Document 2:

Hydrologic connectivity: Draft definitions

For 6 March 2025 IRST meeting

From Ellen Bishop

I've discussed how to best to define hydrologic connectivity (HC) for the Roads-Streams Scoping proposal with IRST members Jeff Light and Michael Furniss. Two definitions and a more refined term for hydrologic connectivity for use in the Roads-Streams Scoping Proposal (RSSP) have been suggested. Attached, please find a:

- summary of statements re hydrologic connectivity in the PFA Roads section
- Jeff Light's thoughts re HC.
- Michael Furniss' thoughts re HC.

Suggested term

Road-Stream Hydrologic Connectivity instead of Hydrologic Connectivity,

Two suggested definitions

<u>Suggestion 1</u>: ***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.*** (The definition would benefit from being specific about where the runoff that entrains sediments, pollutants, and contaminants comes from. It might also include what intensity ("design")) events it applies to, such as heavy rainfall or rapid snowmelt.)

<u>Suggestion 2</u>: ***The connection of water and its included sediments with the natural surface waters of the State of Oregon**. ("Sediments" may be further defined in the RSSP.)*

Considerations included in these definitions

- The PFA and most definitions in the literature include transported sediment in their definition of hydrologic connectivity. Some include other transported materials including tire fragments, engine oil, and biological materials including spores and pathogens. Thus, the definition for the RSSP might specify that "hydrologic connectivity" includes more than just water and the term is a proxy for all materials delivered to the stream from forest road networks that can adversely affect habitat for fish and amphibians of concern.
- Water, both surface and intercepted ground water, is the means of delivery of these materials.
- These considerations are included in the Introduction to Dube', et al, 2010.
- At the Feb. 19 meeting, IRST members clearly stated that the definition should be simple and easily understood.

Roads, Hydrologic Connectivity, and Sediment: Quotes from the PFA:

1. **Goals of the PFA: Includes this bullet point, p. 6-7.**
   Provide science-driven adaptive management process through the establishment of an Adaptive Management Program that involves a rigorous look at the efficacy of existing and future forest practice regulations, and a science-driven process for analyzing the need for any changes.
2. **Hydrologic connectivity of roads: Introduction: Roads: p. 43-42**
   Forest roads have the potential to impact the covered species by blocking access to habitat and by allowing sediment delivery to watercourses. **Networks of forest roads can affect forest hydrology by increasing overland flow, increasing drainage density, and intercepting sub-surface flow (**Wemple et al., 2001; Trombulak and Frissell, 2000; Gucinski, 2001; Van Meerveld et al., 2014).

   Forest roads can increase surface runoff and alter stream flow, although these effects vary in time and space depending on how recently the road has been constructed, where the road is located on the hillslope, and the scale of analysis (Wemple et al., 2001).

   Networks of forest roads can also act as a source of fine sediment to streams (NCASI, 2001; Reid and Dunne, 1984). Forest roads can also be an area of potentially high hydrologic connectivity between the road surface and streams (La Marche and Lettenmaier, 2001).

   Hydrologically connected roads can deliver increased runoff, sediment, and chemicals associated with roads, including spills, tire debris, or oils generated on the road surface or cutslope.

   Road-related sediment can fill pools, cover spawning gravel, and aggrade stream channels (Furniss et al., 1991).

3. 4.1.7 Disconnecting Roads from Streams Page 45.
   Road drainage structures that deliver runoff directly to streams can affect sediment loads, peak flows, and transport of pollutants to streams. Furniss et al. (2000) showed that hydrologically connected roads can deliver increased runoff, sediment, and chemicals associated with roads, such as spills or oils generated on the road surface or cutslope.

4. "Hydrologic disconnection" means the removal of direct routes of drainage or overland flow of road runoff to waters of the state. Page 48.

5. Section 4.2: Goals: Page 49
   The overarching goal of the Private Forest Accord road management package is a balanced

regulatory approach in which landowners continue to operate all roads as necessary, minimize new road construction, and build and maintain roads to achieve habitat and water quality requirements that ensure the viability of covered species.

