STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

To Aid In Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station **October 2005**

Woody Debris Transport at Road-Stream Crossings

by Sam A. Flanagan

Road-stream crossings and the culverts used to convey streamflows across the road are well documented sites of erosion potential. The constriction imposed by culverts present obstacles to a number of materials naturally transported through wildland stream channels; most notably water, woody debris, and sediment. When the capacity of the culvert and crossing is exceeded, streamflow that overtops the road surface often initiates a suite of erosional consequences that include impacts to water quality, stream habitat and biota, and the temporary loss of vital transportation corridors that typically require costly repairs. All too often these sites are repaired only to fail again with little understanding of the failure mechanisms.

Recent work by Furniss et al. (1998) following large floods in the Pacific Northwest indicates that sediment and woody debris are often the key mechanisms of failure for road-stream crossings. Certainly, many regulations and guidelines for culvert sizing are often accompanied with a requirement to consider associated debris and sediment loads. Unfortunately, little guidance is available on how best to size culverts for the associated debris and sediment that is the dominant cause of road-stream crossing failure (refer to Cafferata et al. 2004 for more recent design suggestions). My study describes the interactions of woody debris and culverts and provides design criteria guidelines for reducing future culvert failures.

Study Objectives

The study spanned a three-year period from 1993-1995 in northwest California. The three principal objectives of the work were to:

1) Describe the process of wood lodgment at culvert inlets,

2) Describe the characteristics of woody debris transported through low-order stream channels, and

3) Suggest design criteria to reduce debris plugging hazard.

How Do Culverts Plug?

Plugging of culverts by woody debris is typically initiated by one or more smaller pieces lodging across the culvert inlet during peak flow periods (figures 1 and 2). The point of contact of the wood with the edge of the culvert barrel becomes a site of continued

STREAM NOTES *is produced quarterly by the Stream Systems Technology Center located at Rocky Mountain Research Station, Fort Collins, Colorado. STREAM is a unit of the Watershed, Fish, Wildlife, Air, and Rare Plants Staff in Washington D.C. John Potyondy, Program Manager*

The **PRIMARY AIM** *is to exchange technical ideas and transfer technology among scientists working with wildland stream systems.*

CONTRIBUTIONS *are voluntary and will be accepted at any time. They should be typewritten, single-spaced, and limited to two pages. Graphics and tables are encouraged.*

Ideas and opinions expressed are not necessarily Forest Service policy. Citations, reviews, and use of trade names do not constitute endorsement by the USDA Forest Service.

CORRESPONDENCE:
E-Mail: rmrs_stream@ fs.fed.us
Phone: (970) 295-5983
FAX: (970) 295-5988

Web Site:
http://www.stream.fs.fed.us

IN THIS ISSUE

- **Woody Debris Transport at Road-Stream Crossings**
- **Riparian Roads and Restoration: Electronic Short Course**

Figure 1. Plugging of culverts is typically initiated by a single piece of wood lodging across the inlet (piece "a"). This piece also serves as a site for further accumulation of smaller debris such as seen on the left side of the inlet. Under the protocols used, piece "b" would not have been considered in the data since it does not span the inlet. Two other noteworthy points are the relatively small culvert diameter relative to the channel width and the length of the wood with respect to the channel width.

accumulation of finer material. Over a period of time, a span that may encompass more than one peak flow event, the capacity of the culvert is diminished (figure 2). As the plug forms, sediment may accumulate along the face of the debris and in the slack water conditions of the increasingly ponded inlet area. In many cases, once the culvert has become plugged and buried, the site appears as though it has been overwhelmed with sediment, when, in fact, a single piece of woody debris not much longer than the culvert diameter is responsible (figures 2 and 3). Additionally, my study found that 48 percent of the wood lodged at culvert inlets was less than the channel width (figure 4), indicating that relatively small pieces of wood, rather than large logs, are usually responsible for initiating plugging.

In order to make contact with the culvert, the piece initiating plugging must be oriented perpendicular to the axis of the culvert. Pieces in transport that are aligned parallel with the channel present relatively low lodging potential if the culvert is aligned with the channel and the piece does not rotate as it approaches the culvert inlet (figures 5d and 5h). Conversely, if the culvert is at an angle approaching ninety degrees to the channel, plugging potential is greatly increased as the wood must rotate in order to successfully pass through the culvert (figure 5i). This is a common scenario at cross-drains with long ditch runs that may entrain wood from roadside vegetation. Plugging of the cross drain may send the excess peak flows down the road prism to the next cross drain, testing the capacity of that structure as well.

