STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

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Conducting Large In-stream Wood Studies: A Call for Common Metrics

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Decades of large in-stream wood studies have documented the role of large wood in controlling channel morphology and fluvial processes, regulating the storage and transport of sediment, organic matter, and nutrients, and providing cover, shelter, and feeding opportunities for fish and other aquatic organisms (fig. 1). Some recent studies on large in-stream wood have begun to take a more holistic perspective, incorporating processes of wood recruitment, retention, and loss at scales from channel segments to entire watersheds. The large number of studies on the physical and ecological effects of wood has also lead to several syntheses of in-stream wood characteristics and dynamics. These syntheses have been useful in identifying regional patterns and gaps in knowledge, but stronger inferences have been hampered by the inherently high spatial and temporal variation of in-stream wood and by measurement error. Our review of numerous in-stream wood studies also revealed inconsistencies in the type of variables measured and methods of measurement. The objectives of this paper are to list the variables that we consider fundamental to studies of in-stream wood, discuss the sources of variability in the measurement of in-stream wood metrics, and suggest additions to study designs and reports that would enhance the value of individual in-stream wood studies. Agreement on the measurement and reporting of variables could resolve some of the uncertainties in understanding in-stream wood patterns.

What is In-stream Large Wood?

The most fundamental questions that need to be first addressed when conducting a large wood study are determining 1) the minimum dimensions of the wood pieces to measure and 2) what portion of the wood piece should be measured. The decision about piece inclusion can be scaled to stream dimensions, such as channel width, which govern storage and transport. In many studies, however, the selection of the minimum dimensions of pieces that constitute large wood is somewhat arbitrary. For example, wood pieces measured typically have diameters ranging between 5 and 20 cm and minimum lengths ranging between 1 and 3 m. Although some have argued

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Figure 1. Photographs showing different examples of large wood distributed within and along several stream channels. Upper left photo: War Creek, WA (Okanogan-Wenatchee National Forest). Upper right photo: Schafer Creek, WA (Olympic National Forest). Lower left photo: South St. Vrain Creek, CO (Arapaho-Roosevelt National Forest). Lower right photo: Peavine Creek, CA (Tahoe National Forest).

that retaining these dimensions facilitates comparisons with studies of terrestrial large-diameter fuels or large wood in other aquatic systems, a more fluvial geomorphology relevant standard may be to derive the minimum dimensions from the prevalence of wood piece sizes in the channel and riparian zone.

Other differences between studies involve including or excluding the measurement of wood pieces that lean over or bridge a channel. It seems reasonable to measure the portion of wood that falls within the bankfull channel dimensions and to characterize the remainder of the piece as being within the riparian zone. This is especially relevant if the in-stream wood piece is part of a living tree. Similarly, sometimes only the part of a piece above a minimum diameter is measured. Although this has minimal influence on wood volume estimates, it can positively bias the mean diameter of wood pieces measured, negatively bias the mean length of wood pieces measured, and obscure relations between in-stream wood and riparian wood.

For any in-stream wood study, it is important to clearly state the minimum size criteria and inclusion rules to be used for measuring wood pieces. Ideally, wood measurement data should be included in an appendix or electronic data repository so that other investigators can sort the data to meet different criteria (e.g., remove all wood pieces with diameters less than 10 cm where 5 cm was the minimum diameter used in the study).

Suggested In-stream Wood Metrics

We identified 35 core variables to measure and report when conducting an in-stream wood study based on their use and importance in previous studies and from our collective field experience (table 1). Each of these variables relates either to the size and characteristics of in-stream wood, to the geomorphic features of the channel and valley, or to the ecological characteristics of the riparian zone adjacent to the study channel reach. Of the 35 variables listed in table 1, the 23 level I metrics are recommended to be included in all in-stream wood studies, whereas the 12 level II variables are those metrics for studies with more specific objectives. Wood variables include the size, orientation, and characteristics of wood in the bankfull channel, as

Table 1. Suggested metrics for research-oriented in-stream wood studies. Level I metrics are those that we propose should be included in all studies; Level II metrics are those that are more study specific.

