An Annotated Bibliography

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INTRODUCTION

This document comprises a snapshot of references relating to interactions between low volume roads and hydrology, particularly for forested land. It is intended to be a companion to the water/road interaction technology series of publications coordinated by the San Dimas Technology Development Center and sponsored by USDA Forest Service Engineering Staff to identify information and methods on hydrological aspects of developing, operating, and managing forest roads. The goals of the effort are to 1) help communicate state-of-the-art water/road interaction information effectively among field personnel, 2) identify knowledge gaps, and 3) provide a framework for addressing future research, development and technology needs on this subject.

The reference items chosen for inclusion here are those that have shaped current thinking on the subject, as well as those that may not be widely known, but that may contain information useful to the intended audience. The publication is not all-inclusive. In fact, there is a large body of literature that generally applies to the subjects represented here. We estimate the items included here represent about 25% of the items that were reviewed. Items were not included for any of the following reasons:

> Publication information was incomplete, and therefore we judged it would be more difficult to obtain the item through easily accessible channels.
>
> We did not have time to review them. In this case, it is hoped they will eventually be included in the on-line version (see below) of this bibliography.
>
> The subject was already covered in some way by other publications. We tried to include at least one publication in all representative subject areas related to water/road interaction in forested areas. The keyword index is available for the reader to access items of a particular interest.

Additionally, there are undoubtedly a large number of publications relating to this subject that we are not aware of.

For the above reasons, and because the subject matter continues to be studied vigorously, an electronic version of this document has been made available. It is our intention to periodically update the electronic version; it can be accessed as shown on the cover letter of the binder or via the FS Web at

http://fsweb.sdtdc.wo.fs.fed.us/programs/eng/w-r/w-r.html

We have tried to provide sufficient information for each item so that readers can 1) judge for themselves whether the item will be of use, and 2) obtain the item. In some cases we were not able to achieve this. In a few cases we included an item, even though we could not provide annotation because the item may be more easily obtained by the reader than by us, or we did not have time to provide a summary.

Some obvious sources of information on these topics were not included. For example, some reference handbooks available from the Federal Highways Administration are not included, nor are classical textbooks on civil engineering, hydraulics, or fish biology.

BIBLIOGRAPHY

1. Abt, Steven R.; Brisbane, Thomas E.; Frick, David M.; McKnight, Charles A. 1992. Trash rack blockage in supercritical flow. Journal of Hydraulic Engineering. 118(12):1694-1696.

Localized system flooding can result from debris clogging of trash racks placed on hydraulic structures. A portion of a drainage structure was physically modeled, including a trash rack located upstream from an inlet drop structure. The drainage system was modeled with trash rack orientations of 1:2 slope and 3:1 slope. The trash rack was systematically blocked until flooding resulted. Trash rack designs were evaluated with flows representing 100-year reoccurrence events simulating partially developed to fully developed conditions of the simulated basin. Supercritical flows prevailed throughout the system. Results indicated that a 40% blockage be assumed for trash-rack analysis in supercritical flow. Assuming that debris is floating may become a fatal flaw in the design process.

Keywords : trash rack; drainage; flood estimation and control

2. Abt, Steven R.; Donnell, Charles A.; Ruff, James F.; Doehring, Frederick K. 1985. Culvert slope and shape effects on outlet scour. Transportation Research Record. 1017:24-30.

Contained in this report are results of a flume study that was conducted to evaluate the effects culvert shape and slope have on outlet scour after 316 minutes of testing. A circular culvert was tested at 0, 2, and 5 percent slopes. The scour hole characteristics of depth, width, length, and volume were correlated to the discharge intensity for each slope. The results indicated that an increase in slope subsequently increased the dimensions of scour. The culvert slope significantly affected the scour volume estimates based on prediction equations currently in practice. Tests of circular, square, arch, and rectangular culverts were made with full flow for 316 minutes. The maximum depth, width, length, and volume of scour were correlated to a modified discharge intensity for each culvert shape. Relationships were derived for predicting outlet scour for each culvert shape. Composite representations were compiled that correlate the dimensions of scour to the modified discharge intensity independent of culvert shape. The results indicate that culvert shape has a limited effect on outlet scour. (A).

Keywords : culvert design; flume study; scour; culvert outlets

3. Abt, Steven R.; Kloberdanz, A.M.; Mendoza, Cesar. 1984. Unified culvert scour determination. Journal of Hydraulic Engineering. 110(10):1475-1479.

The ability to predict the magnitude and geometry of scour is useful in the control and management of localized erosion. Localized scour prediction procedures resulting from previous studies generally apply to specific noncohesive materials seldom encountered in the field. The problem to be investigated is to present a design procedure for estimating the dimensions of scour in a variety of noncohesive materials at culvert outlets. Test programs to evaluate how an impinging jet affects the geometry of localized scour in five noncohesive bed materials were conducted in recirculating flumes of various dimensions. A single relationship is derived which estimates the dimensions of scour based upon the discharge, culvert diameter, material mean grain diameter, and material standard deviation.

Keywords : scour; erosion control; culvert outlets; culvert analysis

4. Abt, Steven R.; Ruff, James F.; Doehring, Frederick K. 1985. Culvert slope effects on outlet scour. Journal of Hydraulic Engineering. 111(10):1363-1367.

Culvert slope may affect the extent of scour that occurs at a culvert outlet. Previous studies for predicting scour hole geometry at culvert outlets do not incorporate a means for adjusting the dimensions of scour for culvert slope. The effects of culvert slope on scour hole geometry are investigated by tests in a flume. A circular steel pipe is projected into the flume, with pipe slopes of 0, 2, 5, 7 and 10 percent. Bed material is uniformly graded sand. Dimensionless depth, width, length, and volume of scour at 316 minutes are correlated graphically. Results indicate that a sloped culvert can increase the maximum dimensions of scour from 10 to 40 percent over the scour dimensions for a horizontal culvert.

Keywords : culvert design; scour; culvert outlets

5. Abt, Steven R.; Ruff, James F.; Doehring, Frederick K.; Donnell, Charles A. 1987. Influence of culvert shape on outlet scour. Journal of Hydraulic Engineering. 113(3):393-400.

Laboratory tests on culverts indicate that the culvert shape significantly influences scour hole geometry. Square, arch, and rectangular culvert shapes are tested for influences on scour hole depth, width, length, and volume. A dimensionless parameter describing modified discharge intensity, D.I.*, is used to account for varied flow geometries. Culvert models in the above shapes are projected into a flume filled with a uniformly graded sand. Flow through the culverts was at selected discharges. A comparison of culvert shapes was performed by normalizing the maximum scour hole parameters for the circular culvert since current outlet scour design procedures are based on circular culvert research. It is observed that the dimensions of a scour hole that develops at the outlet of an arch, square or rectangular culvert significantly varies from the scour hole dimensions from a circular shaped culvert.

Keywords : scour; flume study; culvert outlets

6. Abt, Steven R.; Ruff, James F.; Mendoza, Cesar. 1984. Scour at culvert outlets in multibed materials. Transportation Research Record. 948:55-62.

An investigation of scour at culvert outlets in noncohesive and SC-type cohesive material is presented. A series of empirical equations was derived to predict the depth, width, length, and volume of scour downstream of culvert outlets under various field conditions. The rate of scour was determined for each material. The effects of culvert shape, tailwater depth, and headwall presence were correlated with the ultimate scour dimensions. The area affected by the scour process was quantified as a function of culvert diameter and discharge. General observations on scour-hole formation, growth, and stabilization are reported. (A).

Keywords : scour; flume study; culvert outlets

7. Adamovich, L.; Webster, J.B. 1968. Road location and construction in U.B.C. Forest Area. The Truck Logger. August:1-5.

Road location methods and construction of two branch roads are described with the intent to demonstrate the development of specialized management practices which may have more general applications. Detailed techniques of road location and design are demonstrated for branch and

spur roads. Construction of two branch roads built in 1967 is described. Intensive reconnaissance, careful positioning of the route on the ground, and slope-staking can produce safe roads and reduce costs in road construction, maintenance and hauling. Culvert and bridge designs are not discussed.

Keywords : road design and construction; road location

8. Adamovich, L.; Willington, R.P.; Lacate, D. [Unpublished]. Bibliography on forest roads and the environment. 25 p.

The bibliography encompasses topics related to roads in the forested environment including construction, environment, aesthetics, erosion and sedimentation, geology, soil, and water. Dates of included papers are 1908 through 1972. Papers are listed by author's last name and are indexed by keywords.

Keywords : forest roads; bibliography

9. Adams, M.A.; Whyte, I.W. 1990. Obstruction removal, culverts, fishways, and fish screens. In: Envirowest, ed. Fish habitat enhancement: a manual for freshwater, estuarine, and marine habitats. Vancouver, BC: Government of Canada, Department of Fisheries and Oceans: 122-169.

Project design criteria for fisheries enhancement are given for removal of fish passage obstructions, culverts, fishways, and fish screens. For each topic, background information relating to fisheries needs is given as well as maintenance and factors influencing costs. Advantages and disadvantages are listed. Examples of use for locations in British Columbia and references complete each section. (C).

Keywords : fish passage; fish; culvert design; culvert fish passage; fishways; fish habitat

10. Adams, Paul W.; Andrus, C.W. 1990. Planning secondary roads to reduce erosion and sedimentation in humid tropic steeplands. In: Research needs and applications to reduce erosion and sedimentation in tropical steeplands; 1990 June; Suva, Fiji. IAHS Pub. No. 192. Wallingford, Oxfordshire, UK: International Association of Hydrological Sciences: 318-327.

Secondary roads can be a major source of soil and water problems in steep terrain. Careful planning can reduce these problems, but vital supportive experience must often be extrapolated from other locations, including temperate regions. We review here some important potential applications and limitations of available information for road design and use in the humid tropics. Of particular concern are rainfall intensities and peak streamflows, which may be over 10 times greater in the tropics than in temperate regions, and the need for economical approaches. Wide road spacing, ridgetop locations, buffer strips, rolling dips, low water fords, timber bridges, and selective surfacing and stabilization with native materials appear to represent some of the most promising opportunities.

Keywords : road design and construction; erosion control; steep slopes and road grades; humid tropics

11. Adams, Paul W.; Andrus, Charles W. 1991. Planning timber harvesting operations to reduce soil and water problems in humid tropic steeplands. In: Proceedings of the symposium on forest harvesting in southeast Asia; 1991 June 17-20; Singapore. Corvallis, OR: Forest Engineering, Inc.: 24-31.

Logging and road construction are increasing in the humid tropics including rugged uplands that previously have been relatively undisturbed. Greater use and management of forest resources represents a vital opportunity for many countries but it can also increase risks of adverse soil and water impact. However careful planning combined with prudent use of experiences from other regions should help avoid many problems. Harvest planning should focus on systems and equipment that reduce soil exposure and compaction and layouts that minimize machine activity near streams and small drainage. Careful scheduling and supervision of road construction and subsequent logging activity and road use are essential and well trained crews and supervisors help ensure that plans are properly implemented. Operations planning should extend through postharvest activities like debris treatment and water bar construction and also include review and monitoring of all forest operations to better understand and apply valuable focal experience.

Keywords : road design and construction; timber harvest; erosion control; humid tropics; forest management and practices

12. Adams, Paul W.; Campbell, Alan J.; Sidle, Roy C.; Beschta, Robert L.; Froehlich, Henry A. 1986. Estimating streamflows on small forested watersheds for culvert and bridge design in Oregon. Res. Bull. 55. Corvallis, OR: Oregon State University, Forest Research Laboratory. 8 p.

Streamflow records were combined with basic watershed data from 80 small forested basins to develop equations for predicting peak flows in Oregon. Area of drainage basin was most strongly and consistently related to streamflows, while mean basin elevation and mean annual precipitation were also related to flows in areas of western Oregon. The equations can be used with these and other site-specific data and risk assumptions to help design adequate culverts and bridges.

Keywords : bridge design; streamflow; culvert design; watershed

13. Adamson, R.B. 1989. Low water crossings: an inexpensive alternative for low volume roads in northern Ontario. Tech. Notes TN-02. Thunder Bay, Ontario, Canada: Northwestern Ontario Forest Technology Development Unit. 4 p (Available: Springfield, VA: National Technical Information Service as stock no. MIC-95-05163INZ).

Water crossings are a significant component of access road construction and maintenance costs. Design of such crossings takes into account predicted streamflows during extreme conditions. If culverts are used, much of the culvert capacity is not used during most of the life span of the crossing. Low water crossings are believed to be an environmentally sound alternative for low volume roads, as they are designed to allow periodic flooding over the road under extreme streamflow conditions. This report describes the installation of a low water crossing in northern Ontario. The type of crossing is known as a vented ford, consisting of a dip in the road with small culverts to handle normal flow, a roadbed and fill designed to resist erosion and to act as a spillway under extreme flooding, and precast barrier walls on the downstream side of the roadway.

Keywords : low water crossing; stream crossing design; road design and construction

14. Agee, James K. 1980. Issues and impacts of Redwood National Park expansion. Environmental Management. 4(5):407-424.

Recent evidence of damage to the Redwood National Forest in California from outside land uses, primarily road building and logging, resulted in a successful park expansion effort. The evolution of Redwood National Park since 1901 is traced. The biological impacts and issues associated with the park's recent boundary expansion are discussed. While some feel that the park expansion was necessary to protect the natural environment and recreational rights of the public, others maintain that the expansion was unnecessary and will disastrously affect the local economy. (1 diagram, 3 graphs, 3 maps, 3 photos, 41 references, 2 tables).

Keywords : road construction effects; logging practices and effects; land management

15. Amaranthus, M.P.; Rice, Raymond M.; Barr, N.R.; Ziemer, Robert R. 1985. Logging and forest roads related to increased debris slides in southwestern Oregon. Journal of Forestry. 83(4):229-233.

Debris slides over a 20 yr. period were inventoried in the Klamath Mountains of SW Oregon. Frequency during the study period was about one slide every 4.3 yr. on each 1000 acres - an erosion rate of about 0.5 yd3/acre/yr. Erosion rates on roads and landings were 100 times those on undisturbed areas, while erosion on harvested areas was 7 times that of undisturbed areas. Three-quarters of the slides were found on slopes steeper than 70% and half were on the lower third of slopes.

Keywords : forest roads; logging practices and effects; landslides; erosion processes; steep slopes and road grades

16. American Iron and Steel Institute. 1967. Section IV--Hydraulics of culverts. In: Highway Task Force, ed. Handbook of steel drainage and highway construction products. New York: American Iron and Steel Institute: 102-127.

Culvert design is based on hydraulic principles combined with hydrology and field data. Those principles are summarized here with examples using nomographs, charts, and graphs. Steps for determining culvert size are outlined with descriptions of hydraulic effects. Emphasis is placed on headwater depth determination. (C).

Keywords : hydraulics; hydrology; culvert design; drainage crossing; drainage

17. Anderson, Henry W. 1971. Relative contributions of sediment from source areas and transport processes. In: Krygier, James T.; Hall, James D., eds. Proceedings of the forest land uses and stream environment symposium; 1970 October 19-21; [Corvallis, OR]. Corvallis, OR: Oregon State University, Continuing Education Publications: 55-63.

The paper reports new findings, offers a reanalysis of older studies, and summarizes pertinent results in the literature. Past land use, forest fires, road building, "poor logging," and conversion of steep lands to grass have increased sediment discharge by factors ranging from 1.24 to more than 4. Projected future use is expected to increase sediment production by a factor of 4, with 80 percent associated with roads and 20 percent with logging. Major floods have increased subsequent turbidity of streamflow by a factor of 2. The increases were greater in logged areas of

watersheds where roads were next to streams and landings were in draws than in undisturbed watersheds. Most landslides were associated with road development, next most with logged areas, and least with undisturbed forest area. The number of turbid days in streamflow varied by a factor of 2.34 with differences in silt plus clay content of soils, by 8.55 with differences in erodibility, and by 4.3 with the percent of gravel. Further, these soil characteristics were predictable from geologic rock types. In a sample calculation, 89 percent of channel bedload became suspended load enroute downstream. Soil creep contributed 15 percent to total sediment discharge from watersheds; channel bank erosion contributed 54 to 55 percent.

Keywords : sediment modeling; logging practices and effects; road construction effects; forest fires; land management

18. Anderson, Henry W. 1974. Sediment deposition in reservoirs associated with rural roads, forest fires, and catchment attributes. In: Effects of man on the interface of the hydrologic cycle with the physical environment: Proceedings, international symposium; 1974 September; Paris, France. IASH Pub. 113. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Experiment Station: 87-95.

Deposition of sediment was measured in 48 northern California reservoirs having catchment areas exceeding 5 square km. The measurements were related by principal components analysis to four categories of variables: catchment, streamflow, snow, and land use. Catchment variables included characteristics of topography, geology, and the reservoir. Streamflow variables included relative intensity and amounts of flow during deposition. Snow variables were calculated from elevational distribution and latitude of each catchment. Intensity of land-use was characterized by development of roads for timber harvesting, mining, and recreation, and by uses not primarily related to roads, such as grazing and forest fires. Roads were of five classes--ranging from highways to dirt roads--and three locations--ridge-top, slope, and streamside. Forest fire variables included current fire history and the extent of high-elevation brushfield associated with burning and grazing. Explained variance in sediment deposition ranged from 78 to 83 percent--depending on the model used in analysis. Variables contributing the most to explained variance were, in decreasing order, snow, geology, streamflow, forest fires, and reservoirs. Roads located near streams contributed the most to deposition--twice as much as did roads located elsewhere. Improved secondary roads near streams were the single greatest contributor. (forest service).

Keywords : sedimentation; catchments; road impacts; forest fires

19. Anderson, Henry W. 1975. Relative contribution of sediment from source areas and transport processes. In: Proceedings, sediment-yield workshop; 1972 November 28-30; Oxford, MS. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 66-73.

Typically forest soils show wide variation in physical characteristics associated with the geologic origin of the parent material and variation in weathering processes. Soils anchored by tree roots often occupy slopes which would be beyond the natural angle of repose for the geologic material. The steep slopes are subject to an erosional process that consists of channel cutting over long periods, mass soil creep, and soil occasionally sliding from lower slopes into the channel. Each of these can be affected by land use. A study of suspended sediment discharge from 23 California watersheds estimated the following increases in sediment production associated with present average land uses as contrasted with absences of such land use in the watersheds: conversion of 14.8 percent of steep forest and brush lands to grassland had multiplied sediment by 4.7; fires in

the last 10 years on 5.3 percent of the watershed areas multiplied sediment by 2.3; 'poor logging' of 1.4 percent of the area increased sediment by 26 percent; and conversion of 0.6 percent of a watershed into low standard roads increased sediment by 24 percent. Thus, associated with these four factors of man's use was a total increase in sediment by a factor of 17 times. Under such conditions major floods can contribute to further deterioration in watershed conditions, as indicated by increased average sediment concentration. Sediment concentration, for like flows, was 2 to 3.7 times greater after the 1965 flood than before. High-elevation watersheds suffered more than low-elevation watersheds; sediment increases in high-elevation watersheds averaged three times that in low-elevation watersheds.

Keywords : sedimentation; watershed; sediment

20. Anderson, J.A. 1995. Depth of rain water on road surfaces. Highways and Transportation. 42(5):1-4.

This paper is concerned with the depth of water resulting from steady rainfall on a plane impermeable surface. The main relevance is to road surfaces but the theory is equally applicable to paved surfaces which drain to a free overfall. The hydraulics of the flow is based on steady state spatially varied flow, and experimental data was available for two types of surface, namely brushed concrete and rolled asphalt. The range of slopes considered varies from zero up to five percent. The effect of crossfall on a road was also considered in conjunction with a range of longitudinal slopes. The results show that for a horizontal surface the maximum depth occurs at the upstream end, assuming a water divide or stop end at the upstream end, with a free overfall or unrestricted flow at the downstream end. As the slope is increased, the position of maximum depth moves downstream towards the outfall, and for the higher slopes the maximum depth occurs close to the outfall. (A) 9 Refs.

Keywords : rainstorm; road surface; hydraulics; pavement; surface drainage

21. Anderson, Lynette; Bryant, Mason D. 1980. Fish passage at road crossings: an annotated bibliography. Gen. Tech. Rep. PNW-117. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 10 p.

A report of special interest to fishery biologists, resource managers, hydrologists, and road engineers, this bibliography lists publications pertinent to road crossings of salmon and trout streams. Topics include bridge and culvert installation, design criteria, mechanics, hydraulics, and economics, as well as their biological effects.

Keywords : culvert design; bridge design; fish passage; drainage crossing; fishways; bibliography

22. Anon. 1980. How long can metal culverts last? American City and County. September:51-53.

Tests on culverts were conducted by the Louisiana Department of Transportation and Development and the Michigan Department of State Highways to predict culvert lifespans. In Louisiana, the culvert durability project involved several different types of corrugated metal pipe, both coated and uncoated galvanized steel and clad aluminum alloy. Results indicate that asphalt coating does provide some additional corrosion protection for galvanized culverts while coating an aluminum culvert with asphaltic material does not appear to slow its rate of deterioration substantially except in an environment of moderate resistivity. The Michigan study noted major deterioration of the

culvert exteriors, with soil acting as the corrosive agent. Coated culverts experienced similar corrosive deterioration as did uncoated culverts.

Keywords : culvert deterioration; culvert durability; service life; corrosion; culvert - aluminum; culvert coating

23. Anon. 1990. Highway drainage design. In: Highway design manual. Sacramento, CA: California Department of Transportation: pages 800-1 to 890-2.

Guidelines for the design of highway drainage features are provided. Drainage policies, design philosophies, procedures and standards, definitions, and references are given in each chapter. Chapter topics include hydrology, cross drainages and culverts, roadway design, subsurface drainage including groundwater, physical standards for materials, size and type of culverts, properties and mechanics of materials for culverts, open channel flow and hydraulic considerations, channel and shore protection, and erosion control. Information is provided in the form of text, tables, charts, nomographs, and maps (C).

Keywords : culvert - highway; drainage design; drainage crossing; handbooks; surface drainage; groundwater and subsurface flow; road drainage

24. Anon. 1995. Sinqumeni stream crossing built to withstand flash floods. Civil Engineering/ Siviele Ingenieurswese. 3(4):15.

Various factors have resulted in all previous crossings at the Sinqumeni stream being washed away. Engineers have taken steps to prevent this from happening again.

Keywords : stream crossing design; flood estimation and control

25. Anon. 1995. Environmental guidelines for access roads and water crossings. Toronto, ON: Ontario Ministry of Natural Resources; 64 p.

This manual provides a collection of guidelines for those involved with access roads on Crown land in Ontario. It will assist them in carrying out their projects with a minimum of disturbance to the natural environment. These guidelines were prepared following an extensive review of guidelines used for similar purposes in other jurisdictions. Section 9 contains a partial list of these other publications. A technical advisory group assisted in developing the manual's final text. Organizations represented within the advisory group included various disciplines within the Ministry, the Ontario Forest Industries Association, the Ontario Lumber Manufacturers Association and the Ontario Ministry of the Environment. The group's participation ensured the publication reflects the knowledge and field observations of experienced people from a cross-section of public and private sector organizations that have an interest in access roads and water crossings in Ontario.

Keywords : forest roads; road drainage; best management practices; handbooks

26. Ashton, William S.; Griffiths, Leslie A. 1990. Culverts. In: Ryan,W.L., Crissman, R.D., eds. Cold regions hydrology and hydraulics. New York: American Society of Civil Engineers: 557-577.

The hydraulic design of culverts is relatively well understood. Modifying culvert design for cold regions entails several common-sense considerations. These include consideration of: ice formation and degradation, lower ground temperatures, and snow movement and deposition. maintenance costs are typically higher for culverts in cold regions. Clearing culverts of ice and snow in the spring prior to breakup is typically the greatest maintenance cost. Most road construction in the arctic occurs when the ground is frozen. Ensuring proper compaction with ice-free material is essential for structural integrity when culverts are installed during the winter. Fishery resource agencies typically require passage of migratory fish species through culverts during high streamflow periods on designated fish streams. This paper discusses several considerations important for culvert location, design, construction, and maintenance in cold regions. (A).

Keywords : hydraulic design; cold regions; culvert design

27. Askin, Robert W. 1992. Armoured fords: an alternative drainage crossing system for debris torrent prone mountain channels. In: Schiess, Peter; Sessions, John, eds. Proceedings of the international mountain logging and eighth Pacific Northwest skyline symposium; 1992 December 14-16; Bellevue, WA. Seattle: University of Washington: 176-186.

This paper reports on the development of an armoured ford crossing for a steep, debris torrent prone drainage channel in the Catherine Creek Watershed on Vancouver Island, British Columbia. The engineering design considered the natural hydrologic, geomorphic, and hydraulic characteristics of the steep channel. The erosion, transport and depositional features of the channels were identified. From this, peak discharge and associated debris torrent magnitudes were estimated. An armoured ford was designed in July 1992, and constructed in August 1992 within a section of channel that had a natural gradient of 15 degrees (27 percent). Performance monitoring of the drainage crossing system will be carried out over the 1992/93 winter season. (A).

Keywords : low water crossing; drainage; debris flow and control; channels; stream crossing; drainage crossing

28. Aust, W.Michael. 1994. Best management practices for forested wetlands in the southern Appalachian region. UNESCO southern Appalachian man and the biosphere: Proceedings, wetland ecology, management, and conservation conference; 1993 September 28-30; Knoxville, TN. In: Water Air Soil Pollution 77(3-4). 457-469.

As mandated by the Federal Water Pollution Control Act, there are 15 best management practices (BMPs) for managing wetland forests, eight of which address road-construction activities and seven that pertain to wildlife management and water supplies. An overview is presented of the BMPs, both federal and state, which involve the southern Appalachian region. Four of the states—Alabama, Georgia, and North and South Carolina—contain almost 90% of the total wetland acreage found in the region. Georgia and North Carolina recognize nine types of wetlands, which is the most for any state in the region. Information is provided on the guidelines pertaining to streamside management zones, forest-regeneration systems, road construction, and timber removal (A). (33 references, 8 tables).

Keywords : land management; forest management and practices; wetlands; road design and construction; best management practices; law and policy

29. Babcock, E.; Johnson, L.; Sonneveil, R.; Spreiter, T. [Unpublished]. Erosion potential at stream crossings: guidelines for use of rite in the rain form G-28, Redwood National Park. 5 p.

A guideline for the documenting and quantifying the eroded and potentially erodible sediment at locations where roads or skid trails cross the stream channels using the form G-28. Prioritize these location for erosion control treatment and estimate cost effectiveness of proposed treatment at each worksite.

Keywords : erosion processes; drainage crossing; stream crossing; skid trail

30. Baker, Calvin O.; Votapka, Frank E. 1990. Fish passage through culverts. FHWA-FL-90-0006. San Dimas, CA: U.S. Department of Agriculture, Forest Service, Technology & Development Center. 67 p. Sponsored by: U.S. Department of Transportation, Federal Highway Administration, Federal Lands Highway Program, Washington, DC.

As the number and range of many fish species have declined and the recreation demand for fish has increased, the importance of protecting the remaining populations has also multiplied. At new culvert installations, fish passage considerations and needs have increased in complexity. A high percentage of existing drainage structures are approaching or have passed their life expectancy. The task of replacing, modifying, and/or retrofitting the surviving structures will dwarf past programs for providing fish passage through culverts. This report is intended to review, summarize, and update current information on fish passage through culverts. The scope of the report is limited to highway drainage structures, not including bridges. This distinction was made in an effort to concentrate on those road drainage structures that are most commonly used in fish passage situations. The publication is primarily issued for the fish biologists, engineers, and hydrologists who will be designing the projects and making current decisions on fish passage at drainage structures. (36 figures, glossary, annotated bibliography).

Keywords : fish passage; culvert - highway; drainage crossing; culvert fish passage

31. Ballinger, Craig A.; Drake, P.G. 1995. Culvert repair practices manual, volume 2 (appendices). Falls Church, VA: Smith (Wilbur) Associates, BTML Division; final report; contract DTFH6188C00. 315 p. Sponsored by: Federal Highway Administration, Office of Engineering and Highway Operations Research and Development, McLean, VA.

This manual has been developed to provide guidance to highway agencies on procedures that may be used to repair a wide variety of types of problems that beset metal and concrete culverts of all types. Many of the procedures are also applicable to the repair of timber and stone masonry culverts. Procedures are also presented on ways to improve the inlet and outlet ends of culverts as well as the streambed channels leading to and from them. Information presented in this manual has been compiled from numerous contacts with representatives of the culvert industry as well as many highway agencies through the United States and Canada. This is a two-volume report. Volume I consists of the text. Volume II presents Appendixes. This is volume II. The report number for volume I is FHWA-RD-94-096. (C).

Keywords : culvert repair; road maintenance; handbooks

32. Ballinger, Craig A.; Drake, Patricia G. 1995. Culvert repair practices manual. FHWA-RD-94-096. McLean, VA: U.S. Department of Transportation, Federal Highway Administration, Turner-Fairbank Highway Research Center, Research and Development. 265 p.

All culverts with openings of more than 20 feet, measured parallel to the roadway, must be inspected on a two-year cycle in accordance with the National Bridge Inspection Standards. (NBIS). Many highway agencies also inspect smaller culverts on the same cycle. The NBIS, and prudent engineering, requires that culverts that are structurally weak or hydraulically inadequate be inspected on a more frequent cycle. This manual has been developed to provide guidance to highway agencies on procedures that may be used to repair a wide variety of types of problems that beset metal and concrete culverts of all types. Many of the procedures are also applicable to the repair of timber and stone masonry culverts. Procedures are also presented on ways to improve the inlet and outlet ends of culverts as well as the streambed channels leading to and from them. Information presented in this manual has been compiled from numerous contacts with representatives of the culvert industry as well as many highway agencies through the United States and Canada. (A). This is a two volume report. Volume I contains information on culvert materials, shapes, construction, problem identification including hydraulic capacity, maintenance, retrofitting, repair, and replacement. Fish passage and beaver control problems are briefly addressed. Volume II consists of appendices on standards, repair and retrofit procedures, specifications, and an annotated bibliography. The report number for Volume II is FHWA-RD-95-089. (C).

Keywords : culvert repair; culvert design

33. Bao, Yixing; Tung, Yeou-Koung; Hasfurther, Victor R. 1987. Evaluation of uncertainty in flood magnitude estimator on annual expected damage costs of hydraulic structures. Water Resources Research. 23(11):2023-2029.

In the risk-based design for hydraulic structures, the major task is the evaluation of the annual expected damage costs caused by floods. Due to the use of a limited amount of data in flood frequency analysis, the computed flood magnitude of a specified return period is subject to uncertainty. A methodology to integrate such uncertainty in the evaluation of annual expected flood damage is developed and illustrated through an example in culvert design. The effect of uncertainty in estimating flood magnitude using different hydrologic probability models with different sample sizes on the annual expected damage cost is examined. Results of the study show that the effect of the uncertainty in a flood magnitude estimate on annual expected damage is quite significant and is sensitive to the sample sizes and the probability distribution models used. (A) 9 refs.

Keywords : risk analysis and design; drainage structures; flood estimation and control; cost and economics; hydraulics

34. Barber, M.E.; Downs, R.C. 1996. Investigation of culvert hydraulics related to juvenile fish passage. WA-RD-388.2 Final technical report. Pullman, WA: Washington State Transportation Center (TRAC), Washington State University.

Culverts often create barriers to the upstream migration of juvenile fish. Fish will not travel upstream under high water velocity conditions. It is hypothesized that low velocity regions exist near culvert boundaries. Therefore, the objective of this study was to determine hydraulic characteristics of culverts with different flow conditions. Methods of predicting flow profiles were

developed by both Chiu and Mountjoy. Two equations were compared to experimental results. The Mountjoy equation proved to yield better results for velocity profile predictions. An area of flow corresponding to a predetermined allowable velocity can be calculated using the Mountjoy equation. This can then be used in the design of culverts as fish passage guidelines. The following technical report contains a detailed description of background information, experimental methodology, the results of experimental tests, and an analysis of both the Chiu and Mountjoy equations. (A).

Keywords : culvert design; fish passage; hydraulics

35. Barber, M.E.; Downs, R.C. 1996. Investigation of culvert hydraulics related to juvenile fish passage. WA-RD-388.1 Final report. Pullman, WA: Washington State Transportation Center (TRAC), Washington State University. 54p.

Culverts often create barriers to the upstream migration of juvenile fish. Fish will not travel upstream under high water velocity conditions. It is hypothesized that low velocity regions exist near culvert boundaries. Therefore, the objective of this study was to determine hydraulic characteristics of culverts with different flow conditions. Methods of predicting flow profiles were developed by both Chiu and Mountjoy. Two equations were compared to experimental results. The Mountjoy equation proved to yield better results for velocity profile predictions. An area of flow corresponding to a predetermined allowable velocity can be calculated using the Mountjoy equation. This can then be used in the design of culverts as fish passage guidelines. The following report contains a summary of background information, experimental methodology, the results of experimental tests, and an analysis of both the Chiu and Mountjoy equations. (A).

Keywords : culvert design; fish passage; hydraulics

36. Bartos, Louis R. 1978. Peak flow hydrology in relation to bridge and culvert design problems in southeast Alaska. In: Proceedings of the national applied wildland hydrology workshop; [Conference date and place unknown]; Atlanta, GA: [Publisher name unknown]: 1-8.

An overview of geomorphologic, soils, vegetation, and precipitation in southeastern Alaska which set the stage for large streamflow amplitudes. Strong relationships of drainage geometry and peak flow events enabled development of sound hydrologic design techniques for bridges and culverts on forest roads for southeastern Alaska conditions. Passage of extreme peak flow events, structural safety, and maintenance of optimum passage for anadromous fish at low flows were adequately achieved through hydrologic design. (A).

Keywords : hydrology; bridge design; culvert design

37. Bassel, James R. 1993. Culvert steamer--the deicing of frozen culverts. In: Roads Tech Tips. San Dimas, CA: USDA Forest Service. 4p.

During cold weather, culverts can become completely plugged with ice by repeated melting in the streambed during warm days and refreezing in the culverts at night or when freezing conditions persist inside culverts during the day. The equipment used to remedy this problem is a liquid propane (LP) steam generating deicing unit (culvert steamer) manufactured by Aeroil Products Co., Inc., which is trailer mounted. Two modifications of this equipment are described. It takes a crew

of two about 10 minutes to set up the equipment on site and 30 minutes to reach the proper steam pressure (18 to 22psi). The thaw rate is about six to eight feet per minute. Specifications, cost, and safety recommendations are discussed. (C).

Keywords : culvert inlets; culvert repair; road maintenance; cold regions

38. Bates, Ken. 1994. Fishway design guidelines for Pacific salmon. Olympia, WA: Washington Department of Fish and Wildlife; working paper 1.5; 1-1 to 13-4.

A handbook containing practical guidelines for the design of fish passage facilities for upstream migrating anadromous fish is presented including specifics for the passage of fish through new or existing culverts. The scale of systems to which these guidelines apply includes mainstem passage in rivers such as the Columbia to small culverts under county roads. A fishway is any structure or modification to a natural or artificial structure for the purpose of fish passage. The fishway is a system that may include attraction features, barrier dam, entrances, auxiliary water system, collection and transportation channels, the fish ladder itself, trash rack, an exit, and operating and maintenance standards. It can be a formal concrete structure, pools blasted in the rock of a waterfall, or log controls in the bed of a channel. A variety of physical, hydrologic, and biologic considerations will determine whether a given obstruction is passable and are necessary predesign data requirements. Water and fish are of course central to the fishway system. Design considerations for culverts must consider the hydraulic effects of culvert size, slope, material and elevation to create depths, velocities, and a hydraulic profile suitable for fish passage. Those criteria are presented along with information regarding baffle design and retrofitting culverts for fish passage. The addition of baffles is not recommended unless under extreme situations as they require maintenance to keep clean and replacement when they fail. Culvert installation standards from the Washington Department of Fisheries and the Alaskan Department of Fish and Game are included as is a glossary of fish passage terms.

Keywords : fish passage; fishways; culvert design; culvert installation; culvert fish passage; fish

39. Bauer, Stephen B.; Harvey, Geoffrey W.; Burton, Timothy A. 1992. Idaho 319 nonpoint source program summary: forest roads inventory and stabilization report. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 89-92.

Forest harvest and haul roads are the largest contributors of sediment to streams from forest practices nonpoint source activities. Many forest haul roads were built before adoption of current best management practices (BMPs), which require 75 feet of buffer between class I streams and road disturbances (except at crossings and where mitigation would allow a variance from the required minimum distance). These historic roads often parallel water courses for long distances immediately adjacent to the water and continually supply sediment to the streams. The Idaho Water Quality Status Report and Nonpoint Source Assessment 1988 (Idaho Dep. Health Welfare, 1989) inventoried over 1,500 stream segments statewide and reported 178 stream reaches that were impaired by poorly situated forest haul roads.

Keywords : forest management and practices; timber harvest; stream management; road construction effects

40. Beasley, R.P. 1972. Cross-slope channels, diversions, and basins. In: Erosion and sediment pollution control. Ames, IA: Iowa State University Press: 170-181. Chapter 8.

Keywords : channels; ditches; basins; erosion control; stream pollution

41. Beasley, R.P. 1972. Water erosion. In: Erosion and sediment pollution control. Ames, IA: Iowa State University Press: 10-23. Chapter 2.

Keywords : erosion control; stream pollution

42. Beasley, R.Scott; Miller, Edwin L.; Gough, Steven C. 1984. Forest road erosion in the Ouachita Mountains. In: Peters, Penn A.; Luchok, John, eds. Mountain logging symposium proceedings; 1984 June 5-7; Morgantown, WV. Morgantown, WV: West Virginia University: 202-213.

The quantity and disposition of sediments eroded from four segments of an established forest road in the Ouachita Mountains of Arkansas were determined for each storm event that occurred between June 1, 1982, and May 31, 1983. Road segments (average length--330 ft) were defined as the centerline distance from a vertical curve crest to the first cross-drain culvert, a mechanism for dispersing water from the upslope ditch onto vegetated side-slopes below the road. Slope gradients of the segments ranged from 1% to 7% and averaged 4%. Measurements at the outlet of each cross-drain were total discharge volumes, discharge rates and peaks, deposited sediment, suspended sediment, and downslope movement of deposited sediments. Concurrent measurements included sediment concentrations in a stream flowing parallel to and about 150 ft. below the road and rainfall amounts, durations, and intensities. Thirty-six storm events produced annual sediment yields from the crowns, ditches, and back-slopes of the road segments ranging from 7 t/ac to 34 t/ac (average 23 t/ac). One storm, which produced 13 in. of rainfall in 24 hr., accounted for about half of the total annual sediment yields. Deposited sediments, most of which moved only a short distance downslope, constituted about 41% of total sediment yields. Close inspection of the slopes below the cross-drains revealed that, for all but the largest storms, much of the suspended sediments was trapped on-site as the road water infiltrated or was ponded in surface depressions. The only exception was a culvert that emptied into a natural ephemeral drainage. Roadbed slope gradient accounted for most of the variation in sediment losses among road segments. Measured rates of soil erosion were 1200% less than previously reported predicted rates.

Keywords : forest roads; erosion control; sedimentation; rainstorm; road erosion; culverts

43. Beaton, J.L.; Stratfull, R.F. 1959. The corrosion of corrugated metal culverts in California. In: Proceedings of the 38th annual meeting of the Highway Research Board; 1959 January; Sacramento, CA: Division of Highways: 1-28.(Also available in: 1962. Field test for estimating service life of corrugated metal culverts. Proceedings of Transportation Research Board. 41:255-272).

The number of metal culverts reported to be in critical condition in northern California appeared to be increasing beyond that considered normal. The problem was to locate areas where accelerated corrosion was likely to occur and to prepare a systematic replacement program. Investigation of culvert deterioration was limited to physical and visual tests. Metal loss was evaluated by rebound of a geologist's pick striking the culvert. The penetration or rebound from the blow of the pick was compared and standardized by comparing it to culvert metal of known

thickness. Results indicate that there were specific types of rust which accompanied accelerated or significant corrosion. The thickness or the type of rust formed on the culvert metal could not be used always as a criterion of the degree of corrosion because the corrosion products for a similar degree vary in relation to the geographic location. In coastal, and other geographic locations, it was observed that accelerated corrosion was linked to the apparent presence of anaerobic bacteria in the watershed. Overall results indicate that the service life of individual culverts is highly variable, depending upon the environment, and that the presence of continuous (or nearly so) water flow indicates a potentially corrosive area.

Keywords : culvert deterioration; service life; corrosion

44. Behlke, Charles E.; Kane, Douglas L.; McLean, Robert F.; Travis, Michael D. 1991. Fundamentals of culvert design for passage of weak-swimming fish. FHWA-AK-RD-90-10. Fairbanks, AK: Alaska Department of Transportation and Public Facilities. 159 p. (Sponsored by: Federal Highway Administration, Alaska Division, Juneau, AK, and Alaska Department of Transportation and Public Facilities, Fairbanks. In cooperation with: Alaska Department of Fish and Game, Habitat Division.).

Properly designed culverts do not produce water velocities that exceed fish swimming abilities. Fish have two different musculature systems for swimming. A white muscle system generates power for short vigorous swimming. A red muscle system furnishes power for long, sustained swimming. The culvert design must account for both swimming modes. Therefore, the engineer must know the hydraulic conditions where the fish swims. These conditions change throughout the culvert. The engineer determines acceptable hydraulic conditions for fish by matching known fish swimming power and energy capacities. Subcritical flow is necessary to pass weak-swimming, upstream-migrating fish. Therefore, this requirement precludes the use of inlet control. The engineer may use artificial roughness to create areas of slower water velocities within culverts. Examples of these are depressed inverts, weir baffles, and deep culvert corrugations. This manual presents design procedures to pass upstream-migrating, weak-swimming fish. The manual also displays criteria for retrofitting existing culverts. This paper does not present cost-effective design criteria for strong-swimming fish. (A).

Keywords : culvert fish passage; fish; fish passage; culvert hydraulics

45. Behnke, R.J.; Zarn, Mark. 1976. Biology and management of threatened and endangered western trouts. Gen. Tech. Rep. RM-28. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 45 p.

Discusses taxonomy, reasons for decline, life history and ecology, and suggestions for preservation and management of six closely related trouts native to western North America: Colorado River cutthroat, Salmo clarki pleuriticus; greenback trout, S. c. stomias; Lahontan cutthroat, S. c. henshawi; Paiute trout, S. c. seleniris; Gila trout, S. gilae; and Arizona native trout, S. apache. Meristic characters, distribution and status, habitat requirements and limiting factors, protective measures, and management recommendations are presented for each taxon.

Keywords : endangered species; fish; fish habitat

46. Belford, David A.; Gould, William R. 1996. An evaluation of trout passage through six highway culverts in Montana. North American Journal of Fisheries Management. 9:437-445.

Combinations of water velocity and passage length in highway culverts were evaluated to determine conditions that enabled or prevented the passage on nonanadromous rainbow trout Oncorhynchus mykiss, brown trout Salmo Trutta, cutthroat trout O. clarki, and brook trout Salvelinus fontinalis. Fish passage through six culverts 45-93 m long was determined by trapping and electrofishing. Water velocities were measured 5 cm above the bottom (bottom velocity) and at 0.6 of the water depth at intervals between rest sites throughout the lengths of the culverts. Nonlinear regression lines specific to species and state of sexual maturity were fit to the combinations of mean bottom velocity and passage length representing the most strenuous conditions that allows the upstream passage of trout. Because of the similarity of the strenuous passage relations among species, the spawning rainbow trout relation could be used as the general criterion for passage of the trout studied. This relation indicated that fish could swim distances of 10, 30, 50, 70, and 90 m with mean bottom velocities up to 0.96, 0.80, 0.74, 0.70, and 0.67 m/sec respectively. (A).

Keywords : fish passage; culvert - highway; fish; culvert fish passage; culvert analysis

47. Ben-Zvi, Arie. 1993. Distribution of flood volumes beyond design discharges. In: Proceedings of the symposium on engineering hydrology; 1993 July 25-30; San Francisco. New York: ASCE, Hydraulics Division: 97-102.

Quantitative prediction of flood volumes beyond design discharges is important for hydrologic design of river constructions, such as bridges and culverts, because these are the volumes which accumulate upstream from the constrictions and inflict damages. The prediction can be made through the various distributions and methods which are currently applied in hydrology. The present work does it through the partial duration series approach, where the attention is concentrated on large values. Observed trends of the upper tails are considered as predictors for probable larger volumes. The trends are defined in accordance with tail thickness', determined from displays of cumulative mean exceedances against threshold volumes. Diverse trends are found for a case study of 8 rivers with 6 design discharges per river. The Generalized Paerto distribution has been selected for description of the magnitudes because of its flexibility with respect to tail thickness. Good fits are found for all the rivers. The best fit for each combination of river and design discharge is recommended for application (A).

Keywords : flood estimation and control; discharge; bridge design; culvert design; hydrologic design

48. Benson, Manuel A. 1962. Factors influencing the occurrence of floods in a humid region of diverse terrain. Geological Survey Water-Supply Pap. 1580-B. Washington, DC: United States Geological Survey. 65 p.

This report describes relations between flood peaks and hydrologic factors in a humid region with limited climatic variation but a diversity of terrain. Statistical multiple-regression techniques have been applied to hydrologic data on New England. Many topographic and climatic factors have been evaluated, and their relations to flood peaks have been examined. Many of the factors that influence flood peaks are interrelated, and part of the investigation consisted of determining the most efficient factor in each of several groups of highly interrelated variables. Drainage area size

was found to be the most important factor. Main-channel slope was found to be next in importance and a simple yet efficient index of main-channel slope was developed. The surface area of lakes and ponds was found to be a factor significantly influencing peak discharges. Of several indices tested the intensity of rainfall for a given duration and frequency was found to be most highly related to the magnitude of peaks. The increase in peaks caused by snowmelt and frozen ground was found to be related to an index of winter temperature--the average number of degrees below freezing in January. After the above-mentioned topographic and climatic characteristics had been taken into account, there remained deviations in peak discharges that showed an evident relation to orographic patterns. An orographic factor was mapped as defined by the peak discharges of record. Multiple-regression equations were developed that related, with acceptable accuracy, peak discharges of 1.2 to 300-year recurrence intervals to 6 hydrologic variables; 3 of the variables were topographic, 2 climatic, and 1 orographic. The remaining unexplained variations in flood-peak occurrence are believed attributable to the chance variation in storms. (A).

Keywords : flood estimation and control; climate; hydrologic analysis

49. Benson, Manuel A. 1968. Measurement of peak discharge by indirect methods. Technical report 90. Geneva, Switzerland: World Meteorological Organization. 161 p.

The discharge of streams is usually measured by the current-meter method. During flood periods, however, it is frequently impossible or impractical to measure the discharges by this method when they occur. Consequently, many peak discharges must be determined after the passage of the flood by indirect methods such as slope-area, contracted opening, flow-over-dam, flow through culvert, rather than by direct current-meter measurement. Indirect methods of determining peak discharge are based on hydraulic evaluations which relate the discharge to the water-surface profile and the geometry of the channel. A field survey is made after the flood to determine the location and elevation of high-water marks and the characteristics of the channel. Detailed descriptions of the procedures used in collecting the field data and in computing the discharge are given in this report for each of the methods. (A).

Keywords : streamflow; measurement methods and monitoring; field survey; stream channel; discharge

50. Beschta, Robert L. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon Coast Range. Water Resources Research. 14(6):1011-1016.

Suspended sediment production after road construction, logging, and slash disposal was significantly increased (P=0.95) on two watersheds in Oregon's Coast Range. A 25% patch-cut watersed showed increases during 3 of 8 post-treatment years. These increases were caused primarily by mass soil erosion from roads. Monthly sediment concentrations before the occurrence of the annual peak flow were increased more than those following the annual peak. Surface erosion from a severe slash burn was the primary cause of increased sediment yields for 5 post-treatment years on a watershed that was 82% clearcut. Monthly sediment concentrations were generally increased throughout the winter runoff period on this watershed. The flushing of suspended sediment in Oregon Coast Range watersheds is apparent form seasonal changes of suspended sediment rating curves. (Sims-ISWS).

Keywords : sedimentation; road construction effects; logging practices and effects

51. Beschta, Robert L. 1981. Streamflow estimates in culverts. Res. Note 67. Corvallis, OR: Oregon State University, School of Forestry, Forest Research Laboratory. 4 p.

Culverts may substitute for more elaborate artificial control sections for estimating streamflow on many mountain watersheds where roads cross streams and drainage ways. The procedure outlined in this note for calculating the velocity and cross-sectional area for flow and discharge through round culverts is based on flow depth and culvert measurements including diameter, slope, and annular corrugations. Flow velocities are estimated using Manning's equation, valid under uniform flow conditions, which are often met just upstream from the outlet of culverts installed on mountain roads. A sample program solving the necessary equations for cross sectional area, velocity, and stream discharge (flow) is given for a hand held calculator (HP 33E).

Keywords : streamflow; culvert hydraulics

52. Best, D.W.; Kelsey, H.M.; Hagans, D.K.; Alpert, M. 1995. Role of fluvial hillslope erosion and road construction in the sediment budget of Garrett Creek, Humboldt County, California; USGS Professional Paper 1454-M. In: Nolan K.M., Kelsey H.M., Marron D.C. eds. Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwestern California. Washington, D.C. U.S. Department of Interior, U.S. Geological Survey: M1-M21.