Anecdotally, culverts that presented a minimal reduction in channel cross-section during high flows allowed wood in transport to pass freely through the culvert (figure 5d). Also, channels which narrowed towards the culvert inlet promoted a parallel alignment of wood during transport. Conversely, channels that widened promoted piece rotation in the turbulent eddies of the widening flows (figure 5e). Presumably these widened sections, all too familiar at many crossings during high flows (figure 1), increase the plugging potential of a site as pieces accumulate and rotate. Likewise, during ponded

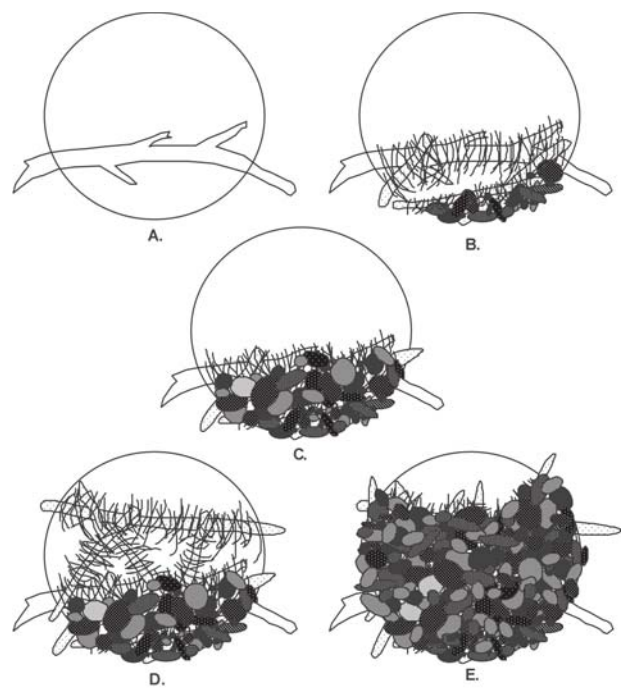


Figure 2. Plugging of culverts by woody debris is typically initiated by a single piece of wood lodging across the inlet (a). This piece serves a locus for the accumulation of detritus and sediment (b). As the plug grows, sediment and detritus seal off a portion of the inlet, reducing its capacity (c). The initiation process may be repeated with a second piece of wood, allowing the plug to grow upwards, further reducing inlet capacity (d and e).

conditions when the culvert inlet is submerged, wood accumulates in the pond (figure 5b). As flow recedes, this mass of wood converges on the inlet en masse, virtually assuring plugging (figure 5c). However, these are anecdotal observations based on a few instances and are best considered untested hypotheses. Any purposeful narrowing of the channel to increase debris capacity must be weighed against observations that wood tends to lodge at channel constrictions (Braudrick et al. 1997).

What Kind of Wood Moves Through Small Channels?

Over the three years of study, peak flows ranged up to a 12-year recurrence interval. A total of 3,114 pieces of fluvial transported wood were captured in fence-like screens installed across 24 channels ranging in width from 0.5 to 3.3 m. Across all channel sizes, 99% of the transported wood was less than the channel width. In the confined channels encompassed by the study sites, excessively long wood either gets hung up in the channel, forming small jam or spannings the channel until it breaks down to a size similar to the width of the channel. Note that these data are for wood transported through channels, rather than wood lodging across culvert inlets. A review of the wood lengths actually plugging culverts (figure 4) suggests that approximately half of the wood lodging across culvert inlets is from the 1% of pieces that are longer than the channel width.

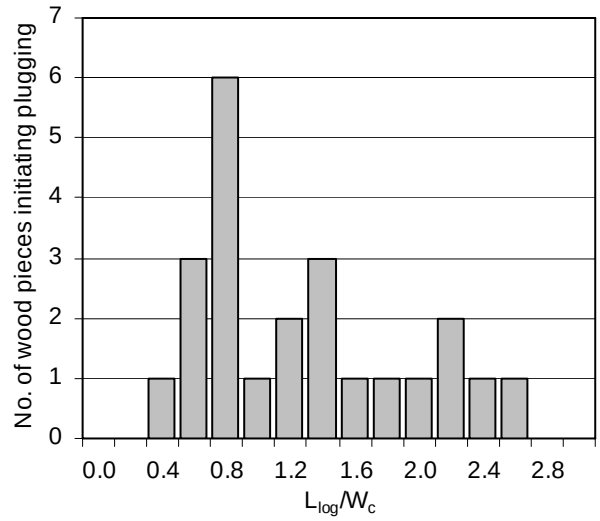


Figure 4. Ratio of wood length to channel width (L_{log}/w_c) for the "initiator pieces" of wood that were lodged across culvert inlets at 23 of 54 plugged sites where channel width data were obtained. An initiator piece of wood is defined as the piece of wood that initiates culvert plugging because it is lodged across the culvert inlet at two points, reducing culvert capacity. Culvert diameters ranged from 0.45 to 1.20 m. Nearly half of the pieces lodged across the inlet are less than the channel width.

