United States
Department of
Agriculture

Forest Service

**Technology &
Development
Program**

7700—Transportation System
2500—Watershed and Air
Management
October 1997
9777 1808—SDTDC

Traveled Way Surface Shape

Traveled Way Surface Shape

Jeffry Moll, P.E.
Senior Project Leader, San Dimas Technology and Development Center

Ronald Copstead, P.E.
Research Engineer, Pacific Northwest Research Station

David Kim Johansen
Geotechnical Engineer, Willamette National Forest

San Dimas Technology and Development Center
San Dimas, California

October 1997

TRAVELED WAY SURFACE SHAPE

WHAT IS IT?

The components of a forest road template are described by terminology shown in figure 1. Traveled way surface shape is the predominant cross section geometry of the traveled way surface, or that part of the roadway available for vehicular passage. At any particular location the traveled way surface should be uniformly sloping toward one edge of the road or crowned such that the center is higher than either edge. The first objective of surface shape is to encourage shedding of water from the surface before it gains enough concentration and velocity to cause unacceptable surface erosion. The second objective is to do this without causing unsafe conditions for traffic or unacceptable effects on the environment. Traveled way surface shape should be designed within the overall drainage plan for the area or watershed. On unsurfaced roads with grades greater than 5 percent or surfaced roads with grades greater than 8 percent surface shape alone may not be sufficient to ensure proper drainage, and surface cross drains may also be needed.

Many issues concerning traveled way surface shape become important when the road is on a cross slope and interacts with hill slope hydrology. Here, surface shape can be planned as one of three types as shown in figure 2: inslope, outslope, or crown.

Insloped roads are shaped to drain all water toward the back slope (uphill or cut bank side) away from road fill material. Water collects, then flows along the back slope or in the roadside ditch, until a surface cross drain or relief culvert directs the flow to the other side and away from the road.

Outsloped roads are shaped to drain all surface water to the downhill or fill shoulder side where it flows away from the road and is dispersed over, or absorbed into, the slope below the road. Outsloping can aid in avoiding concentration of surface runoff. A berm is sometimes used to direct the water along the downhill shoulder away from sensitive fill slopes or to sites suitable for release. It must be properly designed to avoid erosive runoff concentrations.

