Eastside Type N Riparian Effectiveness Research Alternatives

Context

Washington State Forest Practices are regulated by means of the Forest Practices Act (Title 222 WAC) and Forest Practices Rules adopted by the Washington Forest Practices Board (WFPB). The WFPB is charged with developing rules that protect the state's public resources while maintaining a viable timber industry. Since much of the land regulated under the act contains habitat for aquatic and riparian-dependent species that have been, or may be, listed under the Federal Endangered Species Act (ESA), the Washington Department of Natural Resources (WDNR) has developed a Forest Practices Habitat Conservation Plan (FPHCP) to provide Federal Assurances that the rules will meet the requirements of the ESA and Clean Water Act (CWA).

The WFPB has set up a formal science-based Adaptive Management Program (AMP) to provide technical information and science-based recommendations that will assist the WFPB in determining when it is necessary or advisable to adjust rules and guidance to achieve the FPHCP resource objectives. The resource objectives are to ensure that forest practices will not significantly impair the capacity of aquatic habitat to: a) support harvestable levels of salmonids; b) support the long-term viability of other covered species; or c) meet or exceed water quality standards, including protection of beneficial uses, narrative and numeric criteria, and antidegradation (WAC 222-12-045).

The WFPB has empowered the Cooperative Monitoring Evaluation and Research committee (CMER) and the FF policy committee (Policy) to participate in the AMP (WAC 222-12-045(2)). In 2012, the WFPB directed CMER to pilot a LEAN process for developing a research alternatives document and study design for the Eastside Type N Riparian Effectiveness Project (ENREP). Per the new 'pilot' process, a Technical Writing and Implementation Group (TWIG) was been formed to develop options for addressing questions related to the effectiveness of riparian prescriptions for non-fish bearing (Type N) streams in eastern Washington.

<u>The Eastside Type N Riparian Effectiveness Project TWIG:</u>

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Rule Group:	Type N Riparian Prescriptions	
Rule Context:	WAC 222-30-022	
Research and Monitoring Program	Effectiveness Monitoring	
2014 Budget	$75,000	

Issue/Problem Statement

The ENREP is needed to determine if, and to what extent, the prescriptions found in the Type N Riparian Prescriptions Rule Group are effective in achieving performance targets and water quality standards, particularly as they apply to sediment and stream temperature in eastern Washington.

Importance of the Issue

Headwater streams make up a large portion of the total stream length and are important sources of sediment, water, nutrients, and organic matter to downstream fish bearing streams (Gomi et al., 2002). Type N Rule Group prescriptions are intended to protect functions provided by the Type N network, yet the effectiveness of the rules remains largely untested. Given the scientific uncertainty of the Type N rules, CMER has ranked the Type N Riparian Effectiveness Program first in importance among 16 research programs:

> "The effectiveness of the Type N riparian management prescription package is uncertain because there are many gaps in the scientific understanding of headwater streams, their aquatic resources, and the response of riparian stands, amphibians, water quality, and downstream fish populations to different riparian management strategies. Consequently, prescriptions are based on assumptions that have been neither thoroughly studied nor validated" (CMER Work Plan, 2014).

Scientific Uncertainties and Complexity:

Headwater basins exhibit a particularly large amount of natural variability because they are the landscape elements where hillslope processes transition into stream networks (Montgomery, 1999; Gomi et. al., 2002). The discharge regime of headwater streams exerts fundamental control over a number of functions including water temperature and sediment transport. Although the effect of forest management on discharge has been studied for more than half a century, it is still not possible to fully predict management-related changes in discharge timing or magnitude, because of the large variability in headwater attributes and functions. In addition to the large variability characteristic of all headwater streams, many eastside Type N streams contain varying lengths and configurations of dry channel, and some have no surface connection to the downslope stream network. These hydrologic characteristics introduce added variation and complexity into the relationships between forest practices and aquatic functions including the transport of wood, sediment, thermal energy, nutrients, and detritus, as well as the maintenance of aquatic habitat quality.

Purpose Statement

The ENREP study will help determine how well the current Type N rules are protecting water quality and some riparian functions. As acknowledged by Policy (6/20/2013), this study will focus on changes in water temperature and sediment, but will consider other resource objectives as constraints allow.

