Roadway and Development Street Standards Manual

DRAFT
Providing safe, reliable, and sustainable roadways for now and into the future.

2019
First Edition

PIMA COUNTY
Transportation
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Glossary

TERMS

AADT – Average annual daily traffic. Total vehicle traffic of a roadway for a year divided by 365 days.

AASHTO – American Association of State Highway and Transportation Officials.

All-Weather – One foot or less of flow depth during the base flood.

Base Flood (100-Year Flood) – A flood with a 1% probability of being equaled or exceeded in any given year. Commonly referred to as the one hundred-year flood.

Curbway – The area between the back of curb and sidewalk/walkway.

Department – Pima County Department of Transportation.

Driveway – A type of private road for local access to one to four dwellings.

DSD – Pima County Development Services Department.

FHWA – Federal Highway Administration, part of the U.S. Department of Transportation.

Functional Limits – The area between the near curb line of the cross street and the beginning of tapers for right- and left-turn lanes.

Floodplain – Any areas within a watercourse which have been or may be covered partially or wholly by flood waters from the vase flood including land that have been, or may be, subject to flooding from storm water runoff, overflow of flood waters from a watercourse, alluvial fans, sheet flood zones, or other property subject to flooding. The floodplain includes the stream channel, the floodway, and the floodway fringe area.

Life Cycle Costs – Agency incurred costs over an improvements life period including initial costs, rehabilitation and maintenance costs, and disposition costs.


OPUS – A web service offered by the National Geodetic Survey (NGS) that computes coordinates for NGS continuously operating reference station network.

PAG – Pima Association of Governments.

PCDOT – Pima County Department of Transportation.

Project – Improvements to be constructed on private or public property at the request of the county or private sector.

Project Limit – The legal boundary within which the permitted improvements are constructed. For private development, the project limits are typically the property lines of the land being developed. For public roadway improvements, the project limits are the public right-of-way boundaries.

Mass Graded – The process of grading subdivision streets and lots or building pads at the same time. A subdivision is not mass graded if individual grading permits are obtained for each lot as part of the building permit process.

Road – An improved or unimproved surface of a street or roadway used for vehicular travel excluding shoulders, thoroughfare, route, or way on land between two points, usually other cities or towns and distant points that allows for travel by motorized vehicles, carts, foot, bicycles, horse, and other similar types of conveyance.
Return of Investment (ROI) – A performance measure, used to evaluate the efficiency of an investment. ROI measures the amount of return on an investment, relative to the investment’s cost. See Life Cycle Costs.

Right-of-way – The width between boundary lines of every way set apart for public travel when any part thereof is open to the use of the public for purposes of vehicular travel.

Roadway – A public route or way on land between two places used for vehicular use including shoulders

Roadside – Strip of land along the side of a roadway.

RFCD – Regional Flood Control District, Pima County.

RWRD – Regional Wastewater and Reclamation Department.

Street – A public way within an urban or developed area with buildings on one or both sides.

Sheet Flooding – Flood flows from flat terrain which are not contained within a well-defined channel.
The Roadway and Development Street Standards Manual (the “manual”) was developed to provide a single reference for design guidance of roadways and streets within Pima County. New to this release is the emphasis on performance management, life-cycle cost analysis and value added design.

The manual supersedes and replaces previous editions of the Subdivision and Development Street Standards Manual (County Code 18.69.040 B) and published Pima County Department of Transportation roadway design standards.

The manual is a living document that is expected to change over time as new technologies transform the way we plan, design, build, and operate transportation systems.

The manual is not a textbook or a substitute for engineering knowledge, experience, or judgement. Its intended audience is roadway design professionals, county departments and officials, and private developers. The document is a digital release and may be found on-line at PCDOT, Pima County Roadway and Street Standards.

AASHTO A Policy on Geometric Design of Highways and Streets serves as the basis for design of roadways and streets in Pima County and should be referenced for material not covered in this manual.

Work in Arizona Department of Transportation right-of-way shall adhere to ADOT’s Roadway Design Guidelines, applicable adopted and published standards, design guidelines, specifications and stored specifications.
1. Content

A. PURPOSE

The purpose of these standards is to inform roadway performance designs maximizing multi-modal mobility, safety and infrastructure return-on-investment while incorporating principles of complete streets and low impact development.

B. SCOPE

These standards apply to public and private roadway construction, reconstruction, rehabilitation and connections thereto within unincorporated Pima County.

C. APPLICATION AND PROCESS

The goal of these standards is to minimize prescribed requirements in favor of maximizing design performance. The design approach will be guided by a Design Summary incorporating design objectives, site constraints and providing design justification based on nationally recognized standards and performance techniques to maximize mobility, safety and life-cycle return on investment.
Classification is the process by which roadways and developments are grouped into classes according to function and character and can play an important part in transportation performance-based management. Classifications can be used to describe and track roadway system performance; set benchmarks and targets; measure outcomes for preservation, mobility, access, and safety; and identify design criteria as to how a roadway is expected to be designed (e.g. lane widths, curbing, sidewalks, right-of-way width). This chapter describes roadway and development classifications. For more detailed information on roadway classifications, refer to FHWA Federal Functional Classification Guidelines (1) and Pima Maps, Streets, Federal Highway Code (2).

A. ROADWAY CLASSIFICATIONS

Two distinctive characteristics between roadway classifications are mobility and access control. Arterials provide mobility for large traffic volumes with limited and spaced out access to reduce interference. Collectors normally offer a balanced combination of mobility and access and act as the go between with arterials and local roads. Local roads emphasize access but handle low traffic volumes with direct property access. The relationship between access and mobility provided by the different roadway classifications is illustrated in Figure 2-0.

Figure 2-0. Access-mobility relationship by functional class
1. **Arterials**

Arterials provide the highest level of mobility for long uninterrupted travel and generally have the higher design standards with multiple lanes. Given the level of mobility that they provide in terms of volumes (1,500 to 27,000 AADT) and speed, direct access to adjacent property is limited.

2. **Collectors**

Collectors provide a lower degree of mobility than arterials. They are designed for travel at lower speeds and for shorter distances. Unlike arterials, collector roads (150 to 6,300 AADT) may penetrate residential and commercial/industrial areas distributing traffic from the arterials to the ultimate destination for many motorists.

3. **Local Street**

Local streets are low volume (less than 700 AADT), low speed undivided roadways with no lane designation. They provide direct access to abutting properties and are not intended for use in long distance travel.

4. **Environmentally Sensitive Roadway, Major Streets and Scenic Routes**

Pima County roadways may be considered either environmentally sensitive and/or a major street. Environmentally Sensitive Roadways (ESR) are roadways that are located within environmentally sensitive lands identified by the County as historically, culturally, or environmentally sensitive. Identification of environmentally sensitive lands and design guidelines may be found on-line at Environmentally Sensitive Lands (3) and Environmentally Sensitive Roadway Guidelines (4), respectively.

The County’s Major Streets Plan identifies major arterial and collector roadways, right-of-way widths to be reserved as development occurs, and establishes setbacks prior to construction of the full roadway cross section. The Major Streets Plan may be found on-line at Major Streets Plan (5).

Roadways that provide exceptional scenic quality that helps define the community’s character are designated as scenic routes and are subject to the requirements of chapter 18.77.040 of the County Code.
B. DEVELOPMENT CLASSIFICATIONS

This section presents the criteria used to classify each development, in part or as a whole, as rural residential, urban residential, conservation residential, or commercial/industrial.

Developers and design engineers are encouraged to meet with Pima County Development Services staff to discuss the proposed project prior to submittal of rezoning applications, development permits, or subdivision plats. A meeting is required when the development meets any of the following criteria:

- The proposed project will have direct access to a street shown on Pima County’s Major Streets Plan (5).
- The project will generate annual average daily traffic (AADT) of 1,000 vehicles or more. For residential subdivisions, this is equivalent to approximately 100 residential units.
- The project will impact regulatory floodplains, erosion hazard areas, or mapped riparian habitat.
- The project will disturb existing vegetation, particularly native vegetation protected by state or federal law.
- The project is a redevelopment or infill of an existing neighborhood or commercial area.

1. Residential Subdivisions

As a general rule, residential subdivisions are those where property is used for dwellings, regardless of the zoning classification, and the lots individually access a local street. The exceptions to the rule are condominium or townhome subdivisions and other multi-family subdivisions that are similar to commercial and industrial developments in terms of access lanes and parking, among other elements.

This manual recognizes two main types of residential subdivisions: rural and urban. The features of each type of subdivision, as well as the criteria for categorizing residential subdivisions as rural or urban is discussed here and illustrated below in Figure 2-1. Besides the two main types of residential subdivisions, Pima County recognizes a special type of subdivision referred to as a “conservation subdivision”.

Designers of subdivisions & developments should meet with DSD staff prior to submitting rezoning applications, development permits, and subdivision plats.
a) Rural Residential Subdivisions

Rural residential subdivisions are characterized by relatively large lots, low driveway density, and minimal disturbance to the natural environment in terms of grading, drainage patterns, wildlife and native vegetation. A residential subdivision shall be classified as rural for the purpose of this manual if it meets the following three conditions:

- The typical minimum lot size is 16,000 square feet
  AND
- The subdivision is not mass graded. Mass grading is the process of grading the subdivision streets and lots or building pads at the same time. A subdivision is not mass graded if individual grading permits are obtained for each lot as part of the building permit process
  AND
- The typical minimum lot width is 80 feet as defined in Chapter 18.03 of the Pima County Code (6).
b) Urban Residential Subdivisions

The lots in urban residential subdivisions are generally smaller than in rural subdivisions. In addition, driveways are more closely spaced (high driveway density) and there are significant changes to the natural environment in terms of grading, drainage patterns, wildlife and native vegetation. In general, residential subdivisions that are not classified as rural shall be classified as urban. Specifically, a residential subdivision shall be categorized as urban for the purpose of this manual if it meets at least one of the following conditions:

- The minimum lot size is less than 16,000 square feet
- The subdivision is mass graded. Mass grading is the process of grading the subdivision streets and lots at the same time.

2. Conservation Subdivisions

Conservation subdivisions promote the establishment and preservation of scenic vistas, natural areas and, where possible and practicable, support interconnected, continuous, and integrated open space systems within an area, particularly when located contiguous to public preserves. In order to achieve the goal of conservation, a special set of street criteria has been developed for conservation subdivisions and is described in Chapter 3; however, their use is restricted to subdivisions that comply with Chapter 18.09.100 of the Pima County Code.

Conservation subdivisions shall generally comply with the requirements for rural residential subdivisions; however, in situations where the minimum lot size, lot width or the type of grading fall within the criteria defined for urban residential subdivisions, the urban standards must be used.

3. Commercial and Industrial Subdivisions

Commercial and industrial subdivisions shall follow the commercial development standards. Apartments, condominiums, and other multi-family residences of four or more units that use a system of parking and access lanes and common parking areas shall be treated as commercial developments. However, and contingent on annual average daily traffic (AADT), multi-family residences may use residential subdivision standards for off-site improvements when connecting to a local residential street.
REFERENCES


3. Design Parameters

A. DESIGN SUMMARY

The Pima County Department of Transportation has adopted Performance-Based Practical Design as the decision making framework for development and design of public roadways with the goal of obtaining the best value for the least cost. Performance-Based Practical Design focuses on the use of fiscally responsible, context sensitive solutions to deliver transportation improvements that maximize mobility, safety, and life-cycle return on investment of the County’s roadway network as a whole.

The requirements set forth in this manual are intended to provide for the design and quality construction of public roadways that can provide functionality and safety for vehicles, pedestrians, and bicycle traffic with an emphasis on mobility, safety, and life-cycle return on investment.

Performance-Based Practical Design allows for flexibility in the selection of design values. Designers are encouraged to evaluate their design from a mobility, safety, and life-cycle return on investment perspective to maximize project value. To this end, a Design Summary form has been developed. The Design Summary is to be used to identify a roadway’s design elements, design values, source material and, when appropriate, basis for deviation from standard design values. The Design Summary form may be found on-line at PCDOT Design Summary Form (18) and is to be submitted to the County for approval.

B. ELEMENTS OF DESIGN

Geometric design of a roadway is comprised of a number of design elements that are combined to produce a facility that serves traffic safety and efficiency and community needs. Several principal elements of design are common to all classes of roadways such as sight distance, horizontal and vertical alignment, superelevation and grades. Designers are referred to AASHTO A Policy on Geometric Design of Highways and Streets (1) for a detailed discussion of specific elements of design.
1. Design Element Characteristics By Roadway Classification

Table 3-0. Design Element Characteristics by Roadway Classification

<table>
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<th>Segment Length (mile)</th>
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<td>Arterial</td>
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<tr>
<td>Collector</td>
<td>Minor</td>
<td>Major</td>
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<tr>
<td>AADT (Rural)</td>
<td>15 -400</td>
<td>150 – 1,110</td>
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<tr>
<td>AADT (Urban)</td>
<td>80 -700</td>
<td>1,100 – 6,300</td>
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<td>Design Speed ** (mph)</td>
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<td>Right-of-way width (feet)</td>
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<td>Direct Access to Property</td>
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<td>Major Terminus</td>
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<td>Arterial or major collector</td>
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<td>Minor Terminus</td>
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<td>Residential collector or local street</td>
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<td>Network Continuity</td>
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* Subdivisions with lots greater than 1 acre can have a segment length of ¼ mile.
** Design speed is equal to the posted speed.
*** Direct access to property can be provided if the maximum segment length is limited to ¼ mile and design speed is 25 mph.

Segment length in Table 3-0 refers to the distance between consecutive breaks in roadway alignment. The following elements create breaks in the alignment (applies to local roads only):

- Knuckles per PCDOT Detail 1A (23) and PCDOT Detail 1B (23).
- Sharp horizontal curves with an intersection angle greater than 60 degrees and a radius not exceeding 300 feet.
- Traffic circles per PCDOT Detail 2 (23) and PCDOT Detail 3 (23).
2. Sight Distance

In the design of streets, driveways, roundabouts and intersections, both stopping sight distance and intersection sight distance must be considered. For information on intersection sight distance refer to Section D, 5.

a) Stopping Sight Distance

The principal design control for both crest and sag vertical curves is the provision of adequate stopping sight distance along the entire length of the curve. All portions of the profile grade line shall meet stopping sight distance requirements for the design speed of the roadway.