The Garrett Creek sediment budget is based on detailed measurements of fluvial hillslope erosion, streamside landsliding, and main-channel sediment storage in Garrett Creek. The study period, 1956 to 1980, which includes both an interval of widespread timber harvest and a sequence of major storms, represents a period of accelerated erosion in the watershed. Of the sediment contributed to the main channel during this time, fluvial slope erosion contributed 63 percent, and streamside landsliding contributed the rest. Of the total sediment input for the 25-year period, only 6 percent remained in storage in the lower main channel of Garrett Creek. (A).

Keywords : erosion processes; sedimentation effects; case studies; landslides

53. Bethlahmy, N. 1967. Effect of exposure and logging on runoff and erosion. Res. Note INT-61. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7p

High-intensity rainfall was applied artificially to plots on eight steep, forested areas in the Payette National Forest in central Idaho. Logged and unlogged sites on northeast and southwest exposures were represented equally. Results show that runoff and erosion are greater on southwest than on northeast exposures, and that even after careful logging, erosion increases on southwest but not significantly on northeast exposures. (A).

Keywords : logging practices and effects; runoff; erosion processes

54. Bethlahmy, N.; Kidd, W.J., Jr. 1966. Controlling soil movement from steep roadfills. Res. Note INT-45. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.

Eight test plots were established on the fill slope of a newly constructed road. One plot was retained as a control, while different soil-stabilizing treatments were used on each of the other

plots. These consisted of various combinations of seeding, fertilizing, mulching, and surface netting. Treatments that included both straw mulch and netting effectively controlled erosion.

Keywords : road erosion; erosion control; steep slopes and road grades; soil conservation

55. Bilby, R.E.; Sullivan, Kathleen; Duncan, S.H. 1989. The generation and fate of road-surface sediment in forest watersheds in southwestern Washington. Forest Science. 35(2):453-468.

Keywords : road surface erosion; runoff; sedimentation

56. Bisson, P.A.; Quinn, Thomas P.; Reeves, Gordon H.; Gregory, Stanley V. 1992. Best management practices, cumulative effects, and long-term trends in fish abundance in Pacific Northwest River systems. In: Naiman, Robert J. editors. Watershed management: Balancing sustainability and environmental change. New York: Springer-Verlag: 189-232. Chapter 7.

Although it is widely believed that forest management has degraded streams and rivers, quantitative relationships between long-term trends in fish abundance and forestry operations have not been successfully defined. In this article we review the difficulties in describing cumulative effects of forest management on fishes of the Pacific Northwest. Despite uncertainties in interpreting long-term trends from catch and escapement statistics as well as widespread programs of hatchery production, many local fish populations are declining. We suggest that trends in the abundance of individual populations are often of limited use in identifying the cumulative effects of forest management within a river system. Shifts in the composition and organization of fish communities may provide more comprehensive evidence of the extent of environmental alteration. Reduced stream habitat complexity has been one of the most pervasive cumulative effects of past forest practices and probably has contributed to significant changes in fish communities, particularly when accompanied by other land use activities that have led to straightened, confined channels. In simplified streams a few fish species have characteristically been favored while others have declined or disappeared completely. Likewise fish culture practices have resulted in overall losses of genetic diversity among species. In order to protect channel complexity and biodiversity, best management practices (BMPs) should include measures to preserve physical and biological linkages between streams, riparian zones, and upland areas. Connections must include transfer processes that deliver woody debris, coarse sediment, and organic matter to streams, as these materials are largely responsible for creating and maintaining channel complexity and trophic diversity. Past forest practice regulations have required attainment of individual water quality standards, such as temperature or dissolved oxygen, and have been aimed at protecting certain life history stages of single species (e.g. salmon eggs in spawning gravels). This approach is inadequate to achieve the goal of restoring and maintaining natural levels of complexity at the level of a stream ecosystem. New BMPs are beginning to address this issue by prescribing riparian management zones with a greater range of vegetative species and structural diversity, thus providing for future sources of large woody debris, floodplain connections, and other linkages important to ecosystem function. Benefits of new BMPs in terms of improved habitat complexity and increased diversity of fishes on the scale of a river basin will require coordinated planning and extensive application, and will take years--perhaps decades--to become apparent. (A).

Keywords : aquatic life; best management practices; fish habitat; fish; watershed disturbance

57. Blakemore, T.E. 1982. An evaluation of waterbar effectiveness in the coast ranges of northern California. Arcata, CA: Humboldt State University. 90 p. M.S. thesis.

This study examined waterbars constructed on skid trails and rill and gully erosion associated with skid trails. Four types of waterbar failures were observed; (1) the waterbar was broken down from raindrop impact or overland flow of water and no longer prevented water form moving down the tail, (2) significant erosion (a gully greater than 5 cm deep and longer than 6 m) occurred at the waterbar outlet, (3) the waterbar was broken down by vehicular traffic, (4) the waterbar was broken down by animal traffic. The last two types of failure were not significant in terms of frequency or associated rill and gully erosion. The most important factor affecting the type 1 failures were operational factors (how the water bar was built), not the physical site factors of terrain slope, precipitation, etc. The waterbar angle, waterbar outlet (clear or blocked), and height of the waterbar were significant indicators of waterbar effectiveness. Forty seven percent of the waterbars built with an angle of less than 30 degrees had a type 1 failure while only 6 percent of the waterbars built with an angle of greater than or equal to 30 degrees had failed. Waterbars built with no outlet for runoff water (blocked outlet) had a 66 percent type 1 failure rate and waterbars with a clear outlet had a 7 percent type 1 failure rate. Distance between waterbars, topographic position and terrain slope were the most important factors influencing the type 2 failures. The material at the waterbar outlet is important but it could not be quantified in this study. Types 1 and 2 failures had similar percentages of the total measured erosion, 46 percent and 42 percent respectively. Waterbars with type 2 failures had a mean erosion per waterbar of 2.18 m3 and waterbars with type 1 failures had a mean erosion per waterbar of 0.74 m3. This was onsite rill and gully erosion and it does not necessarily imply total soil lost into streams. Out of 960 waterbars surveyed (ages of 1 to 11 years since logging), there were 209 type 1 failures and 64 type 2 failures. Some physical site factors that influenced waterbar effectiveness were terrain slope, topographic position, and type of skid trail construction. The waterbar failure rate and erosion amounts increased with increased terrain slope and erosion amounts increased significantly on slopes over 50 percent. The type 2 waterbar failure rate and erosion amounts increased on skid trails built in ravines (within 30 m of a stream channel). Waterbars built on throughcut trails (cut banks on both sides) had very high type 1 failure rates (60 percent). The relationship between the total volume of gully erosion and the volume of this displaced soil that entered a stream was examined. About half the soil displaced by gully erosion reached a stream. The “delivery ratio” remained fairly constant for the first 11 years after timber harvesting.

Keywords : dips and waterbars; road design and construction; erosion control structures; skid trail

58. Boise State University. 1984. Sedimentation yield from cut and fill slopes: Silver Creek research evaluation, Boise National Forest. Boise, ID: Boise State University, Department of Geology and Physics and U.S. Department of Agriculture, Forest Service, Boise National Forest; project completion report; CA INT-80-003-CA. 96 p.

Keywords : sedimentation; sedimentation effects; cut slope; fill slope; case studies

59. Boyer, J.T. 1981. Potential erosion from montane zone roads. Fort Collins, CO: Colorado State University. M.S. thesis.

This study was conducted during 1980 to collect soil erosion data from a representative low-density subdivision in the montane zone. Soil loss and deposition was measured on s system of open plots with a “bedstead” sampler designed for this study. Micro elevation changes of the soil surface were monitored with the “bedstead,” then converted to volume and weight of soil loss

or deposition. Soil loss data was also collected during infiltrometer runs using simulated rainfall. Soil characteristics related to erosion were studied with a portable infiltrometer and using standard laboratory procedures. An estimate of total erosion within the study area and relative contributions of source areas was calculated based on extrapolation of observed plot data. The total erosion figure arrived at for road development during the study period in the 2.59 square kilometer (1 sq. mi.) subdivision was estimated at 736 metric tonnes (811 tons) or 42.2 tonnes per kilometer (75 tonnes/mile) of road. Relative contributions of the source areas were: road cut banks -64%, road surface - 16%, and road fill banks - 20%. (A).

Keywords : erosion processes; forest roads

60. Bradley, Jeffrey B.; Reiser, Dudley W. 1991. Effects of fine sediment intrusion on spawning gravel in southeast Alaska. In: Proceedings of the 1991 national conference on hydraulic engineering; 1991 July 29-August 2; Nashville, TN. New York: ASCE: 453-458.

The supply of sediment to forest streams in Southeastern Alaska is related to the inherent instabilities of landforms, stream channels and the effects of logging practices. Debris avalanches, flows and slides supply a large proportion of sediment to first order streams in steep terrain at the upper portion of watersheds. In lower reaches with relatively mild terrain, sediment inputs occur mainly as a result of streambank erosion and from routing of sediment from upstream reaches. Sediment supply and transport in forest streams can be accelerated above natural levels by timber harvesting and road building activities. There is a perception, without adequate data collection and evaluation to support it, that timber harvest activities in the Tongass National Forest of southeast Alaska have significantly increased sediment introduction to stream channels subsequently harming the anadromous and resident fishery. The primary purpose of this investigation was to identify the effects of fine sediment intrusion on salmon habitat, and to develop a detailed data collection program for the Tongass National Forest. (A) 3 Refs.

Keywords : sedimentation; fish habitat; stream channel; logging practices and effects

61. Brater, E.F. 1939. The unit hydrograph principle applied to small water-sheds. Transactions of the American Society of Civil Engineers. 2083:1154-1192.

The investigation was conducted to determine whether the unit hydrograph principle is applicable to small streams and, if so, to determine its usefulness as a tool in the analysis of surface run-off. The study is based on continuous records of run-off and rainfall taken from twenty-two small water-sheds by the Appalachian Forest Experiment Station. The water-sheds lie in the high rainfall belt of the Southern Appalachians. They vary in area from 4.24 acres to 1,876.7 acres, and in cover type, from old-growth forest to complete denudation. Part I addresses the selection of unit hydrographs and the preparation of distribution graphs on the twenty-two streams. The method of selecting the unit hydrographs from the discharge records of the water-sheds is presented, with a general consideration of the principles involved in the selection. The various factors to be considered in the separation of surface run-off from groundwater flow are discussed, and a method of procedure for making this separation on hydrographs from small streams is suggested. Distribution graphs were derived from each of the unit hydrographs, and the graphs from each stream were superimposed upon one another to permit the selection of a composite distribution graph for the stream. A detailed study was made of the rainfall that produced the unit hydrographs for the purpose of determining more definitely the conditions that govern the formation of such graphs. Part II consists of applications of the distribution graphs for the purpose of further testing the adequacy of the theory, and to indicate the value of the unit hydrograph as a tool in the

analysis of run-off phenomena. Composite distribution graphs were analyzed for the purpose of disclosing any correlation between the shapes of the distribution graphs, especially the peak percentages and the widths of bases, with the physical characteristics of the water-sheds. The distribution graphs of three of the streams were then utilized in the construction of pluviagraphs for comparison with actual hydrographs of run-off. The pluviagraph studies led logically to a consideration of surface run-off coefficients. Finally, a method is submitted for the use of the unit hydrograph principle as a practical method of predicting surface run-off.

Keywords : hydrograph; runoff; hydrologic analysis; watershed

62. Brown, Bert A.; Hall, Peter M. 1993. Sacramento drainage manual hydrologic procedures. In: Proceedings of the symposium on engineering hydrology; 1993 July 25-30; San Francisco. New York: American Society of Civil Engineers, Hydraulics Division: 1115-1120.

For a period of over two years, HDR Engineering, Inc. (HDR) and HYDMET have been working with the City and County of Sacramento to develop a Drainage Manual. This Manual contains seven sections including goals and policies, hydrology, street drainage and storm inlets, storm sewers and appurtenances, culvert and bridge hydraulic design, open-channels, and storage. The draft Manual is currently being reviewed by the City and County and should be finalized sometime this year. This paper will address the hydrologic procedures incorporated in the Draft Drainage Manual, the basis for their development, and difficulties encountered during the development phase of the Manual. A second paper to be presented at this symposium (Hall, Wegener, and Crouch) provides an overview by the County of Sacramento of subsequent refinements to the hydrologic procedures in the draft Manual which are now being proposed as interim procedures until additional field information is collected during the next 5 years. (A) refs.

Keywords : drainage structures; handbooks; hydrologic design; culvert design

63. Brown, G.W.; Krygier, J.T. 1971. Clear-cut logging and sediment production in the Oregon Coast Range. Water Resources Research. 7(1):1189-1198.

The impact of road construction, two patterns of clear-cut logging, and controlled slash burning on the suspended sediment yield and concentration from three small watersheds in the Oregon coast range was studied for 11 years. Sediment production was doubled after road construction but before logging in one watershed and was tripled after burning and clear-cutting of another watershed. Felling and yarding did not produce statistically significant changes in sediment concentration. Variation in the relation between sediment concentration and water discharge on small undisturbed streams was large. (knapp-usgs).

Keywords : sedimentation; clear-cutting; logging practices and effects; road construction effects; impact analysis

64. Brown, Thomas C.; Binkley, Dan. 1994. Effect of management on water quality in North American forests. Gen. Tech. Rep. RM-248. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 27 p.

Although the quality of water draining forested watersheds is typically the best in the Nation, some forest management practices can seriously impair streamwater quality. Sediment is the main concern. High suspended sediment levels, and adverse changes in stream channels, are potential

problems in several regions, especially after road construction, and some harvesting and grazing practices. Impacts are most serious where fish reproduction is affected. Nitrate and water temperature are less serious problems. Harvesting can increase nitrate levels markedly, in some locations; and removal of overstory from along streambanks can raise water temperatures enough to impair fish survival. Best management practices (BMPs) can avoid most of these harmful effects. Additional work is needed, in some locations, to encourage BMP use and to tailor BMP specifications to site-specific conditions.

Keywords : water quality; forest management and practices; sedimentation; best management practices

65. Brown, Thomas C.; Brown, Douglas; Binkley, Dan. 1993. Laws and programs for controlling nonpoint source pollution in forest areas. Water Resources Bulletin. 29(1):1-13.

Recent federal legislation strengthened nonpoint source pollution regulations and helped to support and standardize pollution control efforts. A comprehensive review of current state and federal programs for forest areas reveals a substantial increase in agency water quality protection activities. These new efforts emphasize monitoring to assess the use and effectiveness of best management practices (BMPs). Recent monitoring reveals that BMP use is increasing and that such use typically maintains water quality within standards. However, information is generally lacking about the cost effectiveness of BMP programs. Carefully designed and executed monitoring is the key to better specification of BMPs and more cost effective water quality protection. (A) 30 Refs.

Keywords : non-point source pollution; regulations; water quality; stream pollution; best management practices

66. Bryant, Mason D. 1981. Evaluation of a small diameter baffled culvert for passing juvenile salmonids. Res. Note PNW-384. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 7 p.

A 90-cm-diameter culvert with off-set baffles was set at a 10 percent gradient in an artificial stream channel on Admiralty Island, Alaska. Coho salmon, Dolly Varden char, and cutthroat trout, all less than 120-mm fork length, were able to move up the 9-m culvert. Additional work is needed to determine an upper discharge limit and to evaluate field installations. (A).

Keywords : baffles; fish passage; culvert installation; fish

67. Burns, J.W. 1972. Some effects of logging and associated road construction on northern California streams. Transactions of the American Fisheries Society. 101(1):1-17.

The effects of logging and associated road construction on 4 California trout and salmon streams were investigated from 1966 through 1969. This study included measurements of streambed sedimentation, water quality, fish food abundance, and stream nursery capacity. Logging was found to be compatible with anadromous fish production when adequate attention was given to stream protection and channel clearance. The carrying capacities for juvenile salmonids of some stream sections were increased when high temperatures, low dissolved 02 concentrations, and adverse sedimentation did not accompany the logging. Extensive use of bulldozers on steep slopes for road building and in stream channels during debris removal caused excessive streambed sedimentation in narrow streams. Sustained logging prolonged adverse conditions in 1 stream and

delayed stream recovery. Other aspects of logging on anadromous fish production on the pacific coast are discussed. (copyright 1972, biological abstracts, inc.).

Keywords : logging practices and effects; road construction effects; sedimentation; fish habitat; impact analysis; stream pollution

68. Burroughs, Edward R.; Foltz, Randy B.; Robichaud, Peter R. 1991. United States Forest Service research on sediment production from forest roads and timber harvest areas. In: Proceedings 2, 10th world forestry congress; 1991; Paris, France. Paris, France: Food and Agriculture Organization: 187-193.

The United States Forest Service is developing a surface erosion model for disturbed forest sites, principally forest roads and timber harvest areas. Simulated rainfall is used on bounded plots of various sizes to generate runoff and sediment production from a wide range of soil textures and land management situations. The usual sequence of rainfall at a selected intensity is a 30-minute application with the soil in a dry condition, followed 24-hours later by a second application, then followed as soon as possible by a third. Two rainfall intensities are used on forest roads: 25 mm/hr and 51 mm/hr to 102 mm/hr. Data from simulated rainfall on small field plots, burned and unburned, with and without the residual root mat removed, showed the increases in sediment yield to be expected from severe slash treatment/site preparation burns. Field plots on timber harvest areas that were unburned and burned with and without machine compaction provided data on the effects of these treatments under natural rainfall conditions. Results of a laboratory study of the hydraulic roughness of overland sheet flow with rainfall and a field study of the hydraulics of concentrated flow in wheel ruts were used in an analytical model of runoff from forest roads. Data from a laboratory study of the relative erodibility of wildland soils were used to estimate interrill sediment detachment as a function of soil texture and clay mineralogy. Simulated rainfall on bounded road plots up to 38 m long showed that wheel ruts increased sediment production by a factor two to four over similar unrutted road sections. The difference in the increase was a function of relative soil erodibility. (A).

Keywords : sediment; forest roads; timber harvest; research; timber

69. Burroughs, Edward R.; Haber, D.F.; Watts, F.J.; Kadoch, T.L. 1983. Measuring surface erosion on forest roads and estimating costs of erosion control--preliminary results. Proceedings of the third international conference on low-volume roads; 1983; Phoenix, AZ. In: TRB Special Report 898. Washington, D.C. National Research Council, Transportation Research Board; 214-221.

Simulated rainfall was applied to three types of roadway on six sections of forest road to measure runoff and sediment yield. The three surfaces were native granitic material, native material treated with dust oil, and bituminous surface treatment. The roads are located within the Silver Creek Experimental Watershed, Boise National Forest, Idaho. Test plots of the roadway were isolated from the adjacent roadway with barriers sealed to the surface. Discharge and suspended sediment were sampled continuously. Rainfall was simulated by a large sprinkling infiltrometer at a rate of 2 in/h for 25-40 min. The first test was conducted on a dry plot, followed by a second test 24 h later. Measurements for each plot included bulk density by depth increments, loose soil on the road surface in pounds per unit area, particle-size distribution for each sample, gravimetric soil moisture before and after each simulated rainfall, and a detailed survey of each plot. Result of runoff and sediment yield measurements are presented. Construction costs for standard and nonstandard items on forest roads were determined by recording the labor and equipment necessary to

complete each activity based on local rates. Programs for estimating costs of erosion-control features were developed for the HP-41CV calculator and minicomputers with BASIC language capability. Cost estimates derived from current estimating procedures are compared with costs developed from observed labor and equipment times (A). Additional notes: Simulated rainfall was applied to three types of roadway on six sections of forest road to measure runoff and sediment yield within the Silver Creek Experimental Watershed (Boise NF -Idaho). Objective was to verify the "ROSED" road sediment model since the version used at that time required calibration for the particular locality where it was to be used. This paper was the result of the first year of a 6 to 10 year study. For the sites studied the results show that 1) sediment yield is correlated directly with the amount of loose soil on the road surface and inversely correlated with the D50 of the loose surface material. Note that native granitic material, dust oil on native material, and a BST were evaluated. The sediment yield from the native material is 3 times that for native material with dust oil and 10 times that for a BST. (P.Bolander).

Keywords : rainfall simulation; cost and economics; sedimentation; modeling; surface erosion

70. Burroughs, Edward R.; King, J.G. 1985. Surface erosion control on roads in granitic soils. In: Jones, E.B.; Ward, T.A., eds. Watershed management in the eighties: Proceedings; 1985 April 30-May 1; Denver, CO. New York: American Society of Civil Engineers: 183-190.

Simulated rainfall was used to generate runoff and sediment yield from forest roads and fillslopes built in granitic soils to test the effectiveness of various surfacing materials, mulches and barriers as erosion control treatments. An empirical equation is presented and used to estimate the relative effectiveness of gravel, dust oil, and bituminous surface treatments in reducing sediment yield relative to that of an unsurfaced road. The equation uses road grade, surface density, and the D50 of loose soil on the surface to predict sediment yield from unsurfaced roads. Gravel, dust soil, and bituminous reduce sediment yield by factors of 4.3, 7.7, and 91 relative to the sediment yield for a comparable unsurfaced road. Dense grass cover (97 percent) on 1.5: 1 fillslopes reduces sediment yield by 99.6 percent of that from a bare slope with a loose soil surface. Wood fiber mulch and sediment barrier of cull logs and logging slash reduce bare slope sediment yield by 91 and 87 percent, respectively. (A).

Keywords : road surface erosion; granitic soil

71. Burroughs, Edward R.; Watts, F.J.; Haber, D.F. [Unpublished]. Measurement of the relative effectiveness of rocked roads and ditches in reducing surface erosion, Rainy Day Road, Nez Perce National Forest, Idaho. 25 p.

Keywords : erosion control; road surface erosion; road design and construction; ditches; gravel roads

72. Burroughs, Edward R.; Watts, F.J.; Haber, D.F. 1984. Surfacing to reduce erosion of forest roads built in granitic soils. In: O'Loughlin, C.L.; Pearce, A.J., eds. Proceedings of the symposium on effects of forest land use on erosion and slope stability; 1984 May 7-11; Honolulu, HI. Honolulu, HI: International Union of Forestry Research Organizations: 255-264.

A sprinkling infiltrometer was used to measure the relative difference in sediment yield from isolated lengths of forest road. Sediment yield was reduced by a factor of 4.3 for gravel surfacing, 3.2 for dust oil, and 28.7 for bituminous surfacing relative to an unsurfaced road. Gravel spread in the ditch reduced sediment yield by a factor of 2.3 relative to an unprotected ditch.

Keywords : erosion control; road design and construction; granitic soil; gravel roads

73. Burroughs, Edward R.; Watts, F.J.; King, J.G.; Haber, D.F.; Hansen, D.F.; Flerchinger, G.N. 1985. Relative effectiveness of rocked roads and ditches in reducing surface erosion. In: Proceedings of the 21st annual engineering technology and soils engineering symposium; 1984 April 5-6; Moscow, ID. Moscow, ID: University of Idaho, Department of Civil Engineering: 251-263.

Keywords : erosion control; gravel roads; ditches; surface erosion

74. California Department of Forestry. 1983. Suggested culvert sizing procedures [for 50-year storm]. Sacramento, CA: California Department of Forestry. 31 p.

Determining the proper size culvert under forest practice rules requires estimating the volume of runoff from a “50-year storm” and calculating the size of culvert which will handle that volume of runoff. Several methods are available for determining the anticipated streamflow from a 50-year storm. Each method has its advantages and disadvantages under certain conditions. No one method is best in all situations, and all methods, to some degree, require an evaluation of local conditions to arrive at a reasonable estimate of the flow volume. Most methods use some form of data averaging, subjective estimates of combined factors, or a simplification of complex processes which reduces the precision of the results. At best they are all approximations of the real world. Five most frequently used methods for predicting stream-flow runoff are presented; rational, California nomograph, magnitude and frequency, SCS curve number, and slope-area method. Procedures, advantages and disadvantages, data needed and examples are given for each method. A culvert sizing technique is included.

Keywords : culvert design; runoff; streamflow

75. Campbell, Alan J.; Sidle, Roy C. 1984. Prediction of peak flows on small watersheds in Oregon for use in culvert design. Water Resources Bulletin. 20(1):9-14.

Using data from 80 Oregon watersheds that ranged in size from 0.54 square kilometers to 2745 square kilometers, equations were developed to predict peak flows for use in culvert design on forest roads. Oregon was divided into six physiographic regions based on previous studies of flood frequency. In each region, data on annual peak flow from gaging stations with more than 20 years of record were analyzed using four flood frequency distributions: type I external, two parameter-log normal, three parameter-log normal, and log-Pearson type III. The log-Pearson type III distribution was found to be suitable for use in all regions of the State, based on the chi-square goodness of fit test. Flood magnitudes having recurrence intervals of 10, 25, 50, and 100 years were related to physical and climatic characteristics of drainage basins by multiple regression. Drainage basin size was the most important variable in explaining the variation of flood peaks in all regions. Mean basin elevation and mean annual precipitation were also significantly related to flood peaks in two regions of western Oregon. The standard error of the estimate for the regression relationships ranged from 26 to 84 percent. (A).

Keywords : culvert design; prediction; discharge

76. Campbell, Alan J.; Sidle, Roy C.; Froehlich, Henry A. 1982. Prediction of peak flows for culvert design on small watersheds in Oregon. Corvallis, OR: Oregon State University, Water Resources Research Institute; final report; project A-053-ORE. 96 p.

Forest engineers must frequently make flood frequency estimates for very small watersheds when designing culvert installations. Empirical formulae and simplified rainfall runoff models, the most commonly used techniques to predict floods from very small watersheds, require considerable engineering judgment to give reasonable results. As an alternative to such methods, this study presents equations to predict peak flows on small watersheds in Oregon. The equations were developed from 80 watersheds ranging in size from 0.21 to 10.60 square miles. Oregon was divided into six physiographic regions based on previous flood frequency studies. In each region, annual peak flow data from gagging stations with more than 20 years of record were analyzed using four flood frequency distributions (Gumbel, two-parameter log-normal, three-parameter log-normal, log Pearson type III). The log Pearson type III distribution was found to be suitable for use in all regions of the state, based on the chi-square goodness of fit test. Flood magnitudes having recurrence intervals of 10, 25, 50, and 100 years were related to physical and climatic indices of drainage basins by multiple regression analysis. Drainage basin area (A) was the most important variable in explaining the variation of flood peaks (Qt) in all regions. Mean basin elevation (E) and mean annual precipitation (P) were also significantly related to flood peaks in two regions in western Oregon. Average percent error for all developed regression equations ranged from 16.1 to 64.1 percent, the smaller errors being associated with the more humid regions. Confidence limits developed for the regression equations provide the engineer with estimates of prediction uncertainties over the range of design flows. These prediction equations provide a better basis for culvert design on small forested watersheds than rules of thumb or empirical models.

Keywords : flood estimation and control; culvert design; culvert installation; prediction; watershed

77. Carr, W.W. 1980. A handbook for forest roadside surface erosion control in British Columbia. Report 4. Victoria, BC: British Columbia Ministry of Forests, Land Management. p33-35.

This handbook is primarily concerned with the establishment of vegetation on forest road construction sites that present a problem with surface erosion and sediment production. The soil and surficial materials exposed by road construction are inherently infertile and low in organic matter. Such areas can be transformed to a state of stable productivity by appropriate measures. (C).

Keywords : forest roads; road erosion; erosion control

78. Carr, W.W.; Ballard, T.M. 1980. Hydroseeding forest roadsides in British Columbia for erosion control. Journal of Soil and Water Conservation. 35(1):33-36.

Erosion following forest road construction is a major cause of stream pollution in British Columbia, Canada. The cost effectiveness of hydroseeding to revegetate disturbed forest roadside slopes was investigated. Hydroseeding trials at two sites demonstrated that a single application of both seed and fertilizer was an effective as sequential application of seed and fertilizer. Mulching proved unnecessary. Untreated plots had no plant cover. Soil eroded to an average depth of 2.3 centimeters between September 1976 and April 1977, an estimated soil loss of 345 cubic meters per kilometer of road. Plant cover on treated plots averaged 65%, which was enough to trap soil eroded from the untreated upslope. (9 references, 5 tables) (C).

Keywords : hydroseeding; erosion control; forest roads; road construction effects; stream pollution

79. Cederholm, C.J.; Salo, E.O. 1979. The effects of logging road landslide siltation on the salmon and trout spawning gravels of Stequaleho Creek and the Clearwater River Basin, Jefferson County, Washington, 1972-1978. Seattle, WA: University of Washington, College of Fisheries, Fisheries Research Institute; Final report -- part III; FRI-UW-7915. 76 p. Sponsored by the Washington State Department of Natural Resources.

The effects of logging road landslides on the sedimentation of salmonid spawning gravels in Clearwater River tributaries were studied for 6 years. Conclusions include: (1) certain steep gradient tributaries like Stequaleho Creek have the energy to flush sediments in relatively short periods of time; (2) other tributaries of lower stream power can retain sediments in spawning gravels for longer periods of time. The principal difference in the physical structure of these streams is related to gradient, discharge, and the amount of large organic debris deposited on the floodplain. The levels of fine sediments (<0.850 mm) have increased from a mean of 8.36% (controls) to 10.69% (test) in Stequaleho Creek, and from 8.36% to 9.12% in the main Clearwater River below Stequaleho Creek. The salmonid intragravel survival to emergence decreased by about 11.60% in Stequaleho Creek and 3.8% in the main Clearwater River over the 6 year period of study. Sediments less than 0.850 mm diameter were found to be accumulating basin-wide in spawning areas influenced by logging road sediments. This subtle buildup of intragravel sediments was positively correlated (1% level) with percent of sub-basin clearcut, miles of logging road per basin square mile, and percentage of basin area in roads. Sediments less than 0.850 mm diameter were significantly inversely correlated with the survival of coho salmon eggs in artificial streams. Also, coho salmon eggs in landslide affected gravels of East Fork Miller Creek survived only 40% as well to hatching and 9% as well to the button-up stage of development when compared to control groups. Surveys over a 6-year period revealed a high degree of variation in abundance of salmon and steelhead redds among streams although the numbers in Stequaleho Creek were no significantly different than other Clearwater tributaries. This variation can partially be explained by annual differences in sport and commercial catches. While logging road-caused landslides can have relatively short-term local impacts on spawning gravels in some tributaries as in Stequaleho Creek, the basin-wide accumulation of sediments is the primary concern. (A).

Keywords : fish habitat; landslides; road impacts; sedimentation effects

80. Cederholm, C.Jeff; Reid, Leslie M. 1987. Impact of forest management on Coho salmon (Oncorhynchus kisutch) populations of the Clearwater River, Washington: a project summary. In: Salo, Ernest O.; Cundy, Terrance W., eds. Streamside management: forestry and fishery interactions: Proceedings of a symposium; 1986 February 12-14; Seattle. Contribution No. 57. Seattle: University of Washington, Institute of Forest Resources: 373-398.

In 1972, declining coho salmon production and visible forestry impacts on coho habitats prompted the initiation of an ongoing fisheries research project in the Clearwater River basin of the Olympic Peninsula. Heavy fishery catches have resulted in a general underseeding of the basin, as demonstrated by stocking experiments and inventories of potential habitat. Because of the resulting lack of a reservoir of surplus juveniles, the number of smolts produced is more sensitive to natural and forestry-related impacts. Forestry-related mortality in the Clearwater basin is primarily due to an increased sediment load and to alterations in the riparian environment that reduce refuge habitat during winter storms. Increased sediment loads come primarily from landslides and surface erosion on heavily used logging roads, while reductions in winter refuge capacity are caused by stream blockages or by destruction of the refuge habitat. Field and laboratory experiments demonstrate that (1) survival of eggs and leavens decreases as the percentage of fine sediments in spawning grovels increases, (2) suspended sediments cause stress to juveniles during summer, (3)

disruption or blockage of small winter refuge channels can reduce smelt survival, (4) aggravation of coarse sediments can cause loss of summer rearing habitats, and (5) streamed stability may be locally reduced by removal of large woody debris. Since the depressed state of Clearwater River Coho stocks has resulted from the combined effects of overfishing and forestry-caused habitat degradation, an integrated approach to natural resource management is needed that includes recognition of both the independent and combined impacts of the fishery and forestry industries. Within a drainage basin, resource management programs must provide for the protection of the full range of habitat types used by the fish.

Keywords : forest management and practices; fish; fish habitat; impact analysis

81. Cederholm, C.Jeff; Reid, Leslie M.; Salo, E.O. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. In: Salmon spawning gravel: a renewable resource in the Pacific Northwest: Proceedings of a conference; 1980 October 6-7; Seattle. Rep. 39. Pullman, WA: Washington State University, State of Washington Water Research Center: 38-74.

In 1971 a series of massive landslides on the west coast of the Olympic Peninsula, which included both logging and road sidecast failures, prompted research on the sedimentation of salmonid spawning habitats. The sedimentation from logging road activities has caused long-term concern for fisheries resources of the Clearwater River. This study included analyses of field situations supplemented by controlled experiments. Significant amounts (15-25 percent) of fine sediments (less than 0.85 mm diameter material) are accumulating in spawning gravels of some heavily roaded tributary basins. This accumulation is highest where the road area exceeds 2.5 percent of the basin area. Tributaries of relatively steep gradient are less likely to accumulate high levels of fines. The survival of salmonid eggs to emergence is inversely correlated with percent fines when the percentage of fines exceeds the natural level of 10 percent. The presence of 2.5 km/km2 of gravel-surfaced roads undergoing an average distribution of road uses is found to be responsible for producing sediment at 2.6 to 4.3 times the natural rate in a drainage basin. Sixty percent of the road-related sediment production is caused by landslides, while 18-26 percent is caused by erosion on road surfaces. However, if fine sediment alone is considered, the production from road surfaces and landslides is nearly equal. (Garrison-Omniplan).

Keywords : road impacts; slope failures; landslides; logging practices and effects; sedimentation; fish; fish habitat

82. Clancy, Christopher G.; Reichmuth, Donald R. 1990. A detachable fishway for steep culverts. North American Journal of Fisheries Management. 10(2):244-246.

A fishway constructed of angle iron and reinforcing bar was installed in a high-gradient culvert to allow the passage of Yellowstone cutthroat trout Onchoryhynchus clarki bouvieri to upstream spawning areas in Cedar Creek, a tributary of the Yellowstone River in southwestern Montana. The structure was detachable from the culvert, inexpensive, and portable. The fishway was still effective 8 years after installation. (A).

Keywords : fishways; fish passage; culvert installation; culvert fish passage

83. Cobourn, John. 1989. Cumulative watershed effects (CWE) analysis in federal and private forests in California. In: Woessner, W.W., and Potts, D.F., eds., American Water Resources Association symposium proceedings on headwaters hydrology; 1989 June 26-30; Missoula, MT. American Water Resources Association Technical Publication Series TPS-89-1. Herndon, VA: American Water Resources Association: 441-449.

NEPA, the Clean Water Act of 1977, and the California Environmental Quality Act require that the effects of past present, and future management activities be considered together to prevent water quality impacts. These cumulative watershed effects (CWE) would create a safety net for water quality. Some of the most detailed CWE analyses in California are being carried out by the hydrologists of the USFS. The methodology, which is detailed, is divided into four phases: calculation of a Natural Sensitivity Index for each watershed; compilation of the acreage of all management activities, including road surfaces, into a Land Disturbance History; field investigation; and evaluation based on the previous three phases (A). (23 references).

Keywords : watershed; forest management and practices; water quality

84. Coghlan, G.; Davis, N. 1979. Low water crossings. Low Volume Roads: Second International Conference; 1979 August 20-23; In: Transportation Research Record 702. Washington, D.C. National Research Council, Transportation Research Board; 98-103.

This paper provides a rationale for planning and constructing low water crossings on low volume roads. Fords, fords with culverts and crossings on low structures are described. Examples are given of good and poor designs using different types of materials and involving a variety of environmental considerations. Examples come from National Forests in Minnesota, Missouri, West Virginia and New Hampshire. (A).

Keywords : low water crossing; road design and construction

85. Coker, R.J.; Fahey, B.D. 1993. Road-related mass movement in weathered granite, golden downs and Motueka Forests, New Zealand: a note. Journal of Hydrology (New Zealand). 31(1):65-69.

Four major storms in July and August 1990 triggered 263 failures on the cutbanks and sidecast of 142 km of access roads. The total volume of material displaced over the 209 km road network in granite was estimated at 193,000 m3, which is about 367,000 tons or approximately 2800 t/km2. This is equivalent to 80 years of sediment yields from surface erosion estimated at 37 t/km2/yr.

Keywords : mass movement; granitic soil; forest roads; rainstorm

86. Cook, Walter L., Jr.; Hewlett, John D. 1979. The broad-based dip on Piedmont Woods roads. Southern Journal of Applied Forestry. 3(3):77-81.

Poor design and location of logging roads is a major cause of erosion of the roads and subsequent sedimentation of streams. The broad-based dip is a low-cost, surface drain designed to minimize erosion while the road is being used, as well as during the period between harvests. The dip is a 20-foot stretch of reverse grade built into the basic grade, slightly outsloped at the bottom.

Keywords : road design and construction; road location; dips and waterbars; surface drainage; erosion control; best management practices

87. Cottman, N.H.; McKay, G.R. 1990. Bridges and culverts reduced in size and cost by use of critical flow transitions. Proceedings of the Institution of Civil Engineers (London), Part 1: Design & Construction. 88:421-437.

This Paper describes an innovative concept for designing channel transitions which will converge wide, shallow, sub-critical flows into high-velocity critical flows. The flows are then passed through deep, narrow throats that are cheaply culverted or bridged. The outflow is finally diverged, spread and decelerated before being passed downstreams with minimum head losses. These 'minimum energy' or 'maximum discharge' designs were first used in Australia in 1961. They offer a means of passing large flows through much smaller, more efficient and more economical culverts and bridges, without the considerable upstream afflux that is the bane of conventional hydraulic structures. The usual problems of erosion, siltation, debris and energy dissipation are discussed, and shown to be either absent or manageable. The concept is very useful in many instances, including that of increasing the capacity of many suitable floodpain bridges at minimal cost. Much experience is recorded, a worked example is presented, and both appropriate and unsuitable sites are described. (Edited author abstract) 6 Refs.

Keywords : bridge design; culvert design; flow capacity; flow velocity; cost and economics; channels; surface water

88. Cruff, R.W.; Rantz, S.E. 1965. A comparison of methods used in flood-frequency studies for coastal basins in California. Geological Survey Water-Supply Pap. 1580-E. Washington, DC: U.S. Geological Survey. 56 p.

The study compares the results of regional flood-frequency studies made by several methods and appraises the relative reliability of these methods. The areas selected for study were the subhumid San Diego area in southwestern California and the humid coastal area in northwestern California. The following six methods of analysis were applied to each region: Index-flood method, multiple correlation, logarithmic normal distribution, extreme-value probability distribution (Gumbel method), Pearson type III distribution, and gamma distribution. The last four methods named involved not only the computation of the statistics appropriate to the distributions, but also the relating of these statistics to basin and climatologic characteristics. On the basis of an empirical, non-statistical test, the following conclusions were reached: 1. All methods of analysis give better results in a humid region than in a subhumid region because streamflow is less variable in a humid region. 2. If historical data, either qualitative or quantitative, are available concerning the magnitude of floods that occurred in the years prior to the collection of streamflow records, the multiple-correlation method of analysis is preferred. Only this method and the index-flood method benefit from the historical data, which, in effect, extend the time base of the analysis. The multiple-correlation method is superior to the index-flood method because it has a far more rational basis and in addition gives better results. 3. Where the peak-discharge data are limited entirely to the period during which streamflow records were collected (no historical data available), a method based on the distribution of the array of peak flows is preferred because of its greater objectivity. Of the four distributions tested, the Pearson type III is the most desirable. It is more flexible than the other three and will generally fit the peak-discharge data best. Although this comparison study of flood-frequency methods was based on small samples from only one part of the United States, the results and conclusions appear to be meaningful because they can be explained rationally. (A).

Keywords : flood estimation and control; basins

89. Cullen, Stephen J.; Montagne, Cliff; Ferguson, Hayden. 1991. Timber harvest trafficking and soil compaction in Western Montana. Journal of Soil Science Society of America. 55(5):1416-1422.

Three soil types in northwestern Montana were examined for the effects of timber-harvest trafficking on soil compaction. Physical properties of ash over limestone till, ash over quartzite till, and Tertiary volcanic soils were determined by assessing the effects on soil bulk density and water-holding capacity. Analyses revealed that bulk density in the moderate and severely trafficked areas was significantly greater than in the nontrafficked areas. Infiltration was significantly lower in both the moderate and severely trafficked areas on all three parent materials. Water retention in trafficked areas of the limestone till soils was significantly less than that found in nontrafficked areas. No significant differences in bulk density and total porosity were found at the 30- and 45-cm depth. (3 graphs, 31 references, 5 tables).

Keywords : timber harvest; soil compaction; soil properties; logging practices and effects; truck traffic; infiltration

90. Dane, B.G. 1978. Culvert guidelines: recommendations for the design and installation of culverts in British Columbia to avoid conflict with anadromous fish. Tech. Rep. 811. Vancouver, BC: Department of Fisheries and Environment, Fisheries and Marine Service, Pacific Region. 57 p.

This report examines the hydraulic criteria that should be satisfied at a culvert installation to ensure that fish can migrate through the facility with a minimum of stress. The report also outlines guidelines that, if incorporated into the culvert design, should produce a facility that will permit the free passage of fish in most situations. The design of auxiliary fish passage structures such as culvert baffles and tailwater control facilities are discussed and exampled by drawings. Consideration is also given to the installation of culverts to avoid conflicts with fish use in the stream both during and after the construction period. Guidance is also given concerning the procedures to follow for necessary approval of a proposed culvert installation by the Fisheries and Marine Service. (A).

Keywords : fish migration; fish passage; hydraulics; culvert installation; culvert fish passage

91. Dasika, B. 1995. New approach to design of culverts. Journal of Irrigation and Drainage Engineering. 121(3):261-264.

The current procedures for the design of culverts are reviewed. Experiments at LaTrobe University, Bendigo, Australia, indicated that the head-versus-discharge relation under inlet control is slightly different from what the design charts give. New generalized relations between head water level and discharge are presented for inlet-control conditions after fitting the experimental data. As the ratio of end depth to the critical depth varies with the slope of the culvert and the discharge, the practice of considering the critical depth should be viewed with caution. The present investigation suggests that the head water depth required to pass a given discharge through a pipe culvert of a given size is much less when the pipe runs full with the tail water level at the top of the pipe at the exit than the head water level required to pass the same discharge under inlet conditions. It is therefore recommended that the culvert be designed to flow under outlet-control conditions with the tail water level coinciding with the top of the pipe. (A) 6 Refs.

Keywords : culvert design; culvert inlets; design chart

92. Davies, P.E.; Nelson, M. 1993. The effect of steep slope logging on fine sediment infiltration into the beds of ephemeral and perennial streams of the Dazzler Range, Tasmania, Australia. Journal of Hydrology. 150(2-4):481-505. (Special issue: O'Loughlin, E.M.; Dunin, F.X., eds. Water issues in forests today. Papers presented at the International Symposium on Forest Hydrology, Canberra, Australia, 22-26 November 1993).

Logging can result in enhanced stream transport of particulate organic matter, which can alter the balance of functional feeding groups and aquatic-community productivity. At a steep-slope cable logging site in Tasmania, Australia, a study was conducted to investigate the effects of stream-bed infiltration by fine sediment. Clearfelling is conducted by skyline cable logging, with roads predominantly on the ridge tops. Sediment traps were placed in the bed of each stream study site. Both ephemeral and perennial streams were evaluated. The fine sediment trapped in both logged and unlogged streams was predominantly inorganic. The fine sediment infiltration in ephemeral, first-order streams was significantly enhanced by logging on steep slopes, by a factor of two to three times that for unlogged streams. Infiltration was greatest during the 2 yr. immediately following logging. Sedimentation from uncontrolled road crossings was also considerable. The nature of the fine bed material changed significantly after logging to a more organically rich sediment (A). (27 graphs, 1 map, 47 references, 2 tables).

Keywords : clear-cutting; logging practices and effects; stream sediment; infiltration; drainage crossing; stream pollution

93. DeVries, Johannes J., ed. 1991. Proceedings of a workshop on county hydrology manuals. 1990 August 16-17; Davis, CA. Mission Viejo, CA: Lighthouse Publications: 125 p.(Sponsored by Water Resources Center, University of California).

Information on 'county level' hydrologic techniques in California based on county hydrology manuals is presented. County hydrology manuals address public works aspects of surface water runoff management for flood control purposes and water conservation. Emphasis of papers is: 1) to give an overview of county hydrology manuals and general hydrologic analysis procedures used for county-level hydrology, and 2) a review of specific hydrologic and stormwater drainage procedures. Papers include: an application of a county adopted hydrology manual for the town of Apple Valley, California, discussions of frequently used hydrologic techniques for small watershed analysis including precipitation, loss rate estimation, and runoff computations, guidelines for detention basin design procedures, and a general review of the rainfall-runoff models.

Keywords : handbooks; hydrologic analysis; hydrology; surface drainage; flood estimation and control

94. Diyaljee, Vishnu; Stoeck, Jane. 1989. Highway erosion remedial measures. In: Sediment transport modeling: Proceedings of the international symposium; 1989 August 14-18; New Orleans, LA. New York: American Society of Civil Engineers: 154-159.

Soil erosion from highway ditches, cut slopes and fill slopes present a continuous problem to roadway designers, geotechnical engineers, and construction and maintenance personnel from environmental, aesthetics and roadway maintenance viewpoints. Very often the prevention of sediment transportation is required before vegetative cover establishes itself on a newly constructed grade. This is required to minimize stream pollution in environmentally sensitive areas, to prevent deep slope, and ditch gullying and to prevent blockage of culvert drainage structures. Over the last 5 to 8 years serious consideration has been given by Alberta Transportation and

Utilities to the problems of soil erosion along the highway system which have defied treatment by conventional methods of erosion control. Such problems have been remedied using improved strawbale designs, concrete mats, geosynthetics, synthetic products, and gabions. (Edited author abstract) 2 Refs.

Keywords : erosion control; soil erosion; stream pollution; highway construction

95. Donahue, John P.; Howard, Andrew F. 1987. Hydraulic design of culverts on forest roads. Canadian Journal of Forest Research. 17(12):1545-1551.

Design of drainage structures is an important part of planning forest roads, which usually includes culverts. Determining the appropriate pipe size for a given site involves estimation of expected flows and evaluation of the hydraulic performance of pipes of different sizes. In this paper a review of the hydraulic relationships applicable to the evaluation of pipe hydraulics is presented. A computer model is introduced that incorporates these relationships. The model is used to compare two algorithms for computing headwater depths, given inlet control (supercritical flow). The relative efficiency of four inlet types was also investigated. Results indicate that potential cost savings exist by altering inlet geometry and that computer-assisted design can facilitate accommodations of conflicting design goals. (A).

Keywords : hydraulics; road design and construction; forest roads; culvert design; modeling; drainage structures

96. Dorman, M.E. 1996. Retention, detention, and overland flow for pollutant removal from highway stormwater runoff. Volume I, Research report. FHWA-RD-96-095. McLean, VA: U.S. Department of Transportation, Federal Highway Administration, Research, Development, and Technology. 168 p. (Available: Springfield, VA: National Technical Information Service as stock no. PB97-122188).

This is volume I of a two-volume report that provides design guidelines and specifications for three types of management measures for the removal of pollutants from highway stormwater runoff. The three types, determined through previous studies to be effective in treating highway runoff, are: retention systems (basins, trenches, and wells), detention basins (wet detention basins, dry extended detention basins, and wetlands), and overland flow (grassed channels and filter strips). These guidelines have been developed based on the experience of the project team, review of available literature, and bench-scale and field testing. This volume is the research report. Volume II contains the design guidelines. (C).

Keywords : basins; wetlands; highway construction

97. Dorman, M.E. 1996. Retention, detention, and overland flow for pollutant removal from highway stormwater runoff. Volume 2, Design guidelines. FHWA-RD-96-096. McLean, VA: U.S. Department of Transportation, Federal Highway Administration, Research, Development, and Technology. 216 p. (Available: Springfield, VA: National Technical Information Service as stock no. PB97-122196).

This is volume II of a two-volume report that provides design guidelines and specifications for three types of management measures for the removal of pollutants from highway stormwater runoff. The three types, determined through previous studies to be effective in treating highway

runoff, are: retention systems (basins, trenches, and wells), detention basins (wet detention basins, dry extended detention basins, and wetlands), and overland flow (grassed channels and filter strips). These guidelines have been developed based on the experience of the project team, review of available literature, and bench-scale and field testing. This volume contains the design guidelines. Volume I is the research report. (C).

Keywords : basins; wetlands; highway construction

98. Douglas, I.; Greer, T.; Bidin, D.; Sinin, W. 1993. Impact of roads and compacted ground on post-logging sediment yield in a small drainage basin, Sabah, Malaysia. In: Gladwell, J.S., ed. Hydrology of warm humid regions: Proceedings, international symposium; 1993 July 19-21; Yokohama, Japan. IAHS Pub. 217. Wallingford, Oxfordshire: International Association of Hydrological Sciences: 213-218.

