Riparian Function and Stream Temperature (RipStream) Project: Background, Analysis Approach, Initial Findings, and Future Analysis

August 1, 2009

PURPOSE AND SCOPE

This attachment provides information to the Board under work plan #1, Strategic Planning, Implementation, and Monitoring, Intermediate Board Issue #1, Oregonians' understanding, acceptance, and support for sustainable forest management. Specifically, the attachment provides a status report on the long-term Riparian Function and Stream Temperature (RipStream) monitoring project. The status report will summarize the project background, analysis approach, initial findings, and future analysis needs.

The Board's 2003 Forestry Program for Oregon (FPFO) states that the Board will continue to support an effective, science-based, and adaptive Oregon Forest Practices Act (FPA) and a strong but flexible Land Use Planning Program as the cornerstones of forest resource protection on private lands in Oregon (Key Action A.1). The background for Strategy A recognizes that a key purpose of enacting the FPA was to ensure that forest operations are conducted to meet state water quality standards adopted under the federal Clean Water Act and implemented by the Department of Environmental Quality (DEQ). The Board's vision includes a commitment to continuous learning, evaluating and appropriately adjusting forest management policies and programs based upon ongoing monitoring, assessment, and research (Vision Statement 9).

With the adoption of the 1994 Water Protection Rules (Oregon Administrative Rules (OAR), Chapter 629, Divisions 635 through 660), the Board of Forestry and the Department of Forestry adopted a formal commitment to resource monitoring (OAR 629-635-0110). Monitoring and evaluation of the water protection rules are necessary because of the innovative approach taken in the rules. Monitoring and evaluation are needed to increase the level of confidence of all concerned that the rules will maintain and improve the condition of the riparian vegetation and waters of the state over time (OAR 629-635-0110(1)). Pursuant to OAR 629-635-0110(3)(d), the Department makes annual reports to the Board about current monitoring efforts, and, if applicable, presents findings and recommendations for changes to forest practices.

The Department designed the RipStream project to meet these monitoring requirements. The joint effort between the Private and State Forests programs evaluates the effectiveness of riparian protection standards in the FPA and the Northwest Oregon State Forest Management Plan (NWFMP). Specifically, the project assesses effectiveness in meeting Department of Environmental Quality (DEQ) water quality standards and the Desired Future Condition for Riparian Management Areas in the Forest Practices Act regarding large woody debris, shade, and vegetation. RipStream focuses on effectiveness in protecting stream temperature and promoting riparian structure that provides necessary functions for the protection of fish and wildlife habitat in small and medium fish-bearing streams the Coast Range. Specific monitoring questions include:

1. Are the riparian rules and strategies effective in meeting DEQ water quality standards for protecting cold water and maintaining temperatures below thresholds for specific life stages of salmonids?
2. Are the riparian rules and strategies effective in maintaining large wood recruitment to streams, downed wood in riparian areas, and shade?
3. What are the trends in riparian area regeneration?
4. What are the trends in overstory and understory riparian characteristics and how do these trends, coupled with channel and valley characteristics, relate to stream temperature and shade?

This initial analysis partially addresses monitoring question #1: Within the first two years post-harvest, did RipStream sites meet stream temperature standards on state and private forests?

Oregon DEQ has two relevant temperature standards, the Biologically-Based Numeric Criteria (Numeric Criteria; OAR 340-041-0028 (4)) and the Protecting Cold Water Standard (PCW; OAR 340-041-0028 (11) (a)). For the Numeric Criteria, human activity (including forest operations) may not raise certain streams' temperatures above 16°Celsius or 18° Celsius (61° F or 64.4° F), depending on the stream. The PCW effectively does not allow human activity to raise stream temperature by more than 0.3 degrees Celsius (0.5° F).

The DEQ water quality temperature regulations were approved by the United States Environmental Protection Agency (EPA, 2004) and allow EPA to consider DEQ state water quality standards as final. The rule states "forest operations that are in compliance with the Forest Practices Act requirements are (except for the limits set out in ORS 527.770) deemed in compliance with this rule." The Board and Department agreed to validate the FPA's assurance of compliance by effectiveness monitoring programs. "[T]he department [of Forestry] shall conduct monitoring on a continuing basis to evaluate the effectiveness of the water protection rules. The monitoring shall determine the effectiveness of the rules to meet the goals of the Forest Practices Act and the purposes stated in the rules, as well as their workability and operability" (OAR 629-635-0110 (3) (a)). RipStream was, in large part, designed to determine the degree to which State and private forestry in Oregon's Coastal Range complies with the DEQ water quality standards.

