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7/22/14

Class II-L Monitoring: Concept Proposals

Conflicts in implementing the original Class II-L rules led to passage of the regulation titled "Class II-L Identification and Protection, 2013" (Revised Class II-L Rules), which went into effect on January 1, 2014. The rule language in 14 CCR § 916.9 [936.9, 956.9] (c)(4) states that:

> *Class II-L watercourses can have greater individual effects on receiving Class I watercourse temperature, sediment, nutrient, and large wood loading than Class II standard (Class II-S) watercourses due to larger channel size, greater magnitude and duration of flow, and overall increased transport capacity for watershed products.*

The new methods used to determine a Class II-L watercourse include:

1. A contributing drainage area of ≥ 100 acres in the Coast Forest District, or ≥150 acres for the Northern and Southern Forest Districts, as measured from the confluence of the receiving Class I watercourse (**Area method**); or
2. An average active channel width of five feet (5 ft) or greater near the confluence with the receiving Class I watercourse. Where field measurements are necessary to make this determination, active channel width measurements shall be taken at approximately fifty foot (50 ft) intervals beginning at the point where the Class II watercourse intersects the Class I watercourse and lake protection zone (WLPZ) boundary and moving up the Class II watercourse for a distance of approximately two-hundred feet (200 ft). The combined average of these five (5) measurements shall be used to establish the average active channel width. Measurement points may be adjusted based upon site-specific conditions, and should occur at riffle locations and outside the influence of watercourse crossings to the extent feasible (**Width method**).

The rule language in 14 CCR § 916.9 [936.9, 956.9] (g)(1)(C) also states the following:

> ***The above method for determination of Class II watercourse type shall sunset on January 1, 2019 pending further evaluation of the efficacy of Class II WLPZ widths and operation requirements in relationship to watercourse characteristics and achievement of the goals specified in 14 CCR § 916.9 [936.9, 956.9] subsection (a). The Department shall report to the Board at least once annually on the use and effectiveness of 14 CCR §***

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916.9[936.9, 956.9] subsection (g) for as long as the rule section remains effective.

The language above (Sunset Clause) calls for monitoring the effectiveness of Class II watercourse and lake protection zones (WLPZ) in achieving the following goals specified in 14 CCR § 916.9 [936.9, 956.9] subsection (a):

1. *Comply with the terms of a Total Maximum Daily Load (TMDL).*
2. *Prevent significant sediment load increase to a watercourse system or lake.*
3. *Prevent significant instability of a watercourse channel or a of a watercourse or lake bank.*
4. *Prevent significant blockage of any aquatic migratory routes for any life stage of anadromous salmonids or listed species.*
5. *Prevent significant adverse effects to streamflow.*
6. *Consistent with the requirements of 14 CCR § 916.9 [936.9, 956.9], subsections (f), (g), (h) and (v), protect, maintain, and restore trees (especially conifers), snags, or downed large woody debris that currently, or may in the foreseeable future, provide large woody debris recruitment needed for instream habitat structure and fluvial geomorphic functions.*
7. *Consistent with the requirements of 14 CCR § 916.9 [936.9, 956.9], subsections (f), (g), (h) and (v), protect, maintain, and restore the quality and quantity of vegetative canopy need to:*
    a. *Provide shade to the watercourse or lake to maintain daily and seasonal water temperatures within the preferred range for anadromous salmonids or listed species where they are present or could be restored; and*
    b. *Provide a deciduous vegetation component to the riparian zone for aquatic nutrient inputs.*
8. *Prevent significant increases in peak flow or large flood frequency.*

The Sunset Clause also calls for an assessment of the effectiveness of the area and width methods for identifying Class II-L watercourses.

Determining the effectiveness of the Class II-L WLPZ prescriptive standards in achieving the goals outlined above is considered validation monitoring and would require extensive planning, resources, and time. However, determining whether there are continuing conflicts in identifying Class II-L watercourses can be done relatively rapidly using existing resources. With this in mind, several monitoring questions, along with general approaches for answering these questions, were developed to address the requirements in the Sunset Clause language, including issues of uncertainties identified during the Class II-L negotiation and revision process.

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Rationale for the Area and Width Methods

The rule language in 14 CCR § 916.9 [936.9, 956.9] (c)(4) (see gray shaded text on page 1) states that Class II-L watercourses have greater individual effects on downstream receiving waters than Class II standard watercourses due to increased fluxes of temperature, sediment, nutrients, and large woody debris. The larger fluxes from Class II-Ls are ascribed to larger channel dimensions, greater magnitude and duration of flow, and greater transport capacity for watershed products.

Both the area and width methods are consistent with the concept of hydraulic geometry. Hydraulic geometry assumes that discharge (Q) is the dominant independent variable that drives variations in channel process and form (Leopold and Maddock, 1953). Equations 1 and 2 are well known hydraulic geometry power functions, where Q is discharge, A is drainage area, W is channel width, and b, c, d, and e are empirical constants:

(1) $Q = eA^d$

(2) $W = cA^b$

The Class II-L identification method uses both drainage area and active channel width to infer channel process and function, as these are strongly related to discharge. Additionally, transport capacity (Q_t) can be defined by the stream power model:

(3) $Q_t = k(\Omega-\Omega_c)^{n\,\Omega}$

where k is an index of material mobility, Ω is stream power, Ω_c is the critical stream power for incipient motion, and n^{Ω} is an exponent between 1 and 1.5 for sediment (Bagnold, 1977). Stream power can be defined as:

(4) $\Omega = \frac{\rho g A^d S}{W}$

where ρg is the unit weight of water, A is area, S is channel slope, W is channel width, and d is an empirical constant (Brummer and Montgomery, 2003). Equations 1 through 4 indicate that discharge and transport capacity varies with channel width and drainage area. Both discharge and transport capacity are important controls on the downstream transport of sediment, nutrients, and large woody debris[1] (MacDonald and Coe, 2007), making the identification methods consistent with the rule language in14 CCR § 916.9 [936.9, 956.9] (c)(4) for these watershed products.

[1] The transport of large woody debris is also strongly dependent upon piece size. Small streams cannot generally move large pieces of wood via fluvial transport (Bilby and Bisson, 1998).

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Conflict Regarding Class II-L Identification Methods

Given that the first iteration of the Class II-L identification methods created conflict between regulators and the regulated public, the first question is the following:

General Monitoring Question 1: Are the Class II-L identification methods resulting in conflicts between Review Team personnel and the regulated public?

General Approach: A general approach to answer this question would be to survey CAL FIRE Forest Practice inspectors to see how often Class II-L determinations were disputed during the review phase of the timber harvesting plan (THP), Modified THP, Nonindustrial Timber Management Plan (NTMP), and Sustained Yield Plan (SYP), Program Timberland Environmental Impact Report (PTEIR)/PTHP processes. Alternatively, pre-harvest inspection (PHI) reports could be evaluated to determine if Class II-L determinations were disputed within the PHI report. Both these approaches would be relatively easy, inexpensive, and could yield information to policy makers quickly. The information can be used to update the Board of Forestry and Fire Protection on an annual basis, as per the Sunset Clause.