Metric, Level	Measurement Notes
Wood – measured for each piece	
Level I	
1. Length	Whole piece and length in bankfull channel
2. Diameter	One or more measurements per piece
3. Orientation	Angle with respect to downstream bank
4. Root wad	Note if present, including orientation with respect to flow
5. Jams	Spatial distribution and size (no. pieces per jam, or total dimensions of jam)
6. Accumulation[a]	11 categories
7. Status[b,c]	Decay class (six categories), burn status (three categories)
8. Stability[d]	Six categories
Level II	
9. Species	Note species or general category (e.g., deciduous/coniferous)
10. Submergence	Measure in relation to stage
11. Age	Tree-ring counting or radiocarbon dates
12. Biomass/density	Based on volume and wood density
13. Function	Characteristics of wood function include sediment storage (note if present; ideally, measure dimensions and grain size), pool scour (note if present; ideally, measure dimensions), backwater pools (note if present; ideally, measure dimensions), flow deflection, energy dissipation, and bank stabilization
Geomorphic (channel and valley) – measured for each reach	
Level I	
1. Channel gradient	Average streambed or water-surface gradient at study reach
2. Channel width	Average bankfull channel width at study reach
3. Flow depth	Either bankfull or at time of measurement
4. Grain size	Bed-material size distribution; D50 and sorting at minimum
5. Discharge	Bankfull, mean annual, peak annual, or at time of measurement
6. Reach length	Length of channel along which wood is measured
7. Channel morphology	Cascade, step-pool, plane-bed, pool-riffle, dune-ripple, braided
8. Drainage area	Area drained by study reach
9. Elevation	At study reach, and range for catchment
10. Valley side slope	Average or maximum side slope values
11. Confinement	Ratio of channel width/valley-bottom width
12. Connectedness	Ratio of channel width/distance to valley wall
13. Disturbance history	Wildfire, blowdown, insect infestation, hillslope mass movements, avalanches
14. Management history	Timber harvest, road density, tie-driven, dams, diversions, etc.
Level II	
15. Bank scour	Visual estimate of percentage of total stream bank length
Riparian – measured for each reach	
Level I	
1. Forested	Yes/no, deciduous/conifer, note cover type if not forested (e.g., willow or herbaceous dominated meadow, bedrock)
Level II	
2. Dominant species	Where forested, note forest type(s)/species of trees
3. Source[e]	Six categories
4. Seral stage	Young, mid-successional, or mature
5. Floodplain survey	Dimensions and spatial density of wood on forest floor
6. Basal area	Measure of the cross-sectional area of standing trees at breast height (may be measured by species)
7. Site potential	Rate of tree growth, time to reach maturity, longevity of trees

[a] *Accumulation classes: debris jam (part of a jam of three or more pieces), tree/rootwad (associated with a living tree or rootwad), boulder (associated with a boulder in the stream), meander (caught on the outside of a bend), bar (sitting on a point, alternate, or mid-stream bar), bedrock (caught on bedrock), beaver dam (incorporated in a beaver dam), bank (embedded in the bank, buried by soil or other bank materials), log step (forms a step in the stream, can be partially buried in streambed or not buried), buried in bed (portion of log buried in streambed, but not functioning as a step), none/other (specify if something else). A piece can have more than one class.*

[b] *Decay classes: rotten (very soft wood that can be pulled apart easily by hand), decayed (moderately soft wood that cannot be pulled apart easily), bare (no bark or most bark is gone), limbs (limbs still attached, may have most or all bark intact), bark (all bark intact, a relatively new piece of wood), needles/leaves (green or brown needles/leaves still attached, very fresh piece of wood, tree may appear to be living).*

