Tab Ca – Low Impact to Hydrology Guidelines Alternate Design Standards

SECTION PAGE

Tab Ca – Low Impact to Hydrology Guidelines Alternate Design Standards

Ca.1. **General**

Ca.1.A) *Requirement.* This Alternate Design Standard presents special conditions, which can be used in conjunction with the previous section – Tab C. All standards not addressed in this section are to be in conformance with Tab C. All applications of Tab Ca standards shall be subject to the review of the DOT Director as **Exclusions**. See Tab H.4 for **Exclusions** Procedures, noting that application of these alternate standards shall be based on the independent judgment of the Civil Engineer is responsible charge of the work or other responsible professional. The following shall be considered as consistent with the purpose and intent of the Alternate Road Standard under the stated conditions:

Ca.1.B) *Purpose and Intent.* Provide Low Impact to Hydrology (LITH) Design Guidelines that can be considered for adoption as County Road Design Standards where appropriate. In addition, LITH design guidelines can be cited for private roads that are not required to meet County road standards for year round access or subdivisions, but which must meet individual County grading permits, use permits, or other standards.

The 1998 University of California Cooperative Extension's (UCCE) "Effects of County Land Use Regulations and Management on Anadromous Salmonids and Their Habitats: Humboldt, Del Norte, Mendocino, Siskiyou and Trinity Counties," included the following in Recommendation #9a to the counties:

> "…Fish-friendly alternatives to generic CalTrans and AASHTO road standards should be developed." :

During the UCCE assessment process, it was determined that the road design standards for the counties were based on crowned, or inslope drainage into ditches. Inboard ditches, in some instances on long or steep gradient and/or in erodible soils can result in downcutting and enlargement of ditches, acceleration of cutbank erosion and/or plugging, and diversion across a road. An additional road design to accommodate outslope road segments, was recognized as desirable. The design, however, would have to meet safety, speed and topographic design considerations.

The U.S. Forest Service, the National Park Service, the USDA Natural Resources Conservation Service, California Department of Forestry and Fire Protection, and many forest and ranch landowners have all endorsed some form of the road design approach commonly referred to as "Low Impact to Hydrology" (LITH). The goal of the LITH design approach is to make roads less disruptive to natural watershed runoff processes. This is generally accomplished by "outsloping roads" in lieu of maintaining inboard ditches and installing "rolling dips" in lieu of ditch relief culverts. The LITH designs result in fewer culverts and ditches to build and maintain, and also allow runoff to pass over the road surface, simulating typical hillslope drainage processes. Traditional road construction with inboard ditches concentrates water into a ditch, keeping if off of the road surface. Because LITH designs remove ditch segments, they increase the amount of water flowing across the road surface. Where a road also serves as a drainage conduit, the road form and surface must be maintained so that wheel depressions, or ruts, do not readily form and re-divert the water down the road. Users of these LITH guidelines are cautioned that in the absence of roadside ditches the road's traveled surface serves a dual drainage purpose and must be maintained so that wheel depressions do not readily form. Minimizing of wheel depressions can be accomplished in various ways: 1) Close the road during the wet season when soft ground is easily deformed by wheel loads, 2) Harden the road surface to resist wheel depressions by constructing engineered fills with application of base rock layer dictated by DOT to the subgrade “R value” per road design standards, 3) Perform frequent road grading to maintain a smooth drainable plane on the outsloped and dipped sections.

The Low Impact to Hydrology Design Guidelines provide Counties and road developers with additional road design standards for very low volume local roads that result in a reduction of road related sediment to streams while meeting safety and road management concerns. These LITH road design criteria meet the requirements of the American Association of State Highway and Transportation (AASHTO) guidelines[1].

The use of LITH Design Guidelines is applicable to “Very Low-Volume Local Roads,“ as defined by AASHTO, as roads with an average daily traffic (ADT) under 400. Typically, it is not recommended that connector roads be designed to LITH Design Guidelines because when a deviation from “normal[2]” driving patterns occurs, it may require drivers to adjust, or “learn” to drive with the change in road slope. Roads designed to LITH guidelines will have to incorporate the following design limitations:

- Lower design speeds.
- Larger horizontal curve radius necessary to accommodate outsloping.
- Flatter profile grades.
- Limitations in the length of LITH designed segments to accommodate safety considerations such as steep terrain; likelihood of ice, snow or other factors.