Relationship to Other Studies:

The ENREP study is a successor to the eastside Forest Hydrology Study (FHS) which describes the spatial distribution of late summer flow and channel characteristics in eastern Washington Type N streams. As part of the CMER Type N Riparian Effectiveness Program, the ENREP study is a companion to:

- The Westside Type N Buffer Characteristics, Integrity, and Function (BCIF) Project;
- The Westside Type N Experimental Buffer Treatment Project in Hard Rock Lithologies;
- The Westside Type N Experimental Buffer Treatment Study in Incompetent Lithologies;

Objectives, Critical Questions, and Data Requirements[1]

The objectives of the ENREP study are to: 1) quantify the magnitude of change in stream flow, canopy closure, water temperature, suspended sediment transport and wood loading within eastern Washington riparian management zones (RMZ) following harvesting within current rule constraints, and 2) evaluate the effects of these changes on downstream waters where possible.

It is expected that completing these objectives will allow us to start to answer the critical question: "Are riparian processes and functions provided by Type Np buffers maintained at levels that meet FPHCP resource objectives and performance targets for shade, stream temperature, LWD recruitment, litter fall, and amphibians?" (FY 2014 CMER Work Plan).

Meeting these objectives and answering the critical question will require a study that tests for changes in resource conditions that result directly from the application of eastern Washington Type N riparian prescriptions (WAC 222-30-022(2)), or other prescriptions that are consistent with achieving the performance goals of FFR (Schedule L-1: Overall Performance Goals).

Options / Alternative Approaches:

The following section briefly outlines potential research approaches and study types that might be employed, and evaluates the benefits and limitations of each for meeting the objectives and answering the critical question in this study. This is step 4 in the TWIG process. If Policy approves follow-up work on an alternative, a study design will be developed. The study design will contain detailed methods for site selection and layout, data collection and analysis.

Meta-analyses

Meta-analyses include literature reviews, syntheses of existing studies, and other methods that contrast and combine results from multiple studies to identify common patterns among study results, sources of disagreement among those results, or other useful relationships that may come to light in the context of multiple studies. Meta-analyses can provide an estimate of the effect size by applying a weighted average to the results of multiple studies and accounting for differences in study assumptions and conditions.

Benefits: Literature reviews and syntheses provide information regarding what is and is not known on the subject matter and what study approaches have or have not been successful. Where

[1] These were validated by Policy on June 6, 2013.

results from numerous studies are available, meta-analyses can be an effective technique for estimating effect size, which may be particularly useful for power analyses. Meta-analyses utilize existing information, so costs are primarily associated with the review and synthesis.

Limitations: Meta-analyses require the availability of information on the processes and impacts of interest, within relevant physical settings. In central and eastern Washington few relevant studies have been conducted, and high-quality data are rare. More broadly, very few studies have been conducted that will provide rigorous estimates of effect sizes for defensible conclusions regarding the effectiveness of eastside forest management practices.

Decision support systems

Decision support systems are formalized methods for integrating information of various types and sources that are used to document and support the decision making process. Decision support models can be used for ecological assessment at any temporal or spatial scale and their value for forest management decision making is well established (Reynolds, 2005). Because they are based on computerized algorithms, they promote consistent decision making and models can be refined and updated as new information becomes available and the understanding of the relevant ecological processes increases. Ecosystem Management Decision Support (EMDS) is an example of software used to develop and run decision support models, which is particularly focused on landscape evaluation and planning (http://www.spatial.redlands.edu/emds/).

Benefits: Decision support systems represent a formalized system for making use of existing information and expert knowledge, so the costs are mostly limited to analyses. This approach can be particularly useful as a “stop-gap” measure for reaching tentative conclusions and formulating recommendations when available data are inadequate for more quantitative, statistical or numerical analyses.

Limitations: These methods require relevant information or expert knowledge of the processes and impacts of interest. For the critical question in this study, ‘are current Forest Practices Rules (circa 2001) effective in protecting water quality’, the needed information does not exist, and expert opinion would be contingent on current literature, extrapolation from other regions, and assumptions with uncertain validity. Stakeholders may have limited confidence in resulting conclusions.

