

How much dirt is in the creek? A probabilistic approach to assessing sediment delivery risk to waterbodies on National Forest System lands in western Montana

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USDA Forest Service- Northern
Region



Thu Jul 12 12:47:24 MDT 2018
5144562
348° S88W 4764mils (True)
39° 2'
Point site sweathouse creek



Forest Service management and sediment

- Management can increase sediment delivery to waterbodies
- Adverse water quality and aquatic habitat effects
- Near-ubiquitous facet of environmental analysis



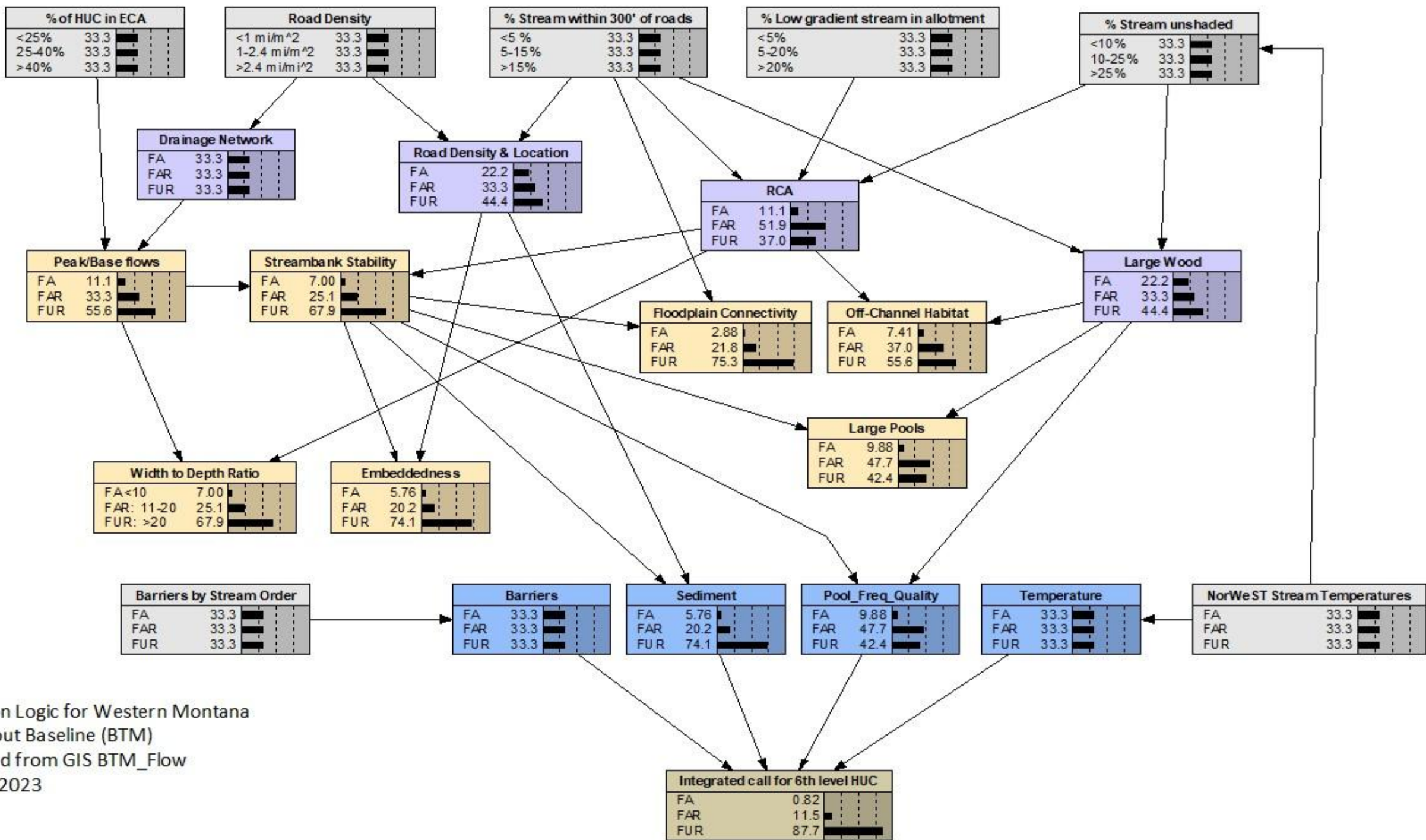
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9 5130741

0° S80E 1778mils (True)

9°

rosion



Decision Logic for Western Montana
 Bull Trout Baseline (BTM)
 Adapted from GIS BTM_Flow
 6 June 2023

Alternative conceptual approach...back to the future...

