Development of a study design for a LiDAR-based water typing model and default physicals to establish the extent of fish habitat in forestlands in Washington State

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4 January 2017

Rule Overview and Intent

The Forest Practices Board adopted rules delineating waters of the state into three categories, Type S waters (shorelines of the state), Type F waters (fish-bearing), and Type N waters (non-fish-bearing). Distinguishing the upstream limits of Type F (or S) waters is particularly important, because presence or absence of fish and fish habitat in streams creates differences in the aquatic resources of concern, the forest management strategies, and the prescriptions applied.

Prior to the rules associated with the Forests and Fish Report (1999), stream typing was based on a set of default physical and beneficial-use criteria. Due to questions about the accuracy of this system, the forest practices rules required the development of a statewide stream map using a multi-parameter, field-verified, GIS logistic regression model to identify the upper extent of Type F streams. The intent of the Stream Typing has been to develop a statewide stream typing map, described as follows in the forest practices rules:

> "The department will prepare water type maps showing the location of Type S, F, and N (Np and Ns) Waters within the forested areas of the state. The maps will be based on a multi-parameter, field-verified geographic information system (GIS) logistic regression model. The multi-parameter model will be designed to identify fish habitat by using geomorphic parameters such as basin size, gradient, elevation and other indicators. The modeling process shall be designed to achieve a level of statistical accuracy of 95% in separating fish habitat streams and non-fish habitat streams. Furthermore, the demarcation of fish and non-fish habitat waters shall be equally likely to over and under estimate the presence of fish habitat. These maps shall be referred to as 'fish habitat water typing maps' and shall, when completed, be available for public inspection at region offices of the department. Fish habitat water type maps will be updated every five years where necessary to better reflect observed, in-field conditions."

WATER TYPING MODEL

A GIS-based logistic regression model was developed, associating geomorphic parameters (i.e., basin size, gradient, elevation, and other indicators) with last fish points in order to determine and map the upstream boundary of Type F (fish-habitat) streams. The forest practices rules specified that once the model was developed, with an accuracy of 95%, the resulting map would be used as rule. CMER through ISAG developed a study design to develop and validate a model. The two projects were the Last Fish/Habitat Prediction Model Development Project and Last Fish/Habitat Prediction Model Field Performance Project. The Last Fish/Habitat Prediction Model Field Performance Project assessed the performance of the model predictions in western Washington.

The model was completed in 2006. Based on the results of the field performance project, the model did not achieve the target accuracy of 95%. DNR in March 2006 still developed water type maps based on the model, but the maps are only used as a starting point for delineating fish habitat, not as rule. The DNR maps are currently used as part of the forest practices application process in combination with the Interim Water Typing System (WAC 222-16-031). This water typing rule specifies physical criteria for identifying fish-bearing streams (channel width, channel gradient, and contributing basin area), unless overridden by a protocol survey for determining fish use.
Based on the results of the Last Fish/Habitat Prediction Model Field Performance Project, and a CMER recommendation that further efforts to improve the model would likely not increase its level of accuracy, Policy decided that additional CMER work on the model was not necessary at that time.

The Board in 2015 proposed the AMPA scope and initiate a pilot project to re-run the existing model in two watersheds using LiDAR data. The objectives of the project included: development of quantitative information about the "footprint" of the interim rule; a comparison of model-based water type designations to on-the-ground FPAs and WTMFs; an investigation of additional model utility, such as the detection of OCH, the ability to predict physicals and assess footprint effects from using different physicals; and to provide information that can inform the Board's basic administrative choices among "map-as-rule" vs. "guidance map with field adjustments".

Per the Board's direction, the Adaptive Management Program initiated a project that compared the existing west side model and an improved Fransen et al model utilizing a high resolution LiDAR based DEM approach against the original ten meter United States Geologic Survey (USGS) DEM with the intent to identified potential opportunities to improve the predictive precision of the model with high resolution topographic information. The proof of concept modeling approach was tested against the 2003 west side model and the Fransen et al improved model in the Mashel watershed and the 2005 east side model in the Darland Mountain watershed.

SUMMARY OF PROOF OF CONCEPT MODEL PROJECT

The objective of the project was to test increased resolution LiDAR-derived topographic models and explore additional model variables that have potential to increase model accuracy. The current west side water typing model failed to achieve the required statistical accuracy of 95% in separating fish habitat streams and non-fish habitat streams. Large sources of error included the inability to detect barriers, the inaccurate location of digital elevation model (DEM) generated streams, and the use of error-prone DEM generated watersheds to quantify upstream basin areas.
The first objective of this project was to replicate work done by Fransen et al to establish fish/non-fish accuracy statistics. Current data on the upper limit of fish occurrence (ULO) was used to generate model accuracies. Statistical accuracy was assessed by total error (ft.) as a percent of total watershed stream length (ft.). Depending on the quality and availability of ULO and Perennial Initiation Point (PIP) data, some mutually agreed upon subset of basins in the watersheds were selected for analysis, rather than the entire watershed.