To achieve this overarching goal, all roads will be designed, constructed, improved, maintained, or vacated to:
a. Prevent or minimize sediment delivery to waters of the state;
b. Ensure passage for covered aquatic organisms during all mobile life-history stages;
c. Prevent or minimize drainage or unstable sidecast in areas where mass wasting could deliver to public resources or threaten public safety;
d. Prevent or minimize hydrologic alterations of the channel;
e. Prevent or minimize impacts to stream bank stability, existing stream channel, and riparian vegetation;
f. To the maximum extent practicable, hydrologically disconnect forest roads and landings from waters of the state; and
g. Avoid, minimize, and mitigate loss of wetland function.

6. Section 4.3.22: FRIA process:

   b. The Initial Inventory (Years 0-5) (p. 55)
   The Initial Inventory occurs concurrently with the Pre-Inventory during the first five years of the FRIA process. As part of the Initial Inventory, an assessment of the complete road network for each RMB must be submitted to ODF within the initial 5-year period of the FRIA.

   In the Initial Inventory, landowners will identify and prioritize sites consistent with the following priorities for work over the FRIA period. Priorities for work will be projects that will provide the greatest environmental benefit (greatest good first), consistent with potential risk of negative impacts to resources protected under the FPA. Generally, projects will be prioritized in the following order, while also taking into consideration operational constraints:
   1) Fish passage barriers, consistent with ODFW requirements.
   2) Erosion and sediment within the road prism (cutslope, ditch, road surface, fill slope), stream diversion potential, **and hydrologic connectivity such that delivery to waters of the state is minimized.**

Hydrologic Connectivity Definition for use in IRST Roads Effectiveness Monitoring Program

Jeff Light

February 23, 2025

Definition

Hydrologic connectivity is a term with very narrow scope and purpose with regard to our work on a road construction and maintenance effectiveness monitoring program for Oregon's forest practices rules governing private forestland management. Though Freeman and others (2007)[1] define this term broadly, and in an ecological context as "the water-mediated transport of matter, energy and organisms within or between elements of the hydrologic cycle", this is too broad for our purposes. Hooke's (2003) definition "the physical linkage of water and sediment through the fluvial system" is closer to the mark, and that of Kastridis (2020) "the linkage between runoff locations and the receiving waters" is closer still. Surfleet and Marks (2021) get at it precisely when they described the issue we are concerned with, which is the "*increased* connectivity of overland flow to water courses (increased drainage density)".

Water is our proxy for all materials delivered to stream systems from forest road networks that can adversely affect fish and amphibian habitat. The delivery of surface water (including intercepted ground water) to streams via forest roads is our primary concern. Water is the means of delivery, and often a mechanism of generation, of these materials. This is presented and discussed thoroughly in the Introduction of Dube et al.'s (2010) road sub-basin scale effectiveness monitoring report for the Washington Dept. of Natural Resources (DNR). Additionally, in their "Preliminary Research Questions for the research topic: Requirements of baseline and trend monitoring of road rules, the Adaptive Management Program Committee noted that ""hydrologic connectivity" is not defined in rule. This term refers to *the degree to which a road is hydrologically connected to a stream* (my emphasis), whereas the definition in rule ("hydrologic disconnection" [OAR 629-600-0100(71)]) focuses on the process for removing this connectivity".

In sum, however we get there, I believe we can settle on a simple definition of hydrologic connectivity that is something like "the degree to which overland flow is connected to natural surface waters".

Metrics/Performance Targets

[1] And apparently taken/modified from Pringle (2003) or (2001).

Ultimately, the work of the IRST will be to provide AMPC and the Board of Forestry with information regarding the effectiveness of rules that aim to reduce the road-related delivery of water and sediment to natural water courses on private forestlands in Oregon. To achieve this, the IRST will have to develop performance metrics to be used with data we gather in our road monitoring program. In their very similar project for the Washington State DNR, Dube et al. (2010, page 12) describe their performance metrics of:

1. Delivering Road Length (RLEN), and;
2. Road Sediment Production Estimates (RSED), based on the model WARSEM.

The IRST can adopt these measures, or develop different ones. This is different from the simpler problem of defining hydrologic connectivity, but we may want to look for ideas as we peruse the literature, or explicitly request that our contractors do so.

Toward a definition of Road-Stream Hydrologic Connectivity

Michael J. Furniss
February 25, 2025

A few suggestions offered:

I propose we term this **"Road-Stream Hydrologic Connectivity"** (or "Road-Stream Hydrologic Connection") as there can be other uses for the generic term "hydrologic connectivity," some of which are positive such as for aquatic organism passage, surface flow continuity, groundwater-surface water connection, and so on.