- Contextualize management-induced sediment delivery risk relative to natural range of variation
- Replication of:
 - TMDL conceptual framework
 - WATSED/NEZSED cumulative sediment analysis
- **BUT...**
- Contextualize as probability distribution rather than a threshold value
- Account for error



<https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcSkmx3BVKWZ9U1Oo mAElyfN3SCsEunyW0mdcQ&s>

What is the natural range of variation?

TABLE 1. LONG-TERM AND SHORT-TERM SEDIMENT YIELDS

Catchment*	Area (km ²)	Conventional		Cosmogenic	
		Record length (yr)	Sediment yield (t·km ⁻² ·yr ⁻¹)	Time scale (yr)	Sediment yield (t·km ⁻² ·yr ⁻¹)
Silver Creek					
1 SC-2	1.2	27	13.2 ± 2.2	5 100	327 ± 42
2 SC-3	1.3	28	8.9 ± 1.4	9 400	174 ± 23
3 SC-5	1.1	28	10.9 ± 1.6	12 000	136 ± 18
4 SC-6	1.6	27	9.3 ± 1.7	11 000	152 ± 22
5 SC-7	0.23	22	14.4 ± 2.5	17 000	90 ± 12
6 SC-8	1.1	13	30.0 ± 10.6	13 000	121 ± 16
Horse Creek					
7 HC-2	0.57	10	7.3 ± 1.3	16 000	97 ± 13
8 HC-4	1.4	10	3.5 ± 0.6	18 000	89 ± 12
9 HC-6	1.0	15	3.3 ± 0.6	19 000	80 ± 11
10 HC-8	1.5	12	11.0 ± 3.0	17 000	90 ± 13
11 HC-9	0.23	10	8.6 ± 1.3	19 000	80 ± 11
12 HC-10	0.65	12	9.9 ± 2.4	17 000	92 ± 13
13 HC-12	0.83	14	8.2 ± 2.3	16 000	101 ± 14
14 HC-14	0.62	12	7.5 ± 2.3	19 000	80 ± 12
15 HC-16	0.21	13	25.1 ± 6.7	27 000	55 ± 8
16 West Fork	17	23	5.0 ± 0.5	18 000	87 ± 12
17 East Fork	14	23	2.5 ± 0.3	20 000	76 ± 11
Tailholt & Circle End Creeks					
18 Tailholt A	2.2	21	11.0 ± 2.5	6 300	264 ± 36
19 Tailholt B	1.6	22	14.6 ± 3.3	6 400	262 ± 34
20 Tailholt C	1.4	22	13.7 ± 2.4	8 200	202 ± 26
21 Tailholt Main	6.6	28	14.0 ± 2.8	7 000	239 ± 32
22 Circle End A	0.8	N.D. [†]	N.D.	7 300	226 ± 29
23 Circle End B	2.3	N.D.	N.D.	7 300	229 ± 30
24 Circle End Main	3.8	25	6.5 ± 1.1	7 700	215 ± 29
Larger Streams and Rivers					
25 Trapper Creek	20	10	9.8 ± 1.6	26 000	57 ± 8
26 South Fk. Red River	98	14	8.0 ± 1.4	25 000	58 ± 8
27 Upper Red River	129	14	10.1 ± 1.6	18 000	87 ± 12
28 Johns Creek	293	10	7.6 ± 1.3	15 000	108 ± 15
29 S. Fk. Clearwater R.	2 149	25	7.6 ± 2.3	17 000	91 ± 12
30 Lochsa River	3 055	72	26.3 ± 2.8	6 700	250 ± 32
31 Selway River	4 945	70	24.5 ± 3.2	8 100	205 ± 28
32 Salmon River	35 079	84	13.7 ± 4.1	6 300	261 ± 36

*Identification numbers are coded to Figure A and Table A (see footnote 1). Sampling and analytical details are given as notes accompanying Table A.