For minimum stopping sight distance on level roadways (grades up to 2% and downgrades up to 6%), the effect of grade on stopping sight distance, and how to calculate stopping sight distance on grades, refer to AASHTO *A Policy on Geometric Design of Highways and Streets* (1).

The provision for stopping sight distance should be sufficient for the average driver to comprehend a possible conflict in the roadway and react appropriately. However, there are circumstances where a driver is confronted with unexpected, unusual, or difficult-to-perceive information sources where sight distance greater than stopping sight distance is needed. For information on decision sight distance, refer to AASHTO *A Policy on Geometric Design of Highways and Streets* (1).

3. Horizontal and Vertical Alignment

Horizontal and vertical alignments have a direct effect on the safety, operational performance, and construction and maintenance costs of a roadway. Both alignments should provide a design consistent with driver expectation, avoiding abrupt, unexpected changes, and be as directional as practical while still generally conforming to the natural terrain and other existing physical constraints.

a) Design Considerations

- When two horizontal tangents of a local street are connected by a curve of less than the minimum radius, a knuckle design per PCDOT Detail 1A (23) or PCDOT Detail 1B (23) is to be used.
- The maximum superelevation rate shall be 0.04 (4%) for local and collector roadways and 0.06 (6%) for arterials.
Grade breaks in vertical alignment of 0.5% or less do not require a vertical curve.

Minimum vertical curve length shall be three times the design speed for comfort or

Rate of vertical curvature (K) shall not exceed 167.

Maximum and minimum vertical profile grades:
- 0.5% minimum grade
- 4% maximum grade break at side-street intersections
- 7% maximum grade in foothill or mountainous areas
- 10% maximum grade local street
- 15% maximum grade local street (Conservation Subdivision)
- 18% maximum grade local street for short distances (Conservation Subdivision)
- 8% maximum grade collectors

b) Horizontal Clearance to Obstructions

**URBAN ROADS**

When the standard three foot curbway is provided, fixed objects such as utility poles or cabinets, traffic barriers, mailboxes, or fire hydrants are to be placed behind the sidewalk unless the object has a recognized breakaway feature and does not block sight distance or is flush mounted and does not present a tripping hazard.

If the curbway width is increased, such objects may be allowed in the curbway provided they are offset from the back of curb at least 5 feet and preferably 8 feet.

**RURAL ROADS**

Rural roads must provide an unobstructed, traversable area (clear zone) beyond the edge of the through traveled way including shoulders, bike lanes and auxiliary lanes for the recovery of errant vehicles. Clear zone distances shall be in accordance with AASHTO Roadside Design Guide (3).

4. Design Controls
Two main roadway design controls are design speed and design vehicle. Unless directed otherwise, the design speed is to be equal to the posted speed. The minimum design speed for each roadway classification is summarized in Table 3-1.

A 20-mph design speed can be used for local streets in mountainous terrain. A street section is considered to be in mountainous terrain if it traverses areas with terrain slopes of 15% or greater, which are both longer than 50 feet when measured in any horizontal direction and higher than 7.5 feet when measured vertically. Residential and major collectors in mountainous terrain must still meet the criteria in Table 3-1.

### Table 3-1. Design Controls - Speed and Vehicle

<table>
<thead>
<tr>
<th>Roadway Classification</th>
<th>Design Speed (mph)</th>
<th>Design Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial (Minor/Principal)</td>
<td>40 or greater</td>
<td>WB-62</td>
</tr>
<tr>
<td>Major Collector</td>
<td>30 to 40</td>
<td>WB-62</td>
</tr>
<tr>
<td>Minor Collector</td>
<td>30 to 40</td>
<td>WB-40</td>
</tr>
<tr>
<td>Local Street</td>
<td>25</td>
<td>WB-40</td>
</tr>
</tbody>
</table>

The standard design vehicles for each roadway classification are presented in Table 3-1. Although the standard design vehicles are listed in the table, the design vehicle is based upon the anticipated vehicle type and volume. For example, a school bus may be appropriate for the design of subdivision street intersections, and an interstate semitrailer may be appropriate for a commercial/industrial development attracting large volumes of truck traffic. For design vehicle dimensions and turning templates, refer to AASHTO *A Policy on Geometric Design of Highways and Streets* (1).

5. Other Features Affecting Geometric Design

Other roadway features can affect or be effected by the geometric design of a roadway and should therefore be accounted for in the roadway design. This section will discuss several of the more common features and their design considerations.

a) Pavement Markings, Signing and Traffic Signals

Traffic control devices are an important aspect of roadway design and should be designed concurrent with the elements of design mentioned within this chapter.
Signing and pavement marking plans shall be provided as needed. Signing and pavement marking submittals must conform to the latest edition of the Pima County/City of Tucson Pavement Signing and Marking Design Manual (21) and FHWA Manual on Uniform Traffic Control Devices (MUTCD) (10).

Signing plans shall include the MUTCD sign code and location. Pavement marking plans shall include pavement marking codes, dimensions, stationing and offsets (if applicable), and signage latitude/longitude.

Traffic signals are to be designed in accordance with the PCDOT Traffic Signal Design Manual (26).

b) Landscape

Landscape should be in keeping with the character of the roadway and development. Refer to PCDOT Standard Operating Procedures (24) for landscaping requirements in the right-of-way.

c) Street Lighting and Intelligent Transportation Systems

Street lighting helps to increase and supplement vehicle headlight visibility at night. Lighting also helps to delineate points and areas of potential conflict and allows for improved traffic operations at times of darkness that may reduce crash frequency and severity.

A return on investment analysis may be provided for street lighting at the following locations:

- Signalized intersections
- Marked crosswalks or trail crossings
- Areas of residential, commercial, and school development, or parks that generate nighttime pedestrian crossings
- Areas at or leading into an intersection that constitute a confusing or unsatisfactory condition that may be improved with lighting
- One of the intersecting streets is a major collector or arterial.

In determining the appropriateness of a street lighting application, consideration should be given to the availability of a power source, the nature of the surrounding area and existing development, and whether the lighting would create a nuisance or hazard based on grade elevation differences of surrounding areas.
Intelligent transportation systems (ITS) play an important role in the operation of the County’s roadway network. Unless directed otherwise, Pima County Department of Transportation projects are to include the installation of 4 inch fiber conduits with inner ducts.

Street lighting and ITS design shall be in conformance with PCDOT Street Lighting and ITS Conduit Design Manual (25), IES Roadway Lighting (12), AASHTO Roadway Lighting Design Guide (4), and COT/Pima County Outdoor Lighting Code (9).

d) Utilities

The following information applies to all public and private utilities including but not limited to communication, petroleum, electric power, gas, water, sewer, cable television, telephone, fiber optics, irrigation, and similar facilities that are located on, over, and under the roadway right-of-way:

- All work performed by utilities within right-of-way is to be performed in accordance with PCDOT Procedures for the Issuance of Right-of-Way Permits and Regulations of Work Under Permit (22).
- All overhead lines, poles, and other above ground utility structures shall be constructed outside the clear zone in accordance with the latest edition of the AASHTO Roadside Design Guide (3) and County codes and policies.
- Below ground facilities are to be located outside of the impact zone per sheet S-16, Chapter 8.
- Pole guys are not permitted within the functional limits of an intersection and discouraged within road right-of-way, especially when adjacent to sidewalks, equestrian paths, and along property frontage where existing and future access may be affected.
- All overhead lines (i.e. telecommunication, cable, phone, etc.) and energized power lines up to 50,000 volts shall be located a minimum distance of 10 feet from any overhead County facility such as but not limited to lighting, signage, and traffic signals (including span wires).
- Surface features such as but not limited to manhole, valve, meter, and splice box covers placed in the pavement shall be located outside vehicular wheel paths, bicycle lanes, and paved shoulders to the extent practicable.
- Service meters, backflow preventers, private service lines, and all features identified by a utility as private are to be located outside of public right-of-way except for sewer house and building connections.
- All above ground utility facilities (AGF) such as but not limited to transformers, splice cabinets, and pressure relief valves are to be placed away from roadways, driveways, alleys, drainage ways and sidewalks/pedestrian facilities.
- AGF shall not block safe cross corner sight distance, impede or hinder
pedestrian access.

- Aesthetic as well as practical considerations related to visibility of private and public signage are to be taken into account prior to placement of AGF. Visibility of existing private and public signage is not to be altered by AGF.

- Air pressure relief valves, natural gas regulators, water backflow prevention assemblies, and other similar facilities should be placed subsurface.

- Where it is necessary for underground utility lines to cross a roadway, the trench for such utility lines shall be constructed per specifications for utility trench construction. Special consideration should be given to the use of a joint or common trench when multiple utilities cross a roadway.

- Abandoned utilities are to be removed from public right-of-way per Chapter 10.50.140 of the Pima County Code (20), policies, and guidelines.

- Sewer connections for homes and businesses within streets are to be coordinated with RWRD and PCDOT.

- Maintenance access shall be provided for sewer manholes located further than 5 feet from the back of curb, including on roundabouts. When access requires traversing sidewalk or curb, mountable curb and 6-inch unreinforced sidewalk shall be used.

### e) Railroad Crossings

Geometric design of roadways crossing railroad facilities shall follow the American Railway Engineering and Maintenance-of-Way Association Manual for Railway Engineering (6).

### f) Transit Guidelines

When a project is constructed adjacent to an existing bus stop or along an existing bus route, coordination with Sun Tran is required to determine if a new bus stop or relocation or improvement of an existing bus stop is necessary.

- Project plans shall show existing and proposed bus stops, including loading pads, benches, signs, trash receptacles, bus shelters and bus pullouts.

- Sidewalks or multi-use pathways, with interconnecting access ramps, consistent with the transportation and public accommodation provisions of the Americans with Disabilities Act should connect the bus stop to the nearest intersection, local commercial development or other passenger destinations, such as educational facilities, senior citizen housing, or medical facilities.

- When a bus stop is constructed on streets that do not include outside curb, the bus stop and associated pedestrian facilities should be placed as far as possible from the edge of pavement, in accordance with applicable AASHTO Roadside Design Guide (3) and PCDOT Bus Stop Guidelines (29).

- Further guidance regarding transit facilities may be found in the PCDOT Transit Guidelines for Roadway Design and Construction (27).
g) Gated Entries

Gated entrances shall be allowed for subdivisions and developments with privately maintained areas and streets. An example of a gated entry is shown in PCDOT Detail 6 (23). Gated entries shall meet the requirements identified below. For information on gates to control access on a private driveway, refer to Section E Driveways.

- Stopping locations for keypads, card-readers, guard shacks, etc. shall be set back from the right-of-way of the cross street to avoid interfering with through traffic and to provide protection for entering vehicles. If a Traffic Impact Study is prepared for the development, it shall include a queuing analysis for the gated entry to ensure sufficient storage capacity. See Chapter 4, B on Traffic Impact Study.
- The gate may not encroach into the travel lane when open.
- Each side of a median-divided roadway/driveway shall be at least 16 feet wide to provide accessibility of emergency vehicles.
- Any equipment or obstructions such as keypads or card-readers shall be installed in a median island.
- The design of the entrance shall allow vehicles that do not go past the gate to turn around without interfering with other traffic.
- The turnaround area shall be located within the development boundary outside of the collector or arterial right-of-way.

h) Survey Monumentation

- Control monumentation for new subdivisions and newly established roadways shall consist of at least two survey control monuments per PCDOT Detail 8 (23) set at opposite ends of the project outside of the roadway but within the right-of-way. Existing Pima County On-line Positioning User Service (OPUS) control points may be used if located within one-half mile of the project. All control points and control monuments for a project (existing and new) are to be included in the reference notes on the Record of Survey.
- GPS data for each new control monument is to be collected and processed using the National Oceanic and Atmospheric Association’s National Geodetic Survey OPUS Solution software (16). The Solution Report is to be included in the Record of Survey detailing the control used and its relationship to the project’s control line. OPUS Solutions can be obtained by uploading data files through the OPUS: Online Positioning User Service (15).
- Control monuments are to be marked as “Reference Markers” in accordance with Section 10, B of the State of Arizona Boundary Survey Minimum Standards (7).
- Sectional monuments including quarter corners shall be re-established following the procedures in the Bureau of Land Management Manual of Surveying Instructions (8) and all applicable statutes and requirements specified in the current State of Arizona Boundary Survey Minimum Standards (7).
6. General Design Requirements

- All residential, commercial/industrial subdivisions and developments shall provide legal, paved, all-weather access to the public roadway system. The developer is responsible for the cost of connecting to the public roadway network.
- Individual direct access for residential lots adjacent to collectors or arterials is not permitted. All residential lots shall be accessed by internal subdivision streets.
- All subdivision lots shall have a minimum street frontage of 30 feet to allow room for the driveway and installation of utilities.
- If parking is designed to be in the lot, at least 20 feet of driveway length shall be provided between the back of sidewalk and garage opening to ensure that cars parked in the driveway do not block the sidewalk.
- Common driveways shall serve a maximum of four lots and shall be limited to a maximum of 150 feet in length to facilitate the provision of municipal services such as fire protection and trash pick-up.
- Roadway infrastructure such as travel and turn lanes, medians, shoulders, curbs, sidewalks, traffic signal equipment and drainage structures shall be located in public right-of-way or private common areas and not within easements. Easements may be granted for certain cross section elements such as utilities and slopes.
- A one foot wide access control easement shall be granted to the County when it is determined that vehicular access to or from a development or subdivision should be prohibited at a particular location.
- Connectivity of pedestrian facilities is required in order to provide a Complete Street System. For additional guidelines regarding pedestrian facilities refer to AASHTO Guide for Planning, Design, and Operation of Pedestrian Facilities (2) and FHWA PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System (11).