Application of LITH standards to existing roads must also consider the following:

- Assessment of dispersing hillslope runoff rather than continued delivery to a point location via ditch or other delivery mechanism.
- Effects of subsurface water flow through base rock in locations with high ground water, seeping, or springs.
- Typically design speed on roads are set by the radius of the horizontal curves. Modifying existing roads even to AASHTO ‘Very Low-Volume Local Roads’ standards[2] may require setting stopping and passing site distance standards per prevailing speeds.

The most important Low Impact to Hydrology (LITH) design principle road designers should keep in mind is to not cut off ANY natural swales, or drainage courses. Convey ALL natural swales across the road using critical dips or culverts with energy dissipaters so that natural drainage waters are delivered to their natural courses at non-erosive velocities. Do not use an inboard ditch to convey water from one natural course then concentrate it at the next road drainage facility. Following this LITH principle alone will accomplish over 90% of the goal of minimizing the road’s disruptive effect to the watershed.

[1] “Guidelines for Geometric Design of Very Low-Volume Local Roads,” American Association of State Highway and Transportation Officials, 2001.
[2] “Normal” driving patterns typically consist of driving on crowned or insloped surfaces. While outsloped segments may occur on roads, they tend to be relatively short in length.

REF: “Road Design Guidelines for Low Impact to Hydrology” Five Counties Salmonid Conservation Program, Howard Dashiell, CA Registered Civil Engineer (principal author) and Mark Lancaster, CA Registered Professional Forester

Ca.2. **Definitions**

Ca.2.A) *Alternate Design Standard - Low Impact to Hydrology:* The standards allow new roads to be designed to LITH guidelines with limits related to public health and safety. These guidelines conform to the AASHTO *Guidelines for Geometric Design of Very Low-Volume Local*

Ca.2.B) *Cross Culvert:* A conduit that moves a natural watercourse under the road.

Ca.2.C) *Crowned Road:* Typical road cross section that slopes away from the center of the road to both shoulders.

Ca.2.D) *Critical Dip.* Combination of crest and sag vertical curves to form a road profile at a stream crossing which reverses grade to form a 0.4 to 0.5 foot deep swale which conducts drainage water flowing down the profile to the shoulder and armored fill slope so that storm water is conducted to natural watercourses at non-erosive velocities. Depending on the designer's cross sectional slope in the swale, critical dips that are surfaced can conduct between 5 to 15 cfs. This can, in some cases, substitute for a cross culvert. A critical dip can serve as an additional surface route for storm water. It could conduct flood flows in conjunction with an obstructed cross culvert with only nominal, wear on improvements while minimizing erosion caused from road fill wash out.

Ca.2.E) *Ditch Relief Culvert:* A small drainage conduit that conveys small amounts of water from inboard ditches to fill slopes at non-erosive velocities.

Ca.2.F) *Fail-Safe:* When related to natural stream crossings, a strategically placed sag curve or critical dip, that prevents a failed drainage facility from diverting drainage down the road profile, or overloading an inboard ditch and impacting another stream crossing can be employed as a fail-safe.

Ca.2.G) *Inboard curve:* Horizontal curve with its center away from the cut bank and the centrifugal force projected out towards the cut bank. Inboard curves with outsloped grading could be called super-elevated.

Ca.2.H) *Inboard Ditch.* The inboard ditch is between the toe of the cut bank and the road.

Ca.2.I) *In sloped Road.* The road cross section is sloped from the fill bank and shoulder in towards the toe of the cut bank or inboard ditch.

Ca.2.J) *Low Impact To Hydrology (LITH).* Road design guidelines that use outsloping and critical and rolling dips and also typically eliminate inboard ditches. These designs can produce less sediment where used appropriately and allow the road to blend into the watershed by passing runoff in a more natural way, resulting in a low impact to hydrology. It has been accepted by many forest and ranch road managers because of its economic and environmental benefits and reduced maintenance needs.

Ca.2.K) *Outboard curves*. Horizontal curve with its center behind the cut bank and the centrifugal force projected out over the fill bank. Outboard curves with outsloped grading could be called reversed super elevated.

Ca.2.L) *Out sloped Road.* Road cross section is sloped from the toe of the cut bank toward the shoulder and fill slope. Outsloped roads may or may not have an inboard ditch.

Ca.2.M) *Rolling Dip:* Combination of small crest and sag vertical curves to form a road profile that reverses grade to form a 0.1 to 0.2 foot deep swale which conducts drainage water flowing down the profile to the shoulder and fill slope. Depending on the designer's cross sectional slope in the swale, surfaced rolling dips can conduct between 0.1 to 1.0 cfs. This can, in some cases, substitute for a ditch relief culvert.