[†]N.D. = not determined.

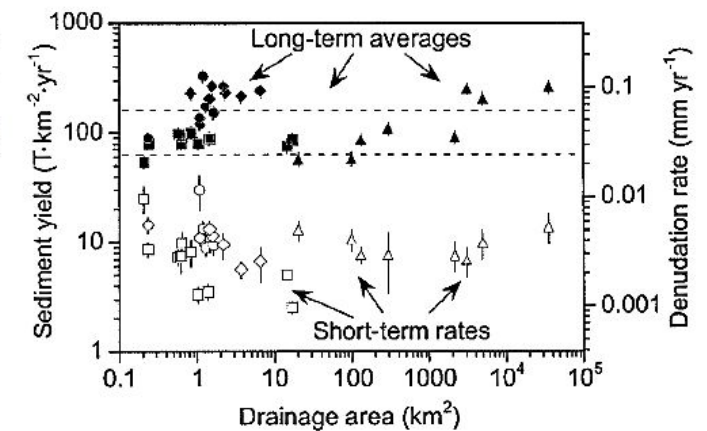


Figure 1. Short-term and long-term sediment yields for Idaho catchments. Catchment sediment yields were measured over 5–27 k.y. using cosmogenic ¹⁰Be in alluvial quartz grains (closed symbols) and over shorter periods by conventional methods (open symbols): sediment trapping at Silver Creek (circles), Horse Creek (squares), and Tailholt and Circle End Creeks (diamonds), and sediment gauging at larger rivers (triangles). Data and methods are given in Table A (see footnote 1); standard errors are shown where larger than plotting symbols. Dotted lines indicate range of expected climate-driven variability in long-term sediment yields, inferred from cosmogenic ¹⁰Be and ²⁶Al measurements at seven Sierra Nevada sites with average annual temperatures ranging from 4 to 15 °C and average annual precipitation ranging from 22 to 178 cm/yr (Riebe et al., 2001b).

times greater than sediment yields measured over 10–84 yr (average = 24 yr) by conventional sediment-trapping and sediment-gauging methods (Table 1; Fig. 1). At all scales, from small experimental catchments (0.2 km²) to large river basins (35 000 km²), long-term sediment yields are consistently much greater than conventional measurements over years or decades would suggest (Fig. 1).