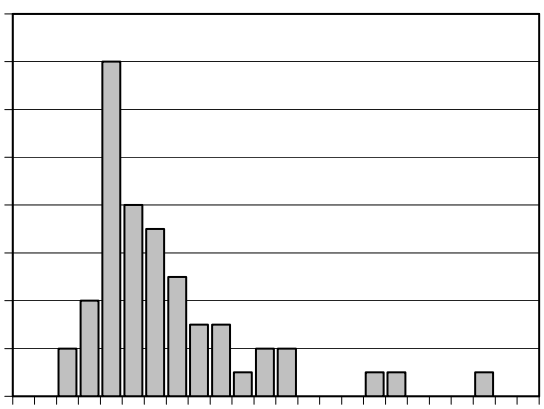


Figure 3. Ratio of wood length to culvert diameter (L_{log}/d) for the "initiator pieces" of wood that were lodged across culvert inlets at 54 plugged sites. An initiator piece of wood is defined as the piece of wood that initiates culvert plugging because it is lodged across the culvert inlet at two points, reducing culvert capacity. Culvert diameters ranged from 0.45 to 1.20 m. The purpose of this figure is to convey the finding that relatively small pieces of wood often initiate plugging rather than large logs.

How Does Wood Supply Influence Plugging?

The amount of forest canopy upstream of the debris screens did not seem to appreciably influence the quantity of debris in transport. Several sites located in relatively sparse, open oak woodlands, had debris quantities captured in the screens that were equal to or greater than the quantities observed in nearby streams with a nearly continuous conifer overstory. In these open settings, wind gusts during storms may introduce large quantities of small wood versus more sheltered coniferous settings.

These observations suggest that the quantity of wood should not be considered limiting. Designs should