[c] *Burn classes: unburned, partially burned, completely burned.*

[d] *Stability classes: unattached/drift (entire piece is contained within bankfull channel and no portion is buried or pinned), bridge (both ends above bankfull channel, center suspended above channel), collapsed bridge (two ends above bankfull channel, broken in middle), ramp (one end in channel, the other end above bankfull channel), pinned (all or a portion is lodged beneath other pieces of wood in the stream), buried (all or a portion is buried in the streambed).*

[e] *Source classes: unknown (source of wood cannot be determined), riparian (sources of wood appears to be valley bottom adjacent to the channel), hillslope (wood originates from a steeper landform adjacent to the valley bottom; either a depositional feature such as a moraine, or the valley wall), floated (fluvial transport from upstream), hillslope mass movement/debris flow, avalanche (recruitment via moving snow), bank undercutting, other (other clearly defined source such as debris flow; explained in comments section).*

well as functional parameters directly associated with wood. Geomorphic variables include the physical characteristics of the stream channel, valley, and drainage basin for the study reach. Each of the variables identified provides insight into the dynamics of wood recruitment and retention within a reach and facilitates comparisons among sites. Riparian variables include the ecological characteristics of the valley reach floodplain or riparian zone adjacent to the channel. The potential delivery distance of wood falling directly into the channel defines the riparian zone.

Additional Study Information and Needs

In addition to the 35 wood metric variables listed in table 1, an explanation of the overall study design deployed in the survey and classification of large wood should be included in publications on in-stream large wood. It is important to explain whether the study reach was chosen to represent particular characteristics of the area, to avoid certain types of management history, to facilitate repeated access, or based on other criteria. In many published papers it is often unclear how or why a particular study reach was chosen. This information is necessary and useful for determining whether a particular dataset should be included in a synthesis.

Very few wood studies provide estimates of in-stream wood loads. If all of the variables described in table 1 are listed in an in-stream wood study, readers can compute the volume of in-stream wood using one of the typical metrics (m^3/100 m, m^3/ha, pieces/100 m). Providing at least one of these wood load metrics in the study report would allow for better comparison between sites and regions.

There are relatively few short-term (<10 year) and even less long-term (≥10 year) published datasets on wood dynamics. Datasets based on monitoring of wood dynamics through time are extremely valuable in understanding temporal variations in wood recruitment, retention, and function, and there is a great need for more of them. For tracking individual pieces of large wood over time, we suggest nailing numbered metal tags into wood pieces during the initial and follow-up wood surveys. This will allow repeat surveys to record wood piece movement through time along with changes in the status, size, stability, and function of wood pieces between visits. New wood entering the study reach during the monitoring period can be readily identified and tagged. Repeat photography of a reach can also be used to document movement and recruitment of new wood.

Summary

Although the variables listed in table 1 may appear unmanageable, many of these variables rely on quick visual assessments or measurements derived from maps. Inclusion of these data in all studies of in-stream wood would substantially facilitate the insights and models that can result from inter-study compilations. The rapidly growing literature of wood characteristics and dynamics from diverse environments makes it particularly timely to propose standard techniques for measuring and reporting the variables. This in turn will allow us to assess regional differences in wood recruitment and retention within different portions of a watershed.

Additional Information

For a more in-depth discussion and complete list of references on this topic, please refer to the following publication: Wohl, E.; Cenderelli, D.A.; Dwire, K.A.; Ryan-Burkett, S.E.; Young, M.K.; Fausch, K.D. 2010. Large in-stream wood studies: a call for common metrics. Earth Surface Processes and Landforms. 35: 618–625. Copies of this article are available online at the STREAM website: http://www.stream.fs.fed.us/publications/documentsStream.html.