Spatial Variation in the Drainage Area and Width Methods

The identification methods for Class II-L watercourses rely on drainage area or the active channel width to classify Class II-L watercourses. While the width method uses a fixed value of 5 ft to identify Class II-L watercourses, the drainage area method recognizes spatial variation in the drainage area required to sustain Class II-L functions and processes. Specifically, the drainage area method uses ≥ 100 acres for the Coast Forest District and ≥ 150 acres for the Northern and Southern Forest Districts. This makes sense since precipitation is generally higher in the Coast Forest District than in the Northern and Southern Forest Districts (Figure 1), and the magnitude of precipitation inputs to a watershed can drive many of the processes and functions that characterize Class II-L watercourses[2]. Also, geology is a factor that controls physiography, permeability, and runoff pathways. When considering the variability in precipitation and geology across non-federal forestlands, it stands to reason that the drainage area necessary to sustain Class II-L functions and processes might be similarly variable.

It can be argued that the active channel width is a more effective indicator of Class II-L functions and processes than drainage area, since channel width scales more directly with discharge and sediment transport capacity than drainage area. However, as demonstrated in Eq. 2 and in Figure 2, there is a relationship between drainage area

[2] The rational method predicts peak runoff as a function of drainage area, runoff coefficient, and rainfall intensity.

and channel width. A refinement of the area and width methods would ideally relate drainage area to active channel width so that there is consistency between the two metrics.

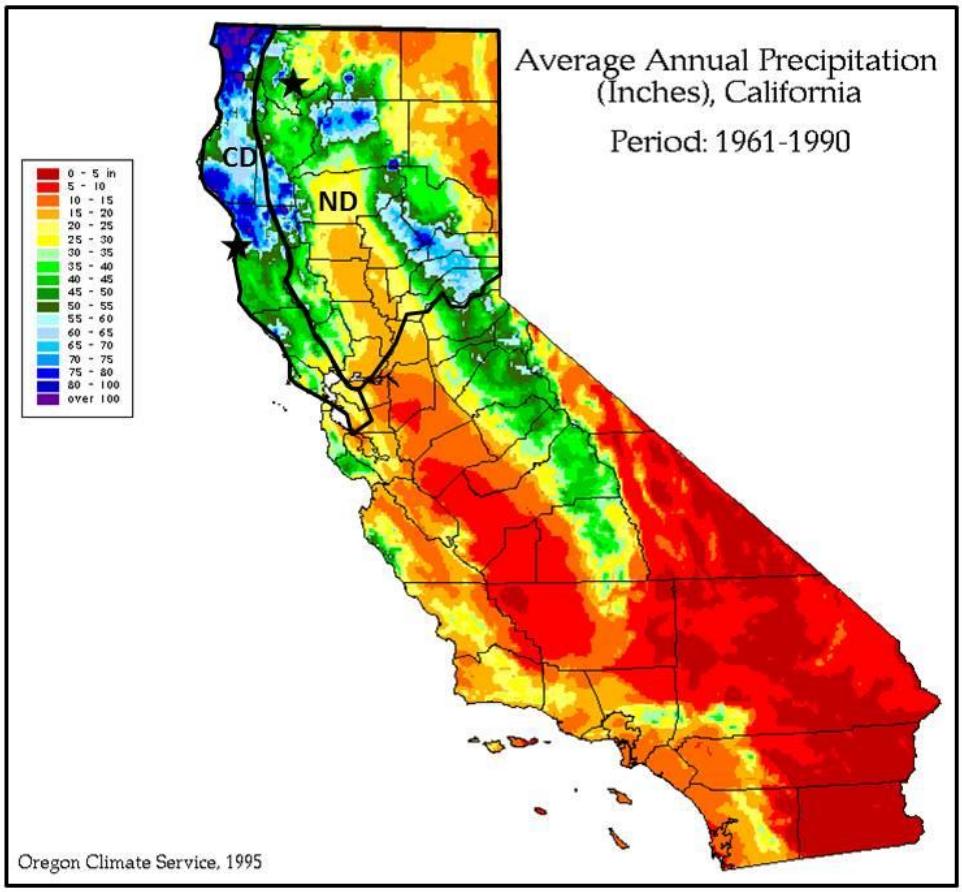

Figure 1. Mean annual precipitation for California for the period between 1961and 1990 (taken from www.wrcc.dri.edu). Polygons represent the approximate boundaries for the Coast (CD) and Northern (ND) Forest Districts. Stars represent the approximate geographic area where the channel width-drainage area surveys in Figure 2 took place.

General Monitoring Question(s) 2: Are the drainage area values consistent with an active channel width of five feet?

General Approach: More surveys relating drainage area to active channel width will be performed in the Coastal and Northern Forest Districts. Figure 2 indicates that either the drainage area necessary to sustain an active channel width of 5 feet can vary by approximately a factor of 2.5 between Forest Disticts. However, Figure 2 represents a very limited sample. Additional sampling will attempt to capture a range of precipitation and geomorphic provinces. Multiple regression can be used to determine the appropriate drainage area based on multiple environmental factors.

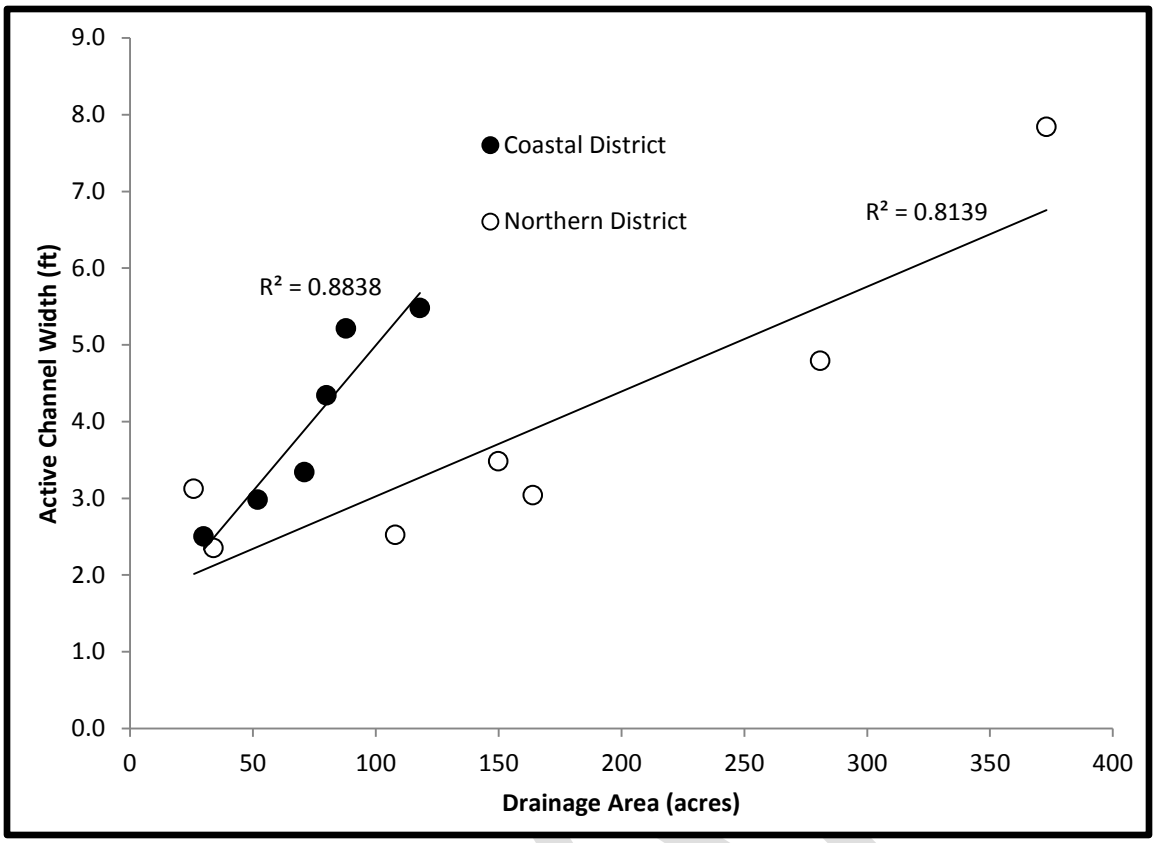

Figure 2. Active channel width versus drainage area for watercourses in the Coast and Northern Forest Districts. Surveys in the Coastal District were performed in the Ten Mile River watershed and Jackson Demonstration State Forest; surveys in the Northern District took place in the Etna and French Creek watersheds.