Ca.2.N) *Suitability Check:* When related to these Low Impact to Hydrology Design Guidelines, is a determination of whether the traditional approach may work just as well or better for the watershed and environment depending on the site conditions.

Ca.3. **Guidelines**

Ca.3.A) *General Standards and Responsibilities.* Same as section C.3.A except, LITH guidelines can be used in conformance with American Association of State Highway and Transportation (AASHTO) "Guidelines for Geometric Design of Very Low-Volume Local Roads" (with an average daily traffic (ADT) under 400).

Ca.3.B) *Cross Slope and Super-Elevations.* The maximum outslope cross slope shall be 6%, provided the designer considers site specific conditions that may include the following:

1) Outboard curves may not be safely outsloped if subject to ice, snow, northern exposure leaving a prolonged wet condition, or there exists a dangerous, deep embankment. The designer may reduce the outsloped cross slope or introduce an insloped or super-elevated design in these conditions. For example, AASHTO guidelines allow a unpaved road designed for 15mph, with a 50ft. min. radius horizontal curve and no super elevation, provided the traction coefficient is at least 0.7. Wet clay and snow conditions fall well below a 0.7 traction coefficient. The designer must account for wet clay if there is no super elevation or where reverse super elevation is possible the designer must give design consideration to larger radius horizontal curves or deviation from the LITH system.
2) Rolling and critical dips should not be combined with outsloped outboard curves in any case.
3) Critical dips should be combined with outsloped inboard curves where the designer wants to provide an additional surface route that could conduct flood flows in conjunction with a cross culvert (that would result in no more than nuisance damage to improvements) and prevent erosion caused from road fill wash out.
4) If a site is subject to dry weather surface water or prolonged seeps, it may require an inboard ditch as such water flowing across an outsloped road could result in a wet spot safety issue.
5) If a site is subject to sub-surface water which could damage paved surfaces, then the designer shall install a water barrier at the edge of pavement or provide an opinion from a soils investigation that sub-surface water is not likely to cause an adverse effect.

Ca.3.C) *Application.* When choosing these Low Impact to Hydrology Design Guidelines, developers and designers should employ suitability checks in relation to advantages for maintenance and the environment. The following factors should be considered:

1) Roads constructed under the Low Impact to Hydrology Design Guidelines should be low volume, local roads.
2) Roads constructed under the Low Impact to Hydrology Design Guidelines with profile grades less than 12% have the best chance for success. Roads with profile grades in excess of 12% should consider traditional inboard ditches and frequent use of ditch relief culverts.
3) When using these Low Impact to Hydrology Design Guidelines where there is only a slight natural cross slope (under 4%), there may not be sufficient grade to drain water and the road could flood. If the profile slope is near 16%, then use of lined inboard ditches with frequent cross drains, suitably located to minimize erosion, should be evaluated. Always consider Traditional Design Guidelines and LITH Guidelines for safety, road gradient, design speed, driving needs, slope, aspect, existing drainage, and other factors. LITH guidelines should be used when they can be safely applied and the advantages to the environment and maintenance costs clearly outweigh the disadvantages.

Designers should always look at safety issues when applying the LITH Design Guidelines. Other methods of spreading water may need to be used if the LITH Design Guidelines cannot be safely employed.

Ca.3. D) *Road Profile Grades.*

1) Overall grades of LITH road designs shall not exceed the maximum specified in the individual county adopted road design and/or fire safe standards. In all cases, the maximum grade shall be sixteen percent, except that the climb out grade may be up to twenty percent provided that the surface is chip sealed or paved and the local fire protection agency will permit such a grade in a short distance.
2) Vertical Curves: Vertical parabolic curves for rolling and critical dips shall be designed for drivability as these small swales are not applicable to classic stopping site distance design controls. The K value, or length of vertical curve per percent change in profile grade, for dips are set forth in Tables 1-3 below.

Unpaved Roads - Design Speed 10 to 20 mph

Resource roads with design speeds of 10-20 mph that might be seasonally closed fall into this category. The roads in this portion of the road system are not vital and need not be improved for speed or driver comfort. Projects developed in this road category may serve summer homes or provide access to non-residential or mountainous, remote property.

All roads using techniques described in the *Handbook for Forest and Ranch Roads*[3] or other LITH designs for rolling and/or critical dips that are required by use permit, ordinance, or map condition must meet the guidelines set forth in Table 1 below.

