Maricopa County
Parks and Recreation Department

Park Road System Guidelines

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MARICOPA COUNTY PARK'S ROADWAY SYSTEM

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1 – THE PURPOSE OF PARK ROADS

The purpose of park roads remains in sharp contrast to that of the federal, state, city and county highway systems. Park roads are not intended to provide fast and convenient transportation; they are intended solely for the safe and efficient accommodation of park visitors and to serve essential management access needs.

The purpose of this document and these standards for the Maricopa County Parks and Recreation Department (County Park System) Roadway System (hereinafter referred to as the PARK ROAD SYSTEM or PARK ROADS) are to set standards for the varied requirements of the Park Road System and to accommodate current or planned park road use, while continuing to preserve the natural and cultural values of the County Park system. This document is also intended to provide more detailed standards for managers, planners, and designers involved in the planning, design and construction of park roads.

These standards are meant to align with the vision and mission of the County Park System. The parks' unique combination of wilderness and cultural interests automatically provides a basic direction for the park's planning and development and is subsequently reflected in the Department's vision and mission.

"Our vision is to connect people with nature through regional parks, trails and programs, inspire an appreciation for the Sonoran Desert and natural open spaces, and create life-long positive memories."

"Our mission, through responsible stewardship, is to provide the highest quality parks, trails, programs, services, and experiences that energize visitors and create life-long users and advocates."

The standards contained herein provide flexibility in the planning and design processes to allow for consideration of variations in types and intensities of park use, for wide differences in terrain, and for protection of natural and cultural resources within the County Park System. The criteria presented have been adapted from available design standards, where appropriate, and have been extended as necessary to meet the unique requirements of park roads. This will provide a framework within which design and construction of park roads should be conducted; however, this document is not intended to encompass a level of detail comparable to that normally found in technical design manuals.

On rehabilitation, restoration and resurfacing (R-R-R) projects, these standards are to be used to the extent practicable and feasible.

These standards shall serve as a guide for park road design but in no case shall replace good engineering judgment.

2 – FUNCTIONAL CLASSIFICATIONS OF PARK ROADS

2.1 Park Road System

A park road system includes those roads within or giving access to a park or other unit of the County Parks' System which are administered by the Maricopa County Parks and Recreation Department.

The County Parks System may encompass many types of environments--mountains, forests, lakes, deserts, and urban areas. Within each park there often exists a variety of terrains and potential visitor experiences. Consequently, park road systems must be appropriately designed to serve a wide range of functions, in accord with the broad statement of the purpose for park roads in Section 1.

For purposes of functional classification, the routes which make up a park road system are grouped based on use into two categories: Public Use Park Roads and Administrative Use Park Roads. These categories are further subdivided into classes. The assignment of a functional classification to a park road is not based on traffic volumes or design speed, but on the intended use or function of that particular road or route.

2.1.1 Public Use Park Roads

All park roads that are intended principally for the use of visitors for access into and within a park area are included in the Public Use Park Road category. This includes all roads that provide vehicular passage for visitors, or access to such representative park areas as points of scenic or historic interest, campgrounds, picnic areas, lodge areas, etc.

Public Use Park Roads are subdivided into the following three classes:

Class I: Primary Access Road.
Roads which constitute the main access route, circulatory tour or thoroughfare for park visitors.

Class II: Circulation Road. Roads which provide access within a park to areas of scenic, scientific, recreational or cultural interest, such as overlooks, campgrounds, etc.

Class Ill: Area Road. Roads which provide circulation within public use areas such as campgrounds, picnic areas, visitor center complexes, concession facilities, etc. These roads generally serve low-speed traffic and are often designed for one-way circulation.

2.1.2 Administrative Use Park Roads

The Administrative Park Road category consists of all public and nonpublic roads intended to be used principally for administrative purposes. It includes roads servicing equipment, maintenance areas and other administrative developments, as well as restricted patrol roads, truck trails and similar service roads.

Administrative Park Roads are subdivided into two classes:

Class IV: Administrative Access Road. All public roads intended for access to administrative developments or structures such as park offices or utility areas.

Class V: Restricted Road. All roads normally closed to the public, including patrol roads, truck trails and other similar roads.

Figure 1 illustrates the application of these functional classifications to a hypothetical park road system.