Effectiveness of Class II-L Identification Methods in Identifying Streams Susceptible to Heat Transfer

The new methods are less certain for identifying watercourses with the potential to transfer heat in the downstream direction. Analytical expressions of hydraulic geometry (e.g., equations 1, 2, and 4) assume a dominant or channel-forming discharge (e.g., bankfull discharge), and are better predictors of channel form and process during higher magnitude discharges. Water temperature increases are typically an issue during the summer months when flows are at or near the annual minimum. As such, it is necessary to determine whether the area or width methods relate to the potential for downstream heat transfer from Class II to Class I watercourses during low flow periods. This was recognized during the Class II-L revision process, where both North Coast Regional Water Quality Control Board and Department of Fish and Wildlife representatives expressed concern that the new rule language did not adequately address thermal impacts.

Thermal inputs, hydrologic connectivity of surface flows, surface flow magnitude, and the duration of flow during the summertime are determinants for downstream heat transfer. Several studies have looked at the spatial and temporal distribution of perennial low flows for headwater streams (e.g., Roth 2010). The Variable Source Concept (VSC) explains that surface water expands headward during storm events and retreats during recessional flows and baseflow conditions (Hewlett and Nutter, 1970). The VSC suggests that perennial low flow is more likely to be found near the Class II/I confluence. Recent studies from the Pacific Northwest, however, have suggested that perennial flow during the summer months does not follow the pattern suggested by the VSC, and that perennial flow retreats headward towards the channel head (Hunter et al., 2005; Jaeger et al., 2007). Source areas for perennial flow were found to be related to lithology, with sedimentary lithologies requiring less drainage area to sustain perennial flow than basaltic lithologies (Figure 3). Streams draining sandstone lithologies also demonstrated downstream movement of perennial flow as drier conditions developed, whereas perennial flow remained more fixed in place as summer progressed in basaltic streams (Jaeger et al., 2007). The spatial occurrence of perennial flow during the summer months was also strongly tied to precipitation magnitude during springtime (Hunter et al., 2005).

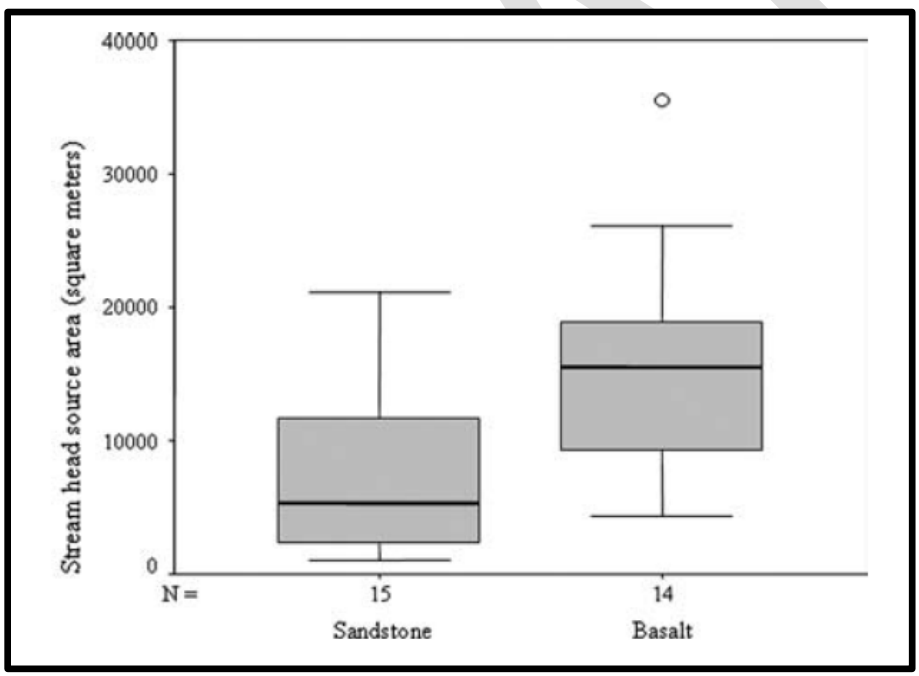

Figure 3. Source area for perennial flow for watersheds underlain by sandstone versus basalt lithologies (from Jaeger et al., 2007). Median source areas varied by approximately a factor of three between lithologies.

Considering that the conceptual framework of the Class II-L identification methods are uncertain for issues related to temperature flux in streams, we pose the following question:

General Monitoring Question(s) 3: Are the Class II-L identification methods effective in identifying watercourses that have the potential to translate thermal impacts to Class I watercourses? Is one method (i.e., width vs. area) better than the other?

General Approach: A general approach to answer this question is to determine whether the drainage area or channel width default can adequately predict the presence of connected perennial flow near the Class I/II confluence during the dry season. A methodology would include the characterization of flow magnitude and connectivity near the Class II/I confluence for watercourses with active channel widths greater than 5 feet or with drainage areas greater than 100-150 acres (Figure 4). The sampling should be stratified by lithology and mean annual precipitation, as these appear to be drivers of perennial flow location and duration. Monitoring should ideally be conducted over multiple seasons to account for interannual variability. A large enough dataset could be used to determine if either the drainage area or width method is better at predicting the conditions that allow for downstream heat transfer. Depending upon the findings of the study, an alternative identification method can be developed that targets temperature issues. This monitoring approach would require a larger investment of time and resources, but is a necessary step to determine if the existing identification methods take into account the potential for thermal impacts to Class I watercourses.

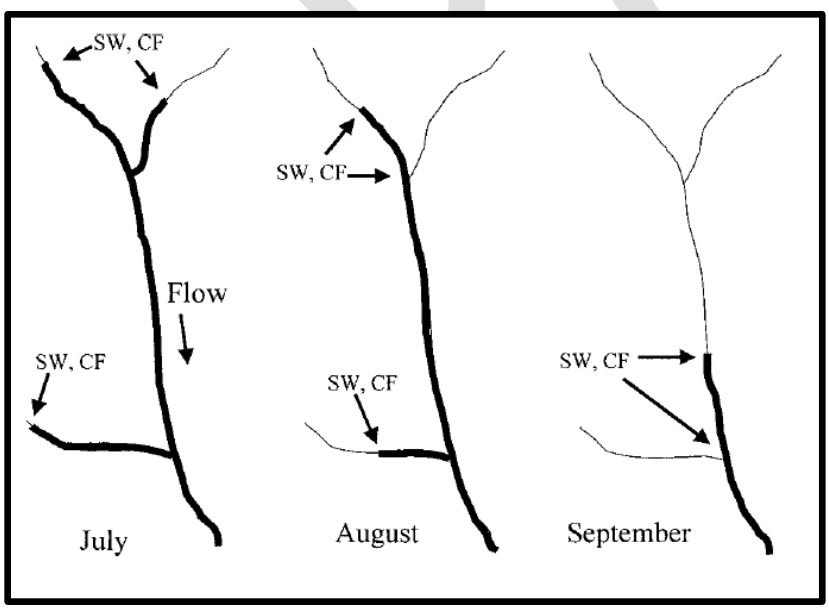

Figure 4. Graphic representation of the spatial incidence of surface water (SW) and connected perennial flow (CF) for a channel network over time (from Hunter et al., 2005). Connected perennial surface flow is more likely to transmit heat downstream.

