Document 3a. Road-Stream Hydrologic Connectivity - Draft Scoping Literature Review

For the 16 April 2025 IRST meeting

Introduction

Reviews of the impacts of roads on hydrologic processes can be found in Dube, PFA, and Kastridis, and will only briefly be summarized here. Rather the focus of this literature review is intended to inform possible road-stream hydrologic connectivity monitoring methods to be presented as scoping proposals in section 3.

- Special attention is given to Dube and Martin, as they were cited in the pfa as examples to build on
- Four levels of RHSC effectiveness monitoring could be considered: 1) simple hydrologic connectivity, 2) sediment inputs to streams, 3) sediment effects on aquatic habitats, and 4) effects on aquatic species populations.
- Emphasis of AMPC questions appears to be on simple connectivity, however, the final question references achieving the biological goals and objectives, which include runoff and sediment as related to covered species habitat needs.
- Given these questions, this scoping proposal and literature review focuses on methods for measuring or estimating connectivity as the first priority but also addresses estimating sediment inputs and habitat/species impacts to a lesser degree.

Hydrologic Connectivity

- How is hydrologic connectivity defined?

hydrologic disconnection is defined in the Oregon FPA as “the removal of direct routes of drainage or overland flow of road runoff to waters of the state” (OAR 629-600-0100 (71)); however, in rule, there is no definition of hydrologic connection. In March 2025, the IRST developed the following as the IRST’s working definition of road-stream hydrologic connectivity:

"A road segment is considered hydrologically connected where surface runoff from road cuts, ditches, running surfaces, and fills exhibits a continuous surface flow path to a natural stream channel."

Measurement

Field methods

- Dubé (2010) recorded 5 levels of connectivity in their field assessment: none, 2 levels of potential, direct via gully or from road structure, or a road paralleling a stream within 20 ft
- RSHC was determined visually by field crew using protocol x
- found observer differences to be pretty large, and this is worth effort to control, especially since we are tasked with before vs after PFA Rx implementation.
- Martin did not describe RSHC determination methods but it is assumed similar to Dube
- FRIA process landowners will assess their own road systems for connectivity using four categories: meets FPR standards, does not meet, vacated, or abandoned
- Other examples of field methods?
- Geomorphic Road Analysis and Inventory Package (GRAIP), a field-based model developed by the Forest Service Rocky Mountain Research Station and Utah State University. The model predicts road to stream hydrologic connectivity, sediment production and delivery to streams, downstream sediment accumulation, risks of shallow landslides caused by roads, gully initiation risk below drain points, and risks to road-stream crossings. (Black 2012; Cissel 2012)
- Predictions of road sediment production are made for each road segment utilizing the information on road attributes, condition, length and slope. These predictions are made based on either locally collected sediment plot data for typical road segments (Luce and Black 1999, Luce and Black 2001)

Modeling

- Rshc models have been developed based on identifying key determinants from field studies
- graip-lite; used in NW Forest Plan aquatic and riparian effectiveness monitoring program (AREMP)
- Any studies on accuracy?

Sampling Design

Spatial

- Given their costs and time required, Field-based methods and field-calibrated models generally must rely on limited samples taken from the broader area of interest
- These targets were tied to subbasins (average area = 6.26 mi2), but Dube opted not to use these because statewide mapping was not complete and the much larger proportion of headwater basins meant that larger mainstem streams might be missed. Instead they opted for four-square-mile sample units based on aggregating quarter sections from the general land survey (Raines 2009). An added benefit is that these sections are more likely to follow property lines.
- At the third and most local sampling level, roads were divided into segments that drain to a common point and share other related characteristics (surfacing, traffic, slope). Other efforts, such as FRIA and GRAIP base their sampling and analyses on road segments with similar drainage and attributes as well.
- FRIA requires large landowners to conduct a complete inventory of their roads, effectively creating a census rather than a subsample; Landowners are encouraged to conduct distinct FRIAs for geographically distinct ownership blocks.

- GRAIP has typically been used to create a census of roads for particular limited ownerships, but an un- or lightly calibrated modeling approach can potentially evaluate all roads in a broad area, assuming at least a GIS inventory of roads and streams. AREMP was able to model RSHC for all roads in their area of interest based on a compilation agency road inventories. However the only road condition change categories available consistently were whether the road segments were active or decommissioned, limiting the detail of the results.

Covariates/Strata

- RSHC is influenced by a number of environmental and human-made influences, which can be either explicitly integrated into the sampling design or simply noted during field work and analyzed posthoc. The former increases chances that statistically-based conclusions can be generated but also increases the sample size needed for each covariate.
- AMPC question 2a specifically asks how results vary by landowner type, which are divided into large (>5000 ac) and small nonindustrial
- Dube encountered challenges aggregating sufficient blocks and getting landowner permissions in more fragmented nonindustrial ownerships with the result that ~95 percent of their sampled area ended up coming from industrial and state/local government owners. A separate effort by Martin (2009) was meant to address this ???
- Delivery influenced by both human-caused factors (location, surfacing, traffic) and environmental factors (slope, soils, geology, rainfall patterns)
- Prior to the Dube study, performance targets had been set for 3 geographic regions (Coastal/Spruce, West of Cascade Crest, East of Cascade Crest), so Dube stratified their sampling by the proportion of eligible lands within each zones.
- What other ODF rule-based covariates might be considered?