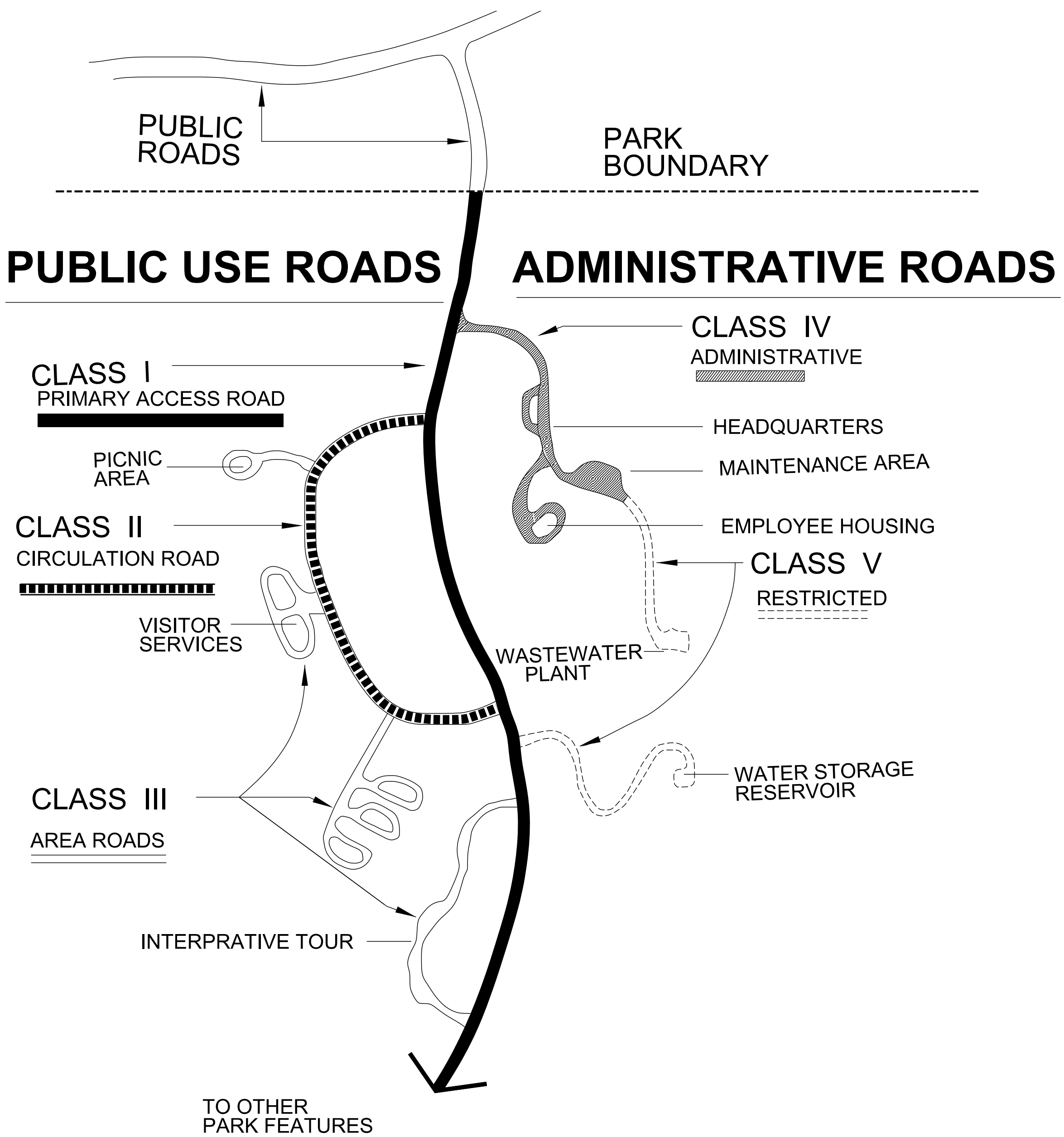

FIGURE 1 – TYPICAL PARK ROAD SYSTEM – FUNCTIONAL CLASSIFICATIONS

3 – FUNDAMENTAL CONSIDERATIONS IN PARK ROAD DESIGN

County parks are unique. In that park roads serve a distinctly different purpose from most other roads and highways, County Park System road standards must also be unique.

Park roads[1] are constructed to provide access for the protection, use and enjoyment of the natural, historical, cultural and recreational resources of the County Park System.

Thus, park roads are often an end in themselves, rather than just a means to an end, in contrast to more conventional highway systems. For some, such as the mobility or sensory impaired, roads may provide the only means of park use, thereby reinforcing the case for their being intimately blended with the resource.

The location and design of park roads must continue to be in accord with the philosophy that how a person views a park is as significant as what they see, thereby ensuring that County parks remain places where people go for a unique and rewarding experience.

In line with this philosophy, provision of park roads should be consistent with approved management plans and be limited to those roads necessary to carry out the approved management objectives for the particular area. To minimize adverse visual and resource impacts, where possible, park roads should be combined with other facilities (pipelines, power lines, etc.) into common corridors. The location, design, construction, and construction materials used for park roads should be consistent with the perpetuation and protection of the resources and aesthetic values of the area. While park roads are designed differently from other roads, they are designed, constructed and maintained within the norms of sound geometric standards for safety and structural sufficiency.

The design of park roads requires a clear definition of the park objectives and management plans. This requires identification of the type of facilities desired, their proposed locations, and the numbers of users to be accommodated at each facility to be identified prior to design of the road system. The road system should be planned for the park's ultimate needs. Construction phasing should be used to match budget constraints.

In most County parks, a road system is already in place, having been constructed in accordance with previous County policies. In updating plans for these parks, the Department of Transportation and the Parks and Recreation Department will evaluate the existing road system and determine whether it needs to be curtailed, expanded, or supplemented by other circulatory modes.

Park roads cannot accommodate all types of vehicles, nor can they accommodate all levels of speed, without violating these principles. While the travel industry continues to develop new

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[1] In this document, the terms "park road," "park" and "County Park" are used generically in reference to all parks or management areas of the County Park System.

kinds of vehicles, the County is not obligated to construct roads or to manage traffic so that all forms of modern transportation technology can be accommodated within the park.

Three recent transportation trends have significantly affected the use of County park roads: There have been substantial increases in the numbers of recreational vehicles (RV's), tour buses, and bicycles using park roads.

The popularity of RV's (such as motor-homes, pickup campers, and passenger cars with travel trailers, which are characterized by greater dimensions, slower operation and frequently inexperienced operators) has grown considerably. The recreation vehicle represents a significant element in the traffic service requirements on park roads. Design of park roads should reflect, to the extent possible where such vehicles are permitted, the fact that RV's have different operational and safety characteristics than automobiles.

Bicycles are also a significant mode of personal transportation, particularly for recreational purposes. Scenic bicycle riding and touring are very popular. Bicyclists riding on park roads shared with automobiles and other vehicular traffic can be hazardous and frightening for both cyclists and motorists. The narrow pavement sections on many park roads create significant hazards where bicycles, often laden with picnicking or camping gear, are mixed with other traffic.

Existing park roads will be analyzed to determine the size and types of vehicles that can be safely accommodated. It may be desirable for vehicles exceeding these limits to be excluded rather than reconstructing the roads to ever higher standards. Appropriate alternatives include: providing parking areas for large vehicles at park entrances; restricting vehicular traffic in certain portions of a park; converting two-way roads into one-way systems; reducing speed limits to protect both visitors and wildlife; and furnishing alternate transportation systems.

Where roads are permitted they should be planned, not merely conform to standards of technical road building excellence. Preserving the integrity of the surroundings, respecting ecological processes, protecting park resources, and ensuring a fully rewarding and safe visitor experience – these are the principles which dictate the means of visitor access and the development of road design standards for the County Park System. Safeguarding these principles and applying the standards that follow is, therefore, a multi-disciplinary undertaking – a process combining the policies and decisions of management with the talents of engineers, designers, planners, architects and landscape architects and incorporating the contributions and expertise of protective and interpretive professionals, cultural resource specialists, and natural scientists.

