NORTH COAST RESOURCE PARTNERSHIP

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2018/19 IRWM Project Application

The North Coast Resource Partnership (NCRP) 2018/19 Project Application Instructions and additional information can be found at the NCRP 2018/19 Project Solicitation webpage (https://northcoastresourcepartnership.org/proposition-1-irwm-round-1-implementation-funding-solicitation/). Please fill out grey text boxes and select all the check boxes that apply to the project. Application responses should be clear, brief and succinct.

Project Applications will be accepted until 5:00 pm, ~~March 8, 2019~~ **March 15, 2019.** It is important to save the application file with a distinct file name that references the project name. When the application is complete, please email to kgledhill@westcoastwatershed.com

If you have questions, need additional information or proposal development assistance please contact:

- Katherine Gledhill at kgledhill@westcoastwatershed.com or 707.795.1235
- Tribal Projects: Sherri Norris, NCRP Tribal Coordinator at sherri@cieaweb.org or 510.848.2043

Project Name:

A. ORGANIZATION INFORMATION

1. **Organization Name: Scott River Watershed Council**

2. **Contact Name/Title**
   Name: Betsy Stapleton
   Title: Board Chair
   Email: 5104stapleton@gmail.com
   Phone Number (include area code): 707-499-7082

3. **Organization Address (City, County, State, Zip Code):**
   514 N Highway 3, Etna Ca. 96027 Mailing: PO Box 355, Etna, Ca. 96027

4. **Organization Type**
   ☐ Public agency

☒ Non-profit organization
☐ Public utility
☐ Federally recognized Indian Tribe
☐ California State Indian Tribe listed on the Native American Heritage Commission's California Tribal Consultation List
☐ Mutual water company
☐ Other:

5. **Authorized Representative** (if different from the contact name)
   Name: Charnna Gilmore
   Title: Executive Director
   Email: charnnagilmore@gmail.com
   Phone Number (include area code): 530-598-2733

6. **Has the organization implemented similar projects in the past?** ☒ yes ☐ no
   Briefly describe these previous projects.
   Scott River Watershed Council has provided fiscal oversight and project management for large ecosystem resopration restoration projects including forest health, sediment and water quality. Project collaborators EFM, and Northern California Resource Center, have extensive experience planning, designing and implmenting forest health, fuels reduction and road sediment reduction projects.

7. **List all projects the organization is submitting to the North Coast Resource Partnership for the 2018/19 Project Solicitation in order of priority.**
   Scott River Headwaters Forest Health, Fire Safety, and Water Quality Improvement Project is the only project being submitted by Scott River Watershed Council.

8. **Organization Information Notes:**

Scott River Watershed Council (SRWC) is a community based non-profit group founded in 1992. Our mission is to facilitate communication and science based collaborative solutions for natural resource concerns in Scott Valley. We promote and support education, restoration, and scientific planning and monitoring in order to ensure the sustainability of the natural and human communities of the watershed, now and for future generations. Our leadership in addressing these complex issues will bring effective solutions to the local community and beyond. Please go to: https://www.scottriverwatershedcouncil.com/ for more information about SRWC.

B. ELIGIBILITY

1. **North Coast Resource Partnership and North Coast IRWM Objectives**

GOAL 1: INTRAREGIONAL COOPERATION & ADAPTIVE MANAGEMENT
☒ Objective 1 - Respect local autonomy and local knowledge in Plan and project development and implementation
☒ Objective 2 - Provide an ongoing framework for inclusive, efficient intraregional cooperation and effective, accountable NCIRWMP project implementation
☒ Objective 3 - Integrate Traditional Ecological Knowledge in collaboration with Tribes to incorporate these practices into North Coast Projects and Plans

GOAL 2: ECONOMIC VITALITY

☒ Objective 4 - Ensure that economically disadvantaged communities are supported and that project implementation enhances the economic vitality of disadvantaged communities by improving built and natural infrastructure systems and promoting adequate housing

☒ Objective 5 - Conserve and improve the economic benefits of North Coast Region working landscapes and natural areas

GOAL 3: ECOSYSTEM CONSERVATION AND ENHANCEMENT

☒ Objective 6 – Conserve, enhance, and restore watersheds and aquatic ecosystems, including functions, habitats, and elements that support biological diversity

☒ Objective 7 - Enhance salmonid populations by conserving, enhancing, and restoring required habitats and watershed processes

GOAL 4: BENEFICIAL USES OF WATER

☒ Objective 8 - Ensure water supply reliability and quality for municipal, domestic, agricultural, Tribal, and recreational uses while minimizing impacts to sensitive resources

☐ Objective 9 - Improve drinking water quality and water related infrastructure to protect public health, with a focus on economically disadvantaged communities

☐ Objective 10 - Protect groundwater resources from over-drafting and contamination

GOAL 5: CLIMATE ADAPTATION & ENERGY INDEPENDENCE

☒ Objective 11 - Address climate change effects, impacts, vulnerabilities, and strategies for local and regional sectors to improve air and water quality and promote public health

☒ Objective 12 - Promote local energy independence, water/ energy use efficiency, GHG emission reduction, and jobs creation

GOAL 6: PUBLIC SAFETY

☐ Objective 13 - Improve flood protection and reduce flood risk in support of public safety

2. Does the project have a minimum 15-year useful life?

☒ yes ☐ no

If no, explain how it is consistent with Government Code 16727.

3. Other Eligibility Requirements and Documentation

CALIFORNIA GROUNDWATER MANAGEMENT SUSTAINABILITY COMPLIANCE

a) Does the project that directly affect groundwater levels or quality?

☐ yes ☒ no

b) If Yes, will the organization be able to provide compliance documentation outlined in the instructions, to include in the NCRP Regional Project Application should the project be selected as a Priority Project?

☐ yes ☐ no

CASGEM COMPLIANCE

a) Does the project overlie a medium or high groundwater basin as prioritized by DWR?

☒ yes ☐ no

b) If Yes, list the groundwater basin and CASGEM priority: Scott Valley Valley Groundwater Basin (1-005). Medium priority basin.
c) If Yes, please specify the name of the organization that is the designated monitoring entity: Siskiyou County Flood Control and Water Conservation District
d) If there is no monitoring entity, please indicate whether the project is wholly located in an economically disadvantaged community.
☐ yes ☐ no

URBAN WATER MANAGEMENT PLAN
a) Is the organization required to file an Urban Water Management Plan (UWMP)?
☐ yes ☒ no
b) If Yes, list the date the UWMP was approved by DWR:
c) Is the UWMP in compliance with AB 1420 requirements?
☐ yes ☐ no
d) Does the urban water supplier meet the water meter requirements of CWC 525?
☐ yes ☐ no
c) If Yes, will the organization be able to provide compliance documentation outlined in the instructions, to include in the NCRP Regional Project Application should the project be selected as a Priority Project?
☐ yes ☐ no

AGRICULTURAL WATER MANAGEMENT PLAN
a) Is the organization – or any organization that will receive funding from the project – required to file an Agricultural Water Management Plan (AWMP)?
☐ yes ☒ no
b) If Yes, list date the AWMP was approved by DWR:
c) Does the agricultural water supplier(s) meet the requirements in CWC Part 2.55 Division 6?
☐ yes ☐ no

SURFACE WATER DIVERSION REPORTS
a) Is the organization required to file surface water diversion reports per the requirements in CWC Part 5.1 Division 2?
☐ yes ☒ no
d) If Yes, will the organization be able to provide SWRCB verification documentation outlined in the instructions, to include in the NCRP Regional Project Application should the project be selected as a Priority Project?
☐ yes ☐ no

STORM WATER MANAGEMENT PLAN
a) Is the project a stormwater and/or dry weather runoff capture project?
☐ yes ☒ no
b) If yes, does the project benefit a Disadvantaged Community with a population of 20,000 or less?
☐ yes ☐ no
e) If No, will the organization be able to provide documentation that the project is included in a Stormwater Resource Plan that has been incorporated into the North Coast IRWM Plan, should the project be selected as a Priority Project?
☐ yes ☐ no

C. GENERAL PROJECT INFORMATION

1. **Project Name: Scott River Headwaters Forest Health, Fire Safety, and Water Qauility Improvement Project**

2. **Eligible Project Type under 2018/19 IRWM Grant Solicitation**
   - ☐ Water reuse and recycling for non-potable reuse and direct and indirect potable reuse
   - ☐ Water-use efficiency and water conservation
   - ☐ Local and regional surface and underground water storage, including groundwater aquifer cleanup or recharge projects
   - ☐ Regional water conveyance facilities that improve integration of separate water systems
   - ☒ Watershed protection, restoration, and management projects, including projects that reduce the risk of wildfire or improve water supply reliability
   - ☐ Stormwater resource management projects to reduce, manage, treat, or capture rainwater or stormwater
   - ☐ Stormwater resource management projects that provide multiple benefits such as water quality, water supply, flood control, or open space
   - ☐ Decision support tools that evaluate the benefits and costs of multi-benefit stormwater projects
   - ☐ Stormwater resource management projects to implement a stormwater resource plan
   - ☐ Conjunctive use of surface and groundwater storage facilities
   - ☐ Decision support tools to model regional water management strategies to account for climate change and other changes in regional demand and supply projections
   - ☒ Improvement of water quality, including drinking water treatment and distribution, groundwater and aquifer remediation, matching water quality to water use, wastewater treatment, water pollution prevention, and management of urban and agricultural runoff
   - ☐ Regional projects or programs as defined by the IRWM Planning Act (Water Code §10537)
   - ☐ Other:

3. **Project Abstract**

The project will target specific, high priority actions that will provide fire safety for people and water delivery infrastructure, and improve water quality for the communities of Etna, Quartz Valley Indian Reservation and Quartz Valley, all economically disadvantaged communities, by reducing road inputs, augmenting large wood in streams and reducing fuel loads. Co-benefits of employment, climate resiliency and salmonid fisheries improvement will acrue.

4. **Project Description**

PROBLEM: The Scott Watershed is experiencing the effects of many years of drought and climate change resulting in prolonged fire seasons, unusually dry timber conditions, and increased fuel loads. Fire danger has been exacerbated by long-term fire suppression, which has resulted in dense stands of young trees that burn at high intensity. This places humans and infrastructure at risk in the inevitable event of high intensity wildfire. Legacy roads are inputting sediment to high value anadromous streams. THE PROJECT PURPOSES: are to 1) Decrease fire risk to humans, the ecosystem, and the City of Etna Water system while improving forest health and reducing GHG production; 2) Decrease sediment inputs to high value anadromous spawning and rearing streams, supporting ongoing restoration efforts for C/ESU listed Southern Oregon Northern California Coho Salmon. SETTING: the Scott Watershed encompasses 812 sq. miles, including 534 sq. miles of forest land. MAJOR PROJECT COMPONENTS: Kidder Creek Road Restoration: Utilizing existing road surveys, 11 high and medium road sites will be treated to reduce sediment production 2) 2) Ruffey Gap Treatment Area: 65 acres of young, overstocked stands within a 200' ridge corridor will be thinned and, along with existing dead fuels from the larger 723 acre area, materials will be slash ground or piled and burned, 3) Sniktaw Fuel Retreatment: Overgrown shaded fuel breaks on 166 acres along Sniktaw will be manually retreated with slash chipped or ground, 4) Patterson Road Restoration 7 high priority road sites identified through existing road surveys and will be treated. Road treatments will consist of culvert replacement, drainage improvements and road outsloping. Project fuel reduction activities are part of a larger landscape scale fuels reduction plan, with specific benefit of community and water infrastructure protection. EXPECTED BENEFITS: Improved water quality, fire risk reduction to humans and City of Etna water system infrastructure and the ecosystem, climate change mitigation benefits, improved conditions for salmonids,employment for members of economically disadvantaged communities and support for Tribal Cultural Values.

5. **Specific Project Goals/Objectives**

Goal 1: Protect City of Etna water supply in the event of wildfire
Goal 1 Objective: Reduce high density, overstsocked tree stands on 723 acres above the City of Etna's water supply infrastructure
Goal 1 Objective: Reduce potential greenhouse gas production by manually thinning dense stands prior to wildfire
Goal 1 Objective: Protect Etna Creek Water Quality by reducing sediment inputs post wildfire
Goal 1 Objective: Improve groundwater inflitration by reducing stand density and canopy cover.

Goal 2: Reduce wildfire risk to City of Etna, a disadavataged community.
Goal 2 Objective: Create a defensible fire break in steep canyon above City of Etna by clearing fuels on 65 acres along a ridge top road
Goal 2 Objective:
Goal 2 Objective:
Goal 2 Objective:

Goal 3: Reduce wildfire risk for the Quartz Valley Indian Reservation and Quartz Valley Community
Goal 3 Objective: Retreat 166 acres of overgrown shaded fuel break along a critical ingress and egress road
Goal 3 Objective:
Goal 3 Objective:

Additional Goals & Objectives (List)
Goal 4: Reduce sediment inputs and improve water quality to Patterson and Kidder Creeks- high value salmonid spawning and rearing streams
Goal 4 Objective: treat 18 high and medium priority road sediment sources
Goal 4 Objective: Reduce sediment inputs by 23,232 tons/yr
Goal 4 Objective: Monitor sediment and water quaility to evaluate environemtal conditions in Kidder, Patterson and Shackelford Creek.

Goal 4 Objective: Augment large wood along 2100 ft of Patterson Creek.

6. **Describe how the project addresses the North Coast Resource Partnership and North Coast IRWM Plan Goals and Objectives selected**.
   Goal 1, 2 & 3: Collaborating local groups are planning the project utilizing local knowdledge and worforce including Quartz Valley Indian Tribe (QVIR) cultural resource values . Goals 4 & 5: Local workforce will be employed in project, increasing economic vitality. Improving forest health and reducing fire risk will support working forests. Reducing sediment will help working landscape meet TMDL obligations. Goals 6 & 7: reducing sediment inputs and augmenting wood will improve habitat for C/ESU listing SONNC coho. Goal 8: Reduced risk of wildfire destruction of City of Etna Water delivery infrastructure will water supply reliability. Goal 11: Overly dense and dry stands of timber are the result of climate change, thinning will improve forest resiliency & address climate impacts. Roadsde thinning will reduce vulnerability to climate change induced wildfire. Goal 12: Prevention of catestrophic wildfire will reduce GHG production, healthier forest will increase GHG sequestration.

7. **Describe the need for the project**.
   Due to climate change and drought, the watershed has experienced increased fire frequency and duration. Specific fire risk and water quality factors in the urban-wildland interface of the Scott Valley have been identified and they are: 1) The City of Etna, and its water supply infrastructure, are at risk for complete loss in the event of wildfire due to dense, young stands of trees in the steep headwaters above the city, 2) The Quartz Valley Indian Tribe, the community of Quartz Valley, and Shackleford Creek are at risk from fire. Kidder and Patterson Creek, imporatant coho streams with on-going restoration efforts, are impacted from degraded water quality due to sediment inputs from roads. Current landscape scale forest health and fuels reduction plans need supplenting to protect communities. Current road sediment reduction funds are inadaquate. QVIR plans restoration on a one mile reach of Shackelford Creek, and protecting this investment from wildfire is important.

8. **List the impaired water bodies (303d listing) that the project benefits:**
   Action Plan for the Scott River Sediment and Temperature Total Maximum Daily Loads

9. **Will this project mitigate an existing or potential Cease and Desist Order or other regulatory compliance enforcement action?** ☒ yes ☐ no
   If so, please describe?
   Proposed NCRP project treatments accelerate implementation of the Scott River TMDL action plan that Ecotrust Forest Management (EFM) must meet to comply with sediment discharge requirements.

10. **Describe the population served by this project.**
    This project will serve the economically disadavataged communities of Etna (pop. 650), Quartz Valley and Quartz Valley Indian Reservation (estimated pop.500). Logging and agriculture have been the historic economic basis, but logging has been severly impacted with increased poverty. EFM, a project partner, whose ownership encompasses ~40,00 acres of timber production lands, is dedicated to revitalizing timber production and economic development in an environmnetally sound manner.

11. **Does the project provide direct water-related benefits to a project area comprised of Disadvantaged Communities or Economically Distressed Communities?**
    - ☒ Entirely
    - ☐ Partially

- ☐ No

List the Disadvantaged Community(s) (DAC)
City of Etna, Quartz Valley and Quartz Valley Indian Reservation.

12. **Does the project provide direct water-related benefits to a project area comprised of Severely Disadvantaged Communities (SDAC)?**
- ☐ Entirely
- ☐ Partially
- ☒ No

List the Severely Disadvantaged Community(s)

13. **Does the project provide direct water-related benefits to a Tribe or Tribes**?
- ☐ Entirely
- ☒ Partially
- ☐ No

List the Tribal Community(s)
Quartz Valley Indian Tribe.
If yes, please provide evidence of support from each Tribe listed as receiving these benefits.

14. **If the project provides benefits to a DAC, EDA or Tribe, explain the water-related need of the DAC, EDA or Tribe and how the project will address the described need.**
Reducing sediment inputs from roads will improve beneficial uses of for salmonids . Reducing dense stands of timber will improve precipitation storage as groundwater. Preventing destruction of City of Etna water supply in the event of fire will prevent cost of temporary water supply and rebuilding of system.

15. **Does the project address and/or adapt to the effects of climate change? Does the project address the climate change vulnerabilities in the North Coast region?** ☒ yes ☐ no
If yes, please explain.
Forest stand density, health and composition have been severely impacted by climate change, and our communities are vulnerable to fire as a result. Stand thinning, and fuels removal will improve health and resiliency in the face of climate change, and reduce fire vulnerability to people and infrastructure in this high fire risk area.

16. **Describe how the project contributes to regional water self-reliance.**
The project contributes to regional water reliance by improving groundwater infiltration after fuels reduction. It also prepares for drought by improving forest health. The landsacpe scale fuels reduction and forest health project that this is a component of may improve streamflow and water self relience .

17. **Describe how the project benefits salmonids, other endangered/threatened species and sensitive habitats.**
Reducing sediment inputs into Kidder and Patterson Creeks, tributaries to the Scott River, and critical coho spawning and rearing tributaries, will provide immediate benefits to salmonids, and supplement on-going and planned habitat restoration work. Long term benefits to salmonids, and to overall watershed health, will be provided by reducing the risk of catastrophic wildfire.

18. **Describe local and/or political support for this project.**
The County Supervisor for Siskiyou District 5 has been notified of the project and has written a letter of support, City of Etna town council has had a presentation on the project, and has written a letter of support. Quartz Valley Indian Tribe has written a letter of support.

19. **List all collaborating partners and agencies and nature of collaboration.**
Collaborators: Scott River Watershed Council, Northern California Resource Center, EFM, and Quartz Valley Indian Tribe. All collaborators have participated in developing project priorities and activities. All will participate in project implmentaion.

20. **Is this project part or a phase of a larger project?** ☒ yes ☐ no
Are there similar efforts being made by other groups? ☒ yes ☐ no
If so, please describe?
EFM has submitted multiple applications to complete landscape scale fuels reduction and forest health activities. They are currently funded by National Fish and Wildlife Foundation to work with Northwest CA Resource Conservation and Development Council for similar road inventory and restoration, which will complment this project. Scott River Watershed Council has ongoung restoration projects in Patterson Creek. QVIR has on-going fuels reduction, sediment and water quality monitoring projects.

21. **Describe the kind of notification, outreach and collaboration that has been done with the County(ies) and/or Tribes within the proposed project impact area, including the source and receiving watersheds, if applicable.**
The County supervisor for the project area has been notified and has written a letter of support. The local tribe, QVIR, is a project partner and fully involved in project activities.

22. **Describe how the project provides a benefit that meets at least one of the Statewide Priorities as defined in the 2018 IRWM Grant Program Guidelines and Tribal priorities as defined by the NCRP?**
1) Protect and Restore Important Ecosystems: Kidder, Patterson and Etna Creeks are high value coho spawning and rearing tributaries to the Scott River. Reducing sediment and improving water quality restores these important ecosystems. Reducing the risk from catastrophic wildfire protects these ecosystems. 2) Utilize Traditional Ecological Knowledge in coordination with Tribe(s): QVIR will provide construction oversight to ensure project activities use traditional ecological knowledge..

23. **Project Information Notes:**

EFM, in collaboration with the Siskiyou Land Trust, is pursuing a trio of permanent, working forest Conservation Easements (CE) on the 39,685-acre Scott River Headwaters property (SRH), the largest block of private forestland in Scott Valley. Forest Management under the CEs will enhance water quality, improve wildlife habitat and forest resiliency, reduce fire risk, and increase carbon storage on SRH from 81 metric tons/acre to over 200 metric tons/acre over an 80 year period. The overall goal for SRH under the three working forest CE proposals is to keep SRH as an intact, working forest enabling permanent management for economic and ecological uplift and reduction of risks from large-scale, catastrophic wildfires and an impaired road network. EFM goals and objectives that will improve SRH's economic and ecological resources include: Maintaining SRH as working forestland in perpetuity by extinguishing subdivision and development rights; increasing carbon stored in SRH forest stands by increasing tree diameters and stand volume; improving forest resiliency and health by managing for larger trees, a diverse mix of native species and age classes, and improved forest structure; and providing high quality wood products in perpetuity. EFM also manages for unique sensitive habitats such as riparian, wetland, and meadow habitats and public water supply watersheds. Fisheries restoration projects have been completed in the Patterson and Mill Creek watersheds and more are planned with partners. EFM will continue to pursue partnerships and funding opportunities to that will enhance timber value, wildlife habitats, recreation opportunities, and the provision of clean, cold water to SRH streams, the Scott River, and the City of Etna water supply. In addition, EFM, has applied for funding to complete an 18 miles fuel break on their holdings along the western edge of Scott Valley. This proposal integrates and augments the activities contained within the larger fuel break proposal. Scott River Watershed Council has a 5-year plan to augment large wood in Patterson Creek, currently funded for 2100 ft. of work. QVIR has a many year history of sediment and water quality monitoring and plans a one mile reach of restoration along Shackleford Creek which will be enhanced by fuels reduction along Sniktaw Road. Additionally, EFM, along with Northwest CA Resource Conservation and Development Council, has funding in hand to complete road sediment inventory and rapid assessment on EFM roads. This work will complement and inform the sediment projects contained within this proposal. SRWC and EFM have an additional proposal focused on improving Aspen grove habitat in the high mountain meadows above this proposed project. Reducing fire risk in the urban wildland interface, as this proposal will do, supports the longevity of these other restoration investments. Together, these projects are reaching the level of a landscape impact, and NCRP funding will fill some critically needed gaps in existing funded work.

D. PROJECT LOCATION

1. **Describe the location of the project**
   Geographical Information
   In Etna, Patterson Kidder and Shackelford sub-watersheds of the Scott River, tributary to the Klamath River, in Siskiyou County. See attached maps

2. **Site Address (if relevant):**
   514 N. Highway 3, Etna Ca. 96027 (SRWC Headquarters)

3. **Does the applicant have legal access rights, easements, or other access capabilities to the property to implement the project?**
   ☒ Yes If yes, please describe
   ☐ No If No, please provide a clear and concise narrative with a schedule, to obtain necessary access.
   ☐ NA If NA, please describe why physical access to a property is not needed.
   EFM owns in fee simple the project property

4. **Project Location Notes:**
   Patterson, Etna, Kidder, and Shackelford Creeks are all productive Southern Oregon/Northern California Coho Salmon spawning and rearing tributaries to the Scott River, Tributary to the Klamath. Sediment reduction and reduction of risk from catastrophic wildfire offer significant benefit to these high value streams.

E. PROJECT TASKS, BUDGET AND SCHEDULE

1. **Projected Project Start Date:** 3/1/20
   Anticipated Project End Date: 12/31/23

2. **Will CEQA be completed within 6 months of Final Award?**
   ☐ Yes   State Clearinghouse Number:
   ☐ NA, Project is exempt from CEQA
   ☐ NA, Not a Project under CEQA
   ☒ NA, Project benefits entirely to DAC, EDA or Tribe, or is a Tribal local sponsor. [Projects providing a water-related benefit entirely to DACs, EDAs, or Tribes, or projects implemented by Tribes are exempt from this requirement].
   ☐ No

3. **Please complete the CEQA Information Table below**
   Indicate which CEQA steps are currently complete and for those that are not complete, provide the estimated date for completion.

CEQA STEP	COMPLETE? (y/n)	ESTIMATED DATE TO COMPLETE
Initial Study	n	8/1/20
Notice & invitation to consult sent to Tribes per AB52	n	4/15/20
Notice of Preparation	n	6/1/2020
Draft EIR/MND/ND	n	9/1/2020
Public Review	n	9/1/2020
Final EIR/MND/ND	n	12/1/20
Adoption of Final EIR/MND/ND	n	2/18/21
Notice of Determination	n	4/1/2021
N/A - not a CEQA Project		

If additional explanation or justification of the timeline is needed or why the project does not require CEQA, please describe.

4. **Will all permits necessary to begin construction be acquired within 6 months of Final Award?**
   ☐ Yes
   ☒ NA, Project benefits entirely to DAC, EDA, Tribe, or is a Tribal local sponsor
   ☐ No

5. **PERMIT ACQUISITION PLAN**

Type of Permit	Permitting Agency	Date Acquired or Anticipated
LSAA	CDFW	3/31/21
401 and Waste Discharge Permit	NCRWQB	3/31/21
404	ACOE	3/31/21

For permits not acquired: describe actions taken to date and issues that may delay acquisition of permit.
We anticipate acquisition to be routine, and do not anticipate any delays. Pre-project scoping converstaions have been udertaken with NCRWQCB and CDFW staff and support for the project has been expressed.

6. **Describe the financial need for the project**.
   Forest health, fire saftety and road sediment reduction projects do not have an economic basis for their implementation without grant funding support. The project is in an economically disadvantged community.

7. **Is the project budget scalable?** ☒ yes ☐ no
   Describe how a scaled budget would impact the overall project.
   If the project budget is reduced by 25% the Patterson Road component of the project would be removed, other portions of the project would be somewhat reduced in scope to fit budget, as well as proportional reductions in administrative expense.

8. **Describe the basis for the costs used to derive the project budget according to each budget category.**
   Labor costs are determined by prevailing wage scale for Siskiyou County. Roadwork costs were based on the 2012 KNF Road Sediment Source Inventoray Risk Assessement and project partner experience in similar work- $20,000 per site inclusive of all costs. Fuels work cost $800-2000 per acre based on steepness and fuel density.

9. **Provide a narrative on cost considerations including alternative project costs.**
   Cost considerations are based on prevailing wage, local availability and pricing of materials, equipment and supplies in our remote community. Utilizing existing collaborator employees and/or existing longterm contractual relationships was determined to be most cost effective due to familiarity with local conditions, having materials and equipment at hand, and avoidence of bidding costs.

10. **List the sources of non-state matching funds, amounts and indicate their status**.

    Northern California Resource Counsel will contribute $5000 (50 hr x$100/hr) In-kind contribution for permit development (committed) . Scott River Watershed Council will contribute $12,480 (120 hr x $104/hr) of In-kind contribution for permit development (Committed). Scott River Watershed Council will match $175,519 funded large wood augmented work in Patterson Creek (National Fish and Wildlife Foundation- $104,299, US Fish and Wildlife Service- $71,220)- (Funded) Quartz Valley Indian Tribe will contribute $18,957.56 (540 hrs x $35.11) In-kind contribution for water quality monitoring (committed) and $30,000 cash for funded fuels reduction work (funded and work completed). EFM will contribute (includes prior two years and NCRP project period): Darin Stringer (Senior Forester) – 333 hours @ $60/hr = $20,000 Dave Powers (Conservation Director) – 286 hours @ 70/hr = $20,000 Matt Kamp (Forest Information Systems, GIS, Modeling) - 250 hrs @ $60/hr= $15,000 In-kind contribution for project field supervision, project management and contractual labor- (Commmittted). NFWF has funded Northwest CA Resource Conservation and Development Council $120,000 for road survey and rapid assessment on EFM roads which will complement and inform this project (funded).

11. **List the sources and amount of state matching funds.**

    EFM has applied for a $3,429,952 Cal Fire grant for the 18 mile fuel break. Status- applied for.

12. **Cost Share Waiver Requested (DAC or EDA)?** ☒ yes ☐ no

Cost Share Waiver Justification: Describe what percentage of the proposed project area encompasses a DAC/EDA, how the community meets the definition of a DAC/EDA, and the water-related need of the DAC/EDA that the project addresses. In order to receive a cost share waiver, the applicant must demonstrate that the project will provide benefits that address a water-related need of a DAC/EDA. The entire project lies with in a DAC as identified in the North Coast regional Partnership DAC mapping tool (https://northcoastresourcepartnership.org/data/). The project provides water related benefits of increased groundwater recharge, improved water quality, protection of water supply infrastructure.

13. Major Tasks, Schedule and Budget for NCRP 2018 IRWM Project Solicitation
Please complete MS Excel table available at https://northcoastresourcepartnership.org/proposition-1-irwm-round-1-implementation-funding-solicitation/; see instructions for submitting the required excel document with the application materials.

14. Project Tasks, Budget and Schedule Notes:

Final designs and plans, mobilization, site prep, demobilization, and close out: All are included in the comprehensive per site budget for roadwork, totaling $20,000 per site. These estimates are based the Klamath National Forest 2012 Road Sediment Source and Inventory (RSSI) and are based on: 1.Plan, design, and engineering at 56% 2 Materials 17%,3. Mobilization and demobilization 2.5%, 4. Equipment 17%, 5. Labor 4%, 6.Planting and sediment control 4%

Construction implementation and contracting: No costs association with this line because projects partners, or their longstanding contracted labor or employees, will be utilized. Permit costs estimated @ $5,000 and requested, permit development as Inkind contribution of collaborators. Project signage: No costs, as project is on a remote location and signage will not provide value. Project success will be posted on applicant and project partner websites and promoted via social media such as Instagram and Facebook. Fuels tratement work estimated @ $800/acre for Sniktaw do to it being an understory retreatment. Estimate of $2,000 acre for 136 acres of ridge top road treatemt ($130,000) and an additional $70,000 for piling and burning dead and down on 723 acres.

F. PROJECT BENEFITS & JUSTIFICATION

1. Does the proposed project provide physical benefits to multiple IRWM regions or funding area(s)?
☐ yes ☒ no
If Yes, provide a description of the impacts to the various regions.

2. Provide a narrative for project justification. Include any other information that supports the justification for this project, including how the project can achieve the claimed level of benefits. List any studies, plans, designs or engineering reports completed for the project. *Please see the instructions for more information about submitting these documents with the final application.*

The Road Sediment reduction component of this NCRP proposal includes addressing up to 10 High Priority and 8 Medium Priority RSSI identified sites on Kidder Creek and Patterson roads. The projected cost for addressing the 10 RSSI high priority and 8 medium priority road sediment sites on the two

roads is $360,000 based on an average cost per site of $20,000. This includes restoration design, permitting and implementation costs. The sediment treatments will likely vary in cost based on site-specific factors and sediment control designs. Lower cost features such as dips and road outsloping would be utilized to eliminate road diversion potential, road collection potential, and road/stream hydrologic connectivity. Adding additional road culverts to break hydrologic connectivity for some sites. Some stream adjacent road segments may need to be relocated away from Kidder or Patterson Creek to prevent sediment delivery. EFM and EFM's Consultants, JRC and Gary Tickner, will conduct pre project road assessment to confirm the continued potential risk at the RSSI sites and to determine whether there are any new significant road sediment sources that may have developed since the KNF 2012 RSSI. Installation of road dips, outsloping, ford restoration, and small to medium culvert replacement will constitute the primary restoration actions at the majority of the sites. A refined cost estimate for restoration of road sites would be developed after site-specific evaluation and design. If addressing the 18 high and medium priority RSSI sites exceeds the amount requested in the NCRP proposal Kidder Creek road's three RSSI high priority sites would be addressed first followed by the eight medium priority sites. Patterson road's seven high priority would then be addressed.
Fuel treatment prescriptions supported by: Johnson, M.C.; Kennedy, M.C.; Petteson, D.L. 2011. Simulating fuel treatment effects in dry forests of the Western United States: testing the principles of a fire-safe forest. Canadian Journal of Forest Research. 41(6): 1018-1030.
The potential for fuels reduction to contribute to groundwater recharge and even stream flow is supported by: "Assessment to Improve Late Spring/Summer Stream Flows, Reduce Fire Intensity and Fire Related Carbon Emissions in the Trinity River Watershed, Project Final Report: March 31, 2017 Trinity County Forest Ecology and Watershed Hydrology"
GHG reduction calculations based Cal Fire ARB GHG calculactor indicating 16 tons per acre x 889 acres x $15/ton= $213,360.

3. **Does the project address a contaminant listed in AB 1249 (nitrate, arsenic, perchlorate, or hexavalent chromium)?** ☐ yes ☒ no
   If yes, provide a description of how the project helps address the contamination.

4. **Does the project provide safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes consistent with AB 685?** ☐ yes ☒ no
   If Yes, please describe.

5. **Does the project employ new or innovative technologies or practices, including decision support tools that support the integration of multiple jurisdictions, including, but not limited to, water supply, flood control, land use, and sanitation?** ☒ yes ☐ no
   If Yes, please describe.
   The KNF Road Sediment Source and Inventory is a decision support tool that was utilized for site selection and treatment costs. The ARB Greenhouse Gas Calculayor was used to determine project GHG reductions.

6. **For each of the Potential Benefits that the project claims complete the following table to describe an estimate of the benefits expected to result from the proposed project.** [*See the NCRP Project*

Application Instructions, Potential Project Benefits Worksheet and background information to help complete the table. The NCRP Project Application, Attachment B includes additional guidance, source materials and examples from North Coast projects.]

PROJECT BENEFITS TABLE

Potential Benefits Description	**Physical Amt of Benefit**	**Physical Units**	**Est. Economic Value per year**	**Economic Units**
Water Supply				
Increased Water Supply Reliability	$19	200 households	only one event	$3,800
Increased Groundwater Recharge	?	?	?	?
Avoided Water Supply Projects		1	only one event	$5,000,0 00
Water Quality				
Sediment reduction	$9	23,232 tons	$209,088/yr	$1,045,4 40 5 yrs
Avoided Culvert Failures	$60,000	2 yr x 5 yrs	$120,000/yr	$600,000
Other Ecosystem Service Benefits				
Fisheries Improvements	?	?	?	?
Habitat Restoration	$120	63 acres	$7,560/yr	$37,800 5/yrs
Wildfire risk reduction	?	166 acres	5 tons per acre	830 tons
Wildfire risk Reduction	?	728 acres	20 tons/acre	14,560 tons
Other Benefits				
Enhanced Fire Fighting Capabilities for City of Etna, QVIR, Quartz Valley	?	?	?	?
Enhanced Tribal Fisheries	?	?	?	?
Enhancement of Beneficial Uses: Tribal Cultural Uses	?	?	?	?
Jobs Created	22	$30,660	$224,842 yr	$674,528 3/yrs
GHG Reductions	16 tons an acre	889 acres x $15/ton	$213,360	$213,360

7. Project Justification & Technical Basis Notes:

Water supply reliability: Prevention of destruction of City of Etna water supply is a rare, ontime event, effecting 200 households, therefore low end of cost range ($19) selected. Increased Groundwater recharge: not signiiicant from this project alone, but maybe significant from larger fuels reduction work this is part of. Avoided water supply projects: total guess at cost of rebuild of Etna water supply if destroyed, but the effect would be catestrophic to the City of Etna beyond actual cost to rebuild would water replacement costs, negative impact to business and tourism. Sediment reduction: Utilizing KNF RSSI sediment estimates for Kidder and Patterson Roads for fixing 17 sites will reduce sediment inputs by 23,232 tons/yr x $9 (conservative $) =$209,088/yr x 5 yrs = $1,045,440. Avoid Culvert failures: each repair estimate @ $60,000 (3x cost of preemptive replacement) x2/yr x 5 yrs= $600,000. Fisheries Improvemnts: Reduction of fine sediment inputs from road improvements coupled with large wood augmentartion will significantly improve spawning and rearing opportunities for steelheda and listed coho. No data available to monitze benefits. Habiatat Restoration, Riparian: 2100 ft long x 1320 ft wide= 63 acres x $120/yr. Enhanced Fire Fighting: Fuels reduction on 728 acres, especially along strategic ridge top road, above City of Etna and City Water Supply will significantly enhance fire fighting, as will fuel break along ingress and egress road for QVIR and Quartz Valley- economic benefit? Enhanced Tribal Fisheries: no data to support metrics, however reduction of sediment and improved habitat have potential to enhance recovery of coho and support steelhead populations. Tribal Cultural Uses: QVIR participation in construction oversight will ensure that fuels reduction work is done in a maner to leave native species that are of benefit for Tribal Cultural uses. Please see QVIR letter of support. Jobs Created: Estimate of 22 jobs created each earning an average of $30,660 over the course of 3 years, totalling ~$674,528 in direct wages over the 3 yr. project. Wildfire risk reduction numbers based on field surveys for fuel density and at different rates for different locations. GHG reductions 16 tons/acre x 889 acres x $16 a ton = $213,360, based on GHG calculator.

Major Tasks, Schedule and Budget for North Coast Resource Partnership 2018/19 IRWM Project Solicitation

Project Name: Scott River Headwaters Forest Health, Fire Safety, and Water Quality Improvement Project

Organization Name: Scott River watershed Council

Task #	Major Tasks	Task Description	Major Deliverables	Current Stage of Completion	IRWM Task Budget	Non-State Match	Total Task Budget	Start Date	Completion Date
A	**Category (a): Direct Project Administration**								
1	Administration	In cooperation with the County of Humboldt sign a sub-grantee agreement for work to be completed on this project. Develop invoices with support documentation. Provide audited financial statements and other deliverables as required	Invoices, audited financial statements and other deliverables as required	0%	$29,606.40	$0.00	$0.00	3/1/20	9/15/20
2	Monitoring Plan	Develop Monitoring Plan to include goals and measurable objectives	Final Monitoring Plan	0%	$2,240.00	$0.00	$0.00	3/1/20	9/15/20
3	Labor Compliance Program	Execute service agreement with Labor Compliance Program company	Submission of Labor Compliance Program	0%	$1,894.40	$0.00	$0.00	3/1/20	9/15/20
4	Reporting	Develop monthly reports describing work completed, challenges, and strategies for reaching remaining project objectives. Develop Final Report	Quarterly and Final Reports	0%	$23,864.40	$0.00	$0.00	3/1/20	12/31/23
B	**Category (b): Land Purchase/Easement**								
1		N/A		0%	$0.00	$0.00	$0.00		
C	**Category (c): Planning/Design/Engineering/Environmental Documentation**								
1	Final Design /Plans	See budget justification		15%	$0.00	$0.00	$0.00	6/1/20	6/1/21
2	Environmental Documentation: CEQA *	Complete environmental analysis on project sites, including cultural resources, wildlife, botany, fisheries and other resources as applicable.	Environmental Information Form; Notice of Determination; Letter from lead agency stating there were no legal challenges during public review; Approved and adopted CEQA documentation	0%	$36,000.00	$3,000.00	$0.00	3/1/20	12/31/20
3	Permit Development *:	All appropriate permits shall be secured for the project from CDFW and NCRWQCB through CDFW Timber review Group	Completed, as necessary, LSAA, Stormwater.404 and 401 certifications.	0%	$5,000.00	$12,480.00	$17,480.00	3/1/20	12/31/20
4	Permit Development *: [PLEASE COMPLETE]								
5	Permit Development *: [PLEASE COMPLETE]			0%	$0.00	$0.00	$0.00		
6				0%	$0.00	$0.00	$0.00		
7				0%	$0.00	$0.00	$0.00		
8				0%	$0.00	$0.00	$0.00		
D	**Category (d): Construction/Implementation**								
1	Construction/Implementation Contracting	See budget justification		0%	$0.00	$0.00	$0.00		
2	Mobilization and Site Preparation	See budget justification		0%	$0.00	$0.00	$0.00		
3	Project Construction/Implementation: Kidder Creek Road Restoration	10 sites per Klamath National Forest Road Sediment Survey and inventory (RSSI) Range of road treatments per design and engineering for drainage and stream crossing sites to prevent sediment. Road outsloping, road dips, improved drainage ditches and culvert replacement are treatment options	10 site treatments completed per plans and specifications.	10%	$220,000.00	$100,000.00	$280,000.00	3/1/17	9/1/23
4	Project Construction/Implementation: Ruffey Gap Thinning and Forest Treatment	100' each side ridge road of hazardous fuels reduction and forest health improvement by thinning, piling and burning. Thinning along a strategic ridge road.	Completion of hazardous fuels reduction and forest health per developed prescription 100' each side of strategic ridge road.	0%	$130,000.00		$200,000.00	6/1/21	9/1/23
5	Project Construction/Implementation: Ruffey gap fuels reduction	Removed post harvest slash and downed material from prior owner logging activities on 100 acres. Pile and burn material	Completion of hazardous fuels reduction and forest health per developed prescription on 100 acres.	0%	$70,000.00		$60,000.00	6/1/21	9/1/23
6	Project Construction/Implementation: Sniktaw Fuel Retreatment	166 acres of understory vegetation removal from previously treated areas. Grinding or chipping of slash material.	Completion of hazardous fuels reduction and forest health per developed prescription on 166 acres.	0%	$132,800.00	$25,000.00	$132,800.00	6/1/23	9/1/23

Project Name: Scott River Headwaters Forest Health, Fire Safety, and Water Quality Improvement Project
Organization Name: Scott River watershed Council

Task #	Major Tasks	Task Description	Major Deliverables	Current Stage of Completion	IRWM Task Budget	Non-State Match	Total Task Budget	Start Date	Completion Date
	Project Construction/Implementation: Patterson Creek Rd Restoration	UP to 7 sites per Klamath National Forest Road Sediment Survey and inventory (RSSI) Range of road treatments per design and engineering for drainage and stream crossing sites to prevent sediment. Road outsloping, road dips, improved drainage ditches and culvert replacement are treatment options	Up to 7 site treatments completed per plans and specifications.		$140,000.00	$60,000.00	$220,000.00	3/1/17	9/1/23
	Project Construction/Implementation:	Patterson Creek Large Wood Augmentation	Augment 2100 ft. of Patterson Creek with Large wood to obtain "fair" wood density ratings.	30%		$175,519.00	$175,519.00	6/1/18	9/1/23
7	Project Signage	See budget justification		0%	$0.00	$0.00	$0.00		
8	Project Close Out, Inspection & Demobilization	Inspect project components and establish that work is complete. Verify that all project components have been installed and are functioning as specified will be conducted as part of construction inspection and project closeout. Conduct project completion photo monitoring. Prepare record drawings.	As-Built and Record Drawings; Project completion site photos. See budget justification.	0%	$0.00	$0.00	$0.00		
9	Project Performance Monitoring	The performance of the project will be monitored in accordance to the Monitoring Plan using the following measurement tools and methods: Continuous Onset temperature probes will be installed on Sniktaw, Patterson, Etna and Kidder Creeks collecting stream temperature every 30 minutes. Collection of flow measurements will occur monthly at the temperature locations using a FlowTracker. All data will be downloaded monthly, checked for accuracy and compiled annually. Information will be summarized in the QVIR Annual Water Quality Monitoring Report.	Raw data and the summarized data report	0%	$0.00	$48,957.60	$48,957.60		
	Construction Administration	Labor Compliance Monitoring	Certified payroll records, records shall be furnished to NVLCS, Audits and investigations as required, Pre-bid documents, contracts for subcontractors in compliance with labor law.	0%	$7,300.00		$7,300.00		
	Construction Administration	Quartz Valley Indian Tribe provide construction management oversight to ensure all project activities support tribal cultural values and maximize tribal benefits.	Final report indicating how project activities and deliverables conformed to and support tribal cultural values.		$16,807.20		$16,807.20		
10	Construction Administration	Complete tasks necessary to administer construction contract. Keep daily records of construction activities, inspection, and progress. Conduct project construction photo-monitoring.	Construction Management Logs; Completed construction administration tasks documented in monthly progress reports	0%	$27,648.00	$0.00	$0.00		
	Total North Coast Resource Partnership 2018/19 IRWM Grant Request				**$843,160.40**	**$424,956.60**	**$1,158,863.80**		
	Is Requested Budget scalable by 25%? If yes, indicate scaled totals; if no delete budget amount provided.				**$632,370.30**	**$318,717.45**	**$869,147.85**		
	Is Requested Budget scalable by 50%? If yes, indicate scaled totals; if no delete budget amount provided.				**$0.00**	**$0.00**	**$0.00**		

Budget Detail for North Coast Resource Partnership 2018/19 IRWM Project Solicitation

Project Name: Scott River Headwaters Forest Health, Fire Safety, and Water Quality Improvement Project
Organization Name: Scott River watershed Council

Budget Detail

Row (a) Direct Project Administration Costs						
Project Management Type	**Personnel by Discipline**	**Number of Hours**	**Hourly Wage**	**% of Cost (if applicable) ***	**Total Admin Cost**	
Labor TBA	Project Manager	328	$59		$19,417.60	Fully Loaded Rate
Labor Charnna Gilmore	Executive Director	160	$59		$9,472	Fully Loaded Rate
Labor Shirley Johnson?Jess McArthur	Admin Support	576	$40		$23,040	Fully Loaded Rate
Labor Amanda Schmolemberger	Bookkeeper	144	$40		$5,760	Fully Loaded Rate
Materials						
Equipment						
Total						
*** What is the percentage based on (including total amounts)?**		**n/a**				
*** How was the percentage of cost determined?**		**n/a**				

Row (b) Land Purchase/Easement

Row (c) Planning/Design/Engineering & Environmental Documentation					
Personnel (Discipline)	**Major Task Name**	**Number of Hours**	**Hourly Wage**	**Total Cost**	
See budget justification for costing of field activities					
Total					

Row (d) Construction/Implementation					
Personnel (Discipline)	**Work Task and Sub-Task (from Work Task Table)**	**Number of Hours**	**Hourly Wage**	**Total Cost**	
Project Manager	Field supervision, coordinate partners and activities, labor compliance interviews	288	$ 56.00	$16,128	Fully Loaded Rate
Bookkeeper	Manage subcontract invoicing and billing	288	$40	$11,520	Fully Loaded Rate
QVIR Subbudget	Supervise Field Activities to ensure compliance with Tribal Cultural Values	240	$70	$16,807.20	Fully Loaded Rate
Labor Compliance Subcontract	See uploaded bid			$7,300	
Materials and Equipment	**Work Task and Sub-Task (from Work Task Table)**	**Number of Units**	**Unit Cost**		
Total					

March 6, 2019

To: North Coast Regional Partnership
2018-2019 IRWM Project Solicitation

From: Crystal Robinson, Environmental Director
Quartz Valley Indian Reservation
13601 Quartz Valley Rd.
Fort Jones, CA 96031

RE: Project Support for Scott River Headwaters Forest Health, Fire Safety and Water Quality Improvement Project

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To Whom it May Concern,

The Quartz Valley Indian Reservation (QVIR) would like express support for this proposal, the *Scott River Headwaters Forest Health, Fire Safety and Water Quality Improvement Project* being submitted by the Scott River Watershed Council.

The proposed activities all bear significant benefits to the Tribal cultural resources. Sediment reductions are necessary to improve coho and Chinook salmon habitat in the Scott River and its immensely valuable tributaries. We believe the Kidder Creek and Patterson road restoration projects are key locations to complete this kind of work for fish while also meeting pollutant reduction recommendations of the Scott River Total Maximum Daily Load. While sediment is a necessary component to the ecology of salmon and water quality processes, sediment in excess can be a detriment. Traditional Ecological Knowledge imparts a much different view of the Scott watershed, a landscape with stable upslope conditions and a meandering, depositional valley floor. This has been lost due to multiple reasons, one being the extensive road network upslope and the lack of upkeep by the previous private timber landowners.

Fire management, fuels reduction and timber harvest practices have also altered watershed conditions significantly. Through selective small diameter timber harvest and clean-up of previous timber sales and burns, projects like the one being proposed by the SRWC herein, are offering a safer environment for landowners while allowing the forest to begin a restorative process. These activities will leave the landscape and communities more resilient to future fire outbreaks and ultimately improve flows and water quality conditions. The projects proposed in Sniktaw and Ruffey Gap treatment areas will begin the processes of regeneration and restoration in these sub basins of the Scott.

The QVIR is located downstream of the Sniktaw area, annually the Environmental Program staff work to create a fire safe landscape within the Reservation. The proposed Sniktaw treatment would be the perfect complement to creating a fire safe community on and off the Reservation in Quartz Valley.

Quartz Valley Indian Reservation will be involved with coordination of the project, if funded, and will also be monitoring water quality conditions in Sniktaw, Etna and Patterson Creek through our annual water quality monitoring program. We are excited to participate in this partnership and hope to continue efforts throughout the Scott basin in future funding cycles.

Please contact me, at crystal.robinson@qvir-nsn.gov or 530-468-5907 ext 318, if you have any questions.

Sincerely,

Crystal Robinson

Crystal Robinson
Environmental Director
Quartz Valley Indian Reservation

CITY OF ETNA

March 14, 2019

To: North Coast Resource Partnership

Re: Scott River Watershed Council Grant Application

Dear North Coast Resource Partnership:

I and the Etna City Council have been shown a grant application to be submitted to you to fund forestry work to be done on private forestlands adjacent to the City of Etna's water supply infrastructure, and within the City of Etna's watershed. We were asked for our thoughts on this project by the applicant, the Scott River Watershed Council.

We met as a Council on March 11, 2019 to discuss the project, and were given a presentation on the project by Betsy Stapleton of the Watershed Council at our most recent normally-scheduled City Council Meeting.

The Etna City Council approves of this project, and hopes to see it funded.

In the summer of 2017 I and most other Etna residents watched, and prepared to evacuate, as the Wallow Fire crested the ridge over Etna Summit and came toward our town. I remember being in awe watching a 747 airliner bank directly over my house to drop fire retardant in full view of my front yard. I remember thinking at the time that possibly the best we could hope for was a total destruction of our city's water infrastructure -- I only hoped it would not be worse. Of course, the next summer came the fires in nearby Paradise, CA, and we all saw just how much worse it can be.

Our water system was ultimately spared thanks to some very courageous, and very expensive, firefighting efforts in 2017, but it is never far from my mind what would happen to our town if a fire came down the hill again. I like to think our town is, by and large, safe from the kind of conflagration that struck Paradise, but our water intake and water treatment plant are exceedingly vulnerable, and we do not have jurisdiction over the surrounding lands to take action ourselves.

Presumably if we lose this infrastructure FEMA and other resources would eventually assist us to rebuild it, but at an enormous cost, not only to the American taxpayer but to the people who live here. We feel it is a much smarter bet to take what actions can be taken now, and we are encouraged by the work done by the Scott River Watershed Council, and yourselves, toward this end. The City of Etna City Council unanimously supports the Scott River Watershed Council's proposal, and we are hopeful you will be able to fund it.