Water yields from a selectively logged basin rose immediately after logging, but transpiration by recovering forest vegetation led to the water yield falling below that of undisturbed forest 12 months after logging ceased. Total annual sediment yields for W8S5 and the Baru in 1989 were 118 and 1632 t/km2/yr respectively. In 1990 they were 117 and 1017 t/km2/yr respectively, and in the first seven months of 1991, 38, and 96, indication the decline in sediment yield from the selectively logged catchment. Major storms that carry a higher percentage of the total annual load from the logged catchment are the prime causes of higher sediment yields during the post-logging phase. These storms remove sediment from the remaining bare ground, especially along abandoned roads and tracks.

Keywords : logging practices and effects; road construction effects; impact analysis; sedimentation

99. Dryden, R.L.; Jessop, C.S. 1974. Impact analysis of the Dempster Highway culvert on the physical environment and fish resources of Frog Creek. Tech. Rep. Series CEN/T-74-5. [Yellowknife, NT, CA?]: Environment Canada, Fisheries and Marine Service, Resource Management Branch, Central Region. 59 p.

The impacts of improper culvert design and effects on the hydrology and fish biology of Frog Creek, N.W.T. are discussed. Fish migration discharge design, as required by Fisheries and Marine Service, Environment Canada for northern highway culverts is defined. At this or lower discharges, flow conditions within the culvert must allow for the upstream passage of fish. Fish migration discharge for Frog Creek, N.W.T. is calculated as 22.4 m3/s (800 cfs). If the culvert at Frog Creek had been designed to allow fish passage at this discharge, the delay to fish migrations would have been only 3 to 4 days. Water velocities in the Frog Creek culvert during 1973 exceeded the maximum allowable velocity of 1.5 m/s (5 fps) for 40 days from May 26 to July 5. Bank erosion downstream from the culvert caused retreat of the river bank at a rate of 15 cm (6 inches) per day. Siltation of the stream resulting from construction was evident, but appeared to be insignificant. During the peak discharge period, extensive ponding occurred upstream of the culvert. Ice buildup inside the culvert occurred primarily during early spring as a result of over-ice flow. High water velocities within the culvert blocked the spawning migration of approximately 600 northern pike Esox lucius (Linnaeus) and appeared to block movements of some broad whitefish Coregonus nasus (Pallas). Fish passage did not become generally possible until July 5, when water velocities of less than 1.5 m/s (5 fps) were attained. After passage became possible, both pike and broad whitefish dispersed equally in upstream and downstream directions. It was estimated that only a small proportion of the total pike population of the Frog Creek drainage was blocked by the culvert. No physiological effects of culvert delay on ripe pike were evident. Feeding habits of

northern pike and broad whitefish are described in relation to available food organisms, as indicated by drift and artificial substrate samples. Age and growth and length frequency distributions for pike and broad whitefish are described. Maximum ages recorded in Frog Creek were 8 years for pike and 6 years for broad whitefish. (A).

Keywords : impact analysis; hydrology; fish passage; fish migration; culvert fish passage; culvert - highway

100. Dryden, R.L.; Stein, J.N. 1975. Guidelines for the protection of the fish resources of the Northwest Territories during highway construction and operation. Tech. Rep. Series CEN/T-75-1. [Yellowknife, NT, CA?]: Department of the environment, Fisheries and Marine Service, Resource Impact Division, Resource Management Branch, Central Region. 32 p.

Based on the results of fisheries investigations conducted between 1971 and 1974 guidelines have been designed to protect the fish resources of the Districts of Keewatin and Mackenzie, as well as Baffin and Southampton Islands, from major disruptions resulting from the construction and operation of highway and road systems. These guidelines are not intended to serve as regulations but merely as an aid in meeting Fisheries and Marine Service requirements, as defined by the Fisheries Act of Canada. Culvert average cross-sectional velocities must not exceed 0.9 m/s (3 fps) when fish passage is a requirement, unless it can be satisfactorily demonstrated that the culvert design includes a selected region wherein velocities are low enough to permit fish passage. This selected region must be continuous throughout the culvert length and of sufficient size to permit the fish to locate it and to swim through it. Alternatives such as baffles should be considered when these velocity criteria can not be met through regular design procedures. The minimum desirable water level within culverts during periods of fish movement should be 20.3 cm (8 inches). In general, no instream construction activity should be attempted from May 1 to June 30 and from September 1 to November 15, as these periods are considered critical to fish migrations and spawning. However, these dates vary slightly with geographical spread and variations in the timing of freeze-up and break-up. The spring or fall restrictions may be lifted if it can be satisfactorily demonstrated that fish spawning activities do not occur during either or both of these periods in the stream under consideration. Three days is considered the maximum time period during which blockage to annual spawning migrations can be tolerated without causing serious disruption to the spawning cycle. During this three day period, the above mentioned velocity criteria need not be adhered to. Variables such as the timing of fish migration and the timing and duration of peak flows will determine when this three day limitation should be in effect. The removal of stream gravel may seriously damage spawning habitat and therefore should not be attempted without first consultation with Fisheries and Marine service. Highway routing should avoid close proximity or paralleling of streams or water bodies, and should cross river systems as far upstream from the river mouth or as far downstream from a lake outlet as possible. Specific restrictions, other than those discussed within these guidelines, may have to be imposed where unique fish species or life history aspects are involved. Conversely, the guidelines may be tempered upon consideration of species composition or the individual characteristics of a stream system. Fisheries and Marine Service is available to provide advice and guidance with respect to the fisheries resource for any highway design for construction proposal in the Northwest Territories. (A).

Keywords : highway construction; road design and construction; fish habitat; aquatic life

101. Duncan, Stanley H.; Bilby, R.E.; Ward, J.W.; Heffner, J.T. 1986. Transport of road-surface sediment model. In: Proceedings of the fourth federal interagency sedimentation conference; 1986 March 24-27; Las Vegas, NV. Moscow, ID: Idaho University, Department of Engineering: 325-334.

Since the majority of road drainage points in western Washington and Oregon enter small, often ephemeral streams rather than large, fish-bearing waters, impact of road-surface sediment on biota in permanent streams depends, to a large extent, on transport through these small watercourses. A series of experimental additions of road-surface sediment was made to two ephemeral streams to examine the downstream transport of this material as a function of discharge and channel characteristics. These small streams were found to store large amounts of sediment washed from road surface. In no instance did either stream transport more than 45 percent of the added material to their mouths, distances of 95 and 125 m. Larger-sized sediment particles were delivered at a lower rate than finer material. Added sediment <0.063 mm in size was transported efficiently through the systems at all but the lowest flows tested. Material between 0.5 and 0.063 mm and from 2.0 to 0.5 mm in size were retained at progressively higher rates, with sediment in the coarser size category never exceeding a delivery of 10 percent of the added material. There were significant differences in the transport of sediment in the two larger size categories between the two streams. These differences were due to a much greater amount of woody debris in the stream with the lower delivery rates, which acted to trap and hold sediment, as well as a slightly longer and less steep channel. (Author 's abstract).

Keywords : road sediment model; road surface; sediment modeling

102. Duncan, Stanley H.; Bilby, R.E.; Ward, J.W.; Heffner, J.T. 1987. Transport of road-surface sediment through ephemeral stream channels. Water Resources Bulletin. 23(1):113-119.

Since the majority of road drainage points in western Washington and Oregon enter small, often ephemeral streams rather than large, fish-bearing waters, impact of road-surface sediment on biota in permanent streams depends, to a large extent, on transport through these small watercourses. A series of experimental additions of road-surface sediment was made to two ephemeral streams to examine the downstream transport of this material as a function of discharge and channel characteristics. These small streams were found to store large amounts of sediment washed from road surface. In no instance did either stream transport more than 45 percent of the added material to their mouths, distances of 95 and 125 m. Larger-sized sediment particles were delivered at a lower rate than finer material. Added sediment <0.063 mm in size was transported efficiently through the systems at all but the lowest flows tested. Material between 0.5 and 0.063 mm and from 2.0 to 0.5 mm in size were retained at progressively higher rates, with sediment in the coarser size category never exceeding a delivery of 10 percent of the added material. There were significant differences in the transport of sediment in the two larger size categories between the two streams. These differences were due to a much greater amount of woody debris in the stream with the lower delivery rates, which acted to trap and hold sediment, as well as a slightly longer and less steep channel. (Author 's abstract).

Keywords : road erosion; sediment modeling; stream channel

103. Eaglin, Gregory S.; Hubert, Wayne A. 1993. Effects of logging and roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries Management. Laramie, WY: Fish and Wildlife Service; 13(4): 844-847.

Logging activities can have a profoundly deleterious impact on nearby stocks of freshwater fish. The impacts of logging and road construction on substrate and populations of two types of trout are examined. Surveys of fish stocks were conducted for 28 stream reaches in the Medicine Bow National Forest, WY. The amounts of fine substrate and overall embeddedness were directly related to roads crossing watercourses and logging activities. The density of culverts along waterways were negatively proportional to trout standing stocks. The primary impact of logging on stream habitat took the form of erosion of soil from road surfaces, ditches, and other disturbed areas at the edges of roads. (14 references, 1 table).

Keywords : logging practices and effects; fish habitat; road construction effects; drainage crossing; fish

104. Eck, Ronald W.; Burks, Randall S.; Morgan, Perry J.; Phillips, Ross A. 1984. Economic analysis of broad-based dips versus conventional drainage structures on forest roads -- preliminary results. In: Peters, Penn A.; Luchok, John, eds. Mountain logging symposium proceedings; 1984 June 5-7; Morgantown, WV. Morgantown, WV: West Virginia University: 192-200.

Preliminary results of an on-going study conducted to address the issue of broad-based dips versus conventional drainage structures were presented. A decision-making framework was developed that can be used as a general guide to factors to consider in selecting a dip or culvert in a particular application. Specific questions which the engineer should address relatives to soils/ geology, hydrology, construction, maintenance and road user factors were identified. The experimental design to be used to collect detailed data at a number of field sites in the Monongahela National Forest in West Virginia was outlined.

Keywords : cost and economics; road design and construction; drainage structures; culvert design; dips and waterbars; insloping; outsloping

105. Eck, Ronald W.; Morgan, Perry J. 1987. Culverts versus dips in the Appalachian Region: a performance-based decision-making guide. Proceedings of the fourth international conference on low-volume roads; 1987 August 16-20; Ithaca, NY. In: Transportation Research Record 1106(2). Washington, D.C. National Research Council, Transportation Research Board; 330-340.

Detailed roadway and environmental information was collected at 19 field sites in the Appalachian region to assess the performance of dips and 18-inch aluminum pipe culverts under a variety of conditions. Performance was rated as either acceptable or unacceptable by a survey team that made a field examination of the drainage structure. Overall, 227 culverts and 255 broad-based dips were assessed. The most common distress types for the dips rated as unacceptable were erosion of the fill slope, rutting, siltation, and ponding. A number of specific conclusions regarding the design and location of dips and culverts were presented to document cases in which one device was more appropriate and cost-effective than another. A decision-making framework, in the form of a flowchart, was developed to assist engineers and foresters in selecting the appropriate drainage device for a particular application. (Edited author abstract) 7 refs.

Keywords : road design and construction; drainage structures; dips and waterbars; culvert - aluminum; culvert survey; insloping; outsloping

106. Edgerton, Roy C. 1961. Culvert inlet failures-a case history. Highway Research Board Bulletin. 286:13-21.

Bent-up ends have been experienced on three large structural plate culverts installed with the upstream ends square and projecting into the fill toe. Installations and failures are described. Bending of the culverts apparently occurred due to the buoyant force resulting from the difference in water surface elevations inside and outside the culverts. Notes describing similar failures and alternative failure mechanisms are included.

Keywords : culvert inlets; case studies; culvert installation

107. Ellard, Jesse S. 1971. Techniques of evaluating effects of water on drainage structures in Alabama. Circular 75. University, AL: Geological Survey of Alabama. 14 p.

Field inspection and classification of galvanized steel culverts was based on an empirical evaluation of existing corrosion and structural conditions. These two conditions were used as the basis of organizing the field data for analysis. Two methods of regression analysis were used in predicting “years to perforation” of galvanized steel culverts . One method uses three variables; pH, resistivity, and dissolved oxygen characteristics of the water passing through individual culverts. Resistivity values in excess of 15,000 ohm/cm and dissolved oxygen values less than 4.5 ppm (parts per million) are values synonymous to a passive corrosion condition. Water with resistivities less than 15,000 ohm/cm and dissolved oxygen values greater than 4.5 ppm appear to be corrosive. A second regression analysis using the method of least squares involved only pH. “Years to perforation” predictions from both methods were found to be similar. (A).

Keywords : culvert analysis; corrosion; drainage structures; service life

108. Ellingwood, B.R. 1995. Engineering reliability and risk analysis for water resources investments; role of structural degradation in time-dependent reliability analysis. Vickburg, MS: U.S. Army Engineer Waterways Experiment Station; ITL-95-3. final report; 56 p.

This report presents the results of a preliminary investigation of the feasibility of incorporating structural degradation into time-dependent reliability analysis of navigation infrastructure on inland and coastal waterways. An appraisal is presented of methodologies for engineering decision that might enable the owner/operator of a navigation facility to perform condition assessments, determine its economical remaining service life, and schedule routine maintenance and repair so as to minimize total operating costs without endangering public safety. The report is developed around the following specific research objectives: (1) Identify mathematical models to evaluate degradation in strength of navigation structures over time in terms of initial construction conditions, service load history, and aggressive environmental factors. (2) Develop a methodology to assess the probability that structural capacity has degraded below a specified level, taking into account initial conditions of the structure, service load history and structural aging, and deterioration. (3) Examine the role played by periodic inspection, nondestructive evaluation and maintenance in maintaining reliability and minimizing overall costs during a projected service period. This feasibility study is based on a review, synthesis and interpretation of existing procedures and data in the structural engineering, material science, and structural reliability literature. It provides a prospectus for subsequent research on reliability-based evaluation of navigation structures, some of which is initiating (A).

Keywords : risk analysis and design; water resources

109. Environmental Protection Agency. 1989. Highlights of section 404: federal regulatory program to protect waters of the United States. Washington, DC: Environmental Protection Agency, Office of Wetlands Protection. 14 p.

This document gives a brief overview of the Section 404 program of the Clean Water Act and EPA efforts to maintain clean United States waters.

Keywords : water quality; Clean Water Act

110. Environmental Protection Agency. 1993. Fact sheets on interagency working group on federal wetlands policy. Washington, DC: Environmental Protection Agency, Office of Water. 17 p.

This document is a series of fact sheets which overview aspects of the interagency working group on the Federal Wetlands Policy.

Keywords : wetlands; law and policy

111. Environmental Protection Agency. 1994. Water quality standards handbook and appendixes. 2nd ed. Washington, DC: Environmental Protection Agency, Office of Water: 890 p.

The Water Quality Standards Handbook, first issued in 1993 (PB92-231851), is a compilation of EPA's guidance on the water quality standards program and provides direction for States in reviewing, revising and implementing water quality standards. The Handbook retains all the guidance in the 1983 Handbook unless such guidance was specifically revised in subsequent years. An annotated list of the major guidance and policy documents on the water quality standards program issued since 1983 is included in the Introduction and material added to the Second Edition by periodic updates since 1993 is summarized in Appendix X. The guidance contained in each of the documents listed in the Introduction is either: (1) incorporated in its entirety, or summarized, in the text of the appropriate section of this Handbook, or (2) attached as an appendix.

Keywords : water quality; law and policy

112. Environmental Protection Agency. 1995. Guidelines for preparation of the 1996 state water quality assessments (305(b) reports). Washington, DC: Environmental Protection Agency, Assessment and Watershed Protection Division; EPA841B95001. 332 p.

The Federal Water Pollution Control Act (PL92-500, commonly known as the Clean Water Act), establishes a process for States to use to develop information on the quality of the Nation's water resources and to report this information to the U.S. Environmental Protection Agency (EPA), the U.S. Congress, and the citizens of this country. Each State must develop a program to monitor the quality of its surface and ground waters and prepare a report every 2 years describing the status of its water quality. EPA compiles the data from the State reports, summarizes them, and transmits the summaries to Congress along with an analysis of the status of water quality nationwide. This process, referred to as the 305(b) process, is an essential aspect of the Nation's water pollution control effort.

Keywords : water quality; Clean Water Act; water resources

113. Environmental Protection Agency. 1995. Interim economic guidance for water quality standards: appendix M to the water quality standards handbook. 2nd ed. Washington, DC: Environmental Protection Agency, Office of Water: 189 p. p.

This guidance is presented to assist States and applicants in understanding the economic factors that may be considered, and the types of tests that can be used to determine if a designated use cannot be attained, if a variance can be granted, or if degradation of high-quality water is warranted. This workbook provides guidance for those seeking to document that uses meeting the fishable/swimmable goals of the Act are not attainable, obtain a variance based on economic considerations, or to lower water quality in a high-quality water. In addition, it provides guidance to States and EPA regions responsible for reviewing requests for variances, modifications to fishable/swimmable designated uses, documentation that fishable/swimmable uses are not attainable, and for approval of antidegradation analyses.

Keywords : water quality; cost, economics

114. Environmental Protection Agency; Arnold, Arnold and Associates; Dames and Moore. 1975. Logging roads and protection of water quality. Seattle: Environmental Protection Agency, Region X; EPA 910/9-75-007. 312 p.

This report is a state-of-the art reference of methods, procedures and practices for including water quality consideration in the planning, design, construction, reconstruction, use and maintenance of logging roads. Most of the methodology also is applicable to other forest management roads. The report is divided into two parts. The first part provides general perspective on physical features and conditions in EPA Region X which are relevant to water quality protection and logging roads. The second part outlines specific methods, procedures, criteria and alternatives for reducing the degradation of water quality. Topic coverage in this part includes road planning, design, construction and maintenance including the use of chemicals on roads. Silvicultural activities are one category of water pollution from nonpoint sources described in public law 92-500. Of all silvicultural activities, logging roads have been identified as the principal source of man-caused sediment.

Keywords : drainage design; road drainage; water quality control

115. Evans, Willis A.; Johnston, Beryl. 1972. Fish migration and fish passage: a practical guide to solving fish passage problems. Washington, DC: U.S. Department of Agriculture, Forest Service; EM-7100-12. 63 p. [plus appendices].

Keywords : fish migration; fish passage; fishways

116. Everest, Fred H.; Beschta, Robert L.; Scrivener, J.Charles; Koski, K.V.; Sedell, James R.; Cederholm, C.Jeff. 1987. Fine sediment and salmonid production: a paradox. In: Salo, Ernest O.; Cundy, Terrance W., eds. Streamside management: forestry and fishery interactions: Proceedings of a symposium; 1986 February 12-14; Seattle. Contribution No. 57. Seattle: University of Washington, Institute of Forest Resources: 98-142.

The term “sediment,” as commonly used by fishery biologists, means fine sediment and excludes up to 90% of sedimentary material in streams. In mountainous terrain, hillslope erosion (primarily mass soil movements) provides periodic inputs of sediment into stream systems, often during

periods of high flow when two major sediment transport mechanisms are active: (1) suspended sediment transport and (2) bedload transport. Suspended sediment consists primarily of silt and clay-sized particles that may be rapidly transported downstream and locally deposited on floodplains and overbank storage locations or that may infiltrate into gravel interstices of the bed. Bedload transport, consisting primarily of coarse sands or larger particles, is complex and sporadic, and has major implications regarding channel morphology and the quality of spawning gravels. It is greatly affected by large roughness elements (logs, boulders, bedrock outcrops, etc.). Hence the impacts of sediment on fish habitat are influenced by both sediment availability and the subsequent routing of these materials through the channel system. The effects of fine sediment on aquatic life have been studied intensively for more than three decades, both in situ and in the laboratory. Laboratory studies have demonstrated potential negative effects of fine sediment on macroinvertebrates, on survival and emergence of salmonid embryos and alevins, and on growth of salmonid fry. But there are significant difficulties in extrapolating these findings to the field. Nearly all laboratory survival studies have used simplified unnatural gravel mixtures to test incubation and emergence of salmonid fry. Also, mitigating factors in streams, such as structural roughness elements and spawning behavior of female salmonids, complicate direct field application of laboratory studies. Nevertheless, forest practice rules designed to minimize fine sediment and turbidity in streams have resulted primarily from laboratory studies. The relatively few studies dealing with the effects of sediment from forest management in natural environments have been less conclusive. Some negative effects observed in the laboratory also occur from acute or chronic sedimentation in the field. The problem with interpreting the results of field studies is that increased fine sediment from forest management is almost always accompanied by other environmental effects. Also, field studies have shown both increases and decreases in salmonid populations associated with forest management. The studies have generally failed to isolate the effects of fine sediment from other habitat changes. A more holistic view of the role of sediment in stream ecosystems is needed. Undisturbed streams in forests have stored abundant sediments in their channels and maintained as equilibrium between sediment input and sediment routing. An abundance of large organic debris and other roughness elements played an important role in the storage and routing of sediments. Forest management has broadly changed sediment storage and equilibrium in streams throughout much of the western United States. The general result has been a concurrent loss of roughness elements and accelerated routing of sediment through fluvial systems. There is evidence that stable channels containing stored sediment and large organic debris are more productive at every trophic level than either degraded channels mainly devoid of sediment or channels that are aggraded and unstable. Thus there seems to be a broad middle ground between too much and too little sediment in salmonid habitats. Forest practice rules designed to minimize introduction of fine sediment into streams are justified, but in themselves do not ensure protection of salmonid habitats. These rules might result in improved water quality and a reduction in fine sediment in gravels, but they do not ensure protection of the physical structure of salmonid habitats. In fact, large losses of productive habitat have occurred while these rules were in force. The long-term emphasis of forest practice rules on control of water quality and fine sediment must be expanded to a more holistic view of salmonid habitat. Protection of streamside vegetation and physical structure of rearing habitat for juvenile salmonids must be given equal emphasis. (Authors) (123 refs.).

Keywords : sediment; fish; fish habitat; impact analysis

117. Fahey, B.D.; Coker, R.J. 1989. Forest road erosion in the granite terrain of south-west Nelson. Journal of Hydrology (New Zealand). 28(1):123-141.

Keywords : erosion processes; forest roads; granitic soil

118. Fahey, B.D.; Coker, R.J. 1992. Sediment production from forest roads in Queen Charlotte Forest and potential impact on marine water quality, Marlborough Sound, New Zealand. New Zealand Journal of Marine & Freshwater Research. 26(2):187-195.

Coarse and fine sediment production from surface erosion was measured at three sites on roads formed in weathered schist in Queen Charlotte Forest, eastern Malborough Sounds, over periods ranging from two to three years. The cutbank contribution was negligible, sidecast fill with partial vegetation cover (average 50%) contributed c.3 kg/m2. Fine sediment production measured on a section of road in strongly weathered schist at 70 m elevation was estimated at 2.3 kg/m2/yr. Extrapolation of the results to the 39 km of forest road and the 21 km of access tracks and firebreaks suggests that about 2000 t of material is being removed by surface erosion each year (62 t/km2 of forest). This could increase to 7000 t or 218 t/km2/yr at the time of harvesting. Log landings could add a further 20%. Background rates of erosion are in the range 300-600 t/km2/yr.

Keywords : sedimentation; forest roads; surface erosion; impact analysis; water quality

119. Farmer, E.E.; Fletcher, J.E. 1976. Highway erosion control systems: an evaluation based on the universal soil loss equation. In: Soil erosion: prediction and control. Ankeny, IA: Soil Conservation Society of America: 12-21.

Nearly two decades of use have confirmed the utility of the universal soil loss equation for soil conservation planning on a site by site basis. The equation has also been applied to construction sites. However, highway construction is a special class of construction activity . From the national experience of building the interstate highway system, we know that highway constructions a high-risk activity with respect to accelerated soil loss and consequent sedimentation of a stream channels and lakes. Although improvement over the past few years has been significant, accelerated soil loss from highway construction activities continues to be a national problem. A lack of knowledge within the highway construction industry of modern erosion control technology, resistance to the adoption of new methods, and a lack of need information have been cited as major contributors to the continuation of the problem. The larger work from which this paper was developed is directed toward improving erosion control practice in highway construction by bringing together a large volume of information on erosions control technology and practices. New information bases were established. For instance, Wischmeier's isoerodent maps are extended to cover the entire United States. This was possible through the high correlation of the R factor (erosion index units in a normal year's rain) with 2-year, 6-hour rainfall data, which is available nationwide. Previous methods for evaluating erosion control systems were modified to improve their performance when used on highway cross-sections. Finally, extensive literature searches provided the best information available on the effect of various erosion control measures that are especially applicable to highway construction situations. These are tabulated in the full report.

Keywords : erosion control structures; soil erosion; soil conservation; highway construction; erosion control; prediction; universal soil loss equation

120. Ferguson, R.I.; Stott, T.A. 1987. Forestry effects on suspended sediment and bedload yields in the Balquhidder Catchments, Central Scotland. Transactions-Royal Society of Edinburgh: Earth Sciences. 78(4):379-384.

Sediment yield is about three times higher in the forested basin and varies more sensitively with streamflow. Erosion of timber loading areas and logging roads is the main sediment source. (A)

Keywords : sedimentation; road impacts; basins; suspended sediment; sediment; catchments

121. Fitch, G.M. 1995. Nonanadromous fish passage in highway culverts. Charlottesville, VA: Virginia Department of Transportation; final report; VTRC 96-R6. 18 p.

Highway culverts may hinder the normal migrations of various trout species in wild trout streams, due to increased flow velocity, shallow water depths, increased turbulence, and perching. This can impede migrational movements, affecting the genetic diversity and long-term survival of some species. Often, the proper installation of culverts can reduce the adverse effects on fish while maintaining hydraulic efficiency. This study characterized the problems with existing culverts to develop guidelines for the future use of culverts in areas with high gradient streams. Installation criteria will ideally limit the use of bridges where culverts are appropriate, and eliminate the use of culverts where they would create fish passage problems. This will reduce installation, maintenance, and retrofitting costs. The study concluded that culverts can be considered the primary option for crossing trout streams if the following criteria are met: * the culvert can be placed on the same slope as that of the streambed, * the slope of the stream is less than three percent, * the flow velocity does not exceed 1.2 meters/second under normal flow conditions, * the barrel of the culvert can be properly countersunk at the outlet to prevent perching. Bridges should be used at those crossings if any of the above criteria cannot be met. Also, baffles should not be used to control stream velocities in new culverts, and concrete aprons should not be used at culvert outlets. If culvert bottoms could be cast to have a roughness coefficient equal to that of the streambed, this would allow greater use of culverts at stream crossings without impeding the passage of trout. (A).

Keywords : culvert - highway; fish passage; fish migration; culvert fish passage; drainage crossing

122. Flanagan, Sam A. 1996. Woody debris transport through low order stream channels: Implications for stream crossing failure. Arcata, CA: Humbolt State University. 34p. M.S. Thesis.

Stream crossings represent a significant erosional risk within a watershed. Knowledge of the processes of stream crossing failure can help land managers better assess the risks posed by crossings. Woody debris is a common initiator of stream crossing failure. This study observed (1) the size distributions of woody debris fluvially transported through 24 small, culverted catchments in three watersheds of northwest California and (2) the characteristics of wood lodged at culvert inlets. Mean and median lengths of wood lodged across culvert inlets were correlated with culvert diameter. Fluvially transported woody debris was exponentially distributed, with abundant smaller pieces. A 95th percentile wood length was chosen to characterize wood lengths among the sites. Channel bed width, the zone of annual bedload transport, was weakly correlated with 95th percentile wood lengths transported. A narrow range of sampled bed widths may explain the scatter in the data. It is hypothesized that relatively wide channel approaches may promote debris lodgement while narrow, restricting channels may favor debris passage through culverts. Culverts oriented at, or near, a ninety degree angle are susceptible to debris lodgement. Susceptibility to plugging cannot be eliminated. Knowledge of the factors influencing plugging is useful for the design and/or assessment of culvert installations. (A).

Keywords : flood estimation and control; bridge design; culvert design; watershed

123. Fleming, George; Franz, Delbert D. 1971. Flood frequency estimating techniques for small watersheds. Journal of Hydraulics Division, American Society of Civil Engineers. 97:1441-1460.

The design of culverts and small bridges requires a reliable method of estimating peak rates of runoff from small watersheds (under 20 square miles). Procedures for estimating volume or peak flow rate, or both, were researched from current literature. Four techniques were considered for testing; simulation, regional frequency, Potter's method, and rational method. Precipitation records of 15 to 20 years for eleven watersheds with catchment areas of 25 square miles or less were compared to computer peak flow estimates. Results indicate that digital simulation of flow provides the closest fit to observed flood frequency curves. The rational method provided the poorest fit to observed curves.

Keywords : flood estimation and control; bridge design; culvert design; watershed

124. Flerchinger, G.N.; Watts, F.J. 1987. Predicting infiltration parameters for a road sediment model. American Society of Agricultural Engineers. 30(6):1700-1705.

Methods for predicting Green-Ampt infiltration parameters for very coarse-textured soils are not well established. Before accurate runoff and erosion predictions can be made for these soils, a large data base and correlations to other soil properties are required. Runoff data were collected and infiltration parameters were determined for simulated rainfall events on forest roads. These results were combined with data from similar studies, and predictive equations were established for the Green-Ampt infiltration parameters using soil texture and porosity. The equations account for 70% of the variation in hydraulic conductivity and 88% of the variation in capillary suction head. (Author 's abstract).

Keywords : sedimentation; infiltration; modeling; rainfall simulation

125. Foltz, Randy B. 1992. Sediment production comparison between the use of normal tire pressure and central tire pressure on forest roads. In: Schiess, Peter; Sessions, John, eds. Proceedings of the international mountain logging and 8th Pacific Northwest skyline symposium; 1992 December 14-16; Bellevue, WA. Seattle: University of Washington: 214-222.

In addition to improved vehicle mobility and reduced road maintenance, the use of reduced tire pressure on heavy trucks has the potential to reduce sediment erosion on forest roads. In the winter of 1992 a test was conducted on an aggregate surfaced road using both reduced tire pressure and normal tire pressure to determine sediment production from each tire pressure regime. The test was conducted for nearly 60 days using natural rainfall and runoff events. A reduction in sediment production of 2:1 was observed when using reduced tire pressure compared to normal tire pressure. These results are in agreement with earlier native surface road tests and demonstrate the ability of reduced tire pressure to lower sediment production from forest roads.

Keywords : sediment; tire pressure; forest roads; road maintenance; erosion control

126. Foltz, Randy B. 1993. Sediment processes in wheel ruts on unsurfaced forest roads. Moscow, ID: University of Idaho. 177 p. Ph.D. thesis.

This study was undertaken to measure sediment production from bounded forest road plots using simulated rainfall. Runoff and sediment were collected from two paired plots exposed to simulated rainfall. One plot contained a wheel rut while the other one did not. These two different plots were

used to determine the effects of shallow concentrated flow on the amount of sediment produced. Sediment production rates from these plots on native surfaced roads are presented. The mean soil diameter ranged from 0.80 mm to 0.05 mm. Sediment rates on the rutted plots with concentrated flow ranged from 1300 kg/ha/mm to 300 kg/ha/mm for the 30-minute, 50-mm/hr intensity. Rates on the freshly graded plots without ruts ranged from 700 kg/ha/mm to 100 kg/ha/mm. A process based model of sediment armoring, believed to be a major process occurring on unpaved forest roads, was developed and tested using the information collected from eight sites over a period of three years (A).

Keywords : sediment modeling; road erosion; wheel ruts; erosion processes

127. Foltz, Randy B. 1994. Sediment reduction from the use of lowered tire pressures. In: Central tire inflation systems: managing the vehicle to surface. SP-1061.Warrendale, PA: Society of Automotive Engineers: 47-52.

The use of lowered tire pressures has the capability to reduce sediment production from unpaved forest roads. A three year test of Central Tire Inflation System (CTIS) and Constant Reduced Pressure (CRP) methods to achieve lowered tire pressures was conducted by the use of CTIS was 80% compared to highway tire pressures. When using CRP tire pressures, the average sediment reduction was 45% compared to highway tire pressures. Both lowered tire pressure systems has shallower, less well defined wheel ruts resulting in less frequent road maintenance requirements. (A).

Keywords : sedimentation; tire pressure; unpaved roads; forest roads; forest management and practices; wheel ruts; sediment

128. Foltz, Randy B. 1994. Reducing tire pressure reduces sediment. Roads/Timber Tech Tip 9477 1306-SDTDC. San Dimas, CA: U.S. Department of Agriculture, Forest Service, Technology and Development Program. 2 p.

Keywords : sedimentation; tire pressure; forest management and practices; forest roads; sediment

129. Foltz, Randy B.; Rauch, Kevin S.; Burroughs, Edward R. 1991. Hydraulic roughness and sediment yield in wheel ruts on forest roads. In: Proceedings of the 1991 national conference on hydraulic engineering; 1991 July 29-August 2; Nashville, TN. New York: American Society of Civil Engineers: 1108-1113.

Clear water flow and sediment yield from simulated wheel ruts in a forest road were measured at five different sites in the Northern Rocky Mountains. These measurements provided information on the Darcy-Weisbach friction factor and Reynolds number relationship. The rill erodibility and critical shear were also determined. (A) 3 Refs.

Keywords : sedimentation; wheel ruts; forest roads; erosion processes; hydraulics

130. Fredrickson, R.L. 1965. Sedimentation after logging road construction in a small western Oregon watershed. In: Proceedings, Federal interagency sedimentation conference; 1963 January 28-February 1; Jackson, MS. Misc. Pub. 970. Washington, DC: U.S. Department of Agriculture, Agricultural Research Service: 56-59.

During the summer of 1959, 1.65 miles of logging road were constructed in a 250-acre forested watershed that rises 2,000 feet in a distance of 1 mile. this study evaluates the change in sedimentation subsequent to road construction. Runoff from undisturbed watersheds in this area remains clear during the summer low-flow months and reaches concentrations of 100 parts per million during winter storm peaks. Runoff from the first rainstorms after road construction carried 250 times the concentration carried in an adjacent undisturbed watershed. Two months after construction, sediment had diminished to levels slightly above those measured before construction. Sediment concentrations for the subsequent 2-year period were significantly different from preroad levels. In about 10 percent of the samples, sediment concentrations were far in excess of predicted values, indicting a stream-bank failure or mass soil movement. Annual bedload volume the first year after construction was significantly greater than the expected yield, but the actual increase was small. A trend toward normalcy was evident the second year. (A).

Keywords : sedimentation; road construction effects; watershed disturbance

131. Fredrickson, R.L. 1970. Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds. Res. Pap. PNW-104. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

In two steep headwater drainages in Oregon, landslides were the predominant source of increased sedimentation of streams following timber harvest. Patch-cut logging with forest roads increased sedimentation relative to a control by more than 100 times over a 9-year period. Landslide erosion was greatest where roads crossed high gradient stream channels. In an adjacent clearcut watershed with no roads, sedimentation increased three times that of the control.

Keywords : erosion control; sedimentation; road construction effects; unstable soil; landslides; logging practices and effects; timber harvest; watershed disturbance

132. French, Richard H. 1992. Design of flood protection for transportation alignments on alluvial fans. Journal of Irrigation and Drainage Engineering. 118(2):320-330.

The method of floodplain delineation on alluvial fans developed for the National Flood Insurance Program (NFIP) may be modified to provide estimates of peak flood flows of specified return periods at transportation alignments, such as aqueducts or railroads, crossing alluvial fans. The modified methodology divides the total length of the alignment into segments, and the peak flow expected in each segment during a flood event-is estimated as a function of the return period of the event, the segment length, and the location of the alignment on the alluvial fan. This estimate of the peak flow can be used to properly size the facilities such as dikes, berms, and culverts to protect the alignment from flood damage. The proposed methodology has potential applications in any environment where transportation alignments must cross alluvial fans on which the hydraulic processes are similar to those for which the NFIP methodology was developed. An example of the use of this methodology is provided. (A) 18 Refs.

Keywords : flood estimation and control; discharge; return period; prediction; drainage design

133. French, Steven P.; Isaacson, Mark S. 1984. Applying earthquake risk analysis techniques to land use planning. Journal of American Planning Association. 50(4):509-523.

Keywords : risk analysis and design; land management; planning

134. Froehlich, W. 1991. Sediment production from unmetalled road surfaces. In: Sediment and stream water quality in a changing environment: trends and explanation [Part of proceedings of the symposia held during the 20th general assembly of the International Union of Geodesy and Geophysics]; 1991 August 11-24; Vienna, Austria. IAHS Pub. No. 203. Wallingford, Oxfordshire, UK: International Association of Hydrological Sciences: 21-29.

Unmetalled roads greatly accelerate runoff and erosion processes and provide the main source of suspended sediment transported by Carpathian rivers. In the instrumented drainage basin of the Homerka stream (19.6 km) systematic measurements of runoff, suspended sediment and erosion of unmetalled roads were carried out both on an experimental slope under cultivation and in the forested area. The average contribution of sediment from the unmetalled roads amounts to about 70-80% of the suspended sediment load of the Homerka drainage basin. (A) 8 Refs.

Keywords : sedimentation; road surface; water quality; runoff; sediment

135. Fukushima, Y.; Beschta, Robert L.; Blinn, T.; Grant, Gordon E.; Ice, G.G.; Swanson, Frederick J. 1987. Estimating discharge and sediment yield from a forest road. In: Erosion and sedimentation in the Pacific Rim: Proceedings of an international symposium; 1987 August 3-7; Corvallis, OR. IAHS Pub. Vol. 165. Washington, DC: International Association of Hydrological Sciences: 265-266.

A forest road is used not only for the transportation of harvested wood, but also for the management of the forest. Soil conservation problems include erosion on the road surface and landsliding from fill banks caused by road drainage. Discharge and sediment yield from a forest road for one year at two observation sites were investigated. The ratios of direct runoff to rainfall amount were high at both sites. The Manning's equivalent roughness was calculated at N = 0.05, using the kinematic wave method. These results indicate that if rainfall conditions and soil properties are known, surface discharge and sediment yield can be predicted for forest roads. Such estimates would be useful for the planning of cross drains for forest roads. (See also W91-06570) (Brunone-PTT).

Keywords : sedimentation; discharge; forest roads; soil conservation; erosion control; landslides; sediment.

136. Furbish, D.J.; Rice, Raymond M. 1983. Predicting landslides related to clearcut logging, northwestern California, U.S.A. Mountain Resources and Development. 3(3):252-259.

Landslides related to clearcut logging area a significant source of erosion in the mountains of northwestern California. Forest managers, therefore, frequently must include assessments of landslide risk into their land-use plans. A quantitative method is needed to predict such risk over large areas of rugged mountainous terrain. Form air photographs, data were collected of conditions associated with a sample of logging-related slides and randomly located stable sites. Discriminant analyses were used to develop an equation that distinguishes the two types of sites--slides and non-slide-- with 81 percent accuracy. The equation can be used to provide an assessment of risk

for undisturbed terrain. Results showed that post-logging failure is most likely to occur near actively scouring streams, just below major convex breaks of slope and within drainage depressions. (A).

Keywords : landslides; logging practices and effects; clear-cutting; mass movement

137. Furniss, M.J.; Roelofs, Terry D.; Yee, Carlton S. 1991. Road construction and maintenance. In: Meehan,W.R., ed. Influences of forest and rangeland management. Special Pub. 19.Bethesda, MD: American Fisheries Society: 297-324. Chapter 8.

Sediment generated by road construction reaches streams through surface erosion and mass movements of destabilized soil, and the effects can be dramatic and long-lasting. Thorough reconnaissance, good planning, and wise route selection are the keys to minimizing the impacts of roads on streams; ad hoc protective steps taken during or after construction are much less effective. After the route is selected, measures to reduce erosion can be incorporated into the road design. Excavations should be minimized. Cut-and-fill slopes should be stabilized with vegetation or artificial structures. Bridges and drainage structures such as culverts should be properly placed and appropriately sized to accommodate runoff and fish passage. The timing of construction with respect to seasonal watershed dynamics can be especially critical. Completed roads should be kept in good condition with an active maintenance program. (Meehan).

Keywords : road construction effects; road maintenance; sedimentation; watershed disturbance; culvert fish passage; rangeland

138. Gabr, M.A.; Brizendine, A.L.; Taylor, H.M. 1995. Comparison between finite element study and simplified analysis of levee underseepage. Tech. Rep. GL-95-11. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station. 46 p.

The computer programs for levee underseepage analyses-LEVEEMSU (finite difference), LEVSEEP (closed form), and SEEP (finite element)-were used to analyze a levee and foundation section described in this report. Results presented in this study illustrate the effect of variations in the ratio of permeability of the foundation to the permeability of the blanket (I%) on the flow predictions, the influence of introducing anisotropic conditions on flow domain, arid variation in the predicted hydraulic gradients in relation to the analysis method. Analysis results are reported in terms of landside exit hydraulic gradients and permeability ratios.

Keywords : modeling; groundwater and subsurface flow

139. Gardner, R.B. 1979. Some environmental and economic effects of alternative forest road designs. Transactions of the American Society of Agricultural Engineers. 22(1):63-68.

Esthetic degradation and erosion constitute the major environmental impacts of forest roads. Recent observations from an experimental road in Montana showed that impacts are strongly related to road cross section width: cut slope, road surface and fill slope, and the attendant clearing. To reduce impacts, a single-lane road was constructed to carry all traffic, including log hauling. Hauling was simulated for 3 other road standards and compared with the experimental road. In this instance, where 6, 787 cu m (1.5-million board feet) of timber was harvested, the single-lane road was probably the best choice. (Sims-ISWS).

Keywords : cost and economics; road design and construction; erosion processes

140. General Accounting Office. 1992. Water pollution: EPA budget needs to place greater emphasis on controlling nonpoint source pollution. Washington, DC: General Accounting Office; Resources, Commuinity and Economic Development Division; GAOTRCED9246. 11 p.

Congress expanded the EPA's role somewhat through the 1987 amendments to the Clean Water Act--called the Water Quality Act of 1987-- but still left primary responsibility for controlling nonpoint source pollution with the states. Section 319 of the Clean Water Act, as added by the Water Quality Act, required states to assess the extent to which nonpoint sources cause water quality problems and develop management program plans for addressing these problems. EPA was charged with reviewing and approving these assessments and plans, and was authorized to provide grants to the states for implementing these management plans. (A).

Keywords : water quality; law and policy; Clean Water Act; non-point source pollution

141. Genskow, John R. 1995. Fish passage in urban streams. In: Domenica, Michael F., ed. Proceedings of the 22nd annual conference: Integrated water resources planning for the 21st century; 1995 May 7-11; Cambridge, MA. New York: American Society of Civil Engineers: 241-244.

This paper discusses fish passage criteria for culverts and how these criteria were applied to planning a culvert rehabilitation project along an urban creek. It also discusses how fisheries issues impact urban 'in-stream' drainage system maintenance and facility rehabilitation projects. (A).

Keywords : fish passage; fish; culvert fish passage; culvert design

142. Gibbons, David R.; Salo, E.O. 1973. An annotated bibliography of the effects of logging on fish of the western United States and Canada. Gen. Tech. Rep. PNW-10. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 145 p.

Comprehensive reference for general effects of logging on fish. (C).

Keywords : bibliography; logging practices and effects; fish habitat

143. Gilbert, G.K. 1917. Hydraulic-mining debris in the Sierra Nevada. USGS Prof. Pap. 105. Washington, D.C. U.S. Geological Survey. 154 p.

[This is] a historical outline of the development and consequences of hydraulic mining in the Sierra Nevada. The geographical effects of mining from the Sierra Nevada to the San Francisco Bay are examined. The erosional effects of roads in the Yuba River basin are briefly discussed. Wagon wheels and horse hoofs are identified in grinding soil into fines that are easily transported. Wheel ruts and side drains concentrates runoff, creating gullies that connect to streams. An average of 1 foot of soil was estimated to be lost from public roads and that 85% of that reached a stream. An estimated 1,600,000 cubic yards of erosion is associated with 920 miles of public road, 400,000 cubic yards for private, and 500,000 cubic yards for obsolete (abandoned) roads.

Keywords : mining

144. Godfrey, S.H.; Long, J.P. 1994. Temporary erosion control measures design guidelines for TxDOT. Research report 1379-1; FHWA/TX-95/1379-1. College Station, TX: Texas Transportation Institute, Texas A&M University System. 101 p. Sponsored by: Federal Highway Administration, Austin, TX, and Texas Department of Transportation, Austin, TX. [Springfield, VA: Available from the National Technical Information Service].

Land disturbing activities such as construction and maintenance operations within the highway rights-of-way are necessary to meet the demands for the traveling public and continuing movement of goods. Unfortunately, these activities are a major cause of erosion and resultant receiving waters pollution. To meet the stringent environmental requirements placed on agencies today designers need appropriate guidance on planning, designing, and selecting best management practices for construction (and maintenance) sites. This research study was initiated to develop design guidelines that would complement TxDOT's existing efforts and provide guidance for further erosion and sediment control research.

Keywords : erosion control structures; law and policy; road design and construction; sediment control

145. Gonsior, M.J.; Gardner, R.B. 1971. Investigation of slope failures in the Idaho batholith. Res. Pap. INT-97. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 34 p.

Precipitation events in the winter and spring of 1965 caused significant erosion and numerous landslides in many parts of the idaho batholith. Most slope failures were associated with roads. An investigation of several representative failures in the Zena creek sale area on the Payette national forest was conducted. Details of the field and laboratory tests are given, and 3 examples of the stability analyses are presented. Causes of the failures are discussed, and recommendations for future construction in similar terrain are made. (A).

Keywords : slope failures; granitic soil; landslides; road construction effects

146. Grant, W.H. 1988. Debris avalanches and the origin of first order streams. In: Swank, W.T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies 66. New York: SpringerVerIag: 103-110.

Debris avalanches and underlying joint systems are responsible for some first order streams. The sequence for development of a stream begins with a small depression at the subsoil intersection of bedrock joints. The depression accumulates groundwater. Chemical weathering proceeds faster in the depression, enhancing its water capacity. This process can continue indefinitely or be interrupted by a violent storm. An avalanche is initiated by hydraulic pressure through the watersaturated subsoil joint. At the storm peak, pressure is strong enough to break the adhesion between rock and watersaturated soil and saprolite. The water-inflated mass of rock and soil slides quickly down hill, leaving a chute which is the Iocus of a new first order stream. (A).

Keywords : debris flow and control; stream channel; hydrology

147. Gray, Donald H.; Leiser, Andrew T. 1982. Biotechnical slope protection and erosion control. New York: Van Nostrand Reinhold: 271 p.

Text on combined vegetative-structural slope protection, which entails the use of mechanical elements (or structures) in combination with biological elements (or plants) to arrest and prevent slope failures and erosion. Both biological and mechanical elements must function together in an integrated and complimentary manner. Principles of static and mechanics are used to analyze and design biotechnical slope protection systems; so too must principles of horticulture and plant science be employed. (authors, excerpt from introduction) Chapters on soil erosion and mass-movement, role of vegetation in the stability and protection of slopes, principles of biotechnical slope protection, structural-mechanical components of biotechnical slope protection, vegetative components and requirements, quasi-vegetative or hybrid slope protection techniques, check dams for gully control, and case histories. Appendices include standard designs and specifications for structural components. (C).

Keywords : case studies; erosion control; erosion processes; mass movement

148. Grayson, R.B.; Haydon, S.R.; Jayasuriya, M.D.A.; Finlayson, B.L. 1993. Water quality in mountain ash forests separating the impacts of roads from those of logging operations. Proceedings of an international symposium on forest hydrology; 1993 November 22-26; Canberra, Australia. In: Journal of Hydrology (Elsevier Science Publishers). 150(2-4): 457-480.

The purpose of the two catchment studies reported here was to allow the effects on water quality of road use and maintenance to be separated from the effects of a logging operation. In the first project, known as the Myrtle experiment, two small catchments in an old-growth mountain ash (Eucalyptus regnans) forest were chosen for a paired catchment study of the effects on physical and chemical water quality (baseflow and stormflow) of logging under a strict code of practice and with no roads crossing runoff producing areas. In the second project, known as the Road 11 experiment, the effect on sediment production from unsealed forest roads of vehicle use and level of road maintenance was assessed. The Myritle experiment showed that the harvesting and regeneration operation did not have a major impact on the stream physical or chemical water quality. Increases were detected in turbidity, iron and suspended solids at baseflows, but these were small in absolute terms and of similar magnitude to the measurement error. The stormflow data revealed no significant influence of the logging operation. The suspension of logging during wet weather, the protection of the runoff producing areas with buffer strips and the management of runoff from roads, snig tracks and log landing areas eliminated intrusion of contaminated runoff into the streams, thereby avoiding the adverse effects of logging. The Road 11 study determined that annual sediment production from forest roads was in the range of 50-90 t of sediment per hectare of road surface per year, with approximately two-thirds being suspended sediment and one-third coarse material. The use of gravel reduced sediment production, provided a sufficient depth of material was used. Increasing the level of road maintenance with increasing traffic load controlled sediment production rates, but when maintenance was not increased, sediment production increased by approximately 40%. The results indicate that by identifying the areas that produce runoff it is possible to prevent contaminated runoff reaching the streams. Roads, on the other hand, produce large quantities of sediment, even when well maintained, so careful consideration of their placement and management is paramount. (A).

Keywords : water quality; logging practices and effects; catchments; road maintenance

149. Greis, John G. 1979. Applying best management practices on Florida's forest lands. Southern Journal of Applied Forestry. 3(2):43-47.