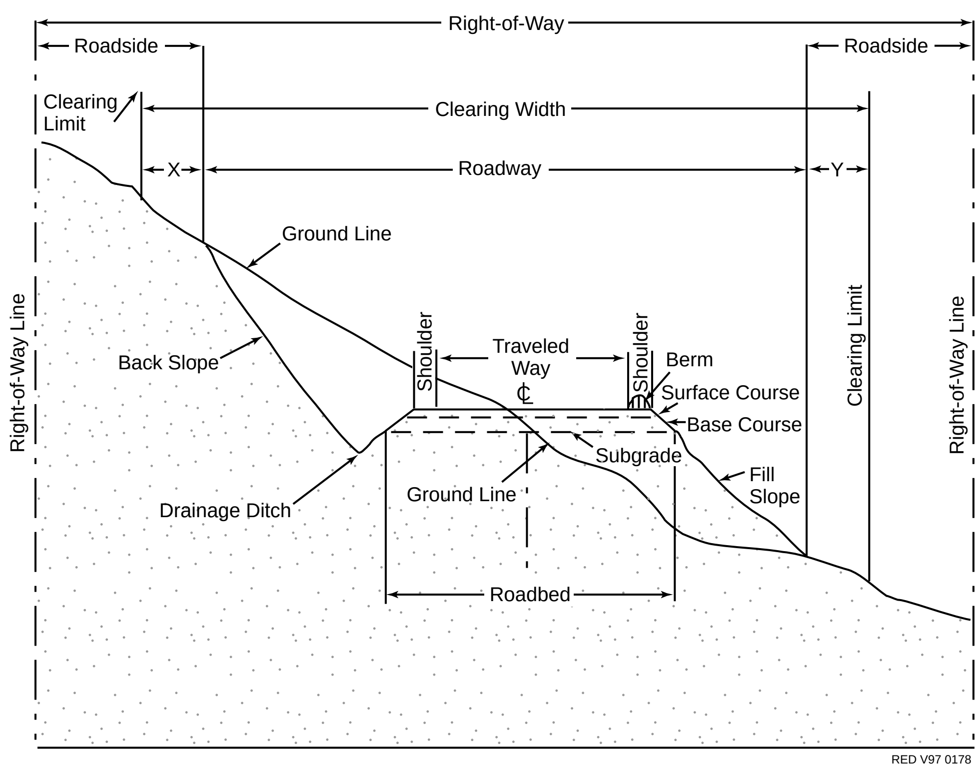

Figure 1—Forest road terminology.