4 – PARK ROAD DESIGN STANDARDS

Road design in the County Park System is based on the need to provide reasonable, leisurely and safe visitor access to natural, scenic, historic and recreational features and on facilitating the administration and protection of park resources.

Development of the existing system of roads in the County Park System took place over a relatively long period of time. Roadway designs that were appropriate for the types and magnitude of vehicular traffic when much of the park road system was constructed may no longer be adequate.

The road standards developed herein provide criteria based on those design elements considered necessary to accommodate the various potential levels of vehicular and pedestrian use that the County Park System management may decide to permit. The absolute controlling factor in application of these standards is the level of actual or permitted and controlled use. The basic alternative available, where application of a particular standard is deemed incompatible with resource protection considerations, is limitation of levels of use, types of use, or both.

In light of the foregoing, these standards have been developed to provide definitive guidelines for those involved in making decisions affecting traffic service and circulation of park visitors. They are intended to be applied uniformly to both new construction and reconstruction of park roads on a County wide basis to the extent practicable, based on projections of actual, planned, and controlled use.

On rehabilitation, restoration and resurfacing (R-R-R) projects, the standards applicable to new construction and reconstruction will in many instances not be attainable. Each R-R-R project must be considered on a case-by-case basis to determine what improvements are feasible.

Where resource preservation issues relating to a particular construction, reconstruction, or R-R-R project preclude application of an appropriate design standard based on existing traffic uses, then an alternative is restriction of use to a level consistent with the roadway geometries which can be developed without adversely affecting preservation of the resource. This may be particularly desirable in unusually sensitive natural areas or at historic sites where the integrity of the original or restored historic fabric may be jeopardized.

Often cited as the most important principle relating to safety in road design is consistency. Attempting to conform all design elements and features to the driver's expectations and avoiding abrupt changes in the application of standards greatly contributes to the provisions of a smooth flowing, accident-free facility.

4.1 DESIGN CONTROLS AND CRITERIA

In road design, various controls and criteria are employed to ensure that the facility will safely accommodate the expected traffic requirements and to encourage consistency and uniformity of operation. Primary considerations in the design of park roads are the types of terrain traversed, environmental constraints, and the desired visitor experience. These considerations are addressed through the selection and application of appropriate design controls. The major road design controls for park roads are design volume, design speed, and design vehicle.

4.1.1 Design Volume

A design volume should be established to represent the anticipated traffic use of the roadway during the park's normal operation. The design volume describes the traffic load that the road must be able to accommodate at an appropriate level of service and determines to a large degree the type of facility and pavement widths required, as well as other geometric features.

4.1.2 Design Speed

Design speed is the primary control that correlates with the physical features of design to achieve a roadway that will safely accommodate traffic for the planned use. The design speed affects such roadway features as curvature, superelevation, sight distance and gradient. Selection of this speed is primarily influenced by the purpose of the particular park road, the desired traffic volumes, the character of terrain, and environmental considerations.

Design speeds should be approximately 40 mph for primary access roads, 30 mph for circulation roads, and 20 mph for area roads. Typical design speeds may be adjusted for the different classes of park roads based on flat, rolling, and mountainous terrain conditions. Long straight road segments that encourage higher speeds than the design speed should be avoided.

Once a design speed is selected, all geometric features should be related to it. Changes in terrain and other physical controls may dictate a change in design speed for certain segments. Any decrease in design speed along a road should not be introduced abruptly; this decrease should be extended over a sufficient distance to allow the driver to adjust to the transition to a slower speed. Pavement and shoulder widths and clearances to walls and rails are less directly related to design speed; however, they can affect capacity, vehicle speeds and safety. Consequently, higher standards for those features should be used on roads with higher design speeds.

The maximum posted speed limit for any park road should not exceed 35 miles per hour. Any exceptions should be approved by the County Traffic Engineer. Posted speed limits should generally be 5 mph less than the design speed.

4.1.3 Design Vehicle

Another major control in geometric design of park roads are the chosen design vehicles, which are based on the types of vehicles that will be permitted to use the facility. The physical dimensions and operating characteristics of design vehicles are used to develop sight distance, cross-section, intersection design, and other geometric design criteria. Existing and anticipated types of vehicles to be using park roads must be examined to establish representative vehicles for use in the process of designing the roadways.

The AASHTO publication *A Policy on Geometric Design of Highways and Streets* identifies various vehicle types and is to be used as a reference for vehicle dimensions and for the minimum turning paths of design vehicles. The governing paths are those of the outer front overhang and the inner rear wheel. The outer front wheel is assumed to follow a circular arc, which is the minimum turning radius as determined by the vehicle's steering mechanism.

The primary design vehicle selected for public use park roads is a motorhome pulling a trailer (figure 2). The above mentioned AASHTO publication details the design vehicle dimensions and its related turning characteristics. For non-public use park roads, other design vehicles may be selected and are not included in this manual.