Physically-based modeling

A hydrological model can be used to predict the impact of management prescriptions on a forested watershed’s hydrological response without some of the limitations of analyses based on field data. Models can be run using fixed vegetation conditions and are, therefore, not confounded by post-impact forest regrowth. Alternatively, models can simulate particular vegetation scenarios to estimate effects of change (VanShaar et al. 2004). For example, Bowling et al. (2000) employed the Distributed Hydrology-Soil-Vegetation Model (DHSVM) to examine potential changes in peak flows related to logging in three western Washington basins. Forcing variables required by DHSVM include precipitation, air and dewpoint temperature, cloud cover, incoming shortwave and longwave radiation, windspeed, vegetation, soils, and elevation. The model was calibrated with data from a 45-month period using a fixed vegetation condition and was used to simulate a control for the treated basins. In another example, Seibert et al. (2010) employed the conceptual HBV hydrologic model to compare simulated peak flows before and after wildfire in three small basins in interior Washington.

Benefits: Once a model has been calibrated, it can be used to predict what would have occurred without intervention and is therefore a substitute for temporal control. Modeling can also be useful in predicting the effects of alternate prescriptions or predicting the effects of change that is problematic to test empirically (e.g., effect of wildfire on peak flows).

Limitations: Most physically-based hydrologic models require several years of both pre-and post-disturbance data, and physically based models for water temperature and sediment transport require large quantities of forcing data for full calibration. Such models are also restricted to our current scientific understanding and the variability of the processes and environmental attributes being examined, thereby creating “parameter uncertainty”.

<u>Empirical research</u>

Empirical research involves obtaining information through direct or indirect observation. This has been CMER’s primary method for information gathering and evaluating rule effectiveness.

Direct observation typically requires some type of field study with site visits. The physical presence of the researcher allows for additional insight beyond what is provided for in the study design, and allows for adjustments to monitoring in response to unforeseen events. Field studies require landowner consent, and are typically conducted over relatively small spatial domains (e.g., site or harvest scale) because of physical and cost constraints. Remote sensing is an alternative to on-site data collection. The term ‘remote sensing’ is generally used in reference to the collection of electromagnetic signals using aircraft or satellites and it has been successfully used to generate information on surface water temperature (passive thermal infrared), vegetation change (passive multiple spectrum), and changes in topography created by sediment transport process (active LiDAR and passive air photo analysis). Airborne remote sensing is particularly useful for collecting data over large spatial domains and in situations where ground access is limited, but the resolution in both space and time is typically low.

Regardless of the method of observation, an empirical approach to the Critical Question presented here must separate natural variability (noise) from the effects of forest practices prescriptions (signal). Natural variability of headwater streams is large, and forest practices rules were developed for the express purpose of minimizing the effect of forest practices, so the signal to noise ratio is expected to be small. An empirical approach to ENREP must therefore incorporate a design that attempts to account for all sources of variability in order to focus the analysis on the effects of interest. The design should also include some level of randomization and replication. Randomization is important, because deliberate selection of sites may create bias in known or unknown ways, and replication gives confidence that the results are broadly applicable.

The discussion below presents some common empirical study designs and addresses the extent to which they maximize the statistical power to detect change and, if change is detected, facilitate testing the inference that the intervention caused the observed effect.

BACI Designs:
When control and impact locations are monitored both before and after intervention, the approach is referred to as Before/After – Control/Impact (BACI). Several variations of the BACI design are in use and they are often considered the gold standard for inferring cause and effect in natural resource studies because they account for both spatial and temporal variability (Downes et al., 2002).

Benefits: A well-designed BACI study, with sufficient sample size and replication, would provide a high degree of statistical power to detect change and strong inferential capability as to the effectiveness of the Forest Practices Rules. Both of CMER's westside Type N buffer effectiveness studies use replicated BACI designs.

Limitations: Replicated BACI designs are relatively expensive because both reference and treatment sites must be monitored before and after impact.

Before-After (BA) Designs:
This approach could have many variants, including monitoring selected stream attributes before and/or after an intervention. The distinction between BA and BACI is the lack of controls.