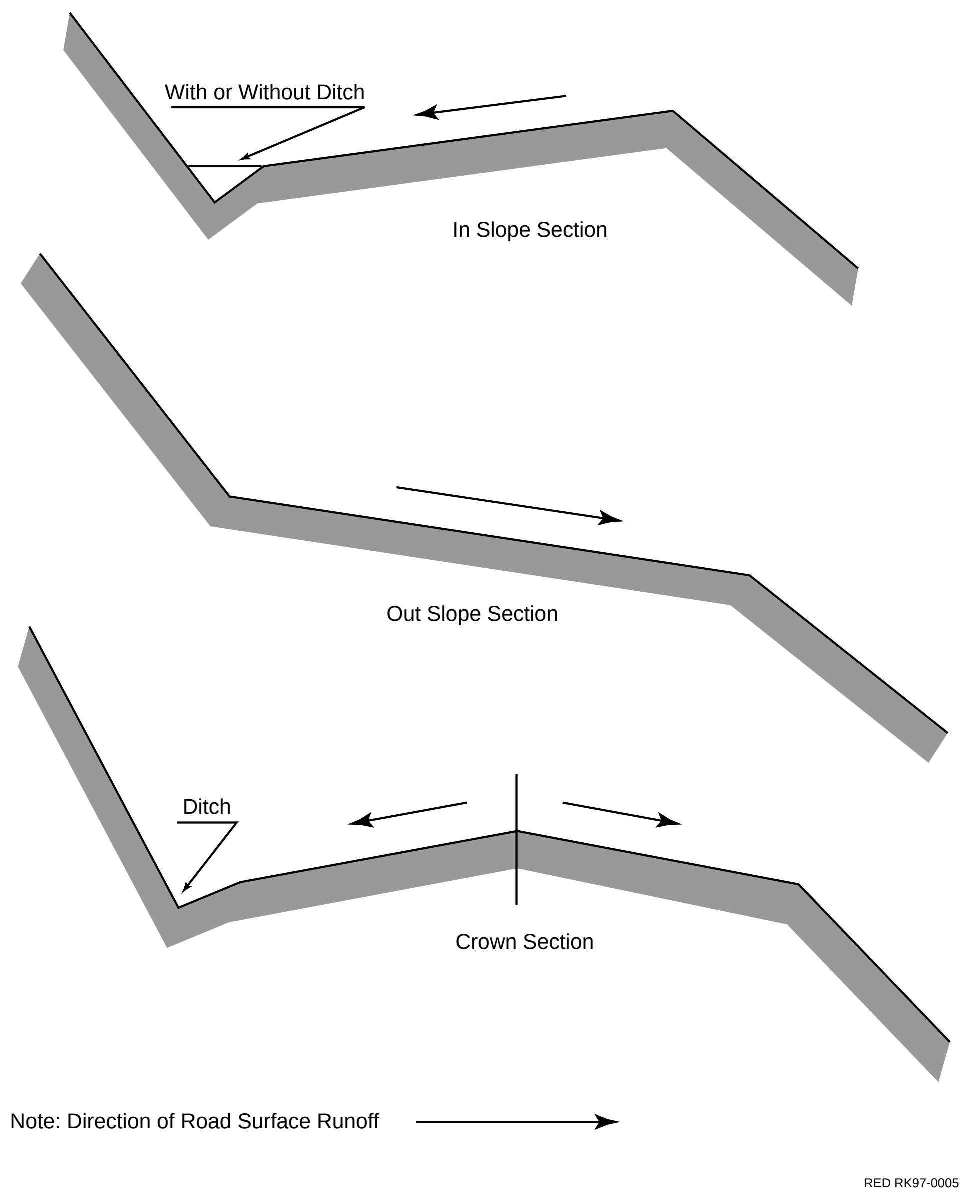

Figure 2—Types of road surface shape.

A crowned surface is a combination of both an outsloped and insloped surface with the high point in the center of the traveled way. It is usually combined with a ditch on the uphill or back slope side to transport runoff to a surface cross drain, relief culvert, or leadout ditch.

Superelevation of curves is a form of either inslope or outslope depending on the surrounding topography and curve direction.

WHEN AND WHERE TO USE IT

All roads should be designed with and maintained to preserve some type of traveled way surface shape to reduce water concentration, surface flow, ponding, and resulting safety and maintenance problems. Any type of surface shape can be used with any surface, be it native, aggregate, or asphalt.

WHAT TO CONSIDER

The specific surface shape selected should consider factors such as safety, the potential negative effects of concentrating uncontrolled drainage on the surrounding area, road grade, alignment, traveled way width, climate, surface materials, soil type, vegetation, local maintenance practices, and considerations for vehicles. The traveled way surface develops wheel path depressions or ruts that can dominate surface drainage. Surface cross drains (such as broad-based dips) may be needed with any surface shape as even shallow ruts caused by wheel loads can interrupt, capture, or redirect cross drainage; water flows longitudinally, gains concentration and velocity, and can lead to erosion of the traveled way surface. For example, on a road with 4 percent cross slope, a 0.5-meter-wide wheel track with a 20-millimeter rut is enough to interrupt cross drainage. Most soil or aggregate surfaced roads will develop a wheel rut of 20-millimeters or more—unless controlled compaction is used--during the first few vehicle passes after construction or maintenance. Asphalt-surfaced roads will take longer to develop ruts but often develop rut depths sufficient to prevent proper cross drainage if usage is heavy; they are also more costly to repair. Asphalt is impervious to water infiltration and causes larger amounts of surface runoff; drainage design should accommodate these larger water volumes.

Many factors affect selection of traveled way surface shape (table 1). An issue for designers of low volume roads located in mountainous or hilly terrain is whether to inslope the traveled way with drainage to ditches relieved by culverts; to outslope the surface, using berms and broad-based dips to divert and control water drainage from the traveled way; or to use crown. Some conditions are conducive to insloping with cross drain pipes, while outsloping combined with broad-based dips works best in others, and crowning offers the opportunity to disperse traveled way surface water towards both back slope and fill slope. On any given road, optimal design may result in a combination of traveled way surface shaping on separate road segments. Results and recommendations from one study done in the Appalachian region of the U.S. comparing culvert drainage methods with broad-based dip usage is summarized in table A1 of the Appendix.

Inslope Considerations

If the traveled way surface is insloped, surface water eventually drains to the ditch or toe of back slope, or to a surface cross drain, which may divert water to either the ditch or over the downhill shoulder. This allows control of drainage release points, as ditch relief culverts are placed at drainage spreading locations—such as convex slopes—which can be provided with erosion protection during construction. In erosion sensitive soils such as shallow decomposed granitics over bedrock, insloping will keep surface drainage away from fill slopes and result in less erosion and fill failure during storm events. Should a back slope failure or slump occur placing material on the inside part of the traveled way surface, inslope may aid keeping water on the road until a planned release point is encountered. This avoids severe erosion of the fill slope. Inslope results in less chance of vehicles sliding off the traveled way when the surface is slippery.