Please do not hesitate to contact me if you have questions. Thank you.

Sincerely,

Erik Ryberg, Mayor, City of Etna

--

Erik Ryberg, Mayor

City of Etna

Post Office Box 460

Etna, CA 96027

(530) 467-5256

e.ryberg.mayor@cityofetna.org

COUNTY OF SISKIYOU
Siskiyou County Supervisor District 5

P.O. Box 750 ▯ 1312 Fairlane Rd
Yreka, California 96097
www.rhaupt@co.siskiyou.ca.us

Cell (530) 925-0444
FAX (530) 842-8013

March 8, 2019

West Coast Watershed
P.O. Box 262
Healdsburg, CA 95448

Subject: Letter of Support for Scott River Headwaters Forest Health, Fire Safety and Water Quality Improvement Project

To Whom it May Concern,

As the Scott Valley elected representative on the Board of Supervisors of Siskiyou County; I am pleased to submit a statement of support for the Scott River Headwaters Forest Health, Fire Safety and Water Quality Improvement Project. This proposal covers watersheds of great importance to the State of California, as well as some of the state's most wildfire-prone communities designated "at risk" under the Healthy Forest Restoration Act of 2003. As you are aware our county and local communities are designated as disadvantaged communities in our state. As such their capacity to fund fuels work are quite limited and must depend on funding sources such as yours.

Siskiyou County has historically encouraged comprehensive projects as this to restore Wildlife Habitats, Forest Fire/Disease Resiliency, Water quality and quantity improvements while providing much needed fire risk reduction to our small towns. The project area covers one of two landscapes designated as a "County Collaborative Pilot Area", adopted by voice vote of the Siskiyou County Board of Supervisors in 2014. It is our desire to encourage this type of work in our uplands that will benefit our downstream communities while restoring much needed comprehensive ecosystem function. In the summer of 2016 and 2017 several of my towns in Scott Valley were under evacuation warnings and orders for months due to ongoing Wildfires in the forests surrounding us. This project would have aided in the fire response using the strategically placed fuels treatments being proposed. Two of my communities located in other watersheds suffered tremendous loss of property and critical infrastructure in recent years. Unfortunately, they did not mobilize quick enough with the foresight to assemble a project of this magnitude to avoid those losses. Wildfire losses are more than property destruction and strike at the heart of a towns human resilience or simply put; their very survival as a society is compromised in the aftermath of a catastrophe. Having funds for rebuilding is often beyond reach leaving preventative work as this their most feasible option.

I believe comprehensive cross private/public property boundary projects designed and supported in collaboration with landowners and agencies will improve the health of our environment and secure the longevity of the forests that surround our communities. This project does just that and has been in the

COUNTY OF SISKIYOU

Siskiyou County Supervisor District 5

P.O. Box 750 ▫ 1312 Fairlane Rd
Yreka, California 96097
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Cell (530) 925-0444
FAX (530) 842-8013

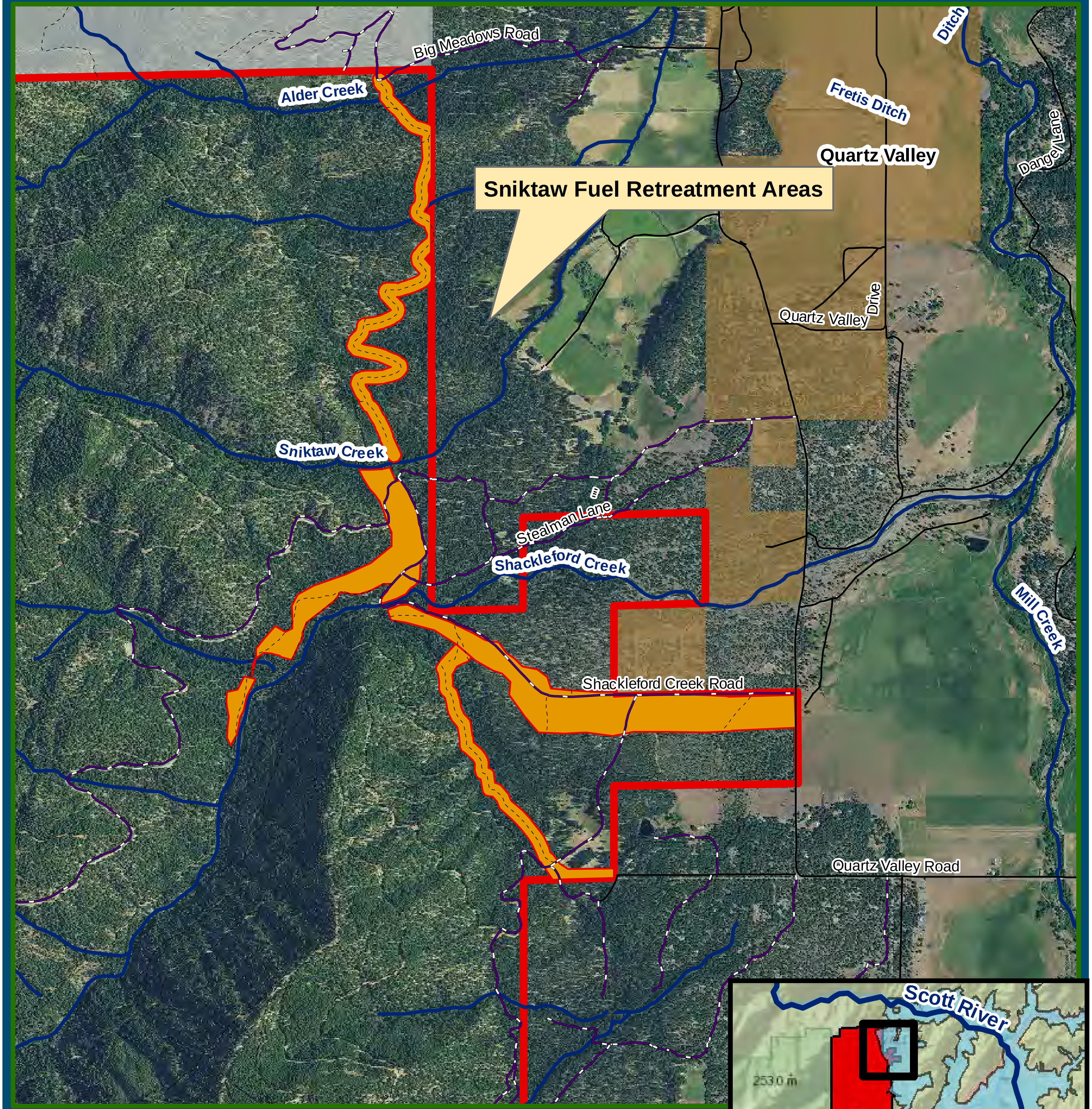
design phase for far too long. Implementation funds for this project are now necessary to ensure the protection of my constituents' property, secure their personal safety and for the improvement of wildlife habitats.

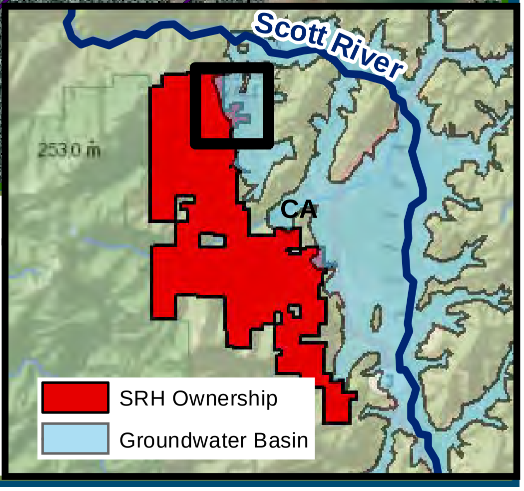
The project goals are of great importance to my constituents and our county. Scott Valley residents will greatly benefit from this innovative work to secure a future that avoids Catastrophic Wildfire loss. I urge you to approve this request so we may proceed in a timely manner with this critical work. I have participated in the development of this work for nearly a decade and personally value its importance. Thank you in advance and please contact me for any additional questions you may have.

Sincerely;

Ray A. Haupt
Siskiyou County Supervisor
District 5

SRH - Proposed NCRP Grant Treatments
Siskiyou County, CA





Fuel Retreatment Areas

SRH : NorthBlock

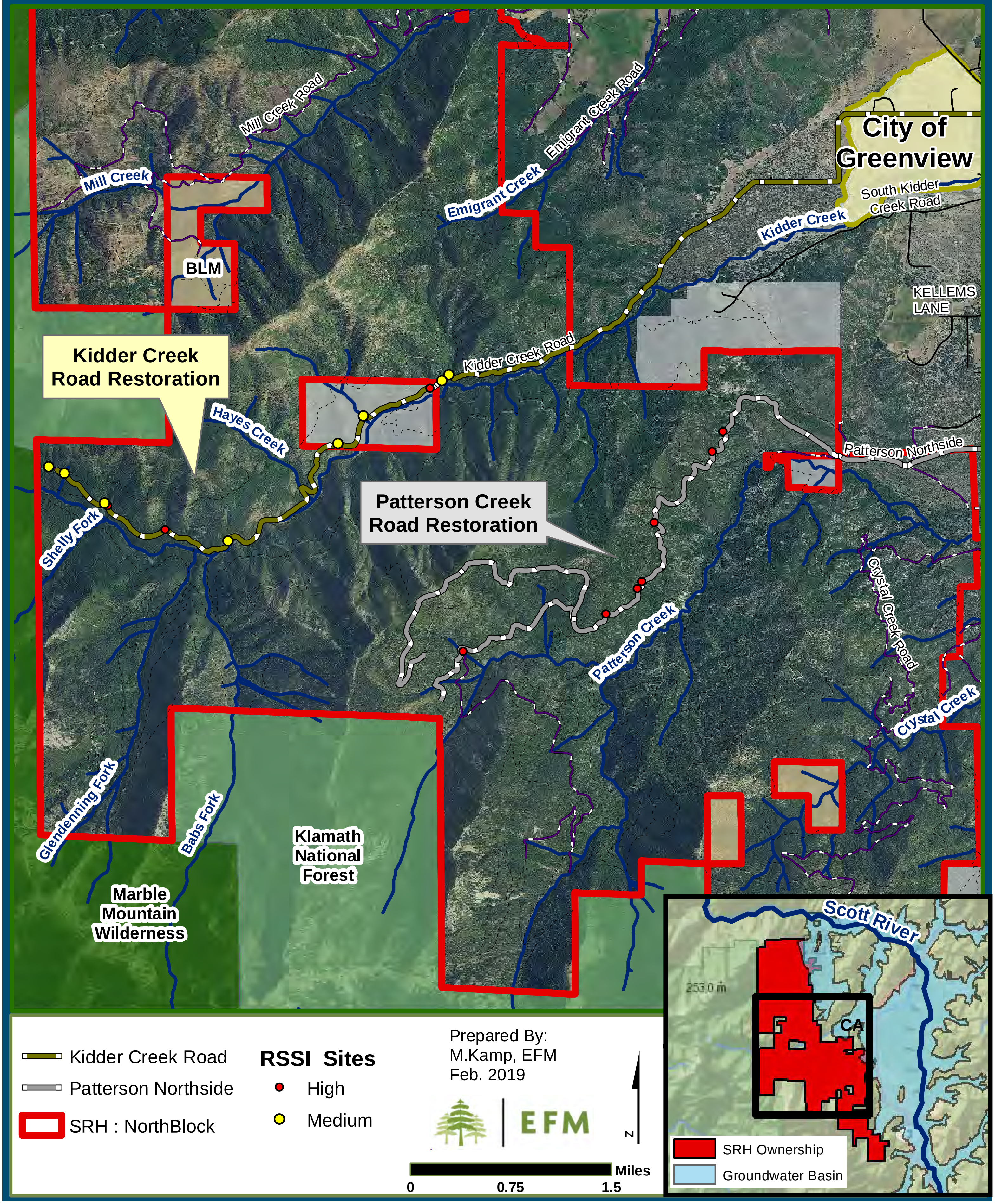
N

Prepared By:
M.Kamp, EFM
Feb. 2019

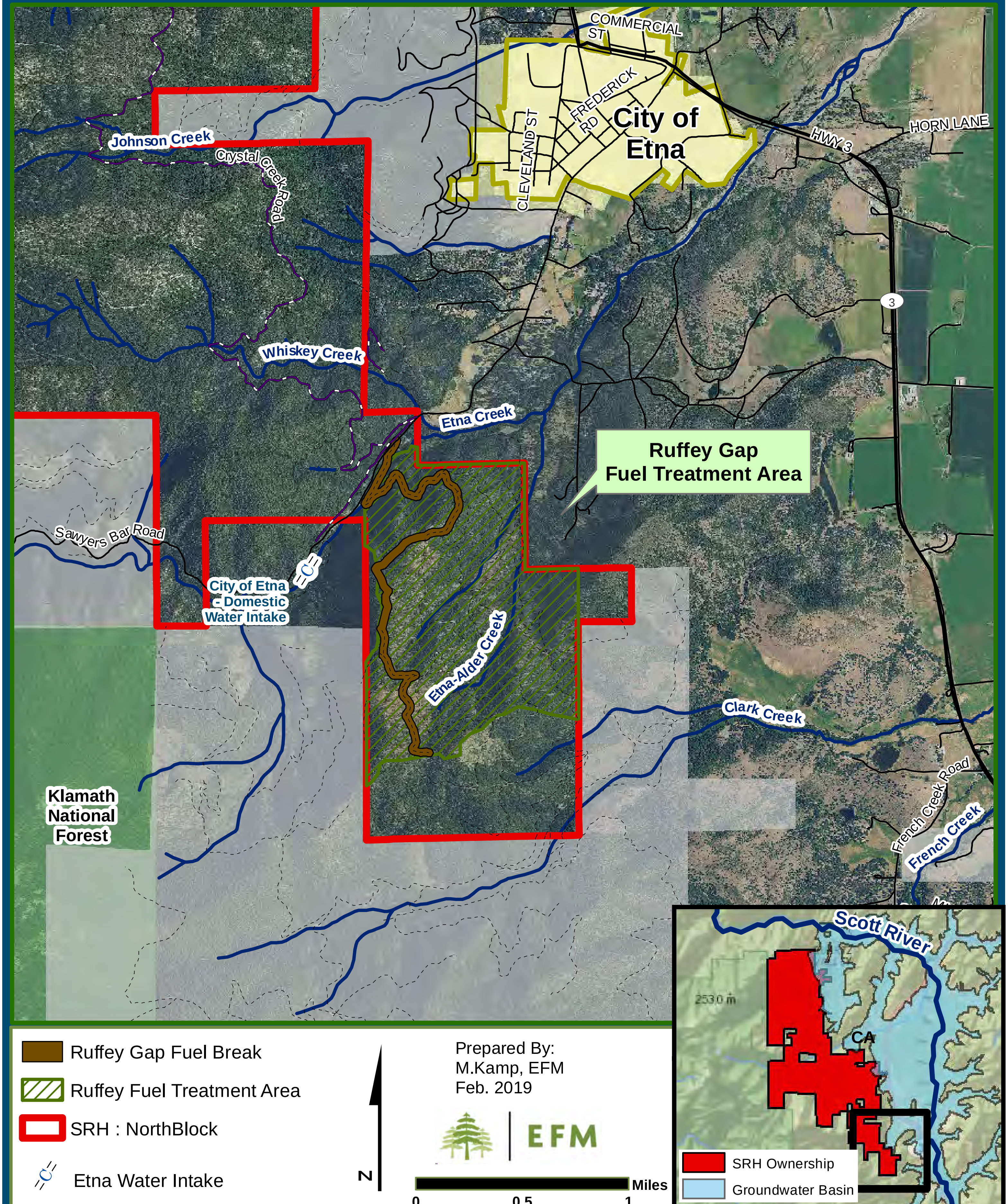
EFM

0 0.25 0.5 Miles

SRH - Proposed NCRP Grant Treatments
Siskiyou County, CA



SRH - Proposed NCRP Grant Treatments
Siskiyou County, CA



California Air Resources Board
Calculator for the
California Department of Forestry & Fire Protection
Forest Health Grant Program
Quantification Methodology
Fiscal Year 2017-2018

VERSION 3--May 15, 2018

Read Me Worksheet

The California Air Resources Board (CARB) is responsible for providing the quantification methodology to estimate greenhouse gas (GHG) emission reductions from California Climate Investment projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF).

This Forest Health GHG Calculator Tool accompanies the quantification methodology for the fiscal year (FY) 2017-18 GGRF Forest Health Program available at: www.arb.ca.gov/cci-quantification

Applicants must use this GHG Calculator Tool to estimate the net GHG benefit associated with the Forest Health projects. **Refer to the quantification methodology document for background and step-by-step detailed instructions.** To use this calculator, follow these steps:

Step 1 Enter general project information: Enter the project name and the contact information for a person who can answer project specific questions from staff reviewers on the quantification calculations. Enter the date that the project completed the GHG calculations.

Project Name:	**Scott River Headwaters Forest Health, Fire Safety and W**
Grant ID, if applicable:	
Contact Name:	**Darin Stringer**
Contact Phone Number:	**541-517-3875**
Contact Email:	**dstringer@ecotrustforests.com**
Date Completed:	

Step 2 Identify the project activity(ies): The applicant must select the appropriate project activity(ies) from the list of five eligible forest health activity types listed in the quantification methodology.

Step 3 Determine the inputs needed: The applicant will use the quantification methodology and the tools identified therein to determine the project information that must be input into this GHG calculator tool for the applicable project component(s) selected in Step 2. This GHG calculator contains a conversion worksheet to assist users in determining calculator inputs.

Step 4 Estimate the GHG emission reductions: The applicant will enter the project details identified in Step 3 into this calculator tool to calculate the net GHG benefit of the project.

Step 5 Submit documentation: Save file for submittal. This file will be submitted with other documentation requirements. See Section C of the quantification methodology for additional documentation requirements.

This Forest Health GHG Calculator Tool allows users to estimate the net GHG benefit from a variety of specific forest health activities. Each eligible project activity identified in Table 1 of the quantification methodology has a worksheet within the calculator. Landscape level projects may include multiple activities of the same or differing types. This GHG calculator tool allows for multiple entries within each workbook. Applicants must input project specific data into the worksheets that apply to the proposed project. Yellow fields indicate a direct user input is required, green fields indicate a selection from a drop-down box is required, and gray fields indicate output or calculation fields that are automatically populated based on user entries and the calculation methods. After the user inputs are entered for each proposed project activity the GHG summary worksheet displays the estimated GHG benefit from each activity type, the estimated net GHG benefit of the project, as well as the estimated net GHG benefit per GGRF dollar requested.

For more information on CARB's efforts to support implementation of Greenhouse Gas Reduction Fund investments, see: https://www.arb.ca.gov/auctionproceeds.
Questions on this document should be sent to: GGRFProgram@arb.ca.gov
Questions on the Forest Health Program should be sent to: calfire.grants@fire.ca.gov

California Air Resources Board
Calculator for the
California Department of Forestry & Fire Protection
Forest Health Grant Program
Quantification Methodology
Fiscal Year 2017-2018

Definitions Worksheet

Reforestation	Carbon within the treatment boundary at the end of the project with reforestation (MT C)	Enter the carbon stored in existing and planted standing live and dead trees within the treatment boundary at the end of the project in reforestation project scenario (from COLE or FVS). If cell is not applicable, leave blank.
	Carbon within the treatment boundary at the end of the project without reforestation (MT C)	Enter the carbon stored in existing standing live and dead trees within the treatment boundary at the end of the project in reforestation baseline scenario (from Table 10 in quantification methodology or FVS). If cell is not applicable, leave blank.
	Quantity of trees to be planted in reforestation activity (number of trees)	Enter the number of trees to be planted as part of the reforestation project activity. If cell is not applicable, leave blank.
	Area subject to reforestation (acres)	Enter the number of acres within the treatment boundary to be planted with trees as part of the reforestation activity. If cell is not applicable, leave blank.
	Area subject to site preparation (acres)	Enter the acres within the treatment boundary subject to site preparation. If cell is not applicable, leave blank.
	Level of brush cover (select from options)	If site preparation is planned, select from the drop down menu the level of brush cover (light: 0-25% brush cover, medium: >25%-50% dense brush cover, or heavy: >50% brush cover and/or stump removal) that best describes land cover of area subject to site preparation prior to project implementation (used to account for mobile source combustion emissions). If cell is not applicable, leave blank.
	Land cover type (select from options)	If site preparation is planned, select from the drop down menu the land cover type (grass, light to medium shrubs, or heavy shrubs) that best describes land cover prior to project implementation. If cell is not applicable, leave blank.
Pest Management	Area within the pest management treatment boundary (acres)	Enter the number of acres within the treatment boundary of the pest management activity. If cell is not applicable, leave blank.
	Area within the pest management impact boundary (acres)	Enter the number of acres within the impact boundary of the pest management activity. If cell is not applicable, leave blank.
	Carbon within the treatment boundary at the end of the project without disturbance or pest management treatment (MT C)	Enter the carbon stored in standing live trees within the treatment boundary at the end of the project assuming no pest management treatment and no threat from pests or disease (from COLE or FVS). If cell is not applicable, leave blank.
	Carbon within the impact boundary at the end of the project without disturbance or pest management treatment (MT C)	Enter the carbon stored in standing live trees within the impact boundary at the end of the project assuming no pest management treatment and no threat from pests or disease (from COLE or FVS). If cell is not applicable, leave blank.
	Percentage of treatment and impact boundaries at risk with pest management treatment (%)	Enter the percentage of treed area or basal area within the treatment and impact boundaries that remains at risk from pests and disease within a 10-year time frame with pest management treatment. Applicants may provide site- and treatment-specific estimates sourced from published, peer-reviewed literature directly applicable to the project site or from a Registered Professional Forester familiar with the threat facing the project site and proposed treatments. At a minimum, projects must consider the following when determining the baseline and project mortality rates within the project site: the local extent and scale of the epidemic, the type of treatment to be implemented, the species threatened by the pest or disease, the species composition and density within the project site, whether the pest is native or exotic, and the climate of the project site. If cell is not applicable, leave blank.
	Percentage of treatment and impact boundaries at risk without pest management treatment (%)	Enter the percentage of treed area or basal area within the treatment and impact boundaries at risk from pests and disease within a 10-year time frame without pest management treatment. Applicants may provide 1) site-specific estimates sourced from the USFS National Insect and Disease Risk Map (NIDRM), 2) site-specific estimates sourced from published, peer-reviewed literature directly applicable to the project site, or 3) site-specific estimates from a Registered Professional Forester familiar with the threat facing the project site. At a minimum, projects must consider the following when determining the baseline and project mortality rates within the project site: the local extent and scale of the epidemic, the type of treatment to be implemented, the species threatened by the pest or disease, the species composition and density within the project site, whether the pest is native or exotic, and the climate of the project site. If cell is not applicable, leave blank.
	Carbon removed as part of pest management treatment (MT C)	Enter the amount of standing live tree carbon to be removed from within the treatment boundary as part of pest management treatment. Applicants estimate the quantity of standing live tree carbon to be removed by analyzing current stand conditions and proposed treatments to be implemented. If cell is not applicable, leave blank.
	Biomass removed via mechanical treatments (BDT)	Enter the amount of biomass to be removed from within the treatment boundary via mechanical treatments (used to account for mobile source combustion emissions). For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
Fuels Reduction	Area within the treatment boundary (acres)	Enter the number of acres within the treatment boundary of the fuels reduction activity. If cell is not applicable, leave blank.
	Annual probability of fire occurrence (%)	Enter the annual probability that area within the treatment and impact boundaries will be subject to wildfire disturbance (mean probability from the FRAP Fire Probability for Carbon Accounting map tool; see Step 3.C in Forest Health Program Quantification Methodolog for further information). If cell is not applicable, leave blank.
	Effective period for fuels reduction treatment (Years)	Enter the length of time fuel reduction treatment is expected to be effective at modifying fire behavior (maximum of 25 years). Applicants can determine the effective period based on modeled or observed change in fire behavior as a result of the treatment and/or the professional judgement of the Registered Professional Forester or Certified Silviculturist designing the treatment. If cell is not applicable, leave blank.
	Carbon within the treatment boundary at the end of the project with fuels reduction treatment but without fire disturbance (MT C)	Enter the carbon stored in standing live trees within the treatment boundary at the end of the project assuming no disturbance from wildfire and fuels reduction treatment was implemented (from FVS). If cell is not applicable, leave blank.
	Carbon within the treatment boundary at the end of the project with fuels reduction treatment and with fire disturbance (MT C)	Enter the carbon stored in standing live trees within the treatment boundary at the end of the project assuming a disturbance from wildfire and fuels reduction treatment was implemented (from FVS and FEE-FVS). Inclusion of carbon stock estimates within impact boundary is optional. If cell is not applicable, leave blank.
	Carbon within the treatment boundary at the end of the project without fuels reduction treatment and without fire disturbance (MT C)	Enter the carbon stored in standing live trees within the treatment boundary at the end of the project assuming no disturbance from wildfire and no fuels reduction treatment (from FVS). If cell is not applicable, leave blank.
	Carbon within the treatment boundary at the end of the project without fuels reduction treatment but with fire disturbance (MT C)	Enter the carbon stored in standing live trees within the treatment boundary at the end of the project assuming a disturbance from wildfire and no fuels reduction treatment (from FVS and FFE-FVS). If cell is not applicable, leave blank.
	Biomass removed via mechanical treatments (BDT)	Enter the amount of biomass removed from within the treatment boundary via mechanical treatment (used to account for mobile source combustion emissions). Applicants estimate the quantity of biomass to be removed via mechanical treatment by analyzing current stand conditions and proposed treatments to be implemented. For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
	For applicants who choose to include the impact boundary for fuels reduction activities	
	Area within the impact boundary (acres)	Enter the number of acres within the impact boundary of the fuels reduction activity. If cell is not applicable, leave blank.
	Carbon within the impact boundary at the end of the project without fire disturbance (optional) (MT C)	Enter the carbon stored in standing live trees within the impact boundary at the end of the project assuming no disturbance from wildfire (from FVS). Inclusion of carbon stock estimates within impact boundary is optional. If cell is not applicable, leave blank.
	Carbon within the impact boundary at the end of the project without fuels reduction treatment but with fire disturbance (optional) (MT C)	Enter the carbon stored in standing live trees within the impact boundary at the end of the project assuming a disturbance from wildfire and no fuels reduction treatment (from FVS and FlamMap). Inclusion of carbon stock estimates within impact boundary is optional. If cell is not applicable, leave blank.
	Proportion of impact boundary likely to burn at high severity without fuels reduction treatment (optional) (%)	Enter the proportion of area within the impact boundary (%) with >50% probability of experiencing high flame lengths (>8 ft), based on Monte Carlo simulations of wildfire across the landscape without fuels reduction treatment (from FlamMap). Inclusion of carbon stock estimates within impact boundary is optional. If cell is not applicable, leave blank.
	Proportion of impact boundary likely to burn at high severity with fuels reduction treatment (optional) (%)	Enter the proportion of area within the impact boundary (%) with >50% probability of experiencing high flame lengths (>8 ft), based on Monte Carlo simulations of wildfire across the landscape with fuels reduction treatment (from FlamMap). Inclusion of carbon stock estimates within impact boundary is optional. If cell is not applicable, leave blank.

Forest Conservation: Avoided Conversion Easement	Area of the treatment boundary (acres)	Enter the acres within the easement. If cell is not applicable, leave blank.
	Area of the treatment boundary at risk of conversion (acres)	Enter the acres within the easement that are at risk of conversion to non-forest use. If cell is not applicable, leave blank.
	Carbon within the treatment boundary at the end of the project with the conservation easement (MT C)	Enter the carbon stored in standing live and dead trees within the treatment boundary at the end of the project with the conservation easement (from COLE or FVS). If cell is not applicable, leave blank.
	Type of conversion threat	Select from the drop down menu the type of conversion threat facing the land. If cell is not applicable, leave blank.
	If conversion threat type is residential, number of unique parcels that would be formed in the at-risk area (parcels)	If conversion threat type is residential, enter the number of parcels, or home lots, that the land would be divided into within the area at-risk of conversion. If cell is not applicable, leave blank.
	Biomass that would be removed from within the conservation treatment boundary and utilized without the conservation easement (BDT)	Enter the amount of biomass that would be removed from within the treatment boundary and utilized for wood products, electricity generation via combustion, and electricity generation via gasification. Estimate biomass that would be utilized if land were converted without the conservation easement. Provide separate estimates for each method of utilization. Applicants estimate the quantity of biomass to be utilized if the area were converted by analyzing the amount of biomass to be removed, based on current stand conditions, and percentage of removed biomass expected to be sent to mill or biomass facility. For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
	Biomass that is expected to be removed from within the conservation treatment boundary and utilized with the conservation easement (BDT)	Enter the amount of biomass that is expected to be removed from within the treatment boundary and utilized for wood products, electricity generation via combustion, and electricity generation via gasification. Estimate biomass to be utilized with the conservation easement during the 50-80 year project but after project closeout (i.e., biomass removal not funded with GGRF but as a result of the area continuing to operate as a working forest). Provide separate estimates for each method of utilization. Applicants estimate the quantity of biomass to be utilized during the 50-80 year project (after project closeout) if the area were protected by analyzing recent harvesting trends on the land and taking into account any new practices being introduced by the terms of the easement. For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
Forest Conservation: Forest Management Easement	Area of the treatment boundary (acres)	Enter the acres within the easement. If cell is not applicable, leave blank.
	Area of treatment boundary subject to active forest management prescriptions (acres)	Enter the acres within the treatment boundary that are subject to active forest management prescriptions through the conservation easement. If cell is not applicable, leave blank.
	Carbon within the active forest management area at the end of the project without the conservation easement (MT C)	Enter the carbon stored in standing live and dead trees within the active forest management portion of the easement at the end of the project without the conservation easement (from FVS). If cell is not applicable, leave blank.
	Carbon within the active forest management area at the end of the project *with the conservation easement* (MT C)	Enter the carbon stored in standing live and dead trees within the active forest management portion of the easement at the end of the project with the conservation easement (from FVS). If cell is not applicable, leave blank.
	Biomass that would be removed from within the active forest management area and utilized for wood products without the easement (BDT)	Enter the amount of biomass that would be removed from within the active forest management portion of the easement and utilized for wood products, electricity generation via combustion, and electricity generation via gasification. Estimate biomass that would be utilized if land were converted without the conservation easement. Provide separate estimates for each method of utilization. Applicants estimate the quantity of biomass to be utilized if the area were converted by analyzing the amount of biomass to be removed, based on current stand conditions, and percentage of removed biomass expected to be sent to mill or biomass facility. For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
	Biomass that would be removed from within the active forest management area and utilized for wood products without the easement (BDT)	Enter the amount of biomass that is expected to be removed from within the active forest management portion of the easement and utilized for wood products, electricity generation via combustion, and electricity generation via gasification. Estimate biomass to be utilized with the conservation easement during the 50-80 year project but after project closeout (i.e., biomass removal not funded with GGRF but as a result of the area continuing to operate as a working forest). Provide separate estimates for each method of utilization. Applicants estimate the quantity of biomass to be utilized during the 50-80 year project (after project closeout) if the area were protected by analyzing recent harvesting trends on the land and taking into account any new practices being introduced by the terms of the easement. For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
Biomass Utilization	For biomass utilization activities that send biomass to a mill:	
	Biomass to be removed from the project area as part of implementing reforestation, pest management, or fuels reduction activities and delivered to a mill (BDT)	Enter the total amount of biomass to be removed from the project area as a result of implementing forest health project activities (i.e., biomass removed as part of site preparation, brush removal, manual or mechanical thinning, etc.) and delivered to a mill. For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material.If cell is not applicable, leave blank.
	Mill efficiency (%)	Applicants can enter either the actual mill efficiency from the mill where trees will be delivered, supported with documentation, or the appropriate default mill efficiency based on the type of wood provided in Table 12 of the quantification methodology. If trees will be delivered to more than one mill with different efficiencies, applicants may provide a weighted mill efficiency. If cell is not applicable, leave blank.
	Wood product class (%)	Enter the percent of removed biomass that will go into each wood product class category (i.e., softwood lumber, hardwood lumber, softwood plywood, oriented strandboard, nonstructural panels, paper, and miscellaneous products. If not available from the mill that wood will be delivered to, assume that 100% of the biomass goes into "miscellaneous products." If cell is not applicable, leave blank.
	For biomass utilization activities that send biomass to a biomass energy facility:	
	Biomass to be removed from the project area as a result of implementing forest health project activities and delivered to a biomass facility generating electricity via combustion (BDT)	Enter the total amount of biomass to be removed from the project area as a result of implementing forest health project activities (i.e., biomass removed as part of site preparation, brush removal, manual or mechanical thinning, etc.) and delivered to a biomass facility generating electricity via combustion. For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
	Biomass to be removed from the project area as a result of implementing forest health project activities and delivered to a biomass facility generating electricity via gasification (BDT)	Enter the total amount of biomass to be removed from the project area as a result of implementing forest health project activities (i.e., biomass removed as part of site preparation, brush removal, manual or mechanical thinning, etc.) and delivered to a biomass facility generating electricity via gasification. For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
	For projects that facilitate the utilization of biomass that would otherwise be removed from outside the project area without GGRF funding NOTE: This section only applies to activities that utilize biomass removed as part of management practices not associated with the project (i.e., the forest treatment was not funded by the GGRF grant but complementary services such as transportation to a biomass facility or mill is funded with GGRF grant money). Only these projects may include the GHG benefit of avoided emissions from an open pile burn, landfilling, or leaving biomass to decay on-site.	
	Biomass that would be removed and open pile burned without project (BDT)	Enter the amount of removed biomass that would be open pile burned in the baseline scenario (separate estimates for each method of disposal). For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
	Biomass that would be removed and landfilled without project (BDT)	Enter the amount of removed biomass that would be landfilled in the baseline scenario (separate estimates for each method of disposal). For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
	Biomass that would be removed and left to decay on-site without project (BDT)	Enter the amount of removed biomass that would be left to decay on-site in the baseline scenario (separate estimates for each method of disposal). For the purposes of this quantification methodology, "biomass" refers to both merchantable timber and woody waste material. If cell is not applicable, leave blank.
GHG Summary	Forest Health GGRF Funds Requested ($)	Enter the Forest Health GGRF funds requested for all project features. This amount is equal to the amount of GGRF dollars the applicant is requesting from CAL FIRE's Forest Health program.
	Total GGRF Funds Requested ($)	Enter the total GGRF funds requested for all project features. This amount is equal to the amount of GGRF dollars the applicant is requesting from CAL FIRE's Forest Health program, plus all GGRF dollars from CAL FIRE or other agencies that have previously been awarded to the same project and any GGRF dollars from agencies other than CAL FIRE that project has or plans to apply for. For a list of GGRF funded programs, go to: https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ggrfprogrampage.htm. If no other GGRF funds are requested, this will be the same amount as the Forest Health GGRF Funds Requested.

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Forest Health Grant Program
Quantification Methodology
Fiscal Year 2017-2018

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Reforestation Worksheet

Enter data below using the appropriate on-site carbon stock accounting tools identified in Table 2 of the quantification methodology. If the reforestation treatment boundary overlaps with another activity's treatment or impact boundary, apportion the acreage as instructed in Table 3 of the quantification methodology.

Reforestation Activity 1

Carbon within the treatment boundary at end of project with reforestation (MT C)		GHG benefit from reforestation activity 1 (MT CO_2e)	0
Carbon within the treatment boundary at end of project without reforestation (MT C)		On-site carbon storage and project emissions in reforestation project scenario (MT CO_2e)	0
Quantity of trees to be planted in reforestation activity (number of trees)		On-site carbon storage in baseline scenario (MT CO_2e)	0
Area subject to reforestation (acres)			
Area subject to site preparation (acres)			
Area subject to herbicide treatment (acres)			
Level of brush cover (select from options)	Medium (>25-50% dense brush cover)		
Land cover type (select from options)	Light to medium shrubs		

Reforestation Activity 2

Carbon within the treatment boundary at end of project with reforestation (MT C)		GHG benefit from reforestation activity 2 (MT CO_2e)	0
Carbon within the treatment boundary at end of project without reforestation (MT C)		On-site carbon storage and project emissions in reforestation project scenario (MT CO_2e)	0
Quantity of trees to be planted in reforestation activity (number of trees)		On-site carbon storage in baseline scenario (MT CO_2e)	0
Area subject to reforestation (acres)			
Area subject to site preparation (acres)			
Area subject to herbicide treatment (acres)			
Level of brush cover (select from options)	Light (0-25% brush cover)		
Land cover type (select from options)	Light to medium shrubs		

Reforestation Activity 3

Carbon within the treatment boundary at end of project with reforestation (MT C)		GHG benefit from reforestation activity 3 (MT CO_2e)	0
Carbon within the treatment boundary at end of project without reforestation (MT C)		On-site carbon storage and project emissions in reforestation project scenario (MT CO_2e)	0
Quantity of trees to be planted in reforestation activity (number of trees)		On-site carbon storage in baseline scenario (MT CO_2e)	0
Area subject to reforestation (acres)			
Area subject to site preparation (acres)			
Area subject to herbicide treatment (acres)			
Level of brush cover (select from options)			
Land cover type (select from options)			

Reforestation Activity 4

Carbon within the treatment boundary at end of project with reforestation (MT C)		GHG benefit from reforestation activity 4 (MT CO_2e)	0
Carbon within the treatment boundary at end of project without reforestation (MT C)		On-site carbon storage and project emissions in reforestation project scenario (MT CO_2e)	0
Quantity of trees to be planted in reforestation activity (number of trees)		On-site carbon storage in baseline scenario (MT CO_2e)	0
Area subject to reforestation (acres)			
Area subject to site preparation (acres)			
Area subject to herbicide treatment (acres)			
Level of brush cover (select from options)			
Land cover type (select from options)			

Reforestation Activity 5

Carbon within the treatment boundary at end of project with reforestation (MT C)		GHG benefit from reforestation activity 5 (MT CO_2e)	0
Carbon within the treatment boundary at end of project without reforestation (MT C)		On-site carbon storage and project emissions in reforestation project scenario (MT CO_2e)	0
Quantity of trees to be planted in reforestation activity (number of trees)		On-site carbon storage in baseline scenario (MT CO_2e)	0
Area subject to reforestation (acres)			
Area subject to site preparation (acres)			
Area subject to herbicide treatment (acres)			
Level of brush cover (select from options)			
Land cover type (select from options)			

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Pest Management Worksheet

Enter data below using the appropriate on-site carbon stock accounting tools identified in Table 2 of the quantification methodology. If the pest management treatment or impact boundary overlaps with another activity's treatment or impact boundary, apportion the acreage as instructed in Table 3 of the quantification methodology.

Pest Management Activity 1

Area within the pest management treatment boundary (acres)	
Area within the pest management impact boundary (acres)	
Carbon within the treatment boundary at the end of the project without disturbance or pest management treatment (MT C)	
Carbon within the impact boundary at the end of the project without disturbance or pest management treatment (MT C)	
Percentage of treatment and impact boundaries at risk with pest management treatment (%)	
Percentage of treatment and impact boundaries at risk without pest management treatment (%)	
Carbon removed as part of pest management treatment (MT C)	
Biomass removed via mechanical treatments (BDT)	

GHG benefit from pest management activity 1 (MT CO_2e)	0
On-site carbon storage and project emissions in pest management project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Pest Management Activity 2

Area within the pest management treatment boundary (acres)	
Area within the pest management impact boundary (acres)	
Carbon within the treatment boundary at the end of the project without disturbance or pest management treatment (MT C)	
Carbon within the impact boundary at the end of the project without disturbance or pest management treatment (MT C)	
Percentage of treatment and impact boundaries at risk with pest management treatment (%)	
Percentage of treatment and impact boundaries at risk without pest management treatment (%)	
Carbon removed as part of pest management treatment (MT C)	
Biomass removed via mechanical treatments (BDT)	

GHG benefit from pest management activity 2 (MT CO_2e)	0
On-site carbon storage and project emissions in pest management project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Pest Management Activity 3

Area within the pest management treatment boundary (acres)	
Area within the pest management impact boundary (acres)	
Carbon within the treatment boundary at the end of the project without disturbance or pest management treatment (MT C)	
Carbon within the impact boundary at the end of the project without disturbance or pest management treatment (MT C)	
Percentage of treatment and impact boundaries at risk with pest management treatment (%)	
Percentage of treatment and impact boundaries at risk without pest management treatment (%)	
Carbon removed as part of pest management treatment (MT C)	
Biomass removed via mechanical treatments (BDT)	

GHG benefit from pest management activity 3 (MT CO_2e)	0
On-site carbon storage and project emissions in pest management project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Pest Management Activity 4

Area within the pest management treatment boundary (acres)	
Area within the pest management impact boundary (acres)	
Carbon within the treatment boundary at the end of the project without disturbance or pest management treatment (MT C)	
Carbon within the impact boundary at the end of the project without disturbance or pest management treatment (MT C)	
Percentage of treatment and impact boundaries at risk with pest management treatment (%)	
Percentage of treatment and impact boundaries at risk without pest management treatment (%)	
Carbon removed as part of pest management treatment (MT C)	
Biomass removed via mechanical treatments (BDT)	

GHG benefit from pest management activity 4 (MT CO_2e)	0
On-site carbon storage and project emissions in pest management project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Pest Management Activity 5

Area within the pest management treatment boundary (acres)	
Area within the pest management impact boundary (acres)	
Carbon within the treatment boundary at the end of the project without disturbance or pest management treatment (MT C)	
Carbon within the impact boundary at the end of the project without disturbance or pest management treatment (MT C)	
Percentage of treatment and impact boundaries at risk with pest management treatment (%)	
Percentage of treatment and impact boundaries at risk without pest management treatment (%)	
Carbon removed as part of pest management treatment (MT C)	
Biomass removed via mechanical treatments (BDT)	

GHG benefit from pest management activity 5 (MT CO_2e)	0
On-site carbon storage and project emissions in pest management project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

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Fuels Reduction Worksheet

Enter data below using the appropriate on-site carbon stock accounting tools identified in Table 2 of the quantification methodology. If the fuels reduction treatment or impact boundary overlaps with another activity's treatment or impact boundary, apportion the acreage as instructed in Table 3 of the quantification methodology.

Fuels Reduction Activity 1

Area within the treatment boundary (acres)	**266**
Annual probability of fire occurrence (%)	0.26%
Effective period for fuels reduction treatment (Years)	25
Carbon within the treatment boundary at the end of the project with fuels reduction treatment but without fire disturbance (MT C)	31,583
Carbon within the treatment boundary at the end of the project with fuels reduction treatment and with fire disturbance (MT C)	16,425
Carbon within the treatment boundary at the end of the project without fuels reduction treatment and without fire disturbance (MT C)	30,627
Carbon within the treatment boundary at the end of the project without fuels reduction treatment but with fire disturbance (MT C)	12,410
Biomass removed via mechanical treatments (BDT)	202
For applicants who choose to include the impact boundary for fuels reduction activities:	
Area within the impact boundary (acres)	
Carbon within the impact boundary at the end of the project without fire disturbance (optional) (MT C)	
Carbon within the impact boundary at the end of the project without fuels reduction treatment but with fire disturbance (optional) (MT C)	
Proportion of impact boundary likely to burn at high severity without fuels reduction treatment (optional) (%)	
Proportion of impact boundary likely to burn at high severity with fuels reduction treatment (optional) (%)	

GHG benefit from fuels reduction activity 1 (MT CO_2e)	4,204
On-site carbon storage and project emissions in fuels reduction project scenario (MT CO_2e)	112,392
On-site carbon storage in baseline scenario (MT CO_2e)	108,188

Fuels Reduction Activity 2

Area within the treatment boundary (acres)	
Annual probability of fire occurrence (%)	
Effective period for fuels reduction treatment (Years)	
Carbon within the treatment boundary at the end of the project with fuels reduction treatment but without fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project with fuels reduction treatment and with fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project without fuels reduction treatment and without fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project without fuels reduction treatment but with fire disturbance (MT C)	
Biomass removed via mechanical treatments (BDT)	
For applicants who choose to include the impact boundary for fuels reduction activities:	
Area within the impact boundary (acres)	
Carbon within the impact boundary at the end of the project without fire disturbance (optional) (MT C)	
Carbon within the impact boundary at the end of the project without fuels reduction treatment but with fire disturbance (optional) (MT C)	
Proportion of impact boundary likely to burn at high severity without fuels reduction treatment (optional) (%)	
Proportion of impact boundary likely to burn at high severity with fuels reduction treatment (optional) (%)	

GHG benefit from fuels reduction activity 2 (MT CO_2e)	0
On-site carbon storage and project emissions in fuels reduction project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Fuels Reduction Activity 3

Area within the treatment boundary (acres)	
Annual probability of fire occurrence (%)	
Effective period for fuels reduction treatment (Years)	
Carbon within the treatment boundary at the end of the project with fuels reduction treatment but without fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project with fuels reduction treatment and with fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project without fuels reduction treatment and without fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project without fuels reduction treatment but with fire disturbance (MT C)	
Biomass removed via mechanical treatments (BDT)	
For applicants who choose to include the impact boundary for fuels reduction activities:	
Area within the impact boundary (acres)	
Carbon within the impact boundary at the end of the project without fire disturbance (optional) (MT C)	
Carbon within the impact boundary at the end of the project without fuels reduction treatment but with fire disturbance (optional) (MT C)	
Proportion of impact boundary likely to burn at high severity without fuels reduction treatment (optional) (%)	
Proportion of impact boundary likely to burn at high severity with fuels reduction treatment (optional) (%)	

GHG benefit from fuels reduction activity 3 (MT CO_2e)	0
On-site carbon storage and project emissions in fuels reduction project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Fuels Reduction Activity 4

Area within the treatment boundary (acres)	
Annual probability of fire occurrence (%)	
Effective period for fuels reduction treatment (Years)	
Carbon within the treatment boundary at the end of the project with fuels reduction treatment but without fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project with fuels reduction treatment and with fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project without fuels reduction treatment and without fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project without fuels reduction treatment but with fire disturbance (MT C)	
Biomass removed via mechanical treatments (BDT)	
For applicants who choose to include the impact boundary for fuels reduction activities:	
Area within the impact boundary (acres)	
Carbon within the impact boundary at the end of the project without fire disturbance (optional) (MT C)	
Carbon within the impact boundary at the end of the project without fuels reduction treatment but with fire disturbance (optional) (MT C)	
Proportion of impact boundary likely to burn at high severity without fuels reduction treatment (optional) (%)	
Proportion of impact boundary likely to burn at high severity with fuels reduction treatment (optional) (%)	

GHG benefit from fuels reduction activity 4 (MT CO_2e)	0
On-site carbon storage and project emissions in fuels reduction project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Fuels Reduction Activity 5

Area within the treatment boundary (acres)	
Annual probability of fire occurrence (%)	
Effective period for fuels reduction treatment (Years)	
Carbon within the treatment boundary at the end of the project with fuels reduction treatment but without fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project with fuels reduction treatment and with fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project without fuels reduction treatment and without fire disturbance (MT C)	
Carbon within the treatment boundary at the end of the project without fuels reduction treatment but with fire disturbance (MT C)	
Biomass removed via mechanical treatments (BDT)	
For applicants who choose to include the impact boundary for fuels reduction activities:	
Area within the impact boundary (acres)	
Carbon within the impact boundary at the end of the project without fire disturbance (optional) (MT C)	
Carbon within the impact boundary at the end of the project without fuels reduction treatment but with fire disturbance (optional) (MT C)	
Proportion of impact boundary likely to burn at high severity without fuels reduction treatment (optional) (%)	
Proportion of impact boundary likely to burn at high severity with fuels reduction treatment (optional) (%)	

GHG benefit from fuels reduction activity 5 (MT CO_2e)	0
On-site carbon storage and project emissions in fuels reduction project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

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Avoided Conversion Easement Worksheet

Enter data below using the appropriate on-site carbon stock accounting tools identified in Table 2 of the quantification methodology. If the forest conservation treatment boundary overlaps with another activity's treatment or impact boundary, apportion the acreage as instructed in Table 3 of the quantification methodology.

Avoided Conversion Easement Activity 1

Area of the treatment boundary (acres)	
Area of the treatment boundary at risk of conversion (acres)	
Percent of the treatment boundary at risk of conversion (%)	0%
Carbon within the treatment boundary at the end of the project with the conservation easement (MT C)	
Type of conversion threat (select from options)	
If conversion threat type is residential, number of unique parcels that would be formed in the at-risk area (parcels)	
Biomass that would be removed from within the conservation treatment boundary and utilized for wood products without the easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for wood products with conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via combustion without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via gasification without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 1 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Avoided Conversion Easement Activity 2

Area of the treatment boundary (acres)	
Area of the treatment boundary at risk of conversion (acres)	
Percent of the treatment boundary at risk of conversion (%)	0%
Carbon within the treatment boundary at the end of the project with the conservation easement (MT C)	
Type of conversion threat (select from options)	
If conversion threat type is residential, number of unique parcels that would be formed in the at-risk area (parcels)	
Biomass that would be removed from within the conservation treatment boundary and utilized for wood products without the easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for wood products with conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via combustion without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via gasification without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 2 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Avoided Conversion Easement Activity 3

Area of the treatment boundary (acres)	
Area of the treatment boundary at risk of conversion (acres)	
Percent of the treatment boundary at risk of conversion (%)	0%
Carbon within the treatment boundary at the end of the project with the conservation easement (MT C)	
Type of conversion threat (select from options)	
If conversion threat type is residential, number of unique parcels that would be formed in the at-risk area (parcels)	
Biomass that would be removed from within the conservation treatment boundary and utilized for wood products without the easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for wood products with conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via combustion without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via gasification without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 3 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Avoided Conversion Easement Activity 4

Area of the treatment boundary (acres)	
Area of the treatment boundary at risk of conversion (acres)	
Percent of the treatment boundary at risk of conversion (%)	0%
Carbon within the treatment boundary at the end of the project with the conservation easement (MT C)	
Type of conversion threat (select from options)	
If conversion threat type is residential, number of unique parcels that would be formed in the at-risk area (parcels)	
Biomass that would be removed from within the conservation treatment boundary and utilized for wood products without the easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for wood products with conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via combustion without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via gasification without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 4 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Avoided Conversion Easement Activity 5

Area of the treatment boundary (acres)	
Area of the treatment boundary at risk of conversion (acres)	
Percent of the treatment boundary at risk of conversion (%)	0%
Carbon within the treatment boundary at the end of the project with the conservation easement (MT C)	
Type of conversion threat (select from options)	
If conversion threat type is residential, number of unique parcels that would be formed in the at-risk area (parcels)	
Biomass that would be removed from within the conservation treatment boundary and utilized for wood products without the easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for wood products with conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via combustion without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the conservation treatment boundary and utilized for electricity generation via gasification without the conservation easement (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 5 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

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Management Easement Worksheet

Enter data below using the appropriate on-site carbon stock accounting tools identified in Table 2 of the quantification methodology. If the forest conservation treatment boundary overlaps with another activity's treatment or impact boundary, apportion the acreage as instructed in Table 3 of the quantification methodology.