In 1976 Florida's Department of Environmental Regulation appointed a Technical Advisory Committee to identify best management practices (BMP's) to prevent nonpoint pollution from forest management activities. The committee has completed an assessment of silviculture-related sediment production, which pointed to access roads as the most serious potential pollution hazard, and has developed a systematic technique of rating inherent site sensitivity to forest management activities. A public education program utilizing federal, state, and industrial resources end stressing voluntary compliance, is envisioned as the most effective means of attaining substantial compliance with the program (A).

Keywords : best management practices; non-point source pollution; forest management and practices; forest roads

150. Grimaldi, Carol. 1995. Improving culvert entrances to increase flow capacity. Field Notes. Washington, DC: U.S. Department of Agriculture, Forest Service, Engineering Technical Information System; 27(May-August): 15-33.

Keywords : hydraulics; culverts; hydraulic characteristics; culvert inlets

151. Groves, Franklin D.; Baughman, Ronald K.; Hundley, M.Eugene; Sherman, Roger L. 1979. Timber haul road construction in southern mountains. Southern Journal of Applied Forestry. 3(3):68-76.

Weyerhaeuser Company and Westvaco Corporation combine to discuss haul road construction in mountainous terrain of Arkansas and West Virginia. Road design, adoption of standards, construction techniques--these and other components are found to be equally important in building cost-effective roads that are environmentally acceptable. Costs range from $5,000 to $35,000 per mile of completed road, depending on steepness and difficulty of terrain (C).

Keywords : road design and construction; steep slopes and road grades; cost and economics

152. Hafley, W.L. 1975. Rural road systems as a source of sediment pollution--a case study. In: Proceedings of the watershed management symposium; 1975 August 11-13; Logan, UT. New York: American Society of Civil Engineers, Irrigation and Drainage Division: 393-405.

Keywords : sedimentation effects; road impacts; case studies; non-point source pollution

153. Hafterson, H.D. 1973. Dip design. Field Notes. Washington, DC: U.S. Department of Agriculture, Forest Service, Engineering Technical Information System; 5(10): 1-18.

Draining water from the surface of unpaved roads before it destroys the riding surface or accumulates sufficient energy to damage the adjacent watershed is a familiar problem to designers of mountain roads. Often, when a dip is doing a good hydraulic job, it becomes so arrogant that it bounces the vehicle hard enough to rap the head of anyone driving over it. This paper presents a dip design technique which simultaneously satisfies these conflicting hydraulic and traffic requirements. A theoretical treatment is presented to develop a thorough understanding of the

problem and to provide a basis for making the field measurements which are badly needed if this more rational design technique is to be used. So far. the technique has been used by basing the design on arbitrarily selected constants and has yielded results which are not too discouraging. It is hoped that this article will encourage readers to make the needed measurements and share their findings through the forum of FIELD NOTES. A wide cross section of opinion is needed, due to the somewhat subjective nature of the measurements. The problem on unpaved roads is to remove water from the road surface. This is difficult to do because traffic on muddy roads creates ruts which the water follows. Insloping or outsloping the road surface has been used with varying degrees of success, depending primarily on the rutting tendency of the road surface. Outsloping on soils which become slippery when wet has resulted in disfavor among road users who have slipped off the road. Various structures, such as open top culverts, do an excellent job when conditions are right but siltation and high maintenance costs are common. Dips in the road profile provide an obvious solution, but, unfortunately, good hydraulic characteristics don't necessarily coincide with good driveability. Most dip designs sacrifice driveability by being too abrupt and are often too shallow to effectively divert water for very long. Dips, when first constructed, divert water from the road easily, but as traffic uses the wet road, ruts are formed which cut through the top of the dip. Effectiveness is further reduced by the mud ridges formed by mud squeezing out of the rut as wheels pass through. These mud ridges in the bottom of the dip act as lateral dikes to prevent water from leaving the ruts. A 3-inch-deep rut with 3-inch-high ridges is enough to cause failure of a typical 6-inch-deep dip. Gravel surfacing through the dip may be the answer to rutting, but often requires expensive maintenance and does not prevent failure caused by reduction of freeboard as sediment accumulates in the bottom of the dip. The solution is to build the dip with enough freeboard so that the rutting action can't cut through and so that there is sufficient sediment storage space to last between maintenance periods. Recalling the head bumping that occurs even on some of the shallow dips makes it obvious that new criteria are needed if dips are to be further deepened (C).

Keywords : dips and waterbars; road design and construction; drainage structures; unpaved roads; surface drainage; road surface.

154. Hagans, D.K.; Weaver, W.E. 1987. Magnitude, cause and basin response to fluvial erosion, Redwood Creek Basin, northern California. In: Erosion and sedimentation in the Pacific Rim: Proceedings of an international symposium; 1987 August 3-7; Corvallis, OR. IAHS Pub. 165. Washington, DC: International Association of Hydrological Sciences: 419-428.

Detailed erosion inventories and geomorphic mapping document the magnitude and causes of fluvial sediment production from hillslopes in the 197 sq km lower Redwood Creek basin. Sediment production from various fluvial erosion processes (gully erosion , 37%; washed out stream crossings, 7%; and surface erosion from bare soil areas, 4%) is nearly equal in volume to material derived from mass movement processes (52%). The leading cause of gully erosion is the diversion of streamflow at logging road and skid trail stream crossings. A simple predictive methodology, based principally on road gradient, successfully identifies stream crossings with a high potential for stream diversion (DP). Undersized culverts, infrequent culvert maintenance and the occurrence of high DP stream crossings have combined with infrequent, severe winter storms to trigger widespread gully erosion. Long-term effects of fluvial erosion include increased hillslope drainage density, enlarged stream channels and downstream effects including bank erosion and decreased pool frequency (A).

Keywords : erosion processes; basins; sedimentation; skid trail; mass movement

155. Hagans, D.K.; Weaver, W.E.; Madej, M.A. 1986. Long term on-site and off-site effects of logging and erosion in the Redwood Creek Basin, northern California. In: Technical Bulletin 409. New York: National Council of the Paper Industry for Air and Stream Improvement: 38-66.

Keywords : logging practices and effects; erosion control; basins

156. Hammer, R.G. 1989. Forest headwaters riparian road construction and timber harvest guidelines to control sediment. In: Woessner, W.W., and Potts, D.F., eds., American Water Resources Association symposium proceedings on headwaters hydrology; 1989 June 26-30; Missoula, MT. American Water Resources Association Technical Publication Series TPS-89-1. Herndon, VA: American Water Resources Association: 127-132.

Harvest of forests on steep mountainous terrain with tractor and cable logging systems requires many miles of road construction. Road construction produces much more sediment than does the timber harvest operation itself. Two major principles to control this forest headwaters sediment are to minimize sediment from the construction and to maintain woody debris stream structures such as log steps, which store sediment. Studies have indicated that slash filter windrows can trap 75% or more of road sediment at low cost. Large woody debris materials to headwater streams form log steps, which store sediment, dissipate stream energy, and provide fish habitat (A). (1 drawing, 2 photos, 2 references).

Keywords : sediment control; riparian zone; road construction effects; timber harvest; steep slopes and road grades; forest management and practices

157. Hanan, Sam; Vaughn, Peter L. 1996. Salmon stream protection: utilization of erosion control devices on the Doe watershed restoration project Okanogan National Forest. In: Erosion control technology... bringing it home: Proceedings of conference XXVII; 1996 February 27-March 1; Seattle. Steamboat Springs, CO: International Erosion Control Association: 77-81.

In 1994, the Okanogan National Forest decided to reconstruct a portion of Forest Service Road 5100100, located above and parallel to Doe Creek. This portion of the road had a history of unstable cut slopes. In addition, the slopes below the road had suffered severe surface erosion caused by snow melt runoff and rain water. Discharged water from ditch relief culverts running under the road was also very severe. These eroding slopes were the source of a large amount of sedimentation in Doe Creek, a principal spawning area for Chinook Salmon. The single lane native surfaced road had a 0.3 meter drainage ditch running along the cut face side with relief culverts transporting water from the ditch under the road and discharging on the fill slope below. The fill slope below the road ranged from 45% to 75%, with silty and sandy soil and boulders scattered through out. The top 3 meters were without vegetation. The project was approximately 336 meters long. It consisted of removing the drainage ditch relief culverts, recontouring the cut slopes, and redirecting drainage ditch out flow to a shallow slope drainage area. Coir log barriers (Biologs) were installed, and small check dams were constructed in some of the narrow eroded channels on the slopes to trap sediment moving from the road towards Doe Creek. After the cut slopes were recontoured, they were seeded and covered with a layer of low velocity excelsior erosion control blankets which were then covered with high strength organic erosion control blankets made of 100% coir fiber (BonTerra CF7). This paper presents a comparison of the performance installation requirements and costs of the sediment trap and erosion control techniques (A).

Keywords : fish; fish habitat; stream pollution; erosion control structures; sediment control; ditch-relief culverts; watershed disturbance

158. Harden, C.P. 1992. Incorporating roads and footpaths in watershed-scale hydrologic and soil erosion models. Physical Geography. 13(4):368-385.

Hydrologic and soil erosion models, even distributed modes, require some degree of generalization of land surface characteristics. Because generalization typically depends on the areal extent of parameter values, surfaces that affect geomorphic/erosional processes out of proportion to their areal extent require special consideration. Increased erosion and sediment yield on roads and trails is frequently reported, but the interactive process relationships between such highly compacted and neighboring, loess compacted surfaces have received little research attention. This paper reviews watershed-scale modeling strategies and presents the results of rainfall simulation experiments conducted on paired path and non-path sites in highland Ecuador and East Tennessee. The results show rural roads and foot paths to be the most active runoff generating components of inhabited mountain landscapes and provide preliminary quantitative and qualitative bases for incorporating the runoff and erosion-initiating effects of rural roads and paths in watershed models (A).

Keywords : modeling; hydrologic analysis; rainfall simulation; watershed disturbance; trails; road impacts

159. Harenberg, W.A. 1980. Using channel geometry to estimate flood flows at ungaged sites in Idaho. Water resources investigations 80-32. Boise, ID: U.S. Department of the Interior, Geological Survey. 39 p.

Measurements at bankfull stage were made at 136 sites to determine whether predictions of flood discharges using channel-geometry characteristics are as good as or better than predictions using basin characteristics. These measurements are used to determine the variable of bankfull width, area, depth, and velocity. These variables are combined with basin characteristics for the sites, ad multiple-regression techniques are used to select the best combination of variables to estimate the selected floods. Generally, discharge estimates obtained from equations using channel characteristics have smaller standard errors than those using basin characteristics, and equations using both basin and channel characteristics have even lower standard errors. (A).

Keywords : flood estimation and control; channels; measurement methods and monitoring

160. Harr, R.Dennis. 1980. Streamflow after patch logging in small drainages within the Bull Run Watershed. Res. Pap. PNW-286. Portland, OR: U.S. Department of Agriculture, Forest Service. 16 p.

Three experimental watersheds in the City of Portland's Bull Run Municipal Watershed were used to determine effects of patch logging on timing and quantity of streamflow. Annual water yields and size of instantaneous peak flows were not significantly changed, but low flow decreased significantly after logging of two small watersheds in small, clearcut patches totaling 25 percent of each watershed's area. (A).

Keywords : logging practices and effects; streamflow; stream sediment

161. Harr, R.Dennis. 1981. Scheduling timber harvest to protect watershed values. In: Baumgartner, David M., comp., ed. Interior West watershed management: Proceedings of a symposium; 1980 April 8-10; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension: 269-280.

The USDA Forest Service is attempting to develop techniques for incorporating watershed values into the planning process described by the National Forest Management Act of 1976. A recent workshop on scheduling harvesting for soil and water concerns revealed several problems associated with the development of such techniques. These problems include: determining the effectiveness of harvest scheduling for protecting soil and water resources; distinguishing adverse effects caused by how and if an activity is done from effects caused by when it is done; and judging the reliability of predictions we can currently make on how harvest activities affect peak stream discharge and sediment routing. Procedures now used to estimate impacts of harvest activities on soil and water resources have weaknesses that limit their usefulness in scheduling harvest to protect soil and water resources (A).

Keywords : timber harvest; watershed disturbance; planning; law and policy; forest management and practices; logging practices and effects; timber; watershed

162. Harr, R.Dennis. 1993. Overview of sediment research on forest land in the Pacific Northwest. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 35-39.Sponsored by: Environmental Protection Agency and U.S. Department of Agriculture.

The effect of forest management activities on erosion has been researched frequently in the Pacific Northwest. This paper briefly summarizes sediment research conducted by the Pacific Northwest Research Station and universities in forested watersheds of Oregon and Washington and describes current research. The literature review is not exhaustive; references are cited only to illustrate the breadth and evolution of sediment research on forest land in the Pacific Northwest. Some research has examined only suspended sediment while other research has included inorganic material of any size transported by streams. In general, results of sediment research focusing on fish habitat and populations or other aspects of stream biology are not included here but appear elsewhere in these proceedings (A).

Keywords : sediment; erosion control; forest management and practices; research

163. Harr, R.Dennis; Fredrickson, R.L. 1988. Water quality after logging small watersheds within the Bull Run Watershed. Water Resources Bulletin. 24(1):1103-1111.

Keywords : watershed; water quality; logging practices and effects

164. Harr, R. Dennis; Nichols, Roger A. 1993. Stabilizing forest roads to help restore fish habitats: a northwest Washington example. Fisheries. 18(4):18-22.

As part of total watershed rehabilitation to improve fish habitats and water quality and to reduce flood hazards, 30--40-year-old, unused, largely impassable roads and landings in the Canyon Creek watershed within the North Fork Nooksack River watershed were decommissioned by stabilizing fills, removing stream crossings, recontouring slopes, and reestablishing drainage

patterns to reduce the landslide hazards. The average cost for decommissioning a road was $3,500 per kilometer (for earth moving by excavator and bulldozer) where considerable amounts of alder brush were cleared and sidecast material was pulled back upslope. Lower costs were associated with lesser earth moving jobs; the highest costs resulted when fills at stream crossings or landings had to be removed. In contrast to unused roads not treated, decommissioned roads and landings were largely undamaged by rain-on-snow runoff that produced a 50-year flood in the North Fork Nooksack River in November 1989 and sustained little damage during rain-on-snow runoff in November 1990 that severely damaged main haul roads in northwest Washington (A).

Keywords : forest roads; fish habitat; watershed; forest management and practices

165. Harrison, Penny H. 1986. The evolution of a new comprehensive plan for managing Columbia River anadromous fish. Environmental Law. 16(3):705-730.

Keywords : road design and construction; case studies

166. Hartsog, W.S.; Gonsior, M.J. 1973. Analysis of construction and initial performance of the China Glenn Road, Warren District, Payette National Forest. INT-5. Ogden, UT: U.S. Department of Agriculture Forest Service, Intermountain Forest and Range Experiment Station. 22 p.

The Idaho Batholith has a history of erosion and sedimentation problems associated with logging and road construction. These problems are particularly acute in areas sensitive to sedimentation. The South Fork of the Salmon River is such an area because it is a spawning and rearing stream for salmon and steelhead trout. Because of a history of watershed damage in the South Fork drainage, the China Glenn Road was the first to be built there for many years. This particular road project sparked unusual interest because it was to be constructed with a minimum amount of environmental impact. A Forest Service engineering research team analyzed the construction and initial performance of the China Glenn Road, Warren District, Payette National Forest, and reported its findings. (A).

Keywords : road design and construction; case studies

167. Hauge, C.J.; Furniss, M.J.; Euphrat, F.D. 1979. Forest practice rules and soil erosion in the Coast Forest District. In: A field trip to observe natural and management-related erosion in Franciscan terrain of northern California: a guidebook. Boulder, CO: Geological Society of America, Cordilleran Section: 1-18.

The Forest Practice Act calls for “soil erosion studies” to assess the relationship between timber harvesting operations and soil erosion. In 1975, the California Department of Forestry initiated an investigation of soil characteristics and erosion rates on California forest lands and an extensive literature review. Soil erosion data were collected on 101 randomly selected 1975 harvest sites in the Coast, Northern, and Southern Forest Districts representing a cross section of geology, relief, climate, and soils typical of the forested area of the State. Results from the soil erosion study and recommended erosion control practices are presented in this paper (C).

Keywords : forest management and practices; erosion control; land management

168. Haupt, H.F. 1959. Road and slope characteristics affecting sediment movement from logging roads. Journal of Forestry. 57(5):329-339.

The amount of erosion and sedimentation occurring below logging roads in steep granitic soil under ponderosa pine cover in southwestern Idaho was studied. Seven road and slope characteristics amenable to quantitative evaluation were studied, four of these were found to influence sediment flow distance significantly. They are slope obstruction index (Soi), cross ditch interval squared (Cdi2), embankment slope length (Esl), and the product of cross ditch interval and read eradient (Cdi Re). These characteristics were incorporated into an equation (Sfd = 1.2871 Soi and 0.0030 (Cdi2) + 3.4918 (Esi) and 0.0468 (Cdi + Rg) - 66.2395) which promises to be valuable in determining buffer strip width. Other factors studied were Road Width (Rw), Road Cut Height (Rch), and Lower Side Slope Gradient (Lssg) (A).

Keywords : sediment modeling; erosion processes; road erosion; steep slopes and road grades; granitic soil

169. Haupt, H.F. 1959. A method for controlling sediment from logging roads. Misc. Pub. No. 22. Ogden, UT: U.S. Department of Agriculture. 22 p.

Controlling sediment form logging roads on cutover ponderosa pine lands of southwestern Idaho is an acute problem. Such roads usually exist under unfavorable hydrologic conditions; often they are subjected to severe summer storms and spring snowmelt runoff. Furthermore they usually are located on steep slopes where they cut into highly erosive soils derived form acid igneous parent materials (primarily granite). This publication describes a method of protecting intervening slopes, other downhill roads, and stream channels from the damaging effects of sediment that originates primarily form roads higher on the slope, The method was developed from an understanding of the processes involved in erosion form roads and how these process operate after an area has been logged (A).

Keywords : sediment; erosion control; road design and construction; dips and waterbars

170. Haupt, H.F.; Kidd, W.J., Jr. 1965. Good logging practices reduce sedimentation in central Idaho. Journal of Forestry. 63(9):664-670.

Timber harvest from 16 small watersheds in the Boise Experimental Forest has been studied since 1953. The logging was completed in 1954. Sedimentation was checked reasonable well due to careful advance planning, close supervision of logging, and application of intensive erosion control measures. Sedimentation originated primarily on haul roads especially those roads near a stream. Buffer strips 30 feet of more wide effectively stopped sedimentation. Most other sedimentation stopped after three years (A).

Keywords : sedimentation; planning; erosion control; logging practices and effects

171. Haupt, H.F.; Rickard, H.C.; Finn, L.E. 1963. Effect of severe rainstorms on insloped and outsloped roads. Res. Note INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.

Three heavy rainstorms that produced from about 7.5 to 10.0 inches of rain in central Idaho in a 10-day period in October 1962, caused considerable damage to newly constructed logging roads. Insloping a roadbed under the time, topographic, soil, and storm conditions described is more desirable than outsloping as a measure for preventing erosion and damage to the roads (A).

Keywords : case studies; road erosion; insloping; outsloping; erosion control

172. Haussman, Richard F.; Pruett, Emerson W. 1973. Permanent logging roads for better woodlot management. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Northeastern Area. 45 p.

PREFACE: This handbook has been prepared to meet the need for proper directions in the construction and maintenance of a transportation system on a typical woodlot. It applies specifically to situations most commonly encountered in the Northeast and is designed to provide a set of principles for a generally applicable type of low-cost, low-speed road. Good judgment must, of course, be used in applying those principles because of the wide variety of topography, soils, climate, and other factors which prevail in different parts of the Northeast. CONTENTS: locating the road, basic considerations (grade, slopes, obstacles, distance from streams, stream crossings), method of locating road, equipment needed, the use of grade and slope stakes, construction (clearing, designs and standards, drainage, culverts, bridges general considerations, fords), maintenance (during the logging operation, after logging), rights-of-way, skidroads and skid trails (landing and skidroad location), bibliography (C).

Keywords : road design and construction; forest roads; best management practices

173. Haviland, J.E.; Bellair, P.J.; Morrell, V.D. 1967. Durability of corrugated metal culverts. Physical Res. Proj. 291, Res. Rep. 66-5. Albany, NY: New York State Department of Transportation, Bureau of Physical Research. 84 p.

To provide data on corrosion and abrasion rates for corrugated metal pipe, two surveys were conducted--one for steel culverts with two to 35 years of service, and another comparing aluminum and steel culverts installed for up to four years in similar environments. Uncoated steel culverts are performing satisfactorily, being unaffected by properties of normal soil and water, but with significantly greater durability when bituminous coated or coated/paved. Uncoated paved aluminum culverts are proving durable, indicating no need for such protection. Abrasion was found to be of minor influence. A statistical method for estimating metal loss, and a design procedure are presented. (A).

Keywords : culvert durability; corrugated metal pipe; corrosion; service life; culvert - aluminum; culvert survey; culvert abrasion

174. Hawkins, Richard H. 1975. The importance of accurate curve numbers in the estimation of storm runoff. Water Resources Bulletin. 11(5):887-891.

Storm runoff as calculated by the runoff curve number method is shown to be of varying sensitivity to both input rainfall and curve number. Using an assumed input error of 10%, a runoff error chart is chart is given. Up to about nine inches of rainfall, runoff is more sensitive to curve number than to rainfall. The importance of accurate curve number selection in this range is stressed. (A).

Keywords : hydrologic analysis; runoff

175. Hawks, Laurie J.; Cubbage, Frederick W.; Haney, Harry L.; Shaffer, Robert M.; Newman, David H. 1993. Forest water quality protection: a comparison of regulatory and voluntary programs. Journal of Forestry. 91(5):48-55.

Nonpoint-source pollution control has become increasingly important in efforts to protect water quality throughout the US. Many currently used silvicultural practices contribute greatly to these nonpoint-source pollution problems through activities such as timber harvesting, site preparation, and road construction. The benefits and disadvantages of voluntary and regulatory frameworks for reducing the nonpoint-source pollution impacts of silvicultural activities are examined. The programs adopted by Virginia and Maryland to improve the water quality of the Chesapeake Bay are detailed (A). (2 photos, 15 references, 4 tables).

Keywords : non-point source pollution; water quality; stream pollution; road construction effects; law and policy

176. Haydon, S.R.; Jayasuriya, M.D.A.; O'Shaughnessy, P.J. 1991. The effect of vehicle use and road maintenance on erosion from unsealed roads in forests: the Road 11 experiment. Rep. MMBW-W-0018. Melbourne, Victoria: Melbourne Water. 131 p.

This study examines the effect of vehicle use and road maintenance level on sediment production from unsurfaced roads in a forested catchment in the Melbourne Water District. Both coarse and suspended sediment levels were measured weekly, the first by using a flume and the second by taking a sample of the runoff water using a Coschocton proportional flow sampler. Results showed that high use and low maintenance produced approximately 35 t/ha/yr. of coarse sediment. That compares with low use - low maintenance South road (control) which, in the long-term, produced approximately 18 t/ha/yr. of coarse sediment. For the North road (treatment), the low use -low maintenance regime produced 30 t/ha/yr., lying between the two high use maintenance regimes. Suspended sediment production was of the order of 23 g/l under low use - low maintenance, ranging up to 35 to 40 g/l under high use - low maintenance. Under high use and high maintenance the suspended sediment rate dropped to 23 g/l (A).

Keywords : road maintenance; erosion processes; forest roads

177. Helvey, J.D. 1981. Flood frequency and culvert sizes needed for small watersheds in the central Appalachians. Gen. Tech. Rep. NE-62. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 7 p.

Streamflow data from nine forested watersheds from two general locations near Parsons, West Virginia; the Fernow Experimental Forest and the headwaters of Clover Run, are analyzed for peak discharge information. Changes in peak discharge associated with watershed treatments are investigated. Both the Gumble and Log Pearson Type III methods are used in the analysis and the results compared and evaluated. Culverts are then sized to carry the expected peak discharge for various drainage areas and computed flood frequency. Variables include channel slope, which determines stream velocity, inlet/outlet control, and expected life of the structure. Estimated culvert diameters (in inches) needed to carry flood water from forested areas ranging from 30 to 100 acres and at recurrence intervals of 5 to 50 years are given in tabular form.

Keywords : flood estimation and control; culvert design; watershed; discharge

178. Henderson, G.S.; Witthawatchutikul, P. 1984. The effect of road construction on sedimentation in a forest catchment at Rayong, Thailand. In: O'Loughlin, C.L.; Pearce, A.J., eds. Proceedings of the symposium on effects of forest land use on erosion and slope stability; 1984 May 7-11; Honolulu, HI. Honolulu, HI: International Union of Forestry Research Organizations: 253-274.

The extent to which road construction causes greatly increased sediment production in Huay Ma Feung stream was investigated in the rainy season of 1983. Storms produced simultaneous peaked suspended sediment and discharge hydrographs with maximum values at 28 000 mg/l and 1.46 m3/s, respectively. Bed load accounts for more than 80% of the total load of 10 494 t/km2. Sedimentological evidence and prevailing soil hydraulic properties indicate that the bulk of sediment originates from roadside gullies, slumps and landslides. (A).

Keywords : road construction effects; sedimentation; catchments; rainstorm; hydrograph

179. Hewlett, John D. 1964. Letter to the editor on article "Groundwater: Definition" by H.E. Thomas and L.B. Leopold. Science. 144(3625):1407-1408.

This letter questions the definition of groundwater used in the article.

Keywords : groundwater and subsurface flow

180. Hewlett, John D.; Patric, James H. 1963. A pilot test of multiple use on a small mountain watershed. In: Proceedings, 42nd annual meeting, Society of American Foresters; 1963 February 8-9; Greenville, SC. Charlottesville, VA: Society of American Foresters: 11-18.

A pilot test of the multiple-use concept on a 356-acre watershed at Coweeta Hydrologic Laboratory is presented. This report discusses that concept in terms of management of the area for water, timber, wildlife, and recreational values. A proper access system is cited as the key to effective resource management.

Keywords : watershed; land management; hydrology

181. Hicks, B.J.; Hall, J.D.; Bisson, P.A.; Sedell, J.R. 1991. Response of salmonids to habitat changes. In: Meehan,W.R., ed. Influences of forest and rangeland management. Special Pub. 19.Bethesda, MD: American Fisheries Society: 483-518. Chapter 8.

Diverse activities on forest and rangelands can affect salmonid habitats in broadly similar ways. The responses of salmonid populations to these changes, however, vary with species, life stage, season, and geographic location, complicating the management of fish resources in altered streams and lakes. For example, a summer temperature increase may enhance coho salmon production in a northern stream but depress it in a southern one. Adults often can avoid conditions that kill less-mobile young. Anadromous and resident populations may respond differently to a habitat change. Species that rear in fresh water may react one way to a perterbation, species that only spawn and incubate there another. These many differences mean that resource managers must be both knowledgeable about the populations in their care and flexible in their management prescriptions. (Meehan).

Keywords : aquatic life; fish; fish habitat; stream channel; stream pollution

182. Hill, J.M.; Singh, V.P.; Aminian, H. 1987. A computerized data base for flood prediction modeling. Water Resources Bulletin. 23(1):21-27.

A computerized geographic information system (GIS) was created in support of data requirements by a hydrologic model designed to predict the runoff hydrograph from ungaged basins. Some geomorphologic characteristics (i. e., channel lengths) were manually measured from topographic maps, while other parameters such as drainage area and number of channels of a specified order, land use, and soil type were digitized and manipulated through use of the GIS. The model required the generation of an integrated Soil Conservation Service (SCS) curve number for the entire basin. To this end, soil associations and land use (generated from analysis of Landsat satellite data) were merged in the GIS to acquire a map representing SCS runoff curve numbers. The volume of runoff obtained from the Watershed Hydrology Simulation (WAHS) model using this map was compared to the volume computed by hydrograph separation and found to be accurate within 19 percent error. To quantify the effect of changing land use on basin hydrology, the GIS was used to vary percentages from the drainage area from forest to bare soils. By changing the basin runoff curve numbers, significant changes in peak discharge were noted; however, the time to peak discharge remained essentially independent of change in area of land use. The GIS capability eliminated many of the more traditional manual phases of data input and manipulation, thereby allowing researchers to concentrate on the development and calibration of the model and the interpretation of presumably more accurate results. (A).

Keywords : flood estimation and control; modeling; geographical information systems

183. Hodgson, Gregor; Dixon, John A. 1989. Logging versus fisheries in the Philippines. Ecologist. 19(4):139-144.

Logging exposes soil to direct effects of wind and rain, but the major cause of soil erosion from tree-cutting is generally the road and skid-trail network necessary for log removal. This erosion causes sedimentation in streams and rivers, which in turn reduces marine life. Bacuit Bay in Palawan, Philippines was the subject of a one year study of the effect of a logging operation in a watershed on tourism and marine fisheries. While only 11% of the forest had been logged by the end of the study, resultant erosion had already caused significant increases of sediment transport and discharge into the bay, and dramatic damage to coral reefs and associated fisheries. The implications to “sustainable” logging are discussed. (3 diagrams, 1 photos, 37 references, 1 tables).

Keywords : logging practices and effects; fish; erosion processes; skid trail

184. Hohenstein, William G. 1987. Forestry and the Water Quality Act of 1987. Journal of Forestry. 85(5):5-8.

Summarizes the provisions of the Water Quality Act of 1987 that are pertinent to forestry activities. Describes nonpoint-source (NPS) and point-source water pollution. Describes the amendment of the Federal Water Pollution Control Act of 1972 with new sections 319 and 407. Section 319 requires each state to prepare detailed water-quality management plans that 1) identify bodies of water not in compliance with water quality standards (WQS) because of NPS pollution, 2) identify categories and individual nonpoint sources that violate standards and 3) describe ways to control NPS pollution. In preparing NPS management plans the states will specify the relationship between state WQS and best management practices (BMPs), and will establish the role of the EPA’s antidegradation requirements in the control of NPS pollution. A recent court ruling found that USDA Forest Service road construction would violate California’s state WQS’s and thus violate the

Clean Water Act. It was also ruled that WQS superseded the use of BMP's as the primary regulatory device. Section 407 requires the two permitting agencies involved in regulating log transfer facilities, the EPA and the US Army Corps of Engineers, to coordinate efforts and process a single permit. Foresters are urged to provide input to the state plans through the public comment requirements of the legislation. (C).

Keywords : law and policy; planning

185. Hoover, M.D. 1952. Water and timber management. Journal of Soil and Water Conservation. 7(1):75-78.

The water produced by forest land increases in importance as our water needs grow because the bulk of our high water yielding areas are forested. With an understanding of the relative values involved and good management, water and timber production are compatible. Too often, timber harvesting causes erosion which reduces the quality of water although logging can and should be done as to avoid damages to the water crop. There are methods for increasing water yields without risking flash floods or water quality but his is possible only on watershed with good soil conditions. Much of our forest land has been damaged by past agricultural use, grazing, fire, and careless logging. The first watershed need on these areas is improvement of infiltration and water storage capacity. The forester should recognize the need and the opportunity for better watershed management (A).

Keywords : water resources; natural resources; forest management and practices

186. Horta, Jose Carlos de O.S. 1991. Cross sections and pavement subdrainage of low-volume roads in Madagascar. Proceedings of the fifth international conference on low-volume roads; 1991 May 19-23; Raleigh, NC. In: Tranportation Research Record 1291. Washington, D.C. National Research Council, Transportation Research Board; 72-78.

Distress of poorly drained pavements typically takes the form of longitudinal settlements and cracks along shoulders (both shoulders of straight aligned stretches and the lower shoulder of super-elevated curves) and results from water penetrating the structural layers of the pavement system, flowing along the transverse and longitudinal grades, and saturating materials of lower areas. Water flowing in the pavement along the longitudinal gradient may feed perched water tables in pavement layers of low embankment sections. Seepage from the perched water tables into the shoulders and subgrade may originate edge slides. Pavement cross-section design should take into account the permeability of available natural materials as well as processed base materials. Adequate provision for prompt outflow of pavement water should be given except for impervious pavements that do not require to be drained and for pavements over pervious subgrades where efficient subdrainage is achieved by percolation to deep-water tables. A catalog containing eight standard pavement cross sections has been proposed for the Malagasy low-volume, bitumen-paved roads and the unit prices of 10 road construction and rehabilitation projects were used to derive comparative construction costs of the different standard cross sections (A).

Keywords : road drainage; drainage structures; pavement; surface drainage; infiltration; cost and economics

187. Hulsing, Harry. 1996. Measurement of peak discharge at dams by indirect methods. In: Techniques of water-resources investigations of the United States Geological Survey: book 3, applications of hydraulics. Washington, D.C. U.S. Government Printing Office: 1-29. Chapter A5.

This chapter describes procedures for measuring peak discharges using dams, weirs, and embankments. Field and office procedures limited to this method are described. Discharge coefficients and formulas are given for three general classes of weirs--sharp-crested, broad-crested, and round-crested--and for highway embankments and weirs of unusual shape. The effects of submergence are defined for most forms. (A).

Keywords : discharge; indirect measurement methods; streamflow; hydrologic analysis

188. Hursh, C.R. 1941. The geomorphic aspects of mudflows as a type of accelerated erosion in the southern Appalachians. Transactions of the American Geophysical Union. Part 2:253-254.

Under certain conditions, high infiltration rates and deep soils give rise to conditions which cause mudflows. After prolonged rainfall, the soil mass is surcharged with water; a major surface break, such as uprooting of large trees, may start mass movement. The nature of movement of the soil mass depends on the slope of the contact zone with stable material (C).

Keywords : debris flow and control; mass movement; infiltration; erosion processes

189. Hursh, C.R. 1944. Report of subcommittee on subsurface-flow. Transactions of the American Geophysical Union. Part 5:(Appendix B):743-746.

Literature on subsurface flow is reviewed, and the lack of records from suitable experimental watersheds is cited as a handicap in interpreting the nature of subsurface stormflow (C).

Keywords : groundwater and subsurface flow; hydrology; watershed

190. Hursh, C.R.; Fletcher, P.W. 1942. The soil profile as a natural reservoir. Proceedings of the Soil Science Society of America. vol 7: 480-486.

A 7-acre watershed was intensively instrumented with groundwater wells to test the concept that the soil profile has a measurable storage capacity and a regulating effect on ground-water discharge. Well elevations were correlated with measured discharge so that aquifer dimensions and porosity required for detention storage could be estimated. Three types of reservoir functions of the soil profile were recognized (C).

Keywords : soil profile; groundwater and subsurface flow; water resources

191. Hursh, C.R.; Grater, E.F. 1941. Separating storm-hydrographs from small drainage-areas into surface- and subsurface-flow. Transactions of the American Geophysical Union. Part 3:863-871.

This classic study of hydrographs from streams and ground-water wells demonstrates that hydrographs from forested catchments at Coweeta are comprised of channel precipitation and

various subsurface flow components rather than overland flow. In accounting for the stormflow volume, the authors describe five sources of stormwater. They also describe the process which became known 20 years later as the concept of variable source area (C).

Keywords : hydrologic analysis; hydrograph; groundwater and subsurface flow; surface water; catchments

192. James, J.M. 1993. Burial and infilling of a karst in Papua New Guinea by road erosion sediments. Environmental Geology (New York). 21(3):144-151.

The anthropogenic impact on karst in Papua New Guinea is briefly introduced and a specific case is presented detailing the effect of road erosion sediments on a small karst. The karst is in the perennially humid tropics and covered with primary rain forest. The road was placed high above the karst on steep friable rock and traverses several of its catchments. The changes to and the rate of burial of parts of the karst and the infilling of the caves are described. The karst drainage has altered, and there is increased water storage. The sediment build-up ceased in less than a year due to vegetation and stabilization of the road embankments. It is concluded that any construction within a catchment leading to a karst should be assessed as to its impact on the karst. (A) 13 refs.

Keywords : case studies; karst; road erosion; sediment; impact analysis; humid tropics; tropical forest

193. Jarrett, Robert D. 1990. Hydrologic and hydraulic research in mountain rivers. Water Resources Bulletin. 26(3):419-429.

Although our current (1990) knowledge of hydrologic and hydraulic processes is based on many years of study, there are river environments where these processes are complex and poorly understood. One of these environments is in mountainous areas, which cover about 25 percent of the United States. Use of conventional hydrologic and hydraulic techniques in mountain-river environments may produce erroneous results and interpretations in a wide spectrum of water-resources investigations. An ongoing U.S. Geological Survey research project is being conducted to improve the understanding of hydrologic and hydraulic process of mountainous areas and to improve the results of subsequent hydrologic investigations. Future hydrologic and hydraulic research needs in mountainous areas are identified (A).

Keywords : hydrologic analysis; hydraulics; steep slopes and road grades

194. Johnson, F.L.; Chang, F.F.M. 1984. Drainage of highway pavements. Centreville, VA: Tye Engineering, Inc.; circular; FHWATS84202, HEC12. 155 p. (Sponsored by: Federal Highway Administration, Office of Implementation, McLean, VA. Available at NTIS).

This edition of Hydraulic Engineering Circular No. 12 incorporates new design charts and procedures developed from laboratory tests of interception capacities and efficiencies of highway pavement drainage inlets. The text includes discussion of the effects of roadway geometry on pavement drainage; the philosophy of design frequency and design spread selection; storm runoff estimating methods; flow in gutters; pavement drainage inlets, factors affecting capacity and efficiency, and comparisons of interception capacity; median inlets; embankment inlets; and bridge deck inlets (C).

Keywords : drainage; pavement

195. Johnson, Peggy A.; McCuen, Richard H. 1989. Slit dam design for debris flow mitigation. Journal of Hydraulic Engineering. 115(9):1293-1296.

A slit dam is a special case of a baffle system. Slit dams are especially suited to control small volumes of debris that can damage or destroy small-watershed infrastructure, such as culverts. As residential development expands near canyon outlets where debris flows are common, as in many parts of southern California and Arizona, the need for engineering facilities to control debris damage increases. Slit dams need to be given greater consideration as a tool for limiting debris damage. Unfortunately, systematic procedures for designing slit dams, as well as selecting reasonable sites for their location, are not available. To overcome this problem, guidelines for the design and location of slit dams are presented here (A).

Keywords : debris flow and control; baffles; best management practices

196. Johnson, Peggy A.; McCuen, Richard H.; Hromadka, Theodore V. 1991. Magnitude and frequency of debris flows. Journal of Hydrology. 123(1-2):69-82.

The objective of this study was to develop a method that could be used to estimate the magnitude and frequency of debris flows. The data base for the study included 29 watersheds in the Los Angeles area, with drainage areas less than 3 square miles . Assuming a log-normal distribution, prediction equations for 2-, 5-, 10-, 25-, 50-, and 100-year return periods were developed as a function of relief ratio, hypsometric index, the interval between burns, and drainage area. Principal components and correlation analyses were used to select the predictor variables. Numerical optimization was used to calibrate the model. The prediction equations can be used to estimate the magnitude of debris flows for ungaged watersheds where estimates are required for debris basin and channel design, protection of culverts and roads, land use planning, and zoning and establishing insurance rates. (C) 17 Refs.

Keywords : debris flow and control; landslides; modeling; return period

197. Johnson, Peggy A.; Simon, Andrew. 1995. Reliability of bridge foundations in unstable alluvial channels. In: Espey, W.H., Combs, P.G., eds., Proceedings of the first international conference on water resources engineering; 1995 August 14-18; San Antonio, TX. New York: American Society of Civil Engineers: 1041-1045.

The reliability of bridge foundations under unstable channel conditions of channel bed degradation and bank widening, is quantified. This provides a basis for making decisions through simple ranking or risk analyses. This same technique can be applied to culverts and to highways to adjacent to unstable streams by changing the definition of failure (A). 5 refs.

Keywords : bridge design; channels; risk analysis and design

198. Johnson, R.C. 1993. Effects of forestry on suspended solids and bedload yields in the Balquhidder Catchments. Journal of Hydrology. 145:403-418.

Sediment monitoring was conducted for 8 yr. in the Balquhidder catchments in Scotland to investigate the effects of forestry practices on sediment loads to the catchments. Sediment samples were taken near the sources and at the catchment outfalls at two catchments that had been disturbed by ploughing, road use, and clear felling. Results indicated that clearfelling had

increased the sediment discharge from forest roads. Ploughing also increased the sediment load significantly. Catchment sediment loads were influenced by precipitation totals and its distribution throughout the study period. Largest sediment loads were produced in the catchment where clearfelling had been used (A). (2 graphs, 17 references, 4 tables).

Keywords : sediment; forest management and practices; catchments

199. Jones, J.A.; Grant, G.E. 1996. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. Water Resources Research. 32(4):959-974.

This study quantified long-term changes in streamflows associated with clear-cutting and road construction and examined alternative hydrologic mechanisms to explain stream hydrograph changes in the Cascades Range, western Oregon. We examined differences in paired peak discharges for 150 to 375 storm events for five basin pairs, using 34-year records from two pairs of 60-to-101-ha experimental basins in the H. J. Andrews Experimental Forest, and 50-to-55-year records from three pairs of adjacent basins ranging from 60 to 600 km2. Forest harvesting has increased peak discharges by as much as 50% in small basins and 100% in large basins over the last 50 years. These increases are attributable to changes both in flow routing due to roads and in water balance due to treatment effects and vegetation succession. (A).

Keywords : stream flow; roads; clearcutting

200. Kaczynski, Vic. 1995. Stream habitat surveys: a tool for stream enhancement. Restoration Manager Notes. 7-11.

Freshwater habitat in the Pacific Northwest suffered severe degradation due to poorly planned forest management practices in the past. Prior to 1972, there were no stream protection rules for forestry. Logging of riparian habitat was common. The environmental impacts of road construction were rarely considered as part of forest management plans. Heavy equipment often operated in stream beds. In addition, state and federal land-management agencies ordered logging companies to remove large fallen trees, logs, and root wads from streams and banks. This type of debris in streams provides essential habitat for fish. Large woody debris was removed from hundreds of miles of streams. Several recently conducted stream habitat surveys pointed out the problems associated with these activities. The Oregon Forest Industries Council initiated reparation activities to remediate some of the damage (A). (4 diagrams, 1 photos, 7 references).

Keywords : stream habitat surveys; forest management and practices; fish habitat; riparian zone

201. Kane, Douglas L.; Wellen, Paula M. 1985. A hydraulic evaluation of fish passage through roadway culverts in Alaska. FHWA/AK/RD-85/24. Fairbanks, AK: Alaska Department of Transportation and Public Facilities, Division of Planning and Programming. 244 p. (In cooperation with the Federal Highway Administration. Available: Springfield, VA: National Technical Information Service as stock no. PB91-193805INZ).

Keywords : fish; fish passage; culvert fish passage

202. Keller, Gordon. [Unpublished]. Low water crossings (Selection, design, and construction of low water crossings). 24p.

Types of low water crossings are enumerated and described. Tradeoffs among culverts, bridges, and fords are described. Determination of design flows, culvert design, Manning's equation, scour conditions, and riprap design are briefly discussed. Bridge site examination form (R5-7700-71, rev 7/75), nomographs for computing flood discharge in California, solution of Manning's equation, headwater depth for CMP culverts and arch culverts, and a chart for size of stone that will resist displacement for various velocities and side slopes are included. A section on soil filter design is also attached. (C).

Keywords : low water crossing; stream crossing

203. Ketcheson, G.L.; Megahan, Walter F. 1996. Sediment production and downslope sediment transport from forest roads in granitic watersheds. Res. Pap. INT-RP-486. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 11 p.

Keywords : road erosion; granitic soil; sediment modeling; forest roads

204. Khine, Moe. 1991. Standardization of culvert flow computations. In: Proceedings of the 1991 national conference on hydraulic engineering; 1991 July 29-August 2; Nashville, TN. New York: American Society of Civil Engineers: 109-114.

Culvert flow computations are generally computed by the Federal Highway Administration's (FHWA) nomographs or its HY8 computer program, the U.S. Army Corps of Engineers' (COE) HEC-2 computer program, and the U.S. Geological Survey's (USGS) culvert program. However, the USGS culvert program is not as widely known as HY8 or HEC-2 programs. FHWA nomographs are also applied in the Soil Conservation Service's WSP2 computer program and FHWA-USGS WSPRO computer program. This paper examines the ability of the programs to analyze different types of flow through the culvert when the inlet is submerged. Although the USGS culvert program can analyze all types of flow, the decision to choose the proper type of flow is left to the user. However, HEC-2 and HY8 programs do not have an option to analyze for full flow with free outlet condition (USGS type 6 flow). This paper presents a procedure to select consistent type of flow through culverts. The differences in results among the present computer programs and suggested procedure can best be illustrated by an example (A). 4 Refs.

Keywords : modeling; culvert analysis

205. Kidd, W.J., Jr. 1963. Soil erosion control structures on skid trails. Res. Pap. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.

Proper treatment of bared skid trails after logging reduces the hazard of potential erosion. Commonly, treatment consists of construction retention structures from logging debris or diversions by using hand shovel or bulldozer. Objectives of this study were; (1) to determine the optimum spacing distances between manmade structures for preventing excessive rilling, and (2) to determine which of several structures or diversions provides the most effective controlled disposal of sediment-laden water that originates on skid trails. Erosion measurements on 569 intervals of 105 logging skid trails revealed the following: (1) erosion is greater and rate of healing is slower on

soil derived form granite than on soil from basalt; (2) more soil is eroded form skid trails unavoidably located in ravine bottoms than from trails on sidehills; (3) control structures that divert water off the skid trail onto undisturbed forest floors are superior to those that only retard water movement and filter out sediment along the skid trail; (4) any increase in spacing between control structures is accompanied by increase in soil movement; and (5) optimum spacing between erosion control structures depends upon the percent of slope, whether location of the skid trail is on a sidehill or in a ravine, and the soil parent material (A).

Keywords : skid trail; erosion control structures

206. Kidd, W.J., Jr.; Haupt, H.F. 1968. Effects of seedbed treatment on grass establishment on logging roadbeds in central Idaho. Res. Pap. INT-53. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 9 p.

Soils derived from the granite of the Idaho Batholigh of central Idaho erode rapidly when disturbed or bared by man's activities. Thus, logging roads needed to develop the timber resource necessary expose a large area of unstable soil to damage by erosion. As a remedial practice, the bared areas are sown with perennial grasses that develop deep, fibrous root systems capable of binding and holding the soil, and that also provide litter cover and protect the soil from raindrop splash. This paper presents the findings of a reseeding study designed to determine (a) whether scarifying a hard-packed roadbed, either before or after broadcasting seed, leads to establishment of a better stand of grass than one grown on an untreated roadbed, and (b) whether a wood-chip mulch, with or without fertilizer, further encourages the growth of grass, A secondary objective was an evaluation of the survival of five well-known perennial grass species growing on an extremely harsh site--the bare surface of a logging road (A).

Keywords : road grass seeding; road construction materials; erosion control

207. Kidd, W.J., Jr.; Kochenderfer, J.N. 1973. Soil constraints on logging road construction on steep land east and west. Journal of Forestry. 71(5):284-286.

The most permanent type of logging disturbance results from road building. Research has frequently found that erosion is not due to the amount of timber cut but is affected by the care taken in logging. Different soil types erode at different rates and must be managed differently, or with more care, especially in steeper lands. Various road location and construction ideas are discussed (A).

Keywords : road construction materials; logging practices and effects; steep slopes and road grades; soil properties

208. King, J.G. 1979. Fillslope erosion from forest roads: Proceedings, 34th meeting; 1979 October 3-5; Boise, ID. Pap. 79-404. St. Joseph, MI: American Society of Agricultural Engineers. -11 p.

Keywords: fill slope; erosion control, forest roads

209. King, J.G.; Tennyson, L.C. 1984. Alteration of streamflow characteristics following road construction in north central Idaho. Water Resources Research. 20(8):1159-1163.

Effects of logging access roads on seven streamflow variables were monitored on six forested headwater watersheds in north central Idaho. The streamflow variables were: annual maximum streamflow; date of maximum streamflow; annual minimum streamflow; annual water yield; and streamflow equaled or exceeded 5% of the year, 25% of the year, and 75% of the year. The watersheds, ranging in area from 28.3 to 147.7 ha, had less than 5% of their area in roads. Two statistically significant (alpha = 0.05) changes occurred following road construction: an increase in the 25% exceedance flows in one watershed and a decrease in the 5% exceedance flows in another watershed. No significant changes were detected in other flow parameters on any of the watersheds. The results indicate that the hydrologic behavior of small forested watersheds may be altered when only a small area is disturbed by roads. (A).

Keywords : road construction effects; streamflow; watershed disturbance; road impacts

210. Kochenderfer, J.N. 1970. Erosion control on logging roads in the Appalachians. Res. Pap. NE-158. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeast Forest Experimental Station. 28 p.

Practical methods of controlling erosion on logging roads are summarized through the different stages--planning, location, drainage, maintenance, and care after logging. The material was derived from existing literature, road lore, contact with experienced land managers, and personal experience. (Kochenderfer-forest service).

Keywords : erosion control; road design and construction; best management practices; road location; drainage design

211. Kochenderfer, J.N. 1995. Using open-top pipe culverts to control surface water on steep road grades. Gen. Tech. Rep. NE-194. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 7 p.

An open-top culvert constructed from used pipe can effectively control surface water on steep sections of “minimum-standard” roads where broad-based dips are not recommended. Open-top pipe culverts are resistant to damage and are relatively permanent. The cost of an open-top culvert is comparable to that of a graveled broad-based dip. (A).