[3] "Handbook for Forest and Ranch Roads" William E. Weaver and Danny K. Hagans, 1994.

TABLE 1

TYPICAL DIP DESIGNS FOR VARIOUS PROFILE GRADES – K=1 to 3*

Kmin. = 1 to 3 for roll crest curve & dip sag curve
Kmin. = 20 for climb out crest curve
Climb out grade shall not exceed 16%
All distances in Feet except for distances in (), which are in meters

Rolling Dip

Original Grade	Roll Length Vertical Curve		Dip Length Vertical Curve		Climb out Length		Climb out Grade	Total length Critical Dip	
< 4%	15.00	(4.57)	15.00	(4.57)	73.00	(22.25)	. 6.2 %	103.00	(31.39)
. 5%	15.00	(4.57)	15.00	(4.57)	73.00	(22.25)	. 7.3 %	103.00	(31.39)
. 6%	15.00	(4.57)	15.00	(4.57)	76.00	(23.16)	. 9.5 %	106.00	(32.31)
. 7%	15.00	(4.57)	15.00	(4.57)	78.00	(23.77)	. 10 %	108.00	(32.92)
. 8%	15.00	(4.57)	15.00	(4.57)	83.00	(25.30)	. 11.3 %	113.00	(34.44)
. 9%	15.00	(4.57)	15.00	(4.57)	88.00	(26.82)	. 11.9 %	118.00	(35.97)
. 10%	20.00	(6.10)	20.00	(6.10)	100.00	(30.48)	. 14 %	140.00	(42.67)
. 11%	20.00	(6.10)	30.00	(9.14)	110.00	(33.53)	. 16 %	160.00	(48.77)
. 12%	20.00	(6.10)	30.00	(9.14)	130.00	(39.62)	. 16 %	180.00	(54.86)
. 13%	20.00	(6.10)	30.00	(9.14)	170.00	(51.82)	. 16 %	220.00	(67.06)
. 14%	30.00	(9.14)	30.00	(9.14)	295.00	(89.92)	. 16 %	355.00	(108.20)
. 15%	Not calculated – Designer's Discretion								

Critical Dip

Original Grade	Roll Length Vertical Curve		Dip Length Vertical Curve		Climb out Length		Climb out Grade	Total length Critical Dip	
< 4%	30.00	(9.14)	30.00	(9.14)	90.00	(27.43)	. 7.3 %	150.00	(45.72)
. 5%	30.00	(9.14)	30.00	(9.14)	95.00	(28.96)	. 8.9 %	155.00	(47.24)
. 6%	30.00	(9.14)	30.00	(9.14)	110.00	(33.53)	. 9.6 %	170.00	(51.82)
. 7%	40.00	(12.19)	40.00	(12.19)	145.00	(44.20)	. 10.4 %	225.00	(68.58)
. 8%	40.00	(12.19)	40.00	(12.19)	160.00	(48.77)	. 12 %	240.00	(73.15)
. 9%	40.00	(12.19)	40.00	(12.19)	200.00	(60.96)	. 14.7 %	280.00	(85.34)
. 10%	40.00	(12.19)	50.00	(15.24)	220.00	(67.06)	. 16 %	310.00	(94.49)
. 11%	40.00	(12.19)	50.00	(15.24)	230.00	(70.10)	. 16 %	320.00	(97.54)
. 12%	40.00	(12.19)	50.00	(15.24)	290.00	(88.39)	. 16 %	380.00	(115.82)
. 13%	40.00	(12.19)	50.00	(15.24)	330.00	(100.58)	. 16 %	420.00	(128.02)
. 14%	50.00	(15.24)	60.00	(18.29)	475.00	(144.78)	. 16 %	585.00	(178.31)
. 15%	Not calculated – Designer's Discretion								

*Designing rolling dips and critical dips is an exercise in vertical profile calculations. Table 1 was developed using the smallest K values allowed and modeled after designs in AutoCAD Land Development Desktop (LDD)© at various profile slopes. Table 1 shows the typical design of both a rolling dip and critical dip at various road profile grades. Designers are required to prepare actual designs in accordance with AASHTO.

The analysis found that designs on road profile grades under 8% took up only about 100 feet of road for rolling dips and about 200 feet of road for critical dips to produce acceptably drivable vertical alignment. Over 8% gradient, the length of road required for and subsequent spacing between dips went up to 200 feet and 400 feet respectively. After the road profile grade exceeded 14%, the climb out grades exceeded the 16% maximum grade rule required by the California Department of Forestry and Fire Protection (Cal Fire) for fire suppression vehicles; thus use of dips on grades exceeding 14% would not appear to be prudent. If the implementation of the LITH design approach is desired and vertical alignments cannot be safely achieved under AASHTO, then the roads can only be outsloped without the installation of dips.