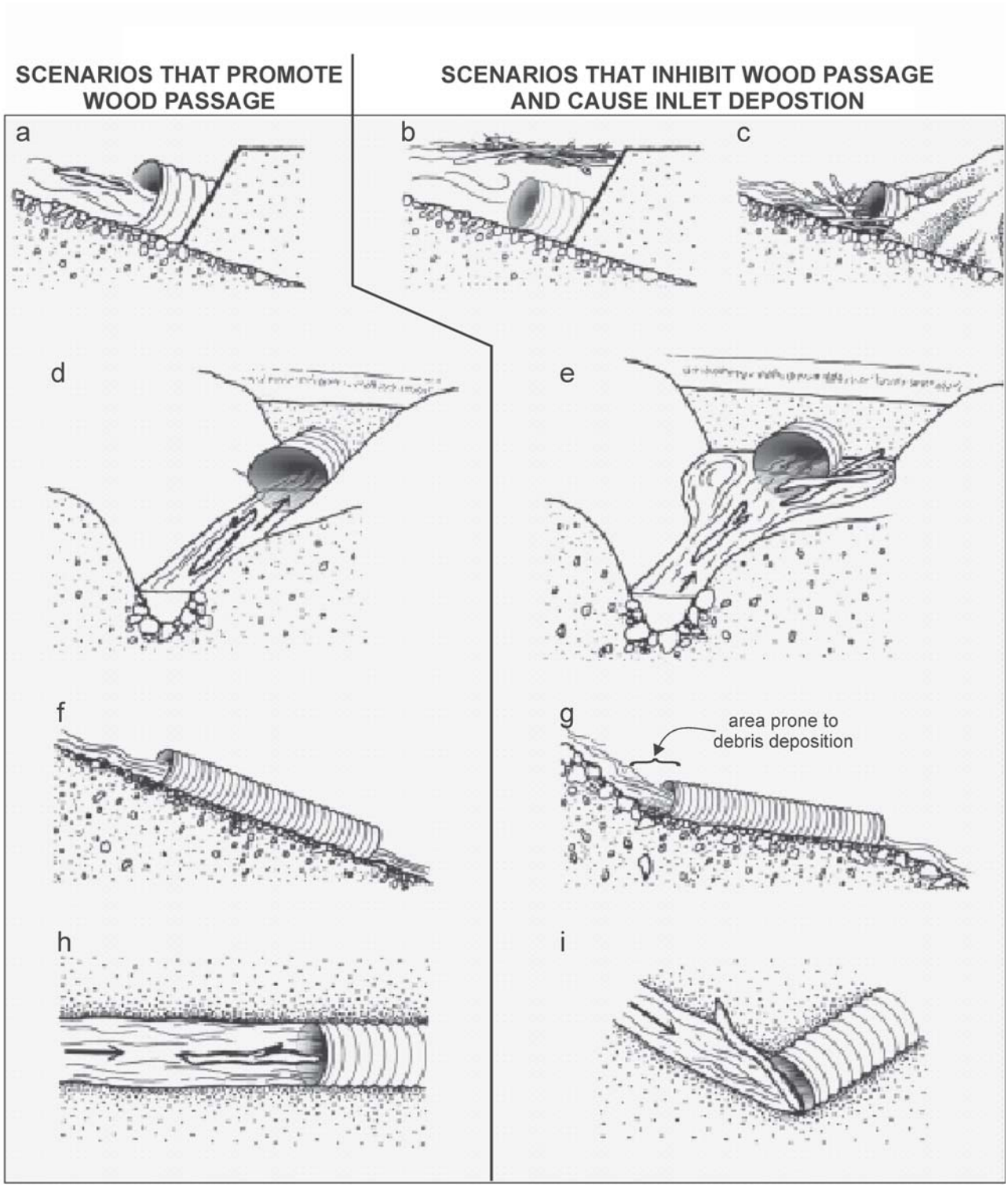


Figure 5. Schematic diagrams illustrating culvert and channel scenarios that 1) promote woody debris passage through the culvert and reduce the risk of culvert plugging (a, d, f, and h) and 2) promote woody debris deposition at the culvert inlet and increase the risk of culvert plugging (b, c, e, g, and i). Figure modified from Furniss et al. (1998).

assume that an endless succession of wood will be transported to the culvert during storm flows, much of it less than the channel width.

Assessment and Design Implications

Although the objective of the study was to suggest design strategies to address debris plugging, these concepts can also be applied to existing crossings to evaluate current hazards. The principal findings are:

- To promote debris transport through culverts, sites should be designed using the following basic criteria:

  1) Avoid designing crossings to pond water at the inlet. The ponded area provides an area for debris accumulation.

  2) Maintain channel cross-section. Nearly half of the pieces initiating plugging are less than the channel width. This suggests a pipe size approximating the width of the channel will present minimal interference to routinely transported wood. Similarly, areas where the channel abruptly widens above the inlet promotes debris accumulation and enhances plugging potential, particularly for the longest pieces which may have been in a favorable parallel orientation prior to arriving at the inlet.

  3) Maintain channel longitudinal profile. Flat culverts on steep streams can create a depositional environment that promotes the accumulation of debris near the inlet.

  4) Align culvert with the channel. Culverts which force a sharp turn in the stream force wood to rotate. For the longest pieces in transport, no space may exist for the piece to rotate and pass through the culvert.

- Debris lodgment across the culvert inlet often results in sediment deposition and eventual burial of the culvert inlet. A casual observation of a failed site might suggest that excessive sediment is the cause of failure when, in fact, one or more pieces of relatively small wood lodged across the inlet is the primary mechanism of failure.

- Culverts should be sized to accommodate the expected sizes of wood in a given channel, rather than quantities of wood. The quantity of wood supplied to culverts is rarely a factor that needs to be considered when designing road-stream crossings in forested settings.

- Although the debris plugging hazard at a road-stream crossing cannot be entirely eliminated at a crossing, the processes influencing debris plugging can be incorporated into the design of road-stream crossings to substantially minimize the hazard.

References

Braudrick, C.A., Grant, G.E., Ishikawa, Y., and Ikeda, H. 1997. Dynamics of Wood Transport in Streams: A Flume Experiment. Earth Surface Processes and Landforms. 22: 669-683.