Management Easement Activity 1

Area of the treatment (easement) boundary (acres)	
Area of treatment boundary subject to active forest management prescriptions (acres)	
Carbon within the active forest management area at the end of the project *without* the conservation easement (MT C)	
Carbon within the active forest management area at the end of the project *with* the conservation easement (MT C)	
Biomass that would be removed from within the active forest management area and utilized for wood products *without* the easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for wood products *with* conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via combustion *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via gasification *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 1 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Management Easement Activity 2

Area of the treatment (easement) boundary (acres)	
Area of treatment boundary subject to active forest management prescriptions (acres)	
Carbon within the active forest management area at the end of the project *without* the conservation easement (MT C)	
Carbon within the active forest management area at the end of the project *with* the conservation easement (MT C)	
Biomass that would be removed from within the active forest management area and utilized for wood products *without* the easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for wood products *with* conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via combustion *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via gasification *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 2 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Management Easement Activity 3

Area of the treatment (easement) boundary (acres)	
Area of treatment boundary subject to active forest management prescriptions (acres)	
Carbon within the active forest management area at the end of the project *without* the conservation easement (MT C)	
Carbon within the active forest management area at the end of the project *with* the conservation easement (MT C)	
Biomass that would be removed from within the active forest management area and utilized for wood products *without* the easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for wood products *with* conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via combustion *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via gasification *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 3 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Management Easement Activity 4

Area of the treatment (easement) boundary (acres)	
Area of treatment boundary subject to active forest management prescriptions (acres)	
Carbon within the active forest management area at the end of the project *without* the conservation easement (MT C)	
Carbon within the active forest management area at the end of the project *with* the conservation easement (MT C)	
Biomass that would be removed from within the active forest management area and utilized for wood products *without* the easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for wood products *with* conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via combustion *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via gasification *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 4 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

Management Easement Activity 5

Area of the treatment (easement) boundary (acres)	
Area of treatment boundary subject to active forest management prescriptions (acres)	
Carbon within the active forest management area at the end of the project *without* the conservation easement (MT C)	
Carbon within the active forest management area at the end of the project *with* the conservation easement (MT C)	
Biomass that would be removed from within the active forest management area and utilized for wood products *without* the easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for wood products *with* conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via combustion *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via combustion with the conservation easement (BDT)	
Biomass that would be removed from within the active forest management area and utilized for electricity generation via gasification *without* the conservation easement (BDT)	
Biomass that is expected to be removed from within the active forest management area and utilized for electricity generation via gasification with the conservation easement (BDT)	

GHG benefit from forest conservation activity 5 (MT CO_2e)	0
On-site carbon storage in forest conservation project scenario (MT CO_2e)	0
On-site carbon storage in baseline scenario (MT CO_2e)	0

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Biomass Utilization Worksheet

For all biomass utilization activities that send biomass to a mill:

Biomass to be removed from the project area as part of implementing reforestation, pest management, or fuels reduction activities and delivered to a mill (BDT)	0
Biomass that would be removed from within the conservation treatment boundary and utilized for wood products without the easement (BDT)	0
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for wood products with the easement (BDT)	0
Mill efficiency (%) (if not known, use default efficiencies in Table 12 of the Quantification Methodology)	0.00%
Carbon transferred to wood products	0
Biomass that will go into Softwood Lumber (%)	0%
Biomass that will go into Hardwood Lumber (%)	
Biomass that will go into Softwood Plywood (%)	
Biomass that will go into Oriented Strandboard (%)	
Biomass that will go into Nonstructural Panels (%)	
Biomass that will go into Paper (%)	0%
Biomass that will go into Miscellaneous Products (%) (100% if product class categories are not available from mill)	
GHG benefit of carbon stored long-term in wood products (MT CO_2e)	0

For all biomass utilization activities that send biomass to a biomass energy facility:

Biomass to be removed from the project area as part of implementing reforestation, pest management, or fuels reduction activities and delivered to a biomass facility generating electricity via combustion as part of the project (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via combustion without the conservation easement (BDT)	0
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via combustion with the conservation easement (BDT)	0
Biomass to be removed from the project area as part of implementing reforestation, pest management, or fuels reduction activities and delivered to a biomass facility generating electricity via gasification as part of the project (BDT)	
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via gasification without the conservation easement (BDT)	0
Biomass that is expected to be removed from within the conservation treatment boundary and utilized for electricity generation via gasification with the conservation easement (BDT)	0
GHG benefit from utilizing biomass for electricity generation (MT CO_2e)	0

For projects that facilitate the utilization of biomass that would otherwise be removed from outside the project area without GGRF funding:

Biomass that would be removed and open pile burned without project (BDT)	
Biomass that would be removed and landfilled without project (BDT)	
Biomass that would be removed and left to decay on-site without project (BDT)	
GHG benefit from avoided biomass disposal emissions (MT CO_2e)	0

GHG benefit from biomass utilization activities (MT CO_2e)	0

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GHG Summary Worksheet

GHG benefit from reforestation activities (MT CO_2e)	0
GHG benefit from pest management activities (MT CO_2e)	0
GHG benefit from fuels reduction activities (MT CO_2e)	4,204
GHG benefit from avoided conversion easement activities (MT CO_2e)	0
GHG benefit from forest management easement activities (MT CO_2e)	0
GHG benefit from biomass utilization activities (MT CO_2e)	0

Net GHG Benefit (MT CO_2e)	4,204
Forest Health GGRF $ Requested ($)	
Total GGRF $ Requested ($)	
Net GHG Benefit/Forest Health GGRF Funds Requested (MT CO_2e/$)	0.00
Net GHG Benefit/GGRF $ Requested	0.00

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Co-benefit Summary Worksheet

Key Variables Summary

Acres planted in reforestation activities (acres)	
Acres treated in pest management activities (acres)	
Acres impacted in pest management activities (acres)	
Acres treated in fuels reduction activities (acres)	
Acres impacted by fuels reduction activities (acres; if calculated)	
Acres conserved via avoided conversion easement activities (acres)	
Acres conserved via forest management easement activities (acres)	
Total acreage treated (acres)	
Total easement acreage conserved (acres)	
Trees planted in reforestation activities (number of trees)	
Renewable energy generated via biomass utilization activities (kWh)	

Protection

0
0
0
266
0
0
0
266
0
0
0

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Conversions Worksheet

Applicants must input values into this Forest Health GHG Calculator Tool that are in the correct unit. Applicants may use this worksheet to convert values from the required tools to those to be input into this calculator.

	Metric Ton Carbon/Hectare		Hectares	0	Metric Ton Carbon
	Metric Ton Carbon/Hectare		Acres	0	Metric Ton Carbon
	Metric Ton Carbon/Acre		Acres	0	Metric Ton Carbon
	Metric Ton Carbon/Acre		Hectares	0	Metric Ton Carbon

	Wood Volume by Forest Type		Wood Weight by Species Type		
######	Mixed Conifer (ft^3)	144.8	BDT for Softwoods	191.5	BDT for Hardwoods
######	Douglas-Fir (ft^3)	730.6	BDT for Softwoods	822.6	BDT for Hardwoods
	Fir, Spruce, or Hemlock (ft^3)	0.0	BDT for Softwoods	0.0	BDT for Hardwoods
	Ponderosa Pine (ft^3)	0.0	BDT for Softwoods	0.0	BDT for Hardwoods
	Redwood (ft^3)	0.0	BDT for Softwoods	0.0	BDT for Hardwoods

	Hectares	0.0	Acres
	Metric Ton Carbon Dioxide Equivalent	0	Metric Ton Carbon
	Short Ton Carbon	0	Metric Ton Carbon
	Bone Dry Ton Biomass	0	Metric Ton Carbon
	Metric Ton Carbon	0.0	Bone Dry Ton Biomass

Conversion Rates

2.47105	Acres/Hectare
3.67	CO_2e/C
0.50	Unit Carbon/Unit Biomass
0.90719	Metric Ton (MT)/Short Ton or Bone Dry Ton (BDT)
24.59	Wood Density of Softwoods from Mixed Conifer Forests (lbs/ft^3)
26.77	Wood Density of Softwoods from Douglas-Fir Forests (lbs/ft^3)
23.21	Wood Density of Softwoods from Fir, Spruce, or Hemlock Forests (lbs/ft^3)
23.71	Wood Density of Softwoods from Ponderosa Pine Forests (lbs/ft^3)
23.46	Wood Density of Softwoods from Redwood Forests (lbs/ft^3)
32.51	Wood Density of Hardwoods from Mixed Conifer Forests (lbs/ft^3)
30.14	Wood Density of Hardwoods from Douglas-Fir Forests (lbs/ft^3)
31.82	Wood Density of Softwoods from Fir, Spruce, or Hemlock Forests (lbs/ft^3)
31.82	Wood Density of Softwoods from Ponderosa Pine Forests (lbs/ft^3)
28.02	Wood Density of Softwoods from Redwood Forests (lbs/ft^3)
2,000	Pound (lb)/Short Ton or Bone Dry Ton (BDT)
2,204.6	Pound (lb)/Metric Ton
1,000	Kilogram (kg)/Metric Ton (MT)
907	Kilogram (kg)/Short Ton or Bone Dry Ton (BDT)

Emission Reduction Factors Worksheet

Reforestation		
Mobile combustion emission factor for reforestation site preparation for light brush cover (0-25% brush cover) (MT CO2e/acre)	0.090	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Mobile combustion emission factor for reforestation site preparation for medium brush cover (>25-50% dense brush cover) (MT CO2e/acre)	0.202	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Mobile combustion emission factor for reforestation site preparation for heavy brush cover (>50% brush cover, stump removal) (MT CO2e/acre)	0.429	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Carbon lost from removal of shrubs and herbaceous understory during reforestation site preparation (grass cover) (MT CO2e/acre)	3.6	Scott, J.H. and Burgan, R.E. (2005) Standard fire behavior fuel models: A comprehensive set for use with Rothermel's surface fire spread model
Carbon lost from removal of shrubs and herbaceous understory during reforestation site preparation (light to medium shrub cover) (MT CO2e/acre)	13.9	Scott, J.H. and Burgan, R.E. (2005) Standard fire behavior fuel models: A comprehensive set for use with Rothermel's surface fire spread model
Carbon lost from removal of shrubs and herbaceous understory during reforestation site preparation (heavy shrub cover) (MT CO2e/acre)	24.0	Scott, J.H. and Burgan, R.E. (2005) Standard fire behavior fuel models: A comprehensive set for use with Rothermel's surface fire spread model
Emission factor for herbicide treatment (MT CO2e/acre)	0.0607	Sonne, E. (2006) Greenhouse Gas Emissions from Forestry Operations: A Life Cycle Assessment. Journal of Environmental Quality, 35, 1439–1450. https://dl.sciencesocieties.org/publications/jeq/pdfs/35/4/1439
Pest Management		
Mobile combustion emission factor for biomass removal (MT CO2e/BDT)	0.06	California Air Resources Board, Detailed California-Modified GREET Pathway for Cellulosic Ethanol from Forest Waste (February 27, 2009) https://www.arb.ca.gov/fuels/lcfs/022709lcfs_forestw.pdf
Fuels Reduction		
Mobile combustion emission factor for biomass removal (MT CO2e/BDT)	0.06	California Air Resources Board, Detailed California-Modified GREET Pathway for Cellulosic Ethanol from Forest Waste (February 27, 2009) https://www.arb.ca.gov/fuels/lcfs/022709lcfs_forestw.pdf
Forest Conservation		
Conversion impact when threatened with conversion to agricultural use	90%	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Conversion impact when threatened with conversion to mining use	90%	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Conversion impact when threatened with conversion to recreational use	80%	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Conversion impact when threatened with conversion to commercial use	95%	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Conversion impact when threatened with conversion to industrial use	95%	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Conversion impact when threatened with conversion to residential use (dependent on number of unique parcels and size of the treatment area entered in Easement--Avoided Conversion tab); Conservation Activity 1	dependent on conservation tab inputs	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Conversion impact when threatened with conversion to residential use (dependent on number of unique parcels and size of the treatment area entered in Easement--Avoided Conversion tab); Conservation Activity 2	dependent on conservation tab inputs	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Conversion impact when threatened with conversion to residential use (dependent on number of unique parcels and size of the treatment area entered in Easement--Avoided Conversion tab); Conservation Activity 3	dependent on conservation tab inputs	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Conversion impact when threatened with conversion to residential use (dependent on number of unique parcels and size of the treatment area entered in Easement--Avoided Conversion tab); Conservation Activity 4	dependent on conservation tab inputs	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Conversion impact when threatened with conversion to residential use (dependent on number of unique parcels and size of the treatment area entered in Easement--Avoided Conversion tab); Conservation Activity 5	dependent on conservation tab inputs	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Biomass Utilization		
Carbon storage factor for softwood lumber	0.463	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Carbon storage factor for hardwood lumber	0.250	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Carbon storage factor for softwood plywood	0.484	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Carbon storage factor for oriented standboard	0.582	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Carbon storage factor for nonstructural panels	0.380	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Carbon storage factor for paper	0.058	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Carbon storage factor for miscellaneous products	0.176	California Air Resources Board, Compliance Offset Protocol U.S. Forest Projects (June 25, 2015) https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf
Fossil fuel displacement emission reduction factor for electricity generated via combustion (MT CO_2e/BDT)	0.23	California Air Resources Board & California Department of Resources, Recycling, and Recovery, Biomass Conversion (September 17, 2013) https://www.arb.ca.gov/cc/waste/biomassconversion.pdf *Note: This methodology assumes that the wood waste is delivered to a biomass energy facility that produces electricity via combustion where the biomass is incinerated in boiler to produce steam which powers a turbine-driven generator that produces electricity. Applicants that propose eligible projects that cannot be calculated using the GHG Calculator Tool, such as projects that utilize biomass energy technology not included in the calculator, may propose the use of alternative GHG quantification methods. See the acccompanying quantification methodology for more details.*
Fossil fuel displacement emission reduction factor for electricity generated via gasification (MT CO_2e/BDT)	0.30	California Air Resources Board, Detailed California-Modified GREET Pathway for Cellulosic Ethanol from Forest Waste (February 27, 2009) https://www.arb.ca.gov/fuels/lcfs/022709lcfs_forestw.pdf Sonoma County Water Agency, Feasibility of Using Residual Woody Biomass to Generate Electricity for Sonoma County (2013) http://www.scwa.ca.gov/files/docs/carbon-free-water/SCWA Bioenergy Feasibility Assessment_WDFeatherman_FINAL REPORT_2014-05-17.pdf *Note: This methodology assumes that the wood waste is delivered to a biomass energy facility that produces electricity via gasification where the biomass is heated in an oxygen-limited environment to produce hydrogen and carbon monoxide rich gas (syn gas) which powers a turbine-driven generator or internal combustion engine that produces electricity. Applicants that propose eligible projects that cannot be calculated using the GHG Calculator Tool, such as projects that utilize biomass energy technology not included in the calculator, may propose the use of alternative GHG quantification methods. See the acccompanying quantification methodology for more details.*
Avoided Open Pile Burn Emissions (ton CO2e/BDT)	0.16	Placer County Air Pollution Control District, Biomass Waste for Energy Project Reporting Protocol (January 2013) http://www.placer.ca.gov/~media/apc/documents/apcd biomass/biomasswasteforenergyproject.pdf
Avoided landfill emissions (MT CO_2e/short ton)	0.21	California Air Resources Board, Draft Method for Estimating Greenhouse Gas Emission Reductions from Diversion of Organic Waste from Landfills to Compost Facilities (March 2016) https://www.arb.ca.gov/cc/waste/waste.htm
Avoided on-site decay emissions (ton CO2e/BDT)	1.25	Placer County Air Pollution Control District, Biomass Waste for Energy Project Reporting Protocol (January 2013) http://www.placer.ca.gov/~/media/apc/documents/apcd biomass/biomasswasteforenergyproject.pdf
Electricity generated per ton of biomass waste via combustion (MWh/bone dry ton of biomass)	0.90	California Air Resources Board & California Department of Resources, Recycling, and Recovery, Biomass Conversion (September 17, 2013) https://www.arb.ca.gov/cc/waste/biomassconversion.pdf Calculated using 4,051,000 MWh of annual energy production divided by 4,500,000 bone dry tons of biomass inputs to determine the avoided energy production per ton of waste.
Electricity generated per ton of biomass waste via gasification (MWh/bone dry ton of biomass)	1.11	Table 5A in: Sonoma County Water Agency, Feasibility of Using Residual Woody Biomass to Generate Electricity for Sonoma County, 2013 http://www.scwa.ca.gov/files/docs/carbon-free-water/SCWA%20Bioenergy%20Feasibility%20Assessment_WDFeatherman_FINAL%20REPORT_2014-05-17.pdf

Conversion Factors	
CO_2e/C	3.67
Unit carbon/unit biomass	0.50
MT/ton	0.907185
lb/MT	2204.62
lb/short ton or bone dry ton (BDT)	2000

ROAD SEDIMENT SOURCE INVENTORY & RISK ASSESSMENT

Klamath National Forest – Forest-wide Compiled Road Inventory (2012)

Abstract

Roads are important and costly structures, with pervasive, persistent and potentially cumulative impacts on steep forested land. Roads contribute the highest per acre sedimentation rate of all watershed disturbances, averaging 58 times background from landsliding and 290 times background from surface erosion. Consequently, road issues are often at the heart of restoration activities. In cooperation with other agencies and groups, the Klamath National Forest has completed a comprehensive sediment source inventory of the nearly 4,375 miles of Forest roads. This substantially completes road inventory across the Forest although there are about 5,350 total miles of Forest system and non-system road. Of the non-inventoried roads, most are not hydrologically connected (do not drain to surface waters, mostly on the Goosenest Ranger District) or have been previously decommissioned. There may also be some unmapped non-system roads that are hydrologically connected and have not been inventoried. These would be an exception since the intent was to inventory all hydrologically connected existing roads, though it is possible that field crews may have not found all unmapped roads.

Overall, 11,162 sites have been inventoried across the Forest. Summary field information shows 7,338 non-bridge channel crossings and 2,436 hydrologically connected cross drains along with 1,266 between crossing sediment sources (landslides or gullies, referred to as "tweeners"). Diversion potential exists at about half of the crossing or cross-drain sites. Slightly more than 10% of the road length is hydrologically connected to natural stream courses through inboard ditches. Estimated total volume of fill material at channel crossing sites is about 3,850,000 cubic yards. If placed on a football field, this volume of material would produce a pile almost 2,300 feet high. Fill volumes averaged 525 cubic yards per site.

Forest road systems are extensive and road-related restoration is generally expensive so it is important to focus potential investments on the sites posing the highest risks, consequences, and impacts. The RSSI rated and ranked each site based on: [1] <u>risk</u> of failure, [2] <u>consequences</u> of failure (sediment delivered), and [3] <u>impacts</u> of failure (to beneficial uses). Important factors included undersized culverts, geologic instability upslope, large fill volume with diversion potential, and stream anadromy. Evaluation of all sites across the Klamath National Forest concludes that 52% of the total fill volume at channel crossings could be attributed to just 10% of the highest ranked sites. In other words, by upgrading channel crossings to reduce the risk/consequences/impacts of failure at only 10% of sites, approximately 50% of total fill volume would be treated. If the top 20% of sites (in terms of fill volume) were treated, 70% of total fill volume at channel crossing sites would be treated.

These findings suggest that targeted restoration has the potential to substantially reduce the risks and consequences from road-related sediment delivery. Road inventory/risk assessment has the demonstrated capability to accelerate watershed recovery in support of the goals of the *Endangered Species Act* and the *Clean Water Act*.

The results of the inventory reside in a geodatabase (a database that contains Geographic Information System or GIS data) accessible to employees of the Klamath National Forest. The database includes a point feature class containing all inventoried points (KnfSites), a line feature class with all mapped Forest system and non-system roads that were part of the inventory (RestRds), and tables with additional information including model ratings for each site.

Setting

The Klamath Road Inventory program includes road and site inventories across the Forest. This inventory was done over many years, from 1999 to 2012, and through the cooperation of many agencies and other groups. Grants and cost-share agreements with California Department of Fish and Game funded the earlier work though in later years most of the work was funded through the Forest Service Legacy Roads program. Much of the earlier field inventory was done by Forest Service crews, or in cooperation with the Salmon River Restoration Council or Resource Management of Fort Jones, California. The last four inventory areas, Scott 2010, SCSC (Swillup, China, Seiad, Cottonwood), Klamath West (included any remain areas on the Klamath NF west-side), and Klamath East, were done under contract by Natural Resources Management of Eureka, California. Don Elder, from the Klamath National Forest and later as a member of the ACT2 Forest Service Enterprise Team, provided primary oversight and contract inspection throughout the process. Mark Reichert, also from the ACT2 Enterprise Team, compiled the data from all the various inventories and authored this report.

Although field inventory protocol and other analysis procedures did change slightly over the years, for the most part the data is consistent enough to create one database that covers all the inventory areas, and allows comparison of inventory sites and roads across the Forest. Also, road work has continued across the Forest, in many cases repairing locations that have been identified as problems in previous road inventories. The database is designed to help track road work that has been done and can be used to update road conditions where field inventory may not accurately represent the current situation.

Table 1 shows all the road inventories that have been done over the years as they are tracked in the database, along with the road miles done for each inventory. In total, 4,373.8 miles of road have been inventoried as part of this process. Another 976.4 miles of road have been specifically excluded from the inventory process for various reasons. Roads previously decommissioned have not been inventoried to this protocol, although they may be inventoried if needed as part of a monitoring plan. New dispersed recreation roads (new Forest System roads added as part of travel management) are generally not inventoried because they are individually too short to meet the road inventory criteria and they rarely, if ever, contain crossing or erosion sites. Some roads that cross isolated parcels of National

Forest System lands, but are generally considered private roads without public access have not been inventoried

. Each road segment receives its own road evaluation independent of the other segments of the same road. Many road segments that follow or cross ridges with short segments in adjacent watersheds have been combined into one segment evaluated as entirely in the primary watershed, provided impacts in the adjacent watershed are minimal (short length at the top of a ridge with no sites). Some roads are additionally segmented as needed to reflect other conditions, i.e. a road partially decommissioned will be segmented at the point where decommissioning begins.

Each road segment is assigned a unique identifying number, its "LinkNo" (Link Number). All sites are "linked" to their appropriate road segment through use of "LinkNo". In this way information such as "number of sites with diversion potential for each road segment" can be computed. In addition, every inventoried site has its own unique identifier, the "Site_Id", which

** Problem - Background

Roads are important and costly structures, with pervasive, persistent and potentially cumulative impacts on steep forested land. Roads contribute the highest per acre sedimentation rate of all watershed disturbances (e.g., Amaranthus, et al. 1985; de la Fuente & Elder 1998; Flanagan, Furniss, et al. 1998a & 1998b; Pacific Watershed Associates 1997; U.S. Environmental Protection Agency 1998; U.S. Forest Service 1989), averaging 58 times landsliding rates compared to undisturbed ground and 290 times surface erosion rates compared to undisturbed ground (de la Fuente & Haessig 1994; Elder 1998). In addition, roads can alter hydrology, habitat connectivity, and routing of wood and sediment. These combined effects have the potential to strongly influence downstream aquatic environments critical to anadromous salmonids and other aquatic species. As the availability of road maintenance funds allocated to the Forest Service decreases (down nearly 50% in the past several years), the necessity to evaluate, prioritize and implement measures which reduce the risk of road related impacts to aquatic systems is greater than ever.

The Klamath National Forest road system sustained over 30 million dollars' worth of damage during the "New Year's Day" flood of the winter of 1996-1997 [hereafter referred to as '1997 Flood']. Stream channels, riparian areas, and fish habitat were impacted by excessive scour and deposition during that storm. The impact was severe in some places. Some of these impacts were caused by sediment delivered from roads. *The Flood of 1997: Klamath National Forest Phase I Final Report* (de la Fuente and Elder 1998) estimated that over half of the large road repair sites were at stream crossings. An estimated 22% of these sites resulted in diversion around plugged culverts.

Two of the primary types of failures occurring at road-stream crossings include "stream diversion" and "fill failure". A stream diversion occurs when a culvert at a stream crossing fails due to hydraulic exceedance and/or plugging by debris or sediment. If this happens at a stream crossing where the road leaves the crossing at a negative slope (downhill), then the water can flow down the road rather than down its' own natural channel. This often has adverse effects on the watershed, such as saturating road fills which causes failures and the potential to generate:

- debris flows, eroding the road surface,
- eroding away huge amounts of soil on unstable hillslopes where water does not naturally flow,
- cascading failures of stream crossings in adjacent drainages into which the stream has been diverted.

Partial or complete failure of crossing fills is the other primary risk posed by stream crossings to downstream aquatic habitat. In addition to the sediment generated, failures of this type can initiate large debris flows that scour channels, fill pools, and strip riparian vegetation from stream banks. Although prediction of crossing failure is difficult, the risk and consequences can be characterized. With this information, risk reduction measures including up-sizing culverts, reduction in fill size, or decommissioning can be targeted toward crossings with high risks for consequences and impacts before they fail. In addition to evaluating crossings for stream diversion potential, this assessment will assess factors influencing culvert and crossing failure. Included are consequences at all road-stream crossings within priority watersheds containing anadromous fish habitat on the Klamath National Forest.

Purpose

The intent of Forest Service policy and approach to transportation planning is to find a balance between the positive benefits of roaded access and the negative road-associated effects on other values and resources. Concerns include clean water, fish, and wildlife; and maintaining choices for future generations.

Road inventories and assessments were conducted to acquire information necessary to prioritize watershed restoration work involving roads so that the most critical, most ecologically-beneficial and cost-effective restoration projects could be more accurately identified and implemented first. The purpose of these road surveys and analyses was to identify specific locations (Sites) where road drainage structures and fill have the potential to adversely impact watershed processes, and then to assess the relative ***environmental risk*** of each identified Site.

The primary objective of the crossing inventory and assessment proposal is to identify high risk/consequences/impact road-stream crossings which pose the greatest threat to aquatic resources, especially sedimentation of anadromous fish habitat. Some or all of the following will characterize high-risk stream crossings:

- large fills at or adjacent to the crossing,
- potential for stream diversion,
- inadequate culvert capacity to pass water, woody debris or sediment,
- unstable geology above site (high debris flow potential) or down slope (high potential for additional erosional effects if crossing fails or diverts stream flow),

Road Rating

Site condition is one step in evaluating and rating roads; the next step is to rate individual roads as to their relative risk, consequences and impacts to aquatic resources. This process and result is termed 'Road Rating' and is distinct from, but depends on site condition. This rating system was developed as part of the Roads Analysis Process [RAP] done on the Salmon River Ranger District during fall of 2001. Relatively minor modifications were made in 2010 when this process was applied to all Forest roads. Prime objective of the Road Rating is to determine which roads pose the greatest threat of increased sedimentation and interruption of the hydrologic regime & riparian reserve integrity. Road ratings will later be validated in an interdisciplinary setting, leading to transportation planning recommendations for individual roads.

Assessment to Improve Late Spring/Summer Stream Flows, Reduce Fire Intensity and Fire Related Carbon Emissions in the Trinity River Watershed

Project Final Report: March 31, 2017

Trinity County Forest Ecology and Watershed Hydrology

Northwest California Resource Conservation & Development Council's

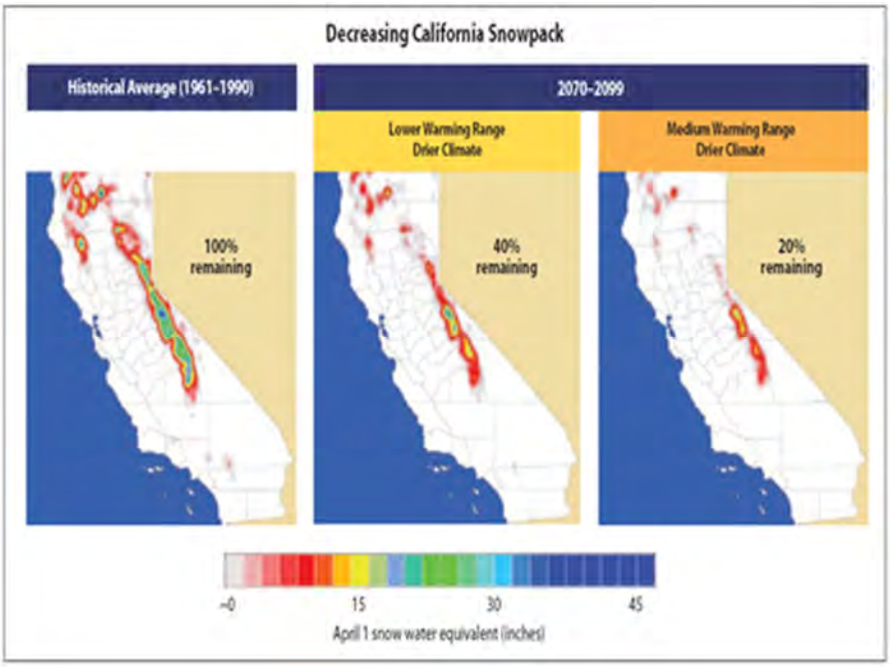
Five Counties Salmonid Conservation Program (5C)

PRECIPITATION/WATER YIELD

Precipitation Patterns

The Trinity River watershed has a Mediterranean climate characterized by wet cool winters and warm dry summers and actual precipitation patterns are the result of oceanic and atmospheric climatic features influenced by local topographic features (Trinity Alps, Pacific Ocean, Trinity Reservoir, etc.). Between 1950 and 2000 winter snow (or snow water equivalent (SWE)) storage throughout the Pacific Northwest and northwestern California declined 30% (Mote, 2003a) and a gradual increase in winter temperatures both globally and within California (Groisman et al, 2001; Lund et al, 2001) reduces snow accumulation and results in earlier snow melt (Figure 4).

Figure 4: Presentation to forest landowner's workshop- June 15th, 2011 Susie Kocher



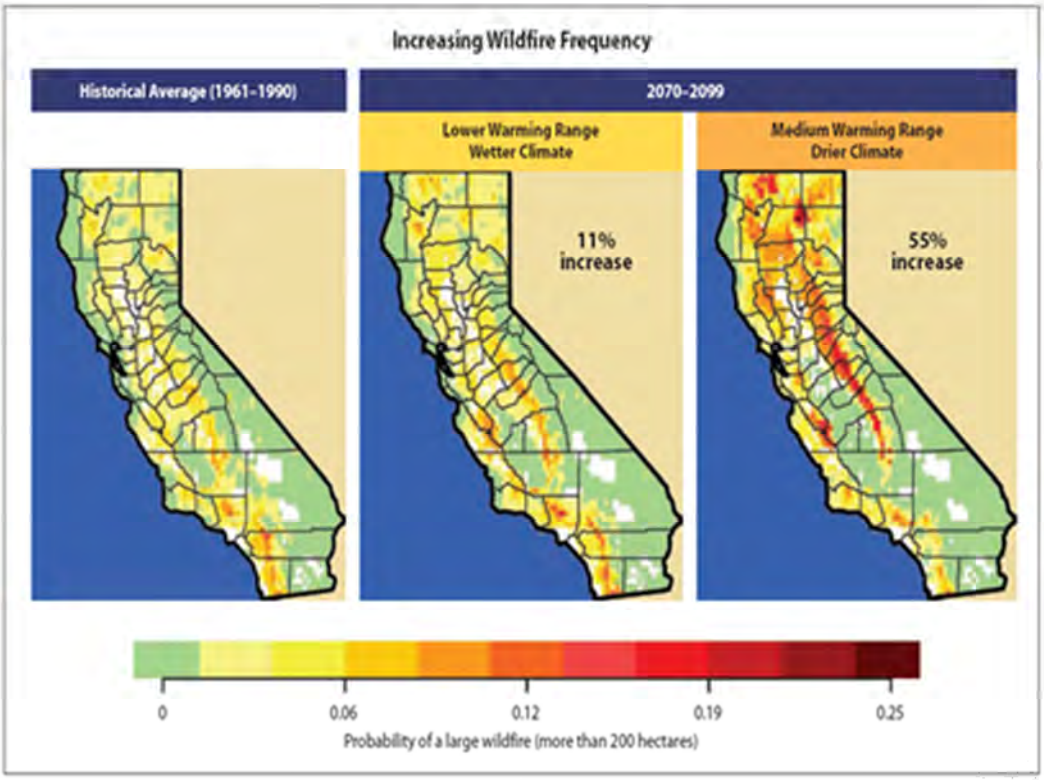
Peréz and Lancaster documented significant changes in precipitation patterns in their 2009 and 2014 reports showing annual precipitation patterns have become more erratic over the past 41 years- compared to the prior 80 year record. Between 1974 and 2016 there has been a 500% increase in the number of extreme wet and extreme dry years[1] compared to the period 1935-1974. Since 1974 there have been 12 extreme precipitation years compared to 7 for the prior 80 year period (1985-1973).

This erratic trend contributes to summer water insecurity, fisheries declines, increased fire intensity and size, severe flooding, and social disruption in communities. The extreme weather patterns have had

[1] Extremely wet or dry in *this* report is defined as more, or less than, 1.5 Standard Deviation from the mean for the Weaverville Ranger Station annual precipitation totals. This translates into years where more than 52.9" precipitation falls or less than 21.2" of annual precipitation falls. The mean annual precipitation is 37.0" for the 121 year record. While annual precipitation extremes have increased over time so has Weaverville's mean annual precipitation. The mean average precipitation shifted from 36.3" per year based on records from 1895 to 1955, to 37.8" per year between 1936 and 2015. The average for the whole 120 year period is 37.0" but the 5% increase in precipitation has been more than offset by the 30% decrease in SWE.

economic impacts with local, state and federal declared disasters in extreme precipitation years. In the past 30 years, fire, flood and drought costs have exceeded $700 million dollars in direct costs. Some studies suggest that the true costs can be 5-20 times higher than that amount for forest fire impacts.

Figure 5: Presentation to forest landowner's workshop- June 15th, 2011 Susie Kocher



5. TRINITY RIVER SNOW WATER STORAGE POTENTIAL

Approximately 43% of the Trinity River watershed within Trinity County (696,319 acres) is above 4000' elevation (Table 1 and Figure 15). The area above 4000' is the critical elevation band for extended snow melt and resulting summer base flows for streams.

Forest Ecologist James Agee in his 2007 book "Stewards Fork" succinctly discussed the influence and timing of snow runoff from the higher elevation portions of the Trinity Alps: "*Coffee Creek has 40 percent of its base area above 6,000 feet elevation. Snow and snowmelt would be expected to be more important in the hydrology of the Coffee Creek drainage than they are in the upper Trinity. Stewart and LaMarche noted that in 1960, the upper Trinity River peak storm flows occurred during a storm in February, whereas Coffee Creek's peak stream flow in June during snowmelt exceeded its peak during the February storm.*"

Table 1. Summary of All Lands Capable of Extended Snow Accumulation within the Trinity River Watershed[2]

Total Acres above `4000' Elevation	
Outside Designated Wilderness	378,690
Chanchelulla Wilderness	7,300
Trinity Alps Wilderness	302,420
Yolla Bolly-Middle Eel Wilderness	7,908
Grand Total	***696,319***
Total Acres above ~4000' Elevation by Watershed	
South Fork Trinity	193,759
Trinity	502,559
Grand Total	***696,318***

Snow depth is influenced by numerous factors including elevation, aspect, climatic conditions, geology, and forest canopy cover. A unique feature of higher elevation areas are "U" shaped valleys formed by glaciers. These valleys form lakes, ponds and wet meadows that capture snow melt and act as sponges, slowly percolating water into the ground (Figure 6 & 7). The stored water acts as a water bank and extends runoff into spring/summer.

Canopy Influence On Snow Water Storage Potential

Forest canopy is the one constantly changing factor that can be readily and reliably managed. Forest canopies intercept snow fall allowing it to sublimate before it can slide off of the needles or melt. Conifer forests, with their evergreen canopies, have greater effects on snowfall interception than hardwood forest canopies, which drop leaves before snow arrives.

The extent of canopy closure has a significant influence on snow water storage. Stands with canopies open enough to allow snow to reach the ground but closed enough to reduce understory brush development are best suited to maximize snow water equivalent (SWE) storage potential (Strock and Lettenmaier, 2002; Varhola, et al, 2010, Lundquist, et al. 2013).

[2] Acreage is based on GIS analysis from Baldwin, Blomstrom, Wilkinson and Associates as part of this assessment. Minor rounding errors or watershed boundary factors may result in insignificant differences in totals.

Stands with ~40-60%[3] canopy closure appear to be optimal to allow snow to fall through to the ground) while partially shading the ground. Partially open canopy levels appear to both shade snow during sunny winter days while allowing warmer air to escape the tree canopy. Studies in the Mediterranean climate of this region suggest that as temperatures rise in February and March, dense closed tree canopies trap and store heat that offset daytime shade benefits (Dobre, et al 2012, Hagberg, et al, 2012). The rise of average winter temperatures in the region in the past 50 years appears to be driving an increase in early winter snowmelt (Mote, 2003, Dobre, et al 2012, Hagberg, et al, 2012). Opening the stand too much (~<30% crown closure) can trigger dense brush growth (Figure 9) which acts similarly to closed forest canopy, trapping snow in the tops of the brush where sublimation removes it before it can form a snow pack on the ground.

Figures 6 and 7. Snow melt runoff from the Coffee Creek watershed at 5000' forms a pond until late May or early June (left). In July the pond has drained leaving a wet meadow, which by August has dried out completely (right).


Fire Influence On Snow Water Storage Potential

Decades of fire suppression has contributed to dense forest stands with interlaced canopies and woody debris accumulations in the understory (Figure 8) that create an explosive fire mix. The addition of fire starts (typically lightning[4]) have contributed to the mega fire conditions that have defined the Trinity River watershed over the past three decades (Table 2 and Figure 10-12). The size of fires, combined with greater burn severity (30%-60% area with moderate to high burn severity (Lydersena, et al 2014)) has outpaced many planning assumptions about fire, water yield and stand management. Fire exclusion has also allowed trees to invade high elevation wet meadows, potentially reducing their water storage benefits.[5]

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[3] Studies of the relation between canopy conditions and snow depth cite the lack of detailed analysis of elevation, aspect, annual climatic conditions (winds, precipitation, temperature and other factors) which limit researchers ability to determine optimal stand conditions for maximizing snow retention and delay melt out period (Varhola, et al. 2010).

[4] For example, Romps et al. (2014), estimates that lightning frequency will increase about 12 percent for every 1° Celsius (1.8° Fahrenheit) in warming. Within the Trinity River watershed lightning sparked fires burn the most acreage. Computer models of climate forecast that by the end of this century, average air temperatures at Earth's surface will rise by 4 °C.

[5] Spring and summer wet meadow soil conditions deprives seedling root systems of oxygen and limits successional regrowth, thereby maintaining open meadows. As the snow pack diminishes and meadows dry up earlier in the season, seedlings mortality is reduced and meadows acreage decreases.

While the need to consider stand thinning for water yield and fuels reduction is critical, mega fires of the past few decades may create adverse cumulative impacts that can constrain management options[i].

Figures 8 and 9: A dense mature, even-aged stand at 5300 feet elevation along the Packers Creek Trail in the Coffee Creek watershed (left) and an open forest canopy at 6,500' along the same trail and watershed (right). The overstocked stand has both a closed crown and significant fuel loads on the forest floor while the very open canopy at the higher elevation has a dense shrub layer. Both stands allow for high snow sublimation losses .

Table 2. Total Acres Burned since 1987	
Outside Designated Wilderness	351,142
Chanchelulla Wilderness	3,872
Trinity Alps Wilderness	216,132
Yolla Bolly-Middle Eel Wilderness	6,341
Acres Reburned Since 1987	108,920
Grand Total	***686,408***

Figure 10. Acres Burned by Decade in Trinity River Watershed in Trinity County.

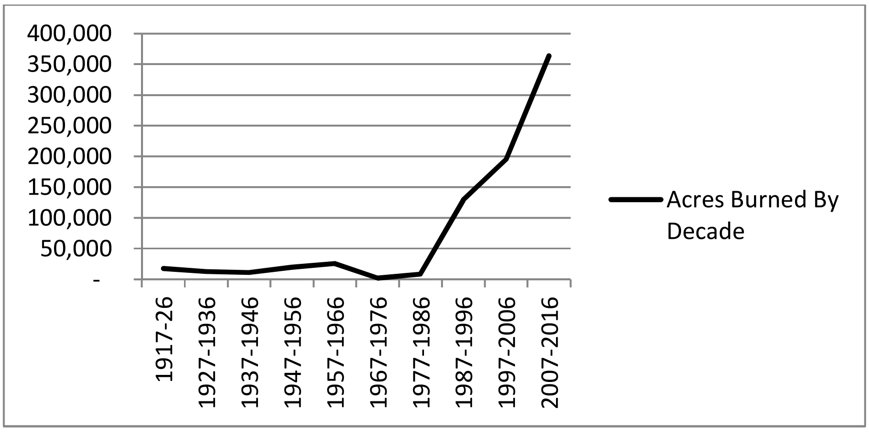


Figure 11: (Above) The 2013 Corral Fire (foreground) and 1999 Meagram Fire (background) form a mosaic including conversion of mature conifers to brush as well as canopy thinning (Photo:Thomas Dunklin).

Figure 12: (Below): Stand conversion from dense conifer pole stand to grass as a result of the 2015 Johnson Fire.

Fire has not burned evenly within the Trinity River watershed. While 28% of the watershed (466,476 acres) has burned since 2006, nearly all of it (459,790 acres) has been in the western two-thirds of the watershed (Figure 13). Approximately 63% of the western 2/3 of the watershed (~676,184.98 acres) has burned since 1987, including 108,920 acres that has reburned in that time period (Figure 14). In contrast, less than 1% of the northeastern third of the watershed has burned since 2006 and less than 2% has burned since 1987. Within the eastern third of the watershed, logging has accounted for approximately 90% of stand changes (~120,000 acres), with fire, insect disease mortality and wind throw accounting for the remaining 10% of stand structural changes.

Figure 13. 30 Year Fire History of the Trinity River Watershed 1987-2016

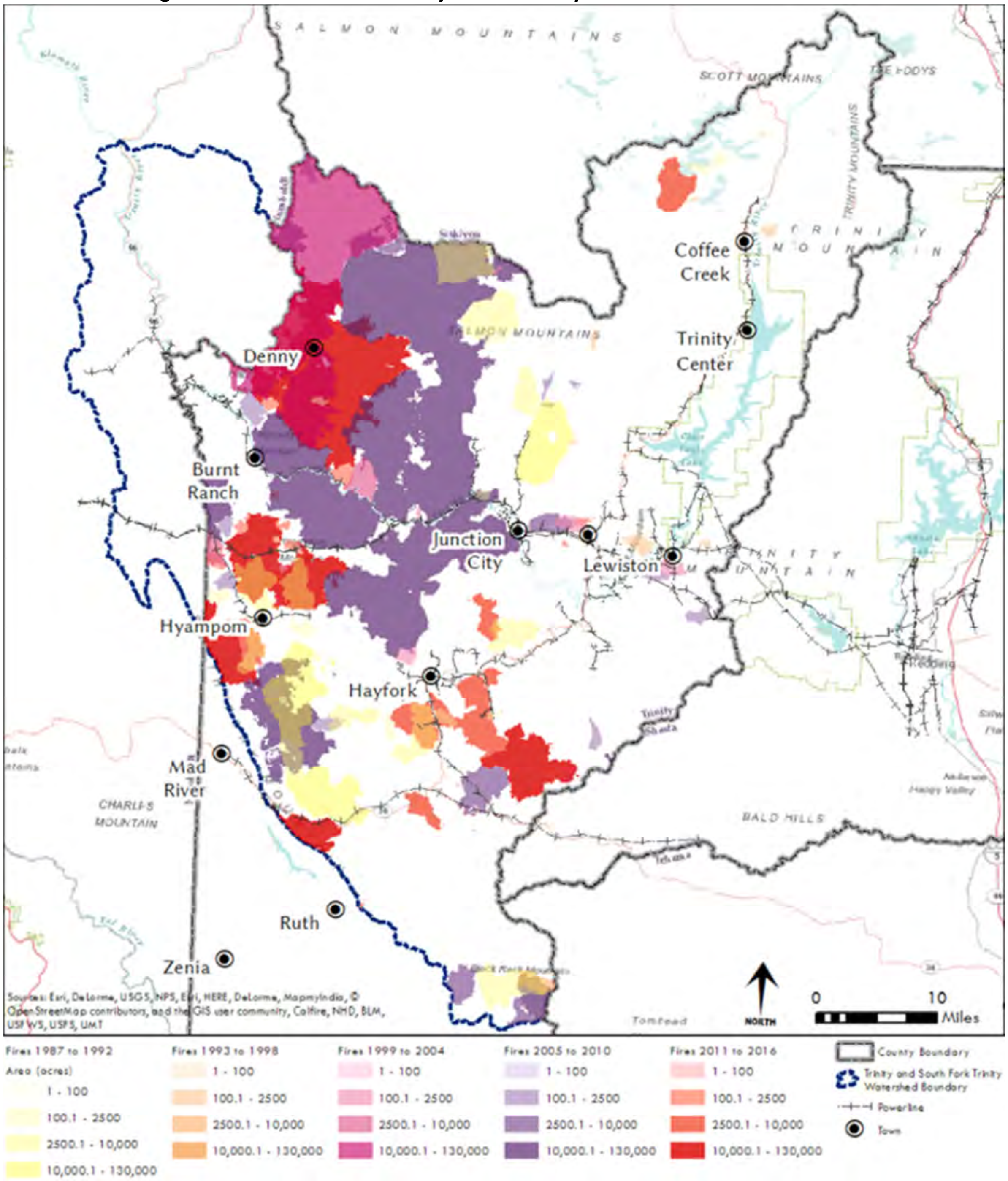


Figure 14. Areas that have burned more than once between 1987-2016

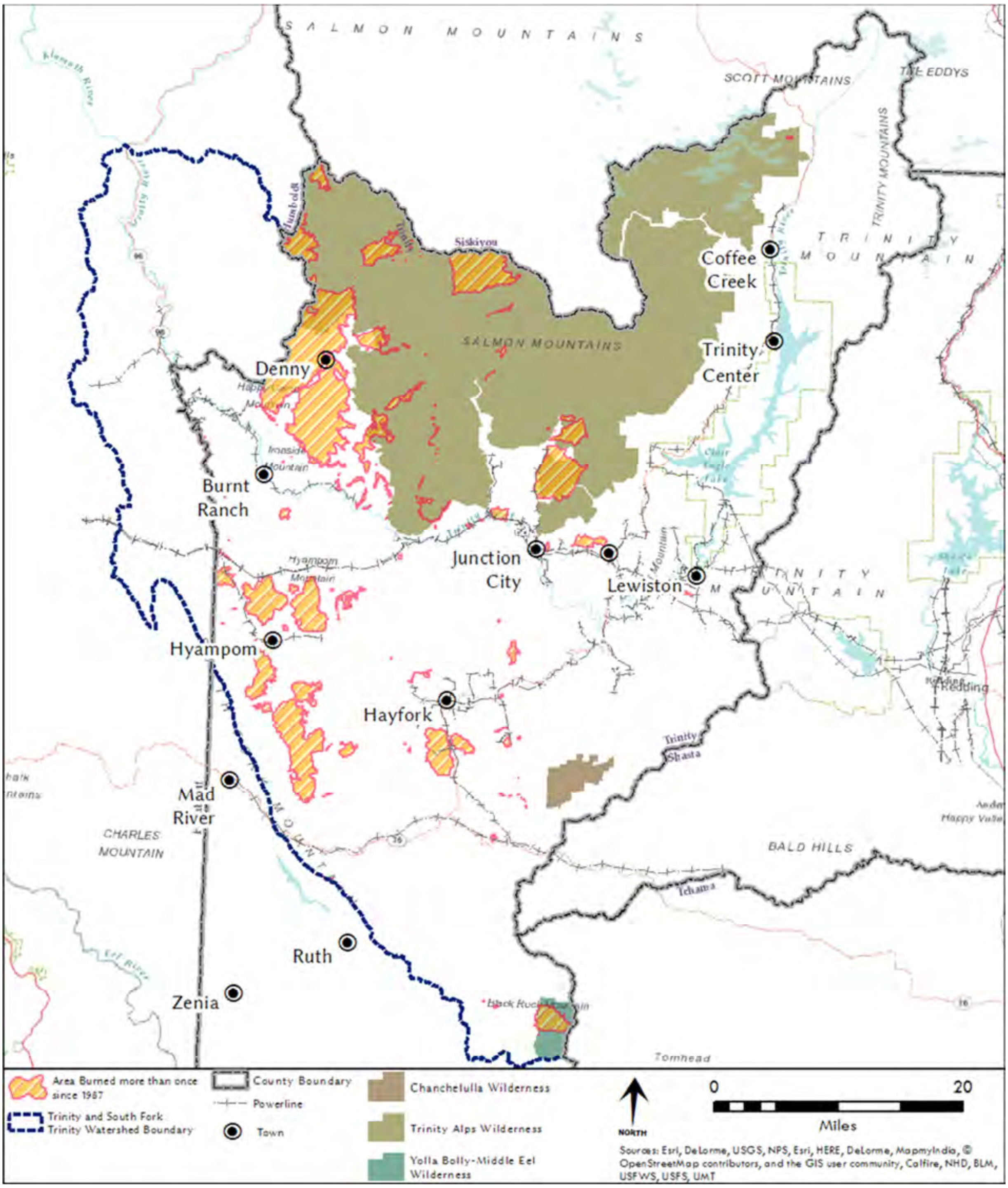
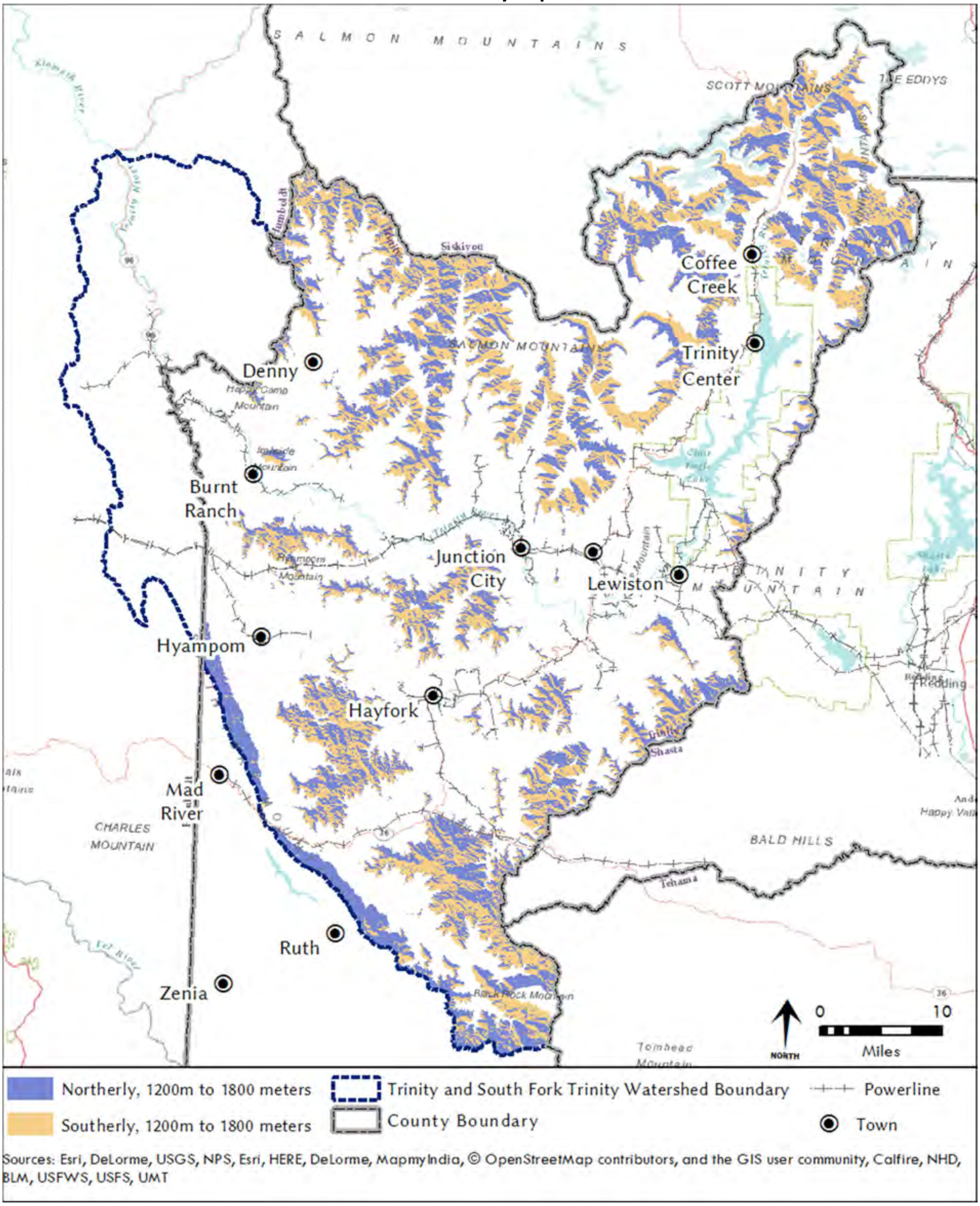


Figure 15. All Areas Of The Trinity River Watershed In Trinity County Between ~4000' and 6000' Elevation By Aspect.