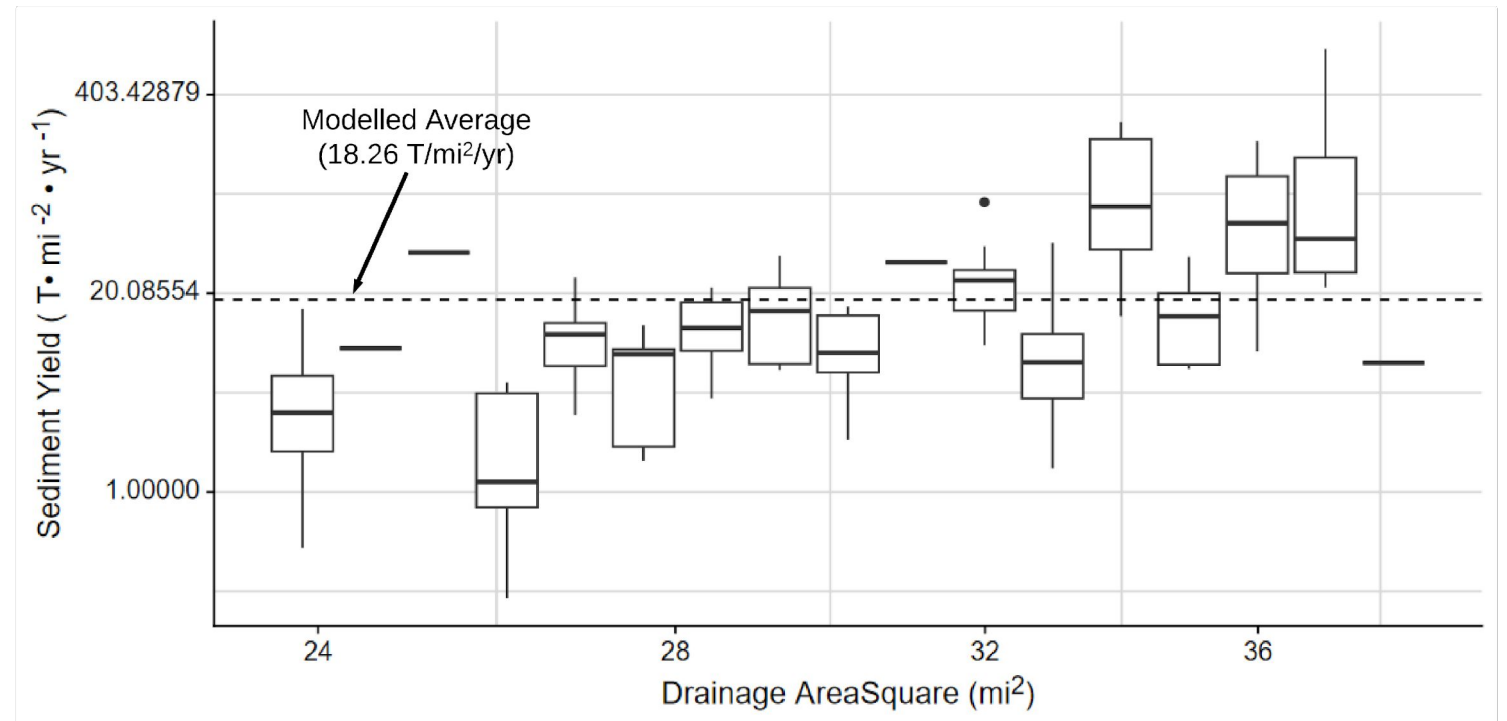
This discrepancy cannot be attributed to artifacts in either of the measurement methods. We previously tested our cosmogenic sediment yield estimates for two small catchments against the accumulation rates

Kirchner et al. 2001

- Varies by broad geologic strata
- Substantial research done in Idaho Batholith
- Less research in Belt metasediments

Developed standalone suspended sediment distributions

- Sourced peer-reviewed and grey literature
- Completed analysis on unpublished USFS data



