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MEMO FROM: Christopher A. Frissell, Ph.D., Principal Scientist

TO: General

RE: Implications of Perry and Jones (2016) study of streamflow depletion caused by logging for water resources and forest management in the Pacific Northwest

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Introduction

This memo discusses the content and some implications of the following scientific paper, published in 2016:

Perry, T.D., and J.A. Jones. 2016. Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA. ***Ecohydrology*** **2016:1-13. DOI 10.1002/eco.1790**

Updating an earlier (Jones and Post 2004) synthesis of long-term paired watershed studies in western Oregon, Perry and Jones (2016) reported in this paper that logged watersheds still show no sign of recovery from prolonged depletion of low streamflows by *ca.* 50% in watersheds logged 40-50 years ago, compared to unlogged watersheds. The study suggests summer, fall and early winter streamflows are today dramatically depleted on a widespread basis across western Oregon and the Pacific Northwest as a consequence of extensive logging and vegetative regrowth in plantations following logging.

Study Design

- The study summarizes results of long-term paired logged and unlogged watersheds in experimental forests in the central Oregon Cascades and southwest Oregon. The data from the 12 instrumented watersheds are among the only time extended series of data available in the Pacific Northwest to measure the long-term effects of logging and post-logging forest succession on stream conditions.

- Unlogged control watersheds of mature and old growth forest provided the measurements necessary to account for the effects of regional environmental trends, including climate change and weather events, on streamflows.

- Each unlogged watershed was paired with a comparable watershed that was logged, and the measured departure of stream flow response between the paired watersheds over time was used to quantify the effects of logging and post-logging vegetative re-growth.

- Variation in logging history among the experimental watersheds, including total area harvested and thinning of some second growth plantations, allows the results to shed light on how effectively different logging practices and patterns might reduce or mitigate the streamflow depletion effect.

- The watersheds in this study are considered representative of a vast population of watersheds across western Oregon and the Pacific Northwest where Douglas-fir is the dominant tree species. The relatively consistent and sustained response of low flow deficits among the study basins supports the applicability of the results to watersheds across the Pacific Northwest.

Findings

- *Mature and old growth Douglas-fir forests appear to e exceedingly efficient in water use and produce steady streamflows compared to second-growth forest plantations*. Unlogged watersheds of mature and old growth forest resilience were relatively unaffected by climate change over 50 years, including a measured trend of increasing air temperature that expected to increase evaporative water stress.

- *Low flow deficits of 50% or greater occurred in all streams where greater than 50 percent of watershed area was logged.*

- *Low flow deficits caused by logging and post-logging forest regrowth persist for at least 40-50 years, without evidence of recovery* to re-logging flows.

- *Low flow deficits occur from late June, through July, August, September, and October.* Depending on weather patterns in a given water year, flow depletion sometimes also occurs later into late fall and early winter months.

- The pattern of response strongly indicates that *flow deficits are caused by more profligate water use by rapidly-growing trees and other vegetation in post-logging plantations*, compared to the much more efficient regulation of water use in mature and old growth forests.

- The results suggest that *reported trends of streamflow reduction in recent decades* (e.g., Luce and Holden 2009) *could be caused as much or more by cumulative effects of logging* than by climate change.

- The study also showed that logging treatments produced peak flow increases that still persist decades post-harvest. However, whereas the duration of peak flow effects is limited to a scale of days of a year, or the likelihood of increased flooding every few years, low flow deficits are expressed over many months in every year.

Key Implications for Forest Managers and Policymakers

- *Past widely-cited textbooks and agency plans and assessments reporting 10-15 years for "hydrologic recovery" after clearcutting are fundamentally incorrect*, and were based on an erroneous and short-sighted view of experimental watershed data. This longer-term analysis shows that neither peak flow increases nor low-flow deficits return to pre-harvest conditions within 40-50 years of logging. Of foremost concern, small low flow increases observed in the first decade post-logging gave way *to prolonged flow deficits, with summer, fall and early winter flows depleted to half or less of their pre-logging value persisting at least several decades.*

- Because low flow deficits in logged forests are apparently caused by fundamental physiological inefficiency of water use by vegetation in re-growing forests, *it appears unlikely that any modification of logging practices can reduce or mitigate the cumulative impact on depletion of streamflows*--other than greatly restricting the area and frequency (reducing harvest rotation) of logging.

- *Staggering the timing of logging did not and likely will not reduce the adverse depletion of low flows.* Sustained low flow depletion occurred in all catchments that were more than 50 percent harvested within the 40-50-year time frame of observations. The flow deficit effect persists for at least 4-5 decades with no measured recovery, so staggering logging within this time frame is ineffective.