7. Connectivity Standards

Pima County promotes a Complete Streets design approach with an interconnected street system (connectivity) that accommodates all users and modes of travel. Connectivity provides improved access for emergency and service vehicles; connects neighborhoods with one another and commercial development and recreational areas; promotes walking, biking and equestrian activity; and reduces vehicle miles traveled resulting in better air quality and longevity of the roadway.

- The design of a subdivision shall attempt to provide multiple direct connections in its local street system without requiring the use of arterial streets and ensure that each lot has a secondary means of access. The minimum number of required external connections to the subdivision is specified in Table 3-2. When required to provide more than one external connection, the connections shall be spaced in such a manner as to maximize radial
connectivity external to the subdivision without necessitating the use of arterial streets.

- The number of connections shown in Table 3-2 may be reduced if the development boundary contains constraints to include but not limited to existing unconnected development, washes with a 100-year flow of 500cfs or greater, crossings requiring Clean Water Act Section 404 permits, riparian areas, conservation lands, wildlife linkages, other natural features, planned lands of incompatible uses, unplanned public lands, and engineering constraints of similar conditions. In these cases, the proportion of the subdivision perimeter subject to the constraints would be calculated and the number of required connections shall be reduced proportionally (e.g., if 1/3 the perimeter of a subdivision is subject to constraints and Table 3-2 specifies 3 connections for the subdivision, then the required number of connections may be reduced to 2).

<table>
<thead>
<tr>
<th>LOTS</th>
<th>CONNECTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 30</td>
<td>1</td>
</tr>
<tr>
<td>31-80</td>
<td>2</td>
</tr>
<tr>
<td>81-200</td>
<td>3</td>
</tr>
<tr>
<td>&gt;200</td>
<td>4</td>
</tr>
</tbody>
</table>

* For master planned communities, this table is applicable to each block.

Each subdivision shall incorporate and continue all roadways stubbed to the boundary of the development by previously approved but unbuilt or existing developments and arterials identified on Pima County Major Streets Plan (19) that cross into the subdivision. Excluded from this requirement are private streets and owners or homeowner associations prohibiting a connection thereto. Incorporation and continuation of roadways per this requirement shall be brought to Development Services attention for direction on roadway requirements.

Subdivisions requiring only one external connection or those containing multiple connections to collectors/arterials may be gated. However, both subdivisions with private or public streets are required to provide public access to adjacent dedicated/established public open spaces, public trails and other amenities, except when access is provided by other means.

- Stub streets designed to connect to future streets on abutting land shall be provided with a temporary turnaround at the end of the street per PCDOT Detail 4C (23).

- Street segments terminating in cul-de-sacs may serve up to 100 lots and shall contain a pedestrian connection from the end of the turnaround to another street when exceeding 660 feet in length, including the turnaround. The pedestrian connection shall be waived when subject to site constraints and surrounding land use.

- Walls bordering collector streets which pass through designated natural open space common areas shall be discouraged in order to accommodate movement of wildlife.

C. CROSS-SECTION ELEMENTS
Cross-section elements are as important to the operation and effectiveness of a roadway as is the roadway alignment. This section provides information and guidance in the selection of cross sectional elements.

1. Element Dimensions

Using the appropriate roadway classification from Chapter 2 on classifications, the required street cross section elements and dimensions should be selected from the roadway sections in Chapter 8 on sections and details.

- For residential subdivision streets, reduced pavement width for collectors is applicable when traffic calming devices are installed at intervals not to exceed 660 feet.
- Reduced pavement width for local streets is applicable when header curb is installed for edge protection or for conservation subdivisions.

2. Side Slopes

Cut and fill slopes for subdivision and department projects shall be constructed in accordance with Chapter 18.81 Pima County Code (20) and AASHTO A Policy on Geometric Design of Highways and Streets (1), respectively.

- Cut and fill slopes over 2 feet in height shall be revegetated or stabilized as shown in Table 3-3. All revegetated areas and method of irrigation and maintenance responsibility until final stabilization must be clearly identified in the landscape plans.

<table>
<thead>
<tr>
<th>Cut or Fill Slope (H:V)</th>
<th>Treatment*</th>
</tr>
</thead>
<tbody>
<tr>
<td>3:1 or less steep</td>
<td>Revegetate</td>
</tr>
<tr>
<td>Steeper than 3:1 to 2:1</td>
<td>Rock rip-rap with filter fabric</td>
</tr>
</tbody>
</table>

* Alternative methods of stabilization may be allowed if certified as stable by a registered geotechnical engineer and approved by the County.
3. Auxiliary Lanes

All access points must be evaluated to determine if an auxiliary right or left-turn lane is warranted:

- Right-turn lane warrants at unsignalized intersections are provided in Appendix A, Figures A-1 and A-2.
- Left-turn lane guidelines at unsignalized intersections shall be in accordance with AASHTO *A Policy on Geometric Design of Highways and Streets* (1).
- Auxiliary lane layout shall be in accordance with Appendix A, Exhibit A-1.
- Consideration should be given to the inclusion of auxiliary lanes at major intersections and along arterial roadways where safety would be significantly improved. Where a right-turn slip-lane with a separation island is being considered, the latest edition of the FHWA *PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System* (11) should be reviewed to assure pedestrian needs are addressed.
- Use of any alternative warrant criteria shall be supported by a traffic analysis approved by the County.
- Developments that require a Traffic Impact Study should evaluate the need for auxiliary lanes. Refer to Chapter 4, Traffic Study.

4. Median and Median Islands

Medians serve a variety of functions such as separating opposing traffic, providing storage for turning vehicles, minimizing headlight glare and providing width for future lanes. Medians on two lane roads shall have openings a minimum of 660 and a maximum of 1,320 feet apart. Median signing and striping shall be in accordance with the latest edition of the PCDOT *Pavement Signing and Marking Design Manual* (21).

Median islands are short sections of medians used primarily at intersections or access drives for aesthetics, protection of pedestrians, or channelizing of intersection movements. The design of any median or median island shall meet the following criteria:

- The width of medians and median islands shall be measured from edge of pavement to edge of pavement.
- The standard width median is 22 feet. Minimum width is 20 feet.
- Landscape placed in the median or median island shall not interfere with the stopping sight distance lines, nor shall it cause sight obstructions within the sight visibility triangles of an intersection. For further information on landscaping refer to Pima County *Standard Operating Procedure* (24).
- Where practical, landscaped medians or median islands may be depressed.
to provide for stormwater harvesting. Refer to RFCD Design Standards for Stormwater Detention and Retention Manual (28) for further information.

- For turning lanes, layout shall meet requirements as provided in Appendix A, Exhibit A-1.
- Lane shifts at intersections are not allowed. Therefore, if a median island is provided on only one of two opposing intersection approaches, sufficient tapers shall be provided on the undivided approach to ensure proper alignment of lane markings.
- Median openings within the functional limits of an intersection are not allowed unless approved by the County.

5. Traffic Barriers

Traffic barriers are systems used to shield motorists from natural or man-made obstacles located along the traveled way and may be used to protect pedestrians and bicyclists from vehicles under certain conditions.

- Roadside obstacles and embankments that may warrant shielding by a roadside barrier require evaluation in accordance with the barrier warranting process identified in the latest edition of the AASHTO Roadside Design Guide (3).
- Barrier warrant analysis shall be included with any plan submitted for review and shall include the location and description of the obstacle, evaluation of the need for a barrier, and the location and design of the barrier.
- ADOT barriers are to be installed in accordance with latest ADOT Construction Standard Drawings (5). Use of non-ADOT barriers will be reviewed on a case-by-case basis.
- The selected barrier shall have been crash tested and approved by FHWA for situations compatible with the intended use.

6. Handrails

Handrails are to be installed for the protection of pedestrians whenever slopes are steeper than 2:1 (H:V) within 3 feet of the walkway or sidewalk and the embankment height is 3 feet or greater. The designer may determine that differences in elevation between the walkway or sidewalk and nearby structures (e.g., headwalls, retaining walls) or terrain under other circumstances may also warrant the installation of handrail. Handrail shall be built per PAG Detail 105 (16).

7. Stub Streets and Cul-De-Sacs
A stub street is a street with a temporary dead end, typically at the boundary of a subdivision but intended to be extended with future development. Cul-de-sacs are streets with a permanent dead end that provides a single point of access. Stub streets and cul-de-sacs are subject to the following design standards:

- A turnaround is required at all dead ends.
- Bulbhead cul-de-sacs per PCDOT Detail 4A (23), Detail 4B (23), and Detail 4C (23) are preferred for turnarounds because of their overall efficiency and maintainability and should be used almost exclusively.
- The maximum slope in cul-de-sac areas shall be 8% in any direction and landscaping and first flush stormwater harvesting may be provided in the center.
- T-shaped and Y-shaped turnarounds per PCDOT Detail 5 (23) may be used on private streets with a maximum AADT of 140.

D. INTERSECTIONS

The goal of intersection design is to provide layouts that allow for the safe and efficient crossing, merging, and diverging of conflicting traffic.

1. Design Considerations

(a) Human Factors

Two of the most important factors that impact the design of an intersection are the perception-reaction time of drivers and walking speed of pedestrians. In Pima County, design values for driver reaction time and pedestrian walking speed are 2.5 seconds and 3.5 feet per second, respectively.

In areas where there is a disproportion number of pedestrians or type of driver (e.g., teenager, elderly) adjustments to the above design values should be considered. The designer is referred to NCHRP Human Factors Guidelines for Road Systems (31) for additional information.

(b) Traffic Demand

The design of an intersection must take into account existing and future traffic volumes for both through and turning movements. Future traffic volumes are based on the 20-year traffic forecasts prepared by the Pima Association of Governments and existing traffic data may be obtained from the Department of Transportation. The documentation and evaluation of existing and future traffic volumes are to be
presented in a Traffic Study. A general range of values for traffic factors used in forecasting future traffic volumes is summarized in Table 3-4.

<table>
<thead>
<tr>
<th>Traffic Factor</th>
<th>Value Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-Factor</td>
<td>0.08 to 0.10</td>
</tr>
<tr>
<td>D-Factor</td>
<td>55/45 to 65/35</td>
</tr>
<tr>
<td>Peak –Hour Factor</td>
<td>0.80 to 0.90</td>
</tr>
<tr>
<td>Heavy Vehicles</td>
<td>2% to 6%</td>
</tr>
</tbody>
</table>

(c) Design Vehicle

The design vehicle is based on the roadway classification and existing and anticipated vehicle type and volume. The standard vehicle type per roadway classification may be found in Table 3-1. For dual left- and right-turn lanes, a SU-30 and WB-62 are to be used in the inside and outside lanes, respectively. A standard school bus vehicle should be considered in areas with school bus activity.

2. Alignment

The alignment of an intersection must take into consideration the following points:

- The centerlines of intersecting streets shall have an angle of intersection as close to ninety degrees as is practical. In no case will an angle of intersection be less than seventy degrees except when connecting to a roundabout.

- Right-of-way lines at the corners of street intersections are to be rounded with a curve radius of twenty-five feet or greater. The radii must be adjusted at skewed intersections to provide sufficient curvature. In all cases, adequate sight distances shall be maintained.

- Intersections should be located along tangent sections of roadway. In no case shall an intersection be located on or near the inside of a sharp curve.

- Signalized intersections should be spaced no closer than 0.5 miles.

- Intersections with more than four entering approaches shall not be used unless the intersection is controlled by a roundabout.

- Roadways must not approach intersections in a horizontal curve.

- Within subdivisions and developments, a tangent section of at least twenty-five feet, measured from the nearest right-of-way line of the cross street, must be provided on all intersection approaches involving at least one collector or arterial roadway. If both intersecting roadways are local streets, a tangent section must be provided between the right-of-way line of the cross street and the intersection of the centerlines per PCDOT Detail 7 (23). The tangent section may be waived if the radius of the curve at the connection point is at least three times the minimum allowable radius.

- Single-lane roundabouts should be considered for two lane and three lane two-way roadway intersections where all-way stop traffic control is warranted.
- The type of roundabout that would be most appropriate for intersection control depends largely on the roadway types, user types, roadway volumes and surrounding land uses. Table 3-5 summarizes the characteristics of single-lane roundabouts and can provide guidance on which roundabout type to utilize.

- For detailed design guidance on roundabouts, refer to the NCHRP Roundabouts: An Informational Guide (14).

### Table 3-5. Single Lane Roundabout Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Mini-Roundabout</th>
<th>Urban Single-Lane</th>
<th>Rural Single-Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Entry Design Speed</td>
<td>15 mph</td>
<td>20 mph</td>
<td>25 mph</td>
</tr>
<tr>
<td>Inscribed Circle Diameter</td>
<td>45 – 80 ft</td>
<td>100 – 130 ft</td>
<td>115-130 ft</td>
</tr>
<tr>
<td>Splitter Island Treatment</td>
<td>Raised if possible, crosswalk cut if raised</td>
<td>Raised with crosswalk cut</td>
<td>Raised and extended with crosswalk cut</td>
</tr>
<tr>
<td>Daily Service Volumes on 4-Leg Roundabout (vehicle/day)</td>
<td>10,000</td>
<td>20,000</td>
<td>20,000</td>
</tr>
</tbody>
</table>

### 3. Spacing

Intersections on the same or opposite sides of the street are to be spaced such that when auxiliary lanes are required sufficient distance is provided to accommodate taper, gap, and storage lengths of the auxiliary lane. In no case are intersections to be spaced less than the minimum distances shown in Table 3-6.

### Table 3-6. Intersection Roadway Spacing

<table>
<thead>
<tr>
<th>Posted Speed on Adjacent Street (mph)</th>
<th>Minimum Intersection Spacing (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 35</td>
<td>150</td>
</tr>
<tr>
<td>40</td>
<td>185</td>
</tr>
<tr>
<td>45</td>
<td>230</td>
</tr>
<tr>
<td>50</td>
<td>275</td>
</tr>
</tbody>
</table>
The minimum intersection spacing shall be measured from pavement edge to pavement edge as shown in Figure 3-0. The County may request increased spacing when warranted by field conditions such as significant weaving or insufficient left- or right-turn peak period queue storage.

