Purpose & Need and UMRWA's Tribal Engagement Plan goals, including: 1) Wildfire Risk & Community Protection, 2) Socioeconomic & Cultural Viability, and 3) Ecological Health & Resilience. Table 1 details the MAC Core and Additional Modules contained within these three themes. The table also details estimates on annual cost for each module. Additional monitoring program-related costs are also detailed it the table. Monitoring questions that are assumed to be completed by USDA FS or that are required to occur pre-implementation are not included in modules but are detailed in the table. The estimated cost to just implement the Core Modules on an annual basis is approximately $158,200 - $175,700. However, actual costs to perform Core and Additional modules will depend on consultant rates, and scope and scale of services. These numbers reported are estimates. Also, should assume a 3.3% increase in costs annually (Venuti et al. 2020). For more details on methods for each module refer to the MAC Monitoring Plan.

Table 1: MAC Project Monitoring Plan Funding Modules

Pre-implementation monitoring required (funding source already determined), or USDA FS- or other entity-led monitoring (In-kind)						
Imp. Q. 4: BMPs – USDA FS led. Eff. Q 16.1: CSO population dynamics (occupancy), existing ARU network (Level 2) – University of Wisconsin. Eff. Q 16.1: Pre-implementation bird surveys (CSO, goshawk, great grey owl) – Funded by USDA FS or partner implementation grants. Post-implementation surveys still would need to be funded (see Ecological Health Module 7). Eff. Q. 18, 20.1, 21.2: Pre-implementation botany surveys – Funded by partner implementation grants. Post-implementation surveys still would need to be funded (see Ecological Health Core Module Part B and Module 9).						
MAC Module	**Focus**	**Objective**	**Questions** (all indicators, unless specified)	**Approach, responsibility, assumptions, cost estimates**	**Benefits/ Tradeoffs**	***Estimated* Annual Cost Range (upper range-25% above estimate)**
Module Theme 1. Wildfire Risk & Community Protection						
Core Module	Remoted-sensed fire-related and other metrics	Quantify fuel loading and fuelbreak condition with available,	Imp Qs: 1, 2, 5	Desktop analysis Consultant Hourly rate: $200 Hours: 80	Relatively low-cost.	$16,000-$20,000

		ready-to-run datasets.	Eff Qs: 10, 11, 12, 13.2-13.4			
Module 2	Remote-sensed fire-related and other metrics	Same as Core Module but assumes datasets are not ready-to-run and need to be generated before utilizing.	Imp Qs: 1, 2, 5 Eff Qs: 10, 11, 12, 13.2-13.4	Desktop analysis Consultant Hourly rate: $200 Hours: 160	Additional time/$ to process data.	$32,000-$40,000
Module 3	Photo points	Fuel load reduction, fuelbreak treatment effectiveness to inform maintenance needs.	Imp Qs: 2 Eff Qs: 10, 13.1	Field-based (assumes 10 plots for 1K-acre project) Implementation team (assumes 2 crew members) Hourly rate: $120 Hours: 24 hrs (3 8-hr days) Travel cost: $500 Pre- and post-season planning, processing (80 hours): $9,600	Relatively quick timeframe to collect field-based information.	$15,860-$19,825
Module 4	Field-based vegetation plots	Quantify fuel loading and fuelbreak condition based on in-field conditions.	Eff Qs: 10, 13.1-13.2	Field-based CSE plots Assumptions: 10 plots for 1K-acre project, 3-hours/plot, 2 plots/day, 5 field days (10-hrs/day) Consultant team: 1 Project Manager, 2-person crew Crew cost, total hours: $24,000 (100 hours x 2	Quantitative field-based data.	$43,000-$53,750