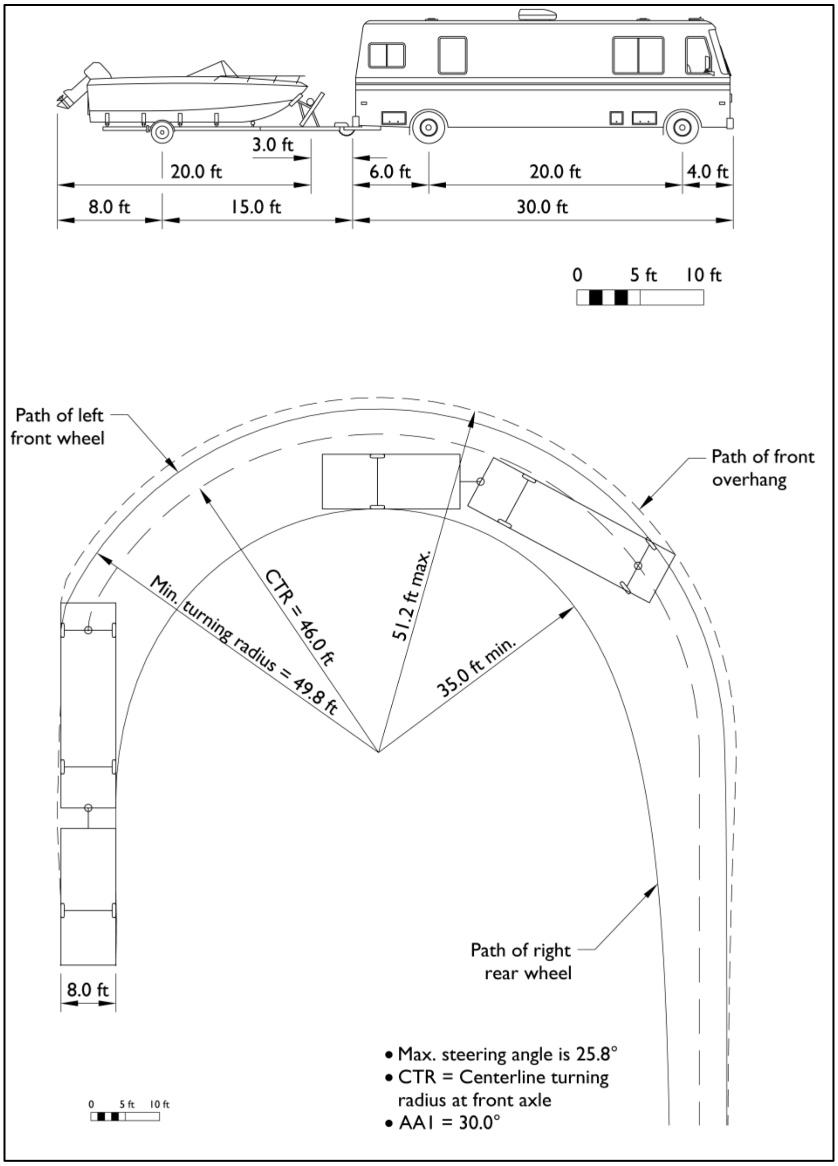

FIGURE 2 – DESIGN VEHICLE AND TURNING PATH

4.1.4 Inter-Relationship of Design Controls

The road design process involves identifying on a segment-by-segment basis the design speed for a planned design volume and selected design vehicle. Design speed for park roads is largely determined by the character of the terrain, the resource traversed, and the planned visitor experience. In cases where these considerations control design speed, the planned design volume and/or design vehicle may require appropriate adjustment.

4.2 DESIGN ELEMENTS

The foregoing controls and criteria have a major influence on the geometries of park roads and other elements of design. The elements which follow have been tailored to meet the special needs and limitations of County Park System roads. While all these elements are closely inter-related, each influencing the others, all must be properly coordinated in their application to a particular project.

Key among the park road design elements are the horizontal and vertical alignments, which have a subtle yet very important inter-relationship. It is the skillful manipulation of these two elements in a manner compatible with the terrain traversed which results in the traditional curvilinear alignment of park roads.

4.2.1 Terrain

The topography of the land influences both horizontal and vertical road alignment but is more evident in vertical alignment. For design purposes, topography is generally classified based on three types of terrain conditions:

- Level terrain is that condition where highway sight distances, in relation to both horizontal and vertical restrictions, are generally long, or can be made so, without construction difficulty or undue adverse effects.

- Rolling terrain is that condition where the natural slopes consistently rise above and fall below the road grade and where occasional steep slopes offer some restriction to normal horizontal and vertical roadway alignment.

- Mountainous terrain is that condition where longitudinal and transverse changes in ground elevation, with respect to the road, are abrupt, frequently requiring benching and sidehill excavation to obtain acceptable horizontal and vertical alignment.

4.2.2 Sight Distance

Sight distance is the length of roadway on which another vehicle or obstruction is continuously visible to the driver. The horizontal alignment and vertical profile shall continuously maintain an unobstructed sight distance of the roadway equal to or greater than the stopping sight distance.

Minimum stopping sight distance is directly related to the design speed of the road. Intersection corner sight distance is a direct function of the design speed of the through road only.

4.2.2.1 Stopping Sight Distance

Stopping sight distance used for road design is the sum of two distances: (1) the distance a vehicle travels after the driver sights a conflicting vehicle or object in the roadway and before braking occurs; and (2) the distance traveled during braking.

The minimum stopping sight distances for roads at various design speeds and grades are shown in Table 2. Stopping sight distances for paved surfaces are to be calculated using a brake reaction time of 2.5 seconds and a vehicle deceleration rate of 11.2 ft/sec^2. Stopping sight distances shall be adjusted for roadway grades using the formula:

$$SSD = 1.47Vt + V^2 \Big/ \left(30 * \left(\frac{a}{32.2} \pm G\right)\right)$$

Where:

SSD = Stopping Sight Distance
V = Design speed, mph
t = Brake reaction time, 2.5 seconds
a = Deceleration rate, ft/sec^2
G = Grade, rise/run - ft/ft

Table 2: Stopping Sight Distance (feet) for Various Downgrades
[Brake Reaction time 't'= 2.5; Deceleration Rate 'a' = 11.2]

Design Speed (mph)	Percent Grade						
	≤2	3	6	9	12	15	18
15	80	80	82	85	89	94	100
20	115	116	120	126	133	141	153
25	155	158	165	173	184	198	217
30	200	205	215	227	242	262	290
35	250	258	271	288	308	336	372
40	305	315	333	354	382	417	465

Note: Design values are rounded up distances.

4.2.3 Vertical Alignment

Vertical alignment consists of tangents connected by parabolic curves. A parabolic curve is used to affect a gradual change between grades. Parabolic curves are identified by their lengths and the algebraic difference of the grades they connect.

4.2.3.1 Grades

Maximum allowable design grades in relation to design speed and type of topography are shown in Table 4.

Table 4: Maximum Design Grades in Percent

Type of Terrain	Design Speed (mph)					
	15	20	25	30	35	40
Flat	8	8	7	7	7	7
Rolling	11	11	10	10	9	9
Mountain	17	16	15	14	13	12

Source: AASHTO, A Policy on Geometric Design of Highways and Streets, 2011 edition, Table 5-8, page 5-26

Maximum design grade should be used very infrequently and should not be considered a value to be applied in most cases. The grades shown in Table 4 relate primarily to the operational performance of vehicles. Other concerns in the selection of a maximum grade are the capability of the soil for erosion resistance, the type of surface and cross-section of the roadway, the drainage treatment, and the length of maximum grade.