**Figure 3-0. Intersection Spacing**

4. Return Radii

- The design radii may be modified as necessary for special conditions such as large volumes of truck traffic and/or skewed intersection angles.

- Where auxiliary lanes are present at arterial/collector intersections, the return radius may be reduced to 25 feet, but in all cases must accommodate the design vehicle. Consideration must be given to the largest vehicle that may use the intersection.

- Three center curves should be considered to accommodate the need for a larger radius.

- Radii larger than 40 feet shall not be used for any street without approval from the County as this may lead to unsafe conditions for pedestrians and bicyclists.

- Uncurbed intersections shall utilize concrete header curb on the radius returns to prevent pavement raveling.

- Curb access ramps shall be provided at all curb returns per PCDOT Detail 207 (32).

- Refer to Table 3-7 for intersection return radii.
5. Intersection Sight Distance

At intersections, an unobstructed and continuous view of both the intersection and the intersecting roadway helps drivers avoid conflicts. The sight triangle at each intersection quadrant must be clear of any visual obstructions including structures, cut slopes, vegetation, and mounds of earth or rock over 30 inches in height. Sight visibility triangles are to be contained within public right-of-way. When sight visibility triangles extend outside of the right-of-way, a sight visibility easement is to be granted to the County. Sight triangles are required to be shown on tentative plats, site plans and construction plans with obstructions in both the horizontal and vertical planes being reviewed. Sight visibility for vehicles making a left-turn from a major road must also be provided. Three intersection sight line cases are addressed in this manual.

Case 1

The required sight visibility triangle for local to local and local to collector intersections where both streets have a design speed of 25 mph is 185 feet to the left side and 125 feet to the right side. Figure 3-1 illustrates how these measurements are translated into sight visibility triangles measured from the edge of pavement to edge of pavement.
Figure 3-1. Local-Local and Local-Collector Sight Visibility Triangles

Case 2

At intersections where the thru street has two-way traffic separated by a median with no opening for the side street, only the left side sight visibility triangle, based on the design speed of the thru street, is required. However, a pedestrian visibility triangle shall be maintained in place of the right side triangle. Figure 3-2 illustrates how these measurements are translated into sight visibility triangles measured from the edge of pavement to edge of pavement.

Figure 3-2. Pedestrian Sight Visibility Triangle

Case 3

The required intersection sight distance for vehicles turning onto a major collector, commercial/industrial collector or arterial shall be calculated in accordance with the following procedure. For this case, Pima County practice is to consider only the sight distance required for a left-turning vehicle.

- Measure the distance on the major road from the edge of pavement to the
first lane the vehicle can turn into for a left-turn. If there is a right-turn lane on the major road to turn onto the minor road being studied, the width of the right-turn lane is not included in the distance measurement. This distance is indicated as “D” in Figure 3-3.

**Figure 3-3. Distance “D” Examples**

Utilize the following equation to calculate the intersection sight distance, designated as “B” in Figure 3-4, required for each approach to the minor road.

\[ B = 1.47 V_{major} t_g \]

Where

A = distance from the Decision Point to the center of the closest approach lane to the minor road from the left or the right. The Decision Point is typically 15 feet from the edge of the major road traveled way, but may be increased to 18 feet depending on the design vehicle. Refer to AASHTO *A Policy on Geometric Design of Highways and Streets* (1) for information on roundabout sight distance.

B = intersection sight distance for a left-turn from a stop condition (feet)
\[ V_{\text{major}} = \text{speed limit on the major road (mph)} \]
\[ t_g = \text{time gap for the minor road vehicle to enter the major road and make a left turn (seconds)} \]

- If \( D \leq 11 \text{ feet} \), then \( t_g = 7.5 \)
- If \( D > 11 \text{ feet} \), then \( t_g = 7.5 + \left( \frac{D}{22} - 0.5 \right) \)
- If steep grades are involved or if the design vehicle is other than a passenger car the time gap value must be adjusted per AASHTO A Policy on Geometric Design of Highways and Streets (1).

**Figure 3-4. Intersection Sight Distance Triangle Examples**
E. DRIVEWAYS

1. Location and Spacing

Driveways are to be located such that they have a minimum impact on the traffic flow and safety of the street. All driveways are subject to the following requirements:

- Driveway spacing along arterial and collector roadways are to be spaced such that when auxiliary lanes are required sufficient distance is provided to accommodate taper, gap, and storage lengths of the auxiliary lane(s). In no case are driveways to be spaced less than the minimum distances shown in Table 3-8.

- Driveway spacing along arterial and collector roadways are to be measured from the nearest driveway edge to nearest driveway edge (Figure 3-6).

- The County may request increased driveway spacing when warranted by field conditions such as significant weaving or insufficient left- and right-turn queue storage during the peak period.

- On undivided roadways, the spacing requirements apply to driveways on both sides of the street. When property frontage is insufficient to meet driveway spacing requirements, shared driveway access is encouraged.
County should be contacted when insufficient frontage is available to meet driveway requirements.

Driveways along a local street are not be located in the radius of the intersecting street.

Corner clearance is the distance between a driveway and the adjacent street intersection. The minimum allowable corner clearance is presented in Table 3-8. The driveway to road spacing shall be measured from nearest driveway edge to nearest road edge (Figure 3-5).

**Table 3-8. Driveway Spacing**

<table>
<thead>
<tr>
<th>Posted Speed On Adjacent Street (mph)</th>
<th>Minimum Spacing (ft)</th>
<th>Minimum Corner Clearance (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>105</td>
<td>150</td>
</tr>
<tr>
<td>30</td>
<td>125</td>
<td>150</td>
</tr>
<tr>
<td>35</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>40</td>
<td>185</td>
<td>185</td>
</tr>
<tr>
<td>45</td>
<td>230</td>
<td>230</td>
</tr>
<tr>
<td>50</td>
<td>275</td>
<td>275</td>
</tr>
</tbody>
</table>

Driveways shall not be located within the functional limits of an intersection unless approved by the County. The functional limits are defined as the area between the near curb line of the cross street and the beginning of tapers for right- and left-turn lanes whether existing or proposed. Refer to Appendix A for auxiliary lane geometry.

Gates to control driveway access to residential property are to be located on private property with sufficient space for a vehicle stopped prior to the gate to be out of the roadway and clear of any sidewalk or path. Gates shall not open into the right-of-way.

Driveways near median openings should be centered with the median opening or be a minimum of 100 feet from the center of the median opening.

Driveways to property that front both an arterial and collector or local road are to be located along the collector or local road.

The maximum number of commercial driveways for any property shall be limited to two per three hundred feet of frontage along any single street.

Residential driveways along arterial and collector roadways should be limited to one.

If return radii are used for the driveway, the returns shall be located within the extension of the property line, to ensure that they do not interfere with the adjacent property unless joint access is approved.
• The edge of all driveways shall be at least 50-feet from the near edge of pavement or the near curb line of an intersecting street.

• Driveway profile is to match the existing road and shoulder grade.

• Paved driveways susceptible to erosion and cross drainage shall have a concrete header per PAG Detail 213 placed adjacent to the pavement.

**Figure 3-5. Driveway to Road Spacing Measurement**

**Figure 3-6. Driveway Spacing Measurement**
2. Design

Driveways function similar to intersections and should be designed consistent with intersection design criteria. When it is not practical to do so they should meet design criteria to the extent practical considering such factors as roadway classification, speed, and traffic volumes relative to the volume and type of vehicles using the driveway.

a) General

- Driveway entrances should be constructed perpendicular to the roadway.
- Driveways along an arterial roadway should provide sufficient maneuvering area within the property to allow a vehicle to exit the property in a forward direction.

b) Driveway Aprons and Return Radius

- On streets with vertical curbs, the use of driveway aprons with curb cuts is preferred to the use of return radii. The design of the driveway apron shall be per PAG Detail 206 (17).
- Return radii per PCDOT Detail 9 (23) may be allowed on curbed roadways instead of standard curb cuts when any of the following conditions occur:
  - The projected Average Daily Traffic (ADT) of the driveway exceeds one hundred vehicles. The projected ADT must be calculated using the trip generation rates published in the latest edition of ITE Trip Generation Manual (13).
  - The posted speed limit on the roadway is greater than 45 mph.
  - The driveway is served by a specific median opening with left turn storage.
  - The type of development, the amount of truck traffic, or the prevailing travel speeds, make curb cuts unsafe or undesirable.

Driveways on rural, uncurbed streets shall have 6-inch by 12-inch concrete headers placed adjacent to the pavement on all returns per PAG Detail 213 (17).

Driveway return radii larger than 40 feet shall not be used without approval from the County as this may lead to unsafe conditions for pedestrians and bicyclists.

The minimum driveway return radii by type of roadway are summarized in Table 3-9.
c) Driveway Width Residential Property
   - Single residential, 14 feet
   - Joint Use residential (maximum 4 joint use properties), 20 feet.

d) Driveway Width Commercial and Industrial Property
   - For two-lane commercial driveways the minimum width shall be 24 feet and the maximum width shall be 30 feet.
   - For a three lane driveway that is striped for one lane in and two lanes out without a median, the maximum width is 36 feet.
   - For driveways greater than 36 feet in width, a median is required. Where a median island is provided to separate inbound and outbound traffic, it shall be not less than 6 feet or more than 16 feet wide.
   - Each side of a median-divided driveway shall be at least 16 feet wide to ensure accessibility of emergency vehicles.

e) Grade
   The vertical profile of a driveway should allow a smooth transition to and from the roadway. A minimum 20 foot long landing area of no greater than 3% slope shall be provided on roadway approaches. The maximum allowable grade for commercial and industrial driveways shall be 6% per PCDOT Detail 9 (23).

f) Angle of Connection
   Connection angles at the intersection of driveways with public roadways should be as close to 90 degrees as practicable, but no less than 70 degrees.

g) Throat Length Commercial and Industrial Property
   The throat length is the distance between the edge of the pavement of the adjacent street and the end of the driveway inside the development (Figure 3-7).
   - Where a driveway median is provided equal to the throat length, the throat length requirement only applies to inbound traffic.

---

Table 3-9. Minimum Driveway Return Radius

<table>
<thead>
<tr>
<th>Functional Classifications</th>
<th>Minimum Return Radius (ft)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Street</td>
<td>25</td>
</tr>
<tr>
<td>Collector or Arterial Street</td>
<td>30</td>
</tr>
</tbody>
</table>

* Radius may require adjustment to accommodate the design vehicle.
When a development requires a Traffic Impact Study (see Chapter 4, B) a queuing analysis should be performed as part of the study to determine expected queue lengths. The throat length should be designed to accommodate the calculated queues.

When there is no queuing analysis, the minimum driveway throat length is 50 feet.

Single lot commercial developments can utilize a 30 foot throat length subject to the following:

- Left turns are not allowed into the development.
- A right-turn lane into the development is provided.
- The parking configuration does not allow for backing vehicles to conflict with entering traffic.

F. Commercial/Industrial Site Design

The design standards for commercial and industrial sites focus on driveway location and design and on-site circulation. For commercial and industrial projects that are required to make improvements to adjacent streets, the off-site improvements shall adhere to the requirements of this manual, as appropriate.

1. Parking Area Design

(a) Parking Lot Layout

- All parking spaces and parking aisles (access lanes) shall be designed in conformance with the parking area dimensions in Table 3-10.
Table 3-10. Parking Area Dimensions and Guidelines

<table>
<thead>
<tr>
<th>ELEMENTS</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
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<tr>
<td>A Parking Angle</td>
<td>9.0</td>
<td>9.0</td>
<td>12.0</td>
<td>23.0</td>
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<tr>
<td>B Space Width</td>
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<td>9.5</td>
<td>12.0</td>
<td>23.0</td>
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<tr>
<td>C Space Depth</td>
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<td>10.0</td>
<td>12.0</td>
<td>23.0</td>
<td>32.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>D Aisle Width</td>
<td>9.0</td>
<td>15.3</td>
<td>12.0</td>
<td>26.4</td>
<td>42.6</td>
<td>34.1</td>
<td></td>
</tr>
<tr>
<td>E Curb Length</td>
<td>9.5</td>
<td>15.7</td>
<td>12.0</td>
<td>28.0</td>
<td>43.4</td>
<td>34.5</td>
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<tr>
<td>F Curb to Curb Bay Width</td>
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<td>16.3</td>
<td>12.0</td>
<td>29.6</td>
<td>44.6</td>
<td>35.2</td>
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<tr>
<td>G Space Center to Center Width</td>
<td>9.0</td>
<td>17.8</td>
<td>12.0</td>
<td>18.0</td>
<td>47.6</td>
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<td>19.0</td>
<td>48.4</td>
<td>40.2</td>
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<tr>
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<td>18.6</td>
<td>12.0</td>
<td>20.0</td>
<td>49.2</td>
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<td>13.0</td>
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<tr>
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<td>57.7</td>
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</tr>
<tr>
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<td>18.0</td>
<td>11.5</td>
<td>63.0</td>
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</tr>
<tr>
<td>70°</td>
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<td>22.0</td>
<td>19.0</td>
<td>9.5</td>
<td>63.0</td>
<td>60.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.5</td>
<td>22.2</td>
<td>19.0</td>
<td>10.1</td>
<td>63.4</td>
<td>60.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>22.3</td>
<td>19.0</td>
<td>10.5</td>
<td>63.6</td>
<td>60.3</td>
<td></td>
</tr>
<tr>
<td>80°</td>
<td>9.0</td>
<td>21.5</td>
<td>24.0</td>
<td>9.6</td>
<td>67.0</td>
<td>-</td>
<td></td>
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<tr>
<td></td>
<td>9.5</td>
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<td>10.1</td>
<td>67.0</td>
<td>-</td>
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<td></td>
<td>10.0</td>
<td>21.5</td>
<td>24.0</td>
<td>10.6</td>
<td>67.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>90°</td>
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<td>20.0</td>
<td>24.0</td>
<td>9.0</td>
<td>64.0</td>
<td>-</td>
<td></td>
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<tr>
<td></td>
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<td>20.0</td>
<td>24.0</td>
<td>9.5</td>
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<td>10.0</td>
<td>20.0</td>
<td>24.0</td>
<td>10.0</td>
<td>64.0</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
• The orientation of Parking Area Access Lanes (PAALs) shall be perpendicular to the building faces to accommodate convenient pedestrian movements.