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Cumulative Watershed Effects of Fuel Management in the Western United States

Fire suppression in the last century has resulted in forests with excess biomass, leading to more severe and larger wildfires, requiring more resources for suppression and mitigation of wildfires, and causing increased onsite and offsite damage to forests and watersheds. Forest managers are now attempting to reduce this accumulated biomass and associated wildfire risk using fuel reduction treatments such as mechanical removal of fuel material and/or consumption of fuel using prescribed fire. As fuel treatment activities become more widespread and larger areas are treated, the potential cumulative effect of project-level fuel reduction impacts on watershed condition and health increases. The technical report, ***Cumulative Watershed Effects of Fuel Management in the Western United States***, was written to synthesize the literature and summarize the current understanding of the cumulative effects of fuel management activities at the watershed scale in the western United States (fig. 1). A companion synthesis for the eastern United States is currently being developed and will focus on examples and applications that are more relevant to that part of the country with regard to fuel management activities and cumulative watershed effects.

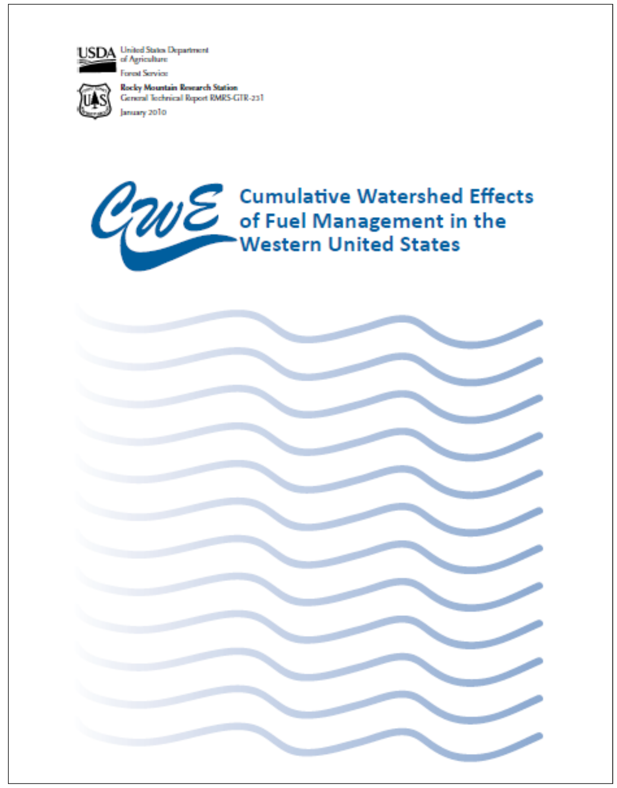

Figure 1. Cover page of the publication, ***Cumulative Watershed Effects of Fuel Management in***

Cumulative Watershed Effects of Fuel Management in the Western United States is an interdisciplinary collection of 14 chapters of the current state of knowledge and understanding of the cumulative watershed effects of fuel management activities in the western United States (fig. 2). Although not presented as such, the 14 chapters can be subdivided into three groups. The first group of papers provides background information on forest attributes and wildfire dynamics, fuel reduction treatment technologies and options, and legislative and policy directives guiding fuel reduction treatments and cumulative watershed effects analysis on federal lands (Chapters 1-4). In Chapter 1, Ryan provides a broad overview of current fuel reduction treatment approaches and the concept of cumulative watershed effects analysis. Additionally, he discusses some of the primary legislative and policy direction that influences the way federal land managers apply fuel reduction treatments and analyze cumulative watershed effects. In Chapter 2, Bailey provides background information on fire regime characteristics and dynamics for the different ecoregions in the United States. The ecoregion scale is useful for assessing wildfire probabilities across the United States, identifying areas of high wildfire risk, and planning for wildfire hazards. In Chapter 3, Graham, Jain, and Matthews provide an excellent summary of forest attributes in the inland western United States by grouping forests as either cold, moist, or dry forests. This grouping is particularly useful because each of these forest types has a unique set of forest vegetation characteristics and compositions that influence where wildfires burn, what wildfires burn, and the overall effects of wildfire on watershed conditions. Accordingly, the cumulative effects that fuel treatments would have on watersheds are highly variable among forest types

Table 1. List of chapters in the publication, ***Cumulative Watershed Effects of Fuel Management in the Western United States***.