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				people at $120/hr) Project Manager cost, total hours: $18,000 (120 hours, $150/hr) to oversee contract, invoicing, data management, analysis and reporting. Travel cost (assume ~250 miles/day, $0.725/mile): $1,000		
Module Theme 2. Socioeconomic & Cultural Viability						
Core Module	Remote-sensed or desktop-derived socioeconomic, cultural data	Quantify socioeconomic, cultural data with available, ready-to-run datasets.	Qs: 8, 9, all Cultural-related questions (TBD)	Desktop analysis Consultant Hourly rate: $200 Hours: 40	Relatively low cost	$8,000-$10,000
Module 2	Remote-sensed or desktop-derived socioeconomic, cultural data	Quantify socioeconomic, cultural data using datasets that will need to be generated before utilizing.	Qs: 8, 9, all Cultural-related questions (TBD)	Desktop analysis Consultant Hourly rate: $200 Hours: 80	Additional time/$ to process data.	$16,000-$20,000
Module 3	Tribal Advisory Committee	Form and convene a Tribal Monitoring Committee to advise on cultural-related monitoring.	All Cultural-related questions (TBD)	Meet virtually quarterly with Tribal reps from across the region.	TBD	TBD
Module 4	Culturally significant botanical field assessments	TBD	Eff Q: 19.2	TBD	TBD	TBD

Module 5	Local jobs/ contracts, and forest products	Utilize modeling to quantify this module at the regional scale.	SE Qs: 8, 9	Treatments for Restoration Economic Analysis Tool (TREAT) model, Consultant Hourly rate: $200 Hours: 40	Higher cost, specialized expertise.	$8,000-$10,000
Module Theme 3. Ecological Health						
Core Module Part A	Remote-sensed vegetation and habitat metrics	Quantify ecological health goals: resource protection areas, forest structure, CSO habitat, CHWR types, late seral habitat, structure heterogeneity, invasive species, and disturbances. Utilize available, ready-to-run datasets.	Imp Qs: 3.1-3.5 Eff Qs: 10, 14, 15, 17.1-17.5, 17.7, 20, 21, 22	Desktop analysis Consultant Hourly rate: $200 Hours: 120	Relatively low cost	$24,000-$30,000
Core Module Part B	Invasive plant species field assessments	• Non-native invasive plant species cover • Reduction in non-native infestation (post-implementation)	Eff Qs: 20.1, 21.2	Non-native invasive cover Consultant Cost/acre: $22/acre (e.g., 1,000-ac project footprint)		$22,000-$27,500
Module 2	Remote-sensed vegetation and habitat metrics	Same as Core Module Part A but assumes datasets are not ready-to-run and need to be generated before utilizing.	Imp Qs: 3.1-3.5 Eff Qs: 10, 14, 15, 17.1-17.5, 17.7, 20, 21, 22	Desktop analysis Consultant Hourly rate: $200 Hours: 240	Additional time/$ to process data.	$48,000-$60,000
Module 3	Photo points	Canopy cover; plant population trends	Eff Qs: 10, 19	Field-based (assumes 10 plots	Relatively quick timeframe	$15,860-$19,825

		in special terrestrial communities.		for 1K-acre project) Implementation team (assumes 2 crew members) Hourly rate: $120 Hours: 24 hrs (3 8-hr days) Travel cost: $500 Pre- and post-season planning, processing (80 hours): $9,600	to collect field-based information	(Module 3 cost would be $0 if performing Wildfire Risk Module 3)
Module 4	Field-based vegetation plots	Quantify ecological health goals: resource protection areas, forest structure, CSO habitat, CHWR types, late seral habitat, aspen/meadows, structure heterogeneity, invasive species, and disturbances.	Eff Qs: 10, 17.1-17.5, 17.7, 19	Field-based CSE plots (assumes same plots as Wildfire Risk Module 4 are being sampled). Assumptions: 10 plots for 1K-acre project, 1 additional hour/ plot on top of Wildfire Risk Module 4, 2 plots/day, 10 field days (10-hrs/day) Consultant team: 1 Project Manager, 2-person crew Crew cost, total hours: $2,400 (10 hours x 2 people at $120/hr) Project Manager cost, total hours: $1,200 (8 hours for additional data	Quantitative field-based data.	$3,600 - $4,500 (annual cost assumes Wildfire Risk Module 4 is occurring)