Similar methods to Hunter et al. (2005) and Jaeger et al. (2007) can be used to determine whether Class II-L identification methods are sufficient to identify streams with the potential to transmit heat during summer months.

Effectiveness of Class II-L Identification Methods in Identifying Watercourses with the Potential to Transport LWD to Class I Watercourses

The transport of LWD from Class II to Class I watercourses is likely to be associated with debris flows or extreme floods (May, 2002; Abbe and Montgomery, 2003; Hassan et al., 2005; Figure 5), but fluvial transport is rare because LWD tends to be large relative to watercourse dimensions and the size of peak flows (Bilby and Bisson, 1998; May and Gresswell, 2003). Mobile wood generally has a length less than the channel width (Flanagan, 2004). Since large wood by definition ranges from 2-3 m long, there is very little fluvial export of large wood from most small streams (Flanagan, 2004).

The area and width methods reflect increasing transport capacity with increasing drainage area and active channel width. However, it is unclear whether they can identify Class II watercourses that transport LWD to Class I watercourses via mass wasting processes.

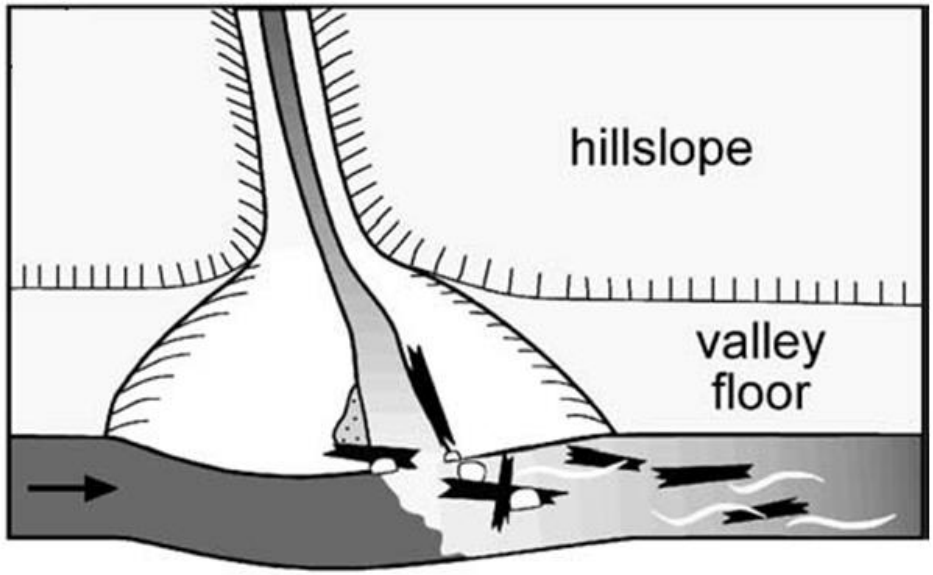

Figure 5. Illustration of debris flow deposit of large wood into a Class I watercourse from a steep gradient, second order ephemeral channel located in a watershed with unstable areas subject to debris slides, flows, and torrents (from May and Gresswell, 2004).

Debris flows typically require initiation on steep hillslope source areas (i.e., slopes > 60 percent), although debris flows can initiate within and erode steep watercourses (i.e.,

15-60 percent) (Benda et al., 2005). Depending upon flow properties and characteristics, debris flow material is usually transported through watercourses ranging from 10-25 percent, with deposition occurring on watercourse slopes as high as 25 percent, but generally lower than 10 percent (Benda et al., 2005). Watercourse slope can be empirically related to drainage area:

(5) $S = kA^{-\Theta}$

where S is watercourse slope, A is drainage area, and k and Θ are coefficients that reflect watercourse profile steepness and concavity (Brummer and Montgomery, 2003). This indicates that debris flow prone channels with the potential to transport LWD can theoretically be identified using the area method and indirectly using the width method (see Equation 2). However, this does not take into account the initiation of debris flows from hillslope source areas.

General Monitoring Question 4: Are the Class II-L identification methods effective in identifying watercourses that have the potential to transport LWD to Class I watercourses through debris flow processes?

General Approach: A general approach to answer this question is to determine whether the drainage area or channel width default can adequately predict the presence of debris flow deposits at or near the Class II/I confluence. However, a more refined approach (e.g., stratification by landslide risk) would have to be developed in consultation with staff from the California Geological Survey. Answering monitoring question four is lower priority than answering monitoring questions one through three.

<u>Validation of Class II WLPZ Standards</u>

The Sunset Clause in the Revised Class II-L Rules calls for the validation of Class II WLPZ standards (see yellow highlighted language, goals 1 through 8). This results in the following question:

General Monitoring Question 5: Are the Class II WLPZ riparian standards effective in achieving the goals outline in 14 CCR § 916.9[936.9, 956.9] subsection (a)?

General Approach: Question 5 belies the complexity of proving the effectiveness of Class II WLPZ standards. This general question would generate multiple sub-questions, and an even larger number of testable hypotheses. The complexity of this task means that it is best incorporated into the study design of an intensively monitored watershed, such as Caspar Creek, Little Creek, or Judd Creek. If necessary, the effectiveness of the WLPZ standards in achieving a specific goal (e.g., achieving temperature standards for TMDL compliance) could be done in isolation. A primary benefit of this type of study is that it will determine whether two types of Class II

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protection standards are necessary. It would also be a necessary step towards water quality certification of the California Forest Practice Rules by the US Environmental Protection Agency (EPA) as BMPs.

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FORPRIEM ver. 2.0 Project Description

February 8, 2016

Background Information and Problem Statement

FORPRIEM ver. 2.0 is a continuation of the FORPRIEM (Forest Practice Rules Implementation and Effectiveness Monitoring) program began in 2008 (Brandow and Cafferata 2014), which itself was a continuation of earlier BOF/CAL FIRE monitoring programs (Modified Completion Report (MCR) monitoring—Brandow et al. 2006, and the Hillslope Monitoring Program (HMP)—Cafferata and Munn 2002). All of these programs were used to determine the adequacy of the implementation and short-term effectiveness of California's Forest Practice Rules developed to protect water quality and riparian/aquatic habitats.

These state-sponsored monitoring programs have yielded considerable data during the past two decades: HMP--1996 through 2001, MCR--2001 through 2004, and FORPRIEM—2008 through 2013. The results from these studies, using comparable data collection and sampling methods, have been generally similar. They have found that (1) individual practices required by the California FPRs are usually effective in preventing hillslope erosion when properly implemented, and (2) overall rule implementation rates are high (approximately 90% or higher depending on the rule section). For example, only approximately 5% of the forest road drainage structures located on randomly located road segments have been found to have problems.