Benefits: BA designs require less effort than a complete BACI study, and therefore would be less expensive to conduct, facilitating more and/or larger study areas. Results could be used to establish correlations, develop hypotheses, or lend support to hypotheses identified by other research.

Limitations: In the absence of control sites, such a study might detect a change in stream temperature, but would be unable to demonstrate that the observed difference was caused by the intervention. There would be no assurance that the change had not also occurred where no treatment took place. Stream temperature varies widely with climate and other time-variable factors, so determining the cause of a change requires knowing whether the observed post-treatment stream temperature was greater or less than what would have been observed if no treatment had been applied. Control sites provide a reliable indicator of this information.

Observational Designs:
Observational studies usually entail analysis of correlations among environmental parameters, such as studying the correlation between water temperature and time since harvest. These designs may include space for time replacements (stands of different ages) and/or reference sites. This approach is similar to the one used in the Mass Wasting Effectiveness Study, and it can be used to evaluate how site conditions (e.g., number of landslides, absolute water temperature) change through time and how those conditions compare against reference sites.

Advantages: This design may require less effort than experimental studies and therefore may be less expensive to conduct or can include more or larger study areas, and they may be the only practical method for empirical research associated with treatments that clearly create harm (e.g., wildfires, mass wasting).

Disadvantages: Like BA designs, observational studies may be confounded by unknown factors, and are primarily used to establish correlations, develop hypotheses, or lend support to hypotheses identified by other research. The lack pre-treatment data eliminates the potential for quantifying change at a site, while the lack of controls limits the ability to infer that the observed condition is related to the independent variables of interest. Even with reference sites, site variability contributes to pooled variance and reduces statistical power.

Best Available Science Comparison

Empirical research is the only approach that allows for direct testing of the current Forest Practices Rules. Meta-analysis and decision support systems rely on existing information and to our knowledge there is no existing research that examines the relationship between water quality and current Forest Practices Rules (circa 2001) in eastern Washington. Physically based modeling is another useful approach, but data requirements for model parameterization and calibration make it a complement to empirical research rather than an alternative to it. Given that the processes of interest change over very small spatial and temporal scales, data collection via airborne remote sensing is unlikely to be feasible, and field studies will almost certainly be required. The need to test for causation in a system designed (but untested) to have a negligible effect size (management impact) almost certainly requires an experimental design.

CMER has previously developed study designs for headwater networks with relatively constant unit area discharge and contiguous surface flow paths for material and energy transport. In these systems, it is assumed that water temperature change can be modeled using fairly simple conceptual models of stream heating and cooling (Caissie et al., 2007; Moore et al., 2005). Preliminary results from the eastside FHS indicate that some eastern Washington Type N basins exhibit hydrologic characteristics that are similar to those that form the basis for the westside studies. While some basins do conform to the 'westside' conceptual model for headwater streams, most eastern Washington Type N basins do not. For example, 86 of the 100 Type Np basins surveyed for the FHS contained dry channel below the uppermost point of surface flow during late summer, and dry Np channel accounted for 21% of the total Np channel length surveyed. Dry channels below the uppermost point of flowing water indicate decreasing specific discharge during later summer, and these systems are likely to require different conceptual models for material and energy transport, and therefore different study designs for evaluating the effects of forest practices.

Recommended (Approach):

Ideally, the ENREP would be able to provide information about rule effectiveness across all of eastern Washington, but the testing of specific hypotheses requires that variability be minimized in order to more accurately estimate effect size for a given population. Information from the FHS indicates that variability of discharge in Type N streams is far greater than previously recognized. As a result, it is likely that the ENREP study will only be able to address some of the resource objectives over a limited range of geophysical conditions and/or management strategies. Hypothesis testing for other resource objectives, alternate rules, and/or physical conditions will require additional research to provide more information about the distribution and duration of dry Type N reaches.

The TWIG has identified a two-part approach that (1) provides for the evaluation of rule effectiveness on Type Np streams with spatially-continuous flow while (2) facilitating the development of a study design to evaluate effectiveness on spatially-discontinuous Type Np streams. Both approaches will utilize FHS modeling efforts to evaluate the distribution of flow regimes that would or could be addressed in each study, including an estimate of the geographic representativeness and applicability of the study to the AMP.