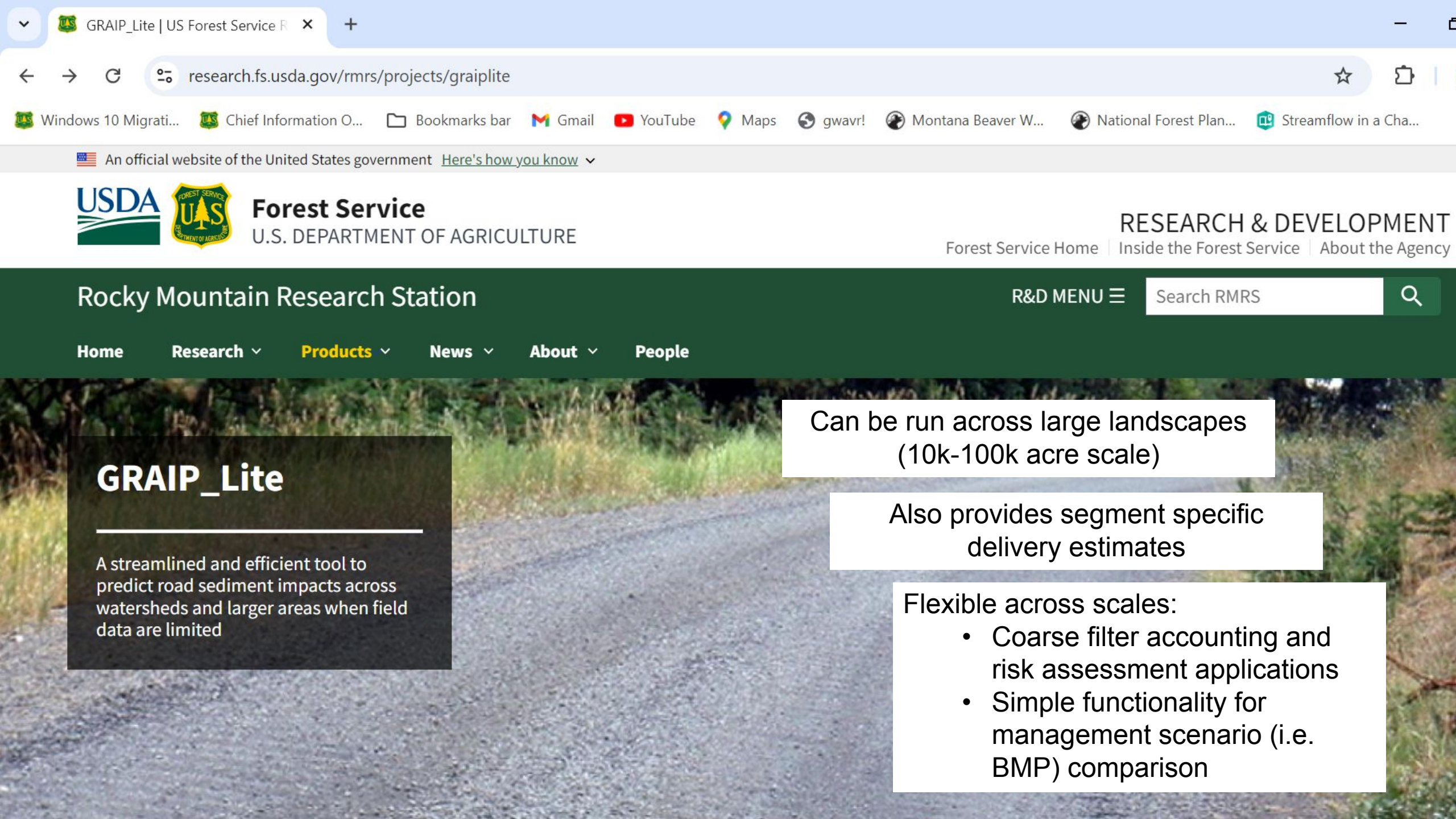
Accounting for
management-in-
duced sediment
delivery

Roads: Assumed large source of
sediment across BTB MPI
domain, greatest risk to aquatic
resources



How to quantify:

**Geomorphic Roads Assessment
Inventory Package-Lite**



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GRAIP_Lite

A streamlined and efficient tool to predict road sediment impacts across watersheds and larger areas when field data are limited

Can be run across large landscapes (10k-100k acre scale)

Also provides segment specific delivery estimates

- Flexible across scales:
- Coarse filter accounting and risk assessment applications
 - Simple functionality for management scenario (i.e. BMP) comparison

Sediment Indicator

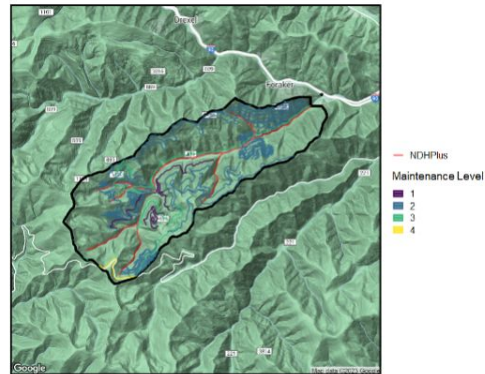
Road Density

- Higher Density = greater road related sediment.
- Treats all roads equal!
- Quick and Easy.
- Miss out on the variability of design, location and maintenance practices.



