++++++++++++++++++++DRAFT 03/12/10+++++++++++++++++++++++

7. Control of Road Drainage (PRACTICE: 2-7)

Objectives:

1. Minimize the erosive effects of water concentrated by road drainage features;
2. Disperse runoff from disturbances within the road clearing limits;
3. Lessen the sediment yield from roaded areas;
4. Minimize erosion of the road prism by runoff from road surfaces and from uphill areas.

Explanation:

Drainage design is one of the most important elements in road design. Use the most economical control measure designed to meet resource and road management objectives and constraints. The economic considerations shall include construction and maintenance costs.

The results of poor or improper drainage design are often dramatic and destructive. The natural equilibrium of slope hydrology is easily upset by the introduction of artificial systems. Other specialists can help to establish the most appropriate onsite water handling objectives. Inadequate drainage may result in releasing or impounding water on National Forest or private land where it is undesirable or damaging.

Proper road location can minimize the need for drainage structures. However, it is essential to use adequate drainage for a stable road.

This is a preventive practice. A number of treatments can be used, alone, or in combination, to control unacceptable effects of road drainage (USDA Forest Service, 1992). Methods used to reduce erosion include but are not limited to such controls as construction of properly spaced cross drains, water bars or rolling dips; installing energy dissipaters, apron, downspouts, gabions, flumes, overside drains and debris racks; armoring of ditches, drain inlets and outlets and removing or adding berms to control runoff. Refer to FHA (2003) and Caltrans (2003) for construction standards for specific erosion-control techniques. Accomplish dispersal of runoff on the road surface by such means as rolling the grade, outsloping or crowning. Installing water spreading ditches or contour trenching can disperse road water after the water leaves the road surface.

Dispersal of runoff reduces downstream peak flows and associated scouring of the channels and sediment transport.

Reduce sediment loads from road surfaces by adding aggregate or paving surfaces or by installing such controls as: sediment filters, settling ponds, and contour trenches. Soil stabilization can reduce sedimentation by lessening erosion on borrow and waste areas, on cut and fill slopes, and on road shoulders.

Implementation:

Project location, design criteria and detailed mitigation are determined and documented during the environmental analysis process. These are then incorporated into the project plan.

Project crew leaders and supervisors will be responsible for ensuring that force account projects meet construction specifications, and project criteria. Contracted projects are implemented by the contractor, or operator. Compliance with plans, specifications, and operating plans is ensured by the COR, ER, or FSR. (spell out these acronyms; many people don't know what they are)

(redundant)

Deleted: This practice is required in contracts when the need is identified in the project planning process.

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All drainage can be classified as one of two types--surface or subsurface. The classification depends on whether the water is on or below the surface of the ground at the point where it is first intercepted or collected for disposal.

For a proper drainage system, use the best combination of various design elements, such as ditches, culverts, drainage dips, crown, in slope or out slope, fords, subsurface drains, and bridges. As the basis for the drainage design, use the most economical system that meets the design criteria derived from land management objectives.

Surface drainage provides for the interception, collection, and removal of water from the surface of roads and slope areas. This is important because water on the surface may interfere with traffic or cause erosion, and if allowed to infiltrate, may cause damage to the subgrade.

The design may need to allow for debris passage, mud flows, and water heavily laden with silt, sand, and gravel. FSM 7722 and FSH 7709.56b cover drainage design and construction policies and procedures.

Review projects that might affect fish migration or passage with an appropriate specialist or resource manager to ensure that the design conforms to the resource management objectives. Recommended reference is "Fish Migration and Fish Passage," EM-7100-12, Department of Agriculture Booklet.

Subsurface drainage intercepts, collects, and removes groundwater that may flow into the base course and subgrade; lowers high water tables; and drains water pockets.

Water is present under the surface because of the infiltration of surface and groundwater. Water seeps down through unsealed surfaces and moves laterally along the top of impervious soil or rock layers. Ground water may pond above impervious strata to form a perched water table.

Properly designed and maintained surface drainage systems may reduce the need for special subsurface drainage structures.

Culverts

BMP 2-17, FSH 7709.56b, and FSM 7722 discuss specific culvert design and construction standards, including design procedures and risk analysis. The information below is intended to guide the selection of appropriate culvert types and locations.

When checking for damage potential include an analysis of probable damage to the structure, the road, and the drainage upstream and downstream from the structure and consider the effects of possible debris loading.