If roads are slick when wet and icy (often due to location) and have some deep fill bank drop offs, the designer may elect to use 2% - 4% outsloping in general and may increase to 5% or 6% in safe areas without outboard horizontal curves. On roads with profile grades over 14% with 3% to 5% outsloping, the use of traditional inboard ditches and frequent ditch relief culverts should be considered as a safer, more effective design.

Private Subdivision - Unpaved Road Design Speed 20 to 30 mph

The roads in this portion of the road system serve the public but are not in the County Maintained system and fit the very low volume AASHTO: *Guidelines for Geometric Design of Very Low Volume Local Roads* criteria. In some instances, road owners or associations consider LITH designs in order to reduce maintenance costs and benefit the environment.

In some counties LITH designs may be cited as road standards for purposes other than for subdivisions, such as road standards for grading ordinances. Because LITH designs remove ditch segments, they increase the amount of water flowing across the road surface. Where a road also serves as a drainage conduit, the road form and surface must be maintained so that wheel depressions, or ruts, do not readily form and re-divert the water down the road.[4]

This criteria would not be appropriate for arterials which support a higher percentage of non-resident traffic. Table 2shows the typical design of both a rolling dip and critical dip at various road profile grades for these design speeds.

[4] In these instances, minimizing of wheel depressions can be accomplished in various ways as determined appropriate for the level of use of the road. For example, for seasonal roads: 1) Close the road during the wet season when soft ground is easily deformed by wheel loads, 2) Harden the road surface to resist wheel depressions by constructing engineered fills with application road base rock designed to soil "R value" test results per road design standards, 3) Perform frequent road grading to maintain a smooth drainable plane on the outsloped and dipped sections.

TABLE 2
TYPICAL DIP DESIGNS FOR VARIOUS PROFILE GRADES – K=14

Kmin. = 14 for roll crest curve & dip sag curve
Kmin. = 20 for climb out crest curve
Climb out grade shall not exceed 20%
All distances in Feet except for distances in (), which are in meters

Rolling Dip

Original Grade	Roll Length Vertical Curve		Dip Length Vertical Curve		Climb out Length		Climb out Grade	Total length Critical Dip	
< 4%	40.00	(12.19)	60.00	(18.29)	105.00	(32.00)	. 7.3 %	205.00	(62.48)
. 5%	40.00	(12.19)	70.00	(21.34)	145.00	(44.20)	. 9 %	255.00	(77.72)
. 6%	50.00	(15.24)	90.00	(27.43)	130.00	(39.62)	. 12 %	270.00	(82.30)
. 7%	60.00	(18.29)	110.00	(33.53)	135.00	(41.15)	. 13 %	305.00	(92.96)
. 8%	70.00	(21.34)	120.00	(36.58)	145.00	(44.20)	. 15.2 %	335.00	(102.11)
. 9%	70.00	(21.34)	120.00	(36.58)	185.00	(56.39)	. 15.8 %	375.00	(114.30)
. 10%	80.00	(24.38)	130.00	(39.62)	240.00	(73.15)	. 15.9 %	450.00	(137.16)
. 11%	90.00	(27.43)	130.00	(39.62)	305.00	(92.96)	. 16 %	525.00	(160.02)
. 12%	100.00	(30.48)	130.00	(39.62)	400.00	(121.92)	. 16 %	630.00	(192.02)
> 12%	Not calculated – Designer's Discretion								

Critical Dip

Original Grade	Roll Length Vertical Curve		Dip Length Vertical Curve		Climb out Length		Climb out Grade	Total length Critical Dip	
< 4%	40.00	(12.19)	70.00	(21.34)	145.00	(44.20)	. 8.8 %	255.00	(77.72)
. 5%	40.00	(12.19)	70.00	(21.34)	150.00	(45.72)	. 10.7 %	260.00	(79.25)
. 6%	60.00	(18.29)	100.00	(30.48)	150.00	(45.72)	. 12.2 %	310.00	(94.49)
. 7%	60.00	(18.29)	120.00	(36.58)	175.00	(53.34)	. 13.7 %	355.00	(108.20)
. 8%	80.00	(24.38)	140.00	(42.67)	160.00	(48.77)	. 15.7 %	380.00	(115.82)
. 9%	80.00	(24.38)	140.00	(42.67)	225.00	(68.58)	. 15.9 %	445.00	(135.64)
. 10%	90.00	(27.43)	140.00	(42.67)	295.00	(89.92)	. 16 %	525.00	(160.02)
. 11%	100.00	(30.48)	140.00	(42.67)	340.00	(103.63)	. 16 %	580.00	(176.78)
. 12%	100.00	(30.48)	140.00	(42.67)	430.00	(131.06)	. 16 %	670.00	(204.22)
> 12%	Not calculated – Designer's Discretion								