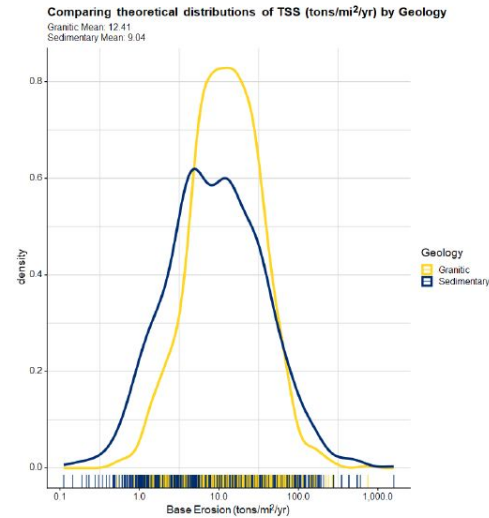
Sediment Delivery

- Alternatives that are more focused on the cons of road density: GRAIP, GRAIP-Lite, WEPP.
- GRAIP and WEPP are intensive data collection.
- GRAIP-Lite can split the middle.



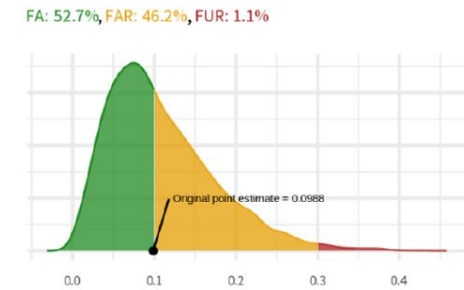
Erosion Context

- Sediment delivery with associated road context is great but what about the natural context (sedimentary, till, granitics, etc).
- Comparing road vs natural proportions might help with this context.

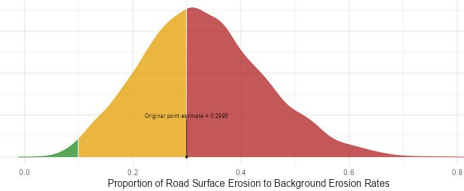


Ratings

- Knowing that we are accounting for error, determine ratings based on changes in proportion.
- Not perfect but will help with uncertainty and understanding context!



Probabilities from the Posterior Predictive Distribution:
FA: 0.8%, FAR: 40.5%, FUR: 58.7%



Date & Time: Mon, May 06, 20 7, 15:44:35 MDI
Position: 11 N 722394 5175603
Altitude: 3437ft
Datum: WGS-84
Azimuth/Bearing: 095° S85E 1.689mils (True)

How much sediment is too much?

REVIEW ARTICLE

Linkages between unpaved forest roads and streambed sediment: why context matters in directing road restoration

Robert Al-Chokhachy^{1,2}, Tom A. Black³, Cameron Thomas⁴, Charles H. Luce³, Bruce Rieman⁵, Richard Cissel³, Anne Carlson⁶, Shane Hendrickson⁷, Eric K. Archer⁸, Jeff L. Kershner¹

Unpaved forest roads remain a pervasive disturbance on public lands and mitigating sediment from road networks remains a priority for management agencies. Restoring roaded landscapes is becoming increasingly important for many native coldwater fishes that disproportionately rely on public lands for persistence. However, effectively targeting restoration opportunities requires a comprehensive understanding of the effects of roads across different ecosystems. Here, we combine a review and a field study to evaluate the status of knowledge supporting the conceptual framework linking unpaved forest roads with streambed sediment. Through our review, we specifically focused on those studies linking measures of the density of forest roads or sediment delivery with empirical streambed sediment measures. Our field study provides an example of a targeted effort of linking spatially explicit estimates of sediment production with measures of streambed sediment. Surprisingly, our review uncovered few studies ($n = 8$) that empirically tested the conceptual framework linking unpaved forest roads and streambed sediment, and the results varied considerably. Field results generally supported the conceptual model that unpaved forest roads can control streambed sediment quality, but demonstrated high-spatial variability in the effects of forest roads on streambed sediment and the need to address hotspots of sediment sources. The importance of context in the effects of forest roads is apparent in both our review and field data, suggesting the need for in situ studies to avoid misdirected restoration actions.