The most effective use of insloping is in highly erodible or unstable soils where water should be directed away from the fill slope to avoid excessive erosion or fill failures during storm events.

An insloped template with ditch requires more clearing width and excavation for the same traveled way width and results in a wider corridor of disturbance and higher construction cost. Ditch relief pipes are also an additional cost. The ditch bottom or toe of cut is at a lower elevation than on an outsloped template, resulting in interception of greater subsurface flow volumes. Insloping concentrates drainage to a greater degree than outsloping. Erosion of the inside edge (toe of cut) or ditch bottom may occur and may lead to shallow back slope failure in sensitive soils, possibly leading to large amounts of slough material becoming available for erosion and transport. This area can be armored with riprap or vegetation to reduce erosion. Where frost heave or other causes of back slope ravel occur causing debris to accumulate at the bottom of back slopes, insloping may result in constant erosion from the road and subsequent sedimentation into the local hydrologic system. Sediment traps may be needed. In some unstable areas, insloping may lead to problems from increased moisture content in road subgrades.

Table 1—Factors affecting selection of traveled way surface shape.

Factor	Inslope	Outslope	Crown
Definition	Shaped to drain toward the back slope	Shaped to drain toward the fill slope	Combination of inslope and outslope with high point in center of traveled way surface.
Drainage	Concentrates runoff against the back slope or ditch	Directs and disperses runoff toward and over the fill slope	Divides runoff between back slope or ditch and fill slope
	Runoff release points are controlled		Other effects may be between inslope and outslope condition due to surface flow division
	Greater chance of runoff accumulating in ditch or on the road if a culvert plugs		
	Greater chance of interception of subsurface flow		
Construction requirements	Requires more excavation and clearing	Requires less excavation and clearing	Will require excavation and clearing quantities between inslope and outslope
Maintenance	Needed for traveled way surface, ditch, and ditch relief structures	Needed for traveled way surface, dips, and fill slopes	Needed for traveled way surface, ditch, ditch relief structures, and fill slopes
Erosion concerns	Ditches, traveled way surfaces, at cross drains and outlets	Traveled way surfaces, fill slopes, dips, and dip outlets	Ditches, traveled way surfaces, at cross drains and outlets, and on fill slopes. Risk of erosion may be less due to surface flow division
Slope stability	Some sites with ditches require deep cuts that may cause overly high and unstable back slopes	Fill slopes may become saturated and unstable	Some sites with ditches require deep cuts that may cause overly high and unstable back slopes. Fill slopes may become saturated and unstable. Risk of either effect may be less due to surface flow division
Storm damage potential	High	Low	Medium
Effect on site	Area of disturbance due to construction is wider	Area of disturbance due to construction is minimized.	Area of disturbance due to construction is greater than for outsloped roads
Operation—vehicle drivability, ride quality	Fair (poor where grade is rolled)	Poor where grade is rolled or worst where dips are used	Good

Table 1—(continued).

Factor	Inslope	Outslope	Crown
Operation—safety (Note: depends on many other factors)	Fair	Poor to fair, depending on climate	Good
Where to use	Unstable or erodible fill slopes, steep grades, climates with snow and ice	Flat grades, where stable fill slopes will allow increasing dispersion of runoff	Unstable or erodible fill slopes, steep grades, climates with snow and ice
Where not to use	Where relief culverts have high probability of clogging, and other options for cross drains are not feasible	Steep road grades, unstable fill slopes	In areas where outslope is adequate
	Where back slopes or ditch surfaces cannot be protected adequately from erosion		

The most effective use of insloping is in the following situations:

- Where outsloping could cause excessive erosion of the fill slope
- Where outsloping is ineffective
- With frequent ditch relief culverts
- On steeper road grades
- Where maintenance of distributed surface runoff is not important for ecological reasons
- Without surface cross drains on higher standard roads
- On roads with slick traveled way surfaces.

These situations all require maintenance appropriate for the amount of traffic so that surface drainage is ensured.