PROJECT BACKGROUND

RipStream study sites are located throughout the Coast Range geographic region on small and medium sized fish-bearing (type F) streams. The project established 33 study sites, 18 located on private forests and 15 located on State forests. The study sites were established in 2002 and 2003. Due to harvest schedule adjustments, final site visits are scheduled for 2011. Private landowners and State Forest personnel volunteered sites that met criteria for inclusion in the study and agreed to leave control reaches uncut for seven years. Site selection criteria included monitoring only Small and Medium fish-bearing (Type F) streams, avoiding beaver and debris torrent-influenced riparian systems, and using only sites in the Coastal range.

All 33 sites have two sections (reaches), an upstream-unharvested (control) reach and a harvested (treatment) reach (see figure 1). In addition, 19 sites have a have a downstream reach to quantify any changes in stream temperature as the stream re-enters canopy cover.

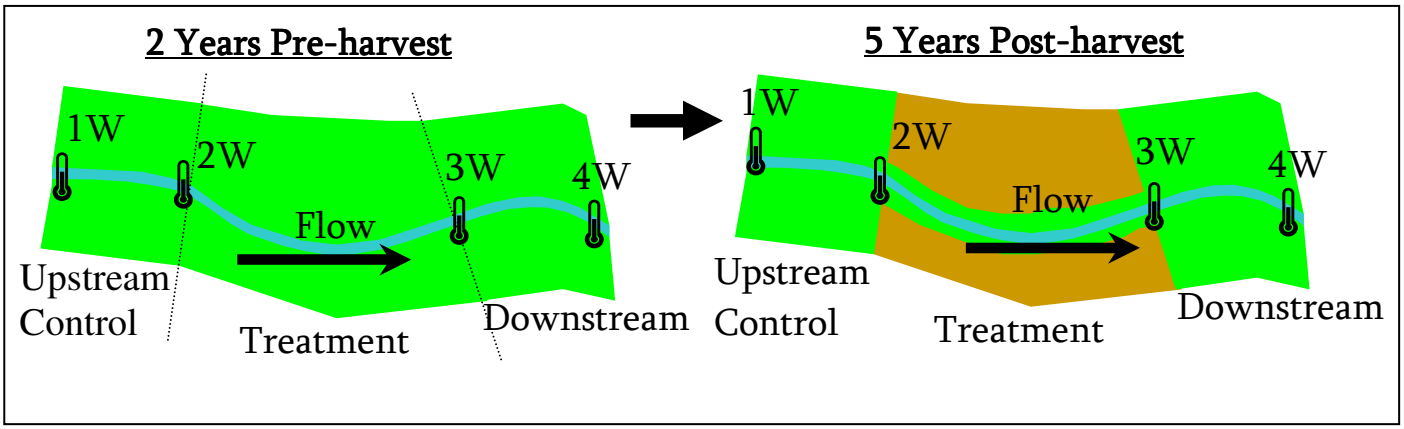

Figure 1. RipStream study design. At each of 33 sites stream temperature and riparian characteristics were quantified in two reaches for two years prior to timber harvest (Upstream Control and Treatment, Downstream). Nineteen of 33 sites also had downstream reaches (no riparian data was collected in these reaches). After two years, the Treatment reach was harvested. All reaches were to be evaluated for five years post-harvest. Currently all sites have at least two years of post-harvest data. Stream temperature is recorded at locations 1W, 2W, 3W, and 4W. These locations are situated at reach endpoints and are used to track temperature change along each reach.

Private landowners agreed to harvest treatment reaches to minimum FPA riparian standards. State Forest managers agreed to harvest treatment reaches to riparian and aquatic strategies as described in the NWFMP. Table 1 describes differences in riparian management areas for State, Private, and Federal lands. Federal riparian management areas are included for comparative purposes only.

Table 1. Riparian Management Area Widths for Private (AR 629-635-0310), State (Northwest Oregon State Forest Management Plan) and Federal (Northwest Forest Plan) forestlands.