Key words: restoration, road density, sediment production, streambed sediment

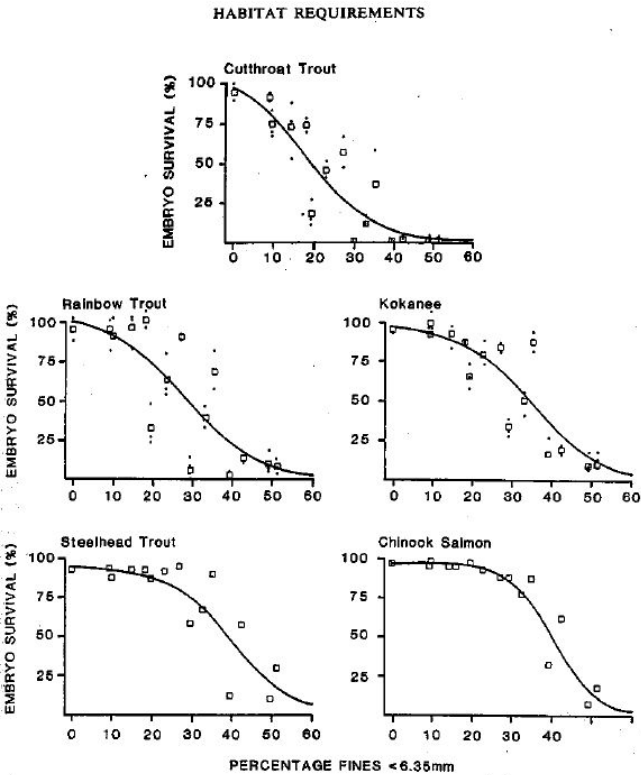


FIGURE 4.9.—Relation between embryo survival and percentage of substrate particles smaller than 6.35 mm for several salmonid species. Chinook salmon and steelhead data are from Tappel and Bjornn (1983); the others are from Irving and Bjornn (1984). Curves were fitted to the data by exponential equations. Squares indicate mean values and dots denote individual replicates.

Bjornn and Reiser 1991

Matrix rating category (WCF category)	Bull Trout Matrix (1998)	Draft Watershed Condition Factor (2023) for Roads and Recreation
FA (Functioning Properly)	In concept, indicators in a watershed are “functioning appropriately” when they maintain strong and significant populations that are interconnected and promote recovery of a proposed or listed species or its critical habitat to a status that will provide self-sustaining and self-regulating populations.	The amount of surface erosion attributed to roads and trails, impacts of stream crossings on aquatic passage and infrastructure resiliency, and proximity and management of developed and dispersed recreation within a watershed indicate the hydrologic regime is substantially intact and unaltered and is essentially functioning properly. [quantitative ranking: GRAIP-Lite erosion <10% of background]
FAR (Functioning at Risk)	... provide for persistence of the species but in more isolated populations and may not promote recovery of a proposed or listed species or its habitat without active or passive restoration efforts.	... the hydrologic regime is moderately altered [quantitative ranking: GRAIP-Lite erosion 10–30% of background]
FUR (Impaired Function)	... suggests the proposed or listed species continues to be absent from historical habitat, or is rare or being maintained at a low population level; although the habitat may maintain the species at this low persistence level, active restoration is needed to begin recovery of the species.	... the hydrologic regime is extensively altered [quantitative ranking: GRAIP-Lite erosion >30% of background]