Short grades, less than 500 feet in length, and one-way downgrades may be 1 percent steeper than those shown in Table 4. In extreme cases (e.g., at some underpasses and. bridge approaches), 2 percent steeper grades may be considered for relatively short lengths for very low-volume roads (less than 400 vpd).

Critical length of grade is usually not a major concern for park roads. Appropriate consideration should be given to this element of design for higher design speeds or roads with large numbers of tour buses, motorhomes, or other recreational vehicles.

Flat and level grades are not objectionable on uncurbed pavement when the crown is adequate to drain the surface laterally. On curbed pavements, a minimum grade of 0.5 percent is normally required, but a grade of 0.35 percent may be used where there is high quality pavement, accurately crowned, and supported by firm subgrade.

4.2.3.2 Vertical Curves

Vertical curves are to be safe, provide a comfortable ride, be pleasing in appearance, and provide adequate drainage.

The major control for safe operation on vertical curves is the provision of ample sight distances for the design speed and roadway grade. Minimum stopping sight distance is to be provided in all cases. Additional stopping sight distance should be provided at decision points (intersections, overlooks, etc.) and more liberal distances should be used where feasible.

For crest vertical curves, the minimum sight distance is to be greater than or equal to the grade-adjusted stopping sight distance. Sight distance criteria shall be based on an assumed eye height of 3.5 feet and an object height of 6 inches.

For sag vertical curves, the minimum headlight sight distance is to be greater than or equal to the grade-adjusted stopping sight distance. Headlight sight distance is the illuminated roadway surface and is based upon a headlight height of 2.0 feet above the road surface with the light beam spreading upward at a one-degree angle from the longitudinal axis of the vehicle.

For one-lane roads, the minimum sight distance is to comply with requirements for crest and sag vertical curves

For driving comfort and roadway appearance, it is desirable to keep the length in feet, of vertical curves, at least three times the design speed, in miles per hour. Wherever practical, crest vertical curves should fall within horizontal curves.

Design of vertical curves is simplified by the use of "K" values where “K” is a coefficient by which the algebraic differences in grade is multiplied to determine the length in feet of the vertical curve which will provide the minimum required sight distance. The minimum length of long vertical curves (where the length of curve is greater than the required stopping sight distance) may be computed from the following formula:

L = KA, where:

L = the length of the vertical curve in feet;
K = the distance in feet required to affect a one percent change in gradient; and
A = the algebraic difference in grades in percent

K is constant for each design speed and its selection is based on sight distance requirements. The formula computes minimum lengths of vertical curve for either crest or sag curves; however, K values are different for each design speed and condition. Tables 5 and 6 give K values to be used for crest and sag vertical curves for long chord grades of 6% or less.

Table 5: Design Controls for Crest Vertical Curves with L>S [Eye height above road surface, h_1 = 3.5’; Object height, h_2 = 0.5’]				
Design Speed (mph)	Long Chord Grade %	Stopping Sight Distance (S) (feet)	Rate of Vertical Curvature, $K = L/A = S^2 / (100*[(2*h_1)^{0.5}+(2*h_2)^{0.5}]^2)$	
			Calculated	K for Design
15	≤ 2	80	4.8	5
	3	80	4.8	5
	6	82	5.1	6
20	≤ 2	115	9.9	10
	3	116	10.1	11
	6	120	10.8	11
25	≤ 2	155	18.1	19
	3	158	18.8	19
	6	165	20.5	21
30	≤ 2	200	30.1	31
	3	205	31.6	32
	6	215	34.8	35
35	≤ 2	250	47.0	48
	3	258	50.1	51
	6	271	55.3	56
40	≤ 2	305	70.0	70
	3	315	74.7	75
	6	333	83.4	84
The minimum required Sight Distance is the grade-adjusted Stopping Sight Distance. The grade of the long chord of the vertical curve is to be used to determine the grade-adjusted Stopping Sight Distance.				

Sag vertical curves are to be designed to maintain a headlight sight distance equal to or greater than the stopping sight distance at the roadway design speed adjusted for the roadway grade.

Table 6: Design Controls for Sag Vertical Curves with L>S [Headlight height above road surface = 2.0'; Upward light divergence = 1°]				
Design Speed (mph)	Long Chord Grade %	Stopping Sight Distance (S) (feet)	Rate of Vertical Curvature, K = L/A = $S^2/(400+3.5S)$	
			Calculated	Design
15	≤ 2	80	9.4	10
	3	80	9.4	10
	6	82	9.8	10
20	≤ 2	115	16.5	17
	3	116	16.7	17
	6	120	17.6	18
25	≤ 2	155	25.5	26
	3	158	26.2	27
	6	165	27.9	28
30	≤ 2	200	36.4	37
	3	205	37.6	38
	6	215	40.1	41
35	≤ 2	250	49.0	49
	3	258	51.1	52
	6	271	54.5	55
40	≤ 2	305	63.4	64
	3	315	66.1	67
	6	333	70.8	71
The minimum required Sight Distance is the grade-adjusted Stopping Sight Distance. The grade of the long chord of the vertical curve is to be used to determine the grade-adjusted Stopping Sight Distance. Source: AASHTO, A Policy on Geometric Design of Highways and Streets, 2011 edition, Table 3-36, page 3-161.				

4.2.3.3 General Considerations in Vertical Alignment

In addition to grade and vertical controls, while providing safe design and respecting the terrain, other considerations in designing vertical alignment include:

a. Grade Lines should follow the terrain as closely as permitted by the design speed to be consistent with the character of the terrain.
b. "Rollercoaster" or "hidden-dip" profiles should be avoided. These types of profiles are aesthetically unpleasant and are hazardous.
c. Undulating grade lines with relatively long grades should be evaluated to determine their effect on traffic operation, particularly where there are significant volumes of tour buses, motorhomes, or other recreational vehicles.

d. "Broken-back curves" (two vertical curves in the same direction separated by short sections of tangent grade) should be avoided, particularly in sags where the full view of both vertical curves is not pleasing.
e. On long grades, the steepest grades should be at the bottom and the lesser grades near the top of the ascent, or a long sustained grade should be interrupted with short intervals of lesser grade, instead of utilizing a uniform sustained grade. This is particularly applicable to low-design speed roads.
f. Grades through at-grade intersections on roads with moderate or steep grades should be 6 percent or less whenever possible.