Chap-ter	Title *Author(s)*
1	**Introduction to Synthesis of Current Science Regarding Cumulative Watershed Effects of Fuel Reduction Treatments** *Douglas F. Ryan (USDA Forest Service)*
2	**Fire Regimes and Ecoregions** *Robert G. Bailey(USDA Forest Service)*
3	**Fuel Management in Forests of the Inland West** *Russell T. Graham (USDA Forest Service), Theresa B. Jain (USDA Forest Service), Susan Matthews (USDA Forest Service)*
4	**Tools for Fuel Management** *Bob Rummer (USDA Forest Service)*
5	**Fuel Management and Erosion** *Pete R. Robichaud (USDA Forest Service), Lee H. MacDonald (Colorado State University), Randy B. Foltz (USDA Forest Service)*
6	**Cumulative Effects of Fuel Treatments on Channel Erosion and Mass Wasting** *Leslie M. Reid (USDA Forest Service)*
7	**Fuel Management and Water Yield** *Charles A. Troendle (METI Corporation), Lee H. MacDonald, (Colorado State University) Charles H. Luce (USDA Forest Service), I.J. Larsen (University of Washington)*
8	**Effects of Fuel Management Practices on Water Quality** *John D. Stednick (Colorado State University)*
9	**Cumulative Effects of Fuel Treatments on Soil Productivity** *Deborah S. Page-Dumroese (USDA Forest Service), Martin F. Jurgensen (Michigan Technology University), Michael P. Curran (British Columbia Ministry of Forests and Range, Sharon M. DeHart (Forest Service Job Corps)*
10	**Potential Effects of Fuel Management Activities on Riparian Areas** *Kathleen A. Dwire (USDA Forest Service), Charles C. Rhoades (USDA Forest Service), Michael K. Young (USDA Forest Service)*
11	**Biological Responses to Stressors in Aquatic Ecosystems in Western North America: Cumulative Watershed Effects of Fuel Treatments, Wildfire, and Post-Fire Remediation** *Frank H. McCormick (USDA Forest Service), Bruce E. Riemen(USDA Forest Service), Jeffrey L. Kershner (DOI U.S. Geological Survey)*
12	**Landscape Scale Effects of Fuel Management or Fire on Water Resources: The Future of Cumulative Effects Analysis?** *Charles H. Luce (USDA Forest Service), Bruce E. Rieman (USDA Forest Service)*
13	**Tools for Analysis** *William Elliot (USDA Forest Service), Kevin Hyde (USDA Forest Service), Lee MacDonald (Colorado State University), James McKean (USDA Forest Service)*
14	**Understanding and Evaluating Cumulative Watershed Impacts** *Leslie M. Reid (USDA Forest Service)*

and highly variable depending on the location and juxtaposition of the forests and fuel treatments within and among watersheds. In Chapter 4, Rummer provides a basic overview of forest operations for fuel treatments along with information to guide the resource manager for selecting the appropriate fuel treatment technology.