Buffer Type	Private	State	Federal
No-cut	20 feet	25 feet	- -
Limited-entry (Small type F)	20-50 feet	25-170 feet	~300 feet
Limited-entry (Medium type F)	20-70 feet	25-170 feet	~300 feet

The study design called for sites to have two years of pre-harvest data followed by five years of post-harvest data collection, though some sites have deviated from this framework due to delayed timber harvests. Currently, all 33 sites have at least two years of post-harvest data. ODF employees Liz Dent and Kyle Abraham published a peer-reviewed manuscript that describes RipStream site conditions pre-harvest in 2008[1].

[1] Dent, L., D. Vick, K. Abraham, S. Shoenholtz, and S. Johnson. 2008. Summer temperature patterns in headwater streams of the Oregon Coast Range. Journal of the American Water Resources Association 44:803-813.

The Department designed the RipStream project to track changes in both harvested (treatment) and unharvested (control) reaches along streams. Water temperature probes, placed at the boundaries of stream reaches (see figure 1), measure hourly temperature for the period June through September. The upstream control reach provides information on the background state of the stream during pre- and post-harvest years. If timber harvest alters water temperature, we would expect to observe this change when we compare the Treatment reach's upstream probe (2W) to its downstream probe (3W) but not in the control reach (1W to 2W). The 19 sites with a downstream reach probe allow quantification of any changes in stream temperature as the stream re-enters canopy cover. RipStream's study design allows analysis of the effects of timber harvest in an ever-changing environment. It also allows quantification of the response of riparian areas over time following timber harvest.

ANALYSES APPROACH AND INITIAL FINDINGS

Oregon DEQ water quality standards require impacts to be determined at the point of maximum impact. In the case of harvest treatments, this maximum impact point occurs immediately downstream of the harvest unit (probe 3W). The standards require converting the hourly temperature data into series of 7-day moving average of daily maximum temperatures (7DayMax). This data transformation is meaningful to fish biologists, as salmon and trout are more sensitive to chronic warming of water than to brief spikes in stream temperature. The analyses used multiple 7DayMax values for each probe – year combination.

The Department limited the current analyses to consideration of the regulatory perspectives of stream temperature. While designed to rigorously address regulatory questions and adhere to regulation specifications, the analyses do not address non-regulatory questions regarding hydrological function or fish habitat alteration. The analyses also do not address changes in stream temperature as the stream re-enters canopy cover in the downstream reach.

Biologically-Based Numeric Criteria

The Numeric Criteria are violated if a stream exhibits a single occurrence of a 7DayMax value above either the 16˚ or the 18˚ C threshold. DEQ sets the threshold (16˚ or 18˚ C) based on stream type (core cold water habitat or salmon and trout rearing and migration use, respectively) as specified in administrative rules.

The Department evaluated patterns of Numeric Criteria rule exceedances by site to determine if further analysis was warranted using a conservative threshold of 16˚ C for all sites. The analysis treated each probe as an independent measurement of stream temperature. The analysis evaluated the series of 7DayMax values by probe and year. The breakdown of 16˚ C violations is as follows:

- Total Number of Sites: **33**
  - **15** sites never exceeded 16 C
  - **18** sites exceeding 16 C

- Of the **18** sites exceeding 16 C:
  - **3** sites exceeded during pre-harvest period only (exceedances due to natural causes)
  - **10** sites exceeded at control (1W, 2W) and treatment (3W) probes during the same year or years (natural causes)
  - **3** sites had control probes exceeded during pre-harvest years while treatment probes exceeded during post-harvest year or years (potentially due to harvest)
  - **2** sites had exceedances at treatment probe post-harvest only (stronger evidence of timber harvest effect)

The Department interprets these results to indicate that timber harvest do not cause stream temperature to frequently or conclusively exceed the Numeric Criteria, and do not find further analysis warranted.

Protecting Cold Water Standard

The PCW applies to state waters whose temperatures normally lie below Numeric Criteria values. The standard prohibits increasing stream temperatures by more than 0.3°C above their "ambient temperature"[2]. This change is quantified at "all sources taken together at the point of maximum impact where salmon, steelhead or bull trout are present." DEQ interprets this to be the point at which a change in temperature is generally expected to be greatest; namely, immediately downstream of a timber harvest (temperature probe 3W). Guidance for evaluating the PCW in Oregon or other states' similar statutes (e.g., Washington) is not available. The Department collaborated with DEQ to determine the most appropriate means for analyzing PCW compliance for RipStream data and constrained the analysis to adhere to the rule language as closely as possible. Our study design did not enable us to directly examine a secondary aspect of the PCW (OAR 340-041-0028 (11) (b)) that has to do with cumulative effects of temperature increases on salmon, steelhead, or bull trout habitat downstream of timber harvest (multiple harvest units). However, in this analysis we provide information regarding the behavior of water temperature for each of our sites' reaches.