Because private engineers take responsible charge for subdivision design, they have the ability to propose designs which go beyond the above table. On roads with profile grades over 12%, the use of inboard ditches and ditch relief culverts more frequently placed should be considered as a safer, more effective design.

Paved Road Design Speed 30 to 35 mph

Because the LITH design approach involves surface sheet flow water on "paved" roads, the possibility of hydroplaning prohibits employing this approach on roads with posted speeds over 35 mph. The use of this system on paved surfaces does allow the dip climb out grade to reach 20% and still accommodate California Division of Forestry fire suppression vehicles.

TABLE 3

TYPICAL DIP DESIGNS FOR VARIOUS PROFILE GRADES – K=14

Kmin. = 14 for roll crest curve & dip sag curve
Kmin. = 20 for climb out crest curve
Climb out grade shell shall not exceed 20%
All distances in Feet except for distances in (), which are in meters

Rolling Dip

Original Grade	Roll Length Vertical Curve		Dip Length Vertical Curve		Climb out Length		Climb out Grade	Total length Critical Dip	
< 4%	70.00	(21.34)	130.00	(39.62)	25.00	(7.62).	8.4 %	225.00	(68.58)
. 5%	90.00	(27.43)	170.00	(51.82)	110.00	(33.53).	10.4 %	370.00	(112.78)
. 6%	100.00	(30.48)	190.00	(57.91)	135.00	(41.15).	12.5 %	425.00	(129.54)
. 7%	110.00	(33.53)	220.00	(67.06)	160.00	(48.77).	14 %	490.00	(149.35)
. 8%	130.00	(39.62)	240.00	(73.15)	180.00	(54.86).	16.2 %	550.00	(167.64)
. 9%	140.00	(42.67)	270.00	(82.30)	195.00	(59.44).	18 %	605.00	(184.40)
. 10%	160.00	(48.77)	290.00	(88.39)	225.00	(68.58).	20 %	675.00	(205.74)
. 11%	170.00	(51.82)	290.00	(88.39)	270.00	(82.30).	20 %	730.00	(222.50)
. 12%	190.00	(57.91)	310.00	(94.49)	360.00	(109.73).	20 %	860.00	(262.13)
> 12%	Not calculated – Designer's Discretion								

Critical Dip

Original Grade	Roll Length Vertical Curve		Dip Length Vertical Curve		Climb out Length		Climb out Grade	Total length Critical Dip	
< 4%	80.00	(24.38)	160.00	(48.77)	100.00	(30.48).	9.3 %	340.00	(103.63)
. 5%	100.00	(30.48)	190.00	(57.91)	135.00	(41.15).	11.3 %	425.00	(129.54)
. 6%	110.00	(33.53)	210.00	(64.01)	150.00	(45.72).	13 %	470.00	(143.26)
. 7%	120.00	(36.58)	240.00	(73.15)	185.00	(56.39).	14.8 %	545.00	(166.12)
. 8%	140.00	(42.67)	270.00	(82.30)	190.00	(57.91).	17 %	600.00	(182.88)
. 9%	150.00	(45.72)	290.00	(88.39)	205.00	(62.48).	18.5 %	645.00	(196.60)
. 10%	170.00	(51.82)	310.00	(94.49)	230.00	(70.10).	20 %	710.00	(216.41)
. 11%	180.00	(54.86)	300.00	(91.44)	300.00	(91.44).	20 %	780.00	(237.74)
. 12%	200.00	(60.96)	310.00	(94.49)	375.00	(114.30).	20 %	885.00	(269.75)
> 12%	Not calculated – Designer's Discretion								

The above table shows that dips placed on roads with profile grades over 12% need climb out grades over 20% if they are to be a practical length, and thus are not acceptable. Also, the distances between dips are too large to accomplish the LITH guidelines. We believe that the LITH design guidelines can be successfully applied to paved county roads but only on flatter profile slopes.