1. Ditch Relief Culverts. Provide ditch relief culverts to periodically relieve the ditch line flow by piping water to the opposite side of the road where the flow can disperse away from the

roadway. The spacing of ditch relief culverts depends on the road gradient, road surface and ditch soil types, runoff characteristics, and the effect of water concentrations on slopes below the road (Table 1).

Low-volume road gradients are often steep because of economics and a desire to disturb the least amount of land. Ditch relief culverts installed in roads with steep grades, particularly in steep mountainous terrain with high intensity storms, have an increased potential for failure. Failure may result in increased ditch scour, extensive erosion of road surfacing, and mass failure of roadway fills.

Analyze alternatives of flatter versus steeper gradients, comparing the cost of construction versus the cost of road repair, maintenance, and damage to the adjacent resources.

Debris blockage causing culvert failure can lead to a domino effect. When one culvert fails, debris and water flow to the next culvert and may result in its failure, and so on. Therefore, include in the design provisions for protecting culverts from debris where a potential problem exists.

Drainage failures may also have a detrimental effect on land below the road. Siltation in streams and degradation of water quality may be increased and fish habitat damaged. Runoff concentration increases surface erosion, mass soil movement, and stream channel scour.

Ensuring proper cover lessens the chance of damage to the culvert barrel and inlet end. To minimize damage, provide adequate cover for the design life of the culvert. This requires anticipating the amount of material that may be lost due to road use and erosion.

Skewing ditch relief culverts from a line perpendicular to the centerline of the road may improve flow characteristics, reduce siltation problems, and reduce the possibility of debris plugging the culvert inlet. Do not use skewing to increase the distance between ditch relief culverts. Skewing may increase the length of culvert necessary for the location. When determining the degree of skew, consider the following factors: (a) the additional cost caused by the additional culvert length, (b) proper dispersion of water below the road, and (c) improved flow characteristics through the pipe. Do not use skewing when water is flowing toward the culvert inlet from both directions, except to reach or fit a natural channel.

Provide for ditch relief culverts during design. Determine the location of the inlet of relief culverts to provide for design of inlet basins. The design of inlet basins should include adequate width for the culvert entrance and for any structure necessary to prevent erosion of the road bed and backslope. Design inlet basin backslopes at a stable slope to minimize the possibility of culvert plugging from ravel or slumping. Where practical, provide a transition taper between the normal backslope and the inlet basin backslope. Inlet structures may consist of hand-laid rock headwalls, ditch dams, inlet basin liners, drop inlets, or other special structures designed for specific conditions at the site.

It is also possible to use culverts placed in natural drainages for ditch relief; however, consider the effect of possible sedimentation or increased flows on the natural drainage.

Designing culverts for later removal may be beneficial for intermittent-use roads that are to be closed for extended periods of time. Culverts designated for removal may be constructed from permanent materials or materials that wear out after their initial use. Base the decision of which type of material to include in the design on economics and risks of environmental damage.

In high-use recreation areas and other visually sensitive locations, consider reducing the visual impact of culverts by painting the ends with asphalt or other materials to reduce color contrast.

2. Wetland Crossings. It is important to design wetland crossings properly to protect the resources that are sensitive to unnatural fluctuations in water level. Marshy and swampy terrain may contain bodies of water with no discernible current, so designing culverts for roads crossing these locations requires some unique considerations.

Design wetland culverts with a nearly flat grade so that water can flow either way and maintain the natural water level on both sides. The culvert may be partially blocked by aquatic growth and installed with the flow line below the standing water level at its lowest elevation. Give special attention to selecting culvert materials that resist corrosion.

Ditches

When planning the geometric design of ditches, consider the resource objectives for soil, water, and visual quality, maintenance capabilities and associated costs, and construction costs. Ditch grades should be no less than 0.5 percent to provide positive drainage and to avoid siltation. The following lists the usual types of ditches and describes their use:

1. Drainage Ditch. Ditches transport water that leaves the road surface or cut slope to the nearest ditch relief culvert or outlet ditch and drain the roadbed. The ditch is constructed between the traveled way and the adjacent terrain.

In some cases, vehicles may use the drainage ditch to avoid collision with other vehicles. The inslope should not be steeper than 2:1. Experience indicates that vehicles can drive safely into a drainage ditch at less than 20 miles per hour if the inslope is 3:1 or flatter. Consider providing clearance for larger vehicles by properly dimensioning ditches.