The second group of papers assesses the effects of fuel reduction treatments on different resources in the watershed along with the challenges of cumulatively analyzing those effects at the watershed scale (Chapters 5-11). In Chapter 5, Robichaud, MacDonald, and Foltz review the effects of roads, thinning operations, and prescribed fire on runoff and erosion, and discuss the current understanding of the cumulative effects of these activities on water yield, stream flow, and sediment production at the watershed scale. They discuss the challenges and difficulties of quantifying the effects of fuel treatments along with associated road activities on stream flow and sedimentation at the watershed scale because of the inherent complexity of the underlying processes and temporal variability of sediment dynamics, and that project-scale effects cannot be simply scaled up or summed to the watershed scale. In Chapter 6, Reid discusses channel erosion and mass wasting processes, environmental factors that most strongly influence erosion processes, the mechanisms by which fuel treatments can influence those controlling factors, and strategies for identifying areas where channel erosion and mass wasting will occur. She also discusses how erosion evaluations can be incorporated into a cumulative watershed effects analysis. In Chapter 7, Troendle, MacDonald, Luce, and Larsen assess the hydrologic effects of fuel treatments in the Rocky Mountain region using the Water Resources Evaluation of Non-Point Silvicultural Sources (WRENSS) procedure. They conclude fuel treatment activities are not likely to remove vegetation in such quantities that there is a detectable change in water yield and streamflow at the watershed scale. In Chapter 8, Stednick discusses the potential effects of fuel management practices on water-quality parameters such as water temperature, suspended sediment, and nutrients. In Chapter 9, Page-Dumroese, Jurgensen, Curran, and DeHart discuss the effects of fuel treatment activities on soil compaction and organic matter content and the impact this could have on residual fuel loads, soil erosion potential, and long-term soil productivity. They suggest using a risk rating system based on soil factors to determine site sensitivity when planning and implementing a fuel treatment project. In Chapter 10, Dwire, Rhoades, and Young discuss the potential impacts of streamside and upland fuel management activities on the structure and function of riparian areas. They conclude that identifying key riparian functions is crucial for minimizing the local and long-term cumulative watershed effects of fuel reduction treatments in riparian areas. In Chapter 11, McCormick, Reiman, and Kershner summarize the effects of wildfire and fuel treatment practices on aquatic and terrestrial resources. They also identify areas of uncertainty about the impacts of fuel reduction strategies on aquatic and terrestrial ecosystems, and recommend future research studies to better inform resource management when conducting fuel treatment activities.

The third group of papers review cumulative watershed effects concepts, methods for conducting a cumulative watershed effects analysis, and computer modeling tools that can be used to assess cumulative watershed effects (Chapters 12-14). In Chapter 12, Luce and Rieman discuss the limitations of limiting cumulative watershed effects analysis of aquatic resources to a single watershed. They argue that a cumulative watershed effects analysis of aquatic resources needs to include several connected watersheds to better understand fish and other aquatic species populations, community dynamics, and persistence from past, present, and future natural and anthropogenic disturbances. In Chapter 13, Elliot, Hyde, MacDonald, and McKean summarize computer models that can be used to evaluate the cumulative watershed effects of fuel management treatments. They discuss the importance of defining the problem, compiling and reviewing existing data, identifying impacts of concern, and identifying the parameters that need to be predicted before choosing a model to predict cumulative watershed effects. In Chapter 14, Reid discusses the history of cumulative watershed effects analysis, complex interactions that complicate cumulative watershed effects analysis and interpretations, various methods used to perform a cumulative watershed effects analysis, and typical errors or deficiencies that have occurred in past cumulative watershed effects analyses. Her review of 62 federal district and appellate court opinions on cumulative watershed effects analysis identifies many of the shortcomings of those analyses and mistakes or assumptions to avoid when conducting cumulative watershed effects analysis in the future.

The publication, ***Cumulative Watershed Effects of Fuel Management in the Western United States***, is an excellent resource for personnel needing to conduct cumulative watershed effects analysis when planning and implementing a fuel reduction treatment project. It assembles in one place the current state of thinking on and understanding of cumulative watershed effects from fuel reduction treatments and other related land management activities.

Hardcopies of ***Cumulative Watershed Effects of Fuel Management in the Western United States*** can be obtained by placing an order with Publications Distribution, Rocky Mountain Research Station, Fort Collins by telephone (970-498-1392), facsimile (970-498-1122), or e-mail (rschneider@fs.fed.us). An electronic copy of RMRS-GTR-231 can also be downloaded at http://www.fs.fed.us/rm/pubs/rmrs_gtr231.html.

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