Given the vague definition of "ambient temperature" and the fact that the characteristics of streams change annually, the analysis evaluates the relationship between adjacent probes (e.g., 2W ~3W) for all possible pairs of years. The evaluation compares the series of 7DayMax values by year. For each year-pair, we asked if the second year in a year-pair had temperatures that were more than 0.3˚ C above predicted values given the previous year's data. Comparisons included pre-harvest to pre-harvest years (estimate background natural exceedances rates), pre-harvest to post-harvest years (look for an effect of harvest), and post-harvest to post-harvest comparisons (did streams tend to continue warming after harvest?). We analyzed 614 year-pair comparisons (33 sites, two to three reaches per site, several years of temperature data per reach) to see if they exhibited exceedances of greater than 0.3 C. A single 7DayMax exceedance detected for a year-pair was treated as a PCW exceedance.

[2] …"stream temperature measured at a specific time and place. The selected location for measuring stream temperature must be representative of the stream in the vicinity of the point being measured" (OAR 340-041-0002 (2)).

Given the calculated exceedance values for all 614 year-pair comparisons, the next analysis examined whether these detected exceedances exhibited a pattern. Stream temperatures may change for a variety of reasons. Stream temperatures are generally expected to increase as water travels downstream. Some years may have warmer air temperatures or less cloud cover than others. Timber harvest can trigger water temperature increases, generally through reduced canopy cover. RipStream's study design, with pre-harvest information and upstream control reaches, allows analysis of the effect of timber harvest from other background temperature influences. The analysis examined nine combinations of stream reach and year-to-year (e.g., pre-harvest to post-harvest) comparisons (Table 2). If timber harvests were affecting temperature, one would expect a disproportionate number of the detected PCW exceedances to occur in the Treatment, Pre-harvest to Post-harvest combination (the center light gray box in figure 2).

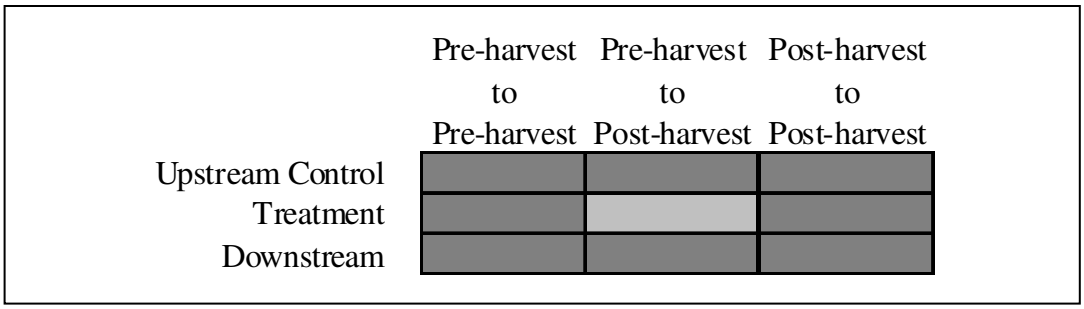

Figure 2. Descriptive diagram of year-pair comparison types. On the top row are the different year-pair timings. On the left side are the different stream reaches. PCW exceedances could be detected in any of the nine resulting boxes. If timber harvest were affecting temperature, one would expect a disproportionate number of PCW exceedances to occur in the center light gray box.

The department developed a set of explanatory different models to test for patterns in the detected exceedance data. Model parameters tested variations of site, year, reach, ownership, and treatment. Each model was further refined to determine if results differed by stream size (Medium or Small Type F). The Department used an objective, statistical technique to compare the performance of the different models. The analysis tests which model or models had the most support.