Keywords : open channel; steep slopes and road grades; road design and construction; surface drainage

212. Kochenderfer, J.N.; Helvey, J.D. 1984. Soil losses from a “minimum-standard” truck road constructed in the Appalachians. In: Peters, Penn A.; Luchok, John, eds. Mountain logging symposium proceedings; 1984 June 5-7; Morgantown, WV. Morgantown, WV: West Virginia University: 215-225.

Soil losses from 11 road sections in the central Appalachians were measured. Nine of the sections were located on a newly constructed “minimum-standard” truck road and two were on a graveled higher standard road. Average annual soil losses on the “minim-standard” truck road ranged from 44 tons/acre for ungraveled road sections to 5 tons/acres for sections surfaced with 3-inch clean limestone gravel. Soil losses on the graveled sections of the “minimum-standard” road were similar to those measured on the higher standard road.

Keywords : soil erosion; road erosion; logging practices and effects; truck traffic; erosion control; gravel roads

213. Kochenderfer, J.N.; Helvey, J.D. 1987. Using gravel to reduce soil losses from minimum standard forest roads. Journal of Soil and Water Conservation. 42:46-50.

Soil losses were monitored for 4 years on 11 sections of forest road in the central Appalachians. The roads were used for both timber management and recreation. Nine road sections were located on a newly constructed, minimum standard truck road and two sections were on a graveled, higher standard road. Average annual soil losses ranged from 47 tons/acre on the ungraveled road sections to 6 tons/acre on the sections surfaced with 3 inches of clean limestone gravel. After the first year, traffic counts averaged 33/week on the minimum standard road and 60/week on the higher standard road. Soil losses on the gravel sections of the minimum standard road were similar to those measured on the higher standard roads.

Keywords : gravel roads; soil erosion; forest roads; soil conservation

214. Koepf, A.H.; Ryan, P.H. 1987. Abrasion resistance of aluminum culvert based on long-term field performance. Transportation Research Record. 1087:15-25.

Culvert pipes not only are placed to drain water but are required to carry bed load materials including rocks. The flow and energy characteristics of bed load materials and their effect on culvert pipes are not well understood. Analysis of mechanics can provide a format for comparing predicted characteristics with field experience data, and results confirm the validity of the assumptions. In 1968 an initial study was reported on 229 aluminum culverts that had been exposed to abrasion for four to seven years. That study proposed a form of energy level for bed load materials and rated the abrasion performance of aluminum culvert through a series of energy ratings. The energy level and abrasion predictions were compared with actual field experience. Long-term culvert abrasion can be predicted when culvert geometry, installation arrangement, and content of bed load materials are established. In 1984 and 1985 the field experience of the originally reported culvert group averaged 20 years of exposure to abrasion. In this paper are presented the results of the 1984-1985 study. The basic method of determining abrasion energy levels had been retained and simplified to emphasize key variables that affect abrasion. The 1985 study indicates that abrasion of aluminum culvert follows the patterns of the previous work. Long-life abrasion typically does not continue at a linear wastage rate but levels off to a much reduced rate, reflecting reductions in total energy as the flow channel stabilizes with age. Abrasion and service life for aluminum culvert inverts may predicted as a function of water flow, culvert entrance arrangement, culvert slope and rock content of streambed load. (A).

Keywords : culvert abrasion; culvert - aluminum; culvert installation; service life

215. Kohl, R.A.; Carlson, C.G.; Wangemann, S.G. 1994. Herbicide leaching potential through road ditches in thin soils over an outwash aquifer. Applied Engineering in Agriculture. 10(4):497-503.

Shallow glacial outwash aquifers provide water to farms, towns, and major cities. The fact that overlying soils are shallow and provide little protection from leachable chemicals suggests the need for careful management of chemical use. This research was conducted to provide data on the leaching potential of 2,4-D and picloram applied to road ditches over shallow aquifers. A comparison of soil profiles in the ditch and adjoining field indicated that an average of 0.3 m (1 ft) of soil was removed from road ditch soils, leaving very shallow soil profiles over the aquifer material. Cumulative infiltration of water into side slopes and ditch bottoms was measured on representative soils together with gravel road runoff to determine a water balance for the ditch.

Undisturbed soil columns were brought into a greenhouse where leaching water could be collected and analyzed for the herbicides, 2,4-D and picloram, the currently used herbicides, which had been applied at recommended rates. The combination of extra leaching water from road runoff added to direct rainfall, and the naturally shallow soils that have been reduced in depth to build the roadbed resulted in two to five times the water passing through to groundwater than through adjoining fields. From 2 to 33% of the applied herbicides came through the undisturbed soil columns after the first storm event. The results indicate that caution should be exercised if the choice is made to use chemical methods of weed control in road ditches. (A) Refs.

Keywords : groundwater and subsurface flow; pollution; drainage; ditches; stream pollution

216. Kohler, M.A.; Nordenson, T.J.; Baker, D.R. 1959. Evaporation maps for the United States. Tech. Pap. 37. Washington, DC: U.S. Department of Commerce, Weather Bureau. 13 p.

Five maps are presented for the continental United States; average annual Class A pan evaporation, average annual lake evaporation, average annual class A pan coefficient, average May-October evaporation in percent of annual, and standard deviation of annual Class A pan evaporation. Development techniques, pertinent formulae, interpretation, use and limitations are given for each map.

Keywords : hydrologic analysis

217. Koski, K.V. 1992. Riparian zone functions and interactions with sediment. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 61-69. Sponsored by: Environmental Protection Agency and U.S. Department of Agriculture.

The complexities of sediment and stream ecosystems make communicating about sediment processes and interactions with water quality and biota difficult. Sediment, a byproduct of silviculture activities, should be examined in context with other factors and activities in the watershed. Researchers must “think like a watershed” to actively prevent sediment pollution. This paper shows how the riparian zone through its many functions (e.g., filter strip, woody debris, streambank, and stream channel stability), can serve as a management surrogate to prevent or minimize sediment pollution. The paper’s focus in on Alaska and the Pacific Northwest; however, its information and concepts are pertinent to stream systems throughout the country.

Keywords : riparian zone; stream channel; sedimentation

218. Kostadinov, Stanimir. 1996. Check dams in the torrent control practice in Serbia: former and present experiences and future perspectives. In: Erosion control technology... bringing it home: Proceedings of conference XXVII; 1996 February 27-March 1; Seattle. Steamboat Springs, CO: International Erosion Control Association: 509-522.

The systematic work on torrent control started in Serbia in the beginning of the Twentieth Century. At that time controls were carried out for protection of the railroad Belgrade-Skoplje (Former Yugoslav Republic of Macedonia)-Athens. Later the volume of works of torrent control intensified, and were the most intensive following the Second World War up to the late seventies of this century. Check dams are the basic type of structures which are applied in the torrent control practice. In the beginning the classical check dams, gravity check dams (rectilinear) and arch

check dams, were applied. In this paper an analysis of the former and present application and effects of the check dams for torrent control in Serbia is given, based upon long-term in situ research and analyses of the state of the check dams which already have been built. Based upon these analyses, a projection is given of the application of check dams in the future, bearing in mind the new requirements, reflected in the strategy of torrent control known as “Bedload Management.”.

Keywords : check dams; debris flow and control; best management practices

219. Krammes, J.S.; Burns, D.M. 1973. Road construction on Caspar Creek watersheds: ten year report on impact. Res. Pap. PSW-93. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 10p.

This paper summarizes data from 10 years of streamflow calibration and 4 years of recording effects of road construction and use in the North and South Forks of Caspar Creek in northern California. Generally, the immediate impact of right-of-way clearing, road building, and bridge construction was best reflected in the suspended sediment yield which, in the first winter was more than four times the preconstruction levels; subsequent winter levels, while above preconstruction, were not excessive. Water temperatures were raised slightly, increasing the production of bacteria, algae, and the insects upon which fish feed. Dissolved oxygen concentrations were not adversely affected by construction activities or by removal of stream-side vegetative cover. Young-of-the-year fish populations decreased immediately after road construction. The combined populations of steelhead and salmon smolts decreased 20 percent, but this decline is estimated to be within the range of natural fluctuation reported for other California streams (C).

Keywords : road construction effects; watershed disturbance

220. Kuczera, George. 1982. Robust flood frequency models. Water Resources Research. 18(2):315-324.

The concept of a robust model is briefly explored. In the context of flood frequency analysis, two necessary properties of a robust model are advanced, namely, resistance and efficiency. Strategies for seeking more robust models are discussed. Because of its versatility, the five-parameter Wakeby distribution can credibly be considered a parent flood distribution. Four regionalized Wakeby parents are employed in simulation studies to search for robust models. These parents were shown by Houghten to be representative of U.S. flood experience in the sense that certain raw flood data characteristics could be represented. A limited range of sampling experiments were undertaken. The results suggest that of the site-specific estimators considered, the two-parameter log normal maximum likelihood estimator is most resistant, with Gumble estimators employing either maximum likelihood or probability-weighted moments displaying comparable resistance. Several estimators which utilize regional flood information were compared. Included were empirical Bayes estimators which are structurally similar to James-Stein rules and regionalized estimators based on the flood index method. These estimators exhibited substantial improvements in aggregate risk performance over their site-specific counterparts, particularly for short record lengths. Regionalized estimators appear to be preferable for short record lengths, while estimators which combine both site and regional flood information are preferable for longer record lengths. When such estimation procedures are considered, other distribution models such as log Person Type III and Wakeby became practical alternatives to the two-parameter log normal model. (A).

Keywords : flood estimation and control; hydrologic analysis; modeling

221. Kumapley, N.K. 1987. Erosion of unsurfaced earth and gravel roads. In: Akinmusuru, J.O., Malomo, S.S., Mesida, E.A., eds. Proceedings of the ninth regional conference for Africa on soil mechanics and foundation engineering; 1987 September 15-18; Lagos, Nigeria. Boston, MA: A. A. Balkema: 397-404.

The erosion of unpaved earth and gravel roads is one of the principal causes of failure of unsurfaced rural access roads, yet the phenomenon is scarcely even mentioned in the technical literature, Discussions relating to soil erosion are almost exclusively restricted to the prevention of soil erosion on cut and fill slopes, unsurfaced road shoulders and unlined drainage ditches. The paper discusses some of the principal factors which influence soil erosion by water, describes the problem of unsurfaced roadbed erosion in a region of crucial economic importance to Ghana and concludes the that the problem of unsurfaced roadbed erosion ought to engage the attention of highway engineers in Africa to a higher degree than it does at present (A).

Keywords : gravel roads; road erosion; erosion processes

222. Kuntze, E. 1982. Northern Elbe culvert. Water Science Technology. 114:263-268.

The entire drainage system of Hamburg, Germany is being reorganized and renovated by the construction of large-diameter sewer pipes. Part of this scheme includes a culvert under the northern Elbe River. The problem is sedimentation of solid matter in a sewerage culvert in the presence of widely variable flows. The matching of the discharge cross section and the hydrograph curve of the discharge amount to assure minimal sedimentation could be achieved by a constantly changing profile geometry. The Elbe culvert will have an air cushion, created by pumping air into the culvert pipe between the bulkhead walls so that a large air pocket is formed over the entire length of the pipe. The discharge area can be varied by changing the air pocket, thus varying the flow speed and sedimentation rate. The Northern Elbe culvert will be opened for sewerage operation in the summer of 1981.

Keywords : drainage design; drainage; drainage crossing; culvert hydraulics

223. LaFayette, Russell A.; Pruitt, John R.; Zeedyk, William D. 1993. Riparian area enhancement through road management. In: Preserving our environment--the race is on: Proceedings of conference XXIV of the International Erosion Control Association; 1993 February 23-26; Indianapolis, IN. Steamboat Springs, CO: International Erosion Control Association: 355-368.

Traditional road location, design, construction, and maintenance have generally had adverse effects on riparian areas. Road locations, drainage methods, and maintenance practices have resulted in a net loss of both acreage and related values in riparian areas, particularly in the arid and semi-arid portions of the West. Results of these activities include drainage of riparian ecosystems, reduced site productivity, loss of fish and wildlife habitat, reduced based flows with increased peak flows, gully development, and accelerated downstream sedimentation. Recent changes in management philosophy and activities are reversing this trend by using road design and maintenance to rehabilitate riparian areas and restore their productivity. Methods being used to accomplish these goals include road obliteration, road relocation, modified culvert designs, raised culvert inlets, modified bridge and ford designs, flow dispersal, stilling basins, and more frequent and effective ditch management. Results have been dramatic, with nearly 405 hectares (1000 acres) of degraded riparian area in the USDA Forest Service Southwestern Region started on the

road to recovery over the past five years. Transportation system management is becoming an effective tool in the rehabilitation of riparian areas across the Southwestern Region.

Keywords : road design and construction; road management; road location; riparian zone; impact analysis; water resources

224. Lane, E.W.; Lei, Kai. 1949. Stream flow variability. Transactions of the American Society of Civil Engineers. 2418:1084-1134.

An index of stream flow variability is suggested, in the form of the standard deviation of the logarithm of the stream discharge. The method of determining the index is described and the values from the flow records of a large number of streams in the eastern part of the United States were obtained. The possibilities of using this index in estimating the duration curve of the stream flow, where flow records are short or nonexistent, is indicated. A study of the indexes, together with the conditions of the respective watersheds, demonstrated that in the northeastern quarter of the United States the geology (including soil cover) and the presence of lakes and swamps are the most important factors in stream flow variability during the greater part of the time and that the other factors have relatively smaller effect. This paper is a condensation of a more detailed paper, a copy of which is deposited in the Engineering Societies Library where it maybe examined, or from which copies or microfilms may be secured. (A).

Keywords : streamflow; discharge; surface water

225. Larse, R.W. 1971. Prevention and control of erosion and stream sedimentation from forest roads. In: Morris, J., ed. Proceedings of a symposium: Forest land uses and stream environment; 1970 October 19-21; Corvallis, OR. Corvallis, OR: Oregon State University, Continuing Education Publications: 76-83.

To minimize erosion and resultant stream sedimentation, prevention and control measures must be given consideration in every aspect of road planning, design, construction and maintenance. In mountainous terrain the forest land manager must establish specific objectives and prescriptions to guide road network construction and utilize the combined professional skills of the forester, engineer, geologist, biologist, and others to set standards for the protection of watershed values, identify alternatives, and offer solutions to specific problems. The decision to road an area should only be made after the resource-serving benefits have been carefully weighed against the cost and effect of roading on the watershed, The decision not-to-road and to accept other alternatives for land-use management must be strongly considered when the probability of lasting damage to soil, water, and other ecological values is recognized (A).

Keywords : erosion control; stream sediment; sedimentation; forest roads

226. Leaf, C.F. 1974. A model for predicting erosion and sediment yield from secondary forest road construction. Res. Note RM-274. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.

One of the more visible and controversial environmental impacts associated with timber harvesting and development in central Colorado is road construction. Better tools are needed to

quantify the effect of soil disturbance on erosion onsite, and the subsequent yield of sediment downstream. This note summarizes available data and proposes a preliminary model for predicting an index of onsite erosion and downstream sediment yield. (witt-ipc).

Keywords : erosion processes; sediment modeling; erosion control; road construction effects

227. Lee, K.W.; Kapple, G.W.; Dawdy, D.R. 1975. Rainfall-runoff relation for Redwood Creek, above Orick, California. Menlo Park, CA: U.S. Geological Survey; open-file report. 14 p.

A digital computer was used to calibrate a model for synthesizing daily runoff for two periods, one in the late 1950's before intensive logging began and another in the late 1960's and early 1970's after intensive logging had been started, in the Redwood Creek basin on the northern California coast. The calibrated models were used with the daily rainfall records for these two periods to provide estimates of synthetic daily runoff records. The synthetic and observed runoff data were compared for each record. These comparisons indicate the runoff increased about 20 percent as a result of changes in hydrology and not climatic changes. (A).

Keywords : runoff; hydrologic analysis; modeling

228. Leutheusser, Hans J.; Drossis, John. 1987. Experiments on culvert flow. In: Hydraulic engineering: Proceedings of the 1987 national conference; 1987 August 3-7; Williamsburg, VA. New York: American Society of Civil Engineers, Hydraulics Division: 159-164.

Laboratory experiments are described which were performed on small-scale models of smooth circular culverts of length-to-diameter ratio varying between 13 and 52, and longitudinal downward slopes ranging from horizontal to 2. 50 percent. Results are presented on headwater requirements for culverts with a sharp-edged entrance and an unsubmerged outlet. (A) 3 refs.

Keywords : culvert hydraulics; hydraulics; experiment; flow capacity

229. Lewis, Gary , L. 1992. Jury verdict: frequency versus risk-based culvert design. Journal of Water Resources Planning and Management. 118(2):166-184.

A federal district court jury in Cheyenne, Wyoming, ruled that an Act-of-God defense could not be used when a railroad culvert backed water on to residential properties during a catastrophic '10,000-year' rainstorm. The culvert capacity not only met but exceeded industry design standards, yet the jury concluded that the railroad was negligent for not installing a structure large enough to accommodate the 'monster' storm. The 5-ft-diameter culvert, installed to replace a larger, deteriorating trestle, is sized by frequency-based methods to discharge the 50-year peak flow rate, with a nominal surcharge anticipated during the 100-year event. It is agreed by both sides that the selected structure could have safely passed more than a 500-year event, but is not able to discharge all the flows from the freak storm. Backwater ponded 9 ft over the top of the culvert, flooding more than 20 basements in one subdivision. The defendant is held liable for the damages and cited as negligent for not anticipating the storm and for failing to consider the risks to the homeowners. Under court order, a large structure is installed. This paper is a review of several matters debated during the trial and in subsequent analyses, presented as a case study from the

writer's perspective. The writer participated as an expert witness who performed the analysis for the defense, but was called to the stand as a witness for the plaintiff. The jury verdict was in favor of the plaintiff. Implications for improvements in drainage design and expert testimony are discussed. (A) 10 Refs.

Keywords : risk analysis and design; flood estimation and control; rainstorm; culvert design

230. Lewis, J.; Rice, Raymond M. 1990. Estimating erosion risk on forest lands using improved methods of discriminant analysis. Water Resources Research. 26(8):1721-1733.

Excess erosion from logging and forest roads has long been of concern to forest managers and the general public. Studies in California concluded that the key to reducing erosion from logged areas was to identify critical sites yielding at least 189 cu m/ha; this led to a definition of a critical site as any 0.81 ha acre area enclosing more than 153 cu m of erosional voids. A population of 638 timber harvest areas in northwestern California was sampled for data related to the occurrence of critical amounts of erosion. Separate analyses were done for forest roads and logged areas. Linear discriminant functions were computed in each analysis to contrast site conditions at critical plots with randomly selected controls. Bootstrapping was used extensively in the development and testing of the equations, in estimating prediction bias, and in placing confidence limits around parameters and posterior probabilities. The resulting three-variable equations had classification accuracy, corrected for prediction bias, of 77.7% for road plots and 69.2% for logged area plots. The variables appear to be expressing three important site conditions related to erosion risk: (1) instability-promoting effects of gravity (slope steepness), (2) the convergence of subsurface water, and (3) strength of materials (parent rock strength). The use of linear discriminant functions facilitates the explicit consideration of erosion risk when planning land-disturbing activities. None of the steps required for the utilization of the equations are particularly difficult, but they do require a more rigorous approach to erosion risk analysis. (Tappert-PTT).

Keywords : erosion control; risk analysis and design; forest roads

231. Limerinos, J.T. 1969. Determination of the Manning coefficient from measured bed roughness in natural channels. Menlo Park, CA: U.S. Geological Survey; open-file report. 78 p.

This report presents the results of a study to test the hypothesis that basic values of the Manning roughness coefficient of stream channels may be related to (1) some characteristics size of the streambed particles and (2) the distribution of particle size. These two elements involving particle size can be combined into a single element by weighting characteristic particle sizes. The investigation was confined to channels with coarse bed materials to avoid the complication of bed-form roughness that is associated with alluvial channels composed of fine bed materials. Fifty current-meter measurements of discharge and appropriate field surveys were made at 11 sites on California streams for the purpose of computing the roughness coefficient, n, by the Manning formula. The test sites were selected to give a wide range in average size of bed material, and the discharges and surveys were made at such times as to provide data covering a suitable range in stream depth. The characteristic bed-particle sizes used in the analyses were the 16-, 50-, and 84-percentile sizes as obtained from a cumulative frequency distribution of the diameters of randomly samples surficial bed material. Separate distributions were computed for the minimum and intermediate values of the three diameters of a particle. The minimum diameters of the streambed particles were used in the study because a particle at rest on the bed invariably had its minimum diameter in the vertical position; this diameter is, therefore the most representative

measure of roughness height. In analyzing the field data, the roughness parameter, n/R1/6, (where R is the hydraulic radius), was related to relative smoothness, R/d, (where d is a characteristics, or weighted characteristic, particle size). The relations best fitting the field data for this study were obtained by using either a characteristic particle diameter equal to the 84-percentile size, or a diameter obtained by weighting three characteristic particle sizes. The results are similar in that they all show an inverse relation between the roughness parameter and relative smoothness, but there is a variation in the form of the relationship. (A).

Keywords: Manning's formula; stream channel

232. Long, Michael T. 1991. Exploration, design, and construction of horizontal drain systems. In: Transportation Research Record 1291. 166

Horizontal drain systems for landslides correction have historically been installed with varying degrees of success. This variability of success has also been apparent in preconstruction exploration, engineering design, and construction and postconstruction monitoring. The USDA Forest Service, Region 6 (Pacific Northwest Region), has accomplished a number of successful horizontal drain projects in the past 5 years. As a result, a system-and-method approach has been developed, along with several low-cost alternative technology tools, for completing the work. This paper is not intended to be an inclusive discussion of all methods, nor an in-depth summary of quantitative detail, but rather a summary and guide to the project approach and a supplement to the current body of literature on horizontal drain systems.

Keywords : drainage design; landslides; drainage

233. Loomis, John B. 1989. A bioeconomic approach to estimating the economic effects of watershed disturbance on recreational and commercial fisheries. Journal of Soil and Water Conservation. 44(1):83-88.

A bioeconomic approach was used to measure the change in value of recreational and commercial fisheries caused by timber harvesting and road building in two national forests. Hydrologic models were linked with fisheries models to predict the change in catchable fish populations due to watershed disturbances. For the Siuslaw National Forest, OR, clearcutting on 87,000 acres resulted in a loss of 84,000 salmon and 24,000 steelhead trout over the 30-year period examined. The economic value of these lost fish to commercial and recreational anglers is $2 million. For the Porcupine-Hyalite Wilderness area in Montana, results indicated a $3.5 million loss in the value of trout fishing over a 50-year period from timber harvesting. (1 graphs, 27 references, 2 tables).

Keywords : cost and economics; watershed disturbance; fish; watershed

234. Luce, Charles H.; Cundy, T.W. 1994. Parameter identification for a runoff model for forest roads. Water Resources Research. 30(4):1057-1070.

Rainfall simulation is a commonly used approach for studying runoff and erosion from forest roads, and a method is needed to estimate infiltration parameters from these experiments. We used two algorithms, the Simplex and Shuffled Complex Evolution, to estimate parameters for a physically based infiltration and overland flow model. Each algorithm was tested by estimation parameters for

92 field-measured hydrographs from forest roads. Nine of the field measured hydrographs allowed us to further test whether estimated parameters could be extended to other antecedent conditions and plot sizes. The results demonstrate (1) the physically based model is able to estimate hydrographs from forest roads, (2) the two algorithms find unique parameter sets in spite of an error surface that suggests identifiability problems between the hydraulic conductivity and pressure parameters, (3) the two algorithms converged to the same parameter values, and (4) that parameters estimated for one antecedent condition and plot size can be extended to others with reasonably small error.

Keywords : runoff; modeling; forest roads; rainfall simulation; infiltration

235. Lucier, Alan. 1993. Research to support Clean Water Act reauthorization. Journal of Forestry. 91(5):45.

Keywords : Clean Water Act; regulations

236. Lynch, James A.; Corbett, Edward S. 1990. Evaluation of best management practices for controlling nonpoint pollution from silvicultural operations. Water Resources Bulletin. 26(1):41-52.

Fifteen years of streamflow and water quality data were evaluated to determine the effectiveness of Best Management Practices (BMP's) in controlling nonpoint source pollution from an 110-acre commercial clearcut located in the Ridge and Valley Province of central Pennsylvania. The analyses addressed both short-and long-term changes in the physical and chemical properties and the hydrologic regime of the stream draining this 257-acre watershed. Overall, the BMP's employed on this commercial clearcut were very effective in preventing serious deterioration of stream quality as a result of forest harvesting. Although statistically significant increases in nitrate and potassium concentrations and temperature and turbidity levels were measured the first two years following harvesting, the increases were relatively small and, with the exception of turbidity, within drinking water standards. Nevertheless, such increases may violate EPA's anti-degradation policy. Nitrate and potassium concentrations and turbidity levels remained above pre-harvesting levels for as long as nine years following harvesting. Clearcutting also significantly increased water yield, which in turn initially lowered the concentrations of most solutes because of dilution. Increased water yields returned to pre-harvesting levels within four years as a result of rapid regrowth. The export of some ions increased; however, the increased export appeared to be insufficient to affect site fertility. Implementation of periodic post-harvest inspections of harvested areas, increasing the width of the buffer zone, and utilizing buffer zones on all perennial and intermittent channels would reduce further impacts of silvicultural activities on water quality.

Keywords : non-point source pollution; best management practices; clear-cutting; forest management and practices; pollution

237. Lyons, J.K.; Beschta, Robert L. 1983. Land use, floods, and channel changes: Upper Middle Fork Willamette River, Oregon. Water Resources Research. 19(2):463-471.

Flow trends and channel characteristics from 1936 to 1980 were evaluated for the Middle Fork Willamette River, which drains a 668-sq km forested watershed in the Cascade Mountains of western Oregon. An inventory of aerial photographs from 1959 to 1972 shows that landslides associated with roads and in clearcuts were 27 and 23 times more frequent, respectively, than in

forested areas. Numerous landslides unloaded sediments directly into the drainage system; most landslides appear to have been initiated during a large flood (return period greater than or equal to 100 years) of December 22, 1964. Analysis of precipitation and peak flows (greater than 100 sq m/s) from 1958 to 1980 by means of power function models suggests a trend of increasing flows as timber harvesting and road building expanded in the basin. Changes in channel pattern, documented from aerial photographs, show major increases in channel width from 1959 to 1967 and a trend of decreasing width from 1967 to 1980. During summer low flows in 1979 and 1980, 65 cross sections of the channel were surveyed to provide detailed measurements of existing channel conditions. Channel widths of 62% of the aggraded reaches were significantly greater (alpha=0.05) than those for nonaggraded reaches. (Author's abstract).

Keywords : channels; flood estimation and control; clear-cutting; landslides; logging practices and effects

238. MacDonald, Lee H. 1992. Sediment monitoring: reality and hope. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 81-87.

Water quality regulation in the United States is largely based on the maintenance and enhancement of the designated beneficial uses of water. The Clean Water Act's overall goals and amendments are couched in terms such as "swimmable," "fishable," and "the propagation of aquatic life." The policies and mechanisms to achieve these goals--water quality standards, best management practices (BMPs), antidegradation, and total maximum daily loads (TMDLs)--all relate back to this concept of the designated beneficial use (U.S. Environ. Prot. Agency, 1988). Monitoring is essential for the effective implementation of each of these policies and pollution control mechanisms (MacDonald et al. 1991).

Keywords : sediment; measurement methods and monitoring; water quality; regulations; Clean Water Act

239. Magenis, S.E. 1988. Trash screens on culverts in urban areas. Journal of Institution of Water and Environmental Management. 2(5):476-484.

This paper deals with the performance of trash screens on culverts on urban watercourses. An assessment of the scope of problems associated with screens has been obtained from a survey of land drainage authorities in urban areas in England and Wales. The findings have been analyzed and this has resulted in the development of four basic design criteria for screens. A detailed survey of the performance of some 17 sites in the river Ravensbourne catchment of the Thames Water Authority was undertaken over a number of years allowing relationships to be identified between debris amounts and types of upstream catchment area, screen/culvert area ratios, and priority of location. The paper describes considerations to be taken when providing a screen and advocates an individual design for each location rather than installing a standard arrangement.

Keywords : trash rack; drainage; culvert design

240. Martin, C.Wayne; Hornbeck, James W. 1992. Erosion, sediment, and turbidity in New England forests. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 75-80.

Streams that drain undisturbed New England forest are typically clear, cool, and of excellent quality and are prized for aesthetics, recreation, human consumption, downstream municipal uses, and fish habitat. Maintaining high quality water in these streams has long been a concern for the general public, environmental organizations, and government agencies. Early concerns culminated with the Weeks Act of 1911, which encouraged Federal purchase of privately owned forests in New England and resulted in creation of the National Forest System. The act's objective was to protect watersheds of navigable streams by halting erosion and subsequent sedimentation resulting from intensive, turn-of-the-century logging. In subsequent years, research and further legislation have provided a sound basis for protecting forests and streams against erosion, sedimentation, and stream turbidity during and after logging. This paper summarizes current knowledge with emphasis on research results from the Hubbard Brook Experimental Forest.

Keywords : erosion processes; stream pollution; forest management and practices

241. Martin, Susan B.; Platts, William S. 1981. Influence of forest and rangeland management on anadromous fish habitat in western North America: effects of mining. Gen. Tech. Rep. PNW-119. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Range and Experiment Station. 15 p.

Keywords : mining; forest management and practices; land management; rangeland; fish habitat; impact analysis; fish

242. Mattice, C.R. 1977. Forest road erosion in northern Ontario: a preliminary analysis. Inf. Rep. O-X-108. Sault Ste. Marie, ON: Canadian Forest Service, Great Lakes Forest Resource Center. 27p.

To determine if forest roads caused significant erosion problems in northern Ontario a preliminary study was conducted in 1972 and 1973. Areas that were potentially more erodible when disturbed were investigated. A crude measure of the severity of erosion was made, based on the accumulation of cross-sectional areas intersected by offset lines. These areas provided an index of the size and distribution of features in relation to slope position and road centerline. The study suggests that most erosional effects are restricted to the road right-of-way. Problems encountered were due partly to a lack of proper management and partly to a lack of knowledge. There is probably a need to test and cost techniques which could reduce the incidence of unavoidable erosion (A).

Keywords : forest roads; erosion control

243. Mavis, F.T. 1943. The hydraulics of culverts. Bull. 56. [?, PA]: Pennsylvania State College. 35 p.

Studies were conducted at the Pennsylvania State College between 1939 and 1942 on valid estimation techniques of flow of water through a given pipe culvert under representative field conditions. Culverts were tested under conditions for the following five types of flow; part full with free outfall, part full with outfall partially submerged, full with outfall completely submerged, full with outfall partially submerged, and full with free outfall. Smooth models of transparent Lucite and smooth transite provided data from which the interrelations of headwater, tailwater, and inlet and outlet invert elevations were analyzed in term of discharge. A nomographic scale, based on test results, is constructed for calculating the hydraulics of culverts. Calculations for sample design problems are included.

Keywords : hydraulics; culvert hydraulics; culvert analysis

244. McCashion, J.D.; Rice, Raymond M. 1983. Erosion on logging roads in northwestern California: how much is avoidable. Journal of Forestry. 81(1):23-26.

A study was made on 344 miles of roads in northwestern California to assess sources of erosion and the extent to which road-related erosion is avoidable. At most, about 24 percent of the erosion measured on the logging roads could have been prevented by conventional engineering methods. The remaining 76 percent was caused by site conditions and choice of alignment. On 30,300 acres of commercial timberland an estimated 40 percent of the total erosion associated with management of the area was found to have been derived from the road system. (A).

Keywords : erosion control; road erosion; road impacts; road design and construction.

245. McClellan, Thomas. 1971. Fish passage through highway culverts. Portland, OR: U.S. Department of Transportation, Federal Highway Administration; final report; 800332. 223 p.

A field review of highway culverts installed with special consideration for the passage of fish was made during the summer of 1970 by Thomas J. McClellan, Professor of Civil Engineering at Oregon State University. The study was undertaken to determine the effectiveness of various provisions incorporated over a period of years to preserve fish habitat in areas upstream from highway crossings of Oregon streams. Culverts installed throughout the State from 1916 to 1970 were evaluated by Professor McClellan in company with Game Commission fish biologists. Sixty-two culvert sites were visited including several designed without special facilities, but representative of field conditions conductive or otherwise to the passage of fish. Notes made of the condition of the installations and adjacent streambed are included with photographs. Biologists' and engineers' evaluations of the installations visited are presented as well as recommendations for consideration by engineers and fisheries personnel concerned with the design of similar facilities Prepared in cooperation with the Oregon State Game Commission. (A).

Keywords : fish passage; culvert - highway; fish habitat; culvert fish passage

246. McCuen, Richard H.; Ayyub, Bilal M.; Hromadka, Theodore V. 1990. Risk of debris-basin failure. Journal of Water Resources Planning and Management. 116(4):473-484.

Keywords : risk analysis and design; debris flow and control; slope failures; basins

247. McCulloch, James S.G.; Robinson, Mark. 1993. History of forest hydrology. Journal of Hydrology. 150(2-4):189-216. (Special issue: O'Loughlin, E.M.; Dunin, F.X., eds. Water issues in forests today. Papers presented at the International Symposium on Forest Hydrology, Canberra, Australia, 22-26 November 1993).

Hydrology as a science and a technology is examined, as are some of the myths on the role of forests in hydrology and water resources. The history of catchment area research is traced, in Europe, and in the USA and East Africa, with particular reference to forest hydrology and, in the earlier years, to water quantity rather than water quality. The importance of associating physical process studies with hydrological systems' investigations, to enhance understanding of why particular catchments behave as they do, is stressed. Recent advances in hydrochemistry have been exploited to elucidate water flow paths within experimental catchments. Stimulated by requirements for research into acidification of surface waters, research catchments have proved to

be valuable outdoor laboratories from which a much improved understanding of the flow processes has been achieved. Conflicting claims about the impacts of forestry are described and discussed. (A).

Keywords : hydrology; catchments

248. McCutcheon, Steve C.; Hayes, John C. 1993. Effects of excess sediment. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 29-31.Sponsored by: Environmental Protection Agency and U.S. Department of Agriculture.

This presentation discusses the effects of excess sediment and why researchers are concerned about them. These effects include: blocking light to the periphyton and algae; smothering the macroinvertebrates and plants; and destroying bacterial slimes and periphyton that serve as the base of the food chain in streams. Excess sediment also reduces dissolved oxygen, caps the bed, and clogs the pores by hydraulic pumping. A low dissolved oxygen level often kills fish eggs, and suspended sediment may change the light transmission and, thus, the water temperature.

Keywords : sedimentation; impact analysis; aquatic life; fish habitat; sediment

249. McEnroe, Bruce M. 1994. Hydraulics of safety end sections for highway culverts. Transportation Research Record. 1471:18-23.

The Kansas Department of Transportation reconstruction project fits pipe culverts with end sections designed for collision safety. These safety end sections are long and narrow with steels bars over the top openings. Scale models of 10 safety end sections were tested in a large water flume in a hydraulic laboratory. The goals were to determine the relationship between headwater depth and discharge under inlet control, the entrance-loss coefficient for full flow, and the susceptibility to blockage by debris for each design. The hydraulic characteristics of the safety end sections compare favorably with those standard end sections. 9 Refs.

Keywords : hydraulics; culvert - highway; culvert inlets; culvert hydraulics

250. McNabb, D.H. 1994. Tillage of compacted haul roads and landings in the boreal forests of Alberta, Canada. IEA ameliorative practices for restoring and maintaining long-term productivity in forest workshops: Proceedings of a workshop; 1991; Asa, Sweden. In: Forest Ecology Management. 66(1-3): 179-195.

Research has shown that tillage of compacted forest soils increases seedling survival and growth. A winged subsoiler was used to loosen severely compacted haul roads and landings in a boreal forest in west-central Alberta, Canada. The effectiveness of the winged subsoiler was evaluated by comparing bulk density of tilled, compacted, and undisturbed soil, and by measuring clod size distribution in the tilled soil. The experimental site is described. Results indicated that tillage significantly decreased bulk density of the compacted soil at three of five haul-road sites. The high soil-water content, however, limited the effectiveness of the subsoiler on many sites. Tillage failed to fracture several of the soils into small clods because the soil was severely remolded and compacted (A). (4 graphs, 27 references, 4 tables).

Keywords : soil compaction

251. Meeuwig, R.O.; Packer, P.E. 1976. Erosion and runoff on forest and range lands. In: Proceedings of the fifth workshop of the United State/Australia rangelands panel; 1975 June 15-22; Boise, ID. Rep. INT R-443. Logan, UT: Utah State University, Utah Water Research Laboratory: 105-116.

This report discusses logging, road construction, grazing, surface mining, and recreation as these major uses affect erosion and runoff on forest and range lands. Fire is also discussed because it greatly affects erosion and runoff. (Witt-IPC).

Keywords : erosion processes; surface drainage; forest fires; road construction effects; logging practices and effects

252. Megahan, Walter F. 1972. Subsurface flow interception by a logging road in mountains of central Idaho. In: Csallany, S.C., McLaughlin, T.G., Striffler, W.D., eds. Proceedings of a symposium on “watersheds in transition”; 1972 June 19-22; Fort Collins, CO. Urbana, IL: American Water Resources Association: 350-356.(Sponsored by the American Water Resources Association and Colorado State University).

Conditions on mountain slopes in the Idaho Batholith are particularly conducive to the formation of subsurface flow. Roads in the area often incise flow levels, thereby transforming subsurface flows into surface flow. A study was designed to measure the amount of subsurface flow intercepted by a road on two representative micro-watersheds in the area. Instrumentation included a climatic station; snow lysimeters; a network of snow stakes, soil moisture-access tubes and piezometers; and apparatus to measure surface and subsurface flows. No surface flows occurred at any time. Subsurface flow were restricted to the spring snowmelt periods of 1970 and 1971. Maximum flows varied slightly between watersheds, but were vastly different between years. Yearly differences were related to amounts and to rates o inflow. A comparison of flows from nearby perennial watersheds suggests that the weather granitic bedrock is more hydrologically active than was previously thought. The amount of subsurface flow intercepted by roads is compared to the flow generated by overland flow for the area disturbed by road construction and the potential for damages is discussed.

Keywords : steep slopes and road grades; groundwater and subsurface flow; surface water; granitic soil; road drainage

253. Megahan, Walter F. 1972. Logging, erosion, sedimentation - are they dirty words. Journal of Forestry. 79(7):403-407.

A general look at natural processing and several regional studies suggest principles for reducing the impact of logging on erosion and sedimentation. It also seeks to provide a perspective on words that trigger varying emotional responses with both foresters and the public.

Keywords : impact analysis; logging practices and effects; erosion control; sedimentation; erosion processes

254. Megahan, Walter F. 1977. Reducing erosional impacts of roads. In: Kunkle, S.; Thames, J., eds. Guidelines for watershed management. Rome, Italy: Food and Agriculture Organization of the United Nations: 237-251.

The impacts of road erosion are many. The most direct is to the road itself; excessive erosion can, and often does inhibit road use or even make the road impassable until restored, often at great expense. Less obvious, but often more important, is the movement of eroded material off the site. This can cause sedimentation which may create excessive damage to downstream cultural and ecological values. Road construction practices that can reduce erosional impacts associated with roads are discussed in this paper.

Keywords : erosion control; watershed disturbance; road construction effects; impact analysis; land management

255. Megahan, Walter F. 1978. Erosion processes on steep granitic road fills in central Idaho. Journal of Soil Science Society of America. 42(2):350-357.

A set of thirty 20.2 m2 (1/200 acre) erosion plots was used to study erosion occurring on steep road fills constructed with Granitic soil materials in the Idaho Batholith. Erosion data were collected for a 31/2-year period from 1969 through 1972. Erosion on bare control plots averaged 3.4 metric tons/km2 per day for water years 1970 though 1972. Erosion was reduced an average of 40% and 95% by tree planting and straw mulching, respectively. Daily erosion rates were consistently higher during summer periods than during snowfree winter periods, presumably because of greater rainfall energy during the summer. Dry creep accounted for at least 15% of the total annual erosion for the years sampled and was as high as 40% in 1971. The erodibility index was a poor predictor of erosion for rain periods. Observations in the area suggest that wind was an important erosion factor on the steep slope studied. The median particle size of eroded materials (D50) tended to decrease throughout the summer and fall until Mid-October when it abruptly increased. Soil crusting during the summer and soil freezing and thawing in the fall may have caused these seasonal trends.

Keywords : erosion processes; granitic soil; steep slopes and road grades

256. Megahan, Walter F. 1984. Road effects and impacts-watershed. In: Proceedings, forest transportation symposium; 1984 December 11-13; Casper, WY. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Engineering Staff Unit: 57-97.

Effects of road construction on watersheds manifest both onsite and downstream. Onsite effects are measured in terms of changes in site productivity. Downstream effects occur because of changes in the hydrologic function of the watershed and are measured in terms of changes in (1) the volume and timing of streamflow, (2) water chemistry and sediment load, and (3) channel morphology. This paper addresses: site productivity, watershed hydrologic function, and erosion treatments as the relate to road construction (C).

Keywords : watershed disturbance; road construction effects

257. Megahan, Walter F.; Bohn, C.C. 1989. Progressive long-term slope failure following road construction and logging on noncohesive, granitic soils of the Idaho batholith. In: Woessner, W.W., and Potts, D.F., eds., American Water Resources Association symposium proceedings on headwaters hydrology; 1989 June 26-30; Missoula, MT. American Water Resources Association Technical Publication Series TPS-89-1. Herndon, VA: American Water Resources Association: 501-510.

Catastrophic failures of steep, forested slopes that result in debris avalanches, flows, and torrents are common occurrences following logging and road construction in the Idaho Batholith. However, piping failures caused by progressive, small-scale liquefaction of the cohesionless, granitic soil materials have not been well documented to date. Since 1984, three such failures were studied on three experimental watersheds in the Silver Creek Study Area. The failures are located in small (1.6 to 5.4 ha) first-order basins best described as low-gradient swales that lacked surface expression of channel development before failure. Two of the failures appear to have been caused by clearcut logging in 1976 and 1982; the third was caused by road construction in 1980. To date, the failure lengths range from 13 to 38 m and have a total volume of soil loss ranging from 6 to 39 cu m. The total erosion from the failures accounts for an average of 1 to 25% of the postdisturbance sediment yield and an annual maximum of 2 to 56% of the sediment yield from the 1.1 to 1.6 sq km study watersheds. Annual erosion rates appear to be related to the annual peak runoff from the experimental watersheds which in turn serves as an index of groundwater conditions. Such failures are important because they are forest management related, continue over a long term, are not easily detected, and may supply eroded material directly to the drainage system. (See also W90-08822) (Author's abstract).

Keywords : slope failures; road construction effects; logging practices and effects; granitic soil; landslides

258. Megahan, Walter F.; Kidd, W.J., Jr. 1972. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. Journal of Forestry. 70(3):136-141.

Erosion plots and sediment dams were used to evaluate the effects of jammer and skyline logging systems on erosion and sedimentation in steep ephemeral drainage's in the Idaho Batholith of central Idaho. Five-year plot data indicated that no difference in erosion resulted from the two skidding systems as applied in the study. Sediment dam data obtained concurrently showed that the logging operations alone (excluding roads) increased sediment production by a factor of about 0.6 over the natural sedimentation rate. Roads associated with the jammer logging system increased sediment production an average of about 750 times over the natural rate for the six-year period following construction.

Keywords : logging practices and effects; sedimentation; granitic soil; steep slopes and road grades; road erosion; road impacts

259. Megahan, Walter F.; Kidd, W.J., Jr. 1972. Effect of logging roads on sediment production rates in the Idaho Batholith. Gen. Tech. Rep. INT-123. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 16 p.

Effects of logging road construction on sediment production rates were studied on small, ephemeral drainages in the Idaho Batholith, a larger area of granitic rock characterized by steep slopes and highly erodible soils. For the 6-year study period, about 30 percent of the total accelerated sediment production from roads was caused by surface erosion; the remainder resulted from mass erosion. Surface erosion on roads decreased rapidly with time after extremely high initial rates. A mass failure of a road fill slope occurred about 4 years after construction, when surface erosion had fallen to a low rate. The sediment production rate attributed to erosion within the area disturbed by road construction averaged 770 times greater (220 because of surface erosion and 550 because of mass erosion) than that for similar, undisturbed lands in the vicinity. Results suggest three guides to use in the control surface erosion on roads and subsequent downslope sediment movement in the Idaho Batholith: (a) Apply erosion control measures

immediately after road construction for maximum effectiveness, (b) ensure that treatments protect the soil surface until vegetation becomes established, and (c) take advantage of downslope barrier (logs, branches, etc.) to effectively delay and reduce the downslope movement of sediment.

Keywords : sediment; granitic soil; road construction effects; steep slopes and road grades; fill slope

260. Megahan, Walter F.; Monsen, S.B.; Wilson, M.D. 1991. Probability of sediment yields from surface erosion on granitic roadfills in Idaho. Journal of Environmental Quality. 20(1):53-60.

A series of 29 bordered plots, 1.8 m wide by 4.6 m long, was used to measure sediment yields from granitic roadfills on forest roads in the mountains of Idaho. Slope gradients on the plots ranged from 34 to 41 degrees. Sediment yield data for the snowfree season were collected for 3 years following road construction. Various site factors were tested by regression analysis for their effects on sediment yield, but only ground cover density and snowfree period rainfall erosivity were statistically significant. Analysis of 22 years of snowfree period rainfall erosivity data showed that erosivity was log-normal distributed, and established the parameters for the probability density function. These data, coupled with the prediction equation from the regression model, were used in a Monte Carlo simulation model to define the probability of occurrence of sediment yields from granitic roadfills, given various levels of ground cover density. A prediction equation based on ground cover density and the snow free period erosivity index explained 55% of the variance in sediment yields. Recently published studies that update the slope gradient and slope length components of the Universal Soil Loss Equation were then used to extrapolate the results of the present study to all lengths and gradients of granitic roadfills. Roads associated with forest management activities were found to be the primary cause for serious downstream cumulative effects of sedimentation in the Idaho Batholith. Erosion control treatments such as the application of mulches, must accomplish site protection during the high erosion period before vegetation has had a chance to become established. (Doyle-PTT).

Keywords : sedimentation; surface erosion; granitic soil; steep slopes and road grades; fill slope

261. Megahan, Walter F.; Monsen, S.B.; Wilson, M.D.; Lozano, N.; Haber, D.F.; Booth, G.D. 1992. Erosion control practices applied to granitic road fills for forest roads in Idaho; cost effectiveness evaluation. Land Degradation and Rehabilitation. 3(1):55-65.

Cost effectiveness of six alternative road embankment construction practices and 16 alternative fill-slope stabilization practices was evaluated as means for controlling erosion on forest roads built on granitic soils in Idaho (USA). A total of 63 bordered erosion plots 1.8 m wide by 4.6 m long were used. eroded material was collected in troughs at the bottom of each plot in the spring and fall. Measurements began in the fall o f1981 and continued until the fall of 1983. Costs were obtained by tabulating actual labor, equipment, and supplies used to install the treatments. Rainfall erosivity values accumulated for the snow-free periods between erosion measurements proved to be a statistically significant covariate for the analysis of treatment effects. There were no significant differences between the three embankment construction practices (sidecast, layer placed, and controlled compaction). But surface rolling did significantly increase erosion in all cases. Nine of the post-construction soil stabilization measures significantly increase erosion in all cases. Nine of the post-construction soil stabilization measures significantly reduced erosion, and one measure significantly increased erosion ($P<0.5$). Stabilization measures that combined mulches with revegetation appeared to be more beneficial for erosion control than either mulches or

revegetation alone. Ranking of the erosion control effectiveness of individual soil stabilization practices were different from the ranking of the cost effectiveness of the practices. Application of alternative treatments is discussed.

Keywords : granitic soil; road design and construction; forest roads; cost and economics; erosion control; fill slope

262. Megahan, Walter F.; Seyedbagheri, K.A.; Dodson, P.C. 1983. Long-term erosion on granitic roadcuts based on exposed tree roots. Earth Surface Processes and Landforms. 8(1):19-28.

Exposed roots were used to estimate soil and bedrock erosion on the cut slopes of a 45-year-old road constructed in granitic soils of the Idaho Batholith. The original roadcut surface was denied by projecting a straight line from the toe of the cut past the end of the exposed root to the intersection of a straight line projected along the surface of the hillslope. A cross-sectioning technique was then used to determine erosion to the present roadcut surface. A total of 41 exposed root sites were used to estimate erosion on a 1350 m-long section of road. Average erosion was 1.0 and 1.1 cm/year for soil and bedrock respectively. Buttressing by tree roots caused lower erosion rates for soil as compared to bedrock. Both soil and bedrock erosion rates showed statistically significant corrections with the gradients of the original cut slope. The bedrock erosion data provide a reasonable estimate of the disintegration rate of exposed granitic bedrock exhibiting the weathering and fracturing properties common to this area. The road is located in a study watershed where long-term sediment yield data are available. Sediment data from adjacent study watersheds with no roads were compared to sediment data from the roaded watershed to estimate the long-term increase in sediment yield caused by the road. The increase amounts to about 2.4m/year. This figure, compared to the average annual on-site erosion, provides and erosion to sediment delivery ratio of less than 10 percent. Based on study results road construction and maintenance practices are suggested for helping reduce roadcut erosion.