2. Trap Ditch. Where necessary, design trap ditches to catch and hold slough and to hold snow. Because it is a form of drainage ditch, the trap ditch can perform all the functions of a drainage ditch.

3. Intercepting Ditch. Where necessary, use an intercepting ditch to protect the roadbed and roadway cut and fill slopes. On the cut side, locate the ditch above the catch point of the cut slope to intercept runoff and channel it away.

On the fill side, the ditch intercepts water traveling along the fill and prevents erosion of the toe of the fill. The location of this type of ditch should be long the toe of fills where the ground is fairly flat and where cut slopes daylight into fill slopes to prevent water leaving outlet ditches from traveling directly against the fill slope.

4. Outlet Ditch. Outlet ditches carry water away from the road to prevent the road subgrade from being saturated or eroded. This ditch is normally used in fairly flat ground when the topography does not allow the water to run away from the road. Locate the ditch at the lower end of a culvert or drain dip, or at the point where a roadside ditch daylights out onto natural ground.

Drainage Dips

Drainage dips intercept and remove surface water from the traveled way and shoulders before the combination of water volume and velocity begins to displace the surface materials. Do not confuse drainage dips with water bars, which are normally deeper and are primarily for drainage and erosion protection of closed or blocked roads.

Drainage dips are useful for low-volume, low-speed roads where there may be extended periods of nonuse. When properly constructed, they can provide a relatively maintenance-free drainage structure.

Drainage dips may be beneficial in heavily debris-laden areas where culverts may plug and create erosion problems during periods of high runoff. They also are useful as a traffic control measure for reducing travel speeds.

The initial construction costs of a drainage dip may be cheaper than purchasing and installing a culvert pipe, constructing the roadside drainage ditch, and maintaining the culvert and ditch. However, unless the dip is properly designed and constructed, the total cost, including maintenance, may be more than if a culvert pipe had been installed.

The disadvantages of dips are low travel speeds, poor riding comfort, difficult blading of the traveled way, and possible adverse affects on water quality.

Road maintenance costs may increase because of discontinuity of the blading operation. Avoid constructing drainage dips on road grades greater than 10 percent because of increased vehicle operation difficulties, added erosion, and resultant maintenance problems. On road grades in excess of 10 percent, consider other surface drainage facilities, such as open-top drains.

Dips should discharge runoff in small amounts before runoff can significantly accumulate (Table 1). Dips skewed from the perpendicular to the road centerline may drain and self-maintain better than dips that are not skewed. However, an unskewed dip normally results in better driving characteristics. The downstream barrier of the dip should not create a "hump" in the grade. Taper the downhill slope to blend with the road gradient.

It may be desirable to stabilize the crest and trough portions of the dip with aggregates or in-place soil treatments to reduce deformation and to maintain stability.

Where tractor-trailer vehicles are the design vehicles, use the following guidelines when designing dips on grades greater than 8 percent:

a. Do not locate drainage dips within the confines of curves that have radii of less than 100 feet.

b. Maintain constant inslope or outslope throughout the length of the drainage dip to avoid the racking of truck frames. Do not deepen the outlet of the dip.

c. Construct transitions at least 60 feet long in both directions from the low point and the crest to avoid abrupt changes in grade.

Table 1. Recommended Maximum Distance between Rolling Dip or Culvert Cross-Drains (feet) [based on USDA Forest Service (1964) and USDA Forest Service (1998)]

Road Grade %	Low to Non-Erosive soils (1)	Erosive soils (2)
0-3	390	250
4-6	300	170
7-9	250	130
10-12	200	115
12+	170	100

(1) Coarse rocky soils, gravel, and some clay;
(2) Fine, friable soils, silt, fine sands

From a practical standpoint, open roads cannot be constructed such that traffic can negotiate the road safely with the close intervals of rolling dips on outsloped roads on steeper grades. The table works fine for spacing of "waterbars" on closed roads.

Inslope, Outslope, and Crown

Roadway surfaces are normally crowned or sloped to remove surface water from the wearing surface. The amount of crown or slope varies with the type of surface, and is generally less for impervious surfaces, such as asphalt, and greater for relatively pervious surfaces, such as gravel or native soils. If the cross slope is too flat, water remains on the road surface for a longer period of time and may penetrate into the base course and subgrade. A large buildup of moisture below the surface may cause instability and severely reduce the road's load-carrying capabilities.