4.2.4 Horizontal Alignment

Horizontal alignment consists of tangents and horizontal curves that are circular curves with constant radius. Criteria for determining minimum radius are based on laws of mechanics with design values depending on practical limits for superelevation and frictional factors representative of pavement surfaces.

4.2.4.1 Maximum Superelevation

Maximum superelevation rates are controlled by several factors that may vary widely: (1) frequency and amount of snow and ice; (2) extent of development in the area; and (3) frequency of slow-moving vehicles. Where snow and ice prevail, superelevation rates normally range from 0.05 to 0.08. Consideration should be given to limiting maximum superelevation on steep grades. Maximum superelevation (e) values used in Maricopa County range upward to 0.08 foot/foot.

4.2.4.2 Minimum Horizontal Curve Radii

A second variable that influences maximum curvature is the side friction factor (f) which varies with speed. The maximum side friction factor for various speeds and the minimum radii for various design speeds and superelevation rates are shown in Table 7.

Table 7: Minimum Horizontal Curve Radii for Paved Roads						
	Design Speed, V (mph)					
	15	20	25	30	35	40
Maximum Side Friction Factor (f_{max})	0.38	0.32	0.27	0.23	0.20	0.18
Maximum Superelevation (e_{max})	Minimum Radius, R_{min} (feet)					
-0.02	50	107	198	333	510	762
0.00	47	99	181	300	454	667
0.02	44	92	167	273	408	593
0.04	42	86	154	250	371	533
0.06	39	81	144	231	340	485
0.08	38	76	134	214	314	444
Minimum Radius Values are calculated from the formula: $R_{min} = V^2 /[15(0.01e_{max} + f_{max})]$						

A maximum superelevation rate of 6 percent is suggested at locations on circulation, area, and special purpose roads where there is a tendency to drive slowly. On roads with a design speed of 20 miles per hour or less, superelevation may not be warranted. On low-volume park roads with gravel or dirt surfaces, different relationships between minimum radius and superelevation exist due to lower side-friction values. In general, longer radius curves are required for a given design speed and rate of superelevation where unpaved road surfaces exist.

In addition to the controls on maximum curvature, there is a need to provide minimum stopping sight distance around curves which may control the minimum radius of curve when sight distance cannot otherwise be provided by removing the sight obstruction.

4.2.4.3 Superelevation Runoff

Superelevation runoff is the general term denoting the length of roadway needed to accomplish the change in cross slope from a section with adverse crown removed, to a fully superelevated section, or vice versa.

Curves are preferably designed with 60 to 80 percent of the superelevation runoff length located on the tangent section adjacent to the curve. Superelevation is often attained by rotating a crowned pavement about the centerline profile, or for narrow roads and one-way sloped roads, by rotating the pavement about an edge.

The minimum superelevation runoff length is determined from the width of rotated pavement and the relative gradient between the profile along the axis of rotation and the outermost pavement edge. The difference in longitudinal gradients varies with the design speed. The maximum relative gradients between the profiles for a rotated twelve foot pavement width are given in Table 8.

Table 8: Design Speed and Relative Profile Gradients (For Rotation of 12’ Wide Pavements)		
Design Speed (mph)	Maximum Relative Gradients (%)	Equivalent Maximum Relative Slope
25	0.70	1:143
30	0.66	1:152
35	0.62	1:161
40	0.58	1:172

4.2.4.4 General Controls for Horizontal Alignment

In addition to the specific design elements for horizontal alignment, there are the following other general controls:

a. Alignment should be consistent with topography and resource protection considerations.
b. Using the minimum allowable radius should be avoided whenever possible.
c. Consistent alignment should be sought; sharp curves at the end of long tangents or at the end of long, flat curves should be avoided.
d. Short lengths of curves should be avoided on flat curves to avoid the appearance of a kink.
e. On compound circular curves, differences in radii should not exceed a ratio of 2 to 1.
f. Reverse curves should be separated by a tangent length that accommodates tangent runoff and superelevation runoff.
g. "Broken-back curves" (two curves in the same direction on either side of a short tangent or large radius curve) should be avoided.
h. Sharp curvature should be avoided on long, high fills.
i. The horizontal alignment should be coordinated carefully with the vertical alignment.

4.2.5 Intersections

Intersections should be planned and located to provide as much sight distance as possible. To achieve a safe design, sufficient sight distance should be provided to allow a driver to cross or to turn onto the intersected cross road without requiring approaching cross road traffic to reduce speed. Intersection design shall provide clear sight triangles (generally speaking, a sight triangle is the minimum required visibility area that is required for a driver to evaluate potential dangers or conflicting vehicles in an intersection in order to make a safe decision and maneuver; this area should be clear of visual impediments such as bushes or shrubs or certain types of signage; the dimensions of the sight triangles depend on the design speeds of the intersecting roadways and the type of traffic control used at the intersection.[2]) based on the intersection control used and determined in compliance with the procedures identified in the AASHTO publication *A Policy on Geometric Design of Highways and Streets*. For departure sight triangles use an eighteen foot (18’) setback from the edge of the intersecting road’s near traffic lane to the decision point (vertex of the clear sight triangle).

[2] AASHTO, A Policy on Geometric Design of Highways and Streets, 2011 Edition, Chapter 9, pages 9-29 through 9-32 – reference approach sight triangle and departing sight triangle for details.

As a general rule, the alignment and grade at or near intersections are more critical than on the open road. Sight distance along the main road, as viewed from the main road or from the intersecting road, should be at least equal to the stopping sight distance for the design speed of the main road. Sight distance considerations also apply where roads intersect with pedestrian, equestrian, bicycle, or trail facilities.

Roads should intersect at, or nearly at, right angles. Roads intersecting at acute angles tend to restrict visibility and traffic flow to one direction. The smallest angle formed by the intersecting roads should not be less than 60°.

Intersections that are slightly offset from each other on opposite sides of the main road should be avoided. More than two roads intersecting at one location tend to cause traffic management problems and should also be avoided.