Keywords : road erosion; granitic soil; cut slope; measurement methods and monitoring

263. Megahan, Walter F.; Seyedbagheri, K.A.; Mosko, T.L.; Ketcheson, G.L. 1986. Construction phase sediment budget for forest roads on granitic slopes in Idaho. In: Hadley, R.F., ed. Drainage basin sediment delivery: Proceedings of a symposium; 1986 August 4-8; Albuquerque, NM. IAHS Publication no. 159. Wallingford, Oxfordshire: International Association of Hydrological Sciences: 31-39.

Sediment yields from the study basins increased an average of 5 times as a result of erosion during the construction period. Total road erosion during construction amounted to 303 m3, distributed as follows: 259 m3 on slopes, 24 m3 in channels, and 21 m3 delivered to watershed outlets, providing a delivery ratio averaging 7% for the construction period.

Keywords : forest roads; granitic soil; sediment modeling; road design and construction; road construction effects

264. Mendenhall, R.F.; Barksdale, J.R. 1987. Use of concrete median (Jersey) barriers as ford walls in low water crossings. Proceedings of the fourth international conference on low-volume roads; 1987 August 16-20; Ithaca, N.Y. In: Transportation Research Record 1106(2). Washington, D.C. National Research Council, Transportation Research Board; 327-329.

The use of precast concrete median (Jersey) barriers as ford walls on low-volume roads is described. Ford walls are used on U.S. Forest Service roads to stabilize low water stream crossings. This is an acceptable practice on roads that have been temporarily closed for 1 or 2 hours as a result of flooding from sudden and intense storm runoff. The barriers are readily available, precast units that can be transported to the site and installed with conventional equipment that is used to maintain low-volume roads. Modified barriers with steel caps have also been used successfully to prevent erosion of the top of the concrete wall as a result of abrasive bedload movement during high water flows. Ford walls that were constructed with concrete median barriers have been used on hundreds of low water crossings in the desert and mountainous regions of the southwestern United States. These barriers have proved to be an efficient, low-cost alternative to conventional, cast-in-place concrete walls. (A).

Keywords : low water crossing; stream crossing design

265. Miller, John F. 1996. Physiographically adjusted precipitation-frequency maps for western United States. Silver Spring, MD: National Weather Service, National Oceanic and Atmospheric Administration. 18 p.

The purpose of this investigation was to prepare a series of charts which more accurately predict the variation of the precipitation-frequency regime in regions of complex and varied topography. The National Weather Service with the support of the Soil Conservation Service prepared a series of charts for the western United States. Basic data for these investigations came from published and unpublished precipitation gage data which are read daily or for which autographic records are available. Storm durations of six and twenty four hours were considered. The frequency distribution used in these studies has been the Fisher-Tippett Type I distribution using the procedure developed by Gumbel. Geographic regions based on physical characteristics are used to develop index relationships based on physical characteristics.

Keywords : prediction

266. Mitchell, G.F. 1995. Implementation of proper erosion and sediment control practices. Final report. FHWA/OH-95/012. [Athens]: Ohio University, Center for Geotechnical and Environmental Research. 94 p. Sponsored by: Federal Highway Administration, Ohio Division, and Ohio Department of Transportation, Columbus, OH (Available from Springfield, VA: National Technical Information Service as stock no. PB95-239174).

The report provides an overview of training in erosion and sediment control practices provided to Ohio Department of Transportation construction personnel. A video and manual were developed to introduce the basics, best management practices, including installation, maintenance and inspection issues, and regulatory information of erosion and sediment control for highway construction. The majority of the participants noted that after the training their perception of the importance of erosion and sediment control was increased and they were better prepared to handle job related erosion and sediment control issues. (A).

Keywords : erosion control; sediment control; highway construction; law and policy; best management practices

267. Mizuyama, Takahisa; Kobashi, Sumiji; Guogiang, Ou. 1993. Development of debris flow. In: Hadley, Richard F.; Mizuyama, Takahisa, eds. Proceedings of the Yokohama symposium, sediment problems: strategies for monitoring and control; 1993 July 19-21; Yokohama, Japan. IAHS Pub. No. 217. Wallingford, Oxfordshire, UK: International Association of Hydrological Sciences: 141-145.

This study provides a method to predict debris flow peak discharge. It was obtained through flume experiments on the development of debris flow. It is found that, in steep torrents, steeper than about 25 degrees, debris flow develops monotonously as it flows down. The longitudinal shape of developing debris flow is a similar triangle. When debris flow comes into flatter reaches, the height of debris flow is kept almost constant. Based on the experimental results, the debris flow peak discharge can be predicted if the total amount of sediment available in the debris flow developing reach and the width of torrents is known. The method was applied to actual debris flows and the calculated flow heights show a good agreement with the values estimated in the field.

Keywords : debris flow and control; prediction; discharge; flume study; steep slopes and road grades

268. Moffitt, Christine M.; Kynard, Boyd; Rideout, Stephen G. 1982. Fish passage facilities and anadromous fish restoration in the Connecticut River Basin. Fisheries. 7(6):2-12.

Keywords : fish passage; fish; fishways

269. Moll, Jeffry E. 1993. Reducing low-volume road impacts on the environment: success in the United States Department of Agriculture, Forest Service. Transportation Research Record. 1426:10-14.

Principles for low-impact roads have been under development since the 1960s. Observation of roads after storms and floods showed minimal damage occurring to well-located roads, with less environmental impacts in adjacent areas. Roads should have rolling grades and should be located to be self-maintaining and to 'lay lightly' on the land. These roads minimize modification of existing drainage patterns. A sufficient number of properly located and designed cross drains should be provided. Location in the best spot is not always possible, however, and roads-related erosion, failures, and environmental damage can still occur. Also, road work may be planned and executed to promote healing of the scars of the past. Raising cross- drain pipe inlets encourages water ponding, soil conservation, the healing of gullies, and increased soil moisture. Road fills may serve as gully plugs or may be constructed with porous characteristics to reduce water concentration on broad, relatively flat meadows. Finally, a 'less is better' approach to road maintenance may aid in sediment reduction. Providing for adequate drainage with the minimum disturbance during ditch pulling, heeling, and surface blading activities also has economic benefits. Tailoring ditch geometries to actual drainage needs, as well as compacting and armoring the soil in the ditch, can reduce sediment levels. Flavel bars are useful in breaking up the concentration of water. (A) 5 Refs.

Keywords : road design and construction; erosion control; culverts; forest management and practices

270. Moore, Tom; Foltz, Randy B.; Cronenwett, Larry. 1995. Central tire inflation (CTI) reduces sediment up to 84%: a new method to help meet new water quality standards & guidelines. Tech Tip 9525 1303-SDTDC. San Dimas, CA: U.S. Department of Agriculture, Forest Service, Technology & Development Program. 1 p.

Keywords : sedimentation; tire pressure; water quality; sediment

271. Morfin, S.; Elliot, W.; Foltz, Randy B.; Miller, S. 1996. Predicting effects of climate, soil, and topography on road erosion with the WEPP model. In: Proceedings of the 1996 ASAE Annual International Meeting; 1996 July 16; Phoenix, AZ. ASAE Paper No. 965016. St. Joseph, MI: ASAE: 11 p

Summary: A sensitivity analysis was carried out to determine the ability of the WEPP model to assist in the design of water bar spacing or buffer zone widths on forest roads. Over 7000 computer runs were analyzed as part of a larger study for this analysis. The model behaved in a predictable manner in addressing effects of topography and soils. There was no apparent relationship between sediment yield and annual precipitation and annual runoff, likely due to complex interactions between rainfall, snowmelt, and surface hydrologic properties.

Keywords : dips and waterbars; erosion control; modeling; road erosion; WEPP

272. Motayed, Asok K.; Chang, Fred M.; Mukherjee, Dipak K. 1983. Design and construction of low water stream crossings, executive summary. FHWA-RD-83-015. McLean, VA: U.S. Department of Transportation, Federal Highway Administration, Research, Development, and Technology. 19 p. (Available: Springfield, VA: National Technical Information Service as stock no. PB86-203931).

This report summarizes a study of low water crossings. The final outcome of the study was a two-volume report. The first volume contains the review and analysis of literature, case histories of several existing low-water stream crossing (LWSC) structures, and documents the research efforts undertaken. The second volume is a guide for the design of LWSCs. This executive summary briefly describes fords, vented fords, and low-water bridges. It also summarizes a decision methodology based on a risk-based design approach which considers least total expected cost, as well as intangible factors such as traffic stoppage, potential danger to life, loss of use of road for emergency purposes, effect on environment, as well as “many other social, environmental, and legal aspects.” Criteria for selection of LWSCs are tabulated, as well as examples of warning signs. The report number for the full report is FHWA-RD-82-163. (C).

Keywords : low water crossing; road design and construction; stream crossing design

273. Mumper, David; Gibbons, David R.; Wilson, Leo; Golde, Marcy J. 1987. Panel discussion: best management practices in the streamside zone. In: Salo, Ernest O.; Cundy, Terrance W., eds. Streamside management: forestry and fishery interactions: Proceedings of a symposium; 1986 February 12-14; Seattle. Contribution No. 57. Seattle: University of Washington, Institute of Forest Resources: 441-457.

Keywords : best management practices; riparian zone; forest management and practices

274. Murphy, Glen; Pyles, Marvin R. 1989. Cost-effective selection of culverts for small forest streams. Journal of Forestry. 87(10):45-50.

Selecting a culvert size for a stream crossing should be based on an economic evaluation of the alternatives. Minimizing the total discounted cost of the culvert (TDC) is a simple method of comparing culverts for a cost effective design. TDC includes hydrologic probability functions and cost components obtained by summing the original installation cost, the discounted annual maintenance costs and the discounted expected costs of culvert failures that could be caused by peak flows. This paper uses two hydrologic probability functions, the probabilities of occurrence of possible annual peak flows in a given year and the probabilities of failure associated with those flows. The product of these two functions gives the probability of failure in a given year. The expected annual failure cost of a culvert is obtained by multiplying the cost of a single failure by the sum of the product of the probability of occurrence of annual peak flow and probability of failure for that peak flow for the series of peak flow classes. An example of the analysis procedure is given for pipe diameters ranging from 36 to 84 inches. Results indicate that the qualitative factors that are often present but not easily quantified for an economic analysis can be used as justification for selecting larger pipes to obtain a lower probability of failure without a significant cost increase.

Keywords : culvert design; stream crossing design; cost and economics; culvert installation; hydrologic analysis

275. National Academy of Sciences, Transportation Research Board. 1979. Design charts for open-channel flow. In: Compendium 5: roadside drainage. Washington, DC: National Academy of Sciences, Transportation Research Board: 65-88. Text 2.

[Excerpts of and including: Preface; Chapter 3--Rectangular, Trapezoidal, and Triangular Channels; Chapter 4--Grassed Channels; Appendix B--Construction of design charts for open-channel flow; Charts: Trapezoidal channel flow (2:1 side slopes), Triangular channel flow, Grassed channel flow]. (A).

Keywords : drainage design; channels; open channel; drainage structures

276. Neary, D.G.; Comerford, N.B.; Swift, L.W., Jr. 1992. Land and riparian interactions with sediment in the Southern United States. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 51-60.Sponsored by: Environmental Protection Agency and U.S. Department of Agriculture.

There is a lack of information on forestry buffer zones. It is appropriate to outline how they function, what plant and soil properties affect them, and draw conclusions based on the more abundant literature concerning the effectiveness of buffer zones in protecting adjoining wetlands and open waters from the effects of farming practices. Thus, this review will synthesize research results in current literature on buffer zones, determine the utility of buffer zones in protecting forested wetlands and surface waters from the sediment nonpoint source pollution impacts of silvicultural operations, and identify information gaps and research needs (A).

Keywords : best management practices; forest wetland; wetlands; sediment control; riparian zone

277. Neary, D.G.; Comerford, N.B.; Swift, Lloyd W., Jr. 1993. Land and riparian interactions with sediment in the southern United States. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 51-60.

This review compares forestry-caused sedimentation rates with other human causes and focuses on the buffer zone as a management tool to mitigate sediment damage to streams. A comprehensive literature review leads to four proposed science questions and a statement of research needs.

Keywords : sedimentation; forest management and practices; riparian zone; land management; sediment

278. Neary, D.G.; Swank, W.T.; Riekerk, H. 1989. An overview of nonpoint source pollution in the southern United States. In: Hook, Donal D.; Lea, Russ, eds. The forested wetlands of the southern United States: Proceedings of the symposium; 1988 July 12-14; Orlando, FL. Gen. Tech. Rep. SE-50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 1-7.

This paper examines nonpoint source pollution (NPSP) in the 13 States of the Southern Region. The definitions, sources, types, and trends of NPSP is of particular concern to wetlands because it is difficult to manage and most States have little knowledge of the effects on wetlands. Information is very limited on the cumulative effects of different NPSP sources on wetlands. Where water quality is deteriorating, NPSP is frequently the major cause. Best management practices implemented by local and State agencies provide the best means of controlling NPSP.

Keywords : non-point source pollution; wetlands; sedimentation; pollution

279. Neary, D.G.; Swift, Lloyd W., Jr. 1987. Rainfall thresholds for triggering a debris avalanching event in the southern Appalachian Mountains. In: Costa, John E.; Wieczorek, Gerald F., eds. Debris flows/avalanches: process, recognition, and mitigation: Proceedings of the Engineering Geology and Quaternary Geology and Geomorphology Division of the Geological Society of America; 1984 November 5; Reno, NV. Boulder, CO: Geology Society of America: 81-92.

In November 1977, a storm system produced intense rainfall that set off debris avalanching in steep terrain of the Pisgah National Forest, North Carolina. All the classical conditions of above-normal antecedent moisture, heavy rainfall followed by intense downpours, steep slopes, and shallow soils were present. Peak hourly rainfall intensities of 90 to 100 mm/hr approach the suggested 24-hour threshold for initiating debris avalanches in mountainous regions and were the key to triggering these slope failures in well-drained and highly permeable forest soils of the Southern Appalachians. Long-return periods of 100 to more than 200 year for destructive events obscure the perception of their importance as an erosional process. Although slope stability is not recognized as a general problem in mountainous areas of the East, debris avalanching is a major contributor to long-term erosion rates and influences formation of some of the more productive forest soils.

Keywords : rainstorm; debris flow and control; steep slopes and road grades; landslides

280. Neary, D.G.; Swift, Lloyd W., Jr.; Manning, D.M.; Burns, R.G. 1986. Debris avalanching in the southern Appalachians: an influence on forest soil formation. Journal of Soil Science Society of America. 50:465-471.

In early November 1977, a storm system formed in the Gulf of Mexico and moved northeast into the Appalachian Mountains. It produced intense, heavy rainfall which triggered debris avalanching in steep terrain of the National Forest. Soil material displaced by the mass wasting was about 2 to 3 10^3/ha along avalanche tracks, which exceeded 1 km in length. Peak stormflows had recurrence intervals ranging from 20 to >100 year. Factors prominent in development of the storm were evaluated using infrared satellite imagery and rain data. Most debris avalanches on one well documented basin originated in shallow soils on upper slopes and ran out onto lower gradient deposition zones. Although debris avalanching in the Appalachian Mountains is a rare phenomenon in human history (100 to 1000+ year return period), it is a major and frequent geomorphic process influencing soil formation.

Keywords : debris flow and control; landslides; rainstorm; steep slopes and road grades; mass movement

281. Normann, Jerome M.; Houghtalen, Robert J.; Johnson, William J. 1985. Hydraulic design of highway culverts. Hydraulic Design Series No. 5, FHWA-IP-85-15. McLean, VA: Turner-Fairbank Highway Research Center, Office of Implementation. 254 p.

Hydraulic Design Series No. 5 combines culvert design information previously contained in Hydraulic Engineering Circular (HEC) No. 5, No. 10, and No. 13 with hydrologic, storage routing, and special culvert design information. The result is a comprehensive culvert design publication. Hydrologic analysis methods are described, and references cited. Culvert design methods are presented for both conventional culverts and culverts with inlet improvements. Storage routing techniques are included which permit the designer to account for ponding effects upstream of the culvert. Unique culvert applications, erosion and sediment control, debris control, structural aspects, and long span culverts are discussed and references cited. Inlet control, outlet control, and critical depth design charts, many of which are newly developed, are included for a variety of culvert sizes, shapes, and materials. New dimensionless culvert design charts are provided for the design of culverts lacking conventional design nomographs and charts. The appendices of the publication contain the equations and methodology used to construct the design charts, information of the hydraulic resistance of culverts, and methods of optimizing culvert design using performance curves and inlet depression. Calculation forms are provided for most of the design methodologies in the manual.(A).

Keywords : hydraulic design; culvert - highway; hydrologic analysis; culvert design; hydrologic design

282. Nutter, Wade L. 1973. The role of soil water in the hydrologic behavior of upland basins. In: Field soil science regime; 1971 August 15-20; New York. Madison, WI: Soil Science Society of America: 181-193.

Except during the most extreme storms, all the precipitation falling on well-vegetated slopes infiltrates and while some reappears in the channel as stormflow, a major portion remains in the basin as dynamic storage. During a storm, the stormflow source area expands out from the stream channel as slopes contribute subsurface flow and the channel system lengthens. After the storm, source areas may continue to expand as subsurface flow feeds the lower slopes near the channel, often leading to a second hydrograph peak. Physical models of hillslope segments have provided some insight into the flow pathways and source areas of subsurface flow.

Keywords : hydrology; soil profile; rainstorm; infiltration; basins

283. O'Donnell, Charles L. 1973. Observations on the causes of bridge damage in Pennsylvania and New York due to hurricane Agnes. Highway Research Record. 479:20-36. [Also available in: National Academy of Sciences, Transportation Research Board. 1979. Compendium 9: erosion control. Washington, DC: National Academy of Sciences, Transportation Research Board: 239-258. Text 10].

This paper evaluates the performance of bridges subjected to a major flood, determines the adequacy of design standards based on bridge performance, and recommends revisions to design standards where inadequacies are apparent. Hurricane Agnes caused severe flooding in Pennsylvania and New York, and several bridges and highways that were damaged by the floods in those states are discussed. The two major causes of bridge damage were scour at abutments and piers and impacting debris.

Keywords : flood estimation and control; storm flow response; bridge design; scour; debris flow and control

284. Ogden, Fred L. 1994. De St-Venant channel routing in distributed watershed modeling. In: Proceedings of the 1994 ASCE national conference on hydraulic engineering; 1994 August 1-5; Buffalo, NY. New York: American Society of Civil Engineers: 492-496.

Distributed hydrologic models of large (greater than 1000 km 2) watersheds must include accurate channel routing methods capable of dealing with a wide variety of flow conditions. Large watersheds are likely to contain reservoirs and large numbers of weirs, culverts and bridge crossings. Furthermore, channel cross-sections and slopes may vary tremendously from the uplands to the basin outlet. Channel routing techniques traditionally used in hydrologic models are not practical in such diverse situations. An implicit solution of the one-dimensional de St-Venant equations using Preissmann's double-sweep finite difference method is developed for distributed watershed modeling. The flow in upland areas is typically ephemeral, exposing the algorithm to significant opportunities for "dry bed" conditions. This implementation addresses the dry bed problem, accommodates internal boundary conditions such as culverts, weirs and reservoirs, and allows parametric expression of cross-sectional properties. (A) 8 Refs.

Keywords : hydrologic analysis; channels; drainage structures; modeling; watershed

285. Ohlander, C.A. 1964. Effects of rehabilitation treatments on the sediment production on granitic road materials. Fort Collins, CO: Colorado State University. 78 p. M.S. thesis.

A study applicable to the mountainous areas of southern and central Idaho was conducted to evaluate the effects of six surface treatments on the fill and overcast material associated with logging roads. The treatments, asphalt-straw, 1 and 3 layers of Erosionet, chipped slash, and surface holes, were applied concurrently with 93 lb./ac of seed and 400 lb./ac of nitrogen fertilizer; the control was neither seeded nor fertilized. Sediment and vegetation production measurements were taken between August, 1962, and July, 1963. Soil samples were taken to help describe the initial conditions and changes within the material. Three stages in slope protection were considered: (1) treatment protection without vegetation, (2) treatment protection with the gradually increasing component due to vegetation, and (3) vegetation protection after the treatment effect becomes secondary. For the first stage, treatment alone, sediment production data were used to indicate treatment effectiveness: Asphalt-straw (242 lb./ac) and 1 layer of Erosionet (302 lb./ac). The sediment production for the other treatments was over 10,000 lb./ac. For the second stage,

treatment and vegetation, sediment production data were used to indicate treatment effectiveness: 1 layer of Erosionet (128 lb./ac), asphalt-straw (138 lb./ac), 3 layers of Erosionet (320 lb./ac), chipped slash (740 lb./ac), surface holes (2,274 lb./ac) and the control (3,346 lb./ac). For the third stage, vegetation only, vegetation production data were used to indicate treatment effectiveness at promoting vegetation cover: 1 layer of Erosionet (2,939 lb./ac), asphalt-straw (1,599 lb./ac), 3 layers of Erosionet (1,341 lb./ac), surface holes (1, 264 lb./ac), chipped slash (900 lb./ac), and the control (20 lb./ac) (C).

Keywords : sedimentation; granitic soil; road construction materials

286. Ottens, J. 1975. Environmental costs in logging road design and construction. Inf. Rep. BC-X-108. Victoria, BC: Environmental Canada, Canadian Forest Service, Pacific Forest Research Centre.

The Wilson Creek Forest Road project in the Nelson Forest District was used from 1972 to 1974 as a case study to develop and verify a cost accounting system to determine the cost of imposing environmental and aesthetic constraints on logging road design and construction. The existing cost accounting system of the B.C. Forest Service Engineering Division was modified and expanded to compile the damage-prevention cost. Environmental protection accounted for 18.6% of the total construction cost.

Keywords : road design and construction; cost and economics; case studies

287. Ottens, J. 1977. Environmental costs in logging road design and construction to prevent increased sedimentation in the Carnation Creek Watershed [Vancouver Island]. Rep. BC-X-155. Ottawa, ON: Fisheries and Environment Canada, Canadian Forestry Service, Pacific Forest Research Center. 28 p.

This study examines the effects of forest road construction on sediment input into streams, and the costs of damage prevention. Streams downslope from a logging road under construction in the Carnation Creek Watershed were sampled for sediment every 2 hours by automatic sediment samplers. Field monitoring of road construction tasks by machine, crew road location, and time of day was used to determine which construction practices caused the highest sediment levels under given hydrological conditions. The results were to have been used to determine which tasks needed to be modified to prevent high sediment discharges and to estimate the extra cost of doing so. However, the results of the analysis were inconclusive. Methodology for determining least-cost logging road design and construction prescriptions to meet stream sedimentation standards is described using sample data (C).

Keywords : impact analysis; sedimentation; cost and economics; watershed disturbance; road impacts

288. Overton, C. Kerry; McIntyre, John D.; Armstrong, Robyn; Whitwell, Shari L.; Duncan, Kelly A. 1995. User's guide to fish habitat: descriptions that represent natural conditions in the Salmon River Basin, Idaho. Gen. Tech. Rep. INT-GTR-322. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 142 p.

The user's guide and reference document describes the physical features of stream channels that represent natural conditions for fish habitat within the Salmon River Basin in Idaho. The term 'natural condition' refers to the structure and pattern of streams that have not been substantially

influenced by human disturbances. Data were collected at four landscape scales watershed, channel reach type, habitat type, and mesohabitat (habitat type attribute). This hierarchical outline facilitates multiscale data analysis; the scales are synonymous with analysis areas for watershed (cumulative effects) and site (individual project) assessments.

Keywords : fish habitat; watershed disturbance; channels; fish

289. Packer, P.E. 1967. Criteria for designing and locating logging roads to control sediment. Forest Science. 13(1):1-18.

A recent completed study developed criteria for the design, location, and construction of logging roads in the northern Rocky mountains to prevent damage to the water resource and to conserve soil. Results reveal which characteristics of watersheds and of secondary logging roads influence erosion of road surfaces and movement of sediment downslope from roads. They define the manner and degree in which these characteristics affect road-surface erosion and sediment movement, and they indicate which characteristics are controllable or alterable by design, management, or choice. They also provide requirements that should be considered in planning and executing timber harvest operations, so that soil and water resources will be protected.

Keywords : dips and waterbars; erosion control; road design and construction; road location; road surface erosion; soil conservation

290. Packer, P.E.; Christensen, G.F. 1964. Guides for controlling sediment from secondary logging roads [Pamphlet]. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

This handbook contains guides for locating and designing secondary logging roads and installing water control structures in a way that will reduce erosion and prevent sedimentation of streams.

Keywords : dips and waterbars; erosion control; road design and construction; road drainage; sediment control; sedimentation

291. Packer, P.E.; Haupt, H.F. 1965. The influence of roads on water quality characteristics. In: Proceedings of the Society of American Foresters; 1965; Detroit, MI. Bethesda, MD: Society of American Foresters: 112-115.

Of man's activities that disturb vegetation and soil in mountainous terrain, few cause more damage to the quality of water than the construction of roads. Roads expose raw mineral soil, which compacts under travel and resists infiltration of water. When gouged into sidehills, roads open up subsurface seepage flow that drain out of road cuts onto road surfaces. The casting of large quantities of soil downslope as road fills creates even larger area of raw mineral soil that can easily erode. This publication addresses three questions: how much sediment comes from forest roads and logging operations? What are the harmful effects on stream biology? and, What are some criteria for road location and drainage that will assure better water quality? (A).

Keywords : road impacts; water quality

292. Patric, James H. 1970. Logging roads and water quality. In: Proceedings, forest engineering workshop on forest roads; 1970 July; Morgantown, WV. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 11-16.

Soil from eroding logging roads is the [most] common and harmful pollutant of forest streams in West Virginia. Some consequences of pollution by soil and other contaminants from logging roads are reviewed. Forest managers can avoid most of this damage to water quality by applying known methods of water control on logging roads (A).

Keywords : erosion control; logging practices and effects; non-point source pollution; road drainage; road erosion; soil erosion; water quality

293. Patric, James H. 1978. Harvesting effects on soil and water in the Eastern Hardwood Forest. Southern Journal of Applied Forestry. 2(3):66-73.

For the eastern United States, there is overwhelming evidence that neither the productivity of forest soil nor the quality of forest water are substantially lessened during or after responsibly managed harvest of wood products. Carelessness, however, damages both resources. The key is forest roads; they cause little adverse effect on soil or water given proper location, drainage, traffic control, and maintenance. The public must better understand that it bears too much of the cost for these measures.

Keywords : road design and construction; forest roads; road location; soil disturbance; water quality

294. Patric, James H.; Kidd, W.J., Jr. 1981. Erosion caused by low-cost roads in the Eastern Forest. In: Forest regeneration (Proceedings of the ASAE Symposium on Engineering Systems for Forest Regeneration); 1981 March 2-6; Raleigh, NC. ASAE Publication 10-81. St. Joseph, MI: ASAE: 22-28.

Geologic and accelerated (man-caused) erosion in the eastern forests are described briefly. Frequently, low-cost roads serving forested land are sites of accelerated erosion and sources of sediment in forest streams. Properly managed, low-cost logging roads can provide adequate access to wood harvest sites and contribute little sediment to streams. On low-cost public roads, the drainage systems needed to maintain all-weather access for automobiles can introduce eroded soil directly into streams. Sedimentation resulting from geologic erosion and augmented by accelerated erosion common to most low-cost roads probably is unavoidable on managed forest land. The augmentation effect is relatively greater in the common small storms of frequent recurrence than in the rarely occurring catastrophic storms.

Keywords : hydrologic analysis; road drainage; road erosion; road management

295. Patric, James H.; Kidd, W.J., Jr. 1982. Erosion on very stony forest soil during phenomenal rain in Webster County, West Virginia. Rep. NE-83-20. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 17 p.

On July 15 and 16, 1979 at least 6 inches of rain fell in central West Virginia during 3 hours, a storm of return period longer than 1000 years. More than 6 miles of logging roads were examined for evidence of soil erosion and sediment delivery to streams.

Keywords : rainstorm; erosion processes; sedimentation; road erosion; road construction materials

296. Pence, Lester M., Jr. 1971. A method of determining the construction grade in a road drainage dip. Field Notes. [Washington, D.C.]: U.S. Department of Agriculture, Forest Service, Engineering Technical Information System; 3(3): 6-7.

[In Region 8 some minimum-standard roads are designed and constructed with outsloped surfaces and Coweeta dips. A design using an outsloped roadway with dips reduces construction costs and is used in lieu of a design with normal drainage facilities (ditches and culverts). A design using dips requires the final road grade to vary from the normal design grade through the dip area. We considered ignoring these dips during design; however, this practice would waste the 113 cubic yards of earth excavated from each dip during construction. Wasting this amount of material would create too great an impact on the resources and environment adjacent to the roadway. Also, when the amount of earth from each dip is multiplied by the number of dips in a roadway, we saw that wasting this amount of material was uneconomical. Therefore, it was concluded that designs must consider these dips by including the material from each dip in the normal roadfill. When the road grade is modified to include the dips, the difference in elevation between the normal and modified grade line must be computed at each point where there are cross sections within the dip area. The new centerline elevation is used to properly place the road template on the cross section. A graphical method of determining these differences in grade line elevation is presented.] (3 figures, 1 example).

Keywords : outsloping; road design and construction; dips and waterbars; road drainage; cost and economics; drainage structures

297. Pence, Lester M., Jr. 1987. A plastic ford--you've got to be kidding. Field Notes. [Washington, D.C.]: U.S. Department of Agriculture, Forest Service, Engineering Technical Information System; 19(1): 15-20.

Describes the use of GEOWEB material for stabilizing ford crossings on a road on the Chattahoochee- Oconee National Forest in north Georgia. Gives costs, advantages, and other uses for the material. (C).

Keywords : low water crossing; road construction materials

298. Pennock, C.M., Jr. 1977. Virginia's water quality control program for loggers. Southern Journal of Applied Forestry. 1(4):2-3.

In 1976 a series of meeting was held throughout Virginia for the purpose of informing loggers about the federal Water Pollution Control Act and the probable impact on the logging industry. Emphasis was placed on voluntary compliance with good management practices to avoid regulatory programs. Increased logging road stabilization is the first tangible result.

Keywords : water quality; logging practices and effects; regulations; Water Pollution Control Act; water quality control

299. Peterson, Dean F.; Mohanty, P.K. 1960. Flume studies of flow in steep, rough channels. Journal of Hydraulics Division, American Society of Civil Engineers. 86(HY 9):55-76.

Based on observations of both natural streams and flume experiments, three classifications of flow in steep, rough, open channels are proposed: tranquil, tumbling, and rapid. The tranquil and rapid regimes are dominated by subcritical and supercritical flow, respectively. In the tumbling regime, the roughness elements induce supercritical flow over their crests followed by individual hydraulic jumps to the tranquil state. The characteristics of flow in each of the proposed regimes are described, and criteria for delineating the regimes are proposed. (A).

Keywords : flume study; stream channel

300. Piehl, Bradley T.; Beschta, Robert L.; Pyles, Marvin R. 1988. Ditch-relief culverts and low-volume forest roads in the Oregon Coast Range. Northwest Science. 62(3):91-98.

Drainage systems associated with gravel-surfaced roads often rely on culverts for moving water through the road prism and for minimizing onsite erosion. The purpose of this study was to determine the characteristics and functional capabilities of ditch relief culverts (DRC's) in the Coast Range of western Oregon. Five hundred and fifteen DRC's were evaluated to determine diameter and length, spacing, inlet conditions, skew angle, slope, and outlet erosion. Most DRC's (86%) were corrugated steel pipe. Pipe diameters were typically 38.1 or 45.7 cm (15 or 18 in.); average length was 10.7 m (35.1 ft.). Cross-sectional area of 74 percent of the inlets had been reduced by sediment deposition, pipe damage, cutbank sloughing, or organic debris; the inlet area of all DRC culverts averaged 81 percent of original. Spacing of DRC's varied by ownership category, with averages of 2.6 to 5.2 DRC's per km (4.2 to 8.4 per mi.). Ditch erosion was minimal except with relatively long culvert spacing. Erosion at culvert outlets increased with culvert spacing.

Keywords : drainage crossing; drainage structures; gravel roads; ditch-relief culverts; culvert design; road drainage

301. Piehl, Bradley T.; Pyles, Marvin R.; Beschta, Robert L. 1988. Flow capacity of culverts on Oregon Coast Range forest roads. Water Resources Bulletin. 24(3): 631-637.

One hundred twenty-eight stream-crossing culverts in the central Oregon Coast Range were evaluated for peak flow capacity and were compared with current design guidelines. Their ability to pass the 25-year peak flow, as mandated by Oregon State Forest Practice Rules, and their maximum flow capacity were determined. Over 40 percent of the culverts were unable to pass the 25-year peak flow at a headwater to diameter ratio of 1. About 17 percent could not pass the 25-year peak flow without headwater overtopping the roadfill. Installing the next larger pipe size at an additional original installation cost of about 14 percent would have allowed nearly all these culverts to pass the 25-year peak flow. Culvert capacity varied with ownership and watershed size. (A).

Keywords : flow capacity; forest roads; culvert installation

302. Platts, William S. 1981. Streamside management to protect bank-channel stability and aquatic life. In: Baumgartner, David M., comp., ed. Interior West watershed management: Proceedings of a symposium; 1980 April 8-10; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension: 245-256.

Livestock grazing, road construction, mining, and logging are the major streamside uses affecting aquatic environments on public lands. The resulting effects have deteriorated these streams because insufficient emphasis has been placed on streamside management. Before scientists can provide land managers with the knowledge needed to manage the land uses and rehabilitate the streams, they must first develop more precise methodology that will detect small changes in environmental conditions from both natural and artificial causes (A). (77 references).

Keywords : stream channel; channels; aquatic life; stream management

303. Powell, B.; Brunette, B. 1991. Reduced tire inflation pressure--a solution for marginal-quality road construction rock in southeast Alaska. In: Transportation Research Record No. 1291, Fifth international conference on low-volume roads; 1991 May 19-23; Raleigh, NC. Washington, D.C. National Research Council, Transportation Research Board; 329-334.

When marginal-quality rock is encountered in Southeast Alaska, the rock often does not provide adequate support for truck haul. The road surface tends to rut and the rock continually breaks down after heavy repeated wheel loads combined with wet conditions. This process reduces the gravel to fine silt and clay-sized particles that will not support construction vehicles. The traditional solution has been to blade this material off the road and haul additional higher-quality rock to support the traffic. This procedure results in higher costs and additional stream sediment. By using radial tires with lowered tire pressures, the road surface became more compact with repeated wheel loads. This result has produced large savings, exceeding $500, 000 on one project, and this concept is expected to provide future contract savings for road building and logging activities (A).

Keywords : sedimentation; gravel roads; forest roads; tire pressure; road maintenance; erosion control

304. Price, M. 1994. Drainage from roads and airfields to soakaways: groundwater pollutant or valuable recharge? Journal of Institution of Water and Environmental Management. 8(5):468-479.

The construction of a road, runway or other paved surface on the outcrop of an aquifer introduces an impermeable area into an otherwise permeable environment. Surface water must be drained from these areas, and the most convenient and inexpensive way of disposing of this water is usually to lead it into soakaways in the unsaturated zone of the aquifer. This approach is acceptable in that it can provide valuable recharge to aquifers in times of low rainfall. However, it carries the risk that pollutants from the surface can also be carried into the aquifer. These pollutants can be generated from (a) normal abrasion, (b) maintenance operations such as de- icing and defoliation, and (c) accidental spillages. Although there is evidence that such drainage can carry a pollutant load, and that drainage entering soakaways can reach a public-supply well, there does not seems to be any evidence available at present of any public supply in the UK being seriously affected by such drainage. (A) 29 Refs.

Keywords : drainage; road surface; groundwater and subsurface flow; pollution

305. Province of British Columbia. 1995. Forest road engineering guidebook. Victoria, B.C. British Columbia, Ministry of Forests; ISBN0772626499. 164 p. (Available on internet at http:// www.for.gov.bc.ca/ tasb/legsregs/fpc/fpcguide/road/fre-toc.htm).

This guidebook provides current information and recommended procedures for designing, building, and maintaining forest roads in British Columbia according to the provincial Forest Practices Code Act and related regulations. The sections in the guide cover topics on survey and design for road layout, construction and modification, and maintenance. In addition, the guide describes processes about which no other documentation is readily available, such as construction of fords and log culverts; and provides information such as minimum expected results, operational practices that meet the objectives in the regulations, sketches of components, and design and construction constraints. Numerical analyses are used to illustrate these procedures (A).

Keywords : forest roads; road design and construction

306. Rada, Gonzalo R.; Schwartz, Charles W.; Witczak, Matthew W.; Siamak, Jafroudi. 1989. Analysis of climate effects on performance of unpaved roads. Journal of Transportation Engineering. 115(4):389-410.

The performance of unpaved roads is strongly dependent upon the moisture content within the roadway profile. Unfortunately, there are no analytical models currently available for quantitatively predicting the influence of depth and time-dependent moisture distribution upon this performance. Existing procedures rely on laboratory or field tests, or indirect empirical correlations, to define the strength characteristics of each roadway layer in terms of a single, generally conservative value intended to reflect worst-case climatic conditions. This paper presents a rational methodology for analyzing the effects of site-specific rainfall and evaporation history upon the performance of unpaved roads. The methodology consists of a predictive model for weather-induced, soil-moisture changes over time; relationships between soil moisture, compaction level, and strength for a variety of typical roadway soils; and a damage analysis model tailored to low-volume unpaved roads. The capabilities of the proposed methodology are demonstrated through a numerical example. Performance predictions from the proposed methodology are comparable to those from more conventional approaches.

Keywords : unpaved roads; climate; modeling; soil properties

307. Rajaratnam, N.; Katopodis, C. 1990. Hydraulics of culvert fishways III: weir baffle culvert fishways. Canadian Journal of Civil Engineering. 17(4):558-568.

This paper presents the results of a laboratory study of culvert fishways with weir-type baffles. Baffles with heights equal to 0.15 and 0.1 times the diameter (D) of the culvert were studied with longitudinal spacings of 0.6D and 1.2D. Equations have been developed to describe the relation between the discharge, slope, diameter, and the depth of flow. It has been possible to predict the barrier velocity that would exist at the baffles. The performance of the weir baffles has been found to be as good as that of the slotted-weir baffles. (A) 9 Refs.

Keywords : baffles; culvert fish passage; culvert hydraulics; fishways

308. Rajaratnam, N.; Katopodis, C.; Fairbairn, M.A. 1990. Hydraulics of culvert fishways V: Alberta fish weirs and baffles. Canadian Journal of Civil Engineering. 17(6):1015-1021.

This paper presents the results of a laboratory study of the hydraulic performance of fish weirs and fish baffles used by Alberta Transportation for improving the fish-passing capacity of culverts. It was found that if the longitudinal spacing of the weirs is limited to 0.6 and 1.2 times the diameter of

the culvert, their performance is comparable to that of the corresponding weir and baffle-weir systems, with regard to the depth of pool between the baffles as well as the barrier velocity. On the other hand, the fish baffles did not perform as well as the fish weirs under the conditions tested. (A).

Keywords : baffles; culvert fish passage; culvert hydraulics; fishways

309. Rajaratnam, N.; Katopodis, C.; Lodewyk, S. 1988. Hydraulics of offset baffle culvert fishways. Canadian Journal of Civil Engineering. 15(6):1043-1051.

This paper presents the results of an experimental study on the hydraulics of culverts with offset baffles to pass fish. Using analytical considerations and experimental observations, a flow equation has been developed between the discharge, diameter, depth, and slope for a culvert fishway with the standard offset baffle system. The velocity field at the slot has also been evaluated. Some further experiments were performed to assess the effect of baffle spacing and height on the hydraulics of the culvert fishway. (A) 14 Refs.

Keywords : baffles; culvert fish passage; culvert hydraulics; fishways

310. Rajaratnam, N.; Katopodis, C.; Lodewyk, S. 1991. Hydraulics of culvert fishways IV: spoiler baffle culvert fishways. Canadian Journal of Civil Engineering. 18(1):76-82.

This paper presents the results of an experimental study on the hydraulics of culvert fishways with spoiler baffles. Four designs were studied with the heights of the baffles equal to 0.09D and 0.15D and longitudinal spacings of 0.53D and 1.06D, where D is the diameter of the culvert. Design equations have been developed relating the flow depth to the flow rate, the diameter and the slope of the culvert for each baffle design. Expressions have also been found for the barrier velocity. (A) 8 Refs.

Keywords : baffles; culvert fish passage; culvert hydraulics; fishways

311. Rajaratnam, N.; Katopodis, C.; Sabur, M.A. 1991. Entrance region of circular pipes flowing partly full. Journal of Hydraulic Research. 29(5):685-698.

This paper presents the results of an experimental study on the characteristics of flow in the entrance region of a circular pipe flowing partly full for slopes of 1, 3 and 5%. An analysis of the water surface and velocity profiles in the centerplane indicates the existence of a near-field of the entrance region. At the end of this region, the depth of flow is essentially constant with the velocity in the outer flow (above the boundary layer) having reached a maximum value but the velocity profile is still evolving (in a limited way), associated with the growth of the boundary layer. In this near-field, the flow may be modeled by potential flow with a thin boundary layer of approximately constant thickness. Correlations have been developed for the main characteristics of this near-field. (A) 2 Refs.

Keywords : culvert hydraulics; culvert inlets; flow velocity

312. Rajaratnam, N.; McQuitty, N.; Katopodis, C. 1989. Hydraulics of culvert fishways II: slotted-weir culvert fishways. Canadian Journal of Civil Engineering. 16(3):375-383.

This paper presents the results of an experimental study on the hydraulics of culvert fishways with a slotted-weir baffle system. Six designs with two baffle heights and three spacings were tested. A flow equation has been developed to predict the flow depth for any given discharge, diameter, and slope. The barrier velocity that would exist at the slot in the baffles has also been predicted in a general manner. This relatively simple slotted-weir baffle system has been found to match the performance of the more complicated but frequently used offset baffle system of similar dimensions. (A) 6 Refs.

Keywords : baffles; culvert fish passage; culvert hydraulics; fishways

313. Rantz, S.E. 1971. Suggested criteria for hydrologic design of storm-drainage facilities in the San Francisco Bay region, California. Menlo Park, CA: U.S. Department of the Interior, Geological Survey, Water Resources Division; open-file report; 69 p.

This report presents basic criteria, in the form of tables and graphs, for each of the four methods of hydrologic design most commonly used in the San Francisco Bay region--flood-frequency analysis, Rational Method, unit-hydrograph method, and runoff simulation by means of hydrologic basin modeling. The term “hydrologic design” as used in this report refers to the computation of either design values of peak discharge or design hydrographs of storm runoff. The hydraulics of open-channel and pipeline flow and the actual design of appurtenances for conveying the runoff are not discussed in this paper. Use of the suggested criteria results in fairly close agreement between peak discharges computed by the flood-frequency and unit-hydrograph methods. Those peak discharges are not directly comparable with discharges computed by the Rational Method, in part because the results obtained by the Rational Method are affected by the values assigned to parameters for overland and channel flow. Those parameters are additional to the ones used in the flood-frequency and unit-hydrograph methods. A demonstration of runoff simulation by use of a hydrologic basin is beyond the scope of this paper--such demonstrations are found in the appropriate references cited. However, this report does present an original technique for transposing storm rainfall in the region, storm transposition being commonly required to obtain the precipitation input used with hydrologic basin models. (A).

Keywords : basins; drainage; hydrologic analysis; flood estimation and control; hydrologic design

314. Reed, L.A. 1984. Suspended sediment discharge in five streams near Harrisburg, Pennsylvania, before, during, and after highway construction. Water Resources Research. 20(11):1753-1761.

Keywords : highway construction; road construction effects; sedimentation; stream sediment

315. Reeves, Gordon H. 1992. Sediment and aquatic organisms in the Pacific Northwest: the need for new perspectives. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 119-121. Sponsored by: Environmental Protection Agency and U.S. Department of Agriculture.

For years, effects of sediment originating from land-management activities (such as timber harvest, agricultural practices, and mining) on aquatic biota have been the focus of numerous studies and a primary concern of resource managers in the Pacific Northwest. With regard to timber harvest, the impact of fine sediments (generally, 85 mm) on survival and growth of developing fish has been studied most frequently. Everest et al. (1987) and Chapman (1988) present comprehensive reviews

of studies examining this issue. Using laboratory studies, they generally find negative correlations between amounts of fish sediments and fish survival and growth. Increased levels of sediment decrease intragravel water flow, which in turn stresses fish by decreasing dissolved oxygen and removal of metabolic waste products.

Keywords : sediment; aquatic life; land management; natural resources; mining; forest management and practices; timber harvest

316. Reeves, Gordon H.; Sedell, James R. 1992. An ecosystem approach to the conservation and management of freshwater habitat for anadromous salmonids in the Pacific Northwest. In: Proceedings of the Wildlife Management Institute North American wildlife & natural resource 57th conference; 1992 March 27-April 1; Charlotte, NC. Washington, D.C. Wildlife Management Institute: 408-416.

Keywords : ecosystem approach; fish habitat; fish

317. Reid, Leslie M. 1981. Sediment production from gravel-surfaced forest roads, Clearwater Basin, Washington. Seattle, WA: University of Washington, College of Fisheries, Fisheries Research Institute; Final Report; FRI-UW-8108. 247 p. Sponsored by the Washington State Department of Natural Resources. Submitted to sponsor by C.J. Cederholm and E.O. Salo. Accepted as a M.S. Thesis at the University of Washington, Department of Geological Sciences.

Erosion on the surfaces of inuse gravel logging roads is a significant source of fine grained sediment in logged basins of the Pacific Northwest. Runoff from ten road segments subjected to a variety of traffic levels was monitored during a series of storms in the central Clearwater basin of Western Washington. The resulting data allowed the construction both of sediment rating curves for different road use levels and of unit hydrographs for different road surface types. These relationships could then be combined with a continuous rainfall record to calculate an average annual sediment yield from road segments of each use level. Road segments used by more than 16 trucks per day are seen to contribute 130 times as much sediment as roads not subjected to truck traffic, and 1000 times as much as roads which have been abandoned. Measurements of sediment production on paved roads indicates that paving a heavily used road will decrease the quantity of sediment reaching streams through road culverts by a factor of 240. These measurements also suggest that sediment production from backcuts is relatively insignificant if roads are in use; backcut erosion is responsible for about 0.4% of the sediment yield from a culvert on a heavily used road. Comparison of the calculated sediment production rates from road surface erosion with those measured for road related landslides shows surface erosion to be 2.5 to 4.1 times as important as road surface erosion in a hypothetical 10 km2, 40% logged basin with a road density of 2.5 km/km2 and a typical distribution of road use intensities. Road surface erosion in such a basin accounts for about 47 t/km2/yr, while road related landslides are responsible for 115 to 194 t/km2/yr. If only sediment finer than 2 mm is considered, however, the contributions from these two sources are more nearly equal. Erosion induced by this road distribution increases sediment production rate in the basin by a factor of 3.4 to 4.9 over the average reported rate of 82 t/km2/yr for undisturbed basins in similar areas. Measurements and estimates of sediment production rates from natural sources in the Clearwater area indicate that there is an average background sediment production rate of 79 t/km2/yr; the most important natural sediment sources are bank erosion and landslides (A).

Keywords : road drainage; road erosion; gravel roads; truck traffic; sedimentation; hydrograph; cut slope; landslides

318. Reid, Leslie M.; Dunne, Thomas. 1984. Sediment production from forest road surfaces. Water Resources Research. 20(11):1753-1761.

Erosion on roads is an important source of fine grained sediment in streams draining logged basins of the Pacific Northwest. Runoff rates and sediment concentrations from 10 road segments subject to a variety of traffic levels were monitored to produce sediment rating curves and unit hydrographs for different use levels and types of surfaces. These relationships are combined with a continuous rainfall record to calculate mean annual sediment yields from road segments of each use level. A heavily used road segment in the field area contributes 130 times as much sediment as an abandoned road. A paved road segment, along which cut slopes and ditches are the only sources of sediment, yields less than 1% as much sediment as a heavily used road with a gravel surface.

Keywords : sedimentation; road surface erosion; gravel roads; pavement; unpaved roads

319. Reid, Leslie M.; Dunne, Thomas; Cederholm, C.Jeff. 1981. Application of sediment budget studies to the evaluation of logging road impact. Journal of Hydrology (New Zealand). 20(1):49-62.

The construction of a partial sediment budget provides a flexible, efficient, and economical means of evaluating changes in sediment production rates generated by changes in land use. Application of the method to a 40% clear-felled area of the northwestern US demonstrates that landslides are responsible for about 60% of the road-related sediment production. An additional 20% is produced by surface erosion on gravel roads, and about 80% of this value is derived from roads along which logs are being transported.

Keywords : road impacts; clear-cutting; landslides; sediment modeling

320. Reiser, Dudley W.; Bjornn, T.C. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America. Gen. Tech. Rep. PNW-96. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 54 p.

Keywords : rangeland; forest management and practices; fish; fish habitat

321. Rice, Raymond M. 1984. The difference between stable and erodible forest roads in northwestern California. Proceedings; 1984 December 3-7; San Francisco. In: EOS. American Geophysical Union; 65(45): 884-885.