Cafferata, P., Spittler, T., Wopat, M., Bundros, G., and Flanagan, S. 2004. Designing Watercourse Crossings for Passage of 100-year Flood Flows, Wood, and Sediment. Sacramento, California: California Department of Forestry and Fire Protection. California Forestry Report No. 1. 34 p. Available online at: http://www.fire.ca.gov/php/rsrc-mgt_forestpractice_pubsmemos.php

Flanagan, S.A. 2004. Woody Debris Transport through Low-order Stream Channels of Northwest California – Implications for Road-stream Crossing Failure. Arcata, CA: Humboldt State University. 114 p. M.S. Thesis Geology. Available online at: http://www.bof.fire.ca.gov/board/msg_supportedreports.html

Furniss, M.J., Ledwith T.S., Love, M.A., McFadin, B.C., and Flanagan, S.A. 1998. Response of Road-Stream Crossings to Large Flood Events in the Pacific Northwest. 9877 1814-SDTDC. San Dimas, CA: USDA Forest Service, San Dimas Technology and Development Center. 12 p. Available online at: http://www.stream.fs.fed.us/water-road/

Sam Flanagan is a Fisheries Biologist, National Marine Fisheries Service, 1655 Heindon Road, Arcata, California 95521, 707-825-5173, sam.flanagan@noaa.gov.

Riparian Roads and Restoration: Electronic Short Course

by Michael J. Furniss

The National Riparian Roads Team was formed in 1999 for the purpose of providing the USDA Forest Service and its partner agencies training on road treatments, techniques, and technologies that could minimize the adverse affects of roads on riparian areas and biota and restore or improve riparian ecosystem health associated with roads. The team has conducted a series of Riparian Roads and Restoration workshops across the country in the last six years to scientific staffs of the USDA Forest Service and partner agencies responsible for managing roads and riparian ecosystems. The workshops were well-received, and led to the USDA Forest Service, San Dimas Technology and Development Center wanting to make an electronic version of the course available for wider use and reference.

The electronic short course of the Riparian Roads and Restoration Workshop was produced by the Pacific Northwest Research Station and sponsored by the San Dimas Technology and Development Center (figure 1). The electronic presentation of the workshop is intended to be used either as a stand-alone course for people who could not attend the Riparian Roads and Restoration workshop, but wish to learn more about