6. Selection Criteria For Stands

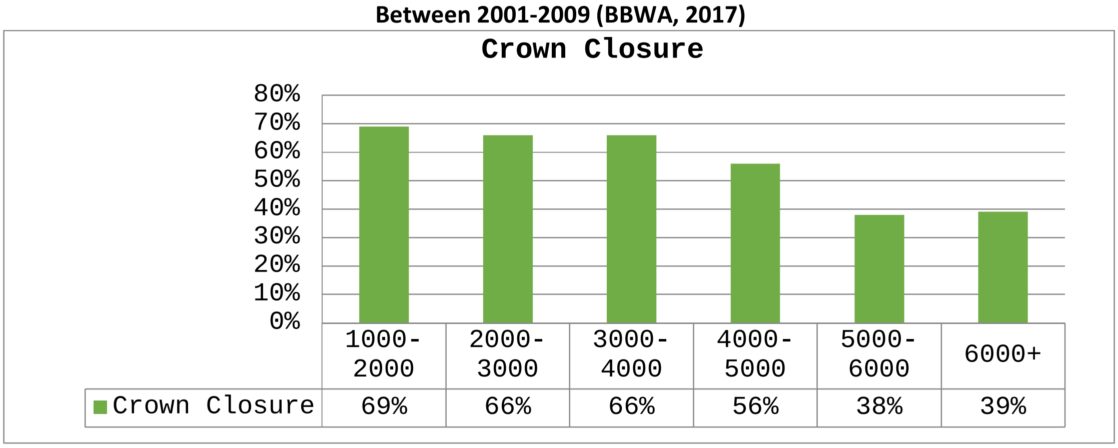
Elevation, aspect, and forest cover explains about 80–90% of the variability in snow accumulation at a watershed scale (Jost, et al.,2007; Anderson et al., 2004; Pomeroy et al., 1998). To assure efficient use of funds, the following criteria were used for selection of stands that could be treated to increase SWE, snow melt extension and potentially reduce fire behavior under moderate fire danger conditions.

Elevation- The 4000' elevation band is the lowest elevation where snow accumulation extends into spring[6], but because it is well below the snow monitoring stations (Big Flat is the lowest at 5100') there is limited data on SWE yields. However, stands below ~4000' elevation are known to have a risk of "rain on snow" events that can exacerbate downstream flooding (Surfleet and Tollos, 2013). Intentionally increasing the snow pack at these elevations is not as beneficial with some increased risk of flooding. While rain on snow can occur at higher elevations it is much rarer.

To determine the optimal upper elevation band in the Trinity River we looked at research that indicates that stands with ~40%-60% crown closure will have the greatest SWE benefits[7]. Forest Inventory and Analysis (FIA) forest canopy closure measurements taken between 2001 and 2009 were examined to find the elevation where canopy closure naturally declines. The 2001 to 2009 data set also captured large stand changes that resulted from mega fires (1987, 1999, 2006 and 2008)[8].

The stand data showed a significant decline of crown closure above 5000' elevation (Table 3). Given the variability of canopy closure by aspect (denser on northerly aspects) the upper elevation for treatment was established as 6000', slightly above the significant change in crown closure found in the FIA data. Approximately ~11% of the watershed in the County (154,000 acres) is above 6000' elevation and receives greater snow fall, but snow depth at the highest elevations often is not as deep as lower slopes due to exposure, wind, gravity (slough), avalanches, and other factors (Grünewald, et al., 2014). Forest stands above 6000' elevation are generally within Wilderness areas and are already sufficiently open to allow for snow to reach the ground.

Table 3. Percent Crown Closure By Elevation Band for Trinity River Watershed for FIA Plots Measured Between 2001-2009 (BBWA, 2017)



[6] 4000' elevation was selected as the baseline elevation based on published snow yield research in the region (e.g. Storck et al., 2002)

[7] Hagberg, et al (2012) found that the medium canopy density (30-60%) strikes the best balance between initial snowfall accumulations and its ability to retain SWE over time.

[8] ~ 516,000 acres (or 65% of all acres burned since 1911) burned between 1987-2009.

Aspect- Elevation plays the most important role in snowmelt, but aspect and forest cover are only slightly less influential (Jost, et al. 2007). A 1960 study of snow accumulation and melt out (USFS, 1979) found that northern aspect plots had higher SWE levels for the same sample period compared to plots on southern aspects. It also found snow melted out 4-5 weeks later on northern slopes compared to snow on southerly facing plots. The influence of aspect on snow pack melt out is obvious to anyone that has climbed up a snow free south facing slope but crossed over to the north side to encounter a deep snow pack.

Stand management for fire behavior is also expected to be more beneficial on northerly aspect stands than on south slope stands. Examination of the 2006 Big Bar complex of fires in the watershed showed that forest stands on northerly facing slopes have lower burn severity compared to stands on southerly slopes in the same fire (Alexander, et al. 2006).

Slightly less than half of the area between 4000' and 6000' elevation in the Trinity River watershed in Trinity County (267,534 acres) has northwest to northeast aspects (Table 4). These reaches provide the greatest opportunity to both increase SWE and extend snow melt out utilizing thinning of forest crowns (Table 4) and influence fire behavior.

Table 4. Total Acres ~4000' Elevation - ~6000' Elevation With Northerly Aspect By Watershed

South Fork Trinity Watershed Total	***99,697***
Outside Designated Wilderness	95,059
Chanchelulla Wilderness	2,214
Yolla Bolly-Middle Eel Wilderness	2,423
Trinity Watershed Total	***167,837***
Outside Designated Wilderness	78,707
Chanchelulla Wilderness	1,108
Trinity Alps Wilderness	88,021
Grand Total	***267,534***

Forest Canopy - There is substantial research linking snow related water yield with forest stand density and thinning. Changes in sublimation rates by thinning forest stands are among the most effective ways land managers can increase snow depth on the ground.[ii] Increasing snow through fall by 33% could increase snow water equivalent amounts by 10%-20% compared to untreated stands (Reid and Lewis, 2004, Storck et al, 2002, Troendle, et al,1980). Thinning can also reduce the melting effects of warm air trapped under dense forest canopies. Snow melt out in February/March can be greater for snow packs under heavily shaded stands than in open areas or under partially shaded stands. The closed canopy traps warm air longer into the night, and in Mediterranean climates, can hasten snowmelt.

While there are numerous studies on the changes in water yield from thinning, there is less certainty on the optimal level of thinning for SWE benefit. This is due partly to the difficulty that researchers have controlling many of the variables that affect snow accumulation and melt rates (e.g. temperature, precipitation, wind, animal damage within plots etc.). Most studies did not have adequate equipment to measure these variables to a precision that would allow for harmonizing data. Because of these and other factors, it is difficult for researchers to develop a single optimal canopy closure level for maximum snow benefit. Instead, authors suggest a range of canopy closure of ~30% to 60%. In many stands a

30% closure is not sufficient to prevent brush development. For that reason we recommend that stands not be thinned below 40% crown closure for maximum water yield into spring/summer. Studies also suggest that stands over 70% crown closure have high rates of sublimation and possible early snow melt due to heat trapped under the canopy.

In selecting an optimal crown closure range for spring/summer snow melt, a review of fire behavior modeling and canopy closure can also be considered. Fire modeling[9] of 96 plots from ~3,200 acres in the Weaver Creek watershed found that a fire in August after a "moderate" fuels reduction thinning would have flame lengths similar to untreated stands for the first 5 years following treatment[10], but that flames lengths 15 years later would be 40% lower than the untreated stands. Only 8.8% stand mortality would occur for the moderate fuels treatment compared to 31.2% mortality for the untreated stand condition. More significantly is the effects in specific stand types such as dense Douglas-fir stands would have 18.7% mortality in the treated stand, while untreated the stands would be expected to be completely killed (BBWA, 2004).

Land Ownership- Snow water/ fuels management thinning objectives, costs, and options, are significantly different depending on land ownership. There are four types of ownership of the 267,534 acres lying between 4000' and 6000' elevation and on northerly aspects (Figure 16).

National Forest Wilderness areas are limited to natural processes such as allowing lower intensity fires to burn and, potentially, allowing prescribed fire to be used to reduce understory and midstory fuels. Wilderness lands, which cannot be actively managed, are not considered further in this assessment. However, the water yield and reduced risks of catastrophic fire benefits of prescribed burns or frequent natural low intensity fires are recognized as being as valuable as stand management options on other lands.

Likewise Sierra Pacific Industries (SPI) lands, which are actively managed to maximize timber production, already meet or exceed the thinning standards proposed in this assessment. For that reason, they are not further analyzed.

The active management option proposed in this assessment would target the 148,011 acres of National Forest lands and private, non-SPI, ownerships between 4000' and 6000' elevation on northwest to northeast aspects.

For private land owners, thinning objectives often include reducing fire danger, generating income, and/or improving forest health. Improvement of downstream water yields for the benefit of others is typically not a primary objective but rather an outcome of stewardship management. For these private landowners, state environmental exemptions for thinning of pre-commercial and commercial stands provide a relatively low cost option. However, low log prices, lack of markets for some species and/or lack of logging contractors may still be disincentives for some landowners to implement thinning projects. State and federal cost share programs, such as CFIP and EQIP, often help offset costs for projects that thin small trees for non-industrial private landowners.

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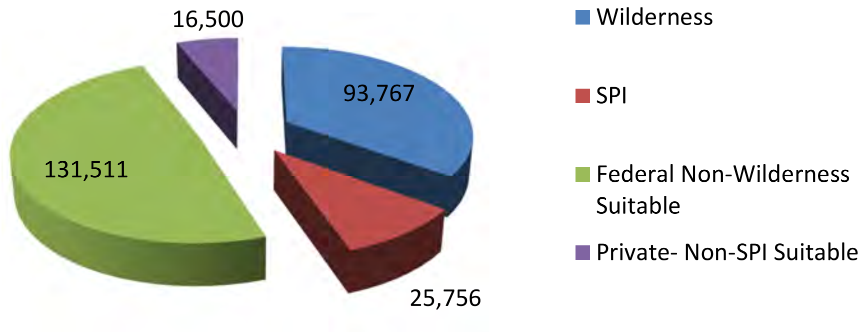
[9] Using USFS Forest Vegetation Simulator/FFE (Fire and Fuel Effects) (USFS, 2003) with the FVS WESSIN variant for fire behavior and each plot assigned an FBPS fuel model (NWCG, 1982) based on vegetation and overstory condition (generally fuel models 8-10).

[10] The flame length in the treated stands was partially due to the influence of a set of hardwood/conifer stand types that are not likely to be found at the elevations of this study, suggesting that the effects reported in BBWA (2004) overstate flame length.

Figure 16. Land Ownership For Areas Between 4000'-6000' Elevation with Northwest to Northeast Aspect



Thinning operations on National Forest managed lands will often have watershed, healthy forest and fire reduction objectives and may focus less on activities with an economic return. The process of implementing any management activity on the National Forest is relatively slow, cumbersome and costly. Environmental compliance often means that projects may take 1-3 years of assessment. Often the costs of implementing treatments will exceed budgeted funds, adding further delay to implementation.

Land Management/ Fire History- Application of the physical and ownership factors are relatively permanent, but land use history is constantly evolving. Of the 148,011 acres of National Forest lands (outside Wilderness areas) and private ownerships between 4000' and 6000' elevation with northwest to northeast aspects, 29,659 acres burned between 2006 and 2015 (Table 5). Fires effects in managed stands that burned in the past 10 years range from light understory clearing to complete stand killing. For that reason, burned lands are withdrawn from the suitable land base for thinning operations to improve SWE and water yields. If stand management activities and historic fire patterns of the past three decades continue in the near future, many stands will burn before any other form of thinning treatment can be completed.

Table 5. Theoretical Treatable Acres ~4000' Elevation - ~6000' Elevation Not Burned Since 2005 by Ownership

Northerly Aspect Total	***118,352***
Federal	101,849
State	3
Private & Other	16,500

Cumulative Effects (Deforestation, Stand Conversion and Watershed Instability)

The extent of recent fire in the western two-thirds of the watershed have resulted in significant disturbances levels that will impact opportunities for some thinning practices. Watershed impacts are greatest in areas of repetitive high intensity fires. Within the watershed, approximately 109,000 acres, of the 689,000 acres burned since 1987 have reburned (Figure 14).

Figures 17 (Below Left) low intensity fire in the understory and moderate burn intensity Figure 18 Below Right of the 2015 Peak Fire, South Fork Trinity River watershed.

Figure 19 (Below) Low intensity prescribed burn in 2015, north of Weaverville

These areas have increased extent of hydrophobic soils, loss of large wood sediment filters, increased rill and gully erosion and greater levels of channel incision. The effects of high intensity fires and repetitive fires hinder watershed recovery. The loss of root strength to stabilize soils following a fire is greatest 10-20 years after the fire. In this period the roots of trees killed in the fire deteriorate and new root growth is not sufficient to provide soil stability.

Burn Area Emergency Rehabilitation (BAER) Reports for the Saddle Fire, Fork Complex and other recent fires in the Trinity River watershed indicate increased risks of accelerated runoff and mass wasting potential in these burned areas.[11] Portions of these areas have converted to hardwood, brush or grass vegetation types, while a significant portion moved from nearly all conifer composition to mixed hardwood-conifer compositions (refer to Appendix A- Photolog of Fire Affected Stands). Some papers suggest that increased water yield under these conditions occurs primarily as winter runoff, may damage watersheds and does not enhance summer flows (Rhodes and Fissell, 2015).

Where water is stored in reservoirs, increased winter runoff may be beneficial if it is captured for summer use. However, capture of winter runoff and storage behind Trinity Dam is limited due to dam safety criteria that does not allow the lake maximum pool storage to exceed 80% of capacity before April 1st of each year.

[11] (http://inciweb.nwcg.gov/photos/CASRF/2015-09-01-1730-2015-Six-Rivers-PostFire-BAER/related_files/pict20150916-220213-0.pdf); Fork Complex http://inciweb.nwcg.gov/photos/CASHF/2015-09-01-1727-2015-ShastaTrinity-PostFire-BAER/related_files/pict20150826-003838-0.pdf).

7. Selected Stands For Detailed Analysis

Application of the selection criteria described in the preceding section identified 118,278 acres from the total 1.63 million acres within Trinity County as suitable for thinning to improve water yield (Figures 20 and 21). The majority of the acreage is concentrated in the Mt. Eddy area and the headwaters of the South Fork Trinity River. Within these areas the largest sections were dropped from detailed analysis because they were primarily owned by SPI and the Forest Service, entirely under National Forest Management, or had significant burn histories over the past 30 years. Additionally, several other areas potentially suitable for water yield based treatments are relatively small and inaccessible and are excluded from this analysis.

Areas selected for detailed assessment (Coffee Creek, Burnt Ranch, South Fork Mountain) have a number of desirable characteristics, they are accessible, incorporate a mix of National Forest and private ownerships, are accessible, represent the diversity of stands in the watershed, and that have not burned in the past 30+ years.

Figure 20 Criteria Used to Select Areas For Detailed Assessment.

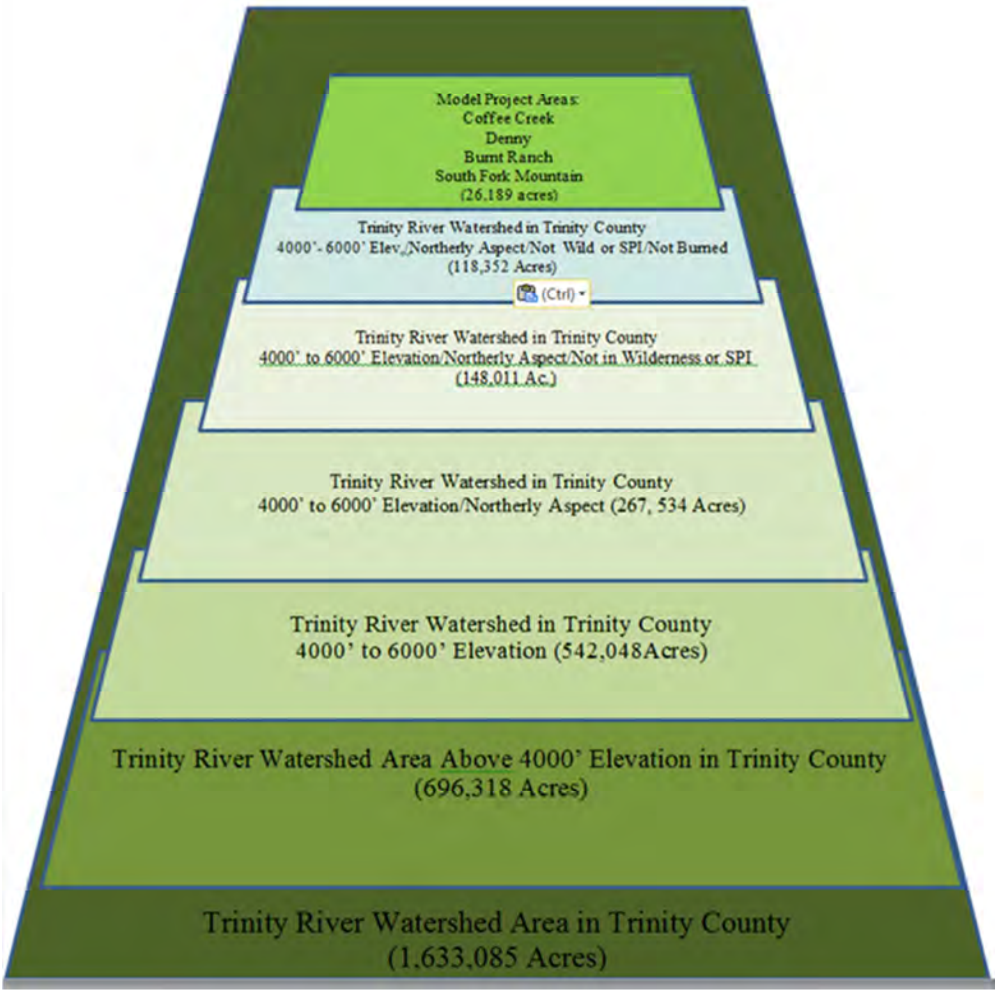
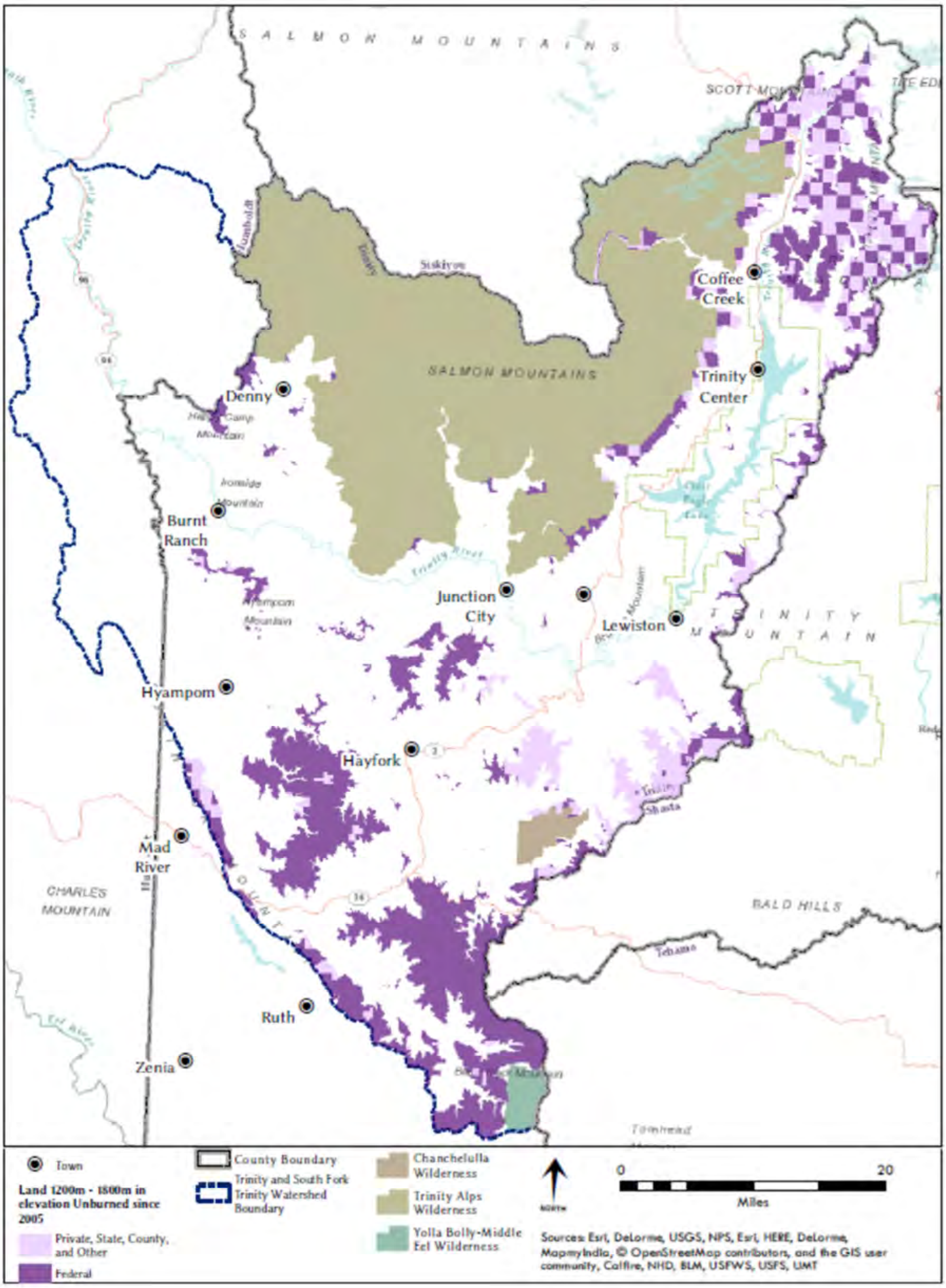


Figure 21 All lands meeting criteria of elevation, aspect and unburned since 2006.

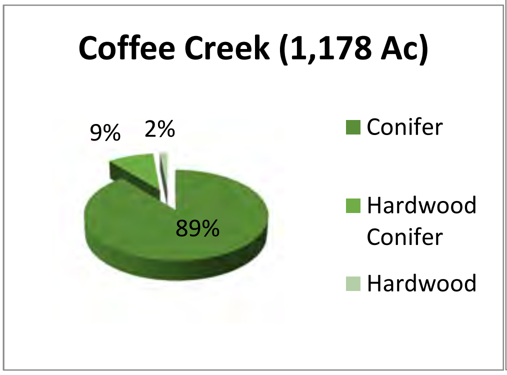


The three areas selected- Upper Coffee Creek, Burnt Ranch, and South Fork Mountain total 10,713 acres with an average elevation of ~4,600 feet.

Coffee Creek- The Coffee Creek Road corridor was selected primarily because of the nearly equal mix of public and private ownership, high ecological and water capacity values, the high potential for fuel break benefits, and the potential effects of a fire moving from the road area into the Wilderness area. With elevations ranging from 4,000 to 5,200, the 1,178 acre project area is relatively flat and is characterized by the Coffee Creek valley and adjacent mountain slopes. The project area is entirely surrounded by the Trinity Alps Wilderness area. Approximately 40% of the area is owned by private landowners holding less than 160 acre parcels. The remainder is under National Forest management.

Wet meadows form the non-forested portions of the area and serve as "sponges" absorbing snow melt and extending runoff late into spring and summer. With designated Wilderness surrounding it, the corridor is the only opportunity to restore more open forest stands, reduce fuels and maintain or enhance wet meadow reaches. The project site represents much of the Trinity Alps vegetation types at these elevations. Conifers stands account for 90% of the assessment area with white fir the dominant species. Jeffrey/ponderosa pine, incense cedar, Douglas-fir, and sugar pine combined make up about half of the stand composition. Past timber harvest and fire exclusion has influenced species composition. Larger diameter tree stands (>20" dbh) account for 54% of the assessment area. Hardwood-Conifer stands (Jeffery and ponderosa pine, Douglas fir, California black oak, interior live oak, and Pacific madrone) make up 9% of the area and pure Hardwood stands (cottonwood, white alder, big leaf maple, and willows) make up only 2% of the area, forming the Coffee Creek riparian and meadow edges. Figures 22-24 summarize the stands

Figure 22 and 23. Coffee Creek assessment area vegetation summaries.



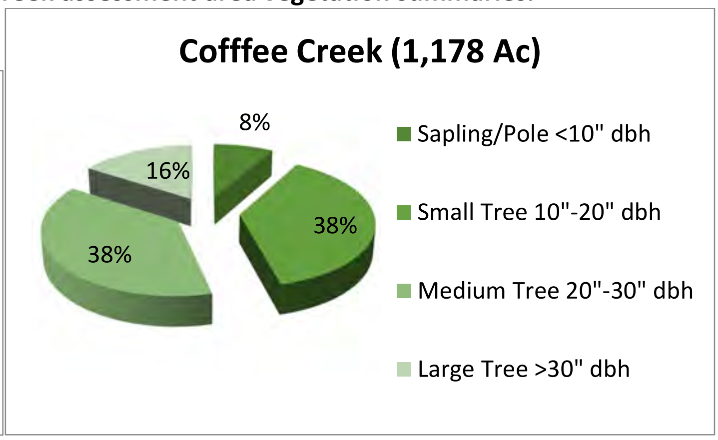
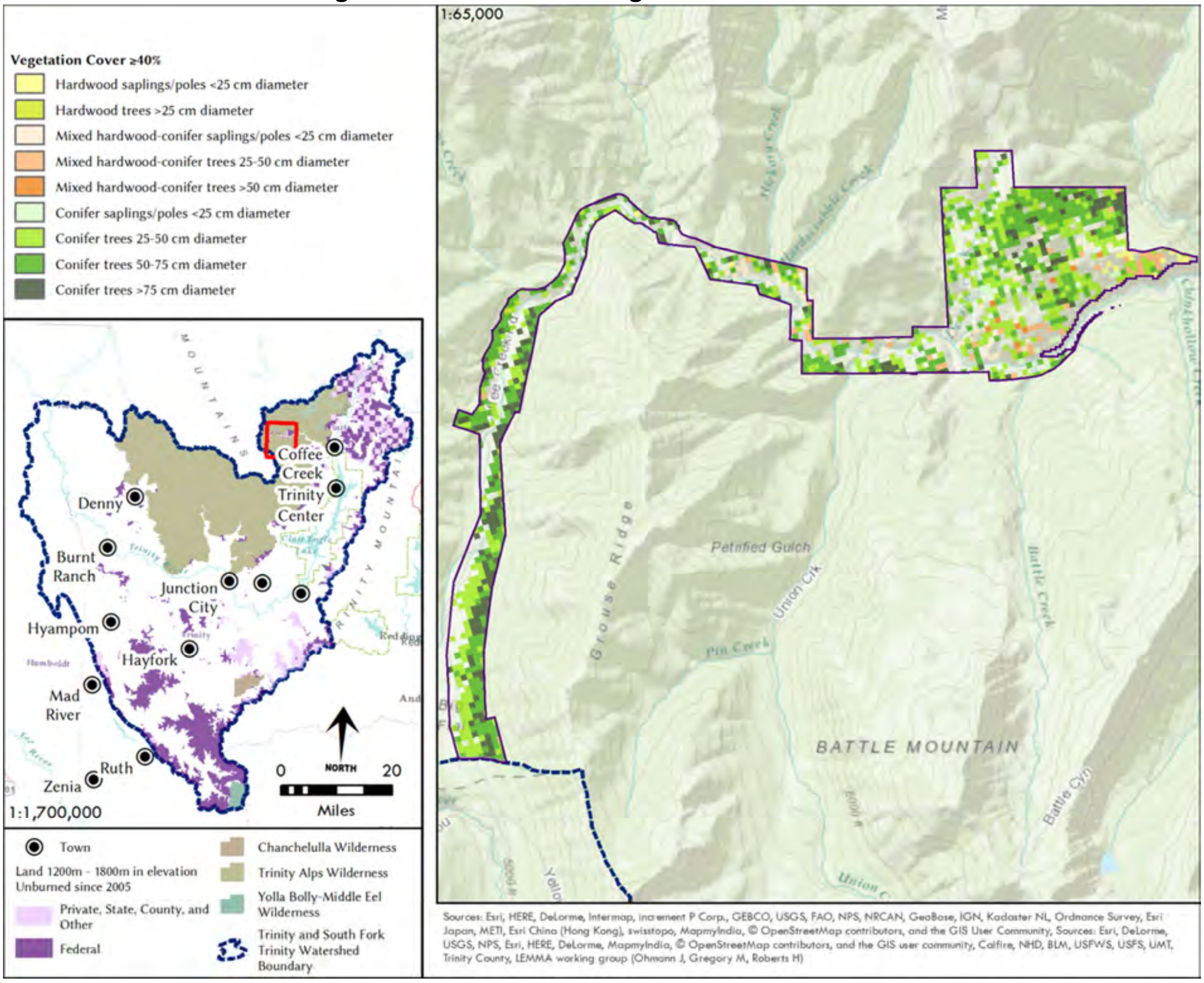


Figure 24. Coffee Creek Vegetation Communities



Increased water yield in this area benefits Trinity Reservoir and downstream river users, but will not significantly affect cold water or endangered fisheries because of the Trinity dam. Fuels reduction programs could have a significant positive effect on Wilderness values.

Water yield

As discussed in a previous sections, the project area selection criteria is intended to target areas for forest thinning that would extend runoff later into spring and summer and not adversely affect watershed processes,. Within the 10,713 acres forming the three assessment areas, stands were aggregated into three broad species groupings (Hardwood, Hardwood-Conifer and Conifer types) and stratified into four average diameter classes(<10" dbh, 10-20" dbh, 20-30" dbh and greater than 30" dbh).

Vegetation data was derived from Landscape Ecology, Modeling, Mapping & Analysis (LEMMA) working group's Gradient Nearest Neighbor (GNN) dataset.[12] This raster dataset represents model output generated by the GNN method (Ohmann & Gregory 2002, CJFR) for assigning forest inventory plot identities to unsampled spatial locations. This model uses satellite imagery processed using the LandTrendr algorithm (Kennedy et. al., 2010). LandTrendr is a trajectory-based change detection method that minimizes annual variability from noise (e.g. differences in sun angle, phenology, atmospheric effects), such that the remaining signal more closely reflects real changes in vegetation.

These data are most appropriately used to characterize vegetation conditions across landscapes, counties, watersheds, or ecoregions (areas larger than stands or patches). In general the data are appropriately used for planning and policy level analyses and decisions. Local map accuracy may be insufficient to support local- (e.g. stand-) scale decisions.

We utilized GIS level vegetation data, stand reconnaissance (basal area), aerial photo review (canopy closure), and limited stand inventory data to estimated basal area/acre and crown closure for each diameter class grouping. Significant portions of the assessment area had basal areas ranging from 150-300 ft^2 per acre and crown closure of 70%-90%. These sites are the focus of thinning treatments.

Table 6 Stand Table For Assessment Areas

Species Groups	Size Class	Diameter Class (dbh)	Coffee Creek	Burnt Ranch	SF Mountain
Hardwood	Small Tree	<10	15	289	89
Hardwood	Medium Tree	>10	3	176	24
MHC *	Small Tree	<10	51	257	47
MHC	Medium Tree	10-20	49	604	414
MHC	Medium Tree	>20	10	694	344
Conifer	Sap/pole	>10	31	86	525
Conifer	Small Tree	10-20	394	883	1,018
Conifer	Medium Tree	20-30	438	931	1,954
Conifer	Medium Tree	>30	187	204	996
Total			**1,178**	**4,124**	**5,411**
***MHC: Mixed Harwood-Confer**					

Stand data and fire modeling in the Weaver Creek watershed was used as a template for modeling thinning assumptions (BBWA, 2004). A review of residual basal area, crown closure and stand conditions was done for units harvested within the USFS "Browns" Project in the Weaver Creek watershed (Figure 30), as well. Modeling completed by BBWA used pre-harvest basal area, diameter distributions and

[12] (Ohmann J, Gregory M, Roberts H) http://lemma.forestry.oregonstate.edu/

crown conditions data similar to many stands in the assessment area. Based on these analogous assessment efforts, this assessment applies a 20% reduction of basal area per treated acre of conifer stands.

Figure 31. A thinned conifer stand in the Weaver Creek watershed where ~30% of the stand basal area was removed leaving ~80-120 ft^2 basal area per acre and a 60% crown closure.

To estimate potential per-acre water yield benefits of forest thinning, we relied on existing research on conifer forest water yields in response to forest stand structural changes (Brown et al., 2005). As Podolak et. al. (2015) notes:

> "*Despite this extensive literature on the relationship between forest harvest and water yield, there are no empirical studies completed yet on the effect of ecologically based forest thinning on water yield in the Sierra Nevada. These synthesis studies show a linear increase in water yield with increases in the percentage of forest removed regardless of the forest type or the precise logging method. Based on these studies, we used the average increase in water yield as a low estimate of water yield change, and the reported maximum increases to estimate the high end: 22–40 mm for 10 percent reduction in forest basal area (i.e., the area of tree trunks) or 0.14–0.41 acre-foot (AF) per acre of forest treated*."

Stands with average diameters of less than 10” and Hardwood stands, which drop their leaves in fall and thus have lower sublimation and heat trapping effects, were not modeled for water yield treatment in this assessment.

8. Results

For our water yield estimate, we utilized the same assumptions as Podolak, et al. (2015) with a low water yield estimate of 0.14 Acre-feet/year (AF) and 0.41 AF/year for high water yield estimate, per 10 percent basal area reduction of dense conifer stands (150 ft2 or higher basal area). Hardwood-Conifer stands with average diameters greater than 10” dbh were modeled assuming a 10% reduction in stand basal area. These stands were assigned a water yield increase of 0.05 AF per treated acre for the low water yield estimate and 0.14 AF for the high water yield estimate. Within Hardwood-Conifer stands reduction of conifer basal area does not result in the same water yield benefits as reductions in Conifer stands, as crown closure varies seasonally and is already more open in the critical periods of snow fall and melt out.

Conifer stands greater than 10” dbh were modeled assuming a 20-40 ft^2 basal area reduction or approximately 20% reduction in average stand density. The maximum acreage targeted for thinning was 25% of any stand group. The 25% area target allows for exclusion of already managed or disturbed stands within the project areas that have met the canopy objectives. It also recognizes the National Forest administratively withdrawn lands (e.g. Riparian Reserves, Roadless Areas) where treatments would not occur. The 25% target is feasible in part based on the private lands portions of the assessment area.

The estimated water yield results assumes that thinning would occur in an even flow, 10 year period with 2.5% of selected stands (228 acres) thinned annually. Research shows that without maintenance (thinning or burning) canopies will regrow and understory species respond such that within approximately 7 years of thinning any water yield benefits have been negated. The net acreage effect of a 10 year thinning cycle with a 7 year linear response/recovery of growth is to create a 16 year period with peak beneficial acreage related water yield occurring in the middle portion of that period (Figure 32).

Based on the assumptions in the model, low and high water yield estimates were generated over the 16 year period of effect (Figure 32). Thinning of dense conifer stands by 20% of basal area (20-40 ft^2/acre) and light thinning 10% of conifer basal area within mixed Hardwood-Conifer stands will yield an average of 0.23-0.65 AF of additional water per year per acre, or 130-368 acre feet of additional water per year (on average) over the 16 year period. The peak yields of 207-589 AF in years 7 through 10 (Figure 33). Greater water yields would be achieved by increasing the acres treated per year or extending the period of active thinning.

Figure 32. Harvest Changes Over Time- the equivalent annual acres of thinning for an even flow thinning regime of 228 acres harvested per year for a 10 year period and a 7 year lag period before the thinned biomass is replaced (assuming a linear growth response in crowns and understory of thinned stands).

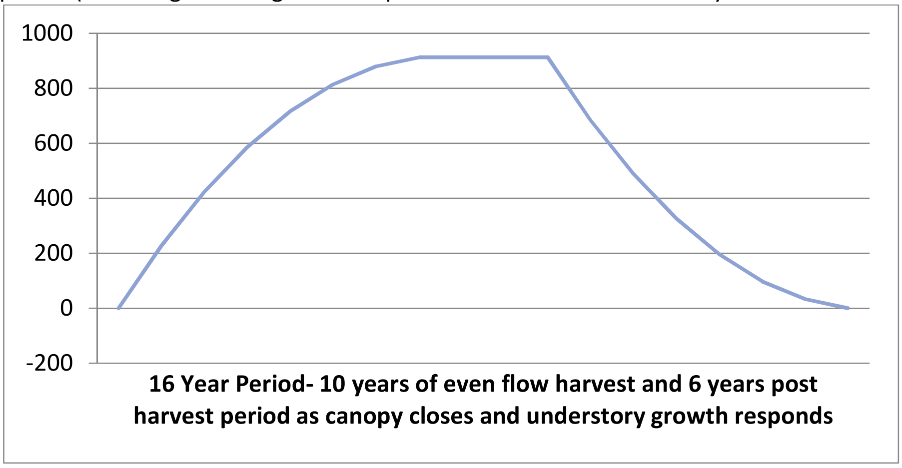
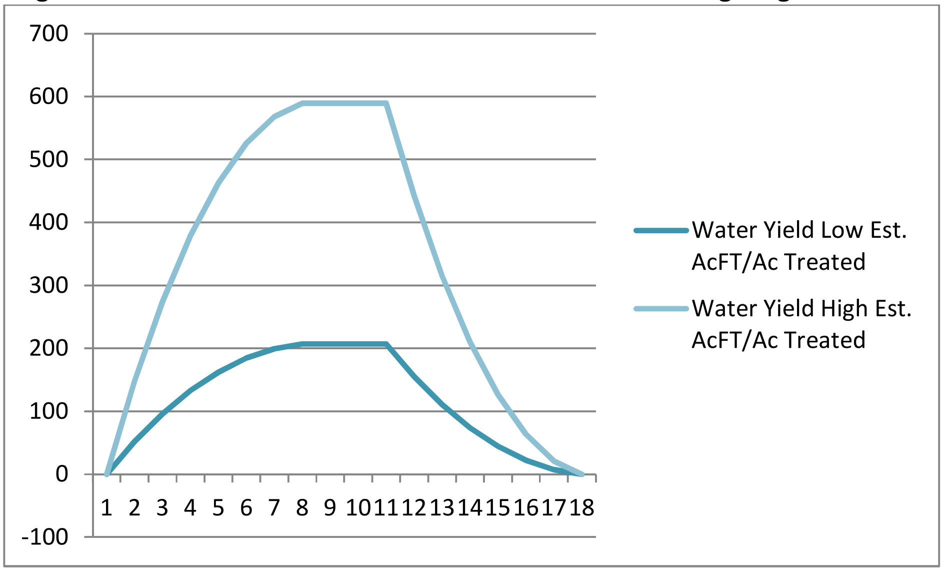


Figure 33. Acre Feet of Annual Water Benefit from Thinning Targeted Stands



Another vegetation management technique used to enhance water yield has been the conversion of conifer forests to hardwood stands. Conifer forests generally intercept more water than hardwoods, especially in snow zones. Snow intercepted in trees often evaporates before ever reaching the forest floor, where it can be absorbed into the soil mantle or runoff. Some studies indicate significant increases in groundwater recharge in hardwoods stands that were previously conifer stands and similar decreases in groundwater recharge in stands that were converted from hardwood to conifer (Dunn and Leopold, 1978).

Planned conversion of conifer to hardwood, brush, or grass stands is not considered a likely feasible option to improve water yield as it is already in progress due to forest conversion by fire. In addition, the Forest Service is not likely to specifically plan timber sales to convert conifers stands to other forest types. Any such planning would likely be appealed and/or litigated under the National Environmental Policy Act and/or the Endangered Species Act. While some conversion of conifer stands will occur on private lands[13] these tend to be done at lower elevations that support year round occupant management.

Carbon Sequestration

Climate change management is outside of the short term control of land managers in the 1.83 million acre Trinity River watershed, but carbon storage and sequestration within the watershed are important climatic benefits and priorities of the state of California's Carbon Cap and Trade Program (http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm .

There are several California carbon sequestration projects within the Trinity River watershed and surrounding watersheds. Projects have been done by the Yurok Tribe, Round Valley Tribes, Green Diamond Resources, Sierra Pacific Industries and others. These projects have stored several million metric ton of carbon dioxide (or its equivalent in other greenhouse gases).   The people of California have invested millions of dollars of in these projects, but increased fire activity threatens to undermine the carbon storage of these forests. Already stand replacing fire has burned into areas covered by carbon offset purchases.

Figure 34 & 35-   High Intensity Oregon Fire 2001(Left) and low intensity burning in the Rail Fire 2015 (Right).

Thinning to increase SWE water yields and reduce the intensity of wildland fires, could also reduce the carbon released from wildfires. As noted in the previous section approximately 2/3 of all burn acreage in the past decade has been of moderate to high severity with associated tree loss.

An estimate of carbon release from fires was done by sampling 735 ARB Forest Protocol compliant carbon inventory plots measured in 2013. In 2015 about 65% of these plots were burned in a series of wildland fires. The burned areas had ~35% low intensity fire effects, 33% moderate intensity effects and 32% had high intensity effects (killing all trees and understory). Plots within the burn areas were then remeasured in 2015/2016. The results were used to estimate the CO2e emitted (the sum of the difference in pre and post fire aboveground and belowground live CO2e). For the plots remeasured, 328,893 metric tonnes of CO2e were available for release into the atmosphere. This is approximately 43 metric tonnes CO2e per acre burned, with the vast majority of that being from vegetation killed in the high severity burn class.

[13] In July 2016 the Trinity County Board of Supervisors imposed a short term moratorium on "less than 3 acres" conversions of private conifer stands in response to an estimated 2,000 to 5,000 illegal conversions that occurred between 2009-2016.

Salvage logging could capture or store some of the potential CO_2e release and a case could be made that the standing dead and belowground dead will not be emitted soon because the char associated with the burned trees is not readily lost back to the atmosphere.

Under the fire regimes of the past decade, high elevation conifer stands will continue to burn with ~65% of area experiencing moderate to high fire severity. With an assumption of ~43 tonnes CO_2e per acre released (with no salvage to store carbon in lumber) an estimate of carbon benefits of thinning to improve SWE can be made.

As noted previously, modeling of plots in the Weaver Creek watershed found that only 8.8% stand mortality would occur for the moderate fuels treatment (with slash treatment) compared to 31.2% mortality for the untreated stand condition for a fire occurring in typical August weather conditions (BBWA,2004). The actual mortality observed in the 2015 fires sampled was approximately 32%, which is similar to the modeled mortality rate of 31% predicted for the Weaver Creek stands.

Applying a simplistic linear relationship would suggest that thinning 2,280 acres and changing fire intensity would retain approximately 20 tonnes of stored CO_2e per acre- if fire should burn through the stands[14]. This would retain approximately 45,664 tonnes of CO_2e within stand vegetation for the 2,280 treated.

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[14] These numbers are based on the following assumptions- the percent of all carbon released in 2015 was divided by tree mortality classes (based on fire severity mapping) and divided by total acres burned to get a standing average carbon volume per acre or 43.3 tonnes/ac. With 32% of acres burned at 100% mortality (releasing ~89 tonnes CO_2e/acre); 33% of acres burned at moderate burn severity with 40% mortality (releasing 36 tonnes CO_2e/acre) and 35% burned at low burn severity with 10% mortality, releasing (~9 tonnes CO_2e/ace) a simple equation can allocate the carbon release by burn severity class on a per acre basis.

Using the BBWA stands measured in 2004 (which have similar basal area and tree distribution characteristics) with a moderate thinning prescription (described previously in this report) the resulting changes in burn severity and CO_2e equivalents could be simplistically calculated as follows: Assuming a single acre burns with 9% of the area under high severity (8.0 tonnes released), 27% under moderate severity (9.6 tonnes) and 64% under low severity (5.7 tonnes) a total of 23.3 tonnes would be released per acre, compared to the 43.3 tonnes measured in the 2015 fires. The net stored carbon would be 20 tonnes/acre.

9. Conclusion

We recommend that policy makers look at forest thinning of stands at sufficient elevation and favorable aspect to improve late spring and summer water yield. Based on the assumptions in the model, low and high water yield estimates were generated over the 16 year period of effect. Thinning of dense conifer stands by 20% of basal area (20-40 ft2 acre) and light thinning 10% of conifer basal area within mixed Hardwood-Conifer stands will yield an average of 0.22 acre feet of additional water per year per acre based on the aggregate stands of the three assessment areas examined.

Thinning can create the right balance of stand openings and ground shade to maximize snow accumulation on the forest floor. At the same time thinning combined with pruning and fuels reduction can create shaded fuel break conditions. While this treatment can be used at all elevations and aspects, to increase summer water yield it is most effective between 4,000 feet and 6,000 feet elevation on northwest to east facing aspects.

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End Notes

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[i] An assessment done by the Nature Conservancy in 2015 called for increased stand thinning to both increase SWE and reduce effects of large fires (Podolak et al, 2015). That paper suggests that increased SWE runoff could increase hydro-electric power production by 6%. The paper suggests that increased revenues from power output can help pay for fuels reduction programs. The paper however, ignored the positive effects of increased runoff from mega fires in the study area (including the >260,000 acre Rim Fire of 2013) as well as the negative watershed impacts of these fires. Moderate to high burn severity fire can thin conifer stands or converts them to early seral (grass/brush) habitats (Figures 6 and 7). Frequent fires with moderate to high severity fires can also increase runoff and other cumulative watershed impacts that may further preclude pre-emptive management options to reduce future fire behavior and improve snow melt timing benefits.

[ii] Hagberg, et al (2012) found that "*four unique canopy densities, ranging from 0%-60%, result in different initial snowfall accumulations and loss rates. It was found that as forest canopy density increases, the amount of snowfall reaching the forest floor decreases. However, vice versa, as canopy density decreases, the ablation rates increase. From this study, it was found that the medium canopy density (30-60%) strikes the best balance between initial snowfall accumulations and its ability to retain SWE over time. The rate of snow sublimation is most drastically affected by the presence of even a slight wind. More specifically, the sublimation rates were observed to be maximized when the humidity was low and wind was present. This study applies specifically to the ponderosa pine type forest of northern Arizona, however, similar trends would be expected in other similar environments*." Strock et al (2010) found that "*during periods when air temperature remained below freezing after snowfall, sublimation was an important mechanism for removal of intercepted snow, with average annual totals of 100 mm SWE. Given that average winter precipitation depths in the region studied here are approximately 2 m, a loss of 100 mm of SWE through sublimation is less significant than in drier climates, were precipitation is less frequent and overall conditions are more conducive to sublimation. Even though this study observed instantaneous sublimation rates in excess of 0.5 mm per hour, meltwater drip and mass release are the dominant process affecting the ground snowpack in maritime mountainous climates. "Field experiments conducted in maritime climates have reported a wide range of snow interception maxima. Sauterland and Haupt (1967) report a maximum interception of 4 mm snow water equivalent (SWE) on conifers while snow interception approaching 30 mm SWE was reported by Bunnell et al. (1985) and Calder (1990)."*

Troendle, et al (1980) summarized the effects of interception and thinning as follows: "*The magnitude and significance of interception losses by forest vegetation to the overall water balance have been documented by Kittredge (1948), Coleman (1953), and others. Interception losses may account for 25 to 35 percent of the annual precipitation, depending on the amount, type, and intensity of precipitation and the type and density of forest vegetation. The increase in net precipitation resulting from forest removal is proportional to the reduction in stand density and can range up to 15 to 30 percent for individual storm events (Kittredge 1948*)" (Forest Service RMRS-GTR-231, 2010). Reid and Lewis (2004) reported that conifer forests interception can be greater than 20% of precipitation. More recent research suggests that overlapping tree crowns can act as heat traps as daylight lengthens in February-March and may partially account for the rapid winter melt out of some snow packs (Lundquist, et al 2013).