Outslope Considerations

The tendency of outsloped road templates to disperse water can reduce erosion by not allowing flows to concentrate. Where equipment operators are well trained to construct and maintain outsloped surfaces and broad-based dips, outsloping can be the least costly method of constructing drainage for a low volume road. Lower cost construction and less area impacted are also advantages. Outsloping is particularly useful on flat road grades for provision of dispersed surface drainage.

It is unusual for a road with heavy haul traffic or frequent light vehicle traffic to receive enough surface maintenance to keep ruts from forming and disrupting outslope drainage. In practice, shallow surface ruts develop which frequently disrupt outslope traveled way surface drainage and cause water to concentrate into wheel paths until a planned dip or unplanned disruption is encountered which diverts water off the traveled way. Unplanned diversions concentrate water into small volumes that may erode fill slopes until natural armoring occurs through vegetation growth or by eroding the fine portion of the soil until enough coarse erosion-resistant rock fragments are left to form a protective covering on the slope. Maintenance of the traveled way surface will tend to shift these locations around. Unless the fill slope is explicitly protected from erosion, outsloping may cause more erosion than insloping. In highly unstable or erosive soils (such as shallow decomposed granite on bedrock) outsloping may result in excessive erosion and shallow slides during storm events. Outslopes on curves can concentrate water onto fills and cause fill slope damage. Some slopes have neither sufficient vegetation nor adequate coarse rock fragments to develop armoring naturally and may never stabilize without the use of special erosion protection measures.

Berms should be used on the fill shoulder of outsloped templates to direct water away from unstable fill slopes or sensitive areas. Berms should be used carefully, as more clearing width and excavation is required to provide the same usable traveled way width as on an unbermed road, and flows will be concentrated on the release area.

Outsloped road templates with grades greater than 7 percent can appear overly steep to a driver and give the impression the vehicle might slide off the road. Outsloped templates can become unsafe to use during slick surface, icy, or snow-covered conditions.

The most effective use of outsloping is in the following situations:

- Where it is important to maintain distributed surface runoff for ecological reasons
- With frequent cross drains.
- On less steep or contour (level) road grades
- Where insloping could cause excessive erosion of the toe of an unstable back slope or ditch
- On closed or obliterated roads to redevelop dispersed hillside drainage.

These situations all require maintenance appropriate for the amount of traffic so that surface drainage is ensured.

Crown Considerations

Crown can be used on grades steeper than 7 percent. A crowned template is used on many double lane roads because the wider surface area generates more surface runoff. Less cumulative surface erosion may occur if the drainage is split between an inslope and outslope section. For the same reason, on single lane roads the erosion potential of crown surface drainage is less than a constant outslope or inslope because the volume of water per unit length of road flowing over fill slopes and in ditches is less.

Crowned single lane road templates drain half of the surface drainage to the back slope side of a traveled way. If a back slope failure occurs on the road, it may extend far enough to divert accumulated ditch water to the outsloped side of the traveled way surface and off the road in a concentrated flow. This can cause considerable erosion of the adjacent fill slopes or hillside if no natural erosion protection exists. Rutting on a single lane crowned template can result in high centering of low clearance vehicles. A single lane crown surfaced template doesn't tend to cause a driver to slide in either direction. Therefore this template feels the safest and is the most easily negotiated. Crowned single lane roads have the tendency to cause drivers to drive in the center of the road rather than on the right side.

Crown is most effective in the following situations:

- Double lane roads
- Road used during slippery conditions
- Single lane roads with steep grades, and planned surface cross drains or ditches and ditch relief culverts.

Superelevation Considerations

Superelevation helps the driver negotiate curves at higher speed. It can be designed into a road to be reconstructed or created through surface maintenance by reshaping a crown surface. Deep fills through draws often settle creating a superelevated traveled way. Depending on the topography, superelevation may result in an insloped or outsloped surface with the considerations discussed above.