RSHC is a powerful indicator of effectiveness in many ways. Its simplicity and the ability of people to understand the concept, even if they have not been involved with road best management practices, is a keystone. While we should be wary of making it more complex than "The degree to which overland flow is connected to natural surface waters," this is an opportunity to define this precisely. Attempting to disambiguate but not letting the simplicity get lost in the multitude of references in the literature, many of which were not primarily focused on this phenomenon.

The definition would benefit from being specific about where the runoff that entrains sediments, pollutants, and contaminants comes from (4 features on roads ought to be included) and what drives the runoff and delivery (rainfall and snowmelt).

Thinking of how this gets operationalized in sampling for research and in best practice, here are some criteria that might be worth grounding in:

1. Simple and easy to understand
2. Observable in the field without specialized expertise or instrumentation (but training OK)
3. Tied to and reported by identifiable road segments (drainage reaches) and drainage areas, such as in Dube et al. 2010)
4. It is usually a binary determination (connected or not), but can it accommodate nuances (such as almost connected?)?
5. Straight-forward field method(s) for observation, recording, data aggregation, and interpretation.
6. Helps distinguish disconnectable vs non-disconnectable segments
7. Recognizes that RSHC is strongly tied to the proximity of roads to streams and stream crossings.

   See:https://docs.google.com/presentation/d/1TTvIX5cWIxoddZPBIvcv1qxpboBnTjzp/edit?usp=sharing&ouid=102191688941803819623&rtpof=true&sd=true

8. Data collection and reporting formats are commensurate across ownerships.

9. It is inexpensive to inventory/sample while obtaining reliable information
10. Adequately indicates the treatment area for "hydrologic disconnections."

See the attached spreadsheet that was part of the PFA negotiations.

I published this in 2000, as follows, though this was not included in the literature review.

> "A working definition of Hydrologically□Connected Road, is: "Any road segment that, during a 'design' runoff event, has a continuous surface flow path between any part of the road prism and a natural stream channel." Hydrologic connectivity will tend to increase with increasing intensity and duration of precipitation or snowmelt, and with increasing antecedent soil moisture content. A suitable "design" runoff event for many purposes might be the 1-year, 6-hour storm, with antecedent moisture conditions corresponding to the wettest month of the year, or similar expression of precipitation depth, statistical frequency, duration, and antecedent soil moisture status." https://www.fs.usda.gov/biology/nsaec/assets/sn_07_00.pdf

I think substituting "during heavy rainfall or rapid snowmelt" instead of a design storm could be more practical.

See:
https://www.pacificwatershed.com/sites/default/files/14_-_appendix_c_-_california_board_of_forestry_and_fire_protection.pdf

See the attached spreadsheet, the Hydrologic Connectivity tab.

So, here is a suggestion for a rigorous definition for discussion.

> ***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 during heavy rainfall or rapid snowmelt.***

We don't need to specify what could be entrained in the runoff. While sediment is the big one for low-volume wildland roads, there are mainline and collector roads that can contribute other undesirable materials, and the list can be long, such as pathogens like POC root rot spores, hydraulic fluid, engine oil, diverse spills, invasive organism propagules, 6PPD, and so on. The accelerated delivery of water alone can be of concern as well as it can change the hydrograph and increase peak flows. Wemple et al (1996), which seems to have popularized this thinking, focused on "channel network extension by roads", focusing on basin broad hydrologic changes.
A simple definition of connectivity encompasses all materials of concern, as this is the mechanism by which they get into the water and have the potential to transmit damage

downstream. Salmonid impacts are a focus, though water quality encompasses the full range of potential impacts of RSHC. Notably, non-sediment contaminants from roads are the focus in urban areas.

We might also want to create a definition of "hydrologic disconnection". While this is also a simple concept, there is an element of durability and failure risk in most treatments that could be incorporated. A listing of options for disconnection demonstrates that this is also a simple, do-able best practice wherever feasible.

Overall, we should look for where things might go awry and where confusion could slip in. It is always a good idea to consider the risk of wasting time and money collecting information that cannot be usefully interpreted across scales.