2012

Road Sediment Source Inventory
and
Risk Assessment

Klamath National Forest

Forest-wide Road Inventory

Project Field Dates: 1998 to 2012

August, 2012

Klamath National Forest
1711 South Main Street
Yreka, California 96097

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ROAD SEDIMENT SOURCE INVENTORY & RISK ASSESSMENT
Klamath National Forest – Forest-wide Compiled Road Inventory

Abstract

Roads are important and costly structures, with pervasive, persistent and potentially cumulative impacts on steep forested land. Roads contribute the highest per acre sedimentation rate of all watershed disturbances, averaging 58 times background from landsliding and 290 times background from surface erosion. Consequently, road issues are often at the heart of restoration activities. In cooperation with other agencies and groups, the Klamath National Forest has completed a comprehensive sediment source inventory of the nearly 4,375 miles of Forest roads. This substantially completes road inventory across the Forest although there are about 5,350 total miles of Forest system and non-system road. Of the non-inventoried roads, most are not hydrologically connected (do not drain to surface waters, mostly on the Goosenest Ranger District) or have been previously decommissioned. There may also be some unmapped non-system roads that are hydrologically connected and have not been inventoried. These would be an exception since the intent was to inventory all hydrologically connected existing roads, though it is possible that field crews may have not found all unmapped roads.

Overall, 11,162 sites have been inventoried across the Forest. Summary field information shows 7,338 non-bridge channel crossings and 2,436 hydrologically connected cross drains along with 1,266 between crossing sediment sources (landslides or gullies, referred to as "tweeners"). Diversion potential exists at about half of the crossing or cross-drain sites. Slightly more than 10% of the road length is hydrologically connected to natural stream courses through inboard ditches. Estimated total volume of fill material at channel crossing sites is about 3,850,000 cubic yards. If placed on a football field, this volume of material would produce a pile almost 2,300 feet high. Fill volumes averaged 525 cubic yards per site.

Because the Forest road system is extensive and road-related restoration is generally expensive, it is valuable to focus potential investments on the sites posing the highest risks, consequences, and impacts. Each site was rated and ranked by considering: [1] risk of failure, [2] consequences of failure (sediment delivered), and [3] impacts of failure (to beneficial uses). For example, a highly ranked site could be one with an undersized pipe, geologic instability upslope, large fill volume with diversion potential, on an anadromous fish stream. Evaluation of all sites across the Klamath National Forest concludes that 52% of the total fill volume at channel crossings could be attributed to just 10% of the highest ranked sites. In other words, by upgrading channel crossings to reduce the risk/consequences/impacts of failure at only 10% of sites, approximately 50% of total fill volume would be treated. If the top 20% of sites (in terms of fill volume) were treated, 70% of total fill volume at channel crossing sites would be treated.

These findings suggest that targeted restoration has the potential to substantially reduce the risks and consequences from road-related sediment delivery. Road inventory/risk assessment has the demonstrated capability to accelerate watershed recovery in support of the goals of the *Endangered Species Act* and the *Clean Water Act.*

The results of the inventory reside in a geodatabase (a database that contains Geographic Information System or GIS data) accessible to employees of the Klamath National Forest. The database includes a point feature class containing all inventoried points (KnfSites), a line feature class with all mapped Forest system and non-system roads that were part of the inventory (RestRds), and tables with additional information including model ratings for each site.

Setting

The Klamath Road Inventory program includes road and site inventories across the Forest. This inventory was done over many years, from 1999 to 2012, and through the cooperation of many agencies and other groups. Grants and cost-share agreements with California Department of Fish and Game funded the earlier work though in later years most of the work was funded through the Forest Service Legacy Roads program. Much of the earlier field inventory was done by Forest Service crews, or in cooperation with the Salmon River Restoration Council or Resource Management of Fort Jones, California. The last four inventory areas, Scott 2010, SCSC (Swillup, China, Seiad, Cottonwood), Klamath West (included any remain areas on the Klamath NF west-side), and Klamath East, were done under contract by Natural Resources Management of Eureka, California. Don Elder, from the Klamath National Forest and later as a member of the ACT2 Forest Service Enterprise Team, provided primary oversight and contract inspection throughout the process. Mark Reichert, also from the ACT2 Enterprise Team, compiled the data from all the various inventories and authored this report.

Although field inventory protocol and other analysis procedures did change slightly over the years, for the most part the data is consistent enough to create one database that covers all the inventory areas, and allows comparison of inventory sites and roads across the Forest. Also, road work has continued across the Forest, in many cases repairing locations that have been identified as problems in previous road inventories. The database is designed to help track road work that has been done and can be used to update road conditions where field inventory may not accurately represent the current situation.

Table 1 shows all the road inventories that have been done over the years as they are tracked in the database, along with the road miles done for each inventory. In total, 4,373.8 miles of road have been inventoried as part of this process. Another 976.4 miles of road have been specifically excluded from the inventory process for various reasons. Roads previously decommissioned have not been inventoried to this protocol, although they may be inventoried if needed as part of a monitoring plan. New dispersed recreation roads (new Forest System roads added as part of travel management) are generally not inventoried because they are individually too short to meet the road inventory criteria and they rarely, if ever, contain crossing or erosion sites. Some roads that cross isolated parcels of National Forest System lands, but are generally considered private roads without public access have not been inventoried. On the Goosenest Ranger District (Klamath East inventory), many roads have not been inventoried because they are in areas with no surface water. Large portions of the Goosenest District have very high infiltration rates where rainfall and snowmelt seep into the ground without forming streams or channels. Roads in these areas have been excluded from inventory. Roads inventoried for Klamath East were those that have some potential for surface water impacts. Finally, some old roads in the Seiad Creek area were not recognized as roads prior to or during the road inventory process, but later on recognized as potential sediment sources during a Watershed Improvement Needs (WIN) inventory. Though the intent of the road inventories was to inventory all Forest system and non-system roads, some old road features have been missed and may be added during other inventory processes.

Table 1: Road Inventories

Inventory Year	Inventory Name	Miles
1999	Indian, Elk, Ti, Irving	492.7
2000	LSF Salmon, Dillon, Clear, SF Scott, Lower Scott, Grouse and Long John	639.7
2001	NF Salmon, USF Salmon, Main Salmon, Grider, Horse	793.5
2002	Mill (Scott Bar), French	75.5
2005	Sugar	13.4
2006	Collins	167.3
2008	EF Scott, Yreka	169.6
2010	Scott, includes Walker addition	274.8
2011	SCSC (Swillup, China, Seiad, Cottonwood)	406.7
2011	Klamath roads 2011 west (Beaver, Doggett, Thompson, Titus)	631.8
2011	Klamath roads 2011 east (Shovel, Butte, Antelope)	708.8
	Total Inventoried	**4373.8**
	No inventory – decommissioned	87.7
	No inventory - new dispersed recreation road	14.4
	No inventory, mostly no legal access	78.2
	No inventory, not hydrologically connected	792.6
	Not inventoried to protocol, done as WIN inventory	3.5
	Total Not Inventoried	**976.4**

In the database longer roads are often split into two or more segments. Most of this segmenting is done based on 7th field watershed boundaries. 7th field watersheds are those within the Hydrologic Unit Coding (HUC) system between about 3,000 and 10,000 acres. These nest into 6th field watersheds (between about 10,000 and 40,000 acres) which nest into 5th field watersheds, and so forth. A given road may have a segment in one 7th field watershed and additional segments in separate watersheds. Each road segment receives its own road evaluation independent of the other segments of the same road. Many road segments that follow or cross ridges with short segments in adjacent watersheds have been combined into one segment evaluated as entirely in the primary watershed, provided impacts in the adjacent watershed are minimal (short length at the top of a ridge with no sites). Some roads are additionally segmented as needed to reflect other conditions, i.e. a road partially decommissioned will be segmented at the point where decommissioning begins.

Each road segment is assigned a unique identifying number, its "LinkNo" (Link Number). All sites are "linked" to their appropriate road segment through use of "LinkNo". In this way information such as "number of sites with diversion potential for each road segment" can be computed. In addition, every inventoried site has its own unique identifier, the "Site_Id", which is a combination of the road number and milepost. In theory, the milepost should correspond to other roads data stored in the Forest Service's roads database. In practice it does not. Often, field crews started inventory on a road (mile post 0.00) at a location different than the Forest's roads database, therefore the road inventory mile posts would not correspond. Occasionally the road milepost situation is even more confusing. For example, the "11" road (the main road up Beaver Creek which turns up Hungry Creek and crosses a watershed divide into Cottonwood creek) was partially inventoried in both SCSC and Klamath West inventories. The SCSC inventory includes the part of the "11" road in Hungry and Cottonwood creeks while Klamath West inventory includes the part along Beaver Creek. Mile posts for the "11" road in these two inventories appear to overlap where in fact they do not. All sites contain spatial information (are in a GIS point feature class) so can be accurately located and are correctly linked to the appropriate segment of the "11" road through "LinkNo".

Problem - Background

Roads are important and costly structures, with pervasive, persistent and potentially cumulative impacts on steep forested land. Roads contribute the highest per acre sedimentation rate of all watershed disturbances (e.g., Amaranthus, et al. 1985; de la Fuente & Elder 1998; Flanagan, Furniss, et al. 1998a & 1998b; Pacific Watershed Associates 1997; U.S. Environmental Protection Agency 1998; U.S. Forest Service 1989), averaging 58 times landsliding rates compared to undisturbed ground and 290 times surface erosion rates compared to undisturbed ground (de la Fuente & Haessig 1994; Elder 1998). In addition, roads can alter hydrology, habitat connectivity, and routing of wood and sediment. These combined effects have the potential to strongly influence downstream aquatic environments critical to anadromous salmonids and other aquatic species. As the availability of road maintenance funds allocated to the Forest Service decreases (down nearly 50% in the past several years), the necessity to evaluate, prioritize and implement measures which reduce the risk of road related impacts to aquatic systems is greater than ever.

The Klamath National Forest road system sustained over 30 million dollars' worth of damage during the "New Year's Day" flood of the winter of 1996-1997 [hereafter referred to as '1997 Flood']. Stream channels, riparian areas, and fish habitat were impacted by excessive scour and deposition during that storm. The impact was severe in some places. Some of these impacts were caused by sediment delivered from roads. *The Flood of 1997: Klamath National Forest Phase I Final Report* (de la Fuente and Elder 1998) estimated that over half of the large road repair sites were at stream crossings. An estimated 22% of these sites resulted in diversion around plugged culverts.

Two of the primary types of failures occurring at road-stream crossings include "stream diversion" and "fill failure". A stream diversion occurs when a culvert at a stream crossing fails due to hydraulic exceedance and/or plugging by debris or sediment. If this happens at a stream crossing where the road leaves the crossing at a negative slope (downhill), then the water can flow down the road rather than down its' own natural channel. This often has adverse effects on the watershed, such as saturating road fills which causes failures and the potential to generate:

- debris flows, eroding the road surface,
- eroding away huge amounts of soil on unstable hillslopes where water does not naturally flow,

- cascading failures of stream crossings in adjacent drainages into which the stream has been diverted.

Partial or complete failure of crossing fills is the other primary risk posed by stream crossings to downstream aquatic habitat. In addition to the sediment generated, failures of this type can initiate large debris flows that scour channels, fill pools, and strip riparian vegetation from stream banks. Although prediction of crossing failure is difficult, the risk and consequences can be characterized. With this information, risk reduction measures including up-sizing culverts, reduction in fill size, or decommissioning can be targeted toward crossings with high risks for consequences and impacts before they fail. In addition to evaluating crossings for stream diversion potential, this assessment will assess factors influencing culvert and crossing failure. Included are consequences at all road-stream crossings within priority watersheds containing anadromous fish habitat on the Klamath National Forest.

Purpose

The intent of Forest Service policy and approach to transportation planning is to find a balance between the positive benefits of roaded access and the negative road-associated effects on other values and resources. Concerns include clean water, fish, and wildlife; and maintaining choices for future generations. In Forest Service Chief Dombeck's *Natural Resource Agenda for the 21st Century*, an emphasis was placed on watershed health and restoration and forest roads. The long-term Forest road policy has four primary objectives: (1) More carefully consider decisions to build new roads, (2) eliminate old, unneeded roads, (3) upgrade and maintain roads that are important to public access, and (4) develop new and dependable funding for Forest road management.

Road inventories and assessments were conducted to acquire information necessary to prioritize watershed restoration work involving roads so that the most critical, most ecologically-beneficial and cost-effective restoration projects could be more accurately identified and implemented first. The purpose of these road surveys and analyses was to identify specific locations (Sites) where road drainage structures and fill have the potential to adversely impact watershed processes, and then to assess the relative ***environmental risk*** of each identified Site.

Other applications include use: [1] in transportation planning efforts, [2] to define existing and target conditions in other more general planning documents, such as ecosystem analyses, larger subbasin and basin assessments, [3] in Forest Service National Roads Policy inventory requirements, [4] in various management projects, such as timber sales, [5] to meet Water Board requirements, such as compliance with TMDL documents (Total Maximum Daily Loads for water bodies listed under Section 303(d) of the *Clean Water Act*) and resulting MOUs, to meet requirements of the Discharge Waiver and project-scale monitoring, and [6] in meeting monitoring requirements of the Forest Service Watershed Condition Framework.

The primary objective of the crossing inventory and assessment proposal is to identify high risk/consequences/impact road-stream crossings which pose the greatest threat to aquatic resources, especially sedimentation of anadromous fish habitat. Some or all of the following will characterize high-risk stream crossings:

- large fills at or adjacent to the crossing,
- potential for stream diversion,

- inadequate culvert capacity to pass water, woody debris or sediment,
- unstable geology above site (high debris flow potential) or down slope (high potential for additional erosional effects if crossing fails or diverts stream flow),
- high value beneficial uses that would be adversely impacted if crossing failed.

A secondary objective is to provide education to residents within the area on road crossing risks, mitigation designs, and how these issues affect aquatic habitat. This knowledge can then be applied to strategic transportation planning on private roads. Outreach education would also familiarize area residents with cooperative efforts in watershed restoration and planning.

Methods

This project can be divided into seven general work elements, as shown in Steps 1 through 7 of **Table 2** below.

Field Inventory Methods

Field inventory work was accomplished using procedures detailed in *Field Guide: Explanation & Instructions for Klamath National Forest Road Sediment Source Field Inventory Form - May 14, 1999 [revised Jan 28, 2010]* (USFS 1999a). See **Appendix A** for a complete copy of *Field Inventory Guide*. The Forest developed this field guide borrowing and modifying concepts, definitions and procedures from the following sources: [1] Pacific Watersheds Associates procedures for assessing road sediment sources (PWA, 1997), [2] stream crossing environmental risk assessment protocol developed by Six Rivers National Forest (Flanagan, et al., 1998a & 1998b), and [3] Forest Service national roads policy as described in *Roads Analysis: Informing Decisions About Managing the National Forest Transportation System* (USFS, 1999b).

In road sediment source field inventories, **all** stream channel-road crossings and **all** hydrologically connected cross drains (ditch relief structures – pipes & dips) were examined and measured (USFS, 1999a). In addition, road-related erosion hazards between channel crossings and hydrologically connected cross drains were surveyed. These sites consisted of landslides (mass wasting) and gullying (surface erosion) features that are currently active or pose future/potential threats of sedimentation. These “between crossing" sites have been nicknamed “tweeners.”

Risk Assessment Methods

With limited resources, it becomes necessary and desirable to prioritize road segments and/or sites for treatment. Although treatments may vary from site-specific recommendations to all inclusive road segment proposals, from minor maintenance fixes to major crossing re-design and reconstruction, all sites are subjected to the same initial prioritization scheme. Site information is taken from data collected in the field and drawn from information available from air photos and existing Forest GIS layers. The priority setting of individual sites combines three general elements: (1) site condition – risk & consequences, (2) potential impacts, and (3) opportunity. A high priority site would be high risk, high consequences, with high potential impacts and high opportunity.

Integration of data elements and groups of data elements are shown in **Table 2** below. Range of values used to assign individual risk/consequence/impact ratings is shown **Table 3**.

Table 2: Project Outline - General Work Elements

✞ **STEP 1 - Pre-Field Inventory Preparation:** - includes:
- photo identification of "ghost" roads and debris flow scoured channels,
- ID sites with history of problems; based on personal experiences, talks w/ Engineering, etc.,
- training of field crews (office & field),
- assessment of upslope watershed risks from disturbances & unstable geology, and
- preparation of maps & photos for field crew use.

✞ **STEP 2 - Field Crew Inventory of Road Sediment Sources:** - includes:
- identification and characterization of crossing sites [stream channels & 'hydrologically connected' cross drains], and significant features between crossing sites, and
- field identification ("mapping") of "ghost" roads & sediment source inventory of them.

✞ **STEP 3 - Journey-Level Oversight/Inventory:** - includes:
- monitoring of crossing inventory work to ensure Forest-wide consistency (QA/QC), and
- some field verification of photo-interpreted features described above.

✞ **STEP 4 - Data Compilation:** - includes:
- entry of field data into spreadsheets and databases,
- entry of field site locations into GIS, and
- calculation of various office-generated site and road parameters.

✞ **STEP 5 - Risk-Consequences-Impacts Assessment (Office):** - includes:
- analysis of data (from Steps 1 - 4 above),
- site ranking, and
- identification of high risk-consequences-impact sites.

✞ **STEP 6 – Treatment Recommendations and Cost Estimates:** - includes:
- treatment recommendations - fix or not?
- estimated cost of treatment

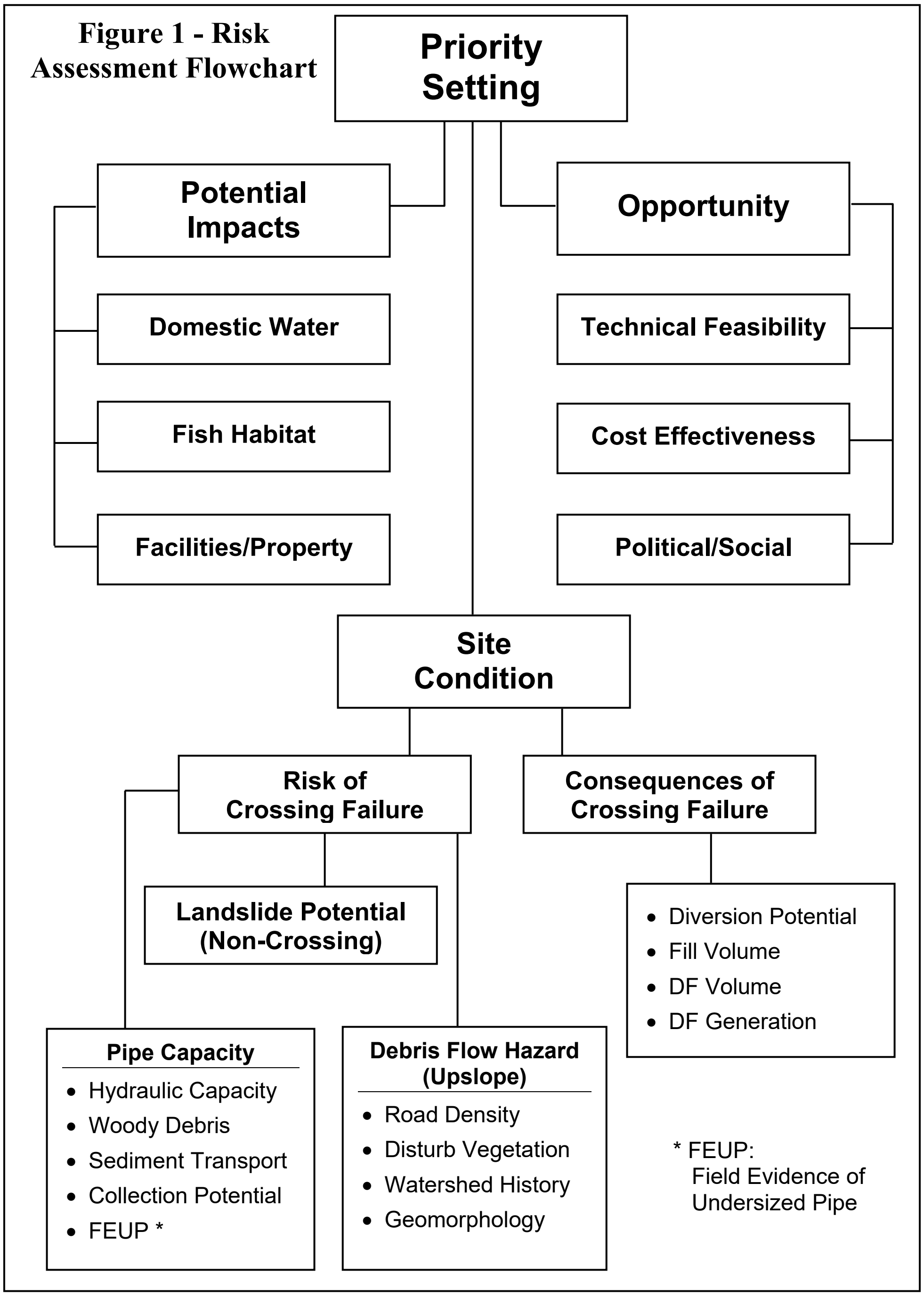
✞ **STEP 7 - Final Report:** - includes:
- narrative with summary of findings, prioritization process, upgrade/repair recommendations
- database tables with field data & risk/consequence/impact ratings for all inventoried sites
- GIS-data which can show high priority sites, by type, by specific concern, by overall ranking (prioritization) for any area of interest

Site Condition = risk + consequences + impacts:

Site condition is composed of three major elements – risk of failure, consequences of failure, and impacts to beneficial uses. In general, "risk" characterizes upslope and site conditions that measure the probability of failure; "consequences" characterize the downslope results of a failure; "impacts" define potential adverse impacts to downstream beneficial uses (e.g., aquatic habitat, facilities). Each of these major components is subdivided further. When all elements are combined, an overall "site condition" rating is obtained. For example, the highest rated crossing sites would be those with the following characteristics: (1) high **risk** of failure from severely undersized culvert pipe, lengthy contributing ditch, high upslope debris flow risk from past history, large upslope vegetative disturbance and/or unstable geology, (2) high **consequences** of failure from diversion potential, large fill volume, and high potential for generation of debris flow, and (3) high **impacts** to aquatic resources and downstream facilities (e.g., road crossings, campgrounds, municipal water supplies). See **Figure 1** for assessment flowchart and **Table 3** for rating elements and scores.

Site **RISK** is the combination of two major elements and a lesser component. The major elements consist of pipe capacity and upslope debris flow hazard. Pipe capacity is a measure of how well individual culverts are designed to handle watershed products; principally water, woody debris and sediment. Hydraulic capacity of culverts is determined using an empirical culvert-sizing model (developed by US Geological Survey; Waananen and Crippen 1977) that takes into account catchment basin area and local precipitation. Crossing culvert ability to pass woody debris is based on a ratio between culvert diameter and upslope channel width. A culvert's ability to transport sediment is based on a ratio between slope of the culvert and upslope channel. Field evidence of undersized pipe and large collection potential of upslope in-board ditch add to the three factors cited above to raise the risk of failure for culvert crossings. Risks associated with upslope debris flow hazards are based on a combination of several elements. Assessment of these risks relies in part on Forest GIS layers. Stability of upslope geomorphology and nature, and extent of upslope vegetative disturbances (such as fire and timber harvest) are determined from these GIS layers. Debris flow history at individual sites is obtained from field inventory, historic air photos, and personal accounts. Number and density of upslope roads are considered. Landslide potential at the site is a lesser component that affects a site's overall risk of failure.

CONSEQUENCES of failure are the second major element that defines site condition. This important element is composed of four unequally weighted factors – fill volume, diversion potential, potential debris flow generation, and volume. Of highest importance (weighting) is fill volume. Fill volume is sediment at-risk that is delivered to the stream system if the crossing fails and is therefore very important when considering adverse road-related sediment impacts on aquatic environment. Another major consequence of crossing failures is the diversion of stream from its natural channel and down the road. This diversion can produce gullies and landslide failures. Crossing failures in the steeper headwaters areas of drainages can generate debris flows, many with significant volumes. Potential for generation and subsequent estimation of volume are based on channel and slope steepness, slope position, and stability of geomorphology at the site.



POTENTIAL IMPACTS characterize the potential adverse impacts to aquatic habitat should failure occur. "Potential impacts" are the combination of adverse impacts to three beneficial uses: domestic water sources, fish habitat, and facilities and property. Impacts must be direct and imply proximity or "closeness".

Domestic potable water sources are rated by number of users: municipal, >5 households, <5 house-holds, and none. Sites at perennial streams and within Riparian Reserves are rated by whether or not anadromous or resident fish species are present. Sites are rated by whether or not facilities (buildings, campgrounds, trailheads, etc.) or other roads are directly down-stream or down-slope.

OPPORTUNITY intends to rate the "do-ability" of recommended treatments and is based on three general criteria: technical feasibility, cost effectiveness, and political/social considerations. These elements are based on subjective professional judgment in an interdisciplinary setting and are not done as a part of this process. Technical feasibility rates how effective a given treatment will be in reducing risk, consequences, or impacts. Cost effectiveness rates a proposed project on cost necessary to control an estimated volume of sediment at risk and is usually expressed in "$ per cubic yard saved." Political/social considerations include such things as land use, land ownership, access needs, etc.

The risk, consequences, and impacts rating elements (and groups of elements) are scored for each site on the basis as displayed in Table 3. A summarized version of Table 3 information is displayed on one page in Table 4.

Table 3: Site Risk - Consequences - Impacts			
Unit	**Assigned Value 1/**	**Site Impact Rating Elements**	**[data source]**
		Pipe Capacities	
Hydraulic Capacity Rating [hc]	 6 4 2 0	an expression of hydraulic capacity Pipe Capacity < Q100 / 4 Pipe Capacity < Q100 / 2 Pipe Capacity < Q100 Pipe Capacity >= Q100 or no pipe or definable drainage area	[calculated]
Woody Debris Rating [w]	 6 4 2 0	an expression of woody debris capacity - culvert diameter / width of channel Pipe Diameter < Channel Width / 2 Pipe Diameter < Channel Width Pipe Diameter >= Channel Width no pipe or no definable channel	[field data]
Pipe Slope Rating [ps]	 3 2 1 0	an expression of ability of pipe to transport sediment - slope of pipe / slope of channel Pipe Slope < Channel Slope x 0.3 Pipe Slope < Channel Slope x 0.6 Pipe Slope >= Channel Slope x 0.6 no pipe or no definable channel	[field data]
FEUP [f]	 6 0	field evidence of undersized pipe yes no	[field data]
Collection Potential to First Cross Drain [cp1]	 3 2 1 0	collection potential - contributing ditch length to first cross drain structure; "best-case scenario" - assumes no cross drain plugging > 500 feet 200 - 500 feet < 200 feet no collection potential	[field data]

Table 3: Site Risk - Consequences - Impacts

Unit	Assigned Value 1/	Site Impact Rating Elements	[data source]
		Pipe Capacities (Continued)	
Collection Potential to Grade Reversal [cp2]	 6 4 2 0	collection potential - contributing ditch length to road grade reversal or other feature that breaks collection potential; "worst-case scenario" – assumes plugging of all cross drain pipes >1,000 feet 250 - 1,000 feet < 250 feet no collection potential	[field data]
Pipe Capacity Rating [PC]	calculated	overall pipe capacity risk rating; based on weighted average of previous six data elements, using the following equations: = [hc + f + cp1 + cp2] for piped cross drains = [hc + f + w + ps] for piped crossings = 0 for all crossings or cross drains without pipes	[calculated] **max = 21**
		On-Site Slide Potential	
Slide Potential Rating [SP]	 6 3 0	active landslide at site fresh slide at site "maybe or suspected" slide - by crew none	[field data] **max = 6**
		Upslope Debris Flow Potential	
Upslope Road/Stream Crossings [ur]	 6 4 2 0	upslope road/stream crossings > 3 road/stream crossings upslope of site (same stream) 2 or 3 crossings upslope (same stream) 1 crossing (same stream) or road/stream crossings (not same stream) none	[field data]

Table 3: Site Risk - Consequences - Impacts			
Unit	**Assigned Value 1/**	**Site Impact Rating Elements**	**[data source]**
		Upslope Debris Flow Potential (Continued)	
Percent De-vegetated Rating [dv]	 3 2 1 0	percentage of site drainage basin devegetated [fire &/or harvest] = >80 % of drainage area 50 - 79 % 20 - 49 % < 20 %	[GIS]
Road Density Rating [rdd]	 3 2 1 0	road density in site drainage basin (miles per square mile - mi/sm) > 3.0 mi/sm 1.0 - 3.0 mi/sm present to < 1.0 mi/sm none; no defined drainage area	[GIS]
Debris Flow History Rating [df]	 6 2 0	debris flow history - from field form clear evidence of recent debris flow at site probable &/or ancient debris flow no evidence observed	[field data]
Geomorphic Character Rating [gm]	 6 4 2 0	geomorphic character of site drainage basin background sedimentation rate based on geomorphic terranes > 175 cu/sq. mi/year background sedimentation rate based on geomorphic terranes > 125 cu/sq. mi/year background sedimentation rate based on geomorphic terranes > 64 cu/sq. mi/year background sedimentation rate based on geomorphic terranes < 64 cu/sq. mi/year	[GIS]
Upslope Debris Flow Rating [UD]	calculated	overall upslope debris flow potential risk rating; based on weighted average of previous seven data elements, using the following equation: = [df +ur + gm + dv + rdd]	[calculated] **max = 24**

Table 3: Site Risk - Consequences - Impacts

Unit	Assigned Value 1/	Site Impact Rating Elements	[data source]
		Consequences	
Diversion Potential Rating [dp]	6 0	diversion potential yes no	[field data]
Fill Volume Rating [fv]	16 12 8 4 0	fill volume at risk > 1,000 cubic yards (cy) 500 - 1,000 cy 100 - 499 cy < 100 cy no fill volume	[field data]
Slope Position Rating [sp]	3 2 1	slope position upper third middle lower third	[GIS]
Slope Steepness Rating [ss]	6 4 2 0	steepness - channel &/or slope at site [from field data] > 35% gradient 15% - 35% gradient 5% - 14% gradient < 5% gradient	[field data]
Site Geomorphic Stability Rating [ts]	6 4 2 0	geomorphic terrane stability - at SITE unstable: geo13 = 1, 2, 9 (**"geo 13"** codes *) sensitive: geo 13 = 3, 4, 10, 11, 12 steep/surficial: geo 13 = 6, 13 gentle slope/stable: geo 13 = 5, 8	[GIS]
Below Site Geomorphic Stability Rating [tb]	3 2 1 0	geomorphic terrane stability – BELOW site easily mobilized: geo 13 = 1, 2, 3, 9, 13 sensitive: geo 13 = 4, 10, 11, 12 gentle granitic/steep meta: geo 13 = 5, 6 stable/gentle meta: geo13 = 8	[GIS]

Table 3: Site Risk – Consequences – Impacts			
Unit	**Assigned Value 1/**	**Site Impact Rating Elements**	**[data source]**
		Consequences (Continued)	
* explanation of **"geo 13"** coding – Geomorphic Terranes: 1 – active landslides 2 – toe zones of dormant landslides 3 – dormant landslides 4 – granitic lands (steep: > 65%) 5 – granitic lands (gentler: < 65%) 6 – non-granitic (steep: > 65%) 7 – east 8 – non-granitic (gentler: < 65%) 9 – inner gorge in unconsolidated material (includes stream proximal toe zones) 10 – inner gorge in granitic bedrock 11 – inner gorge in non-granitic bedrock 12 – debris basins 13 – unconsolidated surficial deposits (alluvium, glacial, terrace, etc.) 17 – east			
Consequences Rating [CQ]	calculated	overall consequences rating; based combination of previous two data elements = [fv + dp + ss + ts + sp + tb]	[calculated] **max = 40**
		Impacts (to Beneficial Uses)	
[ws]	 3 2 1 0	water supply sources at risk – potable surface water sources anywhere downstream municipal source > 5 domestic sources or campground any potable source (< 5 domestic) none	[other]
[fb]	 3 2 1 0	site within Riparian Reserve buffer on fish-bearing & perennial streams site within Riparian Reserve buffer on anadromous or TES aquatic species stream site within RR buffer on fish-bearing (i.e., resident only) stream site within RR buffer on non-fish-bearing perennial streams no perennial stream at site and site not within RR buffer	[GIS]
[fa]	 3 2 1 0	downstream facilities at risk non-road facilities at **direct risk*** (e.g., buildings, campgrounds, trailheads) multiple (>1) road/stream crossings downstream single crossing downstream none (or bridge only)	[other]
* **direct risk** means facility is: (1) directly downslope/downstream – a "straight" shot and (2) within same or next higher order stream and (3) less than one mile downstream and (4) located on floodplain (<= 100 year)			

Table 3: Site Risk – Consequences – Impacts			
Unit	**Assigned Value 1/**	**Site Impact Rating Elements**	**[data source]**
		Impacts (Continued)	
Impacts Rating [IP]	calculated	impacts rating; based on combination of previous three data elements = [ws + fb + fa]	[calculated] **max = 9**
		OVERALL RATING	
Overall Rating [OR]	calculated	overall rating – from integration of all data elements and components above =[PC + SP + UD + CQ + IP] (21) (6) (24) (40) (9)	[calculated] **max = 100**

1/ Assigned Value – highest values are greatest hazard

Table 4: Site Condition Summary		
Unit	Values	Maximum Possible Value
Hydraulic Capacity Rating [hc]	0, 2, 4, 6	6
Woody Debris Rating [w]	0, 2, 4, 6	6 (0)
Pipe Slope Rating [ps]	0, 1, 2, 3	3 (0)
Field Evidence of Undersized Pipe (FEUP) [f]	0 or 6	6
Collection Potential to Cross Drain [cp1]	0, 1, 2, 3	3 (0)
Collection Potential to Grade Reversal [cp2]	0, 2, 4, 6	6 (0)
Pipe Capacity Rating [PC]	**[hc]+[w]+[ps]+[f]** for crossings **[hc]+[w]+[cp1]+[cp2]** for cross drains	**21**
On-Site Slide Potential [SP]	**0, 3, or 6**	**6**
Upslope Road/Stream Crossings [ur]	0, 2, 4, 6	6
Percent De-vegetated Rating [dv]	0, 1, 2, 3	3
Road Density Rating [rdd]	0, 1, 2, 3	3
Debris Flow History Rating [df]	0, 2, or 6	6
Geomorphic Character Rating [gm]	0, 2, 4, 6	6
Upslope Debris Flow Rating [UD]	**[ur]+[dv]+[rdd]+[df]+[gm]**	**24**
Diversion Potential Rating [dp]	0 or 6	6
Fill Volume Rating [fv]	0, 4, 8, 12, 16	16
Slope Position Rating [sp]	1, 2, 3	3
Slope Steepness Rating [ss]	0, 2, 4, 6	6
Site Geomorphic Stability Rating [ts]	0, 2, 4, 6	6
Below Site Geomorphic Stability Rating [tb]	0, 1, 2, 3	3
Consequences Rating [CQ]	**[dp]+[fv]+[sp]+[ss]+[ts]+[tb]**	**40**
Water Supply Rating [ws]	0, 1, 2, 3	3
Fish-Bearing Stream Rating [fb]	0, 1, 2, 3	3
Facilities at Risk Rating [fa]	0, 1, 2, 3	3
Impacts Rating [IP]	**[ws]+[fb]+[fa]**	**9**
Overall Rating [OR]	**[PC]+[SP]+[UD]+[CQ]+[IP]**	**100**

Road Rating

Site condition is one step in evaluating and rating roads; the next step is to rate individual roads as to their relative risk, consequences and impacts to aquatic resources. This process and result is termed ‘Road Rating’ and is distinct from, but depends on site condition. This rating system was developed as part of the Roads Analysis Process [RAP] done on the Salmon River Ranger District during fall of 2001. Relatively minor modifications were made in 2010 when this process was applied to all Forest roads. Prime objective of the Road Rating is to determine which roads pose the greatest threat of increased sedimentation and interruption of the hydrologic regime & riparian reserve integrity. Road ratings will later be validated in an interdisciplinary setting, leading to transportation planning recommendations for individual roads. In general, roads with high risk/consequences/impacts are recommended for treatment actions: ‘stormproofing’, if the road is needed, ‘decommissioning’, if the road is not needed.

Overall rating of individual roads and road segments [called ‘Total Road Rating’] is a numerical value derived by the summation of individual ‘Indicators’. Outline, description, indicators and numeric values are found in Table 5. The following is a brief description of how the indicators are calculated.

Surface Erosion

This indicator provides model-estimated sediment delivery from road-related surface erosion. This model is based on the Universal Soil Loss Equation [USLE] modified specifically for this analysis. Model generated values were calculated using the USLE, defined by the following equation:

A = [.7]*R*LS*D*K*C

where:

A = estimated sedimentation (cy/ac/yr)
R = rainfall/runoff factor
D = delivery factor
K = soil erodibility factor (by Soil Map Unit [SMU] “k” values)
[.7] = converts tons to cubic yards (cy)
LS = slope-length/slope-steepness factor
C = cover factor

Three Arc/Info GIS coverages listed below were overlain, values derived for ‘R’, ‘LS’, and ‘K’, then multiplied to calculate {[.7]*R*LS*K*C} portion of the USLE. Cover factor (‘C’) values for all roads is assumed to be 0.5.

(1) <precip> = annual precipitation; >60", R=40; <60", R=20
(2) <soils> = Order 3 soils layer; K = "k" value associated with each SMU
(3) <slope35> = DEM-generated slope classes; >35%, LS=7.32; <35%, LS=2.50

For **unclassified** (non-system) roads, delivery factor, ‘D’ = 0.29 and soil erodibility factor, ‘K’ = “k” value from Soil Map Unit coverage. These values are for an average road – with a mixture of surface types, templates, and levels of use (traffic).

Table 5: Road Ratings			
Unit	**Assigned Value 1/**	**Road Rating Elements**	**Maximum Value**
Elements Derived from Geographic Information System (GIS)			
Universal Soil Loss Equation Rating [USLE]	 10 8 6 4 2 0	model-derived road erosion results > 20 cubic yards per mile per year > 10 cubic yards per mile per year > 5 cubic yards per mile per year > 2.5 cubic yards per mile per year > 1.25 cubic yards per mile per year < 1.25 cubic yards per mile per year	10
Mass-Wasting Model Rating [GEO]	 20 16 12 8 4 0	model-derived road mass-wasting results based on geomorphic terrane > 1000 cubic yards per mile per decade > 500 cubic yards per mile per decade > 250 cubic yards per mile per decade > 100 cubic yards per mile per decade > 50 cubic yards per mile per decade < 50 cubic yards per mile per decade	20
Riparian Reserve Rating [RR]	 6 4 2 1 0	percentage of road segment in Riparian Reserve > 80% of road in Riparian Reserve > 40% of road in Riparian Reserve > 20% of road in Riparian Reserve > 2% of road in Riparian Reserve < 2% of road in Riparian Reserve	6
Steep Slope Rating [S]	 6 4 2 1 0	percentage of road segment on steep slopes (>45%) > 75% of road on steep slopes > 50% of road on steep slopes > 25% of road on steep slopes > 2% of road on steep slopes < 2% of road on steep slopes	6
Cumulative Watershed Effects Rating [CWE]	 8 6 4 2 0	based on the CWE value for the watershed road is in > 0.90 (near or exceeding threshold) > 0.66 > 0.50 > 0.25 < 0.25	8
Road GIS Rating	calculated	GIS rating – sum of all GIS elements =[USLE + GEO + RR + S + CWE] (10) (20) (6) (6) (8)	[calculated] **max = 50**

Table 5: Road Ratings			
Unit	**Assigned Value 1/**	**Road Rating Elements**	**Maximum Value**
Elements Derived from Field Inventory			
Crossing and Cross Drain Rating [xings]	 6 4 3 2 1 0	based on number of stream crossings and connected cross drains per mile of road > 10 crossings or connected cross drains per mile > 5 crossings or connected cross drains per mile > 3 crossings or connected cross drains per mile > 1.5 crossings or connected cross drains per mile > 0 crossings or connected cross drains per mile no crossings or connected cross drains	6
Hydrologic Connectivity Rating [hcon]	 6 4 3 2 1 0	based on length of road hydrologically connected, derived from connected ditch length > 50% hydrologically connected > 20% hydrologically connected > 8% hydrologically connected > 2% hydrologically connected > 0% hydrologically connected no part of road hydrologically connected	6
Diversion Potential Rating [dp]	 8 6 4 2 0	based on number sites with diversion potential > 4 sites with diversion potential per mile > 2 sites with diversion potential per mile > 1 site with diversion potential per mile > 0 sites with diversion potential per mile no sites with diversion potential	8
Undersized Culvert Rating [uc]	 8 6 4 2 0	based on number sites with undersized culverts /1 > 3 sites with undersized culverts per mile > 1.5 sites with undersized culverts per mile > 1 site with undersized culverts per mile > 0 sites with undersized culverts per mile no sites with undersized culverts	8
Between Crossing Site Rating ("tweeners") [t]	 5 3 2 0	based on number "tweener" sites > 2 "tweeners" per mile of road > 1 "tweeners" per mile of road > 0 "tweeners" per mile of road no "tweeners" on the road	5
Highly Rated Site Rating [hr]	 5 4 3 2 0	based on number of highly rated sites /2 > 4 highly rated sites on the road 3 or 4 highly rated sites on the road 2 highly rated sites on the road 1 highly rated site on the road no highly rated sites on the road	5

Table 5: Road Ratings			
Unit	**Assigned Value 1/**	**Road Rating Elements**	**Maximum Value**
Elements Derived from Field Inventory			
Rating based on Sum of Overall Site Ratings [or]	 12 10 8 4 0	based sum of overall site ratings > 150 sum of site ratings on the road > 50 sum of site ratings on the road > 25 sum of site ratings on the road > 0 sum of site ratings on the road no rated sites on the road	12
Road Inventory Rating	calculated	Inventory rating – sum of all inventory elements =[xings + hcon + dp + uc + t + hr + or] (6) (6) (8) (8) (5) (5) (12)	[calculated] **max = 50**
Total Road Rating	calculated	sum of GIS and Inventory Rating =[GIS rating + Inventory Rating] (50) (50)	[calculated] **max = 100**

/1 Undersized culverts are for this inventory those with a pipe capacity site rating of 9 or higher. This assures that only pipes with multiple indicators of undersizing will be considered undersized.
/2 Highly-rated sites are those with overall site ratings of 45 or greater.

For **classified** (system) roads, 'K' and 'D' values are calculated for individual road segments based on changes in surface type and template. Maintenance level is used as a surrogate for level of use or traffic. Roads with heavy use produce more sediment by surface erosional processes than roads with lower use. Multipliers are employed to integrate use levels; these are displayed in Table 6.

Table 6: Multipliers

Surface type [modifies 'K']	Value	**Template** [modifies 'D']	Value	**Use** [maintenance level]	Multiplier
native (& unspecified)	"k" soil	unspecified	.29	0 (unspecified)	.5
pit-run aggregate	.10	outsloped	.15	1	.5
crushed aggregate	.02	insloped	.40	2	1
asphalt- pavement	.01	crowned	.30	3	2
chip-seal	.02	flat	.23	4	2
cinders	.05			5	2

Mass Wasting

This indicator provides model-estimated sediment delivery from road-related landsliding. This model uses road coefficients for sediment delivery rates based on geomorphic terrane (see below). These coefficients were developed from a study within the Salmon River subbasin (de la Fuente and Haessig, 1994) and displayed in Table 7.

Table 7: Delivery Rates

Geomorphic terrane #	Description	Delivery rate [cubic yards/acre/decade]
0	No data (same as #8)	18.72
1	Active landslides	1,000.00
2	Toe zones of dormant landslides	225.00
3	Dormant landslides	225.05
4	Granitic bedrock: steep slopes, >65%	1,005.48
5	Granitic bedrock: gentle slopes, <65%	36.33
6	Non-granitic (metamorphic) bedrock: steep slopes, >65%	81.84
7	Cascade volcanic rocks	1.00
8	Non-granitic (metamorphic) bedrock: gentle slopes, <65%	18.72
9	Inner gorge, in unconsolidated deposits	375.58
10	Inner gorge, in granitic bedrock	1,201.31
11	Inner gorge, in non-granitic (metamorphic) bedrock	285.28
12	Debris basins	25.20
13	Unconsolidated surficial deposits – glacial, terrace, etc.	7.45

Stream Proximity

This indicator provides the length of road that lies within the hydrologically defined Riparian Reserve. This Riparian Reserve was created by buffering streams as follows: (1) 340' for fish-bearing streams, and (2) 170' for non-fish-bearing streams.

Slope Steepness

This indicator provides the length of road that occupies slopes steeper than 45%. Slope class GIS layer was built from 30-meter DEMs [digital elevation model]. This procedure significantly underestimates the amount of steep ground. Therefore, specifying slope class of >45% in GIS actually defines slopes in the range of 55% to 60%.

Cumulative Watershed Effects

This indicator provides the 'CWE combination rating' of the 7th-field watershed (drainage) through which the road passes. If a road traverses multiple 7th-field watersheds, value from the dominant drainage (the 7th-field watershed the road is mostly in) is used. 'CWE combination rating' for each watershed is shown in *CWE 2004 - Cumulative Watershed Effects Analysis* and is based on the integration of three numerical models – surface erosion, mass-wasting, and ERA/TOC [ratio of equivalent roaded acres to threshold of concern, or 'risk ratio'].

Site Summary Ratings

The remaining road rating elements are derived from field inventory sites and the sites ratings as they apply to each road. Table 8 describes how these elements are used in the road rating.

Results / Discussion

The principal product of the Road Sediment Source Inventory & Risk Assessment is the KnfRoadSedimentSourceInventory.mdb geodatabase. This database contains the spatial and tabular results compiled from the various road inventories done across the Forest. It is accessible to Forest personnel for editing and report generation. While some fields are intended to be edited as needed by knowledgeable personnel, others are automatically re-calculated based on editable fields through a recalculation macro. Details about working with this database are in a separate document.

Listed in Table 8 are the "top 10" roads, sorted by 'Total Road Rating', in descending order. In general, highly rated road segments are characterized by the following: (1) high number of channel crossings over length of the road, (2) high percentage of road length directly connected to stream network, (3) high number of sites with diversion potential, (4) high number of sites with road-related gullies and landslides, (5) high number of 'highly-rated' individual crossing sites, and (6) many crossings, of which many are highly-rated (i.e., weighted sum overall site ratings for a given road segment).

Table 8: Road Rating Results – Top 10 roads

Road	7th Field Watershed	Length (miles)	Crossing sites (no)	Hydro connected (%)	Under-sized culverts (no)	Diversion potential sites (no)	Other sediment sources (no)	Highly rated sites (no)	Total Road Rating	Treatment Cost Estimates ($)
48N03	Upper WF Beaver Creek	0.58	6	54%	2	5	0	1	84	$84,900
39N30	Negro Creek-SF Salmon River	5.94	35	52%	16	25	2	4	82	$711,589
40S16	Deer Creek-Beaver Creek	1.31	7	76%	5	5	0	1	81	$151,078
39.4	Eddy Gulch	2.74	19	26%	9	15	12	2	80	$109,743
37N07	Rays Gulch-SF Salmon River	5.97	56	60%	21	46	6	3	79	$894,038
11	Soda Creek-Beaver Creek	4.19	10	39%	7	7	0	8	79	$396,197
39	McNeal Creek-SF Salmon River	2.72	28	83%	7	28	0	3	78	$493,765
45N49	Deadwood Creek	4.62	14	42%	8	14	1	3	78	$414,405
46N45	McKinney Creek	8.25	64	61%	14	58	0	11	76	$1,260,825
48	West Branch Indian Creek	1.53	14	66%	8	12	6	9	75	$475,392

PRIORITIZED SEDIMENT REDUCTION IMPLEMENTATION PLAN

Project Information:

Field crews collected site information. Risk assessment phase was conducted using this field information and following the outline shown in **Figure 1**. This process rated all inventoried sites on the basis of (1) risk of failure, (2) consequences of failure, and (3) potential impacts from failure. These individual elements were combined to yield an **overall rating**. Overall rating values for each site are displayed in the database. Overall rating values identify high risk/consequences/impact sites. Opportunity criteria (see right side of **Figure 1**) must then be applied in order to fully 'prioritize' each site. This last step is beyond the scope of this project and will be done in Forest planning processes.

In addition to site-specific information, project data provide road and road segment information for use in transportation planning efforts. Site-specific data can be viewed spatially to characterize individual roads. For example, a high concentration of high risk/consequences/impact sites would highlight this road as a candidate for upgrading or decommissioning, where large crossing fill volumes would be removed during upgrading or decommissioning. Numerous sites with diversion and/or collection potential along a specific road would suggest this road for a project that constructed 'critical dips'.

Transportation Planning:

Transportation planning, via the Forest Service Roads Analysis Process (RAP) has been done for many parts of the Forest. Road inventory information is important in informing recommendations during the RAP. Recommendations include identification of roads for one of the following actions: (1) upgrade or 'stormproofing', (2) decommissioning, (3) storage or radical stormproofing, (4) changes in closure status, (5) changes in maintenance level, (6) administrative action (e.g., add to system, special use permit), and (7) status quo (no action). This process is conducted in an interdisciplinary setting where all resource interests are represented.

These recommendations are based in large part by balancing needs & benefits versus environmental risk & road costs (simplistically, a type of cost/benefit analysis). In general and at extreme ends of the spectrum, if a road is critically essential to Forest land managers or the public and it poses high environmental risks (typically through threat of accelerated sedimentation), the road is recommended for upgrade. If a road is not critically essential and poses high risks, it would become a candidate for decommissioning. Therefore, upgrading or decommissioning high-risk roads would accomplish sediment reduction. Less costly sediment reduction measures could involve more restrictive closure status or upgrading of maintenance level.

Site information and road information from this project was used to aid in these management recommendations.

Road Treatments:

While acknowledging that recommendations as to which individual roads will receive which action should be made within the RAP process, this project can provide a list of potential sediment reducing road treatments. These treatments are shown in **Table 9** below. As noted at the bottom of **Table 9**, these categories of action are listed in order of increasing costs, construction complexity/difficulty, and project preparation documentation.

Road treatments can be generally divided into those that "winterize" a road and those that "stormproof" a road. Winterizing is a road maintenance activity (see **Table 9**, category [1]). Winterizing a road can reduce chronic and persistent fine-grained sediment generated by surface erosion processes within the road prism during typical winter flow conditions. Road surface grading can reduce the potential for road surface rilling and gullying. Ditch and culvert inlet cleaning can ensure road surface flows remain within designed drainage structures and not on the road itself.