Roads may be insloped (graded toward the cut) or outsloped (graded toward the embankment) depending on the resistance of the soil to erosion and based on the benefits of dispersing water gradually (outslope) or concentrating it into a specific location (inslope). Where the soil is unstable or subject to major erosion, the design should provide for inslope grading. It may be necessary to stabilize ditches or the toe of the cut slope on insloped or crowned roads to reduce erosion. Out-sloping or insloping of the roadway surface for removal of water becomes less effective as grade increases.

The decision to inslope or outslope depends, in part, on the natural slope hydrology; that is, how the undisturbed slope handles water. Convex topography tends to disperse water and concave topography tends to concentrate water into defined drainages. Outsloping roads complement convex topography, while insloping roads with well-placed cross drainage tend to work best with concave topography.

It is usually unnecessary to use ditches with outsloping roads, and they may not be necessary with insloping. Make this determination based on the erosive characteristics of the soil, precipitation, runoff ratios, gradients, and the length of run before the water can be removed.

Outsloping can be hazardous when roads become slippery. The cross grades of roads are usually 4 percent or less because slow moving vehicles, such as logging trucks, have a tendency to slip sideways when they lose their momentum on slippery surfaces. This is particularly troublesome on horizontal curves.

Subdrainage Systems

The design should provide subdrainage to remove water from the subgrade or pavement structure, to improve stability and load bearing capacity, to decrease the danger of frost action, or to reduce a safety hazard caused by freezing water on the traveled way.

Design subsurface drainage systems to accomplish the following: (1) intercept groundwater that cannot be intercepted by side ditches before entering the travelway, (2) reduce the hydrostatic pressure behind structures, (3) release ground-water into suitable channels without causing erosion or silting, and (4) last as long as the travelway or structure.

Because each site is different, conduct a field investigation to determine the best solution. The field investigation may include:

1. Reviewing available soil and geological studies or gathering new data.
2. Making borings or digging test holes to locate groundwater.
3. Inspecting natural lakes and slopes in the area and studying the natural drainage patterns.
4. Measuring discharge when possible.
5. Testing slope stability.

Perforated pipe drains are a common solution, but they do not function properly unless some method is used to prevent the holes from plugging. The following are several alternatives that prevent plugging, depending upon the characteristics of the soil:

1. Use a prefabricated drain, which consists of a geotextile covering one or both sides of a drain core material. The core provides open channels for water flow.
2. Surround the pipe with an open-graded aggregate material, which, in turn, is surrounded by a geotextile. The use of fabric material eliminates the need for an inverted filter consisting of various-sized gravel and sand layers.
3. Use a graded aggregate filter. (Use of this filter has diminished with the advent of geotextiles.)

Other types of subsurface systems include the following:

1. Drilled drains. For this system, place perforated pipes in holes drilled into cut or fill slopes to intercept the groundwater flow.
2. French drains. This system is identical to the pipe under-drain system, except a perforated pipe is not used. Use a large rock for the drainage path.
3. Engineered drainage systems. This type of system usually consists of a porous, chemically inert medium covered on one or both faces with a geotextile material. Place the system directly in a trench or against a structure and back-fill it with excavated material. This system can eliminate the need for special backfill necessary with the pipe under-drain and French drain systems.

Select a system that best meets the structural requirements and the corrosive conditions of the soil and water.

Because of the complexity of soils in many areas, it is advisable to consult materials specialists about the use and performance of the various types of geotextiles and graded aggregate filters. See section FHA (2003) and Caltrans (2003) for a further discussion of geotextiles.

Subdrainage systems may effectively reduce final road costs by decreasing the depth of base rock needed and reducing subgrade widths. This, in turn, results in less clearing and excavation. Maintenance savings also may be possible as the result of a more stable subgrade.

The solutions to subdrainage problems can be expensive. Consider as alternatives road management techniques, such as reducing traffic loads or removing traffic until a subgrade dries out.

References

FSM 7722

FSH 7709.56b

U.S. Department of Agriculture Manual EM 7100-12, Fish migration and fish passage

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USDA Forest Service, 1998, Water/road interaction: Introduction to surface cross drains. Water/Road Interaction Technology Series. Res. Rep. 9877 1806 – SDTDC. September. Washington, DC. San Dimas Technology & Development Program. 16 pp. *A water-roads interaction toolkit is also available on a CD.*

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