• Passenger drop-off points, separated from street traffic and access lanes are to be provided in conjunction with the following uses: hotels, motels, hospitals, clinics, schools (with fifty or more pupils), day care centers, religious facilities with one hundred or more seats, and recreational facilities.

• All parking lots shall provide unrestricted access for emergency and service vehicles. The designer shall utilize geometric characteristics of the SU-30 design vehicle with forty two-foot turning radius.

• Parking spaces in paved parking areas shall be permanently marked with striping in accordance with the Manual on Uniform Traffic Control Devices. Striping shall be, white paint or plastic, and extend for a minimum of ten feet for interior lines. End lines shall extend the full length of the space.

• The minimum dimensions for standard parking spaces shall be 9 feet by 20 feet. Handicapped accessible spaces shall be a minimum of 13 feet by 20 feet. However, two accessible parking spaces may share a common access aisle (Figure 3-8).

Figure 3-8. Handicapped Parking with Shared Aisle
Parking areas and spaces shall be provided with bumper barriers, wheel stops or wheel stop curbing, designed to prevent parked vehicles from extending beyond the property lines, damaging adjacent landscaping, walls or buildings, or overhanging pedestrian walkways.

Parking areas shall not be designed to require or encourage vehicles to back into a street, pedestrian access way, or alley in order to leave the lot or maneuver out of a parking space.

A back-up spur shall be provided at the end of a row parking if no ingress or egress is provided at the end. The spur shall be least 6 feet in depth, with a 3-foot radius, and shall have a wheel barrier. A minimum distance of 3 feet shall be provided between the wheel side of the barrier at the back of the spur and any wall, screen, or other obstruction over 6 inches in height as shown in Figure 3-9.

Figure 3-9. Dimensions of Back-Up Spur

2. Pedestrian Facilities

Sidewalks shall be provided on all sides of the lot that abut a curbed public street.

A continuous internal pedestrian walkway, no less than 4 feet in width, shall be provided from the public sidewalk or right-of-way to the principal entrance of buildings at the site. At a minimum, walkways shall connect focal points of pedestrian activity such as transit stops, street crossings and building entry points.

All pedestrian walkways internal to the site shall be distinguished from driving surfaces through the use of durable, low maintenance surface materials such as pavers, bricks, or concrete. Surfacing may include porous materials, or cool toppings to reduce radiant heat from the pavement surface.

3. Bicycle Facilities
• Bicycle parking spaces shall be provided as specified in Pima County Code Chapter 18.75 (20).

• When bicycle racks are installed, they must adhere to the following guidelines:
  - Bicycle racks must be securely anchored to the ground, floor, wall or ceiling.
  - Bicycle racks must be designed so that the bicycle frame and one wheel can be locked to the rack with a high security, U-shaped lock if both wheels are left on the bicycle.
  - Bicycle racks must be designed such that a bicycle six feet long can be securely held with its frame supported so the bicycle cannot be pushed or fall in a manner that will damage the wheels or components.
  - A single bicycle rack must be designed and located to accommodate two bicycles.
  - Bicycle racks must not have sharp edges that can be hazardous to pedestrians, particularly individuals with visual disabilities.
  - A bicycle rack must be a minimum of two and one half feet from a wall or other obstruction.
  - An access aisle at least five feet wide must be provided between two rows of bicycle parking.
  - Examples of acceptable bicycle rack designs are shown in Figure 3-10.

4. Drive-Thru Queuing

The minimum storage requirements for the most common types of drive-thru facilities are presented in Table 3-11. The required storage lengths shall be accomplished without interfering with the through streets or the parking area access lanes. For drive-thru facilities not included in the table or facilities known or expected to have higher than typical trip generation, the storage length shall be determined by an engineered queuing analysis.

<table>
<thead>
<tr>
<th>Drive-Thru Facility</th>
<th>Vehicle Storage per Lane</th>
<th>Required Storage per Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast-Food</td>
<td>9</td>
<td>180’</td>
</tr>
<tr>
<td>Bank</td>
<td>7</td>
<td>140’</td>
</tr>
<tr>
<td>Coffee Shop</td>
<td>14</td>
<td>280’</td>
</tr>
<tr>
<td>Car Wash (self-service)</td>
<td>2</td>
<td>40’</td>
</tr>
<tr>
<td>Day Care</td>
<td>9</td>
<td>180’</td>
</tr>
<tr>
<td>Dry Cleaner</td>
<td>2</td>
<td>40’</td>
</tr>
</tbody>
</table>

Figure 3-10. Bicycle Rack Design Example

https://store.transportation.org/Item/CollectionDetail?ID=180&gclid=EAIaIQobChMlMtcnaorWqj3wVrkMhsCh230AjxEAAYASAAEgL3A_D_BwE


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https://store.transportation.org/Item/CollectionDetail?ID=105


https://store.transportation.org/Item/PublicationDetail?ID=4133


https://www.arema.org/AREMA_MBR/AREMA_MBR/AREMASTore/MRE.asp


https://btr.az.gov/sites/default/files/documents/files/ARIZONA%20BOUNDARY%20SURVEY%20MINIMUM%20STANDARDS%281%29_0.pdf


http://www.blmsurveymanual.org/


https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm


http://www.pedbikesafe.org/PEDSAFE/


https://www.ies.org/store/


https://www.ite.org/technical-resources/topics/trip-and-parking-generation/trip-generation-10th-edition-formats/


https://pubsindex.trb.org/view/2010/M/1082903


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23. Pima County. *Standard Details.* Department of Transportation, Tucson, AZ.

http://webcms.pima.gov/cms/one.aspx?portalId=169&pageId=63368

24. Pima County. *Standard Operating Procedures.* Department of Transportation, Tucson, AZ.


   [http://www.trb.org/Main/Blurbs/167909.aspx](http://www.trb.org/Main/Blurbs/167909.aspx)
4. Traffic Study

Public and private development projects are to be evaluated to determine their impact on the adjacent roadway network and to insure that transportation improvements maximize mobility, safety, and return on investment. The Traffic Study provides the evaluation, analysis, and mitigation of improvement impacts on the roadway network and furnishes the assessment, justification, and recommendations for public roadway improvements.

This chapter will discuss the Traffic Memorandum (TM) and Traffic Impact Study (TIS). A brief letter report for small private improvements may be submitted in lieu of a TM or TIS if approved by the County.

Requests to deviate from the recommendations of the TM or TIS shall be supported by a traffic analysis approved by the County.

A. TRAFFIC MEMORANDUM (TM)

A Traffic Memorandum is required for development projects that generate less than 100 gross trips during the AM and/or PM peak hour and meet one or more of the following conditions:

- The development triggers the need for left- or right-turn lanes as outlined in Chapter 3, C, 3 on auxiliary lanes.
- The development has an access point connecting to a County maintained roadway within 500 feet of an interstate interchange.
- The development has an access point connecting to a County maintained roadway within 300 feet of a railroad crossing.
- The development generates more than 25 trips during the peak hour and has an access point connecting to a County maintained roadway within 500 feet of an intersection that has a three year crash rate 10% greater than the three year system crash rate. The intersection crash rates/system crash rates may be obtained from the latest Unsignalized Intersections and Signalized Intersections reports at PCDOT Volume, Crash & Ordinance Data (3).
- The development generates more than 25 trips during the peak hour and has an access point connecting to a County maintained roadway segment that has a three or five year crash rate 10% greater than the three year system crash rate. The segment crash rates/system crash rates may be obtained from the latest Low Volume Road Segments (≤ 10,000 VPD) and High Volume Road Segments (>10,000 VPD) reports at PCDOT Volume, Crash & Ordinance Data (3).
- There is a previous TM that is more than 3 years old and
  - Additional developments have been approved in the vicinity of the
project that impact the site, or

- Current traffic has increased by 15% or more over the traffic volumes shown in the TM, or

- A County capital improvement project is within ¼ mile of the proposed project and involves changes to lane configurations, traffic signals, roadway lighting, pedestrian/bicycle facilities, or drainage improvements.

B. TRAFFIC IMPACT STUDY (TIS)

A Traffic Impact Study is required on agency projects and development projects that meet any of the following conditions.

- The project generates 100 or more gross trips during the morning (AM) and/or afternoon (PM) peak hour.

- There is a previous TIS that is more than 3 years old, and
  - Additional developments have been approved in the vicinity of the project that impact the site, or
  - Current traffic has increased by 15% or more over the traffic volumes shown in the TIS, or
  - A Capital Improvement Project (CIP) project is within ¼ mile of the proposed project and involves changes to lane configurations, traffic signals, roadway lighting, pedestrian/bicycle facilities, or drainage improvements.

C. TM AND TIS GENERAL REQUIREMENTS

- Criteria for format and scope of the TM and TIS may be obtained from DSD Traffic Impact Studies/Traffic Memoranda Procedures (1).

- The number of trips generated is to be calculated using the latest edition of the ITE Trip Generation Manual (5) or from a trip generator curve that has been developed specifically for that development and approved by the County. Trip factors based on proposed land use and other useful information is posted on the Development Services website to aid in the trip generation calculation and TM threshold determination. Please note the Chief Building Official may issue a Certificate of Occupancy limiting the number of authorized building occupants commensurate with the input information used for trip generation. It is therefore strongly suggested that trip generation/occupancy data not be underestimated in order to preserve the full occupant loading of buildings as determined by the building code.

- Hourly volume information for traffic counts may be obtained from PAG Traffic Counts (2).

- A project that is an addition to an existing use or a previously approved project that resubmits for modifications or changed use is subject to these requirements. The trip generation of the existing use shall be added to the trip generation of the addition to determine the gross trips.
• A project that has a prior approved TM may submit a revision to the TM unless the gross trip generation is 100 or more, in which case a TIS is required.

• Any change or update to an approved TIS or TM shall include the originally approved TIS or TM with the update submittal as reference material.

• The TIS and TM must be prepared under the supervision of and be sealed by a registered professional engineer in the State of Arizona who has demonstrated proficiency in traffic engineering and transportation planning.

• The TIS should address such issues as the number of through traffic lanes, the need for auxiliary lanes, the need for signalization improvements, the need for raised medians, the location of median openings, and alternative mode improvements (sidewalks, multiuse paths/trails, bicycle lanes/paths, equestrian trails, and transit facilities). The recommendations shall guide the design of the proposed roadway and intersections, as well as the specific design of the traffic engineering features.

D. TIS SCOPE REQUIREMENTS

• TIS Categories: Based on the size and phasing of the proposed development, the TIS categories shown in Table 4-0 have been established as the basis for defining the study area and study horizon per Table 4-1.

<table>
<thead>
<tr>
<th>TIS Category</th>
<th>Morning or Afternoon Peak Hour Trips¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100-499</td>
</tr>
<tr>
<td>2</td>
<td>500-999</td>
</tr>
<tr>
<td>3</td>
<td>≥ 1000 Single Phase Development</td>
</tr>
<tr>
<td>4</td>
<td>≥ 1000 Multi-Phase Development</td>
</tr>
</tbody>
</table>

¹. The peak hour with the greatest number of trips should be utilized to determine the TIS category

• Crush volumes: Developments where the peak volume occurs in less than one hour (such as schools) should use a peak hour factor (PHF) of 0.55 or less and account for peak loads through internal site circulation design. The ITE publication School Site Planning, Design, and Transportation (9) provides further information related to schools.

• Analysis time period: Both the morning and afternoon weekday peak hours need to be analyzed. If the peak traffic hour in the study area occurs during a time period other than normal peak travel periods, those peak hours must also be analyzed in addition to the normal peak travel periods.

• Data Collection Requirements: All data is to be collected in accordance with the latest edition of the ITE Manual of Transportation Engineering Studies (4) or as directed by the County, if not specifically covered in the ITE manual.

• Turning movement counts: All existing cross-street intersection turning moving
counts are to be obtained during morning and evening peak periods as identified in Table 4.0. Turning movement counts associated with developments that have crush volumes should be taken at five minute intervals. Available turning movements may be extrapolated a maximum of three years with concurrence of the Department of Transportation. The current and projected daily traffic volumes shall be presented in the report.

- **Study Area and Horizon:** Based on the TIS Categories per Table 4-0, the minimum study area and study horizon shall be determined in accordance with Table 4-1. The study area for the proposed development shall include traffic controlled intersections, site access driveways and major unsignalized intersections. Unsignalized intersections where at least one of the intersecting streets is a collector or arterial are considered major unsignalized intersections.

### Table 4-1. Design Attributes by TIS Category

<table>
<thead>
<tr>
<th>TIS Category</th>
<th>Study Horizons (^1)</th>
<th>Minimum Study Area (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1. Opening year</td>
<td>1. Site access driveways</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. All signalized intersections and/or major unsignalized intersections within 1/4 mile</td>
</tr>
<tr>
<td>2</td>
<td>1. Opening year</td>
<td>1. Site access driveways</td>
</tr>
<tr>
<td></td>
<td>2. Five years after opening</td>
<td>2. All signalized intersections and/or major unsignalized intersections within 1/2 mile</td>
</tr>
<tr>
<td>3</td>
<td>1. Opening year</td>
<td>1. Site access driveways</td>
</tr>
<tr>
<td></td>
<td>2. Five years after opening</td>
<td>2. All signalized intersections and/or major unsignalized intersections within 1 mile</td>
</tr>
<tr>
<td></td>
<td>3. Twenty years after opening</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1. Opening year of each phase</td>
<td>1. Site access driveways</td>
</tr>
<tr>
<td></td>
<td>2. Five years after build-out</td>
<td>2. All signalized intersections and/or major unsignalized intersections within 1 mile</td>
</tr>
<tr>
<td></td>
<td>3. Twenty years after build-out</td>
<td></td>
</tr>
</tbody>
</table>

1. Assume full occupancy and build-out for single phase developments.
2. An enlarged study area may be required at the direction of the County.