Stormproofing a road can reduce sedimentation from episodic mass wasting and fluvial gullying, triggered by intense precipitation events and resultant high flow regimes. Categories [2] through [7] of **Table 9** are stormproofing measures. Treatments listed under 'Drainage Problems' address road surface erosion. 'Dips' fix high flows on road surfaces and ditches to (collection potential) and from (diversion potential) channel crossings. 'Major Crossing Re-design' treatments typically reduce fill volumes, allowing the channel crossing to handle debris flows and flood stage hydraulic flows; passage of fish and coarse woody debris is permitted. 'Landslide Remedies' address mass wasting potential from unstable road cuts, fills, or entire road prism. 'Storage' and 'Decommission' treatments are used to stormproof unused roads.

For all types of treatments, "sediment saved" is equal to the total volume of fill at the crossing site. This assumption is advocated by Pacific Watershed Associates (Weaver and Hagans 1999) and implicitly accepted by California Department of Fish & Game. There is a danger in this assumption. This assumption skews "cost effectiveness" numbers toward construction of critical dips to fix diversion potential and away from major crossing upgrades that reduce substantial fill volumes (e.g., construction of coarse-rock vented ford crossings). This could have the effect of preferentially funding "diversion potential" efforts at the expense of major crossing upgrade projects.

An example of this may be illustrated with a crossing containing 1,000 cubic yard (CY) of fill. To construct a critical dip to fix diversion potential may involve removal of 50 CY of material at a total cost of $3,000 – yielding cost effectiveness of $3 per CY of sediment saved [$3,000 / 1,000 CY]. After completion of this project, 950 CY of "at-risk" fill volume would still remain. To upgrade the crossing by constructing a coarse-rock vented ford might involve the removal of 900 CY of fill at a total cost of $50,000 - yielding cost effectiveness of $50 per CY of sediment saved [$50,000 / 1,000 CY]. After completion of this project, only 100 CY of "at-risk" fill volume would still remain. Based on "cost effectiveness" values [$3 vs. $50], there is a risk that the critical dip project would be funded instead of the major crossing upgrade alterative.

This report does **not** take the position that diversion potential projects should be ignored in favor of major upgrade efforts. Both types of treatments need to be considered. Decisions need to be based on risk/consequences/impacts at individual sites. For example, a site that poses little risk from debris flow or undersized pipe, small to moderate fill volume consequences, and minor impacts would be low priority for a major upgrade. However, it could be a candidate for a critical dip. On the other hand, a site with large fill volume at risk to debris flow or undersized pipe should be considered for a vented ford crossing upgrade or crossing redesign that removes significant fill volume. When considering diversion potential treatments for road segments, critical dips need to be used to break collection potential or outsloping of the entire segment.

This approach is consistent with the results of the 1997 Flood assessment (de la Fuente and Elder 1998). Of inventoried flood damage sites on Forest roads, approximately 400 of 800 sites involved failures at stream crossings. An estimated 22% of the 400 stream crossing sites resulted in diversion around plugged pipes. Often damage was minor. Effects from diverting streams amounted to an estimated 72,360 CY of failed material or a rate of 9 **CY/mile/decade** (assumes 4,000 miles of Forest road; 1997 Flood, as an event with ~20 year recurrence interval). Road failures at stream crossings where **no** diversion occurred resulted in an estimated 656,360 CY of failed material or a rate of 82 **CY/mile/decade**. Correcting diversion potential will reduce risk, but only a portion of it. Where upslope debris flows caused crossing failures, critical dips would not have been effective. In other words, debris flows did not divert, but punched through crossing fills like a freight train.

This report suggests a broad approach based on looking at fixes for entire roads/road segments or sub-watersheds (drainages). High risk/consequences/impact roads or areas should be considered rather than focusing on high risk/consequences/impact sites in isolation. For example, within an identified high priority 7^{th}-field watershed, high risk/consequences/impact roads should be targeted. Variety and mixes of fixes should be considered, such as outslope sections of road, major crossing upgrades at certain sites, fix diversion and collection potential in areas, and rock (hard surface with engineered crushed aggregate) sections of road. This mix of road upgrades collectively 'stormproof' the road – making it better able to withstand the next flood event.

Table 9: Road Treatments - Categories of Actions

Listed in order of **increasing**
- ✓ Costs
- ✓ Construction complexity/difficulty
- ✓ Project preparation documentation (e.g., NEPA, ESA, Engineering design)

[1] <u>Maintenance:</u>
- ➢ Unplug inlets
- ➢ Clean ditches
- ➢ Grade gullies in road surface

[2] <u>Dips:</u>
- ➢ Critical dips at crossing to fix diversion potential
- ➢ Dips to break collection potential or hydrologic connectivity
- ➢ Dips at "eroding pipeless swales"

[3] <u>Drainage Problems:</u>
- ➢ Road designs that cause gullies
- ➢ Adding pipes to break hydrologic connectivity
- ➢ Out sloping road

[4] <u>Major Crossing Re-design:</u>
- ➢ Upgrade crossing to reduce fill volume
- ➢ Upgrade crossing to allow passage of debris flows
- ➢ Other storm proofing measures (e.g., upgrade culvert size, fill slope stabilization)
- ➢ Upgrade crossing to allow fish passage where restricted

[5] <u>Landslide Remedies:</u>
- ➢ Buttress unstable cuts
- ➢ Engineered reinforced fills (e.g., "burrito walls", Hilfiker walls)
- ➢ Remove failed material

[6] <u>Storage:</u>
- ➢ Make road geo/hydrologically stable ("hydrologic obliteration"),
- ➢ But with option of future entry (i.e., not off system)
- ➢ Take-off not recontoured; pipes removed but some left on site

[7] <u>Decommission:</u>
- ➢ Make road geo/hydrologically stable ("hydrologic obliteration"),
- ➢ With NO intention of future entry (i.e., off system)
- ➢ Take-off recontoured; all pipes removed

Project and Watershed Monitoring Activity Recommendations

Watershed/road restoration projects resulting from road inventories and RAP planning would be monitored in the following three ways:

(1) Implementation Monitoring [Were project design standards and specifications achieved?];

(2) Effectiveness Monitoring [Were project objectives met? – Was implemented project effective at meeting these objectives?] and;

(3) Validation Monitoring [Are the assumptions underlying project decisions accurate?].

In addition, all watershed restoration activities involving roads would be subject to random monitoring for compliance with Best Management Practices standards and guidelines.

The ultimate effectiveness and validation monitoring of watersheds where restoration work has been implemented will occur when these treated watersheds are subjected and tested by future high precipitation and runoff events. The test will be to see if future large storms cause less road-related damage because of decommissioning and stormproofing/upgrading actions that have been implemented.

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Simulating fuel treatment effects in dry forests of the western United States: testing the principles of a fire-safe forest

Morris C. Johnson, Maureen C. Kennedy, and David L. Peterson

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Abstract: We used the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) to simulate fuel treatment effects on 45 162 stands in low- to midelevation dry forests (e.g., ponderosa pine (*Pinus ponderosa* Dougl. ex. P. & C. Laws.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) of the western United States. We evaluated treatment effects on predicted post-treatment fire behavior (fire type) and fire hazard (torching index). FFE-FVS predicts that thinning and surface fuel treatments reduced crown fire behavior relative to no treatment; a large proportion of stands were predicted to transition from active crown fire pre-treatment to surface fire post-treatment. Intense thinning treatments (125 and 250 residual trees·ha^{-1}) were predicted to be more effective than light thinning treatments (500 and 750 residual trees·ha^{-1}). Prescribed fire was predicted to be the most effective surface fuel treatment, whereas FFE-FVS predicted no difference between no surface fuel treatment and extraction of fuels. This inability to discriminate the effects of certain fuel treatments illuminates the consequence of a documented limitation in how FFE-FVS incorporates fuel models and we suggest improvements. The concurrence of results from modeling and empirical studies provides quantitative support for "fire-safe" principles of forest fuel reduction (sensu Agee and Skinner 2005. For. Ecol. Manag. **211**: 83–96).

Résumé : Nous avons utilisé le module complémentaire sur le feu et les combustibles du simulateur de la végétation forestière (« Fire and Fuels Extension – Forest Vegetation Simulator » (FFE-FVS)) pour simuler les effets du traitement des combustibles sur 45 162 peuplements dans des forêts sèches situées à une altitude allant de faible à moyenne (p. ex. pin ponderosa (*Pinus ponderosa* Dougl. ex P. & C. Laws.), douglas vert (*Pseudotsuga menziesii* (Mirb.) Franco)) dans l'ouest des États-Unis. Nous avons évalué les effets des traitements sur le comportement d'un feu potentiel à la suite du traitement (type de feu) et sur le risque de feu (indice d'embrasement des cimes). La simulation prédit que l'éclaircie et le traitement des combustibles de surface réduiraient les feux de cime comparativement à l'absence de traitements; une forte proportion de peuplements potentiellement sujets à un feu de cime avant d'avoir été traités ne seraient plus sujets qu'à un feu de surface après avoir été traités. Des traitements d'éclaircie forte (125 et 250 arbres résiduels·ha^{-1}) seraient plus efficaces que des traitements d'éclaircie faible (500 et 750 arbres résiduels·ha^{-1}) selon les prédictions. La simulation a prédit que le brûlage dirigé serait le traitement des combustibles de surface le plus efficace tandis qu'il n'y avait pas de différence entre l'absence de traitement des combustibles de surface et la récupération des combustibles. Cette incapacité à distinguer les effets de certains traitements des combustibles illustre la conséquence d'une limite documentée concernant la façon dont la simulation incorpore les modèles de combustibles et nous suggérons des améliorations. La convergence des résultats provenant de la modélisation et des études empiriques appuie de façon quantitative les principes de sécurité incendie qui prônent la réduction des combustibles (sensu Agee et Skinner 2005. For. Ecol. Manag. **211** : 83–96).

[Traduit par la Rédaction]

Introduction

Dry forest types prevalent in western North America historically exhibited high-frequency, low- to moderate-severity fire regimes (Agee 1993; Taylor and Skinner 1998). Past management practices such as livestock grazing, wildfire suppression, and timber harvest have modified the fuelbed characteristics (vegetation composition and structure) and fire behavior of these dry forest types (Weaver 1943; Biswell 1959; Dodge 1972; Hessburg and Agee 2003; Hessburg et al. 2005). They now have large amounts of fuel loads and ladder fuels such as tall grasses, shrubs, tree branches, and understory trees (Parsons and DeBenedetti 1979; Bonnicksen and Stone 1982; Peterson et al. 2005). As a result, these forests are more susceptible to active crown fire and higher burn severity than they were historically (Laudenslayer et al. 1989; MacCleery 1995; Arno and Allison-Bunnell 2002).

Fuel treatments are advocated to reduce fire hazard caused by increased stem densities in low- to moderate-severity fire regimes (Graham et al. 2004; Peterson et al. 2005). Rather

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than stop wildfires (Finney and Cohen 2003), treatments are meant to decrease fireline intensity (i.e., rate of heat energy released), reduce crown fire initiation, and support suppression operations (Agee 1996). Silvicultural thinning practices such as thinning from below and pruning and the subsequent removal of surface fuels are effective options to reduce stand density, remove ladder fuels, and increase stand heterogeneity (Graham et al. 2004). With millions of hectares of dry forests in the western United States requiring fuel treatment, forest and fire managers need recommendations and information to support science-based decision making for fuel management (Graham et al. 1999; Peterson et al. 2005; Schmidt et al. 2008). Agee and Skinner (2005) proposed four guidelines to assist managers in developing effective treatments to reduce crown fire hazard and to understand treatment consequences: reduce surface fuels, increase canopy base height, decrease canopy bulk density, and retain large fire-resistant trees. These principles of a "fire-safe" forest are based on our current knowledge of crown fire theory (e.g., Van Wagner 1977) and are intended to increase the resilience of stands to wildfire (Agee and Skinner 2005).

Several constraints, including insufficient funding, logistics, and safety, prevent robust experimental testing of the effects of different fuel treatments (Finney and Cohen 2003). Consequently, most validation of fuel treatment effects on mitigating fire hazard is done post hoc without high-quality pre-wildfire data (Pollet and Omi 2002; Finney et al. 2006). As an alternative, simulation models provide quantitative prediction of the effects of modifying fuelbed characteristics on crown fire hazard and the probability of crown fire initiation (Graham et al. 2004). The Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) (Reinhardt and Crookston 2003) simulates forest growth and potential fire hazard and fire type of different vegetation types in the United States. FFE-FVS is the standard simulation model used by most federal, state, and tribal government agencies (Dixon 2003). In this study, we evaluated how FFE-FVS predicts the effects of fuel treatments (i.e., combinations of thinning and surface fuel treatments) on simulated fire hazard and potential fire behavior type in a set of stands from dry forests of the western United States. This study extends conceptual and analytical work on fuel treatments and fire behavior from the fuel treatment guidebook (Johnson et al. 2007). Unlike other studies that have used FFE-FVS to examine treatment effects for only a few stands in specific geographical areas (Fiedler et al. 2001; Calkin et al. 2005; Skog et al. 2006), we used a large set of stand data from several geographic regions to perform a virtual test of the four principles of a fire-safe forest (Agee and Skinner 2005) across a broad range of dry forest conditions.

Methods

Model description: FFE-FVS

We used FFE-FVS (version 6.21) (Reinhardt and Crookston 2003) to simulate the effects of thinning and surface fuel treatments on potential fire hazard and fire behavior at small spatial scales (tens of hectares). FFE-FVS can simulate a fire or estimate the potential effect of a fire under user-specified weather and fuel conditions. A simulated fire modifies stand and fuels conditions (e.g., kills trees, reduces fuel loading) and alters the trajectory of stand succession and fuel dynamics. FFE-FVS calculations of potential fire effects are conducted before the effects of a fire are simulated.

FFE-FVS is a consolidation of two computer modules, FVS and FFE. FVS is an individual-tree, distance-independent, growth-and-yield model that simulates tree growth, mortality, and the effects of a variety of silvicultural treatments (Dixon 2003). Stands are the basic unit of management, and projections depend on interactions among trees within the stands. Twenty variants have been developed and calibrated to cover most forestlands in the United States (Fig. 1). For example, the Southern Oregon/Northeastern California (SO) variant was fit to data representing forest types (33 species or species groups) in southern Oregon and northeastern California (Keyser 2008). The variant is applicable to a variety of tree species, forest types, and stand structures in the Deschutes, Fremont, Winema, Klamath, Lassen, Modoc, Plumas, Shasta, and Trinity national forests and corresponding Bureau of Land Management and industry lands (Keyser 2008). Data used to develop these equations were derived from numerous forest inventories, silvicultural stand examinations, research plots, and tree plantation studies (Keyser 2008). Major species modeled in the SO variant include western white pine (*Pinus monticola* Dougl. ex D. Don), sugar pine (*Pinus lambertiana* Dougl.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), white fir (*Abies concolor* (Gord. & Glend.) Lindl.), mountain hemlock (*Tsuga mertensiana* (Bong.) Carrière), incense cedar (*Libocedrus decurrens* Torr.), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), noble fir (*Abies magnifica* Rehd.), and ponderosa pine (*Pinus ponderosa* Dougl. ex P. & C. Laws.). For this study, we used seven of the 20 FVS variants (Fig. 1) and present the results of two of those variants in detail (with the remaining five in the supplementary material[1]).

FFE simulates snag dynamics and woody fuel accumulation and decomposition through time using fuels information projected by FVS (Reinhardt and Crookston 2003). Fire behavior and crown fire hazard are computed using methods developed by Rothermel (1972), Albini (1976), and Scott and Reinhardt (2001).

Using the stand characteristics, FFE-FVS calculates two indices of crown fire hazard: torching index and crowning index (Table 1). Torching index is the windspeed (kilometres per hour) required for crown fire initiation and crowning index is the windspeed (kilometres per hour) required to support an active crown fire. Lower values of each of these indices indicate increased fire hazard. FFE-FVS also uses the stand data to classify the stand as one of four types of potential fire behavior associated with increasing fire hazard: surface fire, conditional fire, passive crown fire, and active crown fire (Table 1). In a stand classified as potential surface fire, a fire is predicted to spread primarily within the surface fuels (dead branches, leaves, needles, low vegetation). With potential conditional fire, conditions for sustained active crown fire spread are met, but conditions for crown fire initiation are not. In such a stand, FFE-FVS predicts that if the

[1]Supplementary data are available with the article through the journal Web site (http://www.nrcresearchpress.com/cjfr).

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Fig. 1. There are 20 total FVS variants, each calibrated separately to a specific geographic area of the United States. We chose seven FFE-FVS variants to evaluate for the current study. The results for the East Cascades and Northern Idaho variants are presented in detail, with the results for the remaining variants presented in supplementary material[1]. 1 mile = 1.61 km.

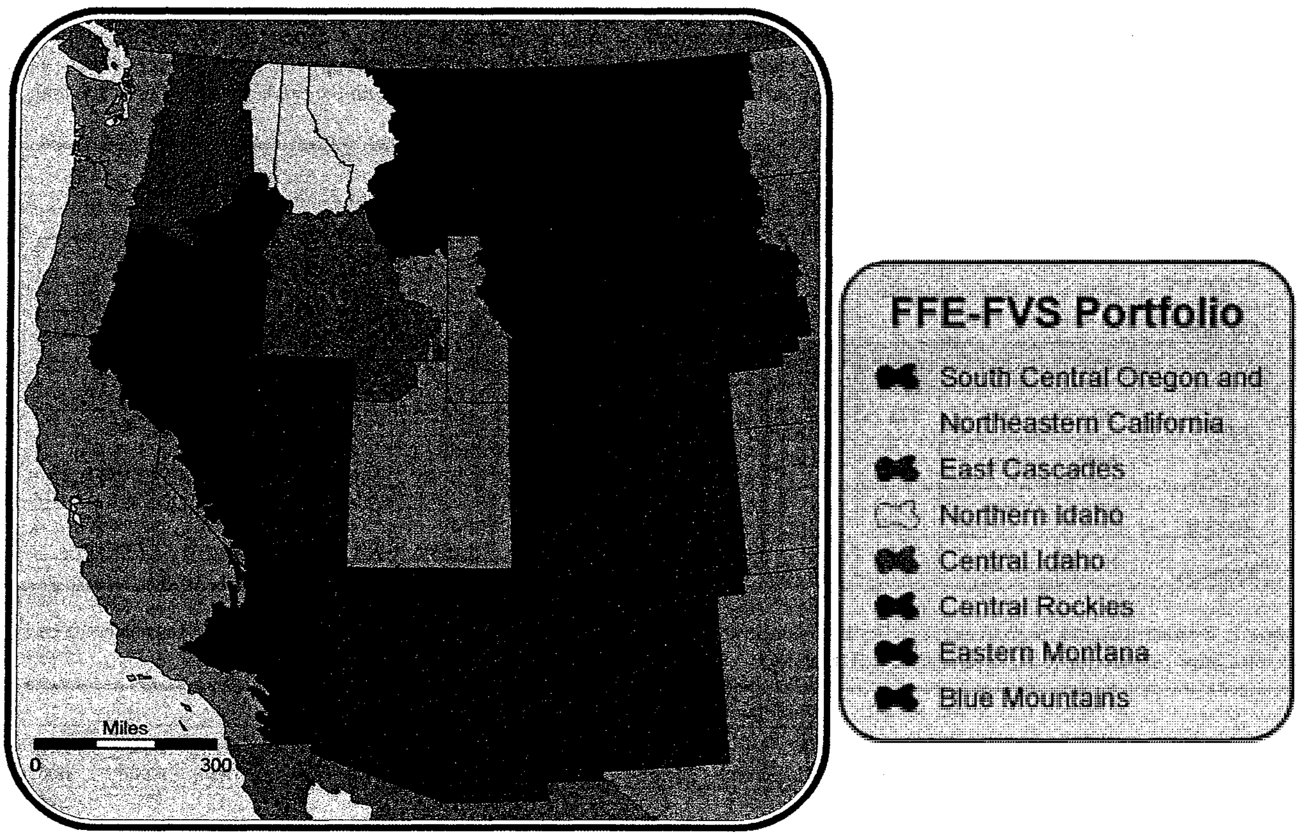

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Table 1. The Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) (Reinhardt and Crookston 2003) simulates forest growth and potential fire hazard (e.g, torching index) and fire type (e.g., active crown fire) of different vegetation types in the United States.

	Description
Fire hazard	
Torching index	The 6.1 m wind speed (km·h^{-1}) at which a surface fire is expected to ignite the crown layer. This depends on surface fuels, surface fuel moisture, canopy base height, slope steepness, and wind reduction by the canopy
Crowning index	The 6.1 m wind speed (km·h^{-1}) needed to support an active or running crown fire. This depends on canopy bulk density, slope steepness, and surface fuel moisture content
Potential fire type	
Surface fire	Spreads primarily within the surface fuels
Conditional surface fire	Conditions for sustained active crown fire spread are met, but conditions for crown fire initiation are not. If the fire begins as a surface fire, then it is expected to remain so. If it begins as an active crown fire in an adjacent stand, then it may continue to spread as an active crown fire
Passive crown fire	Individual or small groups of trees ignite, but solid flaming in the canopy cannot be maintained except for short periods
Active crown fire	The entire fuel complex becomes involved, but the crowning phase remains dependent on heat released from the surface fuels for continued spread

fire begins as an active crown fire in an adjacent stand, it may continue to spread as an active crown fire (Scott and Reinhardt 2001). With potential passive crown fire (torching), a fire is predicted to occur when individual or small groups of trees ignite, but solid flaming in the canopy cannot be maintained except for short periods. In a stand classified as potential active crown fire, FFE-FVS predicts that the entire fuel complex becomes involved in a fire, but the crowning phase remains dependent on heat released from the surface fuels for continued spread (Van Wagner 1977). In this study, we evaluated simulated fuel treatment effects on the predicted torching index and the potential fire type classification.

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Fig. 2. Study design. Seven FFE-FVS variants were evaluated in total, with the results for East Cascades and Northern Idaho (shaded) presented here in detail. Results for the remaining variants are presented in the supplementary material[1]. For each variant, the pre-treatment fire type and torching index were identified by FFE-FVS for each stand. (*a*) The stands in each variant were partitioned by their pre-treatment fire types. (*b*) Twelve combinations of thinning and surface fuel treatments were simulated for each stand in each pre-treatment fire type for each variant (in the example above, there are 800 stands in the Northern Idaho variant classified pre-treatment as potential active fire type). Post-treatment simulated values were change in log torching index (Δti) (eq. 1) and post-treatment potential type (Post-trt fire type). Twenty-eight separate analyses were conducted for each of the response variables (Δti, post-treatment fire type), with the predictor variables of thinning treatment and surface fuel treatment.

(a)

Variant	Pre-treatment fire type Surface	Conditional	Passive	Active
East Cascades	387	1123	276	340
Southern Oregon and Northeastern California	3630	2587	2054	983
Northern Idaho	893	2888	208	800
Central Idaho	463	1311	322	234
Central Rockies	5048	3487	6171	6297
Eastern Montana	201	2233	177	494
Blue Mountains	495	769	557	275

(b)

Stand
1
2
.
.
.
n=800

Surface fuel treatment	Thinning treatment (residual density; trees·ha^{-1}) 750	500	250	125
No action	Δti_{11}	Δti_{12}	Δti_{13}	Δti_{14}
	Post-trt fire $type_{11}$	Post-trt fire $type_{12}$	Post-trt fire $type_{13}$	Post-trt fire $type_{14}$
Extraction	Δti_{21}	Δti_{22}	Δti_{23}	Δti_{24}
	Post-trt fire $type_{21}$	Post-trt fire $type_{22}$	Post-trt fire $type_{23}$	Post-trt fire $type_{24}$
Prescribed fire	Δti_{31}	Δti_{32}	Δti_{33}	Δti_{34}
	Post-trt fire $type_{31}$	Post-trt fire $type_{32}$	Post-trt fire $type_{33}$	Post-trt fire $type_{34}$

Table 2. Weather variables used to estimate fire behavior across all stands pre-treatment and post-treatment and weather parameters used in the simulation of prescribed fire as a surface fuel treatment.

			Fuel moisture (%)						
Measurement type	Windspeed (km·h^{-1})	Temperature (°C)	1 h (<0.6 cm)	10 h (0.6–2.5 cm)	100 h (2.5–7.6 cm)	1000 h (>7.6 cm)	Duff	Live woody	Live herb
Fire behavior	40	29	3	4	6	10	15	70	70
Prescribed fire*	16	21	12	12	14	25	125	150	150

*Percentage of stand burned equals 75%.

Stand examination data

We downloaded data for 109 227 stands from a relational database that contains measurements collected in the field from national forests (FSVeg). The database contains plot vegetation data from field surveys such as Forest Inventory Analysis data, stand exams, inventories, and regeneration surveys (USDA Forest Service 1992). Of these 109 227 stands, we retained 45 162 (41%) that met the following selection criteria: initial stand density ≥750 trees·ha^{-1} (tph) (corresponding to the least intense thinning treatment in our study), slope ≤30% (standard maximum slope for fuel treatments), and species composition including at least 1% of dry tree species typically dominant in dry forests of the western United States (e.g., *Pinus ponderosa*, *Pseudotsuga menziesii*). We discarded several stands with low canopy fuels and dominated by hardwoods because FFE-FVS could not calculate fire hazard in these stands. We partitioned the stands into seven of the 20 FFE-FVS variants (Fig. 1): East Cascades, South Central Oregon and Northeastern California, Northern Idaho, Central Idaho, Central Rockies, Eastern Montana, and Blue Mountains. For each stand in each of the seven variants, we used FFE-FVS to predict the initial pre-treatment potential fire behavior type and torching index (Fig. 2*a*) with the same weather-related variables (e.g., fuel moisture and windspeed) for all variants (Table 2).

Thinning and surface fuel treatments

We developed a treatment matrix to emulate Agee and Skinner's (2005) four principles of a fire-safe forest (Fig. 2*b*). Four thinning treatments and three surface fuel treatments were programmed into FFE-FVS batch processing format for each variant. All four thinning prescriptions were to thin from below to a target residual density: 750, 500, 250, or 125 tph. Only trees up to 46 cm diameter breast height were removed in the simulation. For each thinning density, three surface fuel prescriptions were simulated: no action (all slash remained in the stand), extraction (all slash removed from the stand), and prescribed fire (trees <15 cm left in the stand, trees of 15–46 cm had boles removed and branches left in the stand). Each treatment combination was simulated separately for each stand, and the torching index and potential fire behavior type were recorded for the first year following treatment. We generated an individual FFE-FVS projection for each stand and treatment combination.

Simulation analysis

The simulations performed by FFE-FVS are deterministic, and in our study, we have a nonrandom sample of stand examination data. Therefore, our analysis applies only to the set of stands evaluated and in the context of the simulation model structure. In effect, we have a census of the stands

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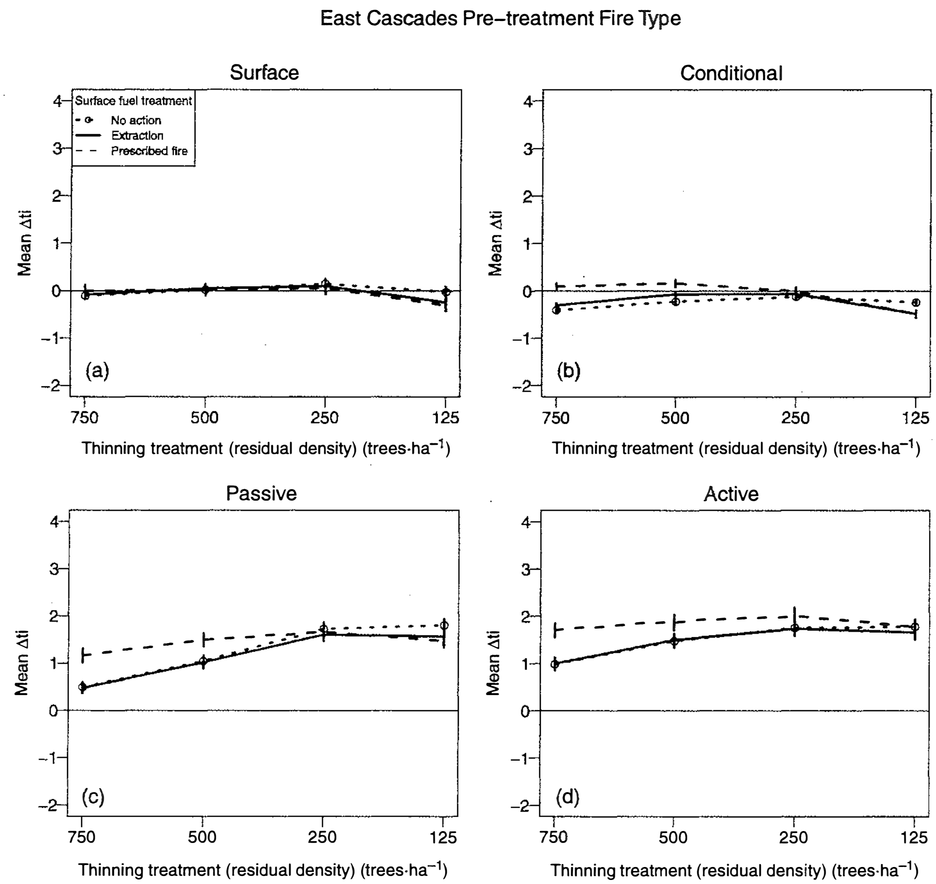
Fig. 3. Interaction plot showing the mean change in log torching index (Δti) for each combination of thinning (four levels) and surface fuel (three levels) treatments for the East Cascades variant for stands classified pre-treatment as (*a*) surface, (*b*) conditional, (*c*) passive, and (*d*) active fire types. Vertical lines represent ±2 SE for each treatment combination mean. Note that the *x*-axis is a categorical variable (thinning treatment) rather than a scalar. All plots are shown on the same *y*-axis to enable comparison of mean values among pre-treatment fire types. A positive value of mean Δti indicates that torching index increases post-treatment, thereby decreasing fire hazard. The mean Δti increases from the less intense thinning treatment (750 residual trees·ha^{-1}) up to the second most intense thinning treatment (250 residual trees·ha^{-1}) and then levels off or decreases from 250 residual to 125 residual trees·ha^{-1}. Overall, the mean Δti is higher for the prescribed fire surface fuel treatment than for the no action and extraction surface fuel treatments.



available to us that meet our criteria. In our analysis of the simulated results, our conclusions rely on interpretation of how patterns change across the treatment combinations. We make suggestions for how the results may apply more generally to dry forest types of the western United States.

Each FFE-FVS variant uses unique algorithms to simulate fire hazard and fire behavior. We therefore performed a separate analysis for each variant. Furthermore, torching index is one component of the classification of potential crown fire hazard in FFE-FVS, so there will be significant dependence between torching index and potential fire behavior type as well as between pre-treatment and post-treatment fire types. To avoid confounding of those variables, we performed separate analyses for stands in each combination of FFE-FVS variant and pre-treatment fire type, resulting in 28 individual analyses each for torching index and pre-treatment potential fire behavior type (Fig. 2). Simulated effects of the fuel treatments tended to be similar across the variants, with minor deviations. For the sake of brevity, we report in detail on two variants that represent distinct trends in the torching index response to fuel treatment (East Cascades and Northern Idaho). The results from the remaining variants are shown in the supplementary material (S1 and S2[1]).

Torching index

To reduce crown fire hazard, the fuel treatment should increase the torching index relative to the pre-treatment stand condition. The most informative response variable for the purpose of management is the difference between the pre-treatment and the post-treatment torching indices. The value of the torching index is ≥0 and tends to be highly right-skewed, which makes interpretation of mean values and associated standard errors difficult because the mean value is sensitive to outliers. To aid interpretation of mean values, we use a log transformation of torching index (+1 to avoid taking the log of zero). The differences in torching index are also highly right-skewed, and they take both positive and negative values. Rather than log transform the change in torching index (which would require standardizing all values to the positive real line before taking the log, thereby losing

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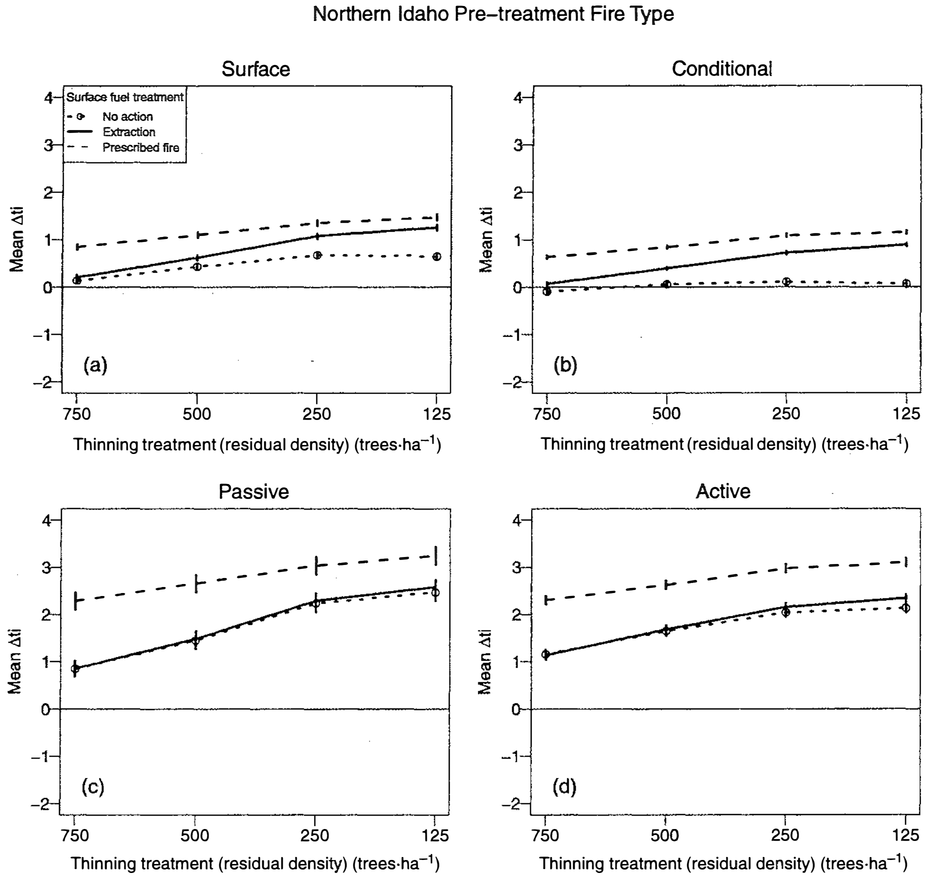
Fig. 4. Interaction plot showing the mean change in log torching index (Δti) for each combination of thinning (four levels) and surface fuel (three levels) treatments for the Northern Idaho variant for stands classified pre-treatment as (*a*) surface, (*b*) conditional, (*c*) passive, and (*d*) active fire types. Vertical lines represent ±2 SE for each treatment combination mean. Note that the *x*-axis is a categorical variable (thinning treatment) rather than a scalar. All plots are shown on the same *y*-axis to enable comparison of mean values among pre-treatment fire types. A positive value of mean Δti indicates that torching index increases post-treatment, thereby decreasing fire hazard. The mean Δti increases from the less intense thinning treatment (750 residual trees·ha^{-1}) to the most intense thinning treatment (125 residual trees·ha^{-1}). Overall, the mean Δti is higher for the prescribed fire surface fuel treatment than for the no action and extraction surface fuel treatments. The no action and extraction surface fuel treatments are similar in their mean Δti for stands classified pre-treatment as passive or active.



interpretability with respect to whether the post-treatment torching index is greater than the pre-treatment torching index), we choose to take the difference of the log-transformed values. This preserves the direction of the change in torching index (Δti), i.e., whether it is positive or negative:

$$[1] \quad \Delta ti = \log(ti_{post} + 1) - \log(ti_{pre} + 1) = \log[(ti_{post} + 1)/(ti_{pre} + 1)]$$

The use of log transformations in this context allows for the appropriate interpretation of means and standard errors for skewed data. A positive value for Δti means that the log (ti + 1) increases with fuel treatment relative to no treatment, which indicates a decrease in fire hazard. A negative value means that the log(ti + 1) decreases with fuel treatment, indicating that fire hazard worsens after treatment. We separated the data by FFE-FVS variants and classification of potential pre-treatment fire behavior type (surface fire, conditional surface fire, passive crown fire, or active crown fire). We calculated the mean Δti for each treatment combination, which yielded 12 means for each combination of variant and pre-treatment fire behavior type. We plotted the mean Δti across stands with changing thinning intensity and for each surface fuel treatment to evaluate differences in mean Δti among the treatment combinations (Figs. 3 and 4). We also report the group means for each treatment combination and calculate the standard error for each cell mean, which are included in the mean plots. In this case, the change in torching index is predicted by the combination of thinning and surface fuel treatment.

Classification of post-treatment potential fire type

Fire managers are concerned with designing and implementing treatments to change potential fire behavior. Although torching index is a component of the classification of potential fire type, a change in the torching index alone does not necessarily explain whether the potential fire behavior type (i.e., fire type predicted if a fire were simulated) will be effectively changed. We calculated the proportion of stands classified by FFE-FVS in each potential fire behavior type after treatment for each treatment combination. For ex-

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ample, suppose that 1000 stands classified pre-treatment as active fire type are evaluated. After treatment, suppose 300 (0.30) of those are still classified post-treatment as potential active crown fire (the treatment did not change their classification), 250 (0.25) as potential passive crown fire (the treatment marginally reduced their hazard classification), 250 (0.25) as potential conditional fire, and 200 (0.20) as potential surface fire (the treatment effectively reduced their hazard classification from potential active type to potential surface type).

The stands of greatest concern for the manager are those classified pre-treatment as potential active fire type. Across those stands, we calculated the proportion classified post-treatment in each of the four potential fire types. We compared those proportions across each combination of thinning and surface fuel treatment and calculated standard errors for the proportion for each treatment combination. This allows us to evaluate how the proportions change with each treatment combination for each FFE-FVS variant. An effective treatment would result in a lower proportion of stands that are classified pre-treatment as potential active type and remain classified post-treatment as potential active type. An effective treatment would also result in a higher proportion of stands that transition post-treatment to potential surface type. For this analysis, the proportion of stands classified post-treatment into each of the possible potential fire types is predicted by the combination of thinning and surface fuel treatment.

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Results

Torching index

There are clear differences among the thinning and surface fuel treatments in predicting mean Δti for each of the seven FFE-FVS variants and four pre-treatment fire types (see Table 3 for cell means for the East Cascades and Northern Idaho variants and supplementary material S1[1] for the remaining variants). For stands with pre-treatment surface or conditional fire type, we observed two separate trends for thinning and surface fuel treatments in the seven variants. These two trends were represented by the East Cascades and Northern Idaho variants. For the East Cascades variant, FFE-FVS predicted that the mean Δti tended to be near zero regardless of the fuel treatment combination (Figs. 3*a* and 3*b*). This response suggests that, in the East Cascades variant for stands classified pre-treatment as surface or conditional surface fire, fuel treatments tend not to change the torching index. We observed this trend in all variants except Northern Idaho. For the Northern Idaho variant, FFE-FVS predicted that the mean Δti tended to be above zero for all surface and conditional fire stands (Figs. 4*a* and 4*b*). This trend indicates that all of the treatment combinations increased the mean Δti, thereby increasing the torching index and improving fire hazard.

For stands with pre-treatment passive or active fire type, FFE-FVS generated similar responses to thinning treatments. Overall, all of the treatment combinations increased mean Δti in the East Cascades and Northern Idaho variants. For both variants, the more intense thinning treatments (125 and 250 trees·ha^{-1}) had a greater Δti than did the less intense thinning treatments (500 and 750 trees·ha^{-1}) (Figs. 3*c*, 3*d*, 4*c*, and 4*d*). In the East Cascades variant, the mean Δti increased from the 750 to the 250 trees·ha^{-1} thinning treatment and then either leveled off or decreased from the 250 to the 125 trees·ha^{-1} thinning treatment (Figs. 3*c* and 3*d*). However, in the Northern Idaho variant, the mean Δti increased as thinning intensity increased and did not level off or decrease from the 250 to the 125 trees·ha^{-1} thinning treatment. The two trends observed in the East Cascades and Northern Idaho were also found in the other variants.

We observed unanticipated responses to the surface fuel treatments. In the East Cascades and Northern Idaho variants, we again observed two distinct trends to surface fuel treatments, one from prescribed fire and the other from no action and extraction. Overall, prescribed fire was most effective at increasing mean Δti. In the East Cascades variant, FFE-FVS predicted a higher mean Δti for prescribed fire at the less intense thinning treatments (500 and 750 trees·ha^{-1}) for all of the pre-treatment fire type classifications except surface (Figs. 3*a* and 3*b*). The mean Δti for the no action and extraction surface fuel treatments was similar for all thinning treatments (Figs. 3*a* and 3*b*). For the intense thinning treatments (125 and 250 trees·ha^{-1}), the mean simulated Δti was similar among the surface fuel treatments across the pre-treatment fire type classifications (Fig. 3). In the Northern Idaho variant, prescribed fire produced the highest mean Δti regardless of thinning intensity and across all of the pre-treatment fire type classifications (Fig. 4). No action and extraction treatments were similar for the passive and active pre-treatment fire type classifications (Figs. 4*c* and 4*d*) but not for the surface and conditional pre-treatment fire type classifications (Figs. 4*a* and 4*b*). For plots of mean Δti for the remaining five variants, see supplementary material S1[1].

Classification of post-treatment potential fire type

There are clear differences among the thinning and surface fuel treatments in predicting the post-treatment potential fire type for stands classified pre-treatment as active crown fire type. For the stands classified pre-treatment as active crown fire type, we present in detail the results for the East Cascades and Northern Idaho variants. For the results of the remaining variants, see supplementary material S2[1].

FFE-FVS predicted that the proportion of stands classified post-treatment as potential active fire type decreased with intense thinning treatment (decreasing residual trees per hectare) (Figs. 5*d* and 6*d*). The proportion of each post-treatment fire type with varying thinning intensity was similar for the no action and extraction surface fuel treatments (Figs. 5 and 6; see supplementary material S2[1]).

The effects of surface fuel treatments on the proportion of stands classified post-treatment in each of the fire type classifications were similar to surface fuel treatment effects observed on mean Δti. Prescribed fire was the most effective treatment for decreasing the proportion of active crown fire stands (Figs. 5*d* and 6*d*). The proportion of stands classified by FFE-FVS post-treatment as potential active fire type was zero for the combination of prescribed fire and less intense thinning treatments (750 and 500 residual trees·ha^{-1}). The effect of no action and extraction surface fuel treatment on the proportion of stands classified post-treatment as active fire type was nearly identical for all variants (Figs. 5*d* and 6*d*).

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Table 3. Cell mean values of change in log torching index (Δti) for the East Cascades and Northern Idaho variants, with stands partitioned by the pre-treatment fire types.

		Thinning treatment (residual density, trees·ha^{-1})							
		East Cascades				Northern Idaho			
Pre-treatment fire type	Surface fuel treatment	750	500	250	125	750	500	250	125
Surface	No action	−0.106	0.024	0.150	−0.022	0.137	0.432	0.672	0.652
	Extraction	−0.080	0.052	0.104	−0.242	0.206	0.620	1.080	1.260
	Prescribed fire	−0.002	0.026	0.058	−0.308	0.846	1.100	1.350	1.470
Conditional	No action	−0.407	−0.222	−0.122	−0.242	−0.095	0.058	0.111	0.069
	Extraction	−0.302	−0.067	−0.064	−0.483	0.069	0.395	0.721	0.890
	Prescribed fire	0.096	0.162	−0.005	−0.483	0.631	0.845	1.080	1.160
Passive	No action	0.497	1.050	1.730	1.810	0.851	1.450	2.230	2.470
	Extraction	0.478	1.020	1.610	1.570	0.854	1.480	2.290	2.580
	Prescribed fire	1.170	1.490	1.670	1.480	2.290	2.650	3.030	3.240
Active	No action	0.983	1.470	1.760	1.780	1.160	1.650	2.040	2.130
	Extraction	0.999	1.500	1.740	1.660	1.130	1.680	2.150	2.340
	Prescribed fire	1.710	1.890	2.010	1.780	2.300	2.620	2.970	3.100

Note: Each value is the mean across stands for each thinning and surface fuel combination for each variant and pre-treatment fire type.

Fig. 5. Proportion of stands for the East Cascades variant that are classified pre-treatment as active fire type and classified post-treatment as (*a*) surface, (*b*) conditional, (*c*) passive, and (*d*) active fire types for each combination of thinning (four levels) and surface fuel (three levels) treatments. Vertical lines represent ±2 SE for each treatment combination proportion. Note that the *x*-axis is a categorical variable (not a scalar). The proportion of stands classified post-treatment as potential active fire type is indistinguishable between the no action and extraction surface fuel treatments and is near zero for all thinning intensities for the prescribed fire surface fuel treatment. For the no action and extraction surface fuel treatments, the proportion of stands classified post-treatment as potential active fire type declined from the less intense thinning treatment (750 residual trees·ha^{-1}) to the most intense thinning treatment (125 residual trees·ha^{-1}).

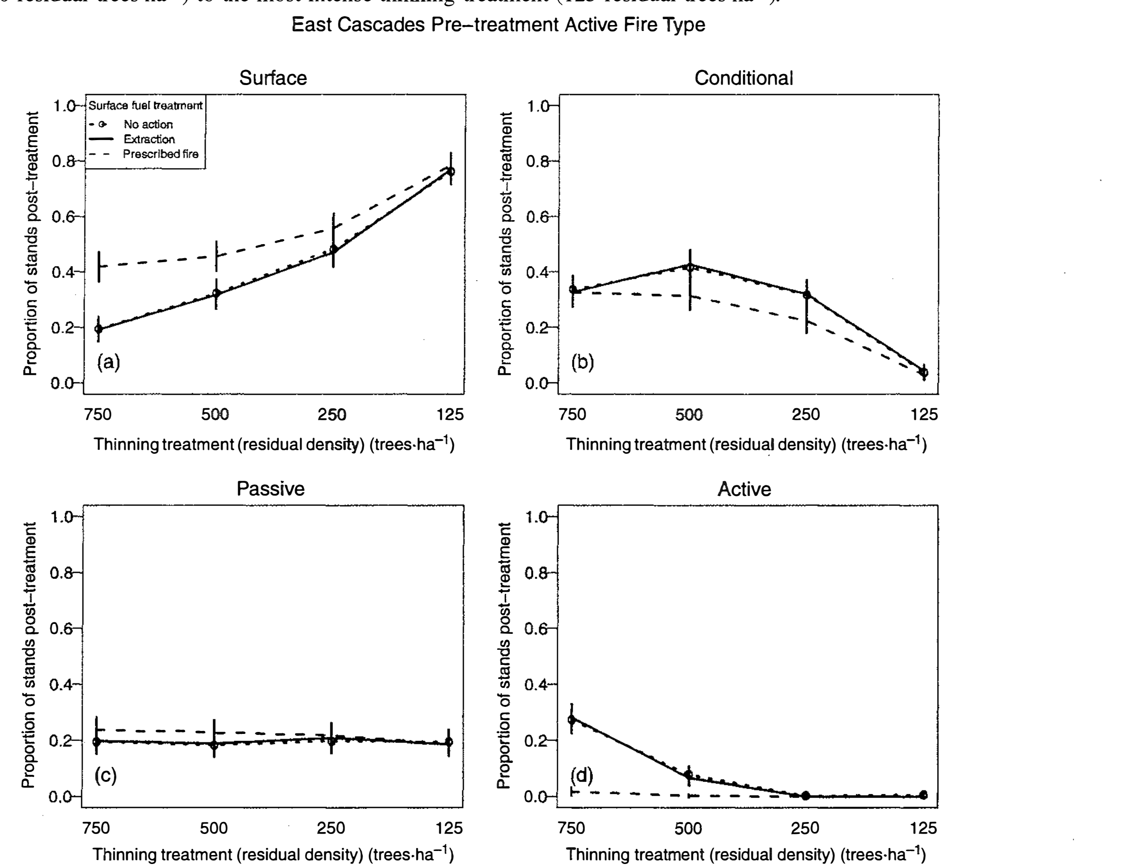

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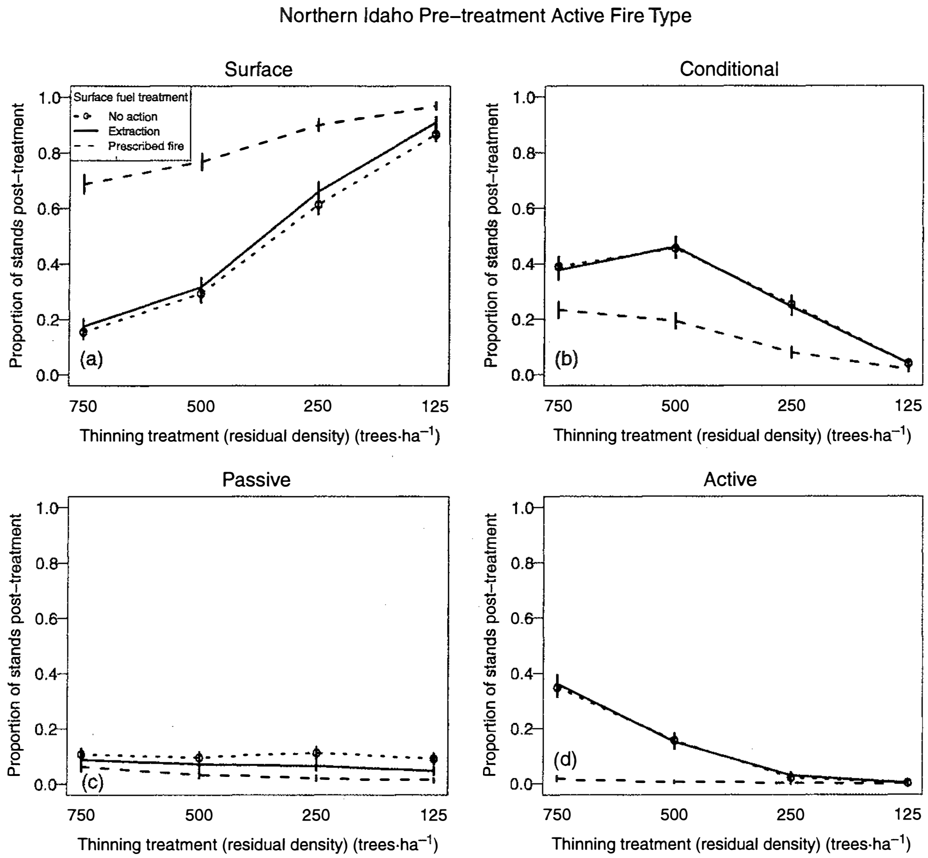
Fig. 6. Proportion of stands for the Northern Idaho variant that are classified pre-treatment as active fire type and classified post-treatment as (*a*) surface, (*b*) conditional, (*c*) passive, and (*d*) active fire types for each combination of thinning (four levels) and surface fuel (three levels) treatments. Vertical lines represent ±2 SE for each treatment combination proportion. Note that the *x*-axis is a categorical variable (not a scalar). The proportion of stands classified post-treatment as potential active fire type is indistinguishable between the no action and extraction surface fuel treatments and is near zero for all thinning intensities for the prescribed fire surface fuel treatment. For the no action and extraction surface fuel treatments, the proportion of stands classified post-treatment as potential active fire type declined from the less intense thinning treatment (750 residual trees·ha^{-1}) to the most intense thinning treatment (125 residual trees·ha^{-1}).