Sixty-five (65) out of 614 comparisons exhibited a PCW exceedance. The most successful model at explaining the pattern of exceedances stated that only the pre- to post-harvest (gray box) comparisons for stream reaches harvested to minimum FPA riparian standards (Private) differed from all other comparisons, and that the other comparisons (including State forest treatment reaches pre- to post-harvest) were all equal (Figure 3A). This model had 12 times the statistical support compared to the model that claimed that all (State forest + Private forest) Treatment reaches pre-post harvest differed from all other comparisons (Figure 2, light gray box compared to dark gray boxes). The second-best model was identical to the Top Model except that it claimed Small F streams differed from Medium F streams (Figure 3B).

The Top Model states that, after controlling for differences among sites, the probability of exceeding the PCW on Private treatment reaches when comparing any pre-harvest year to either the first or second year post-harvest was 40% (95% Confidence Interval = 27% to 54%). The

probability of exceedance on all other reaches (upstream control, downstream control, State treatment) and year-pair categories (pre- to pre-harvest, pre- to post-harvest, or post- to post-harvest) combined was 4.6% (95% CI = 2.3% to 8.8%). These results are statistically significant.

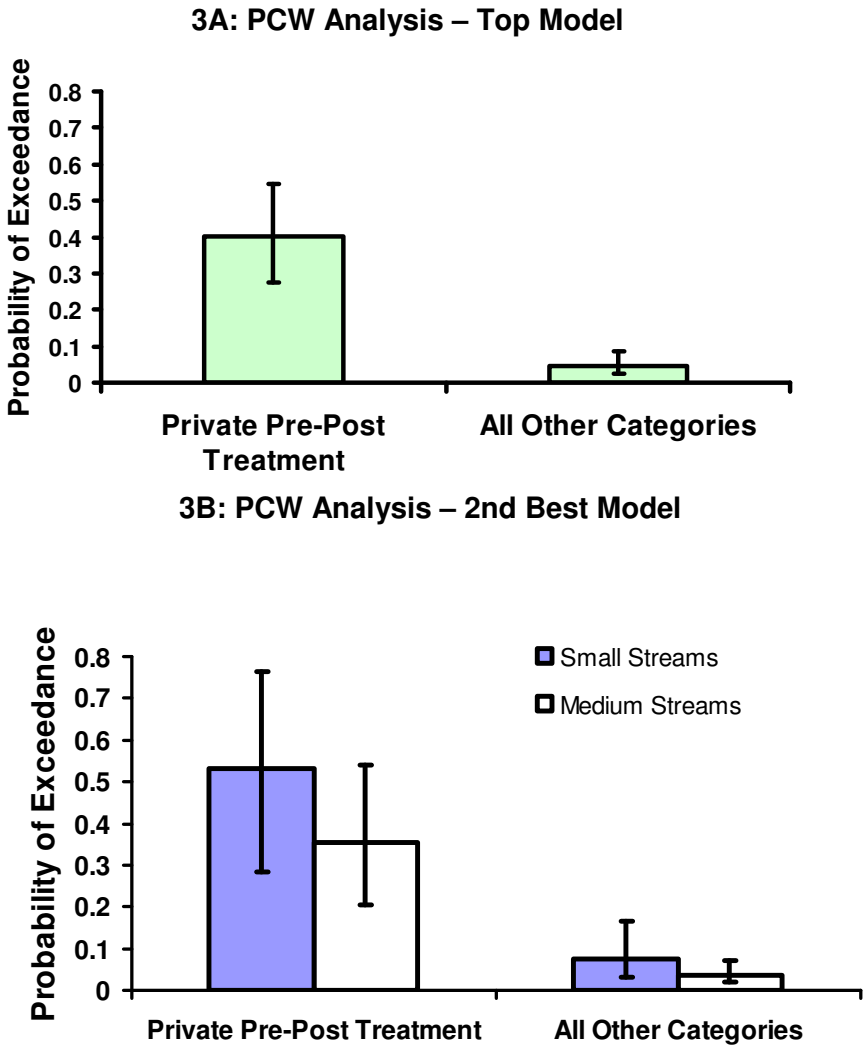

Figure 3. Probability that a year-pair comparison will exceed the Protecting Cold Water standard (PCW) after controlling for differences among sites. Error bars represent 95% Confidence Intervals. Figure 2A, representing the Top Model (i.e., model that best described the data), indicates that Private site Treatment reach comparisons of pre-harvest years to post-harvest years exceed the PCW more frequently than a category including all other reach and year-pair comparisons. Figure 2B represents estimates for the second best-performing model and resembles the Top Model except that it treats Medium and Small Type F streams as behaving differently.