The University of Washington Precision Forestry Cooperative presented to Policy the preliminary results of the project to update the water typing model with LiDAR data at their September 2016 meeting. Several conclusions, opportunities, and recommendations were outlined in that presentation. These were:

Conclusions

- LiDAR data helps the model be more accurate, both by addressing the original model's westside under-prediction and eastside over-prediction of the end of fish habitat.
- Large datasets make the model computations slow, which may present a challenge in the future.
- Comparing stream networks based on LiDAR data with those based on previously mapped streams often causes the stream networks to look differently, both in location and geometry.
- Not all water type modification forms (WTMFs) are created equally, so it takes time for the modeling team to ensure they are referencing the correct ones.
- The pilot project ended up coding the whole system in modern programming code so in the future it will be quicker to evaluate different resolutions.
- A revised model will need to evaluate fish habitat.

Opportunities

- Investigate independent variable creation to determine if altered methodology is more appropriate for higher-resolution digital elevation models (DEMs).
- Refine the "digital culverts" idea from the pilot project.
- Leverage existing investment in the updated coded process to investigate additional resolutions and alternative flow accumulation models.
- Expand the pilot project to include additional watersheds and if needed, collect additionally field-verified end-of-fish data with protocol surveys to support a more robust model validation.
- Consider a pilot project to re-formulate the model using high-resolution DEMs with field-verified end-of-fish data.

Recommendations

- Consider re-building the model over 3-4 years.
- Determine desired accuracy and how to measure it.
- Develop models that operate on the appropriate spatial scale to provide the level of accuracy desired. It is likely this would result in more models developed and calibrated on smaller geographic areas to meet desired accuracy targets.
- Refine the "digital culverts" to increase the accuracy of the modeling and aid in future model development.
- Determine a methodology to identify the extent of fish habitat to use for training and validating the model(s) as they are developed.

Other project tasks included: building a hydrologically correct DEM from the USGS 1/3 arc-second National Elevation Dataset (approx. 10 meters) and DNR Stream layer; deriving stream locations, gradients and contributing areas from the modified DEM using a minimum contributing area for stream initiation of 1.5 hectares (~3.7 acres); developing stream points at ~10 meter intervals and "strings" from derived stream locations; developing attribute stream points with independent variables (basin area, basin weighted precipitation, upstream and downstream gradients, elevation) and measurement and processing variables (stream mile, stream order); digitizing or otherwise locate ULO points from the WA DNR Water Type Modification data on stream network. Some adjustments were need to be made for lateral ULO points to ensure proper model behavior; running logistic regression model to predict fish presence/absence for all points on the stream network. Report error for stream point prediction using a cut point of 0.5; running stopping rule using a minimum basin area calibrated to known perennial initiation points in the watershed. Report error distance for end-of-fish predictions; and generating maps and descriptive statistics to identify potential sources of model error.

PHYSICAL DEFAULT CHARACTERISTICS

On 18 May 2016, Policy received a Proposal Initiation for the evaluation of the physical default characteristics for the purposes of water typing. The emphasis of the proposal was to better understand how default physical characteristics were developed, identify additional data that can be used to assess the current default physicals, and determine if they can be refined to be more accurate and minimize error.

BACKGROUND OF PHYSICAL DEFAULTS

In 1996, the Forest Practices Board (Board) adopted a consensus package of actions including an emergency water typing rule with defaults for presumed fish use and a fish survey protocol to determine fish use. Due to the uncertainty associated with the science used to develop the default physicals, it is unclear if they are sufficient in meeting the identified objectives. The Board recognized that the default physicals would likely need to be modified to more correctly reflect fish use as more and better data became available. Key principles critical in the development of a water typing rule were also identified those being a high degree of accuracy, minimized risk, and balance of the remaining uncertainty.

When the Board adopted permanent rules for implementing the FFR in 2001, the model was not complete. The Board adopted two administrative rules: one deemed the "permanent" rule, described the model; and a second "interim" rule, which continued the use of protocol surveys and physical defaults. Both the protocol surveys and default physicals were temporary solutions and never intended to be permanent solutions. Recently the Board's attention has focused on the water typing model and a review of the uncertainties related to the default physical criteria. Since 1996, field-verified data indicate that the current default criteria often do not accurately reflect the extent of fish use or fish habitat as they were intended. This apparent error in the method has reduced the utility of default physical criteria and has led to the Board's recommendation to develop a study design that could be used to develop more accurate default physical criteria that is coincident with the extent of fish habitat expressed as Type F waters.