These general patterns were similar across all seven variants (see supplementary material S2[1]).

Discussion

Crown fire hazard and fire behavior

The results of our study are consistent with findings from other computer simulations and post-fire empirical studies that support the efficacy of fuel treatments for reducing crown fire hazard and severity in dry forest types across the western United States (Agee et al. 2000; Raymond and Peterson 2005; Stephens and Moghaddas 2005; Cram et al. 2006). FFE-FVS predicted that fuel treatment efficacy (indicated by a positive Δti and a transition from potential active fire to potential surface fire) was contingent on thinning treatment intensity. The intense thinning treatments (125 and 250 trees·ha^{-1}) were more effective than the less intense treatments (500 and 750 trees·ha^{-1}) in reducing fire hazard because these resulted in the greatest positive change in torching index (Figs. 3 and 4) and the greatest proportion of stands classified post-treatment as surface fire type (Figs. 5*a* and 6*a*). There were two distinct trends predicted between the East Cascades and Northern Idaho variants. In the East Cascades variant, the fuel treatment combinations decreased fire hazard only in stands classified pre-treatment as potential passive and active fire types (Fig. 3), as indicated by the near zero change in mean torching index for the surface and conditional pre-treatment fire type classifications and the positive change in mean torching index for the active and passive pre-treatment fire type classifications. In contrast, in the Northern Idaho variant, fuel treatments decreased fire hazard for stands classified in all of the pre-treatment potential fire types (Fig. 4), as indicated by the positive mean change in torching index.

These predictions by FFE-FVS for the stands that we evaluated should not be surprising because they validate the obvious conclusion that stands classified as potential surface and conditional fire types should have a low priority for treatments. The fuelbed characteristics of stands with surface and conditional fire type (low fuel loads, high canopy base height) prevent crown fire initiation, reduce fireline intensity, and reduce fire behavior. However, thinning treatments may sometimes be warranted in stands classified as conditional surface fire because the structural characteristics of these

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Table 4. Fire behavior and fuel model assignments after thinning and surface fuel treatments (i.e., no action, extraction, and prescribed fire).

		Thin to 125 trees·ha^{-1}			Thin to 250 trees·ha^{-1}		
Response variable	Pretreatment	No action	Extraction	Prescribed fire	No action	Extraction	Prescribed fire
Crowning index (km·h^{-1})	24	48	48	53	34	34	39
Torching index (km·h^{-1})	17	155	69	51	173	116	93
Flame length (m)	140	6.6	9.2	9.2	7	8	9
Canopy base height (m)	3	37	37	37	36	36	36
Canopy bulk density (kg·m^{-3})	0.15	0.06	0.06	0.05	0.11	0.11	0.09
FFE-FVS fuel models	9 (82%) 10 (18%)	11 (62%) 5 (21%) 10 (15%) 1 (2%)	5 (92%) 1 (8%)	5 (78%) 1 (22%)	11 (45%) 5 (43%) 10 (11%) 8 (1%)	5 (91%) 10 (0.07) 8 (3%)	5 (100%)
Fire type	Active	Surface	Surface	Surface	Conditional	Conditional	Conditional

Note: The example is for an active fire type stand from the East Cascade FFE-FVS variant. Numbers in parentheses represent the weighted average of the NFFL fuel model (Albini 1976; Rothermel 1972) used to calculate fire behavior. The dynamic model approach in FFE-FVS selects two or more fuel models based on fuelbed characteristics, calculates the resulting fire behavior model for each model, and then takes a weighted average of the result.

stands (e.g., high canopy bulk density) can support and sustain an active crown fire (Scott and Reinhardt 2001). For example, stands characterized by conditional fire type in and around urban interface zones may be ideal for treatments designed to increase stand heterogeneity by reducing overstory continuity and canopy bulk density.

FFE-FVS predicts that thinning intensity influences fuel treatment efficacy in the stands that were evaluated. The more intense thinning treatments (125 and 250 trees·ha^{-1}) were predicted to be more effective than the less intense treatments (500 and 750 trees·ha^{-1}) in increasing mean Δti for stands classified pre-treatment as active or passive fire types (Figs. 3*c*, 3*d*, 4*c*, and 4*d*) and increasing the proportion of stands that transition from potential active fire type to potential surface fire type (Figs. 5*a* and 6*a*). In the simulation, more intense thinning treatments are associated with the removal of more ladder fuels and an increase in the vertical distance between the ground and the base of the live canopy (Van Wagner 1977; Agee 1996). The residual stand densities defined by the more intense thinning treatments are consistent with reconstructions of historical stand structures. Arno and Allison-Bunnell (2002) suggested that historical surface fire regimes perpetuated ponderosa pine dominated stands with 74–250 trees·ha^{-1}. Harrod et al. (1999) concluded that 125 trees·ha^{-1} represented historical stands in eastern Washington, and Covington and Moore (1994) proposed that 106 trees·ha^{-1} was typical for southwestern stands.

Implementing the most intense thinning treatments (125 and 250 trees·ha^{-1}) would require a major shift in stand structure compared with traditional stand prescriptions. Forest managers would need to design thinning treatments to increase the spacing between residual trees. For example, thinning prescriptions designed to retain 125 or 250 trees·ha^{-1} are equivalent to spacing between trees of 9 m × 9 m or 6 m × 6 m, respectively. In a stand with 1683 trees·ha^{-1}, the spacing between trees would be 2.4 m × 2.4 m; this spacing would triple or quadruple with the intense thinning treatment. Some forest and fire managers are already experimenting with treatments to increase the spacing between residual trees. Managers with the US Bureau of Land Management Medford district in southern Oregon are designing and implementing fuel projects with 8 m × 8 m residual spacing to adequately reduce fire hazard (Medford District Bureau of Land Management 2008).

The results from our simulation predict that the intense thinning treatments reduce fire hazard. In the field, the 125 and 250 trees·ha^{-1} thinning specifications may have unintended consequences for fuelbed characteristics and environmental variables that could increase wildfire behavior and fireline intensity. For example, the rapid release of growing space may stimulate ladder fuels (shrub and herb regeneration), increase surface windspeed, reduce dead fuel moistures, and increase surface fire intensity (Agee 1996; van Wagtendonk 1996). Regardless of these negative effects, the post-treatment forest structure should reduce crown fire initiation and fire severity (Agee 1996; Graham et al. 2004).

Surface fuel treatment effects

The FFE-FVS model predicts that for the less intense thinning treatments (500 and 750 trees·ha^{-1}), the prescribed fire surface fuel treatment tended to increase mean torching index relative to the no action and extraction surface fuel treatments (Figs. 3 and 4). This treatment also reduced the proportion of stands that are classified post-treatment as potential active fire type (Figs. 5 and 6) relative to the extraction and no surface fuel treatment; those two treatments exhibited similar responses with respect to fire hazard. In the field, prescribed fire modifies potential fire behavior by reducing fuel loads, duff and litter depths, and shrubs (Graham et al. 2004; Moghaddas and Stephens 2007). In high-density stands, prescribed fire can indirectly raise the canopy base height of a stand. In FFE-FVS, prescribed fire is simulated to reduce surface fuel loads and to raise the canopy base height of the stand through conventional heating (crown scorch). As a result, the prescribed fire surface fuel treatment is shown as the most effective option even at the less intense thinning treatments.

FFE-FVS predicted that, in the East Cascades variant, the fire hazard response was more similar among the three possible surface fuel treatments at the two more intense thinning treatments (125 and 250 trees·ha^{-1}) than at the two less intense thinning treatments (500 and 750 trees·ha^{-1}) (Figs. 3 and 5). In the Northern Idaho variant, fire hazard was lower for prescribed fire than for no action and extraction surface fuel treatments across the thinning treatment intensities (Figs. 4 and 6). According to these results, FFE-FVS considers that in some regions and regardless of surface fuel treatments, the reduction in canopy bulk density and increase in canopy base heights from the more intense thinning treatments are sufficient to reduce crown fire hazard without associated surface fuel treatment.

One of the principles of a fire-safe forest advocated by Agee and Skinner (2005) is to reduce surface fuels generated from thinning treatments. Reducing surface fuels following thinning treatments can reduce fireline intensity (potential flame length) and crown fire initiation. Crown fires occur when surface fires create enough energy to preheat and combust live canopy fuels. Several studies have shown that fireline intensity in thinned stands was significantly reduced only when treatments were accompanied by reducing the surface fuels (Graham et al. 1999; Stephens et al. 2009). In contrast, we found that FFE-FVS tended to predict no difference between the extraction and no action surface fuel treatment (Figs. 3–6). In many cases, the responses were similar across the surface fuel treatments for the thinning treatments that probably generated the highest slash loads (125 and 250 trees·ha^{-1}). The similarity among these responses contradicts our current understanding of fuel quantity and fire behavior. We would expect the most effective surface fuel treatments to be prescribed fire, extraction, and no action, respectively. It is possible that a limitation of the FFE-FVS model, described below, explains this discrepancy.

Model and study limitations

The FFE-FVS documentation outlines a number of limitations that present opportunities for model improvement, one of which is illustrated by the current study. The simulation results presented here imply that for the intense thinning treatments (125 and 250 trees·ha^{-1}), the effect of thinning on fire behavior without surface fuel treatments is equivalent to the effects of the extraction and prescribed fire surface fuel treatments. These nonintuitive response patterns are probably due to how FFE-FVS assigns fuel models to calculate fire behavior. Rather than use measured fuel loadings (Ottmar et al. 2007), FFE-FVS relies on a limited set of 13 National Forest Fire Laboratory stylized fuel models that represent fire behavior in homogeneous surface fuels (Rothermel 1972). These 13 fuel models may therefore limit the capability of the model to differentiate the effects of varying surface fuel treatments.

The FFE-FVS developers understood the potential limitations of using 13 fuel models to predict fire behavior for different management scenarios, and they tried to improve fire behavior calculations by designing a dynamic modeling approach. In the logic of this approach, one or more fuels are selected, the fireline intensity is calculated for each one, and a weighted average flame length is then computed by interpolation. The FFE-FVS dynamic modeling approach was designed to simulate a continuous transition in fire behavior instead of the ordinal-type transition that would occur between fire behavior fuel models (Reinhardt and Crookston 2003).This logic is reasonable, but it does not overcome the limitations of the small set of available fuel models to represent the effects of the surface fuel treatments. In our simulations, when extraction and prescribed fire surface fuel treatments were implemented, the model recognized the fuelbed modification and then selected a set of new fuel models. In many cases, FFE-FVS selected the identical fuel model or a combination of fuel models following different surface fuel treatments (Table 4). The selection of multiple fuel models masks any change in fire behavior that might be expected from the surface fuel treatments.

FFE-FVS is an evolving and dynamic tool for fire and forest managers. In the near future, the logic of fuel model selection will be restructured to incorporate Scott and Burgan's (2005) 40 fuel models, developed to represent a broader diversity of fuels and fire behavior (Dixon 2003). When this update is completed, the FFE-FVS model may be more sensitive to calculating the effect of surface fuel treatments. The capability to use actual fuel loading to directly simulate fire behavior (e.g., Ottmar et al. 2007) would potentially reduce the lack of precision now associated with fuel model assignment in FFE-FVS.

Forest and fire managers have many other questions about the efficacy of fuel treatments. What is the longevity of the fuel treatments in various forest types? Is there a threshold at which stand conditions become hazardous that could be used to guide fuel treatments? Most analyses, including our own, do not address these types of questions. To evaluate such questions, we would need to project our data through time. For this reason, we contemplated performing 50-year stand projections for each region to monitor changes in fire hazard. However, we decided against doing so because of the large number of assumptions that we would have had to incorporate into the model projections. For example, our main concern was estimating the density of seedling regeneration and mortality rates after each thinning and surface fuel treatment. We would need to develop different regeneration matrices (regeneration densities) for each region, for each thinning density (125, 250, 500, and 750 trees·ha^{-1}), and for each surface fuel treatment (leave slash, remove slash, and prescribe burn). As the FFE-FVS model evolves, we expect answers regarding the longevity of fuel treatment to become available.

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Conclusions

Fuel treatment planning and management decisions are based on different considerations and encompass an array of choices available to policymakers and land managers. Credible scientific evidence is critical to understanding and informing those choices (Guldin et al. 2003). As demonstrated in this study, simulation modeling has the capability to examine a broad range of treatment options and a large number of forest stand conditions in diverse geographic locations. However, simulation results are limited in their scope of inference and are bounded by the limitations of the modeling system; they are not a substitute for strong empirical evidence (Peterson et al. 2005). Additional data that validate the effectiveness of fuel treatments in the field, combined with simulation modeling, will provide greater confidence for developing fuel treatment prescriptions.

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Supplementary material S1. Mean change in log torching index

Each of 28 combinations of FVS/FFE variant (7 variants) and pre-treatment potential fire type classification (4 classifications) was evaluated for the mean change in log torching index for twelve fuel treatment combinations. A positive change indicates that fire hazard has improved post-treatment and a negative change indicates that fire hazard has worsened post-treatment. We calculate cell mean values for each explanatory variable.

Table S1.1. Cell mean values of Δti for every region with stands partitioned by the pre-treatment fire types. Each value is the mean across stands for each thinning and surface fuel combination for each region and pre-treatment fire type.

Mean Δti		Pre-treatment fire type															
		Surface				Conditional				Passive				Active			
		Thinning treatment (tph left)															
Region	Surface fuel treatment	750	500	250	125	750	500	250	125	750	500	250	125	750	500	250	125
E Cascades	NA	-0.106	0.024	0.150	-0.022	-0.407	-0.222	-0.122	-0.242	0.497	1.050	1.730	1.810	0.983	1.470	1.760	1.780
	Extraction	-0.080	0.052	0.104	-0.242	-0.302	-0.067	-0.064	-0.483	0.478	1.020	1.610	1.570	0.999	1.500	1.740	1.660
	Prescribed Fire	-0.002	0.026	0.058	-0.308	0.096	0.162	-0.005	-0.483	1.170	1.490	1.670	1.480	1.710	1.890	2.010	1.780
S Oregon & NE California	NA	0.031	0.108	0.035	-0.017	-0.251	-0.068	0.036	0.100	0.513	0.771	1.150	1.340	0.305	0.611	1.070	1.340
	Extraction	0.116	0.253	0.300	0.341	-0.083	0.076	0.035	-0.016	0.442	0.796	1.370	1.700	0.321	0.657	1.150	1.410
	Prescribed Fire	0.119	0.202	0.170	0.105	-0.190	-0.062	-0.154	-0.253	0.969	1.140	1.370	1.490	0.539	0.801	1.040	1.110
N Idaho	NA	0.137	0.432	0.672	0.652	-0.095	0.058	0.111	0.069	0.851	1.450	2.230	2.470	1.160	1.650	2.040	2.130
	Extraction	0.206	0.620	1.080	1.260	0.069	0.395	0.721	0.890	0.854	1.480	2.290	2.580	1.130	1.680	2.150	2.340
	Prescribed Fire	0.846	1.100	1.350	1.470	0.631	0.845	1.080	1.160	2.290	2.650	3.030	3.240	2.300	2.620	2.970	3.100
C Idaho	NA	-0.216	-0.140	-0.041	-0.082	-0.271	-0.184	-0.227	-0.310	0.033	0.285	0.886	1.200	0.281	0.707	1.130	1.220
	Extraction	-0.166	-0.088	-0.139	-0.385	-0.216	-0.050	-0.265	-0.712	0.036	0.285	0.814	1.050	0.238	0.605	0.878	0.940
	Prescribed Fire	-0.446	-0.325	-0.277	-0.406	-0.049	0.005	-0.237	-0.636	0.275	0.649	0.971	1.100	0.732	0.967	1.170	1.170
C Rockies	NA	-0.210	-0.208	-0.181	-0.109	-0.162	-0.194	-0.276	-0.339	0.566	0.749	1.090	1.400	0.818	0.963	1.100	1.180
	Extraction	-0.238	-0.275	-0.339	-0.319	-0.094	-0.100	-0.305	-0.397	0.539	0.705	0.993	1.260	0.948	1.140	1.220	1.260
	Prescribed Fire	-0.303	-0.309	-0.352	-0.315	0.250	0.093	-0.308	-0.409	0.933	1.020	1.170	1.350	1.590	1.530	1.380	1.390
E Montana	NA	-0.188	-0.296	-0.638	-0.904	-0.381	-0.392	-0.727	-0.947	0.193	0.583	1.360	1.490	1.510	1.890	2.070	1.990
	Extraction	-0.091	-0.206	-0.585	-0.870	-0.289	-0.288	-0.879	-1.380	0.195	0.569	1.320	1.420	1.430	1.770	1.840	1.750
	Prescribed Fire	-0.706	-0.701	-0.822	-0.925	-0.464	-0.627	-1.170	-1.510	0.958	1.240	1.420	1.420	1.850	1.970	1.970	1.930
Blue Mountains	NA	-0.198	-0.099	-0.014	-0.299	-0.276	-0.041	0.161	0.027	0.245	0.646	1.200	1.300	1.140	1.630	2.020	1.980
	Extraction	-0.051	0.083	0.157	-0.285	-0.155	0.094	0.261	-0.228	0.331	0.753	1.360	1.510	1.180	1.720	2.110	1.910
	Prescribed Fire	-0.180	-0.090	-0.109	-0.407	0.322	0.473	0.374	-0.308	1.140	1.310	1.470	1.550	2.290	2.550	2.570	1.990

We present in Figures S1.1-S1.7 the mean change in log torching index (Eq 1 in main text) predicted by FVS/FFE for each of the seven variants evaluated and separated by the pre-treatment potential fire behavior type classification.

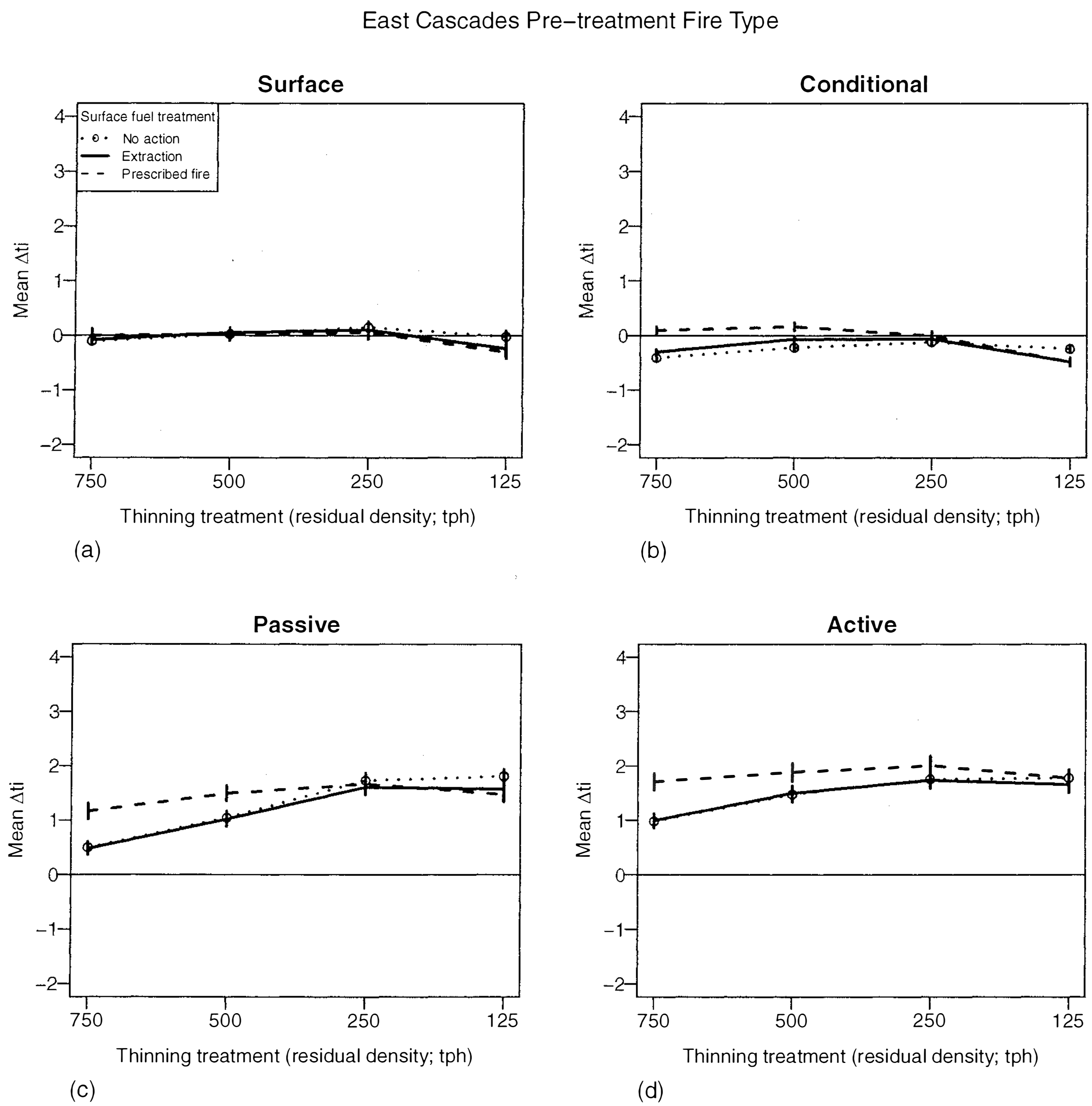

Figure S1.1. Mean change in log torching index (Eq 1 in main text) predicted by FVS/FFE for the FVS/FFE East Cascades variant separated by the pre-treatment potential fire behavior type classification. The factor thinning treatment (4 levels) is on the x-axis, and each line type signifies the surface fuel treatment.

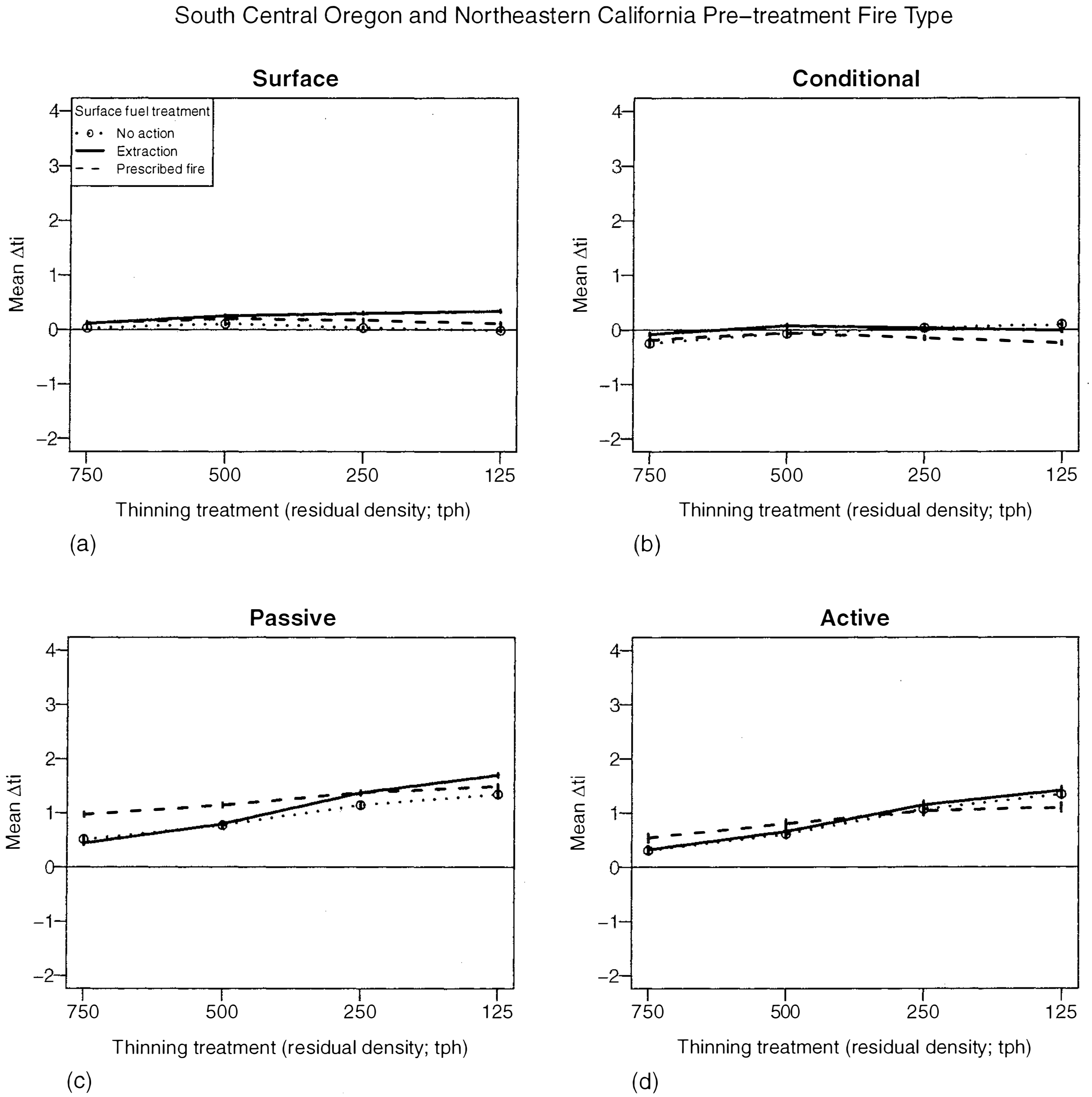

Figure S1.2. Mean change in log torching index (Eq 1 in main text) predicted by FVS/FFE for the FVS/FFE Southern Oregon and Northeastern California variant separated by the pre-treatment potential fire behavior type classification. The factor thinning treatment (4 levels) is on the x-axis, and each line type signifies the surface fuel treatment.

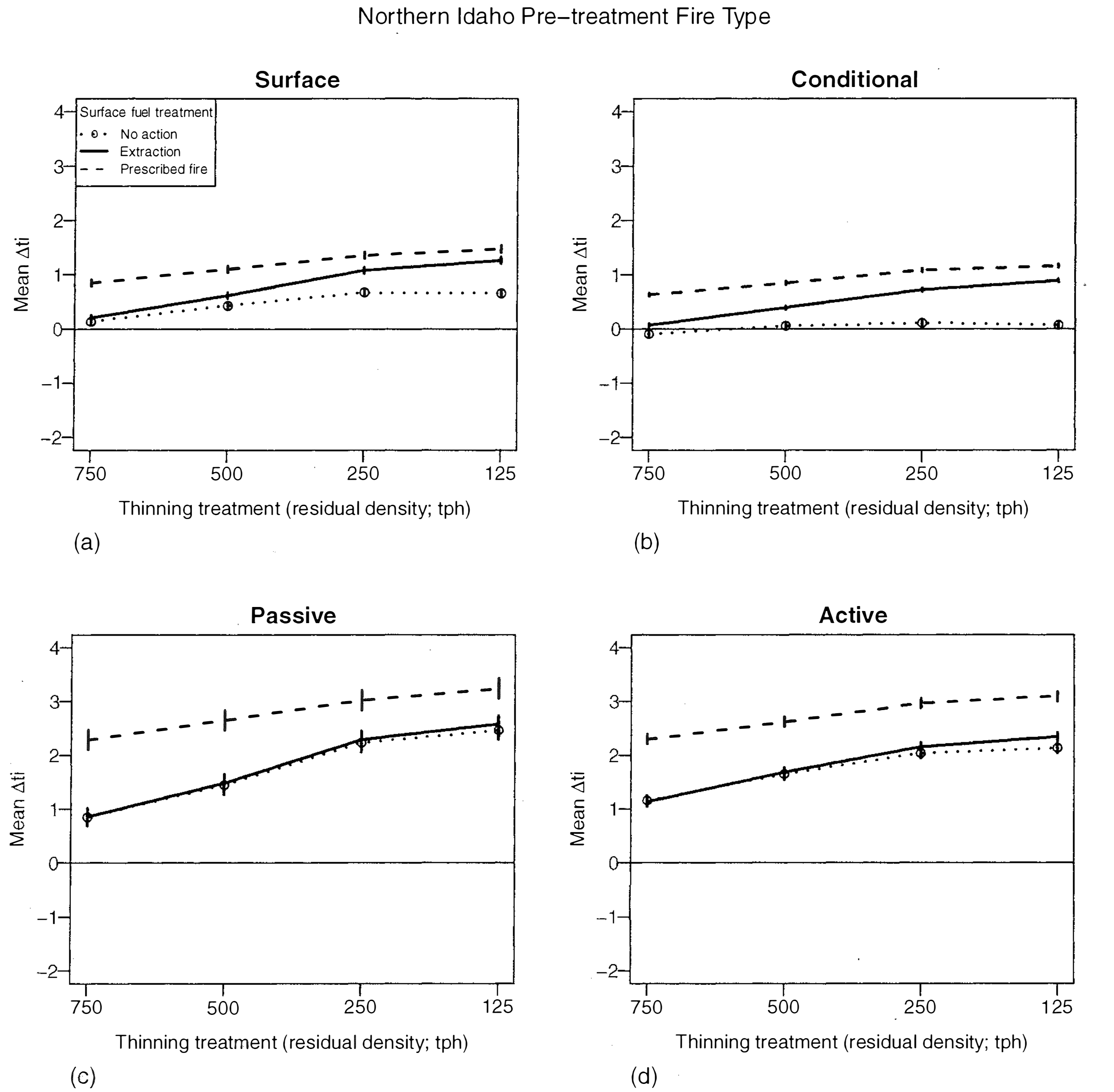

Figure S1.3. Mean change in log torching index (Eq 1 in main text) predicted by FVS/FFE for the FVS/FFE Northern Idaho variant separated by the pre-treatment potential fire behavior type classification. The factor thinning treatment (4 levels) is on the x-axis, and each line type signifies the surface fuel treatment.

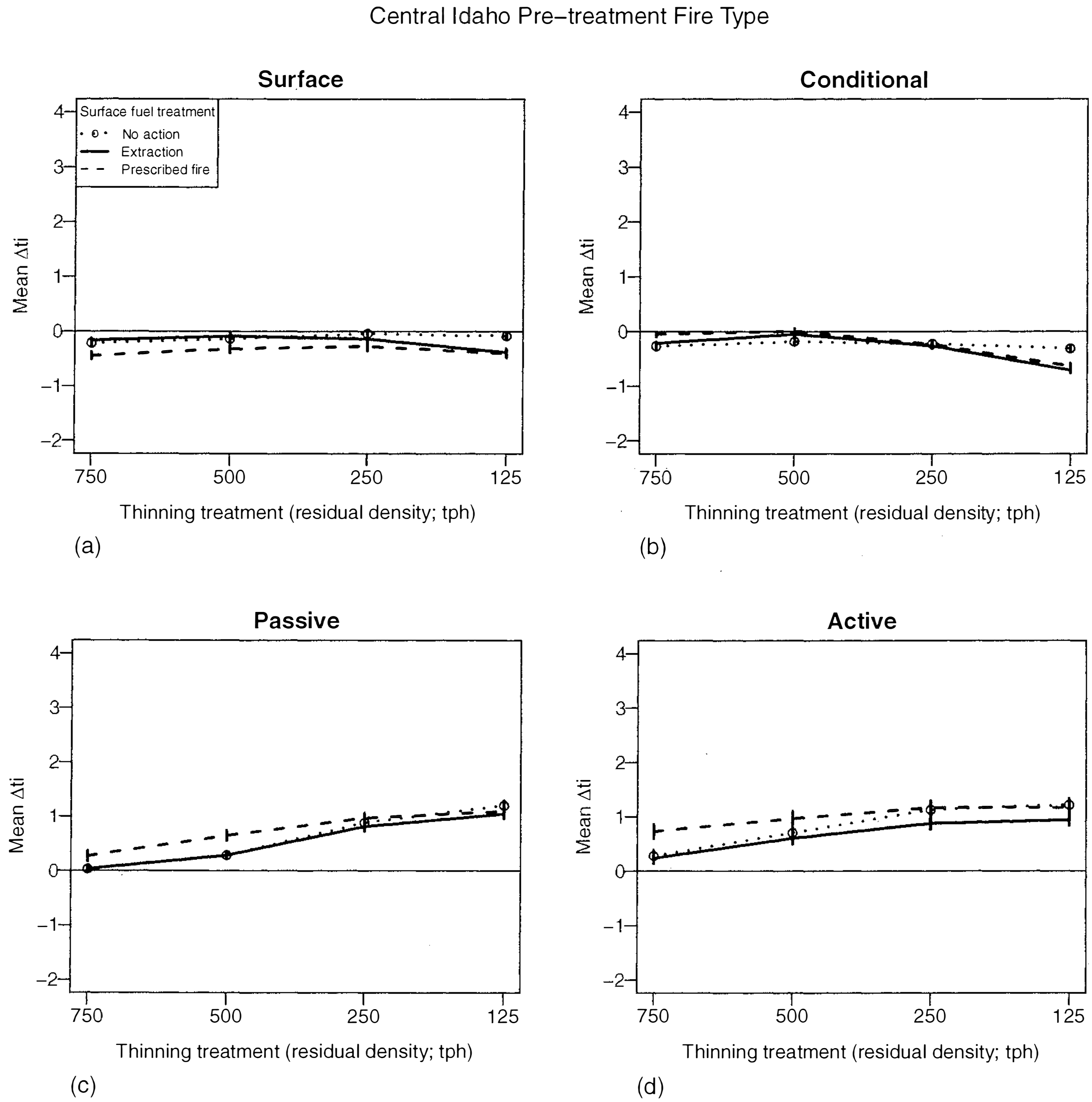

Figure S1.4. Mean change in log torching index (Eq 1 in main text) predicted by FVS/FFE for the FVS/FFE Central Idaho variant separated by the pre-treatment potential fire behavior type classification. The factor thinning treatment (4 levels) is on the x-axis, and each line type signifies the surface fuel treatment.

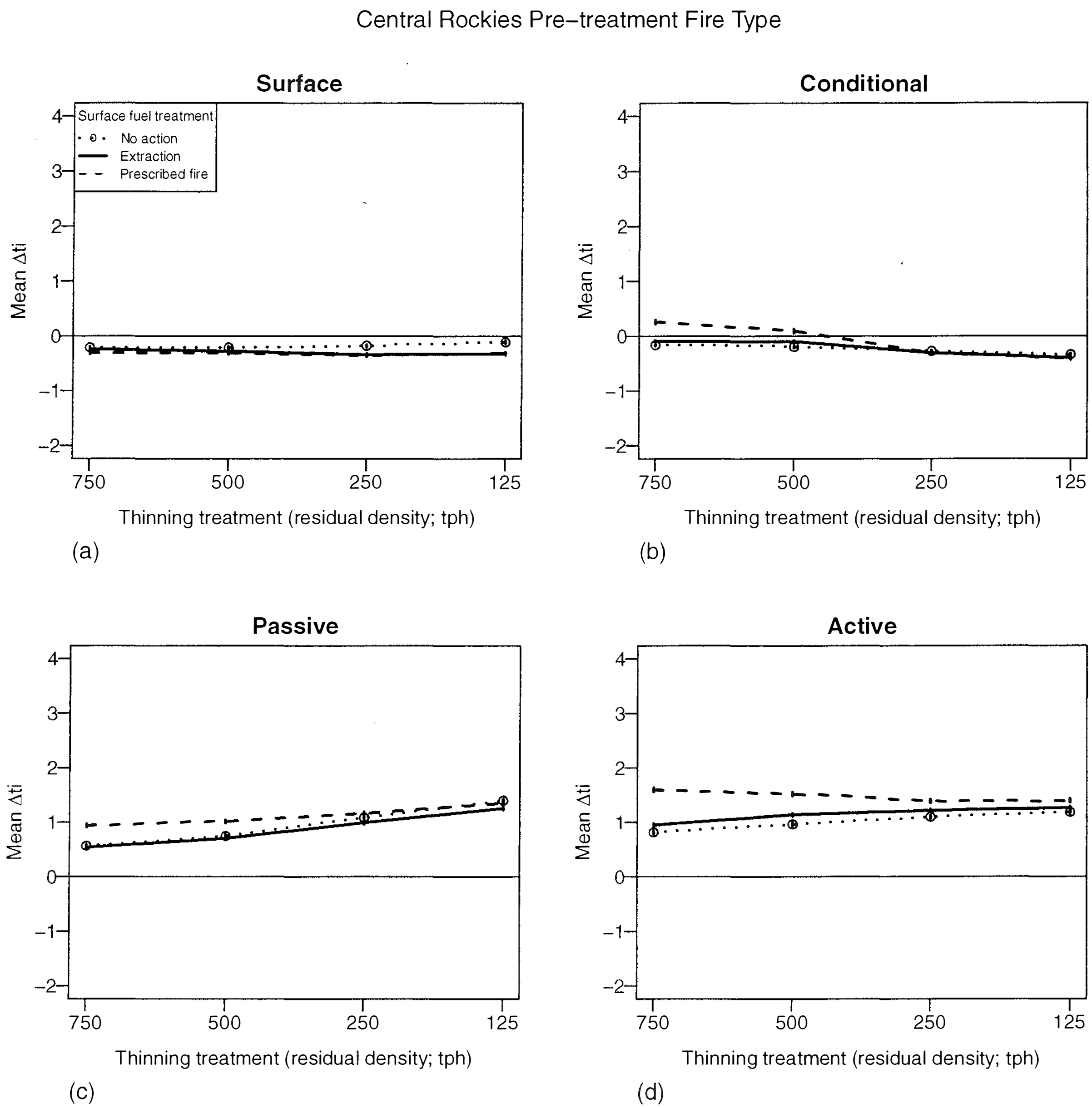

Figure S1.5. Mean change in log torching index (Eq 1 in main text) predicted by FVS/FFE for the FVS/FFE Central Rockies variant separated by the pre-treatment potential fire behavior type classification. The factor thinning treatment (4 levels) is on the x-axis, and each line type signifies the surface fuel treatment.

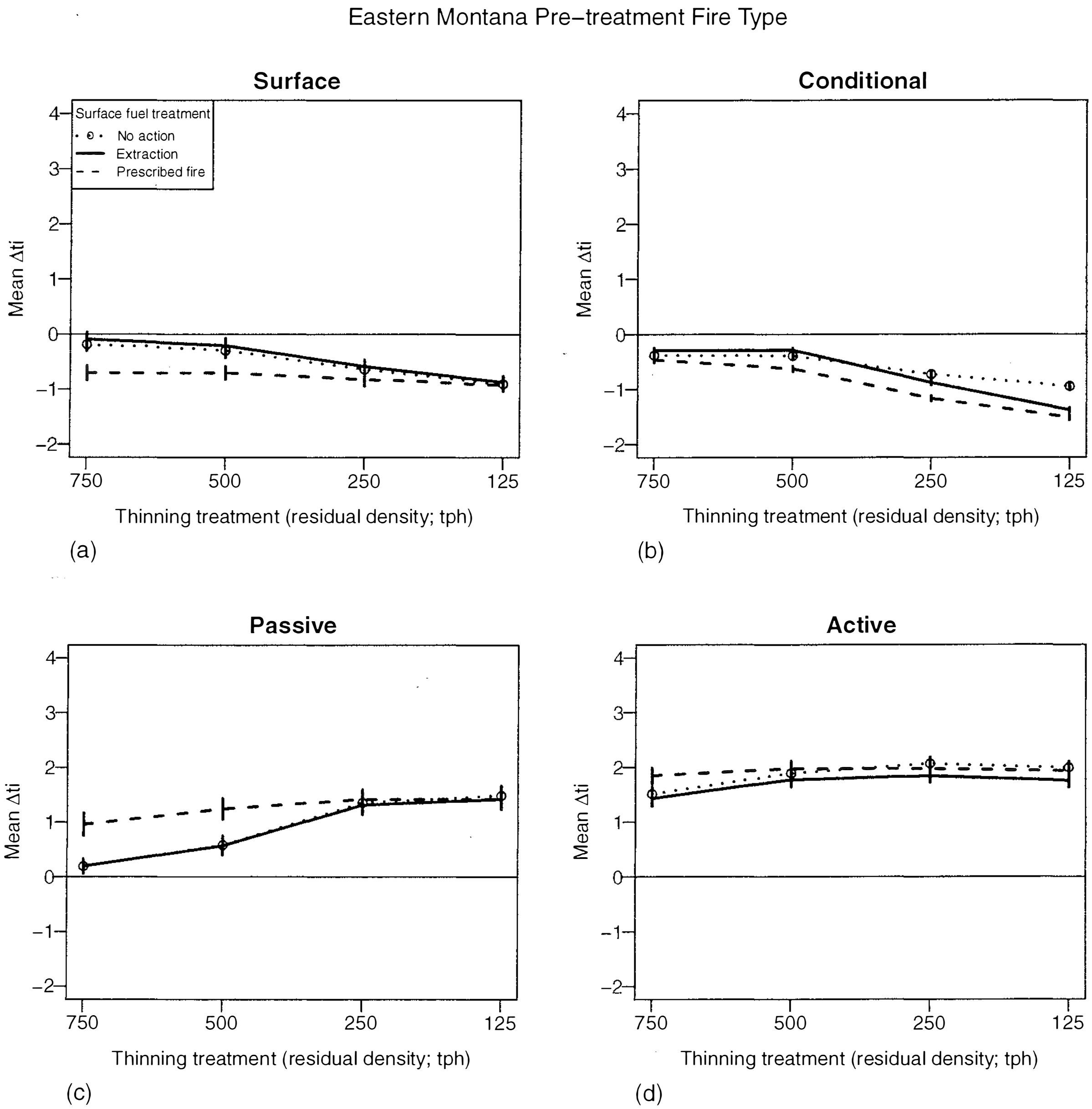

Figure S1.6. Mean change in log torching index (Eq 1 in main text) predicted by FVS/FFE for the FVS/FFE Eastern Montana variant separated by the pre-treatment potential fire behavior type classification. The factor thinning treatment (4 levels) is on the x-axis, and each line type signifies the surface fuel treatment. For this variant the treatment prescriptions actually worsened fire hazard for those stands classified pre treatment as surface or conditional.

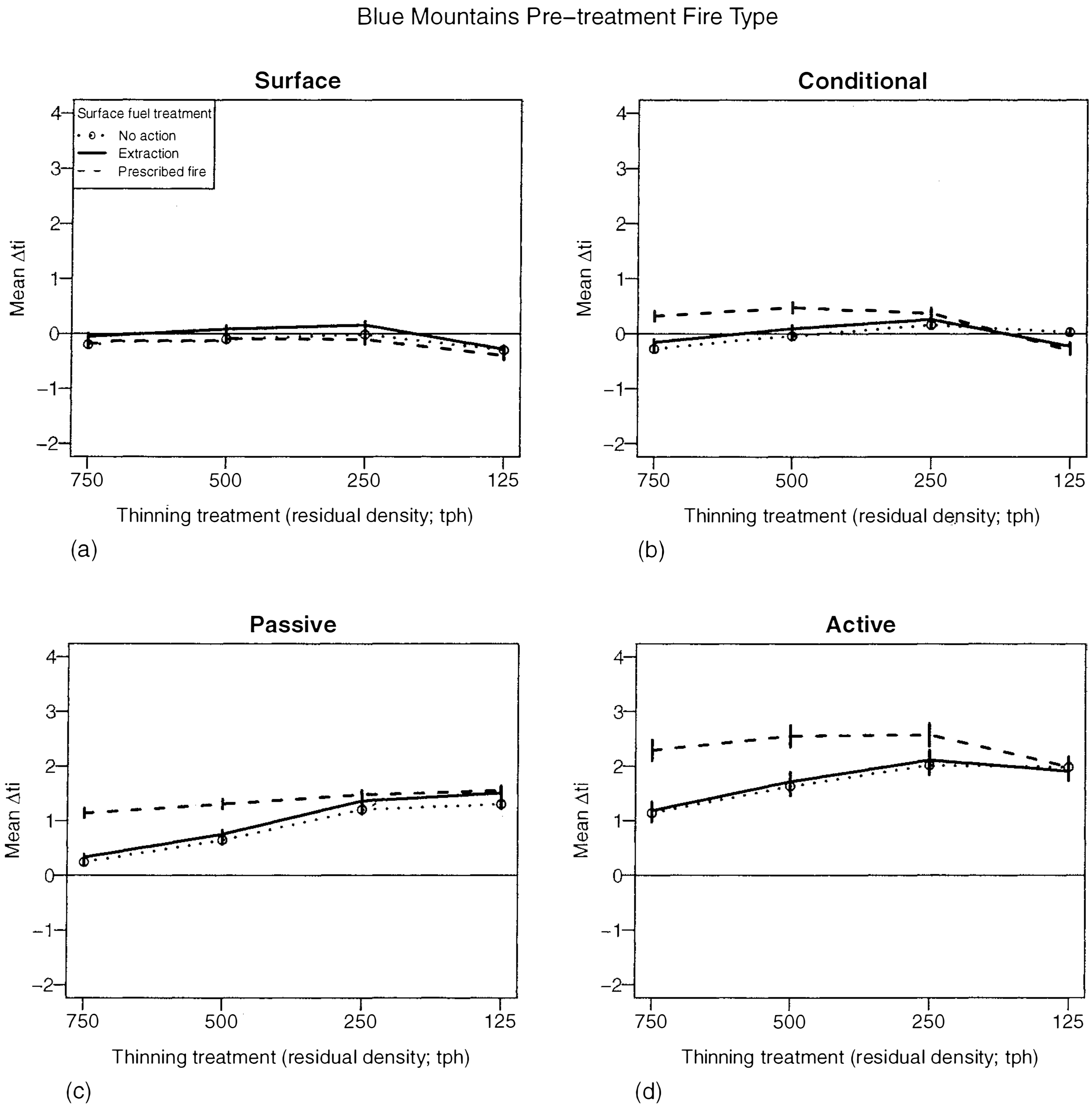

Figure S1.7. Mean change in log torching index (Eq 1 in main text) predicted by FVS/FFE for the FVS/FFE Blue Mountains variant separated by the pre-treatment potential fire behavior type classification. The factor thinning treatment (4 levels) is on the x-axis, and each line type signifies the surface fuel treatment.

Supplementary material S2. Post-treatment potential fire behavior type

Each of 28 combinations of FVS/FFE variant (7 variants) and pre-treatment potential fire type classification (4 classifications) was evaluated for the post-treatment potential fire type classification under each of 12 treatment combinations. There are four possible potential fire type classifications (surface, conditional, passive, active), which are ordinal in their fire hazard (surface with the lowest fire hazard, active with the highest fire hazard). The management objective would be for the fuels treatment to reduce the fire hazard (e.g., a stand classified pre-treatment as potential active fire behavior type classified post-treatment as potential surface fire behavior type indicates a reduction in the fire hazard).

We present in Figures S2.1-S2.7 plots of the proportion of stands classified in each of the four post-treatment potential fire types, for each of the 12 treatment combinations.

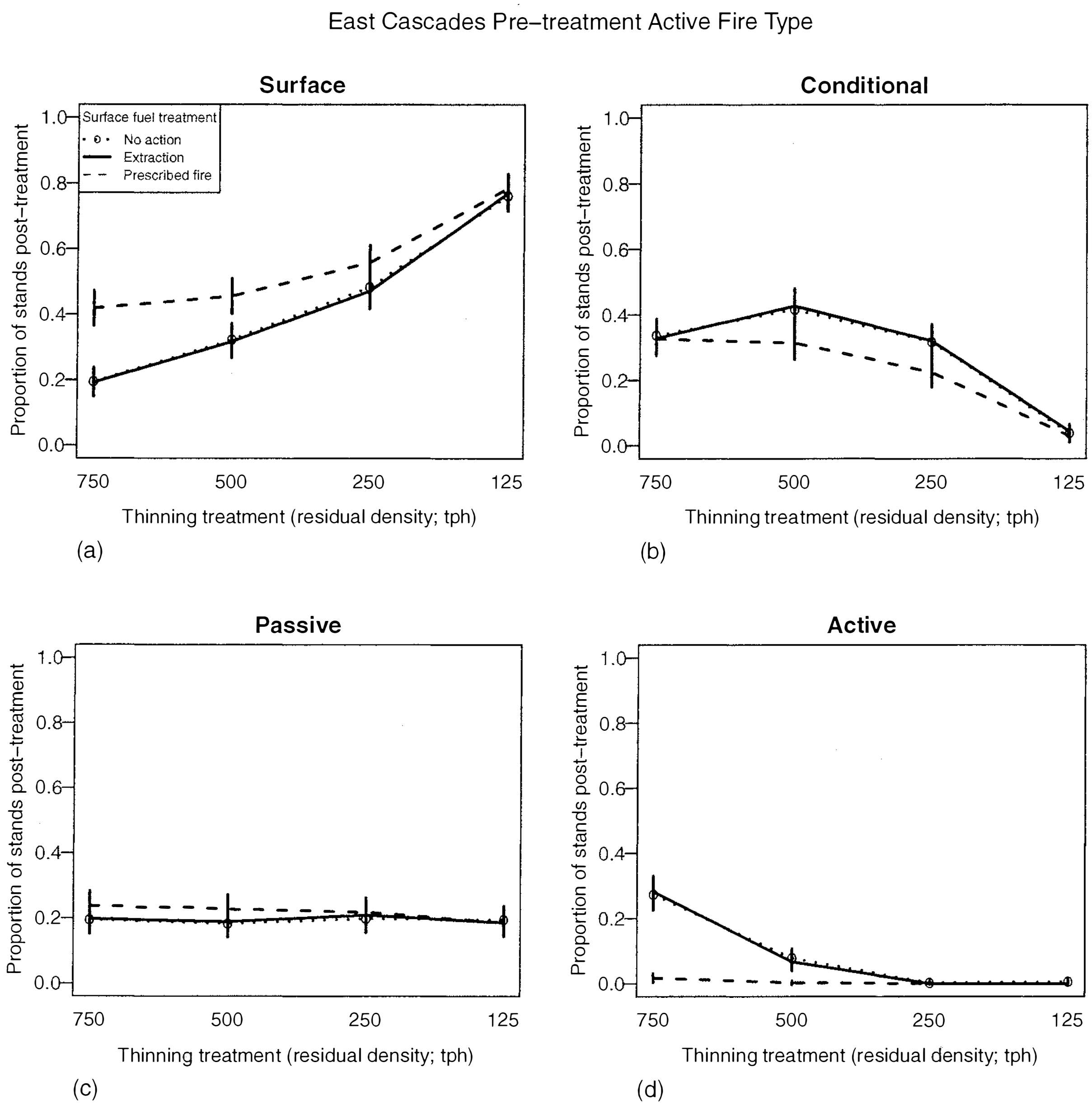

Figure S2.1. Plot of the proportion of stands classified in each of the four post-treatment potential fire types, for each of the 12 treatment combinations for the East Cascades variant. Each point in each section represents the proportion of stands that are classified post-treatment in that potential fire type for that combination of thinning and surface fuel treatments. Vertical segments represent +/- 2 standard errors for each proportion.