The results additionally indicate that the second-best model (which considers Small F streams as behaving differently than Medium F) does not explain the data better than the Top Model. The implication of this finding, as depicted in Figure 2b, is that Medium F streams exceed the PCW

along Private Treatment reaches in a similar manner as the Small F streams. These results suggest that the minimum FPA riparian protection standards do not necessarily ensure that forest practices comply with the PCW standard on either type of stream.

The analysis indicates that State Forest treatment reaches did not perform in a similar manner as Private forest treatment reaches. The Department conducted a separate analysis on only State Forest sites, using a similar set of models as described above. The best State Forest model stated that each reach (regardless of the year-pair comparison) differed from one another. This model had almost five times the statistical support as the State Forest model that most resembled the original Top Model: State Forest Treatment reaches comparing pre-post harvest differed from all other State forest comparisons.

SUMMARY OF FINDINGS

Our results indicate that RipStream sites largely meet the DEQ Biologically-Based Numeric Criteria. However, timber harvests to the minimum FPA riparian protection standards along Private Medium and Small Type F streams exceed the PCW at a greater frequency than would be expected by chance, where the probability of exceeding the PCW (i.e. greater than a 0.3°C temperature increase) on Private treatment reaches was 40%. The Department found no evidence to suggest that timber harvests on State lands exceed the PCW more frequently than expected under natural background conditions.

These findings are limited to consideration of the regulatory perspectives of stream temperature. While designed to rigorously address regulatory questions and adhere to regulation specifications, the findings do not address questions regarding hydrological function or fish habitat alteration. The findings do not address the magnitude or persistence of temperature effect or changes in stream temperature as the stream re-enters canopy cover in the downstream reach.

While these findings are preliminary, they are consistent with the most recent evaluation of studies on small and medium fish-bearing stream requirements in Oregon prior to this study. (ODF/ODEQ Sufficiency Analysis, 2002)[3]. This evaluation found the following:

> "Most medium Type F streams…did not have changes in shade levels outside the range of measurement error, with only two out of eight sites resulting in shade reductions greater than 10 percent. A substantial proportion of the small Type F streams (four out of nine), exhibited shade reductions in excess of 10 percent in the year following harvest activity."(p.26)

This would equate to about 35% of the sites measured in the previous study, similar to the 40% statistic cited above, with shade level reductions in excess of 10%. Observed temperature responses to shade level reductions in excess of 10% are not unexpected; however, this previous study did not include data collection to quantify the significance of the temperature effect of observed changes in shade.

[3] Oregon Department of Forestry and Department of Environmental Quality Sufficiency Analysis: A statewide Evaluation of FPA Effectiveness in Protecting Water Quality. Oregon Department of Forestry. Salem, Oregon. 2002

One of the next steps in RipStream, as described below, is to try to determine the significance and magnitude of the temperature effect on the 40% (or 35%) of streams that are experiencing increases in temperature post-harvest. This information will be important for the Board of Forestry to consider in fulfilling their statutory obligations to "establish best management practices and other rules applying to forest practices as necessary to insure that to the maximum extent practicable nonpoint source discharges of pollutants resulting from forest operations on forestlands do not impair the achievement and maintenance of water quality standards" (ORS 527.765).

FUTURE ANALYSES

Next analytical steps include:

- Determining the magnitude of stream warming or cooling attributable to timber harvest according to a less restrictive, more powerful analysis
- Exploring the behavior of stream temperature in the downstream control reaches
- Expanding the analysis to address differences in stream temperature responses among sites
- Examining stream temperature behavior in relation to treatment reach length, changes in shading, stream gradient, and other factors

The RipStream project generated a rich data set for analyzing why certain sites underwent a change in water temperature and others did not. The Department is currently developing an analysis to examine what site changes or features contributed to temperature increases. For example, analysis depicted in Figure 4 suggests that a change in site shading between pre-harvest and post-harvest may play a role.