Intersections on sharp curves and grade combinations that make vehicle control difficult should be avoided. The grade line of the main road should be carried through the intersection and the grade line of the intersecting road should be adjusted to match the main road. The grade of the intersecting road approaching the main road should be 6 percent or less and when practical, should be flattened to approximately 1 percent for a distance sufficient to accommodate stopping and storage of the design vehicle.

It is advisable to provide sufficient width for a vehicle to pass another vehicle stopped at the intersection. The combination of the width of the main road and the radius of the taper of the intersecting road should provide adequate width for vehicles entering or leaving the main road. For intersections where significant volumes of turning maneuvers occur, consideration should be given to providing turning lanes. Where turning lanes are used, adequate lengths for merge/diverge lanes should be provided.

4.2.6 Number of Lanes

The number of lanes should be sufficient to accommodate the design traffic volume. For low-volume park roads, capacity conditions do not normally govern design and two travel lanes are appropriate.

4.2.7 Cross-Section

The roadway cross-section consists of traveled ways, auxiliary lanes, shoulders, medians and roadsides. Proper roadway width is selected on the basis of numerous factors including park resource considerations, volume of traffic, types of traffic, safety, terrain, and design speed. A typical cross-section of park road is illustrated in Figure 3.

4.2.7.1 Traveled Way

The traveled way is that portion of the roadway available for movement of vehicles, exclusive of shoulders and auxiliary lanes. It is usually comprised of two or more traffic lanes.

4.2.7.2 Shoulders

The term shoulder describes that portion of the roadway that is contiguous with the traveled way, and intended for the accommodation of stopped vehicles or for emergency use. With appropriate surfacing, shoulders may be used by pedestrians and bicyclists. Where there is appreciable traffic volume, narrow roads with narrow shoulders often give poor traffic service, may have high accident experience, and require frequent and costly maintenance. The low traffic volumes and relatively low operating speeds on most park roads do not warrant wide shoulders. However, wide shoulders may be environmentally and aesthetically objectionable, and may encourage undesirable random stopping or parking. As design volumes, design speeds or vehicle sizes increase, additional shoulder width is required for safety.

Table 9: Cross Sectional Elements

Roadway classification	Number of Lanes	Lane Width** (feet)	Lane Surface	Paved* Shoulder Width (feet)	Earthen Shoulder Width*** (feet)
Calss I Primary Access Roads	2	11-12	Paved	5	4
Class II Circulation Roads	2	10-12	Paved	5	0
Class III Area Roads	1-2	One lane: 9-12 Two lane: 8-10	Paved	2	4
Class IV Administrative Access Roads Class V Restricted Roads	1-2	Varies	Paved or Unpaved	Varies	0

*All pavement edges not bound by curb, gutter or sidewalk shall have a Type A Pavement Edge per MAG Std. Detail 201.

**Widening of traffic lanes should be provided on the inside of sharp curves. Where tour buses or recreational vehicles are allowed an additional foot of lane width is required, not to exceed 12 feet.

The total roadway width (including shoulders) for low volume, one-lane, one-way roads should not exceed 14 feet because of the tendency of drivers to use a wider facility as a two-lane road.

FIGURE 3 – TYPICAL SECTION OF PARK ROAD

4.2.8 Bikeways

Bicycling is encouraged on all functional classifications; therefore consideration must be given to providing safe travel ways. Separate bikeways are normally the safest alternative and should be considered. Where this is not practical and where a wider road section can be accommodated, shoulder areas may be improved to provide reasonable separation of bicycles from higher speed traffic.

Shoulder areas intended for bicycle use shall be paved at least 5 feet wide and should be delineated and marked to indicate the usage. Two-way bicycle traffic on the same shoulder is not allowed. On low-volume, low-speed roads, the sharing of travel lanes may be considered.

4.2.9 Surface Type

The type of roadway surface to be used is determined by the volume and composition of traffic, the desired visual appearance, environmental considerations, soil conditions, availability and cost of materials, and the extent and cost of maintenance. Table 9 shows the suggested surface types for various design volumes. High volume traffic justifies high-type pavements with smooth riding qualities and good nonskid properties in all weather. Most park roads should have a surface which will retain the cross-section, which will adequately support the planned volume and weights of vehicles without failure, will keep non-routine maintenance to a minimum, and which will be harmonious with the park environment.

4.2.10 Surface Crown

Surface cross-slope must be provided to ensure adequate drainage. However, excessive surface sloping can cause steering difficulties. Cross-slope for paved surfaces desirably should be 0.02 ft/ft. For unsurfaced dirt or gravel roads provide a cross-slope ranging from 0.03 to 0.06 ft/ft for adequate drainage of the roadway surface. On one-lane roads with low type surfaces, a one-way crown is usually provided. Roads of this type should be slope graded to provide for proper drainage.

4.2.11 Roadside Slopes and Drainage

Where terrain conditions permit, backslopes, foreslopes, and roadside drainage channels should have gentle, well-rounded transitions. Each end of a cut- or fill-slope should be rounded to provide a natural appearance. Flatter foreslopes are generally more stable and facilitate revegetation. The maximum rate of foreslope depends on terrain conditions and the stability of soils as determined by local experience.

The ditch foreslope used in design should be related to design speed, type of terrain, soil type, and resource management considerations. The ditch foreslope is to be 6:1 or flatter for primary access park roads.

Cut sections shall provide adequate ditches or other drainage features to ensure positive drainage. The ditch is to accommodate the design flows and provide for satisfactory drainage of the pavement base. When needed, underdrains are to be used. In the case of rock cuts, drill holes or tool marks should not be visible from the roadway.

Drainage structures, channels and ditches must be hydraulically designed based on sound principles of hydrology and not adversely impact floodplains.

4.2.12 Clear Zone

Providing a clear zone adjacent to a road involves a tradeoff between crash severity potential and aesthetics. A driver who leaves the road should be provided a reasonable opportunity to regain control and avoid serious injury. On the other hand, the philosophy of county park roads dictates that natural roadside features should be preserved where practical. Because of the character of the traffic and the relatively low operating speeds on county park roads, wide clear zones are not as critical as on high-speed, high-volume facilities. For these reasons, dimensions smaller than those used on these higher order roads are appropriate[3].