**Trip Generation**
• **Trip Generation:** The latest edition of the ITE *Trip Generation Manual* (5) shall be used for selecting trip generation rates. The guidelines contained in the Trip Generation Manual shall be used to determine whether the average trip generation rate or equation should be used. Other rates may be used with the approval of the County in cases where the Trip Generation Manual does not include trip rates for a specific land use category, or includes only limited data, or where local trip rates have been shown to differ from the ITE rates. If the development is a chain development, then the developer can calculate their own applicable trip generation curve based on other sites if ITE rates do not apply.

• **Trip Projection:** The trips must be projected for the study horizon years allocated by the TIS category.

• **Trip Distribution and Assignment:** Projected trips shall be distributed and added to the projected non-site traffic on the roadway network. The projected traffic volumes must be shown for all roadways internal to the development and for all other roadways within the study area. The specific assumptions and data sources used in deriving trip distribution and assignment shall be documented by the study.

• **Capacity Analysis:** Level of Service (LOS) shall be computed for signalized and major unsignalized intersections as identified in Table 4-1, in accordance with the latest edition of the TRB *Highway Capacity Manual* (6). While the use of the operational methodologies presented in the *Highway Capacity Manual* is always desirable, analyses utilizing calibrated vehicle probe data and the planning method included in the FLDOT *Traffic Analysis Handbook* (7) are acceptable for analysis planning of new facilities.

• **Traffic Signal Needs:** Analysis of traffic signal needs shall be provided for all major collector/major collector and larger intersections per the FHWA *Manual on Uniform Traffic Control Devices* (8). If the warrants are not met for the opening year, they should be evaluated five years after opening for Category 2, 3 and 4 Traffic Impact Studies.

• **Crash Analysis:** An analysis of the five-year crash data within the study area shall be conducted to determine if the level of safety in terms of crash rates and severity index needs improvement due to the addition of site traffic.

• **Queuing Analysis:** An analysis shall be conducted for all turn lanes within the study area.

• **Improvement Analysis:** The roadways and intersections within the study area shall be analyzed with and without the proposed project to identify any projected impacts in regard to level of service and safety.

• The minimum design requirements for all intersections and roadway segments shall be Level of Service (LOS) D with no intersection through lane movement falling below LOS D and no intersection turning movement falling below LOS E. If the TIS shows that the impact of a development will bring the LOS below those thresholds during the study horizon, mitigation alternatives to improve the LOS to at least those thresholds must be analyzed as part of the study.

• If the performance of the existing intersection or roadway is already below those thresholds (e.g., below LOS D for through movements) the study must also evaluate the need for turning lanes on all major unsignalized intersections. In addition, if the delay is increased by 10% more than the existing, mitigation measures must be taken to decrease the delay to the 10% threshold.
• **Alternative Modes:** Multi-modal conflict points with vehicles must be identified. Recommendations must be made to facilitate reasonable operation of alternative modes, especially at the interface with the roadway network.

• Private driveways with significant traffic volumes are to be evaluated.

• Additional information concerning subdivision and development Traffic Impact Studies and Traffic Memorandum may be found at DSD Traffic Impact Studies/Traffic Memoranda Procedures (1).

**REFERENCES**

1. DSD. *Traffic Impact Studies/Traffic Memoranda Procedures*. Development Services Department, Pima County, AZ.  

   [http://gismaps.pagnet.org/trafficcounts/](http://gismaps.pagnet.org/trafficcounts/)

3. PCDOT. *Volume, Crash & Ordinance Data*. Pima County Department of Transportation, Tucson, AZ.  


   [http://www.trb.org/Main/Blurbs/175169.aspx](http://www.trb.org/Main/Blurbs/175169.aspx)

   [https://www.fdot.gov/planning/systems/programs/sm/traffic/default.shtm](https://www.fdot.gov/planning/systems/programs/sm/traffic/default.shtm)

   [https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm](https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm)

https://ecommerce.ite.org/IMIS/ItemDetail?ProductCode=TG10-A
5. Drainage

Roadways are frequently subjected to flooding either by runoff traversing the road at drainage crossings or conveyed as shallow street flow. The goal of drainage design is to mitigate the effects of roadway improvements so that drainage conditions at the project limits are maintained and stormwater is conveyed and controlled in a safe and responsible manner. Field and topographic conditions should be considered in conjunction with these standards, and engineering judgment should be exercised in all cases to minimize adverse effects to adjoining property and to right-of-way while maintaining traffic safety.

The design and construction of public drainage improvements such as culverts, storm drains, and channels are to be based on hydraulic efficiency, structural integrity, durability, and life-cycle costs. Life-cycle costs analysis (LCCA) shall consider the total anticipated costs to the County of the drainage feature over its service life. The designer is encouraged to contact the County for information pertinent to LCCA.

Roadways are to be all-weather unless approved otherwise by the County, and drainage improvements are not to extend beyond the project limits unless approved by the County or appropriate authority and are to be compatible with upstream and downstream drainage conditions. Base flood levels are not to be increased more than one-tenth of a foot or increase flood velocities more than ten percent or one foot per second, whichever is less, at any property line unless mitigation measures are implemented to address the change in condition such as (1) installing drainage improvements to prevent flood damage and (2) obtaining drainage easements to encompass an increase in flood limits when outside the project limits. In no case shall a habitable structure be subjected to increased flood limits due to the improvements. Computations and exhibits shall be provided to the extent that pre- and post-developed flood limits, depths and velocities are equal.

Clear and unobstructed access must be provided to drainage structures for operational and maintenance purposes. When access extends beyond the right-of-way, easements shall be conveyed to the authority responsible for maintenance of the structure. For structures maintained by the County, PCDOT should be contacted for type, size and location of easement.

Drainage improvements are to conform to the requirements of this manual, Federal Emergency Management Agency (FEMA), PC Chapter 16 – Floodplain.
A. HYDROLOGY

Stormwater runoff from upstream tributary areas that discharge across a roadway shall be evaluated for the 1% chance storm unless directed otherwise by the County. Pima County Regional Flood Control District’s Technical Policy TECH-015 Acceptable Methods for Determining Peak Discharges shall be used as the basis for determining peak discharges. Refer to Table 5.0 for recurrence intervals and probabilities of occurrences.

Table 5-0. Recurrence intervals and Probabilities of Occurrences

<table>
<thead>
<tr>
<th>Recurrence Interval (years)</th>
<th>Percent chance of occurrence in any given</th>
<th>Peak Discharge (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>50</td>
<td>Q2</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>Q5</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Q10</td>
</tr>
<tr>
<td>25</td>
<td>4</td>
<td>Q25</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>Q50</td>
</tr>
<tr>
<td>100</td>
<td>1</td>
<td>Q100</td>
</tr>
<tr>
<td>500</td>
<td>0.2</td>
<td>Q500</td>
</tr>
</tbody>
</table>

The volume of stormwater runoff from watersheds within a roadway right-of-way that discharge to stormwater control facilities such as storm drains, roadside ditches, culverts, and spillways shall be determined using the Rational Method, 10% chance storm, and a maximum 5 minute time of concentration. Runoff directed to stormwater control facilities that include both roadway and upstream tributary areas shall be calculated using the 10% chance and 1% chance storms, respectively and RFCD PC-Hydro software with the upstream flow added to the roadway drainage values.

B. HYDRAULICS

This section provides information necessary for the design of drainage structures that collect, direct and convey storm water runoff. Drainage structures include, but are not limited to, open channels, culverts, ditches, swales, channels, at-grade crossings, storm drains, curb openings, scuppers and bridges.
1. Open Channels

Pima County Regional Flood Control District’s Technical Policy, TECH-016 Acceptable Methods for Floodplain Delineation (22), shall be used to determine open channel flow in engineered channels and floodplain flow in natural washes. At the direction of the Regional Flood Control District, two-dimensional modeling may be required in distributary flow areas. When open channels are proposed to intercept flows approaching the right-of-way, open channel flow modeling is also necessary.

Open channel design shall be in accordance with the RFCD Drainage and Channel Design Standards for Local Drainage (17), COT Standards Manual for Drainage Design and Floodplain Management (6), RFCD Floodplain Management Ordinance 2005-FC2 Revision (24), and FHWA Hydraulic Design of Energy Dissipators for Culverts and Channels (8), or other applicable methodology approved by RFCD and Pima County.

2. Cross Drainage

Stormwater runoff crossing a roadway is to be handled by culverts, bridges, at-grade crossings and low-water crossings depending on the design period and peak discharge. When a roadway is proposed perpendicular to sheet flow, an at-grade crossing is preferred in order to (1) limit water surface elevation increases beyond right-of-way, (2) minimize obstructions to flow, (3) avoid sedimentation issues, and (4) minimize construction of off-site training dikes.

All drainage crossings over a roadway are to be designed so that 1% chance storm discharge (Q100) is one foot or less (all-weather crossing).

Cross drainage structures shall not allow overflow to adjacent drainage basins, and when located within natural washes or major watercourses shall be evaluated using open channel hydraulic modeling to determine pre- and post-development floodplain and flow characteristics of the natural wash.

a) Subdivisions and Developments

A subdivision shall have at least one paved, permanent all-weather street to each lot within the development. Subdivision and development drainage improvements shall adhere to the requirements in Chapter 16.36 – Subdivisions and Development of the Pima County Code (13).
Common areas or privately maintained drainage easements shall be provided within a subdivision for cross drainage. In addition, public easements beyond the right-of-way limits shall be granted to Pima County where it is necessary to gain access to protect or maintain drainage features within the public right-of-way and watercourses regulated by Chapter 16.36. Easement size and location shall be approved by the County and RFCD.

b) Culverts

- Culverts must be suitably protected with traffic and pedestrian barriers. Adequate distance should be provided for pedestrian access within the roadway typical section. Refer to AASHTO Roadside Design Guide (2) for further discussion on clear zone, crash attenuation, traversable and recoverable slopes and barriers.
- Culvert outlet velocity shall be 3 feet per second or greater to reduce culvert maintenance needs.
- Sedimentation at the inlet and outlet is to be considered.
- Culverts are required at all drainage crossings in accordance with Table 5-1 Culvert Design Flow except when at-grade crossings are allowed under Subsection C on at-grade crossings.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Design Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Street</td>
<td>Q10 under roadway, Q100 &lt; 1 foot in depth with dip</td>
</tr>
<tr>
<td>Minor Collector</td>
<td>Q25 under roadway, Q100 &lt; 1 foot in depth with dip</td>
</tr>
<tr>
<td>Major Collector</td>
<td>Q50 (Q100 if possible) under roadway, Q100 &lt; 1 foot in depth in dip</td>
</tr>
<tr>
<td>Arterial</td>
<td>Q100 under roadway (Unless a lesser storm event is approved by the County)</td>
</tr>
</tbody>
</table>

- Hydraulic calculations for pipe and box culvert flow shall be in accordance
with methodologies contained in the latest edition of the FHWA *Hydraulic Design of Highway Culverts* (9), or other programs or methodologies accepted by RFCD and Pima County.

- Headwalls or engineered slope protection shall be required at inlets for pipes greater than 30 inches in diameter, multiple pipe culverts, and reinforced concrete box culverts. For channels in supercritical flow, wingwalls and headwalls shall be required. Straight headwalls without wingwalls are discouraged. The use of traversable designs for culvert end sections should be considered when pipe ends are located within the clear zone.

- Erosion protection must be provided at culvert outlets in accordance with the latest version of RFCD *Drainage and Channel Design Standards for Local Drainage* (17), COT *Standards Manual for Drainage Design and Floodplain Management* (6) and RFCD *Floodplain Management Ordinance 2010-FC-5* (24) or other applicable methodology approved by RFCD and Pima County. If the length of protection needed to reduce flow velocity becomes excessive, another form of protection should be used.

- Energy dissipators for culvert outlets, when required, shall be designed in accordance with the latest version of RFCD *Drainage and Channel Design Standards for Local Drainage* and Pima County *Floodplain Management Ordinance 2010-FC-5* (24), or other applicable methodology approved by RFCD and Pima County.

- The top of the headwalls and wingwalls shall, at a minimum, be placed 6-inches above the design headwater elevation. Where no headwall or wingwall is proposed or flows from drainage crossings and associated channels occur adjacent to embankments, an impervious treatment shall, at a minimum, be placed 6-inches above the design headwater elevation. Erosion protection shall be provided at the top of and around headwalls, wingwalls, retaining walls and other similar drainage structures.

- All culverts with headwalls shall extend at least the distances outlined in Chapter 3, B, 3b on horizontal curve clearance to obstructions to protect errant vehicles and pedestrians. Where culverts cannot be extended for this distance, guardrail or other suitable traffic barriers must be used as discussed in Chapter 3, C, 5 on traffic barriers.

- Arizona Department of Transportation’s (ADOT) *Structure Detail Drawings, Drainage Structures* (SD6.01, 6.11, 6.30 Series) (5) may be used for RCBC and culvert headwall design; otherwise, the design shall be by a professional engineer licensed in the state of Arizona using the load and resistance factor design (LRFD) methodology.

- Pipe culverts shall have a minimum diameter of 24 inches and 100-year service life. If needed to meet clearances which would otherwise require significant site engineering to accommodate, 18 inch pipes may be used.

- Box culverts shall be a minimum of 3 feet in height.

- Alternative culvert sizes will be considered on a case-by-case basis.

- Reinforced concrete pipe shall be used for culverts under arterial roadways, unless an alternative material is approved by the County. Refer to Section 5 on alternative pipe materials.