Data collected form 481 km of roads were used to investigate the relationship between erosion, road design, and site conditions. Erosion was categorized into either being road caused or due to disturbance unrelated to the road, This study only investigated road-related erosion. A random sample of half of the data was used to develop a discriminate function which classified road segments into those which were associated with less than 25 m3 /km of erosion and those yielding more. The function correctly classified 44.3% of the road segments.

Keywords : forest roads; erosion processes; road design and construction; road erosion

322. Rice, Raymond M.; Datzman, Patricia A. 1981. Erosion associated with cable and tractor logging in north-western California. In: Davies, T.R.H.; Pearce, A.J., eds. Erosion and sediment transport in Pacific Rim steeplands. IAHS-AISH Pub. 132. Washington, DC: International Association of Hydrological Sciences: 362-385.

Erosion and site conditions were measured at 102 logged plots in northwestern California. Erosion averaged 26.8 m3/ha. A log-normal distribution was a better fit to the data. The antilog of the mean of the logarithms of erosion was 3.2 m3/ha. The Coast District Erosion Hazard Rating was a poor predictor of erosion related to logging. In a new equation that 'explained' about 40 percent of the variability in erosion, yarding method was associated with a 3.7-fold difference in erosion, aspect with a 4.3-fold difference, geologic type with a 13.5-fold difference, and slope with a 16-fold difference. The analysis suggests that an additional source of variation was operative that may be related to how the logging was done. Further investigations, therefore, should focus more on the conduct of logging operations than descriptions of the site logged (A).

Keywords : erosion processes; logging practices and effects

323. Rice, Raymond M.; Rothacher, J.S.; Megahan, Walter F. 1972. Erosional consequences of timber harvesting: an appraisal. In: Proceedings of symposium: watersheds in transition; 1972 June 19-22; Fort Collins, CO. Urbana, IL: American Water Resources Association: 321-329.

Timber harvesting is the most important human activity affecting the condition and performance of forested watersheds. Erosion in an undisturbed forest usually represents a minimum for the site. Consequently, increased erosion is an almost certain by-product of logging. While erosion rates in mountainous forested watersheds are highly variable, there is consistency in the relative importance of different types of erosion and the consequences of the various disturbances. Landslides and creep are the principal forms of natural erosion in mountainous regions under a wide variety of climates and site conditions. Erosion rarely occurs uniformly in a forest watershed. Usually erosion features are deep and include a large portion of subsoil and weathered parent material. Normally, bared areas are quickly invaded by pioneer species and initially high rates of sediment production decline rapidly. Due to the tendency for sediment to come mainly from localized unstable areas, land stratification can be used to reduce the erosional consequences of human activities. Usually, the cutting of trees by itself does not significantly increase erosion. However, clearcutting on steep unstable slopes may lead to increased mass erosion. The road system developed for the timber harvest far overshadows other activities as a cause of accelerated erosion. Since the potential for accelerated erosion is so closely correlated with the road system the adoption of logging methods which require fewer roads can substantially reduce erosion resulting from timber harvest.

Keywords : erosion processes; landslides; logging practices and effects; road erosion; watershed disturbance

324. Rice, Raymond M.; Tilley, Forest B.; Datzman, Patricia A. 1979. A watershed's response to logging and roads: south fork of Caspar Creek, California, 1967-1976. Res. Pap. PSW-146. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 12 p.

The effect of logging and roadbuilding on erosion and sedimentation are analyzed by comparing the North Fork and South Fork of Caspar Creek, in northern California. Increased sediment production during the 4 years after road construction was 326 cu yd/sq mi./yr--80 percent greater

than that predicted by the predisturbance regression analysis. The average sediment load during the 3 years of logging increased by 957 cu yd/sq mi/yr--275 percent greater than the predicted values. Although the erosion or sediment increases do not appear to be degrading site quality, average turbidity levels in the South Fork exceeded water quality standards.

Keywords : watershed disturbance; logging practices and effects; road construction effects; erosion processes; sedimentation

325. Rice, Raymond M.; Wallis, J.R. 1962. Logging effects on streamflow and sedimentation in a High Sierra watershed. Forest Industries. 89(1):38-40.

Keywords : logging practices and effects; streamflow; sedimentation; watershed disturbance

326. Richards, Dennis L. 1985. Microcomputers in urban drainage design. In: Microcomputer applications within the urban transportation environment: Proceedings of a national conference; 1985 June 19-21; San Diego, CA. New York: American Society of Civil Engineers: 765-770.

Microcomputers offer an inexpensive method for increasing the efficiency and effectiveness of drainage design personnel. This paper discusses some of the benefits and uses of microcomputers in urban drainage design and discusses programs being developed for hydrologic analysis, culvert design, roadway inlet analysis, and stable channel design. It also provides a description of a 3-day workshop being developed by the Federal Highway Administration for presentation to state highway drainage engineers. (A) 6 refs.

Keywords : modeling; drainage; hydrologic analysis; culvert design; drainage design

327. Riggs, Henry C. 1978. Streamflow characteristics from channel size. Journal of Hydraulics Division, American Society of Civil Engineers. HY1:87-96.

A common hydrologic problem is the estimation of the mean flow or the flood-frequency characteristics of an ungaged stream. Traditional methods include estimation from rainfall records, and use of relations between streamflow records and basin characteristics. These methods were developed for humid regions and assume more or less uniform flow contributions from all parts of the basin and are inadequate in arid or semiarid regions, in regions where precipitation is highly variable in space, or where geologic controls are dominant. For streams where the traditional methods are inadequate, channel width seems to be the single best estimator of a flood characteristic. Channel size is the result of all the topographic, geologic, and climatic characteristics upstream. This paper describes the need for such a method, its origin and development, the manner in which it has been used by the United States Geological Survey, reliability of flow estimates, some proposals for improvement, and practical applications. (Author's introduction).

Keywords : streamflow; channels; flood estimation and control; prediction

328. Ring, Stanley L. 1987. Design of low water stream crossings. Proceedings of the fourth international conference on low-volume roads; 1987 August 16-20; Ithaca, NY. In: Transportation Research Record. National Research Council, Transportation Research Board; 1106(2): 309-318.

A description is provided of the major steps and considerations in the design of a low water stream crossing. The decision to build a low water stream crossing is based on the road classification. A primitive road is an excellent candidate. The first step is to select the frequency of overtopping that can be tolerated and then calculate a discharge Q//e. A series of pipes are selected with this overtopping discharge value in mind to minimize the roadway fill over the stream. The design procedures offer criteria for the grade line design and for the final cross-section of the roadway. General construction details and guidelines for the selection of materials and final signing are also presented. (Edited author abstract) 4 refs.

Keywords : low water crossing; stream crossing design; road design and construction

329. River Basin Planning Staff. 1985. Water quality planning forest roads: special study No. 1B extension. San Francisco: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, and U.S. Department of Agriculture, Soil Conservation Service. 52 p.

The purpose of this study is to provide information on the effects of road construction and maintenance in or near forest stream and lake protection zones. The study had two major objectives: (1) to evaluate erosion and sedimentation effects of roads in or near the stream and lake protection zone (SPZ); and (b) to develop guidelines for road location, construction, and maintenance that are useful for general forest management and in the forest practice making process. The study was conducted in 39 areas in the Sacramento River Basin where logging roads were located near in SPZ's. Erosion was measured using a modified Universal Soil Loss Equation (USLE) and by physically measuring erosion that occurred within the road prism and estimating the percentage of that erosion which reached the stream as sediment. Macroinvertebrate benthic organisms were sampled and analyzed using the Cairns' Sequential Comparison Index (SCI), Euclidean Distance, and Shannon-Weaver Diversity techniques. Average erosion using USLE estimates was 11 tons/acre/year with an estimated 6 tons/acre/year reaching the stream as sediment. Actual soil loss measurements showed erosion to be about 80 tons/acre/year and sediment yield to be 50 tons/acre/year mostly form the roads. There was a weak correlation between erosion or sedimentation and any of the biological indicators. The high degree of variation in the amounts of sediment in the stream yielded widely varying responses in the benthic macro-invertebrate communities. In general, the sediment delivered to streams from roads and SPZ's, when those roads and SPZ's were built or maintained according to the Forest Practice Rules, seemed to have minimal impact on the streams benthic macroinvertebrate population.

Keywords : water quality; forest roads; road construction effects; road design and construction; universal soil loss equation; erosion processes

330. Roberts, Brian C. 1995. Best management practices for erosion and sediment control. FHWA-FLP-94-005. Sterling, VA: Federal Highway Administration, Eastern Federal Lands Highway Design. 187 p. Sponsored by: U.S. Department of Transportation, Federal Highway Administration, Federal Lands Highway Program.

The purpose of this manual is to provide guidance in preventing erosion and controlling sediment on highway construction projects. It addresses the selection of erosion and sediment control measures and the development of erosion control plans. Construction and inspection of the measures are presented for each practice.

Keywords : erosion control; sedimentation; best management practices; highway construction

331. Robichaud, Peter R.; Foltz, Randy B.; Luce, Charles H. 1993. Development of an on site sediment prediction model for forest roads and timber harvest areas. In: Hadley, Richard F.; Mizuyama, Takahisa, eds. Proceedings of the Yokohama symposium, sediment problems: strategies for monitoring, prediction and control; 1993 July 19-21; Yokohama, Japan. IAHS Pub. No. 217. Wallingford, Oxfordshire, UK: International Association of Hydrological Sciences: 135-141.

USDA's Water Erosion Prediction Project (WEPP) was initiated to predict sheet and rill erosion and to calculate annual sediment production on crop and rangelands. WEPP has been developed to replace the Universal Soil Loss Equation. Efforts are under way to extrapolate the WEPP cropland and rangeland model to forest areas. The development of a weather simulator is described, which will be capable of estimating weather parameters without nearby weather records. Model parameterization is described for road construction and timber harvest, based on field experiments. Parameters being addressed include: runoff flow in wheel ruts and drainage ditches; the effects of gravel surfaces, mulches on fillslopes, rock blankets in drainage ditches, and tire pressure; and the effects of site preparation on the residual root mass. (13 references).

Keywords : sediment modeling; forest roads; WEPP; universal soil loss equation; erosion control

332. Rodriguez-Iturbe, Ignaccio; Gonzales-Sanabria, Marcelo. 1982. A geomorphoclimatic theory of the instantaneous unit hydrograph. Water Resources Research. 18(4):877-886.

The instantaneous unit hydrograph (IUH) is conceived as a random function of climate and geomorphology varying with the characteristics of the rainfall excess. The probability density functions (pdf's) of the peak and time to peak of the IUH are analytically derived as functions of the rainfall characteristics and the basin geomorphologic parameters. The main characteristics of these pdf's are studied, and a new approach to hydrologic similarity is initiated under the concept of the geomorphoclimatic IUH. For a given set of geomorphologic characteristics and a particular intensity and duration of rainfall, the peak and time to peak of the IUH corresponding to those values can be easily estimated. (A).

Keywords : hydrograph; climate

333. Rooseboom, A. 1985. Practical culvert hydraulics: a South African perspective. In: Papers presented at the 2nd international conference on the hydraulics of floods & flood control; 1985 September 24-26; Cambridge, England. Cranfield, England: BHRA, Fluid Engineering Center: 499-512.

Culverts and stormwater drains are common and relatively costly items in street and road drainage. They are often designed by persons who are not specialists in hydraulics. The result is that many of these elements are improperly designed. This paper presents a flexible system which has been developed for determining the design flood return period. It also includes a simplified system for performing practical design calculations. These calculations relate to culvert sizing, increasing the capacity of culvert barrels, outlet velocities and erosion protection measures downstream. (A) 4 refs.

Keywords : hydraulics; culvert design; road drainage; surface drainage

334. Rossmiller, Ronald L.; Dougal, Merwin D. 1982. Tapered inlet design using specific energy curves. Journal of Hydraulics Division, American Society of Civil Engineers. 108(HY1):127-1135.

Design charts to simplify the hydraulic design of tapered inlet culverts for both rectangular and circular sections are presented. The use of these design charts greatly reduces the opportunity for error and the amount of time needed to design a tapered inlet. The use of these tapered inlet culverts in the state of Iowa has resulted in the savings of millions of dollars in construction costs over a period of years. In addition, many of these raised inlet culverts have enabled the highway department to provide ponds for recreation or for stock watering, and have helped control channel degradation and bank erosion. (A).

Keywords : culvert inlets; culvert design; design chart

335. Rothwell, R.L. 1977. Suspended sediment and soil disturbance in a small mountain watershed after road construction and logging. In: Swanson, R.H.; Logan, P.A., eds. Proceedings, Alberta Watershed Research Program symposium; 1977 Aug 31 - Sept 2; Edmonton, AB. Inf. Rep. NOR-X-176. Edmonton, AB: Fisheries and Environment Canada, Canadian Forestry Service, Northern Forest Research Centre: 285-300.

The effects of road construction and logging on water quality in Marmot Creek Experimental Watershed were studied in terms of suspended sediment and soil disturbance. The objective of the study was to demonstrate that water quality deterioration associated with forest harvesting can be prevented by careful planning of road construction and logging. Roads were constructed in Cabin subbasin 2 years before logging. Logging was done by clear-cut blocks, with logs skidded by rubber-tired skidders and crawler tractors. Suspended sediment record was obtained on a daily basis during the summer flow season, 4 years before roads and logging and 3 years afterward. Soil disturbance and erosion caused by roads and logging were evaluated by mapping and reconnaissance of disturbed areas. Soil exposure from roads and logging affected 25% of the total area of Cabin subbasin. Soil exposure on cut blocks averaged 32%, with most of it caused by skidroads. Mapping and reconnaissance of disturbed areas showed very little erosion and no sediment transport toward streams. Analysis of sediment data showed no increases in sediment concentrations or discharges that could be associated with roads or logging (A).

Keywords : sedimentation; soil conservation; road construction effects; suspended sediment; logging practices and effects

336. Rothwell, R.L. 1978. Watershed management guidelines for logging and road construction in Alberta. Inf. Rep. NOR-X-208. Edmonton, AB: Canadian Forestry Service, Northern Forest Research Centre. 43 p.

This report provides watershed management guidelines for logging and road construction to minimize erosion, sedimentation, and deterioration of water quality. The guidelines, which have been developed specifically for Alberta's foothills and mountainous region, are based on an extensive literature survey of research and practices in North America. Sections: introduction, erosion and watershed damage, watershed management guidelines for logging, watershed management guidelines for road construction (road gradient, road width, aspect, side-hill slopes, topography, geology and soils, stream protection, stream crossings, cuts and fills, drainage, subsurface drainage, berms, road maintenance). (4 appendices, 39 figures, 13 tables, glossary, references).

Keywords : erosion control; water quality; logging practices and effects; road design and construction; handbooks

337. Ruff, James F.; Abt, Steven R.; Mendoza, Cesar; Shaikh, A.; Kloberdanz, A.M. 1982. Scour at culvert outlets in mixed bed materials. FHWA/RD-82/011. Sterling, VA: Federal Highway Administration. 103 p.

The study of localized scour at culvert outlets has been on-going to control and manage erosion along highway embankments. An investigation of scour at culvert outlets was undertaken to refine and extend the state-of-the-art prediction of the dimensions of scour holes. Over 100 experiments ranging from 20 to 1000 minutes in duration were conducted in cohesive and non-cohesive bed materials. Culverts having 4-inch (10.2 cm), 10-inch (25.4 cm), 14-inch (35.6 cm), and 18-inch (45.7 cm) diameters were tested with discharges from .11 cfs (.003 cms) to 29.13 cfs (.82 cms). Tailwater elevations were maintained at zero, 0.25D and 0.45D +/- 0.05D above the culvert inlet where D is the diameter of the culvert. The results yielded a series of empirical relationships expressing the depth, width, length, and volume of scour as a function of the culvert diameter and discharge. Parameters including the shear number, equivalent depth, pipe shape, soil gradation, and extent of scour were investigated. General observations concerning scour, hole formation, growth and stabilization were reported. (A).

Keywords : scour; erosion control; prediction; culvert outlets

338. Ryan, William L.; Crissman, Randy D., eds. 1990. Cold regions hydrology and hydraulics. New York: American Society of Civil Engineers: 827 p.

This monograph contains 26 papers which are individually abstracted and indexed. The topics covered are: Measurements and evaluation of winter precipitation, snow packs, drifting snow, snow avalanches, mountain glaciers; frozen ground effects on infiltration and runoff, surface water supplies, ground water, water quality and wetland considerations; measurements and interpretation of streamflow data; Aufeis formation and prevention; formation and growth of lake ice, river ice, breakup ice jams; considerations in design and operation of hydropower intakes, culverts, and fish habitats.

Keywords : cold regions; hydrology; hydraulics

339. Saltzman, William; Koski, R.O. 1971. Fish passage through culverts. Salem, OR: Oregon State Game Commission; special report. 9 p.

A series of culvert velocity curves has been developed by the U.S. Army Corps of Engineers and the Engineering Section of the Oregon Game Commission. The curves predict water velocities encountered at different water levels in round corrugated steel culverts from two to seven feet in diameter and on gradients from 0.25 to 5.0 percent. Maximum allowable velocities for fish passage are combined with the rating curves to give design criteria for fish passage. Fish passage design criteria for other methods of stream crossing techniques including pipe-arch culverts and box- type concrete culverts are mentioned.

Keywords : fish passage; culvert design; culvert fish passage; flow velocity; fishways; stream crossing design

340. Sands, Stephen R.; Harned, James A.; Sites, Mark A.; Stahl, James R. 1995. Conveyance distribution to define flow boundaries at culverts. In: Domenica, M.F., ed., Proceedings of the 22nd annual conference on integrated water resources planning for the 21st century; 1995 May 7-11; Cambridge, MA. New York: American Society of Civil Engineers: 804-807.

This paper presents a method to quantitatively analyze the location of the effective flow areas at culvert/bridge openings using a one-dimensional flow model based on the conveyance distribution in the cross-section contiguous to the culvert/bridge. The conveyance distribution method can be applied to a full spectrum of storm events and associated peak flows to result in independent water surface elevation results and effective flow boundary locations for a particular storm event. A comparison of standard one-dimensional model, one-dimensional model with effective flow boundaries defined using the conveyance distribution method, and two-dimensional hydraulic model results of an actual complex bridge opening is performed to verify the conveyance distribution method of effective flow boundary definition (A).

Keywords : flow capacity; culvert hydraulics; bridge design; modeling

341. Sauder, E.A. 1984. Utilizing alternative logging methods to reduce mass wasting. In: O'Loughlin,C.L.; Pearce,A.J., eds. Proceedings of the symposium on effects of forest land use on erosion and slope stability; 1984 May 7-11; Honolulu, HI. Honolulu, HI: International Union of Forestry Research Organizations: 223-230.

Examination of slope failures in logged areas showed that: failure-prone sites could be identified; road failures were primarily caused by overloading steep slopes and by poor road-drainage practices; and yarding disturbance appeared to contribute to several failures within clearcuts. On marginally-stable slopes, the roads must be recognized as an integral part of the logging system.

Keywords : logging practices and effects; slope failures; steep slopes and road grades; surface drainage

342. Scatena, F.N. 1990. Culvert flow in small drainages in montane tropical forests: observations from the Luquillo Experimental Forest of Puerto Rico. Tropical Hydrology and Caribbean Water Resources. July:237-246.

This paper describes the hydraulics of unsubmerged flow for 5 culverts in the Luquillo Experimental Forest of Puerto Rico. A general equation based on empirical data is presented to estimate culvert discharge during unsubmerged conditions. Larger culverts are needed in humid tropical montane areas than in humid temperate watersheds and are usually appropriate only for drainages less than 1 km2. However, since culvert size is an exponential function of flow frequency, the cost of designing for 25-year flows is not appreciably greater than the costs associated with culverts based on 10-year flows. (A).

Keywords : culvert hydraulics; surface water; tropical forest; drainage; culvert design

343. Schmidt, Larry. 1978. The use of risk in specifying job quality. Hydrology Notes 8. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region. 8 p.

Management activities involving natural resources have an element of risk involved. Hydrologists have traditionally calculated risks usually related as the return interval for a given climatic event. The concept is often confusing to other land managers who at times fail to understand that the

costs associated with reduced risks are exponential. Through the use of the "Risk Objective Statement" it is possible to better define a reasonable return period for a climatic event for a given project life and risk. The return period may be calculated from an equation, graphs, or a table. Examples are based on erosion control, sediment control and culvert design. (A).

Keywords : risk analysis and design; hydrology; natural resources

344. Schmiege, Donald C. 1980. Influence of forest and rangeland management on anadromous fish habitat in western North America--processing mills and camps. Gen. Tech. Rep. PNW-113. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 22 p.

Keywords : rangeland; forest management and practices; fish; fish habitat; logging practices and effects

345. Sentar Consultants Ltd. 1995. Fish habitat protection guidelines: road construction and stream crossings. Revised. Saskatoon, Sask. Sentar Consultants Ltd. 31 p.

These guidelines are intended to eliminate or minimize the impact of stream crossings and road construction on adjacent lakes and streams in Saskatchewan. The guidelines first outline the legislation and policies relating to the construction of stream crossings and roads adjacent to water bodies in the province. The guidelines then examine the effects of stream crossings, sedimentation, and erosion on fish habitat and behavior. This is followed by topics specifically related to protection of fish habitat: Scheduling of construction activities to avoid conflicts with fish migration, spawning, and incubation periods; route planning to avoid conflicts with fish passage and habitat; reservation of undisturbed vegetation along edges of water bodies; design of bridges and culverts; installation of culverts and other crossings; stream crossing approaches; control of deleterious substances; road maintenance; decommissioning; and control of erosion and sedimentation. A glossary is included.

Keywords : fish habitat; road design and construction; stream crossing design

346. Shera, W.Patrick. 1980. A hierarchical watershed coding system for British Columbia. RAB Tech. Pap. 3. Victoria, B.C. Ministry of Environment, Resource Analysis Branch. 22 p.

A method to store and retrieve information about watersheds developed by the Resource Analysis Branch of the Province of British Columbia, entitled RAB Watershed Code System, reflects the natural directional and hierarchical nature of stream channels and watersheds. Designed for computer data storage, sorting and retrieval, the system is based on the subdivision of watersheds into greater and greater detail. This is accomplished by delineation of major catchments based on map scale of 1:250 000 followed by channel designation and watershed delineation based on a map scale of 1:50 000. Code numbers sequentially assigned to each watershed based on hierarchical organization of watersheds within watersheds give a geographic representation to those numerical values. Lakes, reservoirs, diversions, and ephemeral streams coded in the system follow the same format. Limitations include the need for sufficient map base coverage for areas under consideration and increased complexity from coding additional levels for very small streams.

Keywords : watershed; geographical information systems

347. Sidle, Roy C.; Pearce, Andrew J.; O'Loughlin, Colin L. 1985. Hillslope stability and land use. Water Resources Monogr. 11. Washington, D.C.: American Geophysical Union. 140 p.

This monograph compiles research findings on soil mass movement into a format usable by practitioners and students. Applications are stressed in the areas of extensive land management practices rather than engineering earthworks. Examples are included to illustrate various prediction, avoidance, and control measures used in managing unstable terrain. [Covers introductory topics related to soil mass movement, and factors and analysis of slope stability. Covers effects of land management (including road construction) on soil mass movement. Covers the avoidance and control of soil mass movement, including engineering and structural control methods, terrain evaluation procedures, field investigation of unstable terrain, and nonstructural avoidance and control measures. (glossary, 400+ references)].

Keywords : mass movement; soil conservation; land management; slope failures

348. Simon, A.L.; Sarikelle, S.; Korom, S.F. 1987. Internal energy dissipators for culverts on steep slopes with inlet control. Transportation Research Record. 1151:25-31.

Results of a model study of internal energy dissipators for culverts on a steep slope and operating under inlet control are discussed. The shortest ring chamber design that effectively reduces the outlet velocity is provided. Ring chamber diameters are expressed as a function of the upstream Froude number. Spacing and dimensions of roughness elements are related to ring chamber diameter. The model results are compared with prototype performance and adjusted to improve their accuracy. Hydraulic design parameters that affect the operation of such culverts are discussed, and practical design procedures are given. (A). 10 Refs.

Keywords : baffles; steep slopes and road grades; culvert inlets; culvert design

349. Simons, D.B.; Li, R.M.; Anderson, B.A. 1982. Soil erosion and sedimentation analysis of forest roads in northern California. Colorado State University Rep. CER81-82DBS-RML-BAA74. San Francisco: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 110 p.

The specific objective of this study was to test and refine a mathematical model that estimates soil loss and rainfall runoff from timber access roads in California. The ultimate goal was to provide a useful predictive model of water and sediment yields for use in road planning, maintenance, location design, and environmental impact evaluation. The field data collection program p[provided the data base essential to the calibration of the model SIMSED. Once calibrated, SIMSED became the primary tool in producing a quantitative procedural guide and an interactive program capable of estimating soil loss and runoff volumes from timber access roads. Both product are able to assess the effects of input conditions and changes in land use practices which lead to the selection of the optimum roadway design alternative. A procedural guide was developed to aid the forest planner with an accurate and effective means of determining the sedimentation discharge from various roadway design alternatives. An interactive road sediment program called SIMAK was developed and is capable of producing the same results as the procedural guide and has the added advantage of executing all time consuming calculations and procedures quickly and efficiently.

Keywords : soil erosion; erosion processes; sedimentation; road erosion; modeling; runoff

350. Simonson, Timothy D.; Lyons, John; Kanehl, Paul D. 1993. Guidelines for evaluating fish habitat in Wisconsin streams. Gen. Tech. Rep. NC-164. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 36 p.

Describes procedures for evaluating the quality and quantity of habitat for fish in small and medium streams of Wisconsin. Provides detailed guidelines for collecting and analyzing specific quantitative habitat information.

Keywords : fish habitat; watershed disturbance; stream habitat surveys

351. Skaugset, A.E.; Pyles, Marvin R. 1991. Peak flow estimation and streamflow simulation for small forested watersheds. In: Design and maintenance of forest road drainage; 1991 November 18-20; Corvallis, OR. Corvallis, OR: Oregon State University: 1-18.

The single piece of hydrologic information that is needed most often for adequate design and maintenance of forest roads is design peak flow estimates for stream crossings. Current forest road layout, especially in steep forest terrain, results in a large number of stream crossings of small, ungaged, forest streams. In the past, methods for estimating design peak flows for these streams included Talbot's formula, the Rational Method, or the SCS method. Because of the lack of applicability to forested streams the preceding methods are not recommended. A method for estimating peak flows in Oregon, Campbell's equations, which correlate peak flows for a given design return period with watershed characteristics, is recommended. For the above four methods; theory, formulas, rationale for use and drawbacks are presented. To estimate magnitude of intermediate flows for fish passage, the Antecedent Precipitation Index (ADI) which requires a record of precipitation intensity and watershed area, is recommended. The development and theory of flow frequency analysis using principles of statistical estimation to make inferences about the total population of streamflows from finite streamflow records is included along with examples.

Keywords : discharge; stream crossing; forest roads; streamflow; watershed

352. Smith, C.D.; Oak, A.G. 1995. Culvert inlet efficiency. Canadian Journal of Civil Engineering. 3:611-616.

The results of experimental work carried out on culvert inlet efficiency at the University of Saskatchewan are reported in this paper. Efficiency is reported in terms of coefficient of discharge when the culvert operates with inlet control, and in terms of the coefficient of entrance loss when the culvert operates with outlet control. A larger coefficient of discharge or a smaller coefficient of entrance loss represents a higher efficiency. Seven different culvert inlets were tested for both inlet and outlet control, and for the headwater level both above and below the elevation of the crown of the pipe at the inlet. The results are reported in nondimensional charts. (A) Refs.

Keywords : culvert inlets

353. Stakhiv, Eugene Z. 1986. Status of risk analysis in water resources engineering. In: Risk-based decision making in water resources: Proceedings of an Engineering Foundation conference; 1985 November 3-5; Santa Barbara, CA. New York: American Society of Civil Engineers: 111-128.

Acceptance of probabilistically based risk-analysis evaluation methods among water resources engineers is rather slow, as it is among other engineering specialties. Academic researchers promote a wide variety of advanced methods to assist in the efficient design of water-related structures ranging from highway culverts, levees, and dam spillways to marine breakwaters. Yet, there is considerable resistance in using these techniques for very fundamental and understandable reasons. Risk analysis is advocated here, as in many other forums, as a way of dealing with the evaluation of important but uncertain decision variables in an explicit and formal manner. (Edited author abstract) Refs.

Keywords : risk analysis and design; water resources; modeling

354. Stanford, J.A.; Ward, J.V. 1992. Management of aquatic resources in large catchments: Recognizing interactions between ecosystem connectivity and environmental disturbance. In: Naiman, Robert J. editors. Watershed management: Balancing sustainability and environmental change. New York: Springer-Verlag: 91-124. Chapter 5.

Management within catchment basins must be approached with an empirically based understanding of the natural connectivity and variability of structural and functional properties of riverine ecosystems. Rivers are four-dimensional environments involving processes that connect upstream-downstream, channel-hyporheic (groundwater), and channel-floodplain (riparian) zones or patches, and these differ temporally. Natural and human disturbances, including biotic feedback (such as predation, parasitism, and other food web dynamics), interact to determine the most probable biophysical state of the catchment ecosystem. Human disturbances can be quantitatively determined by deviations from an observed biophysical state (baseline), but usually this requires long-term ecological data sets. A case history of the Flathead River-Lake system in Montana (USA) and British Columbia (Canada) is summarized to illustrate how disturbances interact at the catchment level of organization. Owing to the natural complexities of catchment ecosystems and the cumulative effects of human disturbances, the rationale and logistics of obtaining long-term data often seem intractable and excessively expensive. The naive alternative is to derive and implement simplistic procedures that are agency specific and often result in management actions that interfere with each other. We argue that integrated management at the catchment level is needed and propose some simple principles, beginning with broader based collegiate training for prospective managers. (A).

Keywords : aquatic life; ecosystem approach; catchments; watershed disturbance

355. State of Washington, King County. 1990. Culvert and bridge design criteria. In: King County surface water design manual. Seattle: Washington State, King County: 4.3.5-1 to 4.3.5-16.

Procedures are presented to provide for the analysis of both inlet and outlet control conditions to determine which of those two conditions are governing flow capacity. Design criteria for headwater elevation, inlet and outlet control of culvert flow are presented in the form of lists. Tables of constants for control equations and nomographs for headwater elevation for inlet or outlet control for use in flow analysis are included. Methods of analysis required to provide for fish passage/migration are given in the form of criteria. Estimating procedures for flow in ungaged streams and design criteria and analysis methods for bridges are also included.

Keywords : bridge design; handbooks; culvert design; culvert fish passage; surface water; culvert inlets; culvert outlets

356. Steinbrenner, E.C.; Gessal, S.P. 1955. The effect of tractor logging on physical properties of some forest soils in southwestern Washington. Proceedings of the Soil Science Society of America. 19372-376.

An increase in tractor logging in recent year and resulting concern regarding skid road compaction led to this investigation of the effects of tractor logging on the physical properties of soils in southwestern Washington. Nine areas of recent tractor logging with adjacent undisturbed mature timber were selected for sampling. Samples were obtained from the undisturbed timber which was used as a control, tractor roads, and tractor cutover on each of these areas. The latter included all of the area not in the major skid road system. the samples consisted of 3-inch soil cores taken at the surface with a special sampling tool. Soil permeability rate, bulk density and pore space distribution were determined for each sample in the laboratory. Results showed that the soils from the tractor cutover had 35% loss in permeability rate, a 2.4% increase in bulk density and a 10% decrease in macroscopic pore space when compared to the timber control. The tractor roads showed a 93% loss in permeability, a 15% increase in bulk density and a 53% loss in macroscopic pore space. The areal extent of the tractor skid roads in this study was found to be 26% of the logged area. (A).

Keywords : logging practices and effects; soil compaction; soil properties; skid trail

357. Stenmark, Christer. 1995. Alternative road construction for stormwater management in cold climates. Proceedings of the 1995 2nd NOVATECH conference on innovative technologies in urban storm drainage; 1995 May 30-June 1; Lyon, France. In: Water Science and Technology. 32(1): 79-84.

A field study of an infiltration and detention facility in northern Sweden is presented. Streets in a housing area were reconstructed to increase the permeable area. Permeable asphalt was used covering a coarse fill material and swales (ditches) were constructed along both sides of the streets. The project will include studies of the water balance during different seasons, frost heave and frost penetration of the streets and the storm water quality. Due to the reduced infiltration capacity during snowmelt periods, detailed studies will be performed on components of the facility that are important for the disposal of meltwater. Some initial tests of the infiltration capacity of permeable asphalt in cold temperatures indicated sufficient capacity during snowmelt periods (A). 8 Refs.

Keywords : road design and construction; storm flow response; cold regions; infiltration; climate

358. Stickney, Patricia L.; Swift, Lloyd W.; Swank, Wayne T., comp. 1994. Annotated bibliography of publications on watershed management and ecological studies at Coweeta Hydrologic Laboratory, 1934-1994. Gen. Tech. Rep. SE-86. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 119 p.

This annotated bibliography spans over 60 years of research at Coweeta from 1934 through part of 1994, and includes earlier papers on forest influences written at the Appalachian Station before the establishment of Coweeta. It is a modification and update of previous compilations of research results at Coweeta and contains a separate section listing theses and dissertations. Papers were included if authors conducted research in the Coweeta Basin, utilized Coweeta data in their analyses, or were partially supported either with funding or assistance by the Southeastern Forest Experiment Station (C).

Keywords : bibliography; research; hydrology; forest management and practices

359. Straub, Lorenz G.; Morris, Henry M. 1950. Hydraulic tests on corrugated metal culvert pipes. Tech. Pap. 5, Series B. Minneapolis, MN: University of Minnesota, Saint Anthony Falls Hydraulic Laboratory. 24 p.

Experimental studies on culverts conducted at the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota, beginning in 1946, included several series of observations on commercial, corrugated metal culvert pipes. The primary purpose of these large-scale tests was to obtain pipe friction and entrance loss coefficients which would be more accurate and dependable than those currently recommended in culvert design literature. Two types of corrugated metal culverts were tested, namely, the circular and the pipe arch types. In each case, three different nominal diameter pipe sections were tested--18, 24, and 36 inches, making a total of six corrugated metal culverts in the test program. Each pipe was 193 feet long and laid on a slope of 0.20 percent. Friction and entrance loss coefficients were established for the culverts under the usual conditions of field operation. With this objective in view, each pipe was tested for the following conditions: (a) Full flow with submerged inlet and outlet, (b) Part-full flow at uniform depth. For each flow condition, several values of head and discharge were used. In addition, five of the culverts were tested with two different entrance conditions: (a) Pipe projecting two feet into the headwater pool, (b) Pipe entrance flush with headwall. For pipes flowing full, the friction factor shows a marked increasing tendency as the Reynolds number increases; Manning's n coefficient also showed an increase over the Reynolds number range investigated. For uniform subcritical flow, the Manning's n did not vary with Reynolds number . Recommendations for n values for circular pipes and pipe arches are given for part-full flow and subcritical flow.

Keywords : culvert hydraulics; corrugated metal pipe; friction in pipes; Manning's formula

360. Suarez, D.; Saunders, G.P. 1986. Hydrologic design and application problems associated with lignite mining: Preprints for presentation at the SME annual meeting; 1986 March 2-6; New Orleans, LA. Prepr. 86-109. Littleton, CO: AIME, Society of Mining Engineers. -10 p.

Typical hydrologic issues are discussed. They fall in the following general categories: design criteria for sizing water control structures (i. e., culverts, diversion and sedimentation ponds, ditches); implementation (construction and operation) difficulties; regulatory compliance; reclamation planning; and protection of groundwater resources. 6 refs.

Keywords : hydrology; mining; drainage structures; ditches

361. Swank, W.T.; Bolstad, P.V. 1994. Cumulative effects of land use practices on water quality. In: Hydrological, chemical and biological processes of transformation and transport of contaminants in aquatic environments: Proceedings of a symposium; 1993 May 24-29; RostovonDon, Russia. IAHS Pub. No. 219. Wallingford, Oxfordshire, UK: International Association of Hydrological Sciences: 409-422.

Water quality parameters monitored along a Southern Appalachian stream gradient were correlated with cumulative alterations in landscape status. The predominantly forested study area had high water quality under baseflow conditions. Water quality parameter values increased markedly under stormflow conditions. Pronounced linear relationships were observed between paved road density, percent nonforest, and other landscape variables with some water quality indicators. (5 graphs, 1 maps, 17 references, 4 tables).

Keywords : land management; water quality

362. Swanson, Frederick J.; Benda, Lee E.; Duncan, Stanley H.; Grant, Gordon E.; Megahan, Walter F.; Reid, Leslie M.; Ziemer, Robert R. 1987. Mass failures and other processes of sediment production in Pacific Northwest forest landscapes. In: Salo, Ernest O.; Cundy, Terrance W., eds. Streamside management: forestry and fishery interactions: Proceedings of a symposium; 1986 February 12-14; Seattle. Contribution No. 57. Seattle: University of Washington, Institute of Forest Resources: 9-38.Chapter 2.

Accelerated sediment production by mass failures and other erosion processes is an important link between management of forest resources and fish resources. Dominant processes and the rates of sediment production vary greatly throughout the Pacific Northwest in response to geologic and climatic factors. The complex sediment routing systems characteristic of the area involve numerous processes that move soil down hillslopes and sediment through channels. Sediment routing models and sediment budgets offer conceptual and quantitative descriptions of movement and storage of soil and sediment in drainage basins. Temporal and spatial patterns of sediment production and routing through basins have many direct and indirect effects on fish. In addition to their role as dominant mechanisms of sediment production in many parts of the region, mass failures also affect the geometry and disturbance regimes of channels and streamside areas. Earth flows locally control the vegetation structure and composition of riparian zones through influences on valley floor width, gradient of side slopes and channels, and frequency of streamside debris slides. Debris flows can have long-term effects on channels and streamside landforms and vegetation. It is important to consider sediment production and the effects of mass failures on channels and riparian zones in the context of an entire drainage basin, because effects vary with location in a basin. Forestry practices can increase production of sediment. Results of experimental manipulations of vegetation on small drainage basins and studies of individual erosion processes indicate that debris slides and road surfaces are commonly dominant sources of accelerated sediment production. Some techniques are available for locating sites susceptible to accelerated erosion, for predicting change in sediment production, for evaluating the biological consequences of accelerated erosion, and for designing mitigation measures, but clearly more work is needed in each of these areas.

Keywords : slope failures; sediment modeling; mass movement; forest management and practices

363. Swanson, Frederick J.; Dyrness, C.T. 1975. Impact of clear-cutting and road construction on soil erosion by landslides in the western Cascade Range, Oregon. Geology (Boulder). 3(7):393-396.

The H. J. Andrews experimental forest can be divided into two zones of approximately equal area, each with strikingly different susceptibilities to erosion by rapid soil movements. A stable zone occurs at elevations above 900 to 1,000 m in terrain underlain by lava-flow bed rock. Since logging and road cutting began in 1950, only two small road-related slides have taken place in the stable zone. In contrast, the unstable zone, located at elevations below 1,000 m and underlain by altered volcaniclastic rock, has been the site of 139 slides during the same period. Slide erosion from clear-cut areas in the unstable zone has totaled 6,030 m3/km2, or 2.8 times the level of activity in forested areas of the unstable zone. Along road rights-of-way, slide erosion has been 30 times greater than on forested sites in the unstable zone; however, only about 8 percent of a typical area of deforested land in the unstable zone is in road right-of-way. At comparable levels of development (8 percent roads, 92 percent clear-cut), road right-of-way and clear-cut areas contribute about equally to the total impact of management activity on erosion by landslides in the unstable zone. The combined management impacts in the unstable zone (assuming 8 percent road right-of-way and 92 percent clear-cut) appear to have increased slide activity on road and clear-cut sites by about 5 times relative to forested areas over a period of about 20 years. (forest service).

Keywords : impact analysis; clear-cutting; road construction effects; erosion processes; landslides; forest management and practices

364. Swanston, D.N. 1971. Principal mass movement processes influenced by road building, logging and fire. In: Morris, J., ed. Proceedings of a symposium: Forest land uses and stream environment; 1970 October 19-21; Corvallis, OR. Corvallis, OR: Oregon State University, Continuing Education Publication: 29-39.

Dominant natural soil mass movement processes active on watersheds of the western United States include (1) debris avalanches, debris flows and debris torrents; (2) slumps and earth flows; (3) deep-seated soil creep; and (4) dry creep and sliding. A dominant characteristic of each is steep slope occurrence, frequently in excess of the angle of stability of the soil. All but dry creep and sliding occur under high soil moisture conditions and usually develop or are accelerated during periods of abnormally high rainfall. Further, all are encouraged or accelerated by destruction of natural mechanical support on the slopes. Logging, road building, and fire play an important part in initiation and acceleration of these soil mass movements. Road building stands out at the present time as the most damaging activity, with soil failures resulting largely from slope loading, back-slope cutting, and inadequate slope drainage. Logging and fire affect stability primarily through destruction of natural mechanical support for the soils, removal of surface cover, and obstruction of main drainage channels by debris (A).

Keywords : mass movement; road construction effects; steep slopes and road grades; logging practices and effects; forest fires

365. Swanstrom, Shannon C. 1995. The trend toward ecosystem-based management in the north Pacific anadromous fisheries. Col Journal of International Environmental Law Policy. 6(1):225-248.

Keywords : fish; ecosystem approach; forest management and practices

366. Swift, L.W., Jr. 1985. Gravel and grass surfacing reduces soil loss from mountain roads. Forest Science. 30(3):657-670.

Soil loss from forest roads was measured on two soils in the southern Appalachian Mountains. Losses from a roadbed without surfacing (bare soil) and later with grass cover were compared with those from roadbeds surfaced with different types and amounts of rock. In the first two months after construction in a deep sandy loam saprolite, soil loss rates were eight times greater from the bare soil site than from roadbeds with 15 to 20 cm of gravel. Loss rates declined in a 6-month period of light traffic and the cumulative loss during the first 8 month after construction was over 200 t/ha from the bare soil roadbed and less than 35 t/ha from roadbeds surfaced with graded crushed rock or large (7.5 cm) washed stone. Loss rates rose as logging traffic began and at the conclusion of the timber sale, roads were reshaped and ungraveled portions grassed. During logging, a site with a thin layer (5 cm deep) of crushed rock became heavily rutted and additional gravel was added. In the third year, erosion rates on this lightly graveled site approximately equaled those of bare soil, twice that of a grassed roadbed. Where the road was built with the B horizon of sandy clay loam, soil losses with 5 cm and 15 cm of gravel were intermediate between the high and low losses from similar surfacings on sandy loam saprolite. Differences in soil loss and trafficability persisted into the fourth year. Maintenance of forest roads disturbed stabilized road surfaces and contributed to soil losses. (A).

Keywords : erosion control; forest roads; gravel roads; road grass seeding; road surface erosion; soil erosion

367. Swift, Lloyd W., Jr. 1984. Soil losses from roadbeds and cut and fill slopes in the southern Appalachian Mountains. Southern Journal of Applied Forestry. 8(4):209-213.

Soil losses were measured on the cut, fill and roadbed surfaces of a forest road at Coweeta Hydrologic Laboratory. Before grass was planted or gravel spread, roadbed surfaces had the least loss per unit area and loss was primarily waterborne fine particles. A large part of the soil loss form fill slopes was due to slippage of wet soils in early spring. Surface erosion of fills was negligible because storm water from the roadbed was not spilled across loose soil. The cut slopes eroded most, principally because soils were loosened by diurnal cycles of freezing and thawing in winter. This study show that inclined surfaces of cut and fill slopes are potential sources of large soil loss but these losses can be mitigated by early establishment of grass cover and by design features to control storm water. Soil loss from roadbeds was greatly reduced by gravel surfacing.

Keywords : cut slope; erosion control; fill slope; road construction materials; road grass seeding

368. Swift, Lloyd W., Jr. 1985. Forest road design to minimize erosion in the southern Appalachians. In: Blackmon, B.G., ed. Proceedings of forestry and water quality: a mid-South symposium; 1985 May 8-9; Little Rock, AR. Monticello, AR: University of Arkansas, Department of Forest Resources: 141-151.

Excessive erosion and low serviceability of roads are continuing problems associated with forest management in the mountains of the Southeastern United States. Road and erosion research at Coweeta Hydrologic Laboratory in western North Carolina dates from roadbank stabilization work in the 1930's. Emphasis has been to develop and demonstrate a low-cost, low-maintenance road design. Results cover such features as: drainage and the broad-based dip, cut-bank design and stabilization, roadbed surfacing, brush barriers and filter strips, culvert sizing, and transportation planning. Application of knowledge gained permits roads to be built and maintained at lower cost while providing practical control of sediment input to streams.

Keywords : forest roads; road design and construction; erosion control; cut slope

369. Swift, Lloyd W., Jr. 1986. Filter strip widths for forest roads in the southern Appalachians. Southern Journal of Applied Forestry. 10(1):27-34.

Filter strip standards currently applied to forest roads in the southern Appalachian Mountains may specify greater widths than are necessary with prevailing construction practices. Measurements of the distance that sediment traveled downslope below newly constructed roads were less than previously reported. Distances were notably less if natural obstructions existed on the forest floor, brush barriers constructed at the edge of the right-of-way, road fills grass-covered, and road outsloped and drained by broad-based dips. Discussion of management considerations lead to proposed revised guidelines for minimum filter strip widths for the southern mountains (A).

Keywords : sediment modeling; best management practices; erosion control; road grass seeding

370. Swift, Lloyd W., Jr. 1988. Forest access roads: design, maintenance, and soil loss. Forest Hydrology and Ecology at Coweeta, Ecological Studies. 66(1):313-324.

The design and construction of, and soil loss from, forest roads have been continuing areas of research and demonstration by the Southeastern Forest Experiment Station since Coweeta Hydrologic Laboratory was established. The low-cost, low-maintenance intermittent-use road

pioneered by Coweeta is widely accepted and adapted to local conditions by government and industry land managers, and strongly recommended by state agencies with the aim of reducing sediment, the principal nonpoint source of pollution from forestry activities. Several principles can be drawn from the Coweeta studies. An inexpensive design and field layout procedure can produce a serviceable and environmentally acceptable road. The most effective road system results from a transportation plan developed to serve an entire basin rather than he sum of individual road projects constructed to serve short-term needs. Soil exposed by construction should be revegetated quickly. Where possible, storm waters should be removed from the road at frequent intervals and in small amounts by outsloping and dips, rather than by consolidation into ditch-lines and culverts. Contour roads and gentle grades require less maintenance and produce less sediment. Gravel surfacing is best, but a grassed roadbed is good where traffic is light and can be controlled to exclude use in wet weather. If only a small quantity of gravel is available, it should be applied on climbing grades, poor trafficability soils, in dips, and near stream crossings. The stream crossing is the most critical part of the entire road, and every effort should be made to protect and vegetate fill slopes and divert storm waters on the road away from the stream. Filter strips and brush barriers prevent sediment from reaching streams. Unnecessary maintenance must be avoided. (See also W89-01691) (Lantz-PTT).

Keywords : forest roads; soil erosion; road construction effects; road design and construction

371. Swift, Lloyd W., Jr. 1993. Access roads. In: Smith, Andrew R., ed. “Nothing could be finer”: a story of soil and water conservation in North Carolina: Proceedings, international meeting of the Soil Conservation Society of America; 1986 August 3-7; Winston-Salem, NC. Raleigh, NC: North Carolina Chapter of the Soil Conservation Society of America: 16-17.

Standards developed at Coweeta for forest access roads are described in this chapter of a special booklet on erosion control practices prepared for distribution at the Soil Conservation meeting (C).

Keywords : forest roads; road design and construction; erosion control

372. Szafron, Brent J.; Fredlund, D.G. 1992. Monitoring matric suction in the subgrade of unpaved roads. In: Proceedings of the 45th Canadian geotechnical conference; 1992 October 26-28; Toronto, ON. Toronto, ON: [Publisher name unknown]: 52-1 to 52-10.

The performance of thin pavements and gravel roads is controlled by the strength of the subgrade soil which in turn is a function of the matric suction. An understanding of the subgrade matric suction profile is important to the design and analysis of pavement structures. Thermal conductivity matric suction sensors and an automated data acquisition system were used to continuously monitor matric suctions in the subgrade of a gravel road. The range of suctions that can be measured by the sensors is 0 to 400 kPa. Continuous measurements can be used to better understand the relationship between microclimatic conditions and the matric suction in the soil. The matric suctions were monitored at several locations in the subgrade over a period of several months. The matric suction profile of the subgrade in this study was not uniform with location. Suctions were generally lower, and possibly even zero near the surface of the shoulder and side-slope of the road. This explains the frequent occurrence of shallow bearing capacity type failures near the outside edge of roads. Infiltration first reduces suctions near the surface. This creates a situation where the strength is decreased in an area where the applied stresses are the

greatest. Subgrade matric suction is influenced by the microclimate. Matric suctions in the outside edge of the subgrade generally increase when precipitation decreased. Matric suction in the traveled portion of the road were less influenced by the microclimate. (A) 4 Refs.

Keywords : groundwater and subsurface flow; unpaved roads; measurement methods and monitoring; road design and construction

373. Tebo, L.B., Jr. 1955. Effects of siltation, resulting from improper logging, on the bottom fauna of a small trout stream in the southern Appalachians. Progressive Fish-Culturist. 17:64-70.