Temporal Sampling

- Timing of sampling is critical for establishing baseline and trend estimates of RSHC.
- Dube faced a number of related challenges which are likely to be similar for the Oregon AMP process.
- First was the time it takes to get a sampling effort executed. The original vision was to have a first sample before significant RMAP work had been accomplished, a second sample mid-way through RMAP efforts, and a third sample after RMAP was completed. However, the first sample was collected in 2006/2007. These results were reviewed by ISPR and approved by CMER in early 2010, and represent a point mid-way through RMAP efforts.
- The new Oregon rules went into effect Jan 2024 and expect landowners to begin identifying and remediating the worst road segments as soon as possible. It will likely take a couple of years for AMP to execute an initial field based assessment, meaning that some restoration will have already occurred. Records from the FRIA process should be able to help identify these post-rule changes, which then could either be dropped or assumed connected in the baseline.
- In terms of trend, timing and budgetary considerations have delayed the follow up sample to Dube which was intended to show trend and efficacy. It is now scheduled to occur in 2028, well after RMAP completion in 2021 (2023-2025 fp_cmer_wrkplan.pdf).

Assessment

- Measurement and sampling choices should be driven by a plan on how to ultimately assess the data.
- Studies reviewed have used relatively simple metrics.
- Dube reported connected road length both per square mile and per mile of stream;
- performance target ranges were established from the low-medium categories of an expert rating of watersheds for aquatic risk
- FRIA will simply report on road length in each of their categories and particularly length of roads transitioning from not meeting to meeting standards
- Aremp measured changes in modeled connected road length by HUC12 (km/km2)
- One challenge with using stream length in an indicator is that this may change as better maps are developed

[perhaps insert table of reference and measures used]

Sediment Delivery

- Chronic sedimentation is typically the main impact from road-stream connectivity on aquatic species, so a number of methods have been devised to measure sediment delivery

Measurement

- Similar to simple hydro connectivity measuring and assessing sediment delivery has been done through both field-based and model-based methods
- A number of field methods have been developed to get the most accurate estimates of sediment contributions to streams from RSHC
  - Tipping buckets, sediment traps
  - turbidity threshold sampling approach (TTS) – uses a pressure transducer and metal flume (Skaugset 2011)
- logistics limit actual field sampling of sediment to relatively small areas, so monitoring at the scale envisioned by AMP has generally been done using field calibrated or even uncalibrated models.
- A number of road-stream sediment models have been developed
  - SEDMODL2 (Boise Cascade and NCASI)
  - WARSEM
  - GRAIP
  - Netmap
  - WEPP Road: for modeling road segments (Elliot and Hall 1997). WEPP Road is a fairly generic tool that is run online using site and road conditions selected from a menu of default choices developed largely based on empirical observations
  - ROADMOD
- Models require somewhat different inputs

- Models have been found to be useful for relative comparisons but absolute accuracy not reliable to a high degree of variation in the drivers not captured by existing datasets (Dube 2011, Fu 2010)
- The more factors measured, generally the greater accuracy but also greater costs

Sampling Design

Spatial

- Dube's sampling scheme was described in the previous section
- Did incorporating sediment alter Dube's design at all?

Covariates/Strata

- Geology
  - Cabrera (2016) stratified by granitic and volcanic geologies
- Stream size
  - is a factor in the interpretation of sediment effects on macroinvertebrate communities. The same amount of sediment in a small stream has a greater potential to effect biota compared to that amount of sediment in a larger stream. (Sheridan)

Temporal Sampling

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Assessment

- AREMP Estimated sediment delivery was summarized for each of the 12-digit hydrologic unit codes (HUC12) with at least 5 percent federal land
  - dividing the estimated sediment delivery values by the subwatershed area to account for subwatersheds of varying size
  - not calibrated for local geology, climate, or other influences, so results were to be interpreted as relative

Habitat/Species Effects

- Ultimate concern of HCP is to maintain viable populations of the species of concern through the provision of adequate habitat
- studies linking particular habitat attributes and the effects on aquatic and riparian species are too numerous to discuss here, but more relevant to this effort are monitoring and assessment programs that have been developed based on the habitat-species links
- WA HCP
- NMFS matrix
- ODFW
- AREMP
- PIBO

Measurement

- NMFS matrix: Increase in Drainage Network, Road Density & Location

- AREMP: pool-tail crest fines & transect substrate particle percentiles

Sampling Design

Assessment

Summary

The scoping review yielded insights that could be valuable for the AMPC when considering future work and for those designing and conducting that work. Insights were gleaned on the process of conducting the review and from the content of the reviewed documents.

- In visual assessments of RSHC, observer differences have found to be large, and this is worth effort to control, especially since we are tasked with before vs after PFA Rx implementation.
- Models have been found to be Useful for relative comparisons but absolute accuracy not reliable to a high degree of variation in the drivers not captured by existing datasets (Dube 2011, Fu 2010)
- We do not have the knowledge or context to know what sediment yield numbers mean or how they inform actions. (what is difference between a 5 cu yd and 15 cu yd annual yield?)