Superelevated curves through deep draws (often with live streams) tend to drain water trapped in wheel paths and on the traveled way surface directly on to road fills where it can erode sensitive fill slope soils and drop sediment directly into the stream below. Fill failures often occur on superelevated curves where water has run down the traveled way from a plugged cross drain or stream crossing and flowed over the road fill. Superelevation of curves can be undesirable when the resulting inslope would cause erosion of sensitive back slopes (see inslope disadvantages). Curves are often located on convex slopes, which are good places for cross drains to help disperse drainage. Superelevation in these areas may make cross drainage difficult and disrupt traffic flow.

Superelevation transitions in conjunction with road grade can result in flat spots that pond water, resulting in safety and maintenance problems. On slippery surfaces (snow and ice), steep superelevated curves may cause a driver to slide off the road if braking, accelerating, or trying to avoid an oncoming vehicle. Superelevation is most effectively used on higher speed roads to aid curve negotiation.

Design and Maintenance Considerations

1. The surface should be bladed and shaped to produce a surface that is uniform, consistent to grade, and crowned or cross sloped as indicated in contract drawings or by the character of the existing surface.

2. Outslope, inslope, or crown surfaces should be sloped at 2 to 4 percent depending on soils, climate, and road grade.

3. For native surfaced roads with grades exceeding 7 percent, a crowned surface shape with surface cross drains is recommended. Inslope and outslope surface shaping can be used on slightly steeper grades by reducing cross drain spacing and by providing rock or asphalt surfacing.

4. Rock surfacing and grass greatly reduce erosion from all road surfaces and ditches.

5. Cross drains should be installed and maintained to capture and direct surface drainage away from the traveled way, and located away from stream crossings to avoid releasing runoff containing sediment directly into live streams. Silt fences or settlement ponds may be required especially near fish-bearing streams.

Frequent maintenance with a grader or dozer blade is needed to avoid developing wheel path ruts that will disrupt surface drainage. Care must be taken to avoid building up a spill berm at the fill slope edge of the blade which can block cross drainage of outslope road surfaces. Avoid undercutting back slopes with the blade to avoid creating unstable slopes. Hand labor may be necessary at some cross drains or culvert inlets to clear woody debris off the road before shaping, or to remove small berms left by the blading that disrupt cross drainage.

LITERATURE CITED

Eck, Ronald W., and Perry J. Morgan, 1986. Culverts Versus Dips in the Appalachian Region: A Performance Based Decision Making Guide. Transportation Research Record 1106.

APPENDIX A

APPENDIX A

RECOMMENDATIONS FOR APPALACHIAN AREA SURFACE SHAPES

Table A1—Summary and recommendations regarding the use of outsloped and insloped traveled way surface shapes in the Appalachian region of the U.S. (Adapted from Eck and Morgan 1986).

Factor	Outsloped with broad-based dips	Insloped with ditches and culverts
Road grade	Dips perform best on road grades flatter than 3 percent	Culverts perform best on road grades flatter than 7 percent
Surfacing type	Armoring dips decreased failure rate	
Fill height	Failure rate of dips increased greatly where fill heights were greater than 3 feet	
Cut/fill transitions	Don’t use dips at cut/fill transitions	Use culverts if the cross drain cannot be located elsewhere
Soil type	Higher failure rates were noted for gravel-sand-silt mixtures, gravel-sand-clay mixtures, and for some silty or clayey fine sands	Not dependent
Surrounding ground slope	Not dependent	Failure rate varied directly with ground slope. May be due to more clogging of inlets with debris on steeper slopes
Aspect	Both designs had higher failure rates on northern aspects	
Position on the slope	Failure rates for both designs increased as the position on slope changed from high (ridgetop) to low (valley bottom)	
Traffic volume	Use dips where the traffic is expected to be less than 5 vehicles per day	Use culverts where the traffic is expected to be more than 15 vehicles per day
	Other factors are more important if the traffic is expected to be between 5 and 15 vehicles per day	
Soil acidity	Not dependent	Acid soil may preclude the use of steel culverts. May want to specify aluminum, plastic, or concrete