Conclusions

Uncertainty exists regarding the utility of the default physical criteria in establishing the extent of fish habitat, demarking the regulatory break between Type F and N waters. Anecdotal evidence suggests that the default physical criteria over predicts the extent of Type F waters when compared with protocol survey-based electrofishing. It has been postulated that a more robust and accurate set of default physical criteria could be developed to capture the extent of fish habitat coincident with the upstream boundary of Type F waters.

Opportunities

Interest exists across caucuses participating in the AMP to establish default physical criteria to define fish habitat. Research to develop a spatially explicit LiDAR based water typing model would include field methods and analysis that could inform default physical criteria in the same domain as the model. Funding for research of the default physical criteria was approved by the Forest Practices Board for the 2017 fiscal year.

Recommendations

- Initiate work on a development of a study design to establish default physical criteria that meet the objectives of the Forests and Fish Agreement.

- A single set of default physical criteria for use throughout the state is inappropriate. Consideration of domain, species, geology, geography, climate, and other factors are critical to the development of default physical criteria and how they will be applied across the landscape. This will result in domain specific default physical criteria.

- The study design needs in include an assessment of the accuracy and bias of default physical criteria developed in each domain.

PROBLEM STATEMENT

The identification of regulatory F/N breaks using west and east side models and default physical criteria have not resulted in a level of accuracy sufficient for acceptance under the forest practices rules. The resource objective and performance target associated with water typing are still important goals of the Board. The problem to be addressed is can the water typing model and default physical criteria be improved resulting in greater precision in the identification of the F/N break.

RULE GROUP RESOURCE OBJECTIVES AND PERFORMANCE TARGETS

Resource Objectives:

- Streams and their associated wetlands should be typed to include fish habitat. Fish habitat is defined in the forest practices rules to mean “habitat, which is used by fish at any life stage at any time of the year, including potential habitat likely to be used by fish, which could be recovered by restoration or management, and including off-channel habitat.

- The rules also direct that the department (DNR) prepare water typing maps, which will be based on a multi-parameter, field-verified, peer-reviewed, geographic information system (GIS) logistic regression model. The multi-parameter model will be designed to identify fish habitat by using geomorphic parameters such as basin size, gradient, elevation, and other indicators.

- The predictive fish habitat model should have a statistical accuracy of +/- 5% with the line of demarcation between fish and non-fish-habitat waters equally likely to be over- and under inclusive.

CRITICAL QUESTIONS

The CMER work plan contains critical questions at both the program and project levels. Critical questions may be revised during the scoping phase of the project, if needed, in consideration of any specific TFW Policy and FP Board guidance regarding the project. The Forests and Fish Report (FFR) provided rationale and guidance for a strategy related to the stream typing system. The Adaptive Management Program has been tasked with developing and validating an updated GIS-based logistic regression model and evaluating default physical criteria to predict the upstream extent of fish habitat. This task falls under the Stream Typing Program, which is categorized as a rule tool.

Table 1. Stream Typing and Default Physicals Critical Questions identified by ISAG.

Critical Questions
How can the demarcation between fish- and non-fish-habitat waters be accurately identified?
Can high resolution LiDAR data be used in conjunction with the old fish model to inform the development of a new and more accurate fish model for predicting the upstream extent of fish habitat to sufficiently satisfy the requirements of the Forest and Fish Agreement?
How well do current default physical criteria (Eastside and Westside) accurately and consistently identify the upstream extent of (detected) fish presence (all species) and/or fish habitat?
Are there (single) sustained gradient or stream size thresholds at which a default physical criteria could be applied regardless of other stream characteristics?
What are the most appropriate/effective methods for documenting fish presence/absence (include electrofishing) in lotic habitats?
Are current Type-F buffer Rx's effective in providing/maintaining fish habitat necessary to support fish populations?

PROPOSED NEXT STEPS

Science used in the Adaptive Management Program needs to be rigorous, objective, transparent, and complete. Once projects are approved by Policy, the study design and results need to be peer-reviewed before they are accepted. Identifying sources of existing data, previous work, and anecdotal evidence will be informative in developing study designs for water typing. Existing data can be used to inform the appropriate sampling frame, strata, scale (spatial and temporal), covariates, signal to noise of methods, etc.

1. In order to accomplish the identified tasks above, it is necessary to assemble an external technical group to develop study designs for a water typing model and default physical criteria to define the extent of fish habitat.

2. The technical team should make the determination of whether it is more efficient to combine modeling and physical criteria into a single study design or develop two

independent studies. Consideration should be given to combining the research at the appropriate spatial scale to reduce costs, improve accuracy, and provide consistency to compare data independently.

3. Study design(s) should be reviewed and implemented at CMER by a technical writing and implementation group (TWIG) or the instream scientific advisory group (ISAG).

4. The funding for the two completed study designs should not exceed $250,000. This includes the work of the UW Precision Forestry Cooperative to make improvements following the initial proof of concept work described above.

5. Deliverables will be an ISPR ready study design(s) by June 30, 2017.