1. **Develop a version of the westside Type N experimental study design modified for use on eastside Type Np basins with spatially-continuous stream flow**.

The westside Type N studies use an empirical approach with a replicated BACI experimental study design. The conceptual model of basin hydrology that the design is based upon is appropriate for Type N basins with continuous stream channels with moderate gradient (e.g., flowing) and relatively constant (or slowly changing) unit discharge. Data from the FHS suggests that there is a significant population of Type Np basins in eastern Washington that conform to this model. This approach would use predictions obtained from the FHS logistic modeling efforts to target basins that conform to this conceptual model (continuous surface flow), and use a modified version of the westside-style Type N Effectiveness study design.

This approach would build upon previously accepted westside study design efforts that, with modification, are well suited for eastside applications. Modifications would include adjustments for differences in available timber harvest strategies, basin area, and other issues including alternate harvest strategies within current rule constraints and potential inclusion of effects on downstream Type F waters, including downstream temperature response.[2] The effort required for modification would be relatively small when compared with developing and approving an entirely new study design, and could significantly reduce implementation time

This approach is likely to require a budget and timeline similar to the Westside Type N Experimental Buffer Treatment Study in Incompetent Lithologies (“SoftRock”).

2. **Conduct follow-up research on eastern Washington Type Np basins with spatially discontinuous surface flow.**

In order to evaluate the effect of Forest Practices Rules on Np streams that have a substantial length of dry Np channel, it is important to improve our understanding of the temporal variability in discharge, including the seasonal connectivity and persistence of dry reaches. The length of

[2] In their 6/6/2013 Memo, Policy directed the TWIG to consider alternate harvest strategies within current rule constraints, but the memo did not mention any specific alternate strategy. If a study design is developed for this approach, Policy will need to help identify specific strategies that are candidates for inclusion as a manipulative treatment.

time and seasonal timing of surface flow has significant implications for the transport of wood, sediment, thermal energy, nutrients, and detritus, as well as the quality of aquatic habitat. These are fundamental components of the ecological function of headwater streams, and directly relevant to the FPHCP resource objectives.

The FHS demonstrates that eastside Type N streams vary widely in length, proportion, and configuration of dry and disconnected reaches. For example, some Type N streams have several dry reaches interspersed with reaches of flowing water. Other streams have only a single dry reach, but its location along the stream length varies among streams. Many other configurations are also present. In addition to large spatial variability, the duration of any configuration of dry reaches is likely to vary. Some reaches may be dry for only a few days per year, while others may contain flowing water for only a few days. The FHS provides no information regarding temporal change in discharge, because it is based on a single pass survey collected during what is assumed to be the driest portion of the year.

Constantz (1998) found that diurnal variations in headwater stream temperatures in the Sierra Nevada Mountains were heavily influenced by whether the stream was gaining or loosing water, and that diurnal stream temperature variation was as much as 40% of the total seasonal variation. Story and colleagues (2003) reported that stream temperature in a shaded reach below a clearing-heated reach varied over the periods of study depending on whether the study reach was gaining or losing water, flowing entirely subsurface, or affected by groundwater or hyporheic exchange. Studies also suggest that temporary streams with flow durations greater than 4 to 5 months are likely to have similar faunal assemblages, whereas the life cycles of macroinvertebrates are altered in streams with less than 3 months of surface flow (Gomi et al., 2002).

The second part of the preferred approach includes empirical case studies to build upon the spatial data gathered in the FHS by evaluating how the extent (and perhaps volume) of surface flow changes in both space *and* time in eastern Washington Type Np basins. These data are required in order to develop conceptual designs for quantifying the effects of forest practices on discontinuous Np streams in eastern Washington. In order to minimize noise, researchers will need to identify systems (subpopulations) that are likely to behave similarly and to group them together for study. Eastside Type N streams may include several distinct subpopulations that would need to be investigated and analyzed separately to avoid contradictory results caused by sampling across them.

This approach is likely to require a budget and timeline similar to the Eastside Forest Hydrology Study.

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