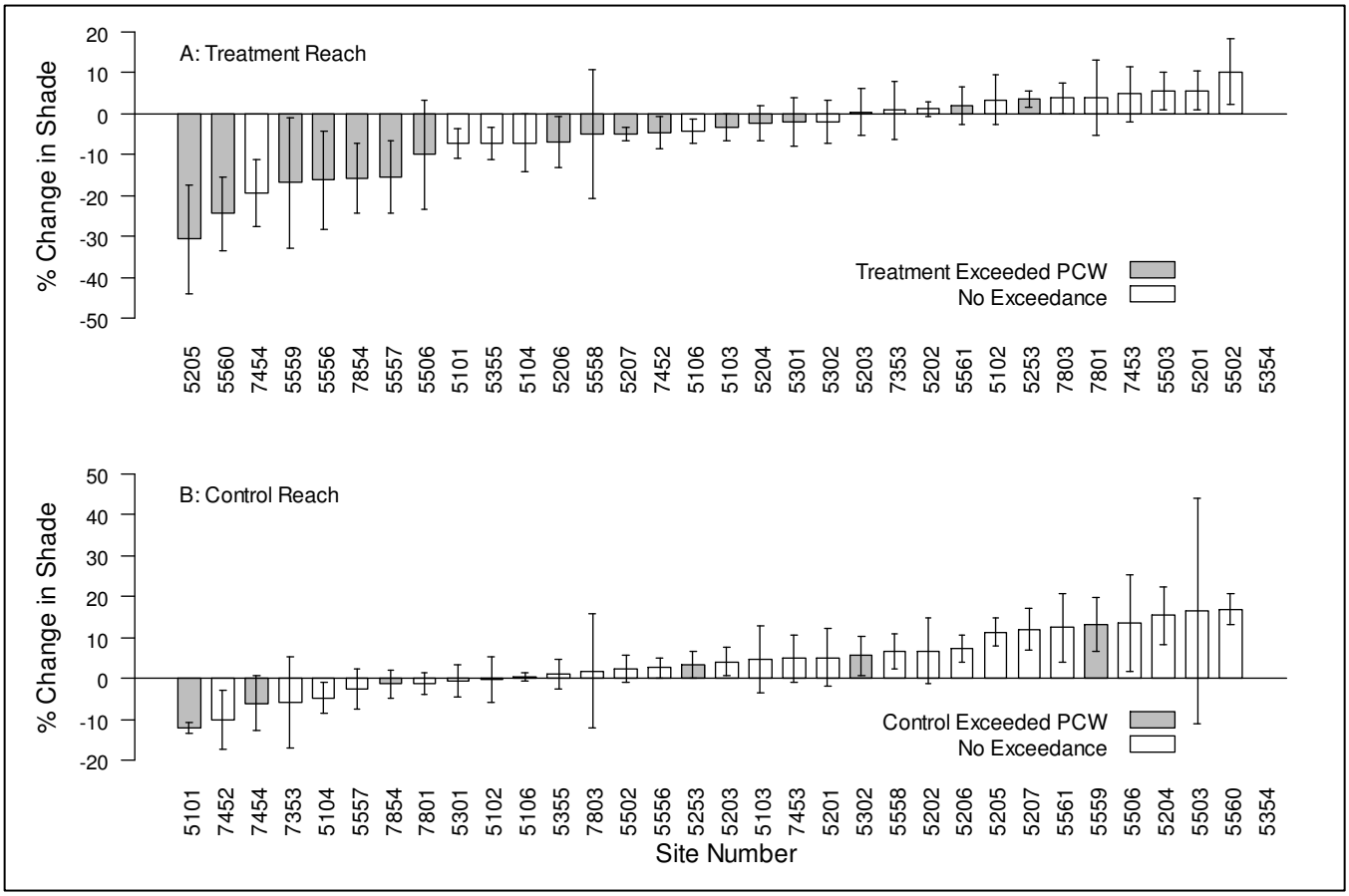

Figure 4. Average changes in shade values, as determined by hemispherical digital photographs taken every 200 feet along Treatment and Control reaches. Photographs were taken during the first year of pre-harvest data collection and during the first year post-harvest. Error bars represent 95% Confidence Intervals. Gray coloration in 4A indicates a site's Treatment reach had at least one pre-harvest to post-harvest year pair comparison that exceeded the PCW. Gray coloration in 4B indicates a site's Control reach pre-harvest to post-harvest comparisons exceeded the PCW one or more times.

In addition, the Department plans to analyze if temperature increases recover in downstream reaches or recovered over the five-year post harvest period, and the relationship of stream temperature changes to riparian and channel features. The Department also plans to analyze the data on large wood recruitment to streams, stand response to harvest, and channel characteristics before and after harvest.