Road drainage, including at watercourse crossing approaches, has been found to need improvement, as has watercourse crossing design, construction, maintenance, and abandonment. The data from these monitoring programs suggest that there may be improvement over time for both watercourse crossing rule implementation and effectiveness, as well as for Class I WLPZ total canopy. The expectation is that with the implementation of the Road Rules, 2013 and Anadromous Salmonid Protection (ASP) rule packages, these trends will continue, and improvement in road drainage at watercourse crossing approaches will be observed. FORPRIEM ver. 2.0 will provide important data to the Board's Effectiveness Monitoring Committee (EMC) to determine if these improvements are indeed observed, or if further refinements in the FPRs are needed.

The original mandate for FPR implementation and effectiveness monitoring related to water quality came from the desire to have the California Forest Practice Rules certified by US EPA as Best Management Practices (BMPs) under Section 208 of the Federal Clean Water Act. While that has not happened to date, the expectation to continue monitoring is high—particularly due to state and federal anadromous salmonid species listings, listing of waterbodies as impaired under Section 303(d) of the Federal Clean Water Act, and stakeholder concerns voiced to the Board of Forestry and Fire Protection (BOF). FORPRIEM monitoring is CAL FIRE's only direct 'project monitoring' of THPs and NTMPs, except for Forest Practice inspections, and remains a very high priority for the Department.

Additionally, the Road Rules, 2013 rule package includes the following two monitoring requirements:

Maintenance and Monitoring of Logging Roads and Landings

14 CCR §§ 923.7 [943.7, 963.7] (k) . . . The Department shall also conduct monitoring inspections at least once during the prescribed maintenance period to assess logging road and landing conditions.

Watercourse Crossings

14 CCR §§ 923.9 [943.9, 963.9] (u) . . . The Department shall also conduct monitoring inspections at least once during the prescribed maintenance period to assess watercourse crossing conditions.

It is the EMC's intent that if FPR monitoring requirements are consistent with the monitoring themes identified in Section 2.3 of its Strategic Plan, the EMC will place significant emphasis on them, ensuring that they are addressed with EMC-supported monitoring projects.[1] It is important to note that gathering input from the BOF's Effectiveness Monitoring Committee on revisions to FORPRIEM and making an attempt to better utilize all Review Team agencies to collect field data are key components of FORPRIEM ver. 2.0. Primary collaborating agencies, in addition to CAL FIRE, are NCRWQCB, CVRWQCB, CGS, CDFW. Data collected as part of FORPRIEM ver. 2.0 will complement data collected for other EMC monitoring projects (e.g., EMC-2015-004).

Selected Specific Monitoring Questions[2]

1. WLPZs
    a. Are Class I, II, and III watercourse rules being properly implemented, including overstory, understory, and total canopy requirements, ground cover requirements, WLPZ widths, etc.?
    b. Are Class I WLPZ post-harvest canopy levels continuing to improve over time?
    c. For a subset of sites, determine if canopy measurements made with a sighting tube compare favorably to those made with hemispherical photography (Danehy et al. 2005).
    d. Are there erosion features within Class I or II WLPZs, and Class III ELZs that are related to the current timber harvesting operations?
    e. Are THP/NTMP mitigation measures specified for WLPZs beyond the standard FPRs properly implemented and effective in preventing erosion and sediment delivery?

[1] These rule requirements are consistent with Section 2.3, Themes 1, 2, 3, and 4.

[2] WLPZs, road segments, and watercourse crossings will continue to be randomly located within plans, as has occurred with past monitoring programs. Other high risk portions of harvest plans may also be added depending on agency priorities. Plans will also be randomly selected, based on a stratified random selection process described on page 3. Short-term effectiveness will continue to be evaluated following at least one over wintering period.

2. Roads
    a. Are the Road Rule, 2013 rule package requirements being properly implemented, including hydrologic disconnection?
    b. Are road drainage structures and facilities constructed and maintained at proper spacing, sufficient to prevent road erosion features on the road surface and fill slopes?
    c. Are road erosion features delivering sediment beyond the toe of the fill, to the WLPZ, or to the high water channel? If so, were the road FPRs properly implemented at this site?
    d. Are THP/NTMP mitigation measures specified for roads beyond the standard FPRs properly implemented and effective in preventing erosion and sediment delivery?

3. Watercourse Crossings
    a. Are watercourse crossings (including culverts, fords, and bridges) designed, constructed, maintained, and abandoned as per requirements in the Road Rules, 2013 rule package?
    b. Are the Road Rule, 2013 rule requirements for watercourse crossings effective in protecting water quality (short-term effectiveness)?
    c. Are watercourse crossing effectiveness categories (e.g., diversion potential, plugging, alignment) improving over time compared to results from prior monitoring programs?
    d. Are THP/NTMP mitigation measures specified for watercourse crossings beyond the standard FPRs properly implemented and effective in preventing erosion and sediment delivery?

Stratified Approach for Plan Selection

The approach will be to develop a methodology for a stratified random sample of completed THPs and NTMP-NTOs to better test the FPRs on a larger percentage of higher erosion risk sites. The current plan is to use the following ArcGIS layers to assess erosion risk:

- 10 m DEM slope (index for shallow landsliding)
- Deep seated landslide susceptibility layer (Wills et al. 2011)
- E-EHR (surface erosion hazard) [note incomplete soil survey data in Calaveras and Humboldt counties at this time] (program currently available from CAL FIRE GIS Program, Santa Rosa)
- Drainage density (National Hydrology Dataset)

A simple algorithm will be developed to combine these parameters for a composite score, similar to that used by McKittrick (1994) to rate erosion potential for super planning watersheds in California (Table 1). A sensitivity analysis is being performed to determine how important vegetation cover is in the E-EHR methodology (i.e., assume 100% cover for all areas, vs lower percent cover for different silvicultural systems). The erosion risk procedure will be beta tested by CAL FIRE GIS and Watershed Protection Program staff. When the working group is satisfied with the algorithm and the modeling results it produces, it will be vetted through the EMC to the Review Team agencies and the public. After a stratification scheme is developed for higher risk plans, the ArcGIS

THP layer and a randomization scheme will be used to select the appropriate number of plans in each risk category (high, medium, and low)—allowing an adequate relationship to the total plan population to be generated.

Subsequent FORPRIEM ver. 2.0 Tasks

- Integrate lessons learned in the HMP, MCR, IMMP (Longstreth et al. 2008), BCTF (BCTF 2011), and FORPRIEM projects into FORPRIEM 2.0.
- Redesign the FORPRIEM field forms to collect data meaningful to all the agencies, as well as addressing the newer BOF rule package requirements (ASP rules, Road Rules, 2013, etc.).
- Investigate methods for electronic field data entry—using smart phones and Survey 123 or similar applications, and/or tablets.
- Learn how to collect WLPZ canopy data with hemispherical photography.
- Investigate and develop procedures to selected monitoring sites by hillslope position (i.e., toe, midslope, ridgetop).
- Develop a spatially explicit database for data storage.
- Develop a methodology manual and training program for all Review Team agencies, so as to more fully integrate CGS, DFW, and RWQCB staff in data collection.
- Develop a detailed QA/QC program simultaneously with the main plan sampling program.