- *While peak flow flooding risks still occur, the long-term low flow depletion effect can be reduced and sometimes avoided if half or more of a catchment is retained in mature, natural forested condition.* In cases where between 25% and 50% of the basin was harvested, with 50-75% remaining in natural mature forest condition, the long-term low flow depletion effects were substantially reduced in magnitude. By contrast, short-term peak flow increases were not ameliorated and were similar in magnitude and persistence to peak flows in 100% harvested basins.

- *Thinning of post-harvest plantations did not measurably ameliorate the long-term low flow depletion effect.* Apparently the growth flush of vegetation "released" by thinning increases water demand and quickly consumes any soil water gain made available by thinning. I.e., water used efficiency remains low relative to unlogged forests.

- The *great majority of forested watersheds in the Pacific Northwest are likely experiencing severe, but previously unrecognized streamflow deficits caused by past and ongoing logging.* From a landscape or regional perspective, we can conclude that any watershed with greater than half its forested area impacted by logging in the preceding 4-5 decades (and probably longer) is highly likely suffering severe and sustained depletion of summer, fall and early winter stream flows (on the order of 50 percent) compared to its historical, pre-logging condition.

- Most private industrial and small woodlot forest ownerships are found in watersheds where more than 50 percent of the landscape has been logged within the past 50 years. On such lands, *any additional harvest exerts harm by prolonging and perpetuating the condition of low flow deficit*.

- Where private forests and public forest lands are comingled, *reduced and limited harvest rates and fully protected mature forest reserves on federal lands could partially offset and mitigate the flow depletion effects* of logging on private lands. However, the degree to which such a mitigation effect scales up from small catchments to larger watershed areas remains unresolved, and may depend in part on the specific spatial pattern of logging relative to affected streams.

- There may be something akin to a *"tipping point" when less than 50 percent of a watershed or landscape of watersheds remains in mature and old growth forest; disturbed beyond this point by logging, severe wildfire, or other catastrophic disturbance.* Beyond this point, sustained low flow depletion is highly likely to be expressed in most if not all but a few smaller streams. Below 50% area logged, depending on the specific distribution of vegetation disturbance, many individual streams could experience severe and prolonged flow depletion, but the effects would likely be ameliorated in at least some areas of the watershed.

Impacts on Water and Fishery Resources

- Late spring, summer and fall low flows are known to strongly affect growth, survival and year class strength, hence productivity of juvenile salmonid fishes in Pacific Northwest streams (Scarnecchia 1981, Hicks et al. 1991, Ebersole et al. 2006, May and Lee 2011). Sustained 50 percent depletion of summer and fall low flows reduces survival and potential production of salmon in trout Pacific Northwest streams. A persistent 50 percent depletion of streamflows likely produces far greater than 50% losses in growth, survival, and productivity of affected waters.

- Reduced low flows cause elevated summer stream temperatures and restrict movement and reduce cover for young and returning adult fish, compounding the stress of crowding in reduced habitat area.

- Because freshwater rearing habitat fundamentally limits productivity of most salmonid species, *logging-driven low flow deficits could be among the principle causes of lagging recovery of Endangered Species Act-listed and other depressed salmon and steelhead populations* across the region.

- *Summer low flows also limit withdrawals for domestic, urban and industrial uses, potentially stalling future economic growth* wherever water use is dependent on surface water supply, as it is throughout much of the Pacific Northwest. Industrial-scale forest management on private and public lands, therefore stands in direct conflict with other human water and land uses.

Impact of Climate change

- *Watersheds and river basins with more than 50% of forest area logged in the preceding 50 or more years are likely to experience further loss of low flows in response to warming and drying of climate* in the coming decades (see Dalton et al. 2017 for a recent update of climate and streamflow forecasts for Oregon), with further deterioration of coldwater fish habitat, water supply, recreation, and other beneficial uses.

- *Streams draining watershed areas dominated by natural, unlogged mature and old growth forests are more likely to retain low flows similar to their historical conditions, therefore also retaining favorable temperature* conditions for coldwater fish habitat and other beneficial uses.

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Related Reading:

Rhodes, J.J., and C.A. Frissell. 2015. The High Costs and Low Benefits of Attempting to Increase Water Yield by Forest Removal in the Sierra Nevada. 108 pp. Report prepared for Environment Now, 12400 Wilshire Blvd, Suite 650, Los Angeles, CA. Online at http://environmentnow.org/pdf/Rhodes-and-Frissell-water-logging-report.pdf