Rationale

Direct parallel with Watershed Condition Framework approach

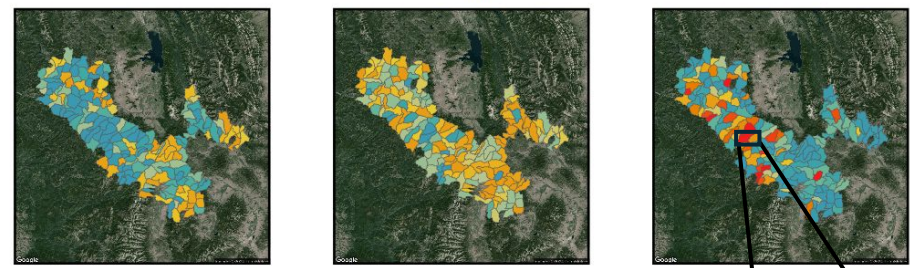
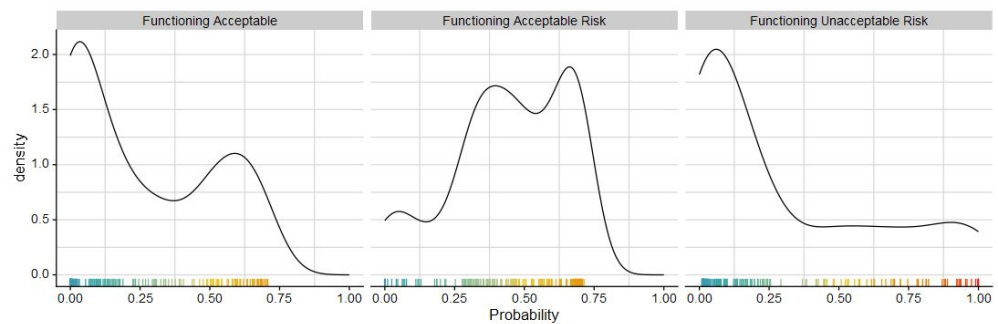
Informed by peer reviewed literature and professional judgement of FS research hydrologists

Anecdotal evidence of effective application of similar benchmarks utilizing the same conceptual framework

Conservative starting point

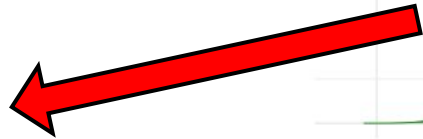
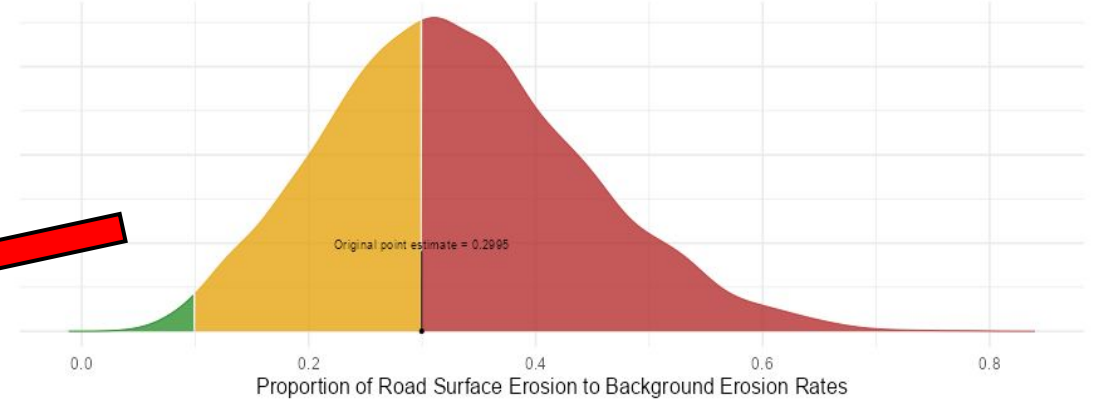
Statistical support from an effect size perspective

Opportunities for future modification



Probabilities from the Posterior Predictive Distribution:

FA: 0.8%, FAR: 40.5%, FUR: 58.7%



main.huc_usc_gl_selection_Lolo_lyr (1)	
Clark Fork River-Second Creek	
main.huc_usc_gl_selection_Lolo_lyr - Clark Fork River-Second Creek	
sdel	32.280498
tlensFS	124.163073
clenFS	26.8685
sprodFS	55.986316
sdleFS	12.804193
tlensFSOp	112.062702
clenFSOp	24.533185
114.7443338°W 47.1531921°N	

RoadSegment - Sediment Delivery [kg per year]

GL_SedDel

- 0.000000 - 140.020586
- 140.020586 - 428.217503
- 428.217503 - 964.301500
- 964.301500 - 2486.145033
- No Sediment Delivery



Summary

- “Fresh take” on longstanding conceptual model for evaluating management-induced sediment delivery effects
 - Used probability distributions rather than thresholds
 - Accounted for error
- Improvement on existing framework used for coarse-filter ESA consultation
 - Multi-scale application opportunities



Questions?

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