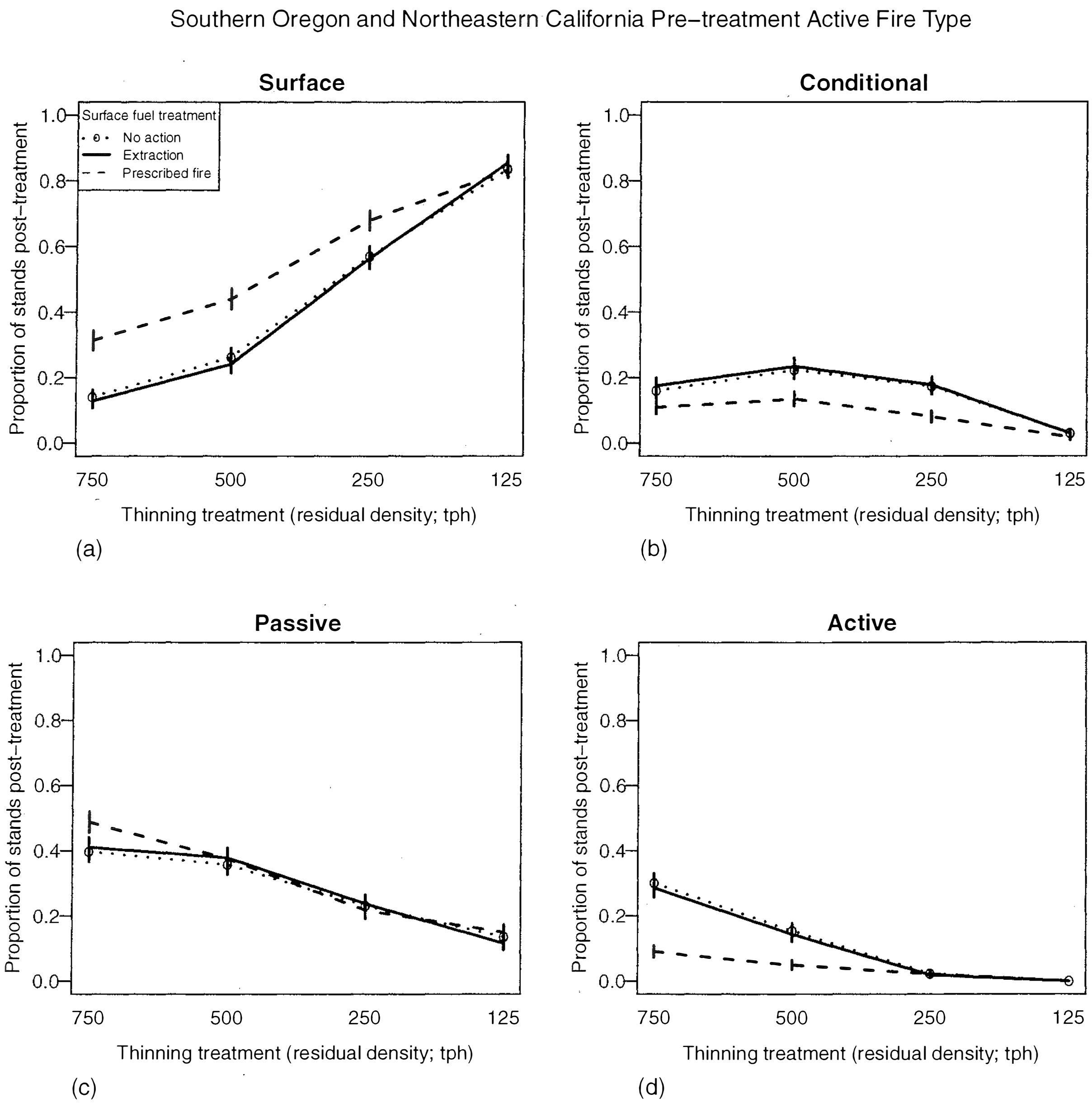

Figure S2.2. Plot of the proportion of stands classified in each of the four post-treatment potential fire types, for each of the 12 treatment combinations for the Southern Oregon and Northeastern California variant variant. Each point in each section represents the proportion of stands that are classified post-treatment in that potential fire type for that combination of thinning and surface fuel treatments. Vertical segments represent +/- 2 standard errors for each proportion.

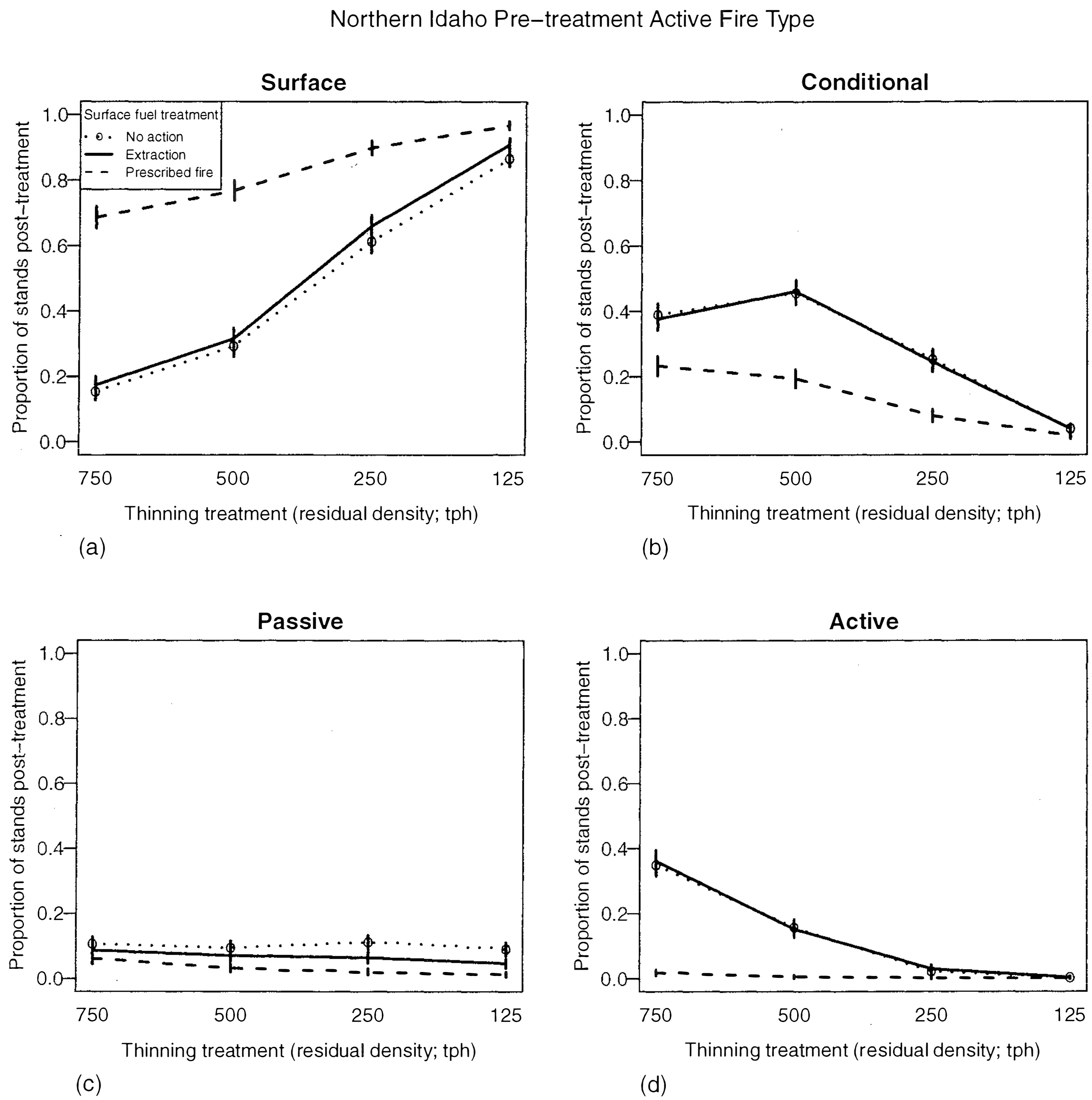

Figure S2.3. Plot of the proportion of stands classified in each of the four post-treatment potential fire types, for each of the 12 treatment combinations for the Northern Idaho variant. Each point in each section represents the proportion of stands that are classified post-treatment in that potential fire type for that combination of thinning and surface fuel treatments. Vertical segments represent +/- 2 standard errors for each proportion.

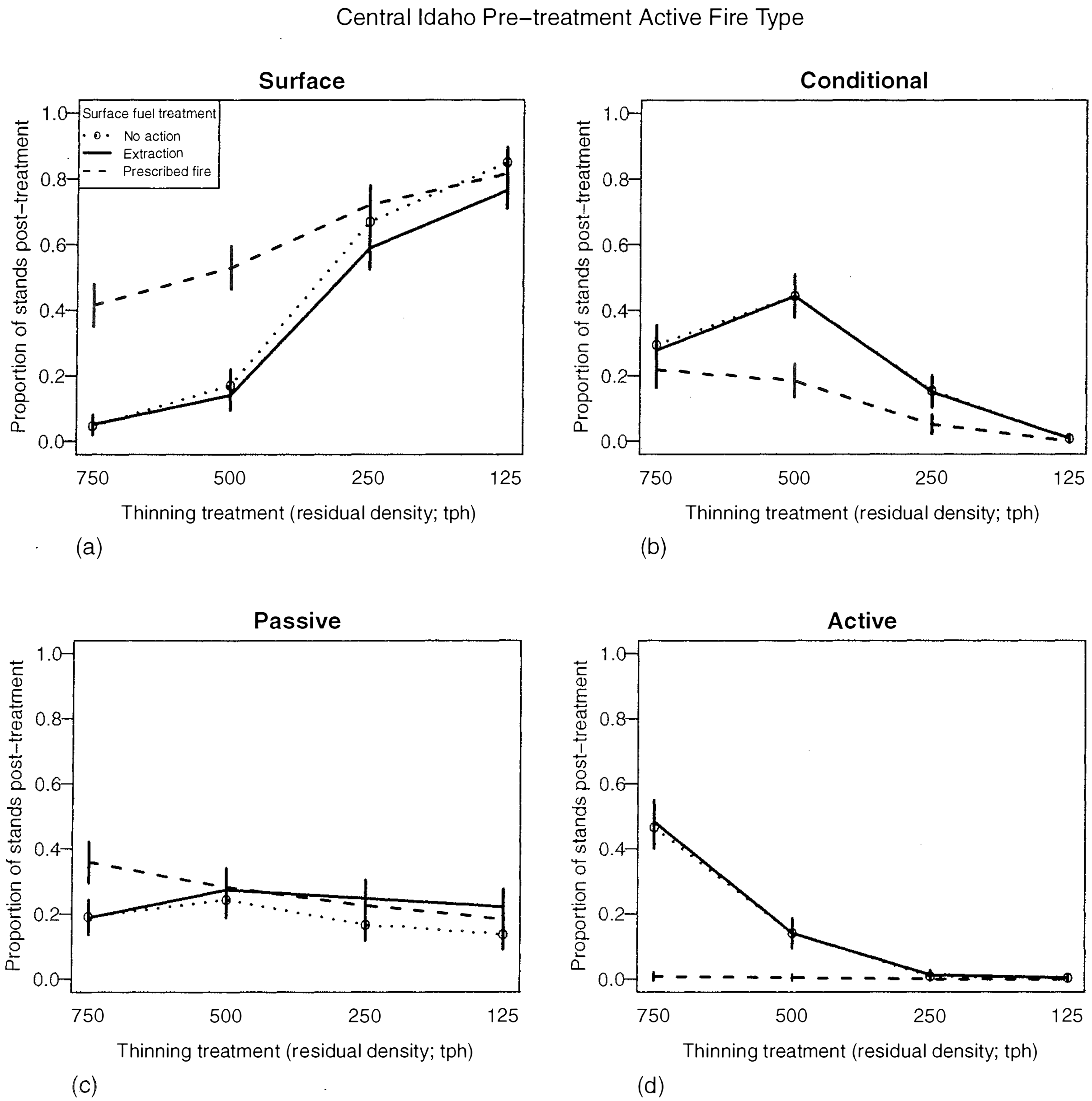

Figure S2.4. Plot of the proportion of stands classified in each of the four post-treatment potential fire types, for each of the 12 treatment combinations for the Central Idaho variant. Each point in each section represents the proportion of stands that are classified post-treatment in that potential fire type for that combination of thinning and surface fuel treatments. Vertical segments represent +/- 2 standard errors for each proportion.

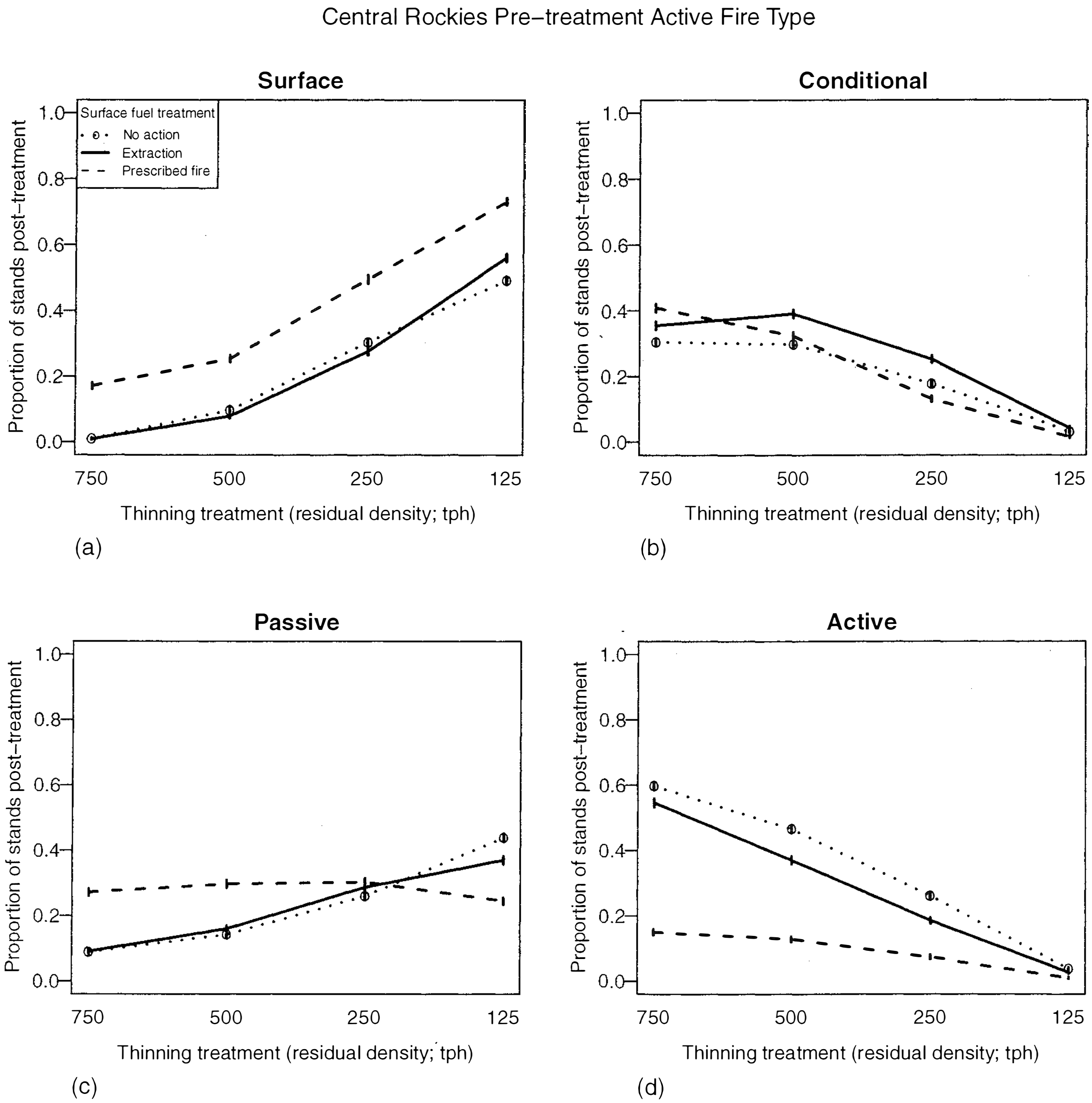

Figure S2.5. Plot of the proportion of stands classified in each of the four post-treatment potential fire types, for each of the 12 treatment combinations for the Central Rockies variant. Each point in each section represents the proportion of stands that are classified post-treatment in that potential fire type for that combination of thinning and surface fuel treatments. Vertical segments represent +/- 2 standard errors for each proportion.

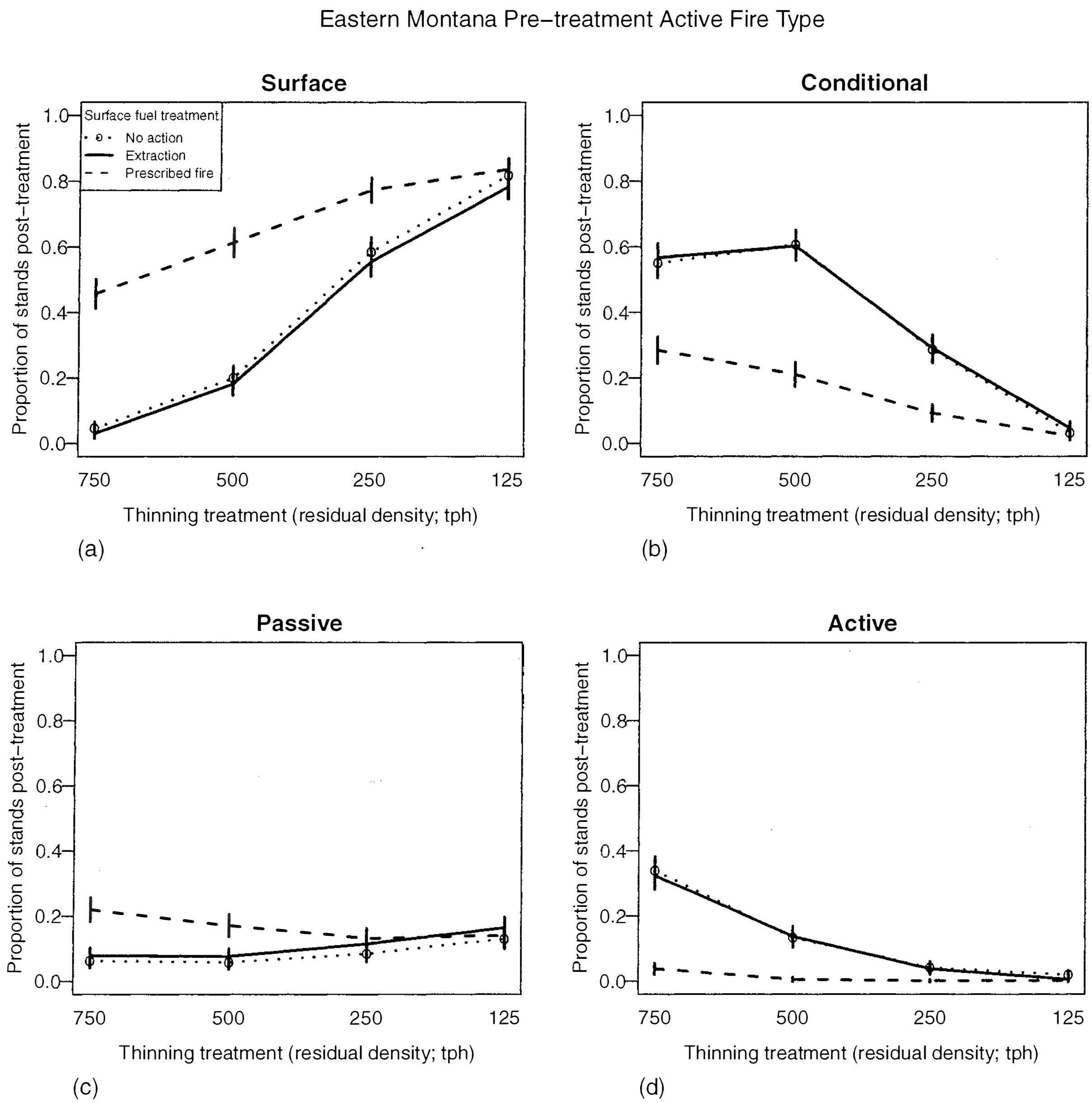

Figure S2.6. Plot of the proportion of stands classified in each of the four post-treatment potential fire types, for each of the 12 treatment combinations for the Eastern Montana variant. Each point in each section represents the proportion of stands that are classified post-treatment in that potential fire type for that combination of thinning and surface fuel treatments. Vertical segments represent +/- 2 standard errors for each proportion.

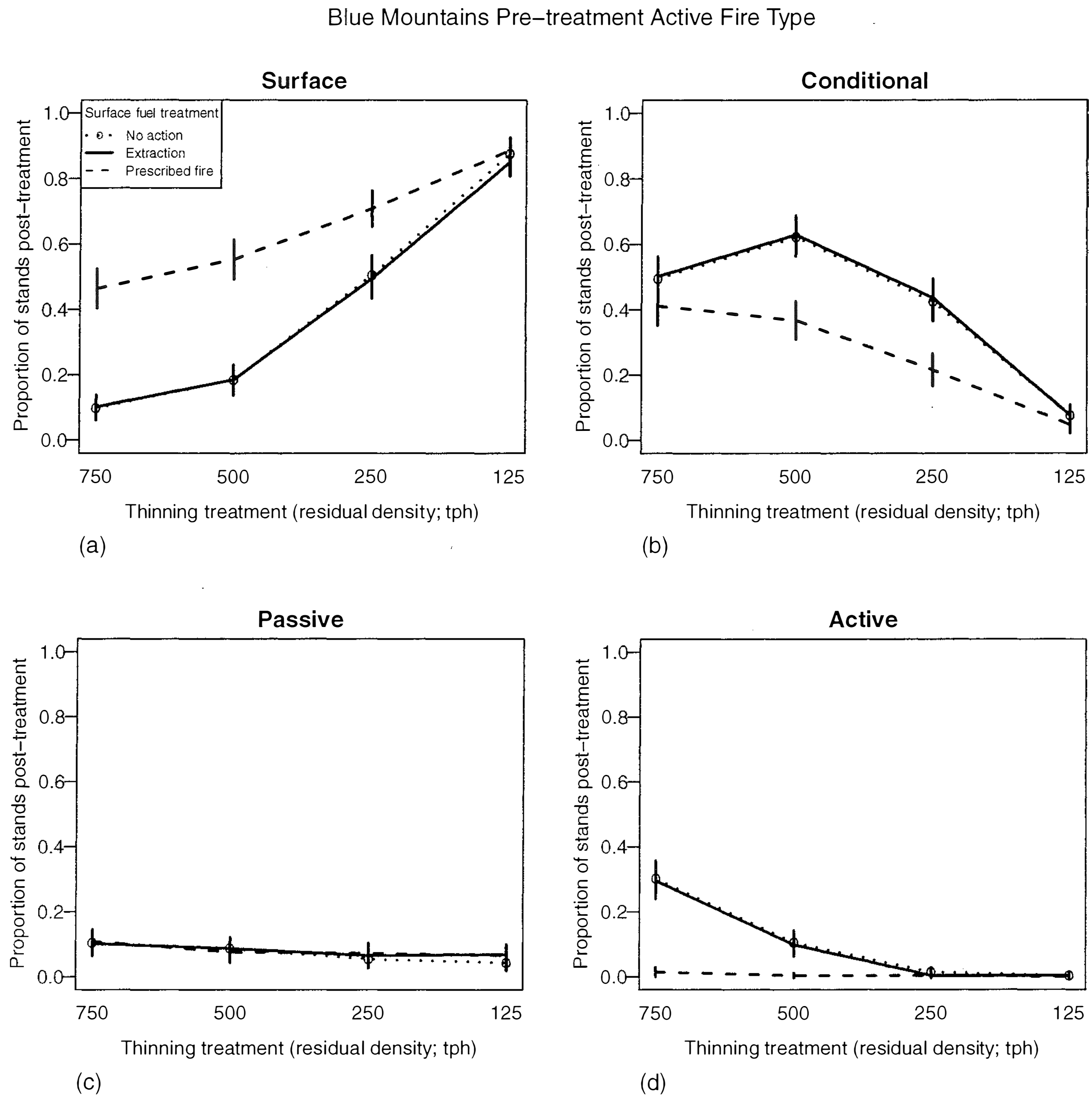

Figure S2.7. Plot of the proportion of stands classified in each of the four post-treatment potential fire types, for each of the 12 treatment combinations for the Blue Mountains variant. Each point in each section represents the proportion of stands that are classified post-treatment in that potential fire type for that combination of thinning and surface fuel treatments. Vertical segments represent +/- 2 standard errors for each proportion.

Klamath National Forest
ROAD SEDIMENT SOURCE INVENTORY & RISK ASSESSMENT
Database User Guide

A compilation of 12 years of road sediment source inventory across the Klamath National Forest is available in a geo-database accessible to Forest employees. This database contains spatial data (roads and road inventory points primarily) along with tabular data important for doing road assessments across the Forest. The database may be edited at any time with updated or corrected information and new results computed through execution of a macro. This paper describes the database features and provides guidance concerning editing and report generation.

The database is stored in the "T" drive ...2500 area in the ...\RdInv directory. The primary road inventory database is "KnfRoadSedimentSourceInventory.mdb". Another geodatabase is also stored at this location "KlamathRdInvAnaly.mdb" which contains many of the spatial layers needed for GIS analysis. Also in this directory are the models and scripts used to re-calculate fields after changes have been made.

<u>KnfRoadSedimentSourceInventory.mdb Database Tables</u>

Feature Classes – contain both spatial and tabular data

- RestRds – line feature class that contains all road information in this database.
- KnfSites – point feature class that carries little information besides SITE_ID (user-defined unique identifier for each point) and LinkNo (links points to roads).
- huc7_cwe – polygon layer of 7th field watersheds across the Forest consistent with the 2004 CWE run described below.

Non-Spatial Tables – contain only tabular data

- tbl_Sites – contains the tabular data needed to rate each crossing or cross-drain site (not "tweeners", those are in a separate table). All sites uniquely identified by SITE_ID (same as with "KnfSites") and all sites in this table need to also be present in "KnfSites" to have spatial representation. And 'type' in each table should be the same for each SITE_ID.
- tbl_SiteFieldData – contains the data as gathered from the field, linked to "tbl_Sites" by SITE_ID. Not all sites in "tbl_Sites" are in this table, in some cases the field data has been lost or was in a different format from this table. However this table is not used for analysis, all necessary information is in "tbl_Sites" but this table does provide an archive of field data that is sometimes useful.
- tbl_Tweeners – contains the tabular data for "tweeners" (between crossing sediment sources, landslides or gullies). All sites uniquely identified by SITE_ID (same as with

"KnfSites") and all sites in this table need to also be present in "KnfSites" to have spatial representation. This table is not used for analysis, and not all "tweeners" ('type' = '4') in "KnfSites" are in this table, just the "tweener" information that was readily available.

- CWE2004_risk_ratios – contains the results from a 2004 Cumulative Watershed Effects assessment run, including the USLE, GEO, and ERA models and a "combo" index that is a combination of results from the three models. The "combo" index is used as the CWE rating for the GIS part of road ratings.

- tbl_RoadTreat – contains the treatment, description, and cost for various road treatments. Links to "past_treat" and "ProposedTreat" in the "RestRds" feature class.

- tbl_SiteTreat – contains the treatment, description, and cost for various site treatments. Links to "treatment" in "tbl_Sites".

- tbl_TypeKey – contains description for each "type" in the "KnfSites" and "tbl_Sites" tables.

The following tables show all of the fields in the more important feature classes and database tables:

"RestRds" Line Feature Class (roads)

Field Name	Data Type	Manual Edit?	Description
OBJECTID	AutoNumber	No	Auto-populated unique identifier.
Shape	OLE Object	No	Spatial coordinates, edits automatically when spatial edits are done.
LinkNo	Integer	Yes	Manually created unique identifier for each road segment, provides the link to the sites.
RID	Text	Yes	Combination of the "Minus3" 7th field watershed identifier and road number, i.e. "04130203 - 44N02". Nearly a unique identifier for each road segment though several roads are sub-divided further based on such things as change of status ('existing' verses 'decommissioned') or surfacing or some such thing.

"RestRds" Line Feature Class (roads)			
Field Name	Data Type	Manual Edit?	Description
Minus3	Text	Yes	7th field watershed identifier with the first 3 fields (6 digits) removed because not needed. For the Klamath National Forest, all watersheds are in the Klamath Basin, HUC code '180102'. An actual 7th field HUC code is '18010204130203'. The "Minus3" version is '04130203', shorter and easier to use. Although an overlay with 7th field watersheds originally made breaks in the roads each time a watershed line was crossed, this created too many short road segments. Many of these "sliver" road segments have been and can be re-combined so that some roads segments identified in a certain watershed will have short pieces in an adjacent watershed.
RdNo	Text	Yes	Road Number, i.e. '44N02', '15', or '52D010A'
OldRdNo	Text	Yes	Previously used road number for those roads that have changed, for instance the non-system road previously labeled 'S-97.2' became the system road '47N02' sometime during the road inventory process.
system	Text	Yes	Label indicating the management of a road, 'FS' for Forest system road, 'FNX' for Forest non-system road, 'FD' for Forest system road that has been decommissioned, and 'FND' for Forest non-system road that has been decommissioned. Other types of roads, such as County (C), are not included in this feature class.
InvYear	Long Integer	Yes	Year road inventory was done. A value of '9999' in this field indicates that field inventory had not been done for this road.
InvNames	Text	Yes	Name of the road inventory, allows backtracking to a specific road inventory report for further information. For roads not inventoried ("InvYear" = '9999'), provides an explanation of why not inventoried.
new_changed	Text	Yes	Either "new" or "changed", lets a user know if this road has been added compared to the original Forest library roads ("new") or has been significantly edited spatially ("changed").
past_treat	Text	Yes	Provides information on past treatment, links to 'treatment' in "tbl_RoadTreat".

"RestRds" Line Feature Class (roads)			
Field Name	Data Type	Manual Edit?	Description
PRJ_NM	Text	Yes	The name of the project for roads that have been treated in the past.
Phase	Text	Yes	Project Phase for those treated roads in projects with more than one phase.
NEPA	Text	Yes	Either "X" for NEPA completed or blank
Designed	Text	Yes	Either "X" for Designed or blank
Funded	Text	Yes	Either "X" for Funded or blank
Complete	Text	Yes	Either "X" for Completed or blank
Comp_date	Long Integer	Yes	Year restoration project completed
Shape_Length	Double	No	Length of feature in meters, automatically calculated based on spatial representation
miles	Double	No	Length of road segment in miles, re-calculated each time the macro is run.
UsleSeg	Double	No	Calculated surface erosion estimate based on the Universal Soil Loss Equation (USLE). This value has been calculated based on the data in the "KlamathRdInvAnaly.mdb" geodatabase and is not recalculated in the macro, and does not need to be recalculated unless there are major changes in the roads layer.
UslePerMi	Double	No	"UsleSeg" divided by "miles"
GeoSeg	Double	No	Calculated landsliding rate based on geomorphic terranes. Recalculated only if needed similar to "UsleSeg".
GeoPerMi	Double	No	"GeoSeg" divided by "miles"
RipResMi	Double	No	Miles of road segment in Riparian Reserves. Recalculated only if needed similar to "UsleSeg".
RipResPerc	Double	No	"RipResMi" divided by "miles"
SteepMi	Double	No	Miles of road segment on steep slopes. Recalculated only if needed similar to "UsleSeg".
SteepPerc	Double	No	"SteepMi" divided by "miles"
CWE	Double	No	The Cumulative Watershed Effects (CWE) rating for the dominant 7th field watershed ("Minus3") each road segment is in. Would need to be recalculated if new CWE results are to be used.
USLE_rate	Long Integer	No	Rating based on "UslePerMi", values displayed in "KNF Road SSI discussion" process paper

"RestRds" Line Feature Class (roads)			
Field Name	Data Type	Manual Edit?	Description
Geo_rate	Long Integer	No	Rating based on "GeoPerMi", values displayed in "KNF Road SSI discussion" process paper
RipRes_rate	Long Integer	No	Rating based on "RipResPerc", values displayed in "KNF Road SSI discussion" process paper
Steep_rate	Long Integer	No	Rating based on "SteepPerc", values displayed in "KNF Road SSI discussion" process paper
CWE_rate	Long Integer	No	Rating based on "CWE", values displayed in "KNF Road SSI discussion" process paper
GISModRat	Long Integer	No	Sum of the previous five values to give the rating based on GIS modeling. Would need to be recalculated if any of those values change, but is not recalculated in the macro.
XingCount	Long Integer	No	Number of crossings and connected cross drains, excluding bridges, for each segment of road. Calculated in the macro from sites.
XingPerMi	Double	No	"XingCount" divided by "miles"
HydroCon	Double	No	Total length of collection potential from site info to get length in feet of road hydrologically connected, calculated in the macro.
HydroConPercent	Double	No	"HydroCon" converted to mileage and divided by "miles"
UcCount	Long Integer	No	Number of undersized culverts for each segment of road. Calculated in the macro from sites.
UcPerMi	Double	No	"UcCount" divided by "miles"
DpCount	Long Integer	No	Number of diversion potential sites for each segment of road. Calculated in the macro.
DpPerMi	Double	No	"DpCount" divided by "miles"
TweenerCount	Long Integer	No	Number of tweeners for each segment of road. Calculated in the macro from sites.
TweenerPerMi	Double	No	"TweenerCount" divided by "miles"
HrCount	Long Integer	No	Number of highly rated sites for each segment of road. Calculated in the macro.
OvRatSum	Double	No	Sum of site ratings for each segment of road
Xing_rate	Long Integer	No	Rating based on "XingPerMi", calculated in macro based on values displayed in "KNF Road SSI discussion" process paper
HydroCon_rate	Long Integer	No	Rating based on "HydroConPercent", calculated in macro based on values displayed in "KNF Road SSI discussion" process paper

"RestRds" Line Feature Class (roads)			
Field Name	Data Type	Manual Edit?	Description
UC_rate	Long Integer	No	Rating based on "UcPerMi", calculated in macro based on values displayed in "KNF Road SSI discussion" process paper
DP_rate	Long Integer	No	Rating based on "DpPerMi", calculated in macro based on values displayed in "KNF Road SSI discussion" process paper
Tweener_rate	Long Integer	No	Rating based on "TweenerPerMi", calculated in macro based on values displayed in "KNF Road SSI discussion" process paper
HR_rate	Long Integer	No	Rating based on "HrCount", calculated in macro based on values displayed in "KNF Road SSI discussion" process paper
OvRatSum_rate	Long Integer	No	Rating based on "OvRatSum", calculated in macro based on values displayed in "KNF Road SSI discussion" process paper
RdInvRat	Long Integer	No	Sum of the previous seven values to give the road inventory rating. Recalculated with each macro run.
TotRdRat	Long Integer	No	Sum of "GisModRat" and "RdInvRat" for the total road rating. Recalculated with each macro run.
risk	Text	No	Groupings of road risk based on "TotRdRat", >= 70 is 'High' risk, >= 30 is 'Mod' (moderate) risk, and < 30 is 'Low' risk. Recalculated with each macro run.
ProposedTreat	Text	No	Proposed treatment based on "risk" and "system". Non-system roads are automatically listed as 'DE', 'High' risk roads are considered 'SPall', other roads with crossing repairs are 'SP16' while roads with only tweener sites are 'SP4'. Definitions for the treatments are in the "tbl_RoadTreat" table. Recalculated with each macro run.
SiteCosts	Double	No	A sum of estimated site costs from "tbl_Sites" table. Recalculated with each macro run.
SegCosts	Double	No	Estimated segment costs based on "ProposedTreat" , "miles", and costs from "tbl_RoadTreat" table. Recalculated with each macro run.
TotCosts	Double	No	Sum of "SiteCosts" and "SegCosts". Recalculated with each macro run.

"KnfSites" Point Feature Class (sites)			
Field Name	Data Type	Manual Edit?	Description
OBJECTID	AutoNumber	No	Auto-populated unique identifier.
Shape	OLE Object	No	Spatial coordinates, edits automatically when spatial edits are done.
LinkNo	Integer	Yes	Manually edited link to road segment, must be managed by anyone editing this feature class.
SITE_ID	Text	Yes	Unique identifier for each site, combination of "RD_NO" and "MILE_POST".
RD_NO	Text	Yes	Road Number, same as "RdNo" in "RestRds".
MILE_POST	Text	Yes	Mile Post as determined by field crew, may not be consistent with Infra because of start location.
TYPE	Integer	Yes	Ties to "tbl_TypeKey"

"huc7cwe" Polygon Feature Class (watersheds)			
Field Name	Data Type	Manual Edit?	Description
OBJECTID	AutoNumber	No	Auto-populated unique identifier.
Shape	OLE Object	No	Spatial coordinates, edits automatically when spatial edits are done.
minus3	Text	Yes	Links to "Minus3" in "RestRds"
HUC14	Text	Yes	7th Field watershed hydrologic unit code
HUC14Name	Text	Yes	7th Field watershed name
HUC12	Text	Yes	6th Field watershed hydrologic unit code
HUC12Name	Text	Yes	6th Field watershed name
HUC10	Text	Yes	5th Field watershed hydrologic unit code
HUC10Name	Text	Yes	5th Field watershed name
HUC8	Text	Yes	4th Field watershed hydrologic unit code
HUC8Name	Text	Yes	4th Field watershed name
TMDL	Text	Yes	Total Maximum Daily Load (water quality evaluation) watershed, either ‘Klamath’, ‘Salmon’, ‘Scott’, or ‘Shasta’
Shape_Length	Double	No	Length of feature in meters, automatically calculated based on spatial representation
Shape_Area	Double	No	Area of feature in square meters, automatically calculated based on spatial representation

“tbl_Sites” Table (site information)			
Field Name	Data Type	Manual Edit?	Description
OBJECTID	AutoNumber	No	Auto-populated unique identifier.
LinkNo	Integer	Yes	Manually edited link to road segment, must be managed by anyone editing this feature class.
SITE_ID	Text	Yes	Unique identifier for each site, combination of "RD_NO" and "MILE_POST".
Rd	Text	Yes	Road Number, same as ‘RdNo’ in "RestRds".
Mp	Text	Yes	Same as ‘Mile_Post’ in “KnfSites”.
type	Integer	Yes	Same as ‘type’ in “KnfSites”; must be the same value as ‘type’ in “KnfSites”.
Dp	Text	Yes	‘y’ if the site has diversion potential, from the field data and may be changed if found to be incorrect or the site has been fixed.
Uc	Text	No	‘y’ if the site has an undersized culvert. This field is populated through the macro based on the results of the ‘PC’ field and should not be edited manually. Any culvert with a ‘PC’ rating of 5 or greater is considered undersized. This assures that any FEUP or grossly undersized pipe according to hydraulic calculation will be considered undersized. For marginally undersized pipes other factors also indicate undersized. A cross drain may be considered undersized only if FEUP.
Hr	Text	No	‘y’ if the site is determined to be Highly Rated. This field is populated through the macro based on the results of the ‘OvRat’ and ‘Uc’ fields and should not be edited manually. A site must have an undersized pipe as described above and have a high ‘OvRat’ to be a Highly Rated site.
Cp	Long Integer	Yes	Collection Potential in feet, equivalent to ‘Cp_xd’ (Collection Potential to first cross drain) in “tbl_SiteFieldData” table except where record does not exist in “tbl_SiteFieldData”. May be edited if found to be incorrect or roadwork has changed collection potential.
drain_area	Long Integer	Yes	Drainage area in acres, derived from watersheds drawn to each crossing for projects. Should only be edited if new site-specific watersheds are drawn.
pipe_dia	Long Integer	Yes	Pipe diameter from field data, may be edited if found to be incorrect or pipe has been

“tbl_Sites” Table (site information)			
Field Name	Data Type	Manual Edit?	Description
			replaced.
exist_Q	Double	Yes	Existing capacity of the pipe in cubic feet per second (cfs). Should be re-calculated with any change, including pipe replacement, cleaning, or installing an end section, based on the formula: (pipe_dia)^2 x 7.3 x π / 576 x (EF)/0.49 x (1 – DF) where EF is the pipe entrance factor and DF is percent dented or filled.
Q100	Double	Yes	Estimated 100 year flood flow in cfs. May be re-calculated if needed, if “drain_area” has changed, based on the formula: 9.23 x (drain_area / 640)$^{0.87}$ x MAP$^{0.97}$ where MAP is mean annual precipitation in inches.
fill_vol	Double	Yes	Fill volume, generally calculated from field data based on a complicated formula that can be examined in one of the project spreadsheets. Approximate fill volume is generally adequate since any following computations are based on the following breakdowns: greater than 1000 cubic yards, between 700 and 1000 cubic yards, between 500 and 700 cubic yards, between 100 and 500 cubic yards, and less than 100 cubic yards.
hydraulic_rat	Long Integer	No	Hydraulic Capacity Rating, calculated in the macro based on relationship between ‘exist_Q’ and ‘Q100’. See “KNF Road SSI discussion.docx” for details.
woody_debris	Long Integer	Yes	Woody Debris Rating, based on relationship between culvert diameter and channel width. From field data, not calculated in the macro and should be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
culvert_sed	Long Integer	Yes	Culvert Sediment Rating, based on relationship between pipe slope and channel slope. From field data, not calculated in the macro and should be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
FEUP	Long Integer	Yes	Field Evidence of Undersized Pipe. From field data, should be changed if incorrect. Value of ‘6’ means “yes, FEUP”, ‘0’ means no.
cp_1drain	Long Integer	Yes	Collection potential to 1st cross-drain rating; based on length of collection from field data. Can be changed if incorrect. See “KNF Road

“tbl_Sites” Table (site information)			
Field Name	Data Type	Manual Edit?	Description
			SSI discussion.docx” for details.
cp_grade_rev	Long Integer	Yes	Collection potential to grade reversal rating; based on length of collection from field data. Can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
PC	Long Integer	No	Pipe Capacity Rating, calculated in the macro based on previously discussed ratings. See “KNF Road SSI discussion.docx” for details. <u>This is a very important field, determines (along with diversion potential) whether or not this is a legacy site in need of repair. A value of ‘5’ or higher means that the pipe needs to be replaced or somehow altered to be assured that it will pass a 100 year flood.</u>
SP	Long Integer	Yes	Slide Potential Rating, based on field data, may be changed if incorrect. Value of ‘6’ for active landslide at site, ‘3’ for maybe or suspected slide at site, and ‘0’ for no landslide at site.
upslope_roads	Long Integer	Yes	Upslope road/stream crossing rating; from field data. Can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
deveged	Long Integer	Yes	Percent de-vegetated rating; from GIS overlay. Can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
rd_density	Long Integer	Yes	Road density rating; from GIS overlay. Can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
df_history	Long Integer	Yes	Debris flow history rating; from field data. Can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
geomorph	Long Integer	Yes	Geomorphic character rating; from GIS overlay. Can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
UD	Long Integer	No	Upslope Debris Flow Rating, calculated in the macro based on previously discussed ratings. See “KNF Road SSI discussion.docx” for details.
dp_rate	Long Integer	No	Diversion potential rating, calculated in the macro based on “DP” yes/no field, value of ‘6’ for yes, ‘0’ for no.
fill_vol_rate	Long Integer	No	Fill volume rating, calculated in the macro based on ‘fill_vol’. See “KNF Road SSI discussion.docx” for details.
slope_pos	Long Integer	Yes	Slope position rating, can be changed if

“tbl_Sites” Table (site information)			
Field Name	Data Type	Manual Edit?	Description
			incorrect. See “KNF Road SSI discussion.docx” for details.
slope_steep_rate	Long Integer	Yes	Slope steepness rating; can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
geom_stab_rate	Long Integer	Yes	Geomorphic stability at site rating; can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
geom_stab_below	Long Integer	Yes	Geomorphic stability below site rating; can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
CQ	Long Integer	No	Consequences Rating, calculated in the macro based on previously discussed ratings. See “KNF Road SSI discussion.docx” for details.
ws_rate	Long Integer	Yes	Water supply sources at risk rating; can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
fb_rate	Long Integer	Yes	Fish-bearing stream rating; can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
fa_rate	Long Integer	Yes	Downstream facilities at risk rating; can be changed if incorrect. See “KNF Road SSI discussion.docx” for details.
IP	Long Integer	No	Impacts Rating, calculated in the macro based on previously discussed ratings. See “KNF Road SSI discussion.docx” for details.
OvRat	Long Integer	No	Overall Site Rating, calculated in the macro based on previously discussed ratings. See “KNF Road SSI discussion.docx” for details.
treatment	Text	No	Expected treatment based on overall site rating and fill size, as outlined in the “tbl_SiteTreat” table. Recalculated each time the macro is run.
cost	Long Integer	No	Expected cost based on “treatment” as outlined in “tbl_SiteTreat” table. Recalculated each time the macro is run.
past_treat	Text	Yes	Previous “treatment” for those sites that have been fixed or partially fixed, copied from “treatment” before editing site characteristics.
treatment_project	Text	Yes	Project name for those sites that have been fixed or partially fixed.
treatment_year	Integer	Yes	Year sites have been fixed.

"tbl_Sites" Table (site information)			
Field Name	Data Type	Manual Edit?	Description
uc_fixed	Text	Yes	Indicator that undersized crossing has been fixed. Either "y" or left blank.

<u>Editing Procedure</u>

The database is currently set up for editing and re-calculating macro-dependent fields through Citrix. Only persons with edit access to the T drive "2500" area can currently edit the database and run the macro. However the entire "RdInv" directory can be copied to another location on the T drive for edit access by Klamath NF personnel. There would need to be some manipulation of the tool in ArcCatalog to make sure pointers are pointing to the correct locations but this can be done relatively quickly.

Most editing will be done in an ArcMap edit session in Citrix, or by opening the database in Access in Citrix. A full editing procedure is too complicated to fully describe here, but a few details are very important to note. Roads segmented because of crossing 7th field watershed boundaries may be recombined to eliminate short sections barely crossing the watershed boundaries. Simply merge the short section into the dominant section, maintaining the attributes of the longer section. But be careful not to orphan sites, that is eliminate a road segment (as identified by "LinkNo") that has a point identified by that "LinkNo". If a new road segments is added, it will need a new, unique "LinkNo", created by adding "1" to the maximum value "LinkNo" previously existing. Any points added to "KnfSites", and the corresponding "tbl_Sites" table, will need to have the correct "LinkNo" assigned based on the correct road segment. Added sites and roads will need to include all the information labeled "Yes" in the 'Manual Edit?' column above.

The most common edits involve diversion potential (dp) and undersized crossings (uc). A 'y' in either one of these indicates that the site is a "legacy" site and that information is carried into the "treatment" column. A blank "treatment" column indicates that the site is not a legacy site but anything else in that column indicates a legacy site.

Diversion potential is easily changed following road work and/or a re-evaluation of site. Simply change the 'y' in the "Dp" to 'n' (or vise versa if that is the case) for each site and the database has been corrected. If "treatment" had been 'dp' and 'y' had been changed to 'n', then "treatment" will be blank after the macro has been run. If a road segment had been storm proofed and all diversion potential fixed, then all sites on the road segment formerly 'y' for "Dp" can be changed to 'n' at one time.

Undersized crossings are more problematic. Since the "Uc" column is updated each time the macro is run, simply changing a 'y' to an 'n' in this column will not work. Another item called "uc_fixed" has been added for those crossings that have been storm proofed so that the site is no longer considered a legacy site. Adding a 'y' to this column will cause the "Uc" column to be set to 'n' when the macro is run regardless of the data in the rest of the table.

Besides the “uc_fixed” column, three other new columns have been added to the database in June, 2015. These are “past_treat”, “treatment_project” and “treatment_year”. These were added in order to allow tracking of restoration activities site by site (as opposed to road segment tracking which already existed in the database). These need to be manually edited whenever site characteristics are changed to account for road restoration activities.

Other site characteristics are typically not edited. These either do not change because of restoration or have little effect on overall results. Many sites have relatively high Overall Site Ratings (“OvRat”) do to site characteristics such as large fills, generally unstable geomorphic character, etc. But as long as these sites do not have diversion potential or undersized crossings, they are not legacy sites in need of restoration.

I have created several “Check” queries in the geodatabase to check for obvious errors. The first one “Check_Site_LinkNo” looks for points in “KnfSites” that have a “LinkNo” that does not exist in “RestRoads”. This query should show no results; any listed results are errors. The other queries look for similar things. All should return no results.

Running the Macro

After edits are complete, navigate to the location of the databases and macro in ArcCatalog. There should be a “RdInvCalcs” toolbox. In this toolbox should be a “RdInvCalcsModel” modelbuilder icon. Double-click this icon and the model will start running. A window will pop up showing the locations of the feature classes and tables to be run against. These should be correct but it is worth checking that the locations are correct. Click “OK” and the model will run, hopefully all the way through, and provide results which incorporate the edits. If the model does not run through, some trouble-shooting will need to be done.

Generating Reports

The easiest way to pull information from the database is to open “KnfRoadSedimentSourceInventory.mdb” in Access. This can be done in Citrix. Along with the data tables and check queries, there are several other queries built to facilitate report generation designed for 6^{th} field watersheds. The query labeled “huc6 List” provides a list of 6^{th} field watersheds across the Klamath National Forest. The query “huc6 Road Report” provides a road report including those things most likely needed for a 6^{th} field watershed assessment. To select a different watershed than the one already in the query, open the query in Design View and change the “HUC12Name” (6^{th} field watershed name) to the desired watershed using “huc6 List” as a guide and re-run the report. The companion queries, ‘huc6 Tweener Report” and “huc6 Xing Report” do not need to be edited because they give results for the same watershed as “huc6 Road Report”. The Tweener report may seem a bit hollow since it will contain only the tweener information that is available in the database, and much of the older inventory tweener data has been lost. The three queries (roads, tweeners, and xings), or any other query generated by a user, can be exported to an Excel spreadsheet using the export tools in Access.