A range of 10' (minimum) up to 15' of recovery area, measured from the edge of the traveled way, shall be provided on primary access roads[3]. These values are recommended for the general case. However, smaller values may be acceptable in areas where environmental or other concerns are great. Clear zone widths on circulation roads and area roads are less critical than on primary access roads[3]. Since these roads experience lower traffic volumes, the potential for hazards due to roadside conditions is reduced. A minimum clear zone width of 7 feet is recommended on circulation roads and area roads. In areas where the crash potential is greater than normal, such as on the outside of sharp horizontal curves, or at the end of long, steep downgrades, or high traffic volumes, liberal clear zone widths should be provided.

When clearing in dense timber, a uniform swath or "hard edge" should be avoided by varying the clearing width and by thinning beyond the normal roadway prism. For cuts, the clearing line should be set far enough from the top of the slope to permit rounding.

4.2.13 Roadside Barriers

A roadside barrier is generally warranted when the consequences of leaving the roadway at a specific location are considered to be more severe than impacting a barrier. On many roadways, barriers are required to shield steep embankments, bridge piers, road sign supports, non-traversable ditches, culverts, and immovable objects such as trees or other rigid objects.

Given the low-volume, low-speed character of county park roads, AASHTO recommendations[4,5] indicate that barriers may not be installed as frequently on county park roads as they might be on higher-volume, higher-speed roadways. Engineering judgment should be utilized to consider the use of barriers at points of unusual danger such as sharp curves and steep embankments, particularly at those points that are unusual compared with the overall characteristics of the road, and where the potential consequences of departure from the roadway are likely to be extremely severe.

Consideration should be given to widening traffic lanes on the inside of sharp curves. Where guardrail is used, the graded width of shoulder should be increased to provide about 2 feet outside the guardrail for support. All tree trunks greater than 4 inches in diameter and other rigid objects located within 3 feet behind the barrier should be removed.

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[15] 2011 AASHTO *A Policy on Geometric Design of Highways and Streets*, p. 5-32
[4] 2001 AASHTO *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)*, p. 49
[5] 2011 AASHTO Roadside Design Guide, p. 12-6

4.3 RESURFACING, RESTORATION & REHABILITATION (R-R-R) PROJECTS

The primary purpose of R-R-R work on park roads is to increase safety and protect capital investment. Park roads on which geometries were established several decades ago are often capable of providing safe, useful service. In such cases, minor improvements which will make the roads serviceable for many more years, versus complete reconstruction, should be considered. The complete reconstruction of such roads to meet these standards could be prohibitively costly and environmentally objectionable.

A primary consideration in the development of R-R-R projects is application of criteria which allows flexibility to adjust to actual field conditions. The geometric information that follows is generally the minimum considered acceptable. For R-R-R work, the intent should be to improve above these minimums, where feasible, and to ensure the highest level of safety possible within existing conditions and constraints.

4.3.1 Traffic Volume

R-R-R projects are undertaken primarily to meet specific current needs. Where significant levels of rehabilitation are involved, a desirable design volume should be established through management decisions based on a 5- or 10-year traffic forecast.

4.3.2 Design Speed

Roads scheduled for R-R-R work should be evaluated based on the desirable design speed which would accommodate the current posted speed, but a minimum design speed should not be established. It is essential, when considering a project for a section of park road, that the geometric conditions beyond the portion to be improved are also evaluated to obtain uniformity and to achieve consistency in design over the entire route. Every attempt should be made to maintain a uniformly safe running speed for a significant segment of the roadway. Consideration should be given to transition sections between portions of a roadway having different design speeds.

4.3.3 Pavement & Shoulder Widths

The criteria for roadway cross-sections established for new construction and reconstruction apply to R-R-R projects, where feasible.

4.3.4 Grades, Curvature & Sight Distance

The geometric features of grades, curvature, and sight distance impact safety and may require an older road to be reconstructed. The level of reconstruction necessary to satisfy these criteria might also cause impacts on surrounding areas, which may be inappropriate. An evaluation of the total resultant impacts should be made before proceeding.

During the project planning phase, all hazardous locations along a roadway should be identified, and the accident records analyzed, to determine if roadway features are contributing to accidents. If accidents are related to grade, cross-section, curvature, or sight distance, consideration should be given to reconstruction improvements at critical locations, or to targeted control of vehicular types, speeds, improved signing, etc..

Generally, the existing geometric features (such as grade, curvature and sight distance) are retained on R-R-R projects. In such cases, each vertical and horizontal curve should be checked for stopping sight distance to determine if it is less than that required for safety at the posted speed. Advisory signs giving the appropriate speed as determined from the limited sight distance should be installed. Where encroachment of vegetation has impaired original sight distance, pruning or removal may be advisable.

4.3.5 Bridges

Approaches for narrow bridges (including one-way bridges) should be signed and delineated in accordance with the Manual on Uniform Traffic Control Devices (MUTCD).

4.4 STRUCTURES, SIGNING, MAINTENANCE

4.4.1 Structures

The engineering design of bridges, culverts, walls, tunnels and ancillary structures should be in accordance with AASHTO Standard Specifications for Highway Bridges. The design process should be multi-disciplinary to address aesthetic, historical, and environmental considerations.

The minimum design loading for new roadway bridges should be based upon proposed use. The vertical clearance at underpasses should be at least 14 feet above the entire roadway width. The clear roadway width for new and reconstructed bridges should desirably be a minimum of the traveled way, plus shoulders, plus 4 feet (2 feet on each side).

Bridge railings should be designed to permit lateral scenic viewing, if appropriate.

4.4.2 Signing and Marking

Although safety and efficiency of operation depend to a major extent on the geometric design of a road, they should be supplemented by standard signing and marking to provide information and warning to drivers. The extent to which signs and markings are used depends on the traffic volume, the type of road, and the average driver's degree of familiarity with the area. The MUTCD contains details regarding design, location and application of road signs and markings as they apply to park roads. Application of appropriate signing and pavement markings is considered part of the design process. The MUTCD should serve as a guide, but should not replace good engineering judgment.

4.4.3 Maintenance

Safe and efficient operation depends upon adequate levels of cyclic and preventative road maintenance and repair. Park roads should be maintained to the standards to which they have been constructed or reconstructed and in a condition that promotes safety and protects capital investment.