Siltation resulting from improper land use practices is regarded as one of the most important factors contributing to a reduction in the acreage of desirable fishing waters. This report presents quantitative data regarding effect of siltation on bottom fauna of trout streams in the southern Appalachians.

Keywords : logging practices and effects; sedimentation; fish habitat; fish; stream pollution

374. Temple, William H.; Cumbaa, Steven L. 1987. Evaluation of metal pipe drainage durability after ten years. Transportation Research Record. 1087:7-14.

This study represents an investigation of the comparative performance of coated and uncoated, corrugated, galvanized steel and aluminum drainage pipe in Louisiana. The highly corrosive environments in some areas of the state make durability requirements of metal pipe as critical as strength requirements Department personnel installed ten types of metal drainage pipes at each of ten locations in 1973. The test sites were selected on the basis of the pH and the electrical resistivity of the soil and the effluent. One pair of each type of culvert was installed at each site. Every two years one designated culvert of each of the pairs was removed and subjectively rated by a panel. The final (10-year) panel ratings reflect the condition of the undisturbed culverts in each pair. It was found that, in general, the 16-gauge asphalt-coated aluminum; the 14-gauge asbestos-bonded, asphalt-coated galvanized steel; and the 16-gauge galvanized steel with a 12-mil interior and a 5-mil exterior polyethylene coating were the test pipes with the most resistance to corrosion at the majority of the test sites. It was also found that, although all of the coatings provided added resistance to corrosion to some degree, the thicker coatings tested provided increased protection to the base metal. Comparisons of actual versus predicted years to perforation are made for galvanized steel in the harsher environments where test culverts actually experienced perforation. (A).

Keywords : culvert deterioration; corrugated metal pipe; service life; corrosion; culvert - aluminum; culvert coating; drainage structures; culvert durability

375. Temple, William H.; Rasoulian, Masood; Gueho, Bruce J. 1981. Evaluation of drainage pipe by field experimentation and supplemental laboratory experimentation. Baton Rouge, LA: Louisiana Department of Transportation and Development, Research and Development Section; interim report 154. 52 p.

This study represents an investigation of the durability properties of coated and uncoated, corrugated, galvanized steel and aluminum drainage pipe in Louisiana. The highly corrosive environments in some areas of the state make durability requirements of metal pipe as critical as strength requirements. Research and maintenance personnel of the Department installed ten types of metal drainage pipes at each of ten locations in 1973. An eleventh type of drainage pipe was added to each location for evaluation in 1975. In 1977 the investigators installed the battery of test culverts at another test site where the environment differed from that of the previous ten locations. Research personnel selected the test sites based on geographical location and on the pH and electrical resistivity values of the soil and effluent. The type of culvert providing the best resistance to corrosion after six years of field exposure at 10 sites is the asbestos-bonded, asphalt-coated, galvanized steel pipe. This is the consensus of a panel which inspected the test culverts in the field and of a laboratory evaluation. Aluminum alloy culverts have shown significant pitting in the environment with pH less than 5 as well as environments with resistivity less than 1000 ohm-cm after six years of service. All of the coatings are exhibiting on degree or another of distress in highly corrosive areas of the state. (A).

Keywords : corrugated metal pipe; culvert durability; culvert deterioration; culvert - aluminum; drainage; experiment; culvert coating

376. Terrene Institute. 1994. Riparian road guide: managing roads to enhance riparian areas [Pamphlet]. Washington, DC: Terrene Institute. 32 p. In cooperation with: Environmental Protection Agency, Region 6 Water Management Division, Water Quality Management Branch.

This booklet is taken largely from another article: LaFayette, Russell A.;Pruitt, John R.; Zeedyk, William D. 1993. Riparian area enhancement through road management. It presents a number of cost-effective road construction practices that are easy to install and maintain. Their use can help local governments maintain clean water and safe roads while simultaneously enhancing and restoring the health and value of riparian areas. The techniques were developed for the USDA Forest Service Southwestern Region, but may be applicable elsewhere.

Keywords : riparian zone; road management; road design and construction; road construction effects

377. Tew, Howard C.; Price, Lane C.; Swift, Lloyd W., Jr. 1985. The layman's guide to private access road construction in the southern Appalachian Mountains. Waynesville, NC: U.S. Department of Agriculture, Soil Conservation Service. 29 p.

This fully illustrated booklet guides the farmer, home owner, summer home developer, contractor or real estate agent through the planning, design, construction and maintenance stages for a good access road. Standards include the broad-based dip and other options options based upon Coweeta forest access road demonstrations.

Keywords : dips and waterbars; road design and construction

378. Thorne, Colin R.; Zevenbergen, Lyle W. 1985. Estimating mean velocity in mountain rivers. Journal of Hydraulics Division, American Society of Civil Engineers. 111(4):612-623.

It is often necessary to estimate the mean velocity in ungaged mountain rivers, but the flow resistance equations available for this purpose require further testing and development. Such rivers

are characterized by coarse bed materials, steep slopes, and low depths. For these conditions, boulders protrude well or completely through the flow, and bed roughness is sail to be large-scale. Recently, three equations specifically intended for large-scale roughness have been developed to address this problem. Data from a mountain river were used to test the equations. All were prone to errors of the order of 30%. The errors were systematic, all the equations tending to overestimate mean velocity compared to observed values. An investigation of the possible sources of error suggested that sampling error in the knowledge of bed material size was a major source of uncertainty in the predicted velocities, but that this and discharge errors could not wholly account for the observed discrepancies. Boulder shape is not represented in the equations, but this was discounted as an important parameter on the basis of a flume study. It was concluded that further research is required to produce a reliable, process based, flow resistance equation for mountain rivers. (A).

Keywords : flow velocity; hydrologic analysis

379. Toews, D.A.A.; Brownlee, M.J. 1981. A handbook for fish habitat protection on forest lands in British Columbia. Vancouver, B.C. Government of Canada, Dept. of Fisheries and Oceans, Field Services Branch, Habitat Protection Div., Land Use Unit: 166 p.

Chapter 2 describes basic aquatic ecology in terms of the aquatic ecosystems upon which salmonids and other important organisms depend. The linkages to surrounding land features, processes, and activities are outlined so that the specific impacts of forestry activities on aquatic ecosystems and organisms may be understood. Chapter 3 outlines the way in which fisheries management and forest management are undertaken in B.C. and explains the procedures that exist for cooperative planning between agencies as well as their day by day working relationships. Following this is an outline of the kind of technical information that is required for joint planning and for the resolution of day to day problems, and the sources of the more detailed information that may be required. Chapter 4 commences with general description of forestry activities and the kind of impacts they have on aquatic organisms and their habitats. Following this are specific sections on the major forestry activities; Prelogging Planning, Falling and Yarding, Forest Roads, Silviculture, and Coastal Log Handling and Transportation. These sections document the full range of potential impacts on aquatic organisms and habitats and the important linkages or cause and effect relationships with the surrounding land and specific forestry practices. Specific measures are offered that can be employed to protect aquatic ecosystems. These measures are primarily designed to be implemented in the early planning stages of forestry development, but many examples of protection steps that can be taken on a day to day basis during logging activity are also shown. Appendices . . . contain pertinent example material or copies of documents or other material too bulky to be included in the main body of the Handbook. A Glossary . . . follows Chapter 4. (Excerpts from reader's guide).

Keywords : aquatic life; best management practices; fish; forest management and practices; handbooks; road impacts

380. Travis, Michael D.; Tilsworth, Timothy. 1986. Fish passage through Poplar Grove Creek culvert, Alaska. Transportation Research Record. 1075:21-26.

An experimental procedure was developed to analyze the ability of a highway culvert to pass fish. By using a visual technique, the swimming performance of Arctic grayling (Thymallus arcticus) was monitored in Poplar Grove Creek, Alaska. The highway culvert is 110 ft long and 5 ft in diameter, and is inadequate for fish passage if the Alaska Department of Fish and Game criteria are applied.

A request for information on fish passage was sent to US and Canadian highway departments and fishery agencies. Eighteen highway departments reported having a good working relationship with resource agencies when addressing fish passage problems. (Edited author abstract) 5 refs.

Keywords : fish passage; culvert - highway; culvert fish passage

381. Trimble, G.R.; Weitzman, S. 1953. Soil erosion on logging roads. Soil Science Proceeding. 17:152-154.

In rugged mountainous country, skid roads used in logging operations cause serious erosion, To determine the important factors in skid-road erosion, and to find ways to reduce this erosion, sample skid roads were studied before, during, and after experimental logging operations on the Fernow Experimental Forest in West Virginia. Erosion was related to grade, length of slope, intensity of use, soil, vegetation, and climatic factors. Degree of erosion was determined for different skid-road conditions. Measures for reducing erosion are recommended for use in locating, construction, using, and maintaining skid roads. Drainage measures such as diversion ditches and water bars are essential. Spacing for water bars are recommended for different grades. (A).

Keywords : road erosion; erosion processes; skid trail; dips and waterbars; logging practices and effects

382. Tsihrintzis, Vassilios A. 1995. Effects of sediment on drainage-culvert serviceability. Journal of Performance of Constructed Facilities. 9(3):172-183.

The primary function of a drainage culvert--to convey the design flow effectively--is often greatly impaired or completely lost due to the presence of deposited sediments. The effect of sediments on the total head loss within the culvert may be quite significant. A case study is presented that describes the performance of a roadway drainage culvert designed for clear-water flow conditions in an alluvial stream carrying sediments. The actual capacity of the culvert is approximately only 20% of the presumed design capacity, as a result of sediment deposition not accounted for in the design. The case study reviews design errors and demonstrates the necessity of sediment-transport calculations when designing roadway drainage culverts in ephemeral alluvial streams. Ignoring sediment transport may have adverse effects, including significant road and adjacent-property flooding as well as continuous and costly maintenance problems. It is more economical to undertake a complete sediment-transport study before design than to deal with continuous maintenance after the project is built. (A, 16 references).

Keywords : sedimentation; drainage crossing; culvert design; flow capacity; culvert analysis

383. Tung, Yeou-Koung; Bao, Yixing. 1990. Optimal design of highway drainage structures. In: Hydraulic engineering: Proceedings of the 1990 national conference, part 1 (of 2); 1990 July 30-August 3; San Diego, CA. Boston, MA: American Society of Civil Engineers, Hydraulics Division: 210-215.

Hydraulic design of a bridge or culvert using a risk-based approach is to choose among the alternatives the one associated with the least total expected cost. In this paper, the risk-based design procedure is applied to pipe culvert design. The effect of the hydrologic uncertainties such as sample size and type of distribution model on the optimal culvert design parameters including design return period and total expected cost are examined in this paper. (A) 7 Refs.

Keywords : drainage structures; drainage crossing; highway construction; risk analysis and design; bridge design; culvert design

384. U.S. Army Corps of Engineers. 1955. Friction losses in corrugated metal pipe. Bonneville, OR: Bonneville Hydraulic Laboratory; civil works investig. 25 p.

Tests to determine friction factors for 3-, 5-, and 7-feet diameter corrugated metal pipe as indicated by head loss measurements were conducted for a range of velocities up to approximately 10 feet per second (fps) for 5- and 7-feet diameter pipe and 16 fps for 3-feet diameter pipe. New, straight, corrugated metal pipe of standard manufacture was assembled in a manner similar to a conventional installation for the tests. Water from the forebay pool of Bonneville Dam was supplied to the test section through 6-foot pipe. From the test section, water flowed into a metering section where the quantity of flow was measured by means of a parallel system of flat-plate orifices; it was discharged into the Columbia River below Bonneville Dam through gate valve controls and short outlet pipes. Results indicate that a close correlation existed between Reynolds number and both Darcy's friction coefficient "f" and Manning's roughness coefficient "n" throughout the range of experimental discharges reproduced for the study. The value of Manning's "n" remained almost constant at 0.024 during observations of open channel flow in unpaved corrugated metal pipe 3- and 5-feet diameter laid on a slope of 0.005. Values of "n" for 5-feet diameter pipe having paved inverts varied with the percent of paving and the depth of flowing water in test pipe laid on a slope of 0.002. The 0.005 slope of the test section and the size of the supply pipe were such that reliable data for open channel flow could not be obtained for the 7-feet diameter corrugated metal pipe.

Keywords : friction in pipes; corrugated metal pipe

385. U.S. Army Corps of Engineers. 1987. Corps of Engineers wetlands delineation manual. Technical Report Y-87-1. Washington, D.C. U.S. Army Corps of Engineers. 169 p.

This document presents approaches and methods for identifying and delineating wetlands for purposes of Section 404 of the Clean Water Act. (C).

Keywords : law and policy; wetlands; Clean Water Act

386. U.S. Bureau of Public Roads. 1970. Corrugated metal pipe. U.S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads. 26 p.

A design method is presented which takes into consideration major factors that influence design and performance of corrupted metal pipe culverts. The design criteria cover corrugated steel and corrugated aluminum pipe culverts of riveted, resistance spot-welded, helical, and bolted fabrication. Two criteria, deflection or flattening of pipe and the critical buckling of pipe wall, consider the mutual function of the metal pipe barrel and the soil surrounding it as a composite structure. The second two criteria discussed, longitudinal seam strength and handling and installation strength, concern the inherent strength of the pipe alone. Design charts developed from the design criteria relating culvert size to fill requirements are provided. Basic installation requirements necessary to obtain satisfactory performance of pipe culverts are included.

Keywords : corrugated metal pipe; culvert design; culvert installation; culvert - aluminum; design chart

387. U.S. Department of Agriculture, Soil Conservation Service. 1978. Estimating sheet-rill erosion and sediment yield on rural and forest highways. WTSC TN Woodland 12. U.S. Department of Agriculture, Soil Conservation Service.

Details a process to evaluate accelerated sheet and rill erosion and yield from rural and forested highways. Based on the universal soil loss equation (USLE) the procedure considers such factors as rainfall, snowmelt, soil erodibility, slope length and slope gradient, and vegetative or mechanical cover. Contains recommended factors and sample calculations.

Keywords : sedimentation; forest roads; erosion processes; universal soil loss equation

388. U.S. Department of Agriculture, Forest Service. 1980. An approach to water resources evaluation on non-point silvicultural sources (a procedural handbook). EPA-600/8-80-012. Athens, Ga. U.S. Environmental Protection Agency, Environmental Research Laboratory. 824 p.

This handbook provides an analysis methodology that can be used to describe and evaluate changes to the water resource resulting from non-point source pollution due to silvicultural activities. This book is official guidance for the Forest Service. (C).

Keywords : erosion processes; impact analysis; logging practices and effects; non-point source pollution; prediction; sediment modeling; water resources

389. U.S. Department of the Interior, Geological Survey. 1986. Feasibility of assigning a probability to the probable maximum flood. U.S. Department of the Interior, Geological Survey, Office of Water Data Coordination. 79 p. (Available on microfiche; Springfield, VA; National Technical Information Service; no. PB87-136883).

The difficulty in assigning a probability to the probable maximum flood (PMF) and in defining the distribution between the 100-year flood and the PMF impairs the ability to use risk-cost analysis. Given this focus, the purpose of the paper is to address the following questions: 1) is the calculation of the PMF within definable confidence or error bands within the state of the art, and 2) how far out on the probability scale can flood probability be determined within definable confidence and error bounds? In practice, computed PMF's are dangerously small or wastefully large. The methodology utilized to answer the above questions involved multiple searches of bibliographic sources covering published material resulting in five categories of methods: 1) extrapolation of frequency methods, 2) joint probability techniques, 3) regional analysis techniques, 4) determination of paleohydrologic extremes, and 5) Bayesian techniques, for determining flood frequency probabilities. Reviewers were looking for a description of the methodology, variations among papers reviewed, and determining whether the methodology captures the PMF. Few of the papers reviewed dealt with extremely rare events. It is the conclusion of the work group that no procedure proposed to date is capable of assigning an exceedance probability to the PMF or to the near-PMF flood in a reliable, consistent, and credible manner. Reviewed methods have not been systematically tested, therefore, selection of a method or assigning a probability to the PMF would be arbitrary.

Keywords : prediction; flood estimation and control; modeling; risk analysis and design

390. U.S. Department of Agriculture, Forest Service. 1995. Improving culvert entrances to increase flow capacity. San Francisco: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Engineering. 22 p.

Of the two conditions which limit the flow capacity of culverts, outlet or inlet control, a majority of culverts found on Forest Service roads flow under inlet control. With inlet treatments, velocities

through the culvert can be increased, creating culverts capable of handling larger storm events. Five different inlet treatments are considered; projecting inlet, mitered inlet, headwall and wingwall, beveled ring inlet, and side-tapered inlet. Design criteria including fish passage at high velocities and economics; performance curves for best design choice; and examples are given for each treatment.

Keywords : culvert inlets; flow capacity; culvert fish passage

391. U.S. Department of Transportation, Federal Highway Administration; U.S. Department of Agriculture, Forest Service. 1996. Fish passage through culverts [video recording]. San Dimas, CA: USDA Forest Service, Technology Development Center: 14 min. VHS.

This video explains how a hydrologist, a fish biologist, and an engineer all play a crucial role in the designing of a roadway over a stream. It describes the types of culverts and some factors to look for in deciding the type to use. The video gives the advantages and disadvantages to both fish and engineers if the culvert is not maintained. The video is appropriate for all engineering and maintenance staff. See Baker and Votapka (1990) for a companion publication. (C).

Keywords : fish passage; road design and construction; drainage crossing; culvert design

392. VanHaveren, Bruce P. 1979. Hydrologic risk and return period selection for water related projects. Tech. Note 337. U.S. Department of the Interior, Bureau of Land Management. 14 p.

Hydrologists are frequently asked to provide design flows or stages for spillways, bridge openings, culverts, diversion dams, waterways, fish improvement structures, and land treatment measures. Too often a return period or recurrence interval is arbitrarily chosen or a standard return period is used by the hydrologist. The design event chosen by the hydrologist should be based on the risk of failure rather than on an arbitrary or predetermined return period, incorporating the fact that risk increases with increasing project life. The purpose of this Technical Note is to assist the hydrologist in understanding hydrologic risk and in communicating this understanding to the land manager. By combining statistical relationships with tables and graphs, a reference is developed for the hydrologist and other specialists involved with water-related projects where the frequency of hydrologic events is a concern. (A).

Keywords : hydrologic analysis; risk analysis and design; fishways; hydraulic design; bridge design; culvert design; return period

393. Vitaliano, Donald F. 1992. Infrastructure costs of road salting. Resources, Conservation and Recycling. 7(1-3):171-180.

In order to melt frozen precipitation on pavement surfaces, most highway maintenance departments currently employ sodium chloride, which is effective and relatively inexpensive but highly corrosive to metals, damaging to roadside vegetation and a potential source of elevated sodium levels in drinking water. A substitute material, calcium magnesium acetate has been identified as an effective and environmentally benign substitute for salt. The purpose of this study is to estimate the damage costs of salt to the bridges and roads of the United States. 27 Refs.

Keywords : road maintenance; road salting; cold regions

394. Wald, A.R. 1975. The impact of truck traffic and road maintenance on suspended sediment yield for a 14" standard forest road. Seattle: University of Washington. M.S. thesis.

This study examined source and transport processes involved in suspended sediment production within a forest road drainage, and compared suspended sediment concentration during different rainstorms on forest roads receiving, and not receiving, truck traffic during winter months. Results indicate that truck traffic, road construction, road resurfacing, and grading contribute to increased suspended sediment yields. Backslope areas were not found to be major sediment sources on logging roads in this study (C).

Keywords : road maintenance; sedimentation; forest roads; truck traffic; impact analysis; suspended sediment; sediment

395. Walkotten, William J.; Bryant, Mason D. 1980. An instrument to measure stream channel gradient and profiles. PNW-345. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 4 p.

A waterlevel to measure streambed profiles and gradients is described. Line of sight is not required for accurate (to 1 cm) measurements. Assembly and use are discussed. (A).

Keywords : stream channel; measurement methods and monitoring

396. Ward, T.J. 1985. Sediment yield modeling of roadways. In: El-Swaify, S.A.; Moldenhauer, W.C.; Lo, A., eds. Soil erosion and conservation. Ankeny, IA: Soil Conservation Society of America: 188-199.

Historically, most erosion monitoring has focused on agricultural lands. In the last 25-30 years, there has been a growing effort to address the problem of erosion from roadways, specifically those in forest environments. Empirical, long-term sediment yield studies have been conducted. More recently, mathematical modeling of long-term storm event erosion and sediment yield has been attempted. Two general approaches are currently in vogue: empirically derived regression models and physical process models. Research in the field of sediment yield monitoring as it relates to forested areas is reviewed and results of model validation are discussed. Sites in which the modeling validation was conducted are: Coweeta Experimental Watershed, North Carolina; mine haul roads in Montana and Idaho; California forest roads; and New Mexico forest roads. Comparisons among the sites indicated that the response of the Coweeta, California, and New Mexico road surfaces was, on average, quite similar. The mine haul roads responded with a bit more runoff from rainfall and significantly smaller sediment yields. One reason that yields were lower was gravel cover on the mine haul road sites. Modeling of roadways using physical process computer models (ROSED for Coweeta, ROSED and SIRSED for mine roads, and SIRSED for California roads) has proved to be an acceptable and representative means of estimating water and sediment yields, although there are some problems remaining. It is now possible to collect data, derive model parameters, and then make relatively good estimates of sediment yields from other rainfall events. (A).

Keywords : sedimentation; modeling; forest roads

397. Warner, Richard C.; Eigel, Joseph; Nebgen, Pamela J.; Bodner, Richard M. 1986. Planning and implementation of remedial landfill reclamation: Papers presented at the 1986 summer meeting of the American Society of Agricultural Engineers; 1986 June 29-July 2; San Luis Obispo, CA. Pap. 86-2145. St. Joseph, MI: ASAE. 1-18 p.

A solid waste landfill was facing a closure order unless stormwater, erosion and sediment problems could be rapidly rectified. A multifaceted comprehensive design plan was instituted using the SEDCAD (SEDIMOT II Computer aided design) model in which alternative sediment basins, interceptors, diversions, grassed waterways, riprap channels, culverts, etc. were evaluated. The plan was implemented in a prioritized manner achieving massive reduction in sediment loading as well as peak flow attenuation. Innovative percolation basin designs reduced storm sediment loads to near zero. (A) 7 refs.

Keywords : modeling; sediment; planning

398. Washington State. 1989. Design policy. In: Hydraulics manual (M23-03). Olympia, WA: Washington State Department of Transportation: 1-7. Chapter 1.

Design policy guidelines for responsibility of initiation and permits, hydraulic reports, storm frequency policy, and risk analysis for drainage facilities are presented. Requirements for information required on hydraulic reports including culvert installation is given in tabular format. Factors considered in determination of design frequency include potential damage to roadway, hazards and inconvenience to motorists, classification of highway, the ADT of the highway and the cost of the hydraulic structure. Design frequency in years for culvert installation is 100 years or largest flood of record. Risk analysis may be appropriate when all design considerations can be equated to dollars. A risk analysis considers the initial cost of the hydraulic structure and compares this to the probably cost of operating and maintaining the structure over its entire useful life.

Keywords : drainage design; law and policy; hydraulics; risk analysis and design; handbooks; drainage structures

399. Washington State. 1989. Hydraulics of culverts. In: Hydraulics manual (M23-03). Olympia, WA: Washington State Department of Transportation: Chapter 3.

Design parameters for culverts with inlet and outlet control made of concrete pipe, corrugated metal pipe, arch culverts, and box culverts of varying sizes are presented in the form of nomographs. Culvert sizing worksheet based on design parameters, hydrology, and culvert hydraulics continues the design steps. End treatments presented for specific site requirements include flared end sections, headwalls, wingwalls, inlet improvements and energy dissipaters. Since debris problems can cause hydraulic capacity problems, deflectors, debris basins, overflow vents, and debris spillway designs are included.

Keywords : hydraulics; culvert design; corrugated metal pipe

400. Watts, F.J. 1974. Design of fishways. Moscow, ID: University of Idaho, Water Resources Research Institute. 62 p.

Types of fish migration and typical fish blockage problems associated with culverts are reviewed. Swimming capability of fish as a function of specie, fish length and water temperature are

discussed. The hydrologic characteristics of streams and the importance of considering the timing of fish runs and peak discharge is reviewed. A procedure for analyzing corrugated metal pipe and pipe arches for recommended swimming velocities is presented. Slot orifice fishways for box culverts (slot orifice placed perpendicular to the flow and skewed wing-wall slot orifice) are discussed. Design aids developed for hydraulic analysis are presented. Instream construction in or near prime fish habitat is discussed. (A).

Keywords : fishways; culvert design; culvert fish passage

401. Watts, F.J.; Burroughs, Edward R.; King, J.G.; Hansen, D.F. 1986. Evaluation of a road sediment model. In: Proceedings of the fourth federal interagency sedimentation conference; 1986 March 24-27; Las Vegas, NV. Moscow, ID: Idaho University, Department of Engineering; 2: 325-334.

The yield and gradation of sediment that resulted from a 1-inch simulated rainfall on unsurfaced roadways were compared to the yield and gradation of sediment predicted by a physical process model, ROSED. The precipitation was applied in 23-30 minutes on three separate plots. Plot lengths ranged from 50 to 100-ft. long with widths of 13-17 ft. Cross slopes ranged from 2 to 4% and longitudinal slopes ranged from 6% to 9%. The unsurfaced roadways were constructed of ' border zone ' soils and were located in the Boise and Nez Perce National Forests. A modified Colorado State University Rainulator was used to apply the precipitation. The runoff from each plot was measured using a flume with stilling well and flowmeter. Grab samples were obtained at one minute intervals to determine sediment yield and to collect adequate sediment for gradation analysis. A sensitivity analysis was performed on each of the parameters that affects the yield and gradation of sediment. Important elements for predicting sediment in the ROSED model are raindrop detachment, sediment detachment by overland flow, and sediment transport by overland flow. Each parameter in a sample data set was systematically varied to determine the effect the parameter has on model output. Known soil properties, geometry and rainfall data for each plot were then used for input and the model was calibrated to obtain output that closely matched the sediment yield and gradation observed in the field. Sediment input parameters that produced the greatest change in model output for sediment yield and gradation were parameters used for computing bed load transport within the model. Using a set of proposed sediment input parameters based on known soil characteristics and known site data, without calibration, the model predicted sediment yields that were within + or - 50% of the actual yield. With calibration the model predicted sediment yields within + or - 1% of the actual yields. The grain size distribution curves and sediment graphs also closely matched measured curves. (See also W87-05791) (Author 's abstract).

Keywords : rainfall simulation; modeling; road sediment model

402. Waylen, Peter; Woo, Ming-Ko. 1982. Prediction of annual floods generated by mixed processes. Water Resources Research. 18(4):1283-1286.

In areas where the annual flood series is generated by more than one distinctive hydrologic process, the Gumbel distribution does not provide a satisfactory fit. Physical evidence is used to identify the flood-generating processes, which in the Cascade Mountains include snowmelt and rainfall. Individually, the snowmelt and rain generated annual floods are adequately modeled by simple Gumbel distributions. These distributions have to be compounded to provide a good fit to the annual floods which are produced by mixed processes. (A).

Keywords : flood estimation and control; modeling; hydrologic analysis

403. Weaver, W.E.; Hagans, D.K.; Madej, M.A. 1987. Managing forest roads to control cumulative erosion and sedimentation effects. In: Proceedings of the California watershed management conference, Report 11; 1986 Nov 18-20; West Sacramento, CA. Berkeley, CA: University of California, Wildland Resources Center: 6 p.

Keywords : erosion control; forest roads; sedimentation effects; road management

404. Weaver, W.E.; Hagans, D.K.; Popenoe, J.H. 1995. Magnitude and Causes of Gully Erosion in the Lower Redwood Creek Basin, Northwestern California; USGS Professional Paper 1454-I. In: Nolan K.M., Kelsey H.M., Marron D.C. eds. Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwestern California. Washington, D.C. U.S. Department of Interior, U.S. Geological Survey: I1-I21.

Gullying was found to be a major process of erosion on roaded prairies and logged lands in the 197-km2 lower Redwood Creek basin. Detailed mapping of over 2,200 hectares of disturbed terrain revealed that 90 percent of the 329,500 m3 of measured gully erosion on nine study sites was caused by the diversion of first-order and second-order streams. Plugged culverts, failure to install culverts at logging-road stream crossings, and bulldozing of soil and logging slash into shallow hillslope stream channels were the leading causes of stream diversions and consequent gullying. (A).

Keywords : case studies; erosion processes; logging practices and effects; road impacts

405. Weaver, W.E.; Madej, M.A. 1981. Erosion control techniques used in Redwood National Park, northern California, 1978-1979. In: Davies, T.R.H.; Pearce, A.J., eds. Erosion and sediment transport in Pacific Rim steeplands: Proceedings, symposium; 1981 January; Christchurch, New Zealand. ISHA-AISH Pub. 132. Washington, D.C. International Association of Hydrological Sciences: 640-654.

Redwood National Park has initiated a rehabilitation program to reduce erosion from lands impacted by timber harvest and road construction. Severity of damage to park lands varies with age and type of logging, underlying geology and hillslope gradient. For each rehabilitation site, detailed geomorphic maps delineated natural and disturbed drainages, slope instabilities, and other erosional problems. Next, heavy equipment disaggregated and outsloped logging roads and excavated fill from stream channels, removed unstable road fill from road prisms, and restored altered drainages to their natural patterns. After heavy equipment work was completed, labor-intensive work crews constructed erosion control structures to stabilize gullies and stream channels, minimize rainsplash erosion and rilling, and promote revegetation of disturbed areas. Checkdams, water ladders and flumes, wattling, wooded terraces, mulches and vegetative techniques were used. Winter maintenance of these structures is essential to assure adequate protection of slopes and drainages through high rainfall periods, Costs and time involved for rehabilitation techniques are included (A).

Keywords : erosion control; road design and construction

406. Webb, Bill. 1994. Deep Creek low water crossing Osceola National Forest. Field Notes. Washington, DC: U.S. Department of Agriculture, Forest Service, Engineering Technical Information System; 26(May-August): 3-6.

The reasons and design rationale for a low water stream crossing on the Osceola NF in Florida are given. Cost tradeoffs between a bridge and the low water crossing are given. Design, construction, initial performance and some benefits of the design are briefly described. Five 8-foot wide, 16-foot long by 24-inch deep double "T" precast sections were used as the main structural elements of the crossing. It was built during a 2-month period in 1992 for a contract cost of less than $60,000. (C).

Keywords : low water crossing; road design and construction

407. Weismann, Richard N. 1989. Model study of safety grating for culvert inlet. Journal of Transportation Engineering. 115(2):130-138.

The basic design of the grating, recommended by previous researchers, was tested using a 1:10 scale model. Testing was performed over a wide spectrum of flood flows, including flows that exceed the culvert capacity. The grating has only a minor effect on the head-discharge relationship, causing a slight increase in the headwater required to pass given discharge. However, the grating may act as a debris control structure and vigilant maintenance may be required to prevent clogging of the culvert inlet. Neutrally buoyant objects were introduced to the flow to assess the performance of the grating. Because of the parabolic shape of the grating, and object carried to the culvert tends to be pushed up the grating and out of the flow. (Edited author abstract) 5 Refs.

Keywords : flow capacity; culvert inlets

408. Weitzman, S.; Trimble, G.R. 1953. Skid road erosion can be reduced. Journal of Soil and Water Conservation. 7(1):122-124.

This can be done, the authors say, by planning an efficient road lay-out that avoids steep gradients, and by installing simple water bars to keep the road drained. These recommendations are based on studies of an experimental logging job in West Virginia, where four different kinds of skid roads were tested (C).

Keywords : erosion control; skid trail; dips and waterbars; logging practices and effects; road location; road design and construction

409. Wemple, Beverly C. 1994. Hydrologic interaction of forest roads with stream networks in two basins, Western Cascades, Oregon. Corvallis, OR: Oregon State University. 88p. M.S. Thesis.

This study assessed how logging-access roads may have contributed to observed historical increases in peak discharges associated with small and large logged basins in the western Cascades of Oregon. The study was conducted on the Lookout Creek (62 square km) and the upper Blue River (118 square km) basins. Potential road effects on hydrology were examined using a combination of field surveys and spatial modeling with a geographic information system (GIS). Road networks were similar in both basins with respect to hillslope position, orientation, and stream crossings, but roads in Blue River were constructed one or two decades later than roads in Lookout Creek. A total of 20% (62km) of the road length was sampled to assess routing of surface flow, using 31 2-km transects stratified by decade of construction and hillslope position. Along each transect, ditches and culvert outlets were examined and this information used to predict the probable routing of water to (1) existing stream channels, (2) newly eroded gullies downslope of culvert outlets, or (3) subsurface flow. Nearly 60% of the surveyed road length appeared to route water directly to stream channels or into gullies. Over time the length of road connected to stream

crossings has decreased, while the length of road discharging runoff that reinfiltrate to subsurface flow has increased, as roads have progressed up hillslopes and onto ridges in Lookout Creek and Blue River. The relatively constant proportion of the road network draining to gullies over time suggests that roads have the potential to become integrated into stream networks, even when constructed on unchanneled hillslope positions. An extended stream network, assumed to exist under storm conditions, was simulated for the basins using a digital elevation model. Although gullies and ditches differ from natural channels, extrapolation of field surveys using the GIS suggested that the roads might extend the stream network by as much as 40% during storm events. It is hypothesized that such an effect could decrease the time of concentration of stormflow and contribute to higher peak discharges observed after clearcutting and road construction in these basins. Differences in the magnitude of road effects on peak flow generation may occur among road systems according to hillslope position of roads, road age, soil saturation, geologic substrate, and climate. These differences may explain the range of observed results from paired-basin studies examining road effects on hydrologic response. (A).

Keywords : discharge; hydrologic analysis; road impacts; runoff; stream flow

410. Whitman, Richard. 1989. Clean water or multiple use?: best management practices for water quality control in the national forests. Ecology Law Quarterly. 16(4):909-967.

The USFS is mandated to manage the national forests for long-term public benefit by balancing competing resources. This includes water quality programs in the forests. Most of the problems stem from nonpoint-sources of pollution, including timber harvesting, road building, and reforestation. An assessment is made of water quality planning under the Clean Water Act, including the planning process and nonpoint source control. Also included are the roles played by the EPA and the states. Changes needed in the internal dynamics of the USFS to ensure that the agency fulfills its multiple-use mandate in a more balanced fashion include removing incentives that keep environmentally sensitive lands in the timber base, improving the agency's commitment to implementing best management practices, and restructuring state water quality standards for forestry-related nonpoint source pollution. (372 references, 1 tables).

Keywords : water quality; forest management and practices; natural resources; timber harvest; best management practices; water quality control

411. Wilkinson, Charles F.; Anderson, H. Michael. 1987. Land and resource planning in the National Forests. Washington, D.C. Island Press: 396 p.

Originally published as a special double issue of the Oregon Law Review in 1985, this volume discusses the law, history, and policy relating to the national forest system. It is a standard reference for the National Forest Management Act (NFMA), and also contains chapters on range, timber, water, minerals, wildlife, recreation, and wilderness. Each chapter contains a section on the evolution of policy and additional sections on planning and regulation relating to that topic. Major legislation other than the NFMA discussed include the Organic Act, the Resources Planning Act, Multiple-Use Sustained-Yield Act, Clean Water Act, Wild and Scenic Rivers Act, and the Wilderness Act of 1964. The National Environmental Policy Act and Roadless Area Review and Evaluations are also reviewed. Includes 2029 footnotes, an afterward and an index. (C).

Keywords : law and policy; planning; Clean Water Act

412. Williams, L.G. 1991. Drainage of a mountain road in Nepal. Journal of Institution of Water and Environmental Management. 5(5):513-518.

The paper describes the contribution made by the drainage engineer to the design of the Arun Road situated in the Middle Himalaya of Eastern Nepal. A description is given of the way in which a limited amount of hydrometric and meteorological data was synthesized into a relatively simple hydrological model which could be used for drainage design. The mountains crossed by the road are environmentally fragile and populated by subsistence farmers, and this demanded that special care be taken in the hydraulic design of bridges, culverts, and associated works in order to minimize the adverse consequences of the road construction. (A) 7 Refs.

Keywords : surface drainage; road design and construction; drainage design

413. Williams, T.T. 1971. Drainage correlation research report, volumes I and II. Montana State Highway Commission, Planning Survey Section.

An important problem in highway design is that of determining flow capacities for drainage structures including culverts. Culvert installations ordinarily are used where the discharge originates from small watersheds of a few acres or a few square miles. The determination of peak discharge magnitudes and corresponding return frequency intervals is essential to economical engineering design. A comprehensive study of peak flows from small watersheds (1 to 100 square miles) was undertaken in 1963 to determine if existing precipitation and climatological data could be used to predict the frequency of flood magnitudes on small watersheds in Montana. Phase one of the study focused on existing precipitation data to determine what correlation exists between such data and peak flows from small watersheds and included a review of various methods currently in use for the prediction of peak flows and frequencies. Phase two undertook to extend the usefulness of the U.S. Geological Survey “Small-Area Peak-Flow-Highway Program by a comprehensive study of four widely separated watersheds. Included in the study were soils, infiltration, precipitation, and watershed characteristics. A review of current hydrologic techniques and watershed data appears in Volume II.

Keywords : road design and construction; flow capacity; drainage; culvert design; culvert installation; research

414. Wilson, Raymond O., Jr.; Little, Charles D., Jr.; Mendrop, Kelly B.; Smith, John B.; Montague, Charles A., Jr. 1995. Channel stabilization methods in the demonstration erosion control project. In: Proceedings of the 22nd annual conference on integrated water resources planning for the 21st century; 1995 May 7-11; Cambridge, MA. New York: American Society of Civil Engineers: 1089-1092.

Erosion is a problem that is faced everyday throughout the United States. Besides the obvious loss of productive topsoil, erosion produces indirect effects such as poor water quality, loss of aquatic and terrestrial habitat, damage to the transportation infrastructure, and increased frequency and duration of flooding due to excessive sedimentation. The Demonstration Erosion Control (DEC) project is an intensive program designed to demonstrate the effectiveness of a watershed or systems approach to reducing erosion, sedimentation, and flooding problems. Various types of erosion control structures are being used as part of the DEC project including high drop grade control structures, low drop grade control structures, box culverts, riser pipes, bank stabilization methods, land treatment methods, flood water retarding structures, debris basins, intermediate dams, channels, levees, and pumping stations. This paper focuses on DEC grade control structures

which include the first four structure types in the above list. The magnitude and location of the erosion problems dictate the type of grade control structure best suited in each case. (A) 2 Refs.

Keywords : channels; water quality; flood estimation and control; sedimentation; erosion control structures

415. Windsor, Carlton L. 1989. Recommended management practices for forested wetlands road construction. In: Proceedings of the symposium: The forested wetlands of the southern United States; 1988 July 12-14; Orlando, FL. Gen. Tech. Rep. SE-50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 51-53.

Two sections of the Federal Water Pollution Control Act of 1973 affect road construction in wetlands. Section 404 regulations list 15 baseline provisions which must be followed in order for a forest road to be constructed and/or maintained and not require a USACE permit. Section 208 requires each state to develop voluntary best management practices (BMPs) to control nonpoint source pollution from forestry practices; road construction practices must comply with these BMPs. BMPs developed in Georgia, Florida, and South Carolina which relate to wetland road construction are examined (A). (7 references).

Keywords : wetlands; forest wetland; road design and construction; best management practices; Water Pollution Control Act

416. Wooldridge, D.D.; Larson, A.G. 1980. Suspended sediment from forest road construction, Fly Creek, Clearwater River Basin, Western Olympics, Washington. 78 p.

Concentrations and total quantities of suspended sediment in portions of Fly Creek, an undisturbed tributary of the Clearwater River in western Washington, were studied during the construction of 1.4 miles of unpaved forest road in the watershed. Fly Creek is a Class A, Excellent, stream with a watershed of 649 acres. Approximately 90% of the 140 to 200 inches of annual precipitation becomes streamflow. The road was constructed in accordance with the Best Management Practices defined by the Washington State Forest Practices Rules and Regulations. Sediment concentrations were determined from water samples taken with ISCO automatic samplers that withdraw 500 ml of water at selected intervals. Only visually turbid samples were analyzed and suspended sediment was measured in mg/l. In the laboratory, a Hach model 2100A turbidometer was used to determine the turbidity. Results show that suspended sediment increased both during and after road construction and that sediment concentrations from the construction were related to the proximity of the construction to the stream and the occurrence of rainfall. Sediment increases were small during construction or log hauling during periods without rainfall. Sediment increases were not dependent on work hours or stream discharge. Sediment increases generally occurred on days after construction or hauling was stopped due to rain. A major impact of the road construction was the rapidity with which rainfall causes the suspended sediment increases. (Seigler-IPA).

Keywords : sediment modeling; forest roads; road construction effects; suspended sediment

417. Wu, Tien H.; Randolph, Brian W.; Huang, Chiung-Shiann. 1993. Stability of shale embankments. Journal of Geotechnical Engineering. 119(1):127-146.

The performance of embankment slopes along a section of I-77 is summarized. Slope failures occurred mostly in embankments constructed of red shales of the Conemaugh, Monongahela, and

Washington formations. Soil moisture, soil suction, pore pressure, and slope movements were measured in four embankments. The results of measurements indicated that saturation of the embankment slopes occurred near the surface by infiltration of rainfall. Laboratory shear tests were used to measure the shear strengths of the embankment materials and of the red shales in their intact state and after various manipulations that simulated compaction and weathering. With seepage parallel to the slope, failure could occur if the in-situ shear strength was close to the lower limit of the peak shear strength measured in laboratory tests on samples of the embankment material. With vertical seepage, failure could occur if the in-situ shear strength was slightly less than the softened shear strength-of samples of intact shale. Since it was not possible to verify the actual seepage conditions, both scenarios are considered possible. (A).

Keywords : slope failures; cut slope

418. Yee, Carlton S.; Blakemore, T.E. 1984. Waterbars--making them more effective. California Forestry Note No. 90. Sacramento, CA: California Dept. of Forestry. 5 p.

Keywords : forest roads; dips and waterbars; road design and construction

419. Yee, Carlton S.; Roelofs, Terry D. 1980. Planning forest roads to protect salmonid habitat. In: Influence of forest and rangeland management on anadromous fish habitat in western North America. No. 4. Gen. Tech. Rep. PNW-109. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 26 p.

Keywords : forest roads; fish; fish habitat; planning

420. Yen, Ben Chie. 1992. Dimensionally homogeneous Manning's formula. Journal of Hydraulic Engineering. 118(9):1326-1332.

The dimension of Manning's roughness coefficient "n", used in open channel flow studies, has been considered as length to the one-third power divided by time, dimensionsless, or length to the one-sixth power. An attempt to clarify the dimension of Manning's "n" and to recommend a slightly modified, dimensionally less confusing Manning formula that is as simple in application as the conventional one is outlined. This modified ng" incorporates gravity, slope, and hydraulic radius. Tables for the modified Manning's "ng", which has the dimension of L to the 1/6, are developed.

Keywords : channels; Manning's formula

421. Young, G.Kenneth; Walker, Sharyl E. 1990. Risk-cost design of pavement drainage systems. Journal of Water Resources Planning and Management. 116(2):205-219.

A practical method for determining the road surface drainage system design with the theoretical lowest total economic cost (LTEC) is developed. The LTEC method determines the design rain which, when used in a rational-based design context, will yield the most economic choices of gutters, inlets, and laterals considering both construction costs and risk costs. The method provides an alternative to the use of fixed return period design criteria. Daily rainfall serves as the random variable used in performing the risk analysis. The right-hand tail of the probability density function for daily rainfall is approximated with a normal curve. A triangular hyetograph of average duration

is assumed to be appropriate for representing an individual rainstorm. A nomograph and data selection guide are provided as design aids. Case studies are presented in an appendix. The method, based on minimizing traffic delay costs, applies to freeways, arterials, and major collectors; local streets with low traffic may be excluded. (A) 14 Refs.

Keywords : risk analysis and design; cost and economics; road surface; drainage; pavement; case studies

422. Young, M.K. 1995. Conservation assessment for inland cutthroat trout. Gen. Tech. Rep. RM-256. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 70 p.

The document focuses on the state of the science for five subspecies of cutthroat trout found largely on public lands in the Rocky Mountain and Intermountain West. These subspecies are restricted to a fragment of their former range, and primarily occupy small, high-elevation streams. Little is known about the three rarest subspecies (Bonneville, Colorado River, and Rio Grande cutthroat trout), and the data on the more abundant subspecies (westslope and Yellowstone cutthroat trout) were obtained from relatively few areas. All subspecies have suffered from introductions of nonnative fishes, habitat degradation and fragmentation, and overfishing (A).

Keywords : fish; fish habitat

423. Yung, Yeou-Koung. 1993. Confidence intervals of optimal risk-based hydraulic design parameters. In: Reliability and uncertainty analyses in hydraulic design. [Place of publication unknown]: [Publisher name unknown]: 81-96.

Random hydrologic data are used in frequency analysis to estimate the probability distributions and the parameters of hydrologic events. The estimated distributions and parameters, which are subject to uncertainty, are used in optimal risk-based design procedures to compute the expected damage cost. Therefore, the solutions from an optimal risk-based design procedure are also subject to uncertainty. This paper applies the bootstrap resampling technique to assess the degree of uncertainty of the optimal solutions from an optimal risk-based design procedure. The method was applied to the optimal risk-based design of pipe culverts (A). 23 Refs.

Keywords : risk analysis and design; culvert design; hydraulic design; hydrologic analysis; hydrologic design

424. Zhang, W.; Cundy, T.W. 1987. Test of a surface runoff and soil erosion model for forest road surfaces. In: Erosion and sedimentation in the Pacific rim: Proceedings of an international symposium; 1987 August 3-7; Corvallis, OR. IAHS Pub. No. 165. Washington, DC: International Association of Hydrological Sciences: 264-265.

A physical based mathematical model of surface runoff and soil erosion on a plane with cohesionless soil is presented. The kinematic overland flow routine of Li et al. (1975) is used, and it allows temporally varied rainfall as input. The model provides the flow depth and velocity in time and space. A modified Einstein equation for laminar overland sheet flow (Zhang, 1985) is used to serve as the governing erosion equation. The model has been calibrated and tested for both steady flow and unsteady flow in flume experiments. It was first fit to the observed data of Kilinc & Richardson (1973) for steady flow. With these data an optimized value for Einstein's "hop"

parameter was obtained. The regression correlation and observed sediment yield were r2= 0.87 using a uniform size sediment, and r2= 0.95 using a mixture of sediment sizes (C).

Keywords : soil erosion; surface drainage; modeling; forest roads; road surface

425. Ziemer, Robert R. 1981. Storm flow response to road building and partial cutting in small streams of northern California. Water Resources Research. 17(4):907-917.

To assess the influence of road building and logging on stormflow response, a pair of watersheds were studied at Caspar Creek near Fort Bragg in northern California from 1963 to 1975. Selection cutting and tractor yarding of 85-year-old second-growth redwood and Douglas-fir forest did not significantly affect large peak streamflows. The first streamflow peaks in the fall, however were increased about 300% after logging. These early fall storms produced small peaks, which had little, if any, hydraulic consequence. the effect of logging on peak flow was best predicted by a variable representing the percent of the are logged, by the sequential storm number within the year.

Keywords : road construction effects; logging practices and effects; storm flow response

426. Ziemer, Robert R.; Lisle, Thomas E. 1993. Evaluating sediment production by activities related to forest uses -- a Pacific Northwest perspective. In: Proceedings of the technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 71-74. Sponsored by: Environmental Protection Agency and U.S. Department of Agriculture.

To deal with nonpoint sources of pollution, such as stream sediment produced by erosion from forest management operations, regulations require land mangers to reduce onsite erosion to keep the amount of sediment discharged from each project area within acceptable limits. Activities developed to meet these regulations are sometimes referred to as best management practices (BMPs). BMPs are designed to reduce pollutant discharge from a single project but may not solve the larger problem concerning the cumulative effect of multiple projects. Land managers and regulatory agencies are increasingly required to address the cumulative effect of each proposed project within the context of all other projects within a specified area. To evaluate physical and biological responses to interacting events or treatments that are separated in either time, space, or both.

Keywords : sedimentation; forest management and practices; non-point source pollution; erosion control; sediment

427. Zrinji, Zolt; Bender, Michael. 1995. Experimental risk evaluation for baffled culvert fishway design. Winnipeg, MB: University of Manitoba, Department of Civil and Geological Engineering, Water Resources Research; report 29. 34 p.

Culverts may be obstacles to migrating fish species. Baffled culvert fishways are considered for high slope design or for remedial work on existing culvert stream crossings. Much of the design practice for installing baffles to aid fish migration is based on experience or standard historical designs. Field evaluations and hydraulic modeling studies are limited but growing. There is a need for more structured use of hydraulic fish passage study results. Although biological uncertainties make it difficult to identify hydraulically and biologically efficient designs, study results may help to understand elements of risk and design robustness for fish passage. A form of sensitivity analysis of interdependent variables is developed and used to evaluate a field-tested design for freshwater

migrants. The presented design approach moves fish passage evaluation from post-design adaptations to pre-design understanding of alternatives. Results of hydraulic modeling studies are used to provide the basis for analysis of uncertainties in discharge, slope, migratory fish length, and water velocity criteria. (A).

Keywords : fish migration; fishways; culvert design; culvert fish passage; baffles