- Reinforced concrete pipe, corrugated metal pipe, spiral rib pipe, and polypropylene pipe may be used under local roads and residential/commercial collectors. An analysis of soil resistivity, pH, and
percent deflection (5% max) shall be considered in pipe selection.

c) At-grade Crossings

At-grade crossings are drainage crossings where the roadway crosses a wash or channel at the same level as the wash or channel bed.

- At-grade crossings are allowed:
  - Within a rural residential subdivision Q100 is less than 500 cfs,
  - Within a rural residential subdivision when Q100 is more than 500 cfs over the entire roadway length due to sheet flooding,
  - When approved by the County for roadways with rural typical sections and Q100 less than 500 cfs.
  - Within an urban residential, commercial and industrial subdivision when approved by the County for sheet flooding conditions crossing local streets.

- Minimum treatments are shown in Table 5-2.

<table>
<thead>
<tr>
<th>Q100 peak discharge</th>
<th>Minimum Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 50 cfs</td>
<td>Concrete headers (6-inch by 12-inch)</td>
</tr>
<tr>
<td>50 to 500 cfs</td>
<td>Concrete Cut-off/Ford Walls</td>
</tr>
<tr>
<td>&gt; 500 cfs</td>
<td>Culvert or Culvert plus low-flow crossing</td>
</tr>
</tbody>
</table>

- Cut-off/ford walls are to be designed 1 foot deeper than the depth of scour determined by the use of the approved general and local scour equations or 70% of the maximum depth of scour. In no case, shall the wall depth be less than 2 feet upstream and 3 feet downstream. Sliding and overturning moments may need to be analyzed for walls deeper than 6 feet. The roadway pavement width shall be increased at the locations of the walls such that the total pavement width is 4’ wider, both upstream and downstream, than the typical roadway section.

- Concrete headers and cut-off walls must extend to the limits of the developed 100-year flow width along the pavement edge.

- At-grade crossings should be built at a minimum 4% cross slope to reduce deposition of sediment. The 4% grade shall be produced by supplying the vertical rise on the upstream side of the dip section with the downstream side meeting the existing grade.

- Within urban residential, commercial, and industrial subdivisions, at-grade crossings exceeding 50 cfs shall place post barricades per PAG Detail 106 (11) outside of the clear zone.

- In order to improve safety and to reduce maintenance, at-grade crossings shall be designed to be self-cleaning by providing an appropriately designed...
superelevated section at the at-grade crossing, installing a sediment trap, or by other means. The method shall be approved by the County.

- When an at-grade crossing has a Q100 depth of flow greater than one foot, a culvert or culvert and low-water crossing combination shall be used to ensure all-weather access.
- If controls for traffic safety or accommodation of sheet flooding conditions dictate a reduced cross slope, sediment reduction may be accomplished by installation of a sediment trap or other means approved by the County.
- Conditions upstream and downstream of both at-grade and low-flow crossings should be evaluated for erosion protection.

d) Low-Water Crossings

Low-water crossings are drainage crossings where the roadway crosses a wash or channel at an elevation higher than the wash and channel bed with pipes typically placed under the roadway.

- Low-water crossings are allowed:
  - Within an urban residential, commercial and industrial subdivisions in combination with the culverts designed to convey the flows identified in Table 5-1, unless an at-grade crossing has been approved for sheet flooding conditions.
  - When approved by the County for roadways with rural typical sections, a Q100 flow greater than 500 cfs, and all-weather criteria is met.

- Low-water crossings shall be designed to protect the roadway embankment and travel surface during the 1% change storm.

e) Bridges

(i) Hydrology/Hydraulics

HEC-RAS shall be used to analyze the hydraulic conditions at bridges. Transitions and friction head losses as well as pier head losses are to be considered.

The bridge waterway opening shall be designed to meet the 1% change storm with the extreme storm event as the check storm criteria. The extreme event is defined as the flood resulting from a storm having a flow rate in excess of the design flood, but in no case a flood with a recurrence interval exceeding 500 years. The waterway opening should be sized and situated such that:

- Backwater is limited, as noted below
- Erosion of banks is limited
• Progressive sedimentation is not encouraged
• General and local scour are minimized
• Required bank protection is minimized

Backwater computations for a bridge shall be based upon approved methodology and on the design conditions which result in the highest value of backwater. Backwater shall be computed with no allowance for scour (i.e. with rigid channel boundaries).

Bridge piers and abutments should be located to provide the following benefits:

• Minimize hindrance to the passage of water and debris.
• Be compatible with the location of piers and abutments of adjacent structures.
• Minimize the depth of local scour.
• Minimize upstream and downstream bank erosion.

Bridge piers should be round or have the upstream end rounded. Solid wall piers should only be used where the direction of flow is well controlled and will remain so in the future. Piers should not be used to align the flow.

(ii) Deck Drainage

Bridge deck drainage systems shall not allow surface drainage to encroach into any traffic lane(s) on the bridge deck, and must be free of ponding or flowing water in each direction of travel during the 10-year storm event. Drainage that collects in pools or sheet flows across the travel lane can slow traffic, plug deck drains, cause hydroplaning, and may form ice, making the roadway slick and dangerous to motorists.

Deck drainage on railroad overpasses should be conveyed in a piping system from deck drain inlets to a properly designed drainage outfall system. The use of piping systems on other bridges or overpasses may also be required, depending upon project requirements. Design methods provided in the latest edition of FHWA Design of Bridge Deck Drainage (7), or other alternate methodology approved by the County shall be used in determining the size and location of bridge deck drainage openings and details. At a minimum, deck drainage must be provided at the quarter points of all spans using standard ADOT deck drains or other approved methods or details. Particular care must be taken regarding bridge deck drainage at the beginning and
end of the bridge deck in order to prevent erosion of the approach roadway embankment.

(iii) Scour and Freeboard

Bridge scour and freeboard shall conform to the guidelines presented in the latest edition of the RFCD and PCDOT Guidelines for Establishing Scour and Freeboard for Bridges in Pima County (23).

(iv) Structural Design

Bridges shall be structurally designed using the load and resistance factor design (LRFD) methodology in accordance with the latest version of AASHTO LRFD Bridge Design Specifications (1).

3. Roadside Channels, Ditches, and Swales

Roadside channels and ditches that parallel the roadway shall be laid out to be either completely within or outside of the right-of-way for the purpose of defining maintenance responsibilities and shall not straddle the right-of-way.

- Channels and ditches shall be designed to minimize their impact on the roadside and shall not be constructed within the shoulder of the road.
- Ditches should be designed with a minimum longitudinal slope of 1%. Steep longitudinal slopes should be evaluated for erosion protection.
- Ditch side slopes should be traversable and recoverable. Side slopes of 4:1 are desirable. Steeper side slopes shall be evaluated for erosion protection requirements and for barrier warrants. See Chapter 3, C, 5 on traffic barriers and Chapter 3, C, 2 on side slope treatments.
- Channels and ditches within a subdivision and commercial development shall not be constructed within the right-of-way unless:
  - The design flow can be handled by the channel or ditch without interfering with the reasonable operation of the roadway, and
  - The channel or ditch is configured in such a manner that is consistent with the cross-section configuration and operational and maintenance needs of that roadway. This includes the potential uses of the roadside by pedestrians, equestrians, bicycles, vehicles (on and off-road types), utilities, traffic control devices or other applicable and relevant roadside features. The depth, foreslope, backslope, profile and hydraulic operation provided shall consider all of these applicable uses in a manner that is reasonable and has been defined by practice and reasonable references (e.g. AASHTO Roadside Design Guide (2)).
• Drainage swales within the public right-of-way that carry roadway runoff shall only be acceptable where Q100 velocities are less than 3 feet per second (or where appropriate protection is provided) and where driveway access is restricted or controlled to prevent ponding.

4. Pavement Drainage

a) Surface Flow

Pavement and shoulders should have a cross slope that directs pavement surface flow away from the roadway. A minimum 2% cross-slope is recommended. The shoulder and pavement cross slope should match. See Chapter 8 on sections and details. Roadways with steep longitudinal slopes may require steeper cross-slopes since drainage will tend to flow along the longitudinal pavement surface. When sidewalks or pathways are located adjacent to and along the outside edge of the shoulder the shoulder cross-slope should be continued through the sidewalk or pathway.

b) Design Considerations

- Pavement flow shall not exceed 100 cfs or 1 foot in depth during the 1% chance storm event.
- The Q100 flow outside of curbs must be contained within the public right-of-way and cannot exceed 3 feet per second in velocity unless erosion mitigation is provided.
- Street drainage design criteria are presented in Table 5-3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum street runoff</td>
<td>100 cfs</td>
</tr>
<tr>
<td>10-year storm containment (local street)</td>
<td>Between curbs</td>
</tr>
<tr>
<td>10-year storm – 2 to 5 lanes - minimum width clear of water in each direction.</td>
<td>10 ft</td>
</tr>
<tr>
<td>10-year storm – 6 lanes - minimum width clear of water in each direction.</td>
<td>20 ft</td>
</tr>
<tr>
<td>100-year storm containment</td>
<td>Within R/W</td>
</tr>
</tbody>
</table>

(1) Clear lane width shall be kept within normal thru travel lanes but may cross between lanes through superelevated transitions. Turn lanes shall not be used for clear lane width.
• On curbed local streets, the runoff from a 10% chance storm must be contained between the curbs of the street, except for roadside stormwater harvesting areas.

• Should the 10% chance storm water surface elevation exceed the top of the curb, storm drains or other treatments shall be provided to keep water from overtopping the curbs.

• Depressed roadways with a sag vertical curve such as an underpass shall be designed for the 1% chance storm.

• Except where at-grade crossings are approved, collector and arterial roadways shall meet the spread criteria in Table 5-3. Bypass gutter flows from intersecting streets shall be reduced as necessary to meet this requirement within intersections.

• A drainage easement will be required whenever any natural watercourse has been altered to such a degree as to need a defined or constructed channel, or periodic maintenance.

• Easements beyond the public right-of-way shall be granted to the County where public drainage improvements or maintenance access lie outside of the public right-of-way.

• Within a subdivision or development, drainage conveyed within a street shall only be discharged from the street right-of-way into common areas or privately maintained drainage easements (does not apply to non-regulatory flows on uncurbed streets).

• On superelevated roadways, drainage interception structures such as catch basins and scuppers shall be installed at the approximate locations, as shown in Chapter 8, sheet S-15 and on the upstream side of intersections, driveways, and median openings.

• Storm water should be intercepted at side curbs in order to prevent curb flow and side street flow from crossing travel lanes.

• Drainage inlets (e.g. curb openings, scuppers, catch basins) are not permitted within crosswalks or within 10 feet of a curb access ramp.

• Pavement drainage within a curbed roadway shall be directed to drainage structures by way of curb. Many major collector and arterial roadway designs will include a storm drain system to accept flow from the pavement; however, flow may be directed off the pavement through a curb opening structure into an open natural or engineered channel adjacent to the roadway. These structures shall be located and spaced in a manner to ensure that spread criterion and design considerations as shown in Chapter 8 on sections and details are followed.

c) Curb Openings

• Refer to Table 5-4 for curb openings and curb depression design standards and PCDOT Detail 10 (15).

Table 5-4. Curb Opening and Curb Depression Design Standards
• If erosion protection extends outside of the right-of-way, a drainage easement shall be provided.

• Should the design require greater conveyance than can be provided by curb openings, then scuppers, catch basins, or other drainage structures must be used.

• Within subdivisions and developments, curb openings and drainage inlets shall be fitted with appropriate barricades to prevent vehicular access.

d) **Scuppers**

Scuppers are structures used to drain flow under a sidewalk generally between a paved area and a drainageway. Scuppers must be designed to accommodate the 10% chance storm without overtopping of curbs. Refer to PAG Detail 205 (11) and PAG Detail 205.5 (11) for sidewalk scupper design alternative.

**Table 5-5. Inlet Capture Ratios**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum length (ft)</td>
<td>10</td>
</tr>
<tr>
<td>Curb transition slope</td>
<td>12:1</td>
</tr>
<tr>
<td>Minimum center to center spacing (ft)</td>
<td>150</td>
</tr>
</tbody>
</table>

Table: On-Grade | Sump  
--- | ---  
Standard Inlets | |  
Grate | 0.50 | 0.50  
Curb Inlet | 0.80 | 0.80  
Combined Curb and Grate | |  
Grate | 0.50 | 0.50  
Curb Inlet | 0.80 | 0.80  
Combined Slotted Drain and Grate | |  
Grate | 0.50 | 0.50  
Slotted Drain | 0.67 | 0.50  

Source: ADOT Roadway Design Guidelines, Table 606.2 (4)

e) **Inlet Sizing**
The safety factors presented in Table 5-5 shall be used for sizing inlets. All storm drain grates shall be bicycle safe if they are within the shoulder or pedestrian access route. Methods presented in FHWA Urban Drainage Design Manual (10) or other methodology approved by the County shall be used to calculate the capacity of inlets and pavement spread.

f) Storm Drain

A storm drain is an underground pipe system that receives runoff from inlets and conveys the runoff to an appropriate discharge point such as a roadside ditch, channel, or drainage structure. Storm drains may convey pavement, off-site, or a combination of pavement and off-site drainage. The latest edition of FHWA Urban Drainage Design Manual (10) is a recommended reference for design guidance of pressure and non-pressure storm drain systems. Design software other than StormCAD shall be approved by the County prior to its use.

Storm drain design information is to be included on storm drain construction drawings and shall include pipe type, stationing, size, discharge values, hydraulic grade line, pipe slope from junction to junction, proposed finished grade at the pipeline center line, and all catch basins, manholes, junction structures, bends, transition structures, connectors, inlets and outlets, and inverts.