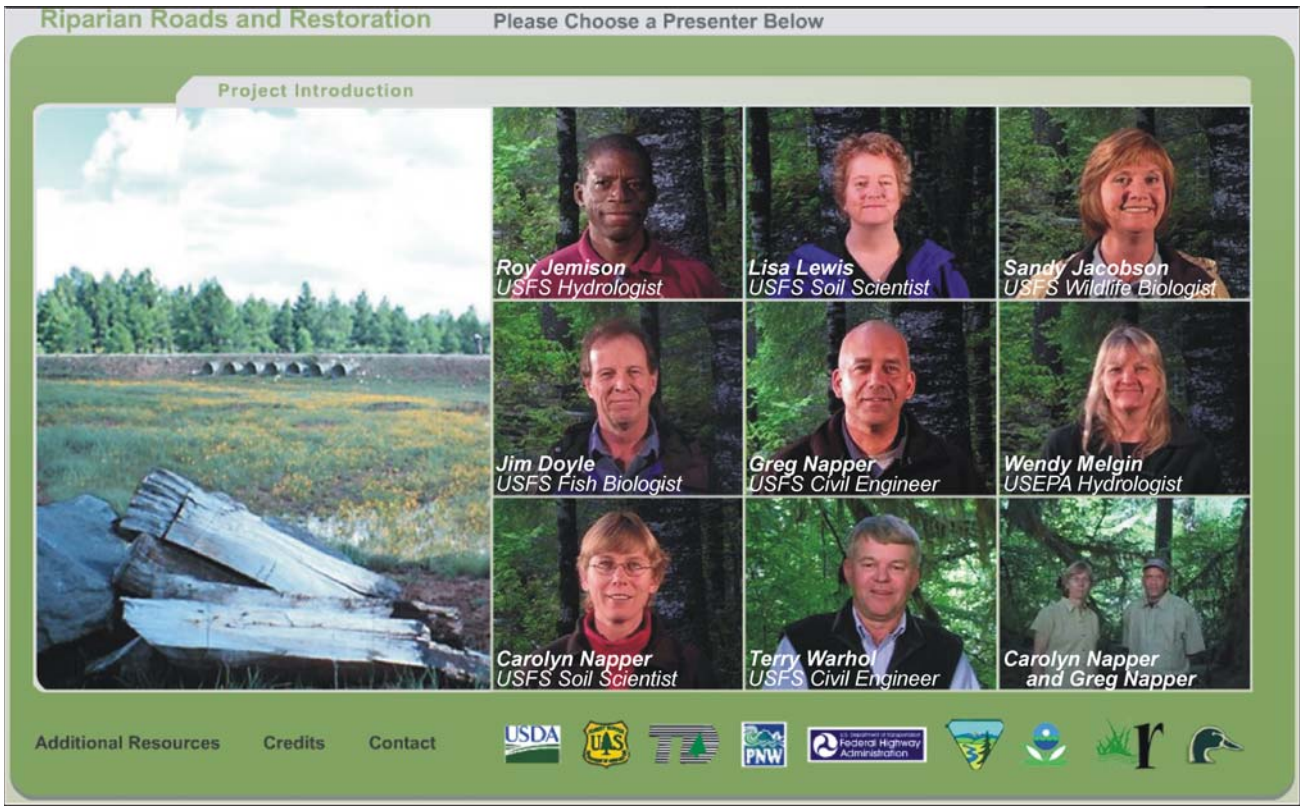


Figure 1. The home screen of the Riparian Roads and Restoration electronic short course (http://www.fsl.orst.edu/geowater/RRR/). Clicking on the photo of the instructors for the course provides an outline of various interactive talks that they present. At the bottom of the home screen is a list of agencies and organizations that supported the Riparian Roads and Restoration workshops and development of the electronic short course.

Figure 2. An example of the PEP interface in the new electronic short course, Riparian Roads and Restoration. Shown here is Roy Jemison (USDA Forest Service, Region 3 Regional Hydrologist) discussing the principles of hydrology as they relate to roads in riparian areas.

this topic, or as a reference for those who attended the workshop.

The electronic short course is a result of a week spent at the H.J. Andrews Experimental Forest, where the presentations were coordinated and rehearsed, slides enhanced, and videos of each presentation produced. The presentations were then put into an electronic publication format, referred to as "Persistent Electronic Presentations" or "PEPs." This publication format compiles presentations of varying, but complementing subject matter into a coherent interface that allows for interactive access and hyperlinking (figure 2). Additionally, this medium allows the user to interactively access presentations of specific interest and repeat presentations as needed to fully comprehend the material.

Mike Furniss and Jeff Guntle of the Pacific Northwest Research Station in Corvallis, Oregon produced the video. A CD of the Riparian Roads and Restoration electronic short course will be published and distributed to USDA Forest Service Offices and project cooperators this Fall by the USDA Forest Service, San Dimas Technology and Development Center. To receive a CD of the electronic short course, call the USDA Forest Service, San Dimas Technology and Development Center at (909) 599-1267 or send an email to mailroom_wo_sdtdc@fs.fed.us. The electronic short course can also be found online at http://www.fsl.orst.edu/geowater/RRR/ (a Flash plug-in is required; most, but not all browsers have it).

The Pacific Northwest Research Station is producing and publishing a variety of short courses and other electronic presentations in this "PEP" format and is intensely interested in feedback. Please send comments and suggestions about this electronic presentation format to me at mfurniss@fs.fed.us.

Michael J. Furniss is a Hydrologist, Aquatic and Land Interactions Forestry Sciences Lab, Pacific Northwest Research Station, Corvallis, Oregon 97331, (541) 758-7789, mfurniss@fs.fed.us.

STREAM NOTES

PRSRT STD
POSTAGE & FEES PAID
USDA - FS
Permit No. G-40

OFFICIAL BUSINESS
Penalty for Private Use $ 300

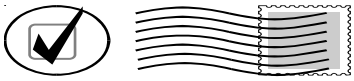
STREAM SYSTEMS TECHNOLOGY CENTER
USDA Forest Service
Rocky Mountain Research Station
2150 Centre Ave., Bldg A, Suite 368
Fort Collins, CO 80526-1891

October 2005

IN THIS ISSUE

- **Woody Debris Transport at Road-Stream Crossings**
- **Riparian Roads and Restoration: Electronic Short Course**

STREAM NOTES



Mailing List Update

Do you want to stay on our mailing list? We hope that you value receiving and reading ***STREAM NOTES***. We are required to review and update our mailing list periodically. ***If you wish to receive future issues, no action is required.*** If you would like to be removed from the mailing list, or if the information on your mailing label needs to be updated, please contact us by FAX at (970) 295-5988 or send an e-mail message to rmrs_stream@fs.fed.us with corrections.

We need your articles.

To make this newsletter a success, we need ***voluntary contributions*** of relevant articles or items of general interest. You can help by taking the time to share innovative approaches to problem solving that you may have developed. We prefer short articles (2 to 3 pages in length) with graphics and photographs that help explain ideas.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, DC 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.