Updated Timeline

The goal is to finish the draft methods document in spring 2016, beta test the revised procedures in summer 2016, schedule training sessions in late 2016, and implement the program by the end of 2016. Data collection is anticipated to occur for a minimum of 3-5 years.

Funding

No additional funding is required from the EMC; CAL FIRE will provide staff to collect data. It is anticipated that with AB 1492 funded positions in place, the other Review Team agencies will also assist in field data collection, as well as other aspects of the project.

Table 1. Potential rating scheme for determining high risk plans.

Category	High	Moderate	Low
Slope (%)	>60 (3)	30-59 (2)	<30 (1)
Erosion Hazard Rating	>66 (3)	50-65 (2)	<50 (1)
Deep-Seated Landslide Rating	8 to 10 (3)	5 to 7 (2)	0 to 3 (1)
Drainage Density (mi/mi^2)	xx (3)	xx (2)	xx (1)
	High	**Moderate**	**Low**
Planning Watershed Rating	10 to 12	6 to 9	4 to 5

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Road Condition Monitoring – Concept Proposal

This document describes a concept proposal to monitor changes in key indicators of forest road performance that result from the implementation of the "Road Rules, 2013 Rule Package" (Road Rules). The proposed monitoring approach is part of a broader strategy to evaluate ecological performance in non-federal forestlands regulated by the California Forest Practice Act and Rules. Roads can alter hydrologic and geomorphic process in ways that can adversely impact aquatic ecosystems (Luce and Wemple, 2001) (Figure 1). As such, a process-based evaluation of the effectiveness of the Road Rules is vital to assessing the overall ecological performance of the California Forest Practice Rules and other forestry-related laws and regulations.

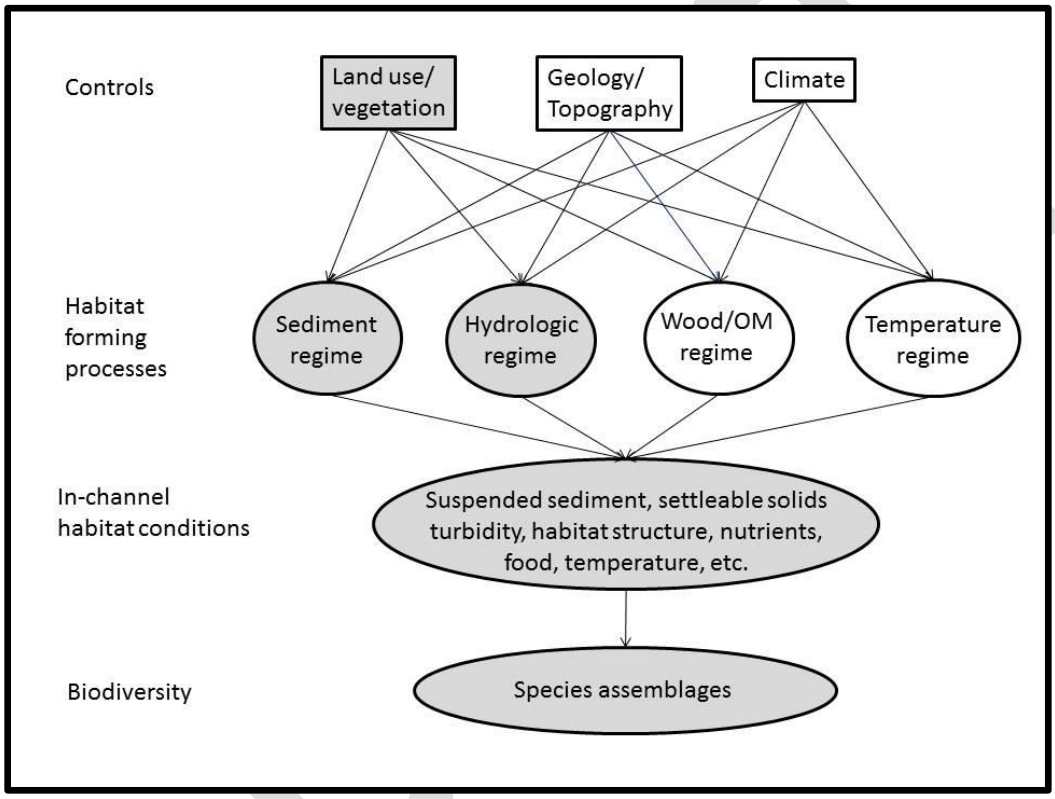

Figure 1. A simplified schematic diagram representing "ecological performance" for a riverine aquatic ecosystem. Shaded boxes represent elements of ecological performance potentially addressed directly or indirectly through a Road Rules effectiveness monitoring study. OM stands for organic material (modified from Beechie and Bolton, 1999).

Road Condition Monitoring (RCM) is part of an overall tiered monitoring strategy related to the evaluation of the Road Rules (Figure 2). Implementation of individual elements of the Road Rules can be monitored through existing monitoring programs such as the Forest Practice Rules Implementation and Effectiveness Monitoring program

(FORPRIEM). However, existing monitoring programs stop short of providing the necessary process-based information to link rules and best management practices to the resource(s) of concern (e.g., water quality, salmonid habitat condition, ecosystem function). RCM provides the intermediate step by assessing the integrated effects of the Road Rules on minimizing hydrogeomorphic process alterations that can drive ecosystem response. The final and most rigorous step would be that of validation/research monitoring, where the suite of Road Rules are evaluated to determine if they prevent significant sediment discharge, impacts to the beneficial uses of water, and aquatic species of concern (Figure 2). Validation monitoring is beyond the scope of this proposal but could be incorporated into future studies at intensively monitored watersheds such as Caspar Creek or Judd Creek.