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				processing, $150/hr). Travel cost: no additional cost above WR Module 4		
Module 5	Drone-based vegetation assessments, Aerial Detection Surveys (ADS)	Tree mortality trends. And quantify ecological health goals: resource protection areas, forest structure, CSO habitat, CHWR types, late seral habitat, structure heterogeneity, invasive species, and disturbances.	Eff Qs: 15.3 and all under EH Module 4.	Drone-based vegetation assessments, Consultant This would be sufficient time to survey an estimated 50-100 footprints of 50-100 acres each over a 3-month period, depending on accessibility, along with validation data at 30-50% of plots.	Quantitative field-based data, specialized expertise and equipment needed.	$97,625 - $122,031
Module 6	Aquatic species, habitats	FYLF, SNYLF and YOTO occupancy	Eff Qs: 16.2, 17.5	Basking field surveys in identified habitat 5 field days (10-hrs/day) Consultant team: 1 Project Manager, 2-person crew Crew cost, total hours: $2,400 (10 hours x 2 people at $120/hr) Project Manager cost, total hours: $1,200 (8 hours for additional data processing, $150/hr).	Quantitative field-based data, specialized expertise needed.	$19,000 - $23,750

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				Travel cost: $1,000		
Module 7	CA spotted owl, goshawk & great grey owl	Population dynamics (location and detection, post-treatment and potentially larger scale)	Eff Qs: 16.1 (Level 1)	Protocol level surveys, Consultant Cost/acre: $14 per acre of suitable habitat (cost will depend on consulting firm awarded contract), costs also assume pre-survey planning and data transfer to FS. (e.g., 1,000-ac project footprint)	Quantitative field-based data, specialized expertise needed.	$24,186 - $30,233
Module 8	CA spotted owl, goshawk & great grey owl	Population dynamics (expansion of ARU network- Level 3)	Eff Qs: 16.1 (Level 3)	Regional ARU data supplemented with project level passive ARU data. Consultant Cost/acre: TBD	Quantitative field-based data, specialized expertise needed.	$23,000 - $28,750
Module 9	Plant (sensitive/rare) species field assessments	USFS rare plant population trends	Eff Qs: 18	FS Rare plant protocol for occurrences and habitat, non-native invasive cover Consultant Cost/acre: $22/acre (e.g., 1,000-ac project footprint)	Quantitative field-based data, specialized expertise needed.	$22,000 - $27,500
Module 10	Soils	Sediment deposition in amphibian habitat.	Eff Qs: 17.6	Field surveys in pools downstream of treatments. 5 field days (10-hrs/day)	Quantitative field-based data, specialized	$3,600 - $4,500

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				Sediment deposition cost could be in conjunction with Ecological Health Module 6. Crew and Project manager cost would be just for 1 additional day. Consultant team: 1 Project Manager, 2-person crew Crew cost, total hours: $2,400 (10 hours x 2 people at $120/hr) Project Manager cost, total hours: $1,200 (8 hours for additional data processing, $150/hr). Travel cost: No additional cost above EH Module 6.	expertise needed.	
Additional tasks, costs to coordinate program and present results						
Monitoring Coordination- Oversee implementation of MAC monitoring program; manage consultants; grant reporting; grant applications; data analysis, data interpretation and reporting; and attend and co-facilitate monthly ACCG Monitoring work group meetings. Assumes hourly rate: $105, and hours/month (variable): 50						$63,000
AGOL Coordination- MAC Monitoring AGOL database management and upkeep; maintain AGOL dashboards; provide technical oversight to consultants utilizing AGOL; POC for FS GIS staff. Hourly rate: $105, Hours/month (variable): 20						$25,200
Total Annual Costs to implement Core Modules (Base budget)						**$158,200 - $175,700**
Total Annual Cost to implement all Modules						**$514,072- $620,540**

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Section 6. Additional Appendices

- Appendix A – Metadata for Monitoring Questions
- Appendix B – AGOL Implementation Plan

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