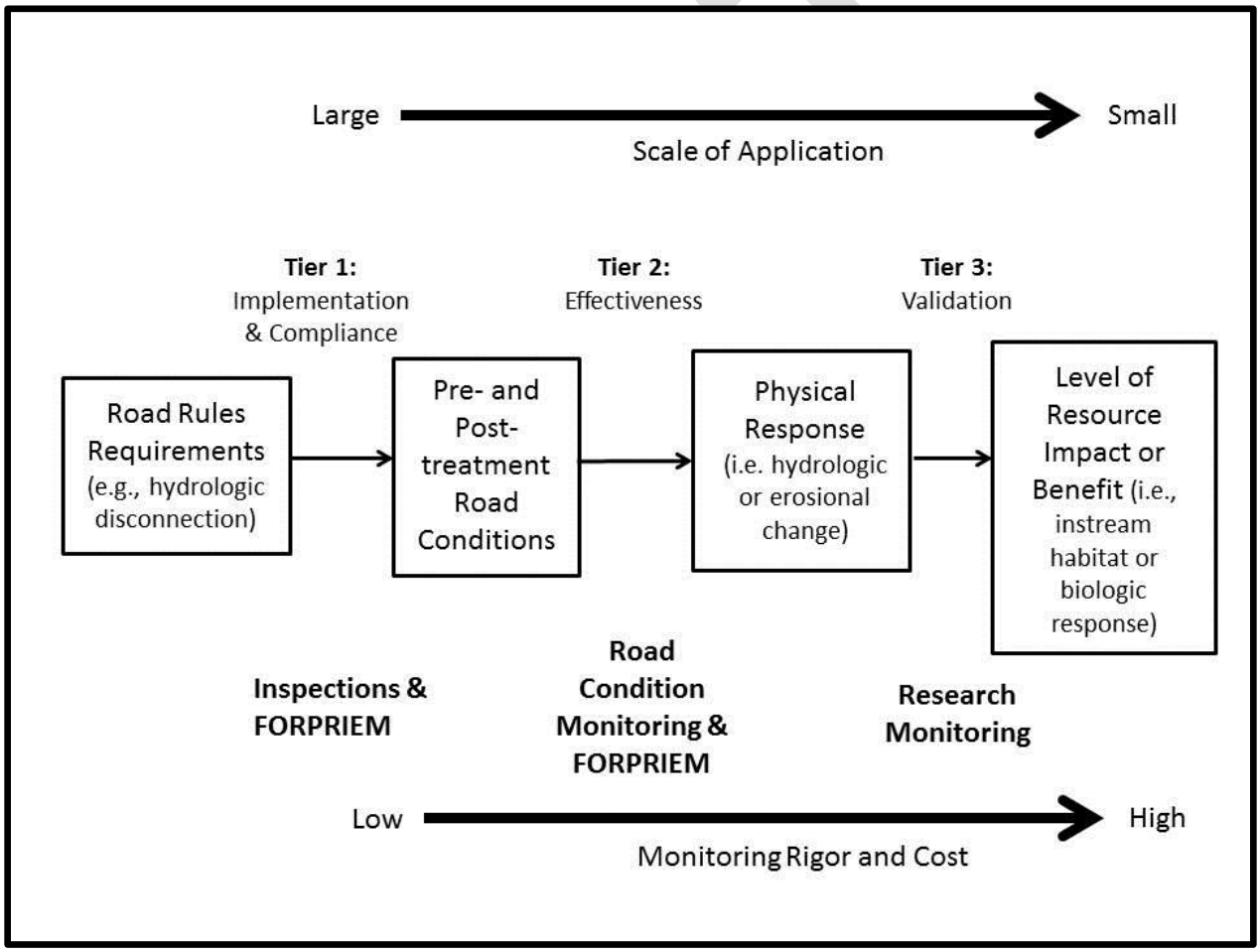

Figure 2. Schematic of a suggested tiered monitoring approach to address the Road Rules (adapted from Veldhuisen et al., 2000 and Raines et al., 2005)

General Monitoring Approach

Roads alter hydrologic and geomorphic processes (Luce and Wemple, 2001), which increases sediment and runoff delivery to watercourses, and can potentially affect beneficial uses and aquatic ecosystem function. Road Condition Monitoring would address how effective the Road Rules are at decreasing the magnitude of erosion, runoff, and sediment delivery at the road segment and THP/plan scale.[1]

Uncertainty regarding the effectiveness of the Road Rules can be addressed by posing the following general monitoring questions:

General Monitoring Question 1: Have road attributes that affect surficial sediment production (i.e., surface erosion) and delivery improved after implementation of the Road Rules?

General Monitoring Question 2: Have road attributes that affect mass wasting and the delivery of mass wasting sediments improved after implementation of the Road Rules.

RCM is intended to address general monitoring question 1, as general monitoring question 2 (i.e., road-related mass wasting) would require a more process-specific sampling strategy.[2] Since the connectivity and erosion potential of the connected road segment controls the magnitude of sediment delivery, the question can be addressed through the development of the following specific monitoring questions:

Specific Monitoring Question 1: Has the length/area of roads draining to watercourses decreased after the implementation of the Road Rules?

Specific Monitoring Question 2: Have the road attributes affecting surface erosion for connected road segments improved since the implementation of the Road Rules?

These specific monitoring questions allow us to generate some initial testable hypotheses such as:

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[1] Some data on previous road rule requirements and their effectiveness exist from past monitoring work conducted as part of the Hillslope Monitoring Program (Cafferata and Munn, 2002). For example, 85% of gullies recorded on random road transects and 70% of rills documented were judged to be caused by road drainage feature problems. Highly erodible surface material and steep road gradient were also frequently cited causes of rilling (see Table 11). Data collected from the FORPRIEM monitoring program (Brandow and Cafferata, in preparation) may be able to be used to beta test some of the parameters being considered for Road Condition Monitoring.

[2] Road Rules effectiveness monitoring related to mass wasting would likely utilize a post-mortem approach where a threshold storm of a predetermined recurrence interval would trigger post-storm sampling. A landslide triggering storm event is necessary to evaluate the effectiveness of the Road Rules related to mass wasting (for example, see Robison et al., 1999).

H_o 1: No reduction in road drainage connectivity to streams has occurred since implementation of the Road Rules[3].

H_A 1: Road drainage connectivity has been reduced after implementation of the Road Rules.

H_o 2: No improvement in road attributes that affect sediment production for connected road segments has occurred since implementation of the Road Rules.

H_A 2: Improvement in road attributes that affect sediment production for connected road segments has occurred since the implementation of the Road Rules.

Testing these hypotheses requires collecting road information at the THP/plan scale for hydrologically connected road segments. Information on the conditions (i.e., variables) that drive sediment production and delivery will be collected pre- and post-Road Rule implementation. Pre- and post-implementation data will also be compared against a theoretical target. For instance, could more have been done to minimize sediment delivery in a cost-effective manner? The preliminary list of proposed monitoring variables is listed below. Arrows indicate the dependence of sediment production on increases in each road attribute (e.g., sediment production goes up as road length increases):

1. Road length ↑
2. Road slope ↑
3. Road width ↑
4. Road drainage configuration (e.g., crowned, outsloped, insloped) ↕
5. Surfacing ↓
6. Presence and dimensions of erosion features (e.g., gullying, rutting, rilling, mass wasting features, etc. ↑
7. Ditch length ↑
8. Ditch width ↑
9. Ditch condition ↕
10. Soil type/erodibility class (e.g., EHR)
11. Slope stability class/rating
12. Drainage outlet condition ↕
13. Cutslope height ↑
14. Cutslope angle
15. Cutslope cover ↓
16. Fill height ↑

[3] Hydrologic disconnection has been required for areas governed by the Anadromous Salmonid Protection Rules since 1 January, 2010.

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17. Fill cover ↓
18. Connectivity class ↕ (see Table 1 for example)

These data can be used to test the null hypotheses presented in the preceding section. Changes in sediment production for connected road segments can be demonstrated by assessing changes in individual attributes (Figure 3), or by combining attributes into sediment production indices (Figure 4). For example, the product of road length and slope raised to an exponent between 1 and 2 (LS^n) is a commonly noted index of sediment production (Luce and Black, 2001; Ramos-Scharron and MacDonald, 2005), and the index provides recognition that some attributes are more important controls than others (i.e., slope). The data can also be integrated into a single metric of sediment production through the use of models (e.g., SEDMODL2, Road:WEPP, GRAIPE Lite). The benefit of modeling sediment production is that it takes into account the suite of interacting practices used to decrease road sediment production (e.g., road rocking and improved drainage). The disadvantage of modeling sediment production is that the absolute values of model outputs can be taken out of context. As such, it is suggested that modeled outputs be presented in a relative fashion, such as a percentage increase or decrease in sediment production relative to pre-implementation.

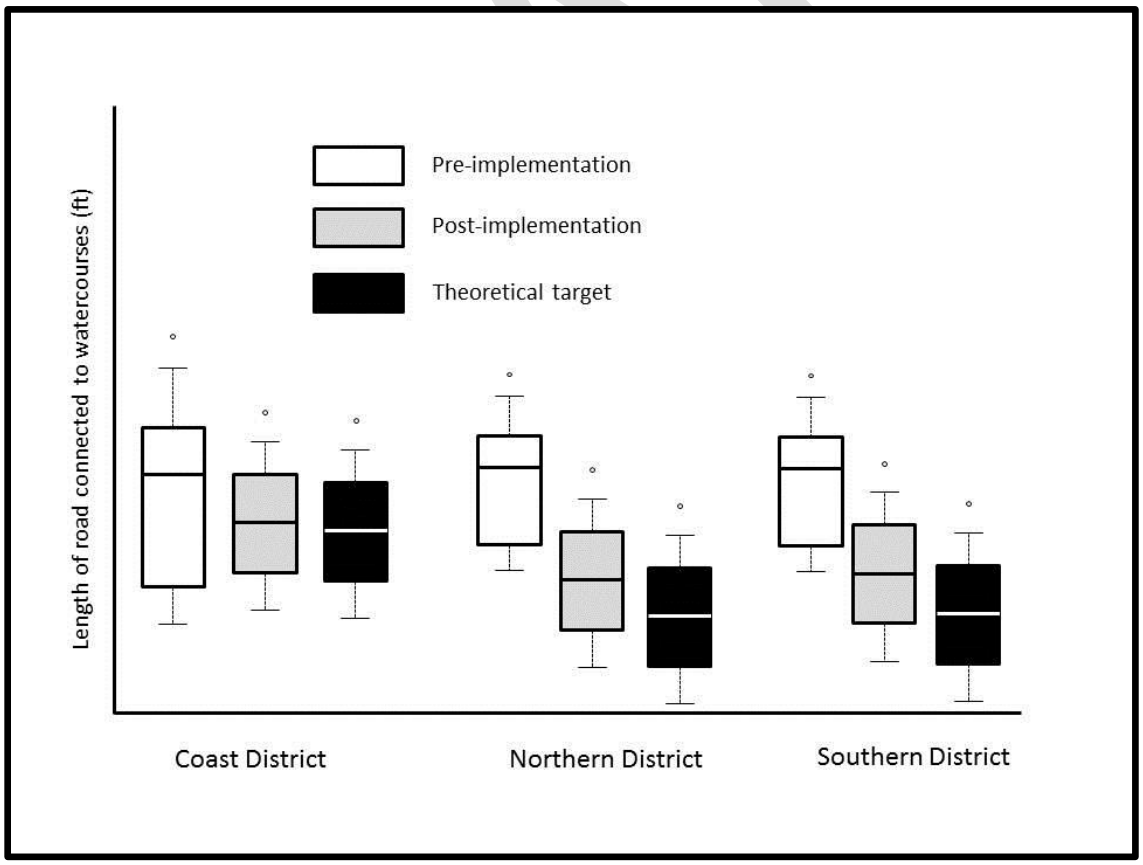

Figure 3. Hypothetical change in hydrologic connectivity for Timber Harvesting Plans by Forest Practice District pre- and post-implementation of the Road Rules. Reducing the length of connected roads decreases the likelihood for hydrologic and geomorphic impacts. The theoretical target refers to the least amount of road connected as per Technical Rule Addendum #5.

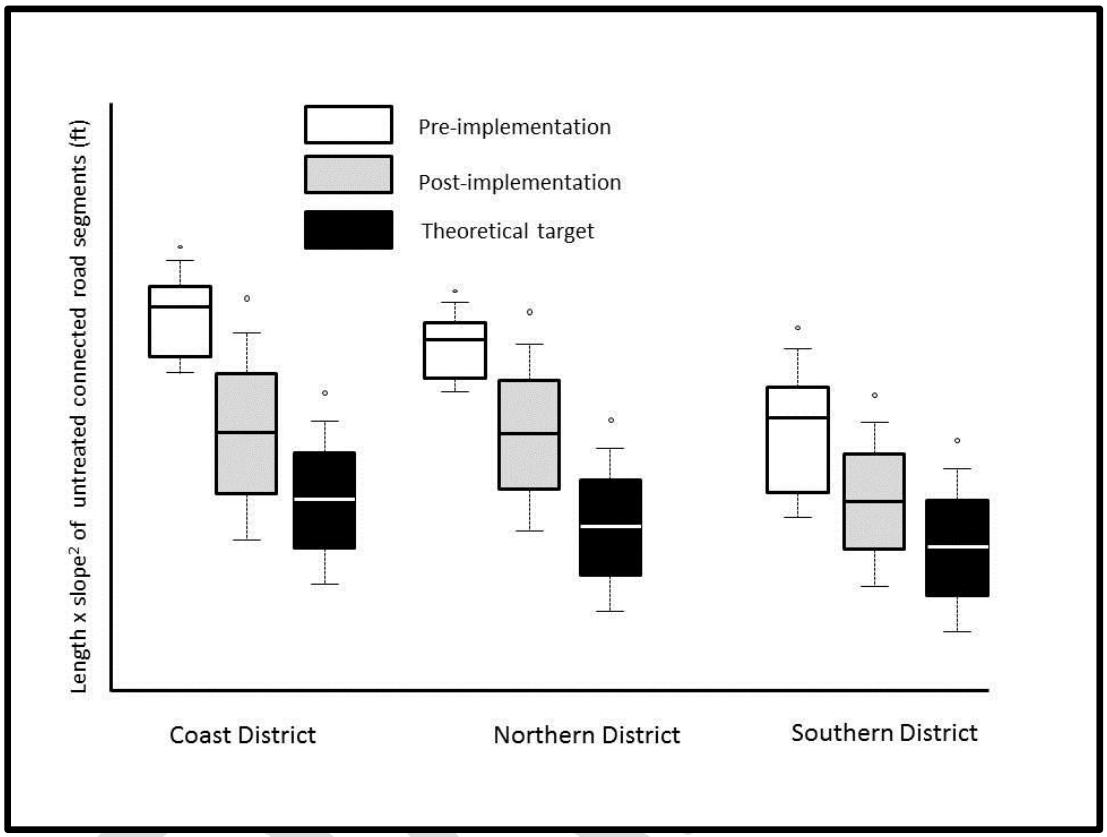

Figure 4. Hypothetical change in the length-slope product (LS^2) for connected road segments treated for surface erosion. LS^2 is highest for longer and steeper road segments. Higher values of LS^2 for connected road segments treated for erosion control represents a decrease in sediment delivery.

Table 1. Connectivity classes for the RCM proposal. Different classes have different causal mechanisms for hydrologic connectivity and different assumptions regarding the magnitude of sediment delivery. Tracking changes of road length/area by connectivity class will provide information on the effectiveness of the Road Rules.

Connectivity Class	Visible Geomorphic Impact	Sediment Delivery Potential	Percent of Sediment Delivery
0	No signs of connectivity below waterbreak outfall with or without evidence of sediment transport	None	0
1	Drains directly into watercourse at a road crossing.	High	100
2	Evidence of diffuse sediment deposit below drainage outlet that is within 50 feet of the bankfull (high flow) watercourse channel	Low/Moderate	35
3	Evidence of diffuse sediment deposits within 50-100 feet of the bankfull (high flow) watercourse channel	Low	10
4	Direct delivery below waterbreak outfall; is connected to watercourse via gully or landslide scar	High	100

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