(i) Design

• Storm drains are to be designed using pressure flow but may transition between pressure and gravity flow at storm drain inlets and outlets. Only with approval of the County is non-pressure flow allowed.
• Storm drains and open channels discharging into or adjacent to culverts or bridges shall be designed to prevent harmful erosion or damage to the structure.
• Mainlines shall be routed through catch basins rather than manholes. When manholes cannot be avoided, they shall be kept outside the pavement either behind curb or within the median, unless otherwise approved by the County.
• Hydraulic grade line shall be a minimum of 1 foot below curb inlets, grates, slotted drains, area inlets, manhole rims, or other free-surface openings in the pavement drainage system, unless otherwise approved by the County.
• Pipe losses due to friction and minor losses at manholes, junctions, bends, transitions, and entrance are to be evaluated, except for junction losses where incoming lateral flow is less than 10% of the combined mainline outflow.
• Minimum full-flow pipe velocity shall be 3.0 feet per second.
• Minimum desirable pipe slope of 0.3 % unless precluded by utility conflicts or
other constraints. In no case shall pipe slope be less than 0.1%.

- Outlet velocities shall be evaluated for outlet protection and energy dissipation requirements.

- Soffits of adjoining pipes in a transition or junction structure shall be placed at the same elevation, unless other constraints such as utility conflicts exist and are approved by the County.

- Connecting and discharging to a public storm drain is not allowed unless approved by the PCDOT. An analysis of the impact to the public storm drain system is required prior to consideration by the County.

Discharge of storm water into a public storm drain is not permitted unless approved by the County.

<table>
<thead>
<tr>
<th>Area Ratio</th>
<th>10-Year Design</th>
<th>100-Year Design</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Main Stream</td>
<td>Tributary</td>
</tr>
<tr>
<td>10,000 to 1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>1,000 to 1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>100 to 1</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>10 to 1</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>1 to 1</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: FHWA, Table 7-3 Urban Drainage Design Manual (10)

Note: This table may also be used for channel design

(ii) Pipe

Storm drain pipe shall be reinforce concrete pipe unless an alternative pipe material has been shown to meet the criteria in Section 5 on alternative pipe materials.

The minimum pipe size for storm drain mainline is 24 inches and 18 inches for laterals. Slotted drain pipe shall be a minimum of 18 inches in diameter and sized using the same hydraulic procedures as for storm drain pipe.

(iii) Pipe Connections
Water-tight connections are required for storm drains and cross culverts under the road prism. Water-resistant connections may be used for storm drains and cross culverts outside of the roadway prism. Testing procedures shall conform to the most current ADOT and PAG specifications.

(iv) Manholes

Storm drain manholes placement within pavement are not allowed unless approved by the County. Manholes shall be spaced according to the following parameters:

- 300 feet for pipe diameters < 30 inches
- 400 feet for pipe diameters > 30 inches to 42 inches
- 500 feet for pipe diameters > 42 inches

Note: For sewer manhole requirements contact Pima County Regional Wastewater Reclamation Department.

(v) Catch Basins

Catch basins used for pavement drainage must be designed to the 10-year storm without overtopping of the curb. When catch basins are used as junction or inlet structures (1) frame and cover are required (2) manhole spacing requirements are to be meet, and (3) modification to catch basin geometry may be required to accommodate multiple pipes of varying sizes. In areas where pedestrian or bicycle traffic is expected, catch basins shall be designed and located to minimize potential hazards to pedestrians and bicyclists.

g) Check Storm

The pavement drainage system shall be evaluated for a 1% chance storm to review flow patterns, hydraulic grade lines, pavement spread, flood routing, hazard analysis, and critical locations where water can pond to appreciable depths.

5. ALTERNATIVE PIPE MATERIALS

Alternative pipe material shall be submitted to the County for approval on a case-by-case basis. The type and thickness of pipe shall be in accordance with ADOT Pipe Selection Guidelines and Procedures (3) and other related guidelines. Alternative pipe shall meet a 100-year service life and a vertical deflection of no more than 5%.
The use of alternative pipe, such as plastic pipe and steel pipe may be allowed within enclosed storm drain systems except where storm drains will convey runoff from tank farms, sites that are at risk for spills (such as gas stations, refueling locations, certain warehouse or manufacturing facilities), and locations where hazardous or flammable liquids can flow into the system.

6. STORMWATER HARVESTING

Stormwater harvesting within the right-of-way is not required by these standards, however, the designer is encouraged to incorporate stormwater harvesting as part of a Complete Streets design approach to enhance the pedestrian experience by sustaining canopy trees and vegetation. Stormwater harvesting features, if designed correctly, will reduce runoff peaks and volumes and can be used to offset the first flush retention and stormwater detention basin requirements. Stormwater harvesting may also offset additional grading required for stormwater detention basins. Guidance on stormwater harvesting features may be found in RFCD Design Standards for Stormwater Detention and Retention (16) and PC/COT Low-Impact Development and Green Infrastructure Guidance Manual (12).

Stormwater harvesting features in the right-of-way are limited to basins in the median or roadside that do not retain more than nine inches of water (first flush retention). These basins must be designed such that the flows do not cause flooding onto the roadway. For streets posted at less than 25 mph, water harvesting within the clear zone may be considered by the County.

In order to ensure that vegetation within roadside stormwater harvesting basins do not interfere with sight visibility, roadside basins should be located at least twenty feet from street intersections and at least five feet from driveway entrances. In addition, roadside stormwater harvesting basins should be setback at least one foot from sidewalks and six inches from the edge of curb where there is no on-street parking and two feet from the edge of curb where there is on-street parking.

In areas where stormwater harvesting is designed to be in the curbway, the sidewalk may be narrowed to 4 feet to provide a greater curbway width, provided that ADA requirements are met. Pima County encourages wider right-of-way for stormwater harvesting and vegetation and under these circumstances the curbway width is not limited.

When stormwater harvesting features are implemented in the right-of-way, vertical curb should be designed with curb core and curb cuts for stormwater features.
Medians and traffic circles designed for stormwater harvesting may use header curb per PAG standard details to maximize the roadway runoff into basins.

When used for stormwater harvesting, curb cuts shall meet the following criteria:

- Curb cuts shall be separated from driveway aprons and other curb openings by a minimum distance of 10 feet.
- Curb cuts shall be located a minimum of 20 feet from an end of a curb return.
- Curb cuts shall be a maximum of 2 feet in width with 45-degree sloped sides.

7. PARKING LOT DRAINAGE

Parking lots may be permitted in the flood plains of regulated watercourses, washes and detention/retention basins, provided that the maximum depth of flooding does not exceed 1 foot during a 1% chance storm event and the velocity is below 2 feet per second. Such parking lots shall have a prominent sign posted at the entrance to the parking area that contains the information that the parking lot is subject to periodic flooding of depths up to 1 foot.

Draining of parking lots can be accomplished by means of curb openings, curb cores, scuppers, catch basins, and storm drain systems in general as discussed in this chapter. Inverted roadway crowns or concrete valley gutters are allowed in parking aisles or between stormwater harvesting basins. The minimum longitudinal slope permitted within parking areas is 0.5%.

Consideration should be given to the inclusion of storm water harvesting basins within parking lots to meet first flush retention requirements. The design of parking spaces and parking aisles should as much as is reasonable maximize storm water harvesting opportunities.

C. DRAINAGE REPORT

Drainage reports are to be prepared and sealed by a Professional Engineer registered in the state of Arizona. Reports for subdivision and development projects shall meet the requirements of RFCD TECH-114 (20) and RFCD Drainage Report and Project Conditions Review Checklist (18). The drainage report for public work projects shall be prepared in accordance with PCDOT Drainage Report (14).
REFERENCES


   https://store.transportation.org/Item/CollectionDetail?ID=152&gclid=EAIaIQobChMl6-tbl6KO3wiYwB-18h3s3KNEAQYASABEqIcqd1D_BwE&AspxAutoDetectCookieSupport=1


   https://store.transportation.org/Item/CollectionDetail?ID=105&gclid=EAIaIQobChMl6seRzYeO3wiVh6DsCh0XAwrNEAQYASABEq1L1uD_BwE


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19. RFCD. **PC-Hydro Software**. Pima County Flood Control District, Tucson, AZ.


23. RFCD and PCDOT. **Guidelines for Establishing Scour and Freeboard for Bridges in Pima County**. Pima County Regional Flood Control District and Pima County Department of Transportation, Tucson, AZ, August 2012.

Flexible and rigid pavement design are based on the procedures and methodology used by the Arizona Department of Transportation in their publication entitled Pavement Design Manual (2) as amended herein. In addition, the designer is referred to PAG Standard Specifications for Public Improvements (3) and Pima County Department of Transportation Supplemental Specifications (4) for material requirements and specifications.

This chapter presents an overview of the flexible pavement design process and design criteria for Pima County. For rigid pavement design, the designer is referred to ADOT Pavement Design Manual (2).

A. DESIGN APPROACH

Step One

Determine the resilient modulus, MR, of the in-place or borrow material that will make up the subgrade on which the pavement structure is to be placed. The resilient modulus is the primary measure of a soil’s strength. The resilient modulus is derived from the Mean R-value (Rmean) which is based on R-value tests (RT) and Pima County correlated R-values (Rpc) which are estimated from measurements of the plasticity index (PI) and percent of soil by weight passing a #200 sieve (minus 200):

- All soil and subgrade sampling and testing shall be in accordance with Appendix B, Geotechnical Investigation and Arizona Department of Transportation, Chapter 1, Materials Preliminary Engineering and Design Manual (3).

- The Mean R-value (Rmean) shall be calculated in accordance with section 2.1.5.2 of ADOT Pavement Design Manual (2) and replacing ADOT correlated R-values (Rc) with Pima County’s correlated R-values (Rpc). Conversion of Rc to Rpc is shown below:

  1. Determine ADOT correlated R-value (Rc) by using the PI, percent passing #200 sieve, and Table 2-3 of ADOT Pavement Design Manual (2)

  or

  Calculate Rc using equations 6-0.

  \[
  \log Rc = 2.0 - 0.006(\text{Percent Passing #200}) - 0.017 (\text{PI}) \quad (6-0)
  \]

  2. Compute Rpc using equation 6-1

  \[
  Rpc = x (Rc)^y \quad (6-1)
  \]

  where X=0.3 and y= 1.2
On the basis of the calculated Mean R-value and pavement selection considerations in Section C, the designer is to select a design R-value.

Construction R-value shall be the design R-value minus 5.

For a soil sample location where the difference between \( R_{pc} \) and \( R_T \) is greater than 12, retests for both actual and correlated R-values shall be performed to verify test results.

At the discretion of the County, tested R-values may be omitted or testing frequencies reduced on projects where the lowest correlated R-value is 50 or above. This should only occur when it has been determined that a higher R-value will not significantly change the pavement design and for material where correlated R-values are believed to accurately represent tested R-values. In such a case, the design will be based on correlated R-values only.

Where a site specific correlation may provide cost saving opportunities, the designer shall consult with the County to determine the number and location of R-value tests (anticipated to be around 10-20 per geologic formation) in order to develop project specific Pima County correlated R-values \( (R_{pc}) \) using equation 6-1 with site specific x and y values. When using this option, a site specific subgrade acceptance chart is to be created.

For small developments or projects, a measured R-value option is acceptable in lieu of using the full correlated design. In such cases, the design R-value is the lowest measured R-value and construction control R-value shall be the corresponding mean PI and mean minus 200 percentage.

Step Two

Estimate the traffic loading the pavement will be subjected to over its design life (i.e. number of 18-kip equivalent single axle loads – ESAL). Refer to Appendix A of ADOT Pavement Design Manual (2) for a discussion on evaluating equivalent single axle loads. The percentage of total traffic in the design lane shall be as follows:

- Two-lane roadway 50% ............[50% each direction x 100% in design lane]
- Four-lane roadway 45% ............[50% each direction x 90% in design lane]
- Six-lane roadway 40% ............[50% each direction x 80% in design lane]

Step Three

Using the design values in Table 6-1 and flexible pavement design equation on page 11 of ADOT Pavement Design Manual (2) determine the structural number (SN) that represents the overall structural capacity needed in the base and surfacing to accommodate the expected traffic loading.

<table>
<thead>
<tr>
<th>Street Classification</th>
<th>Reliability</th>
<th>( Z_r )</th>
<th>( S_o )</th>
<th>Po</th>
<th>Pt</th>
<th>( \Delta \text{PSI} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial</td>
<td>95%</td>
<td>-1.645</td>
<td>0.35</td>
<td>4.2</td>
<td>2.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Collector</td>
<td>90%</td>
<td>-1.282</td>
<td>0.35</td>
<td>4.1</td>
<td>2.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Local Street</td>
<td>80%</td>
<td>-0.674</td>
<td>0.35</td>
<td>4.0</td>
<td>2.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Step Four

Based on the SN from step three and design criteria, develop a pavement structure:

- Structural coefficients for surface and base material are follows:
  - Asphaltic Concrete (Asphalt Rubber) ......................0.44
  - Asphaltic Concrete (AC) ........................................0.44
  - Cement or Bituminous Treated Base ......................0.28
  - Cement or lime Treated Subgrade ......................0.23
  - Aggregate Base (AB) ..............................................0.12
  *Note: The structural coefficient for AB shall be adjusted by a drainage coefficient (Mi) of 0.92 for projects in the Tucson area.

- Cement or bituminous treatment of the subgrade may be considered in lieu of removing and replacing poor native soil. The minimum thickness of these courses is 6-inches. Lime stabilization and geotechnical membranes may also be considered.

- Minimum structural numbers in Table 6-2 are not to be used as a substitute for soil sampling and calculating a structural number per step three. The developed pavement structure should be based on the greater of the calculated SN and minimum values in Table 6-2.

Table 6-2. Minimum Structural Numbers and Pavement Sections

<table>
<thead>
<tr>
<th>Street Classification</th>
<th>Minimum SN</th>
<th>Minimum AC</th>
<th>Minimum AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial</td>
<td>2.75</td>
<td>2.5” (Mix 2) TL</td>
<td>5” to 8”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5” (Mix 1) BL</td>
<td></td>
</tr>
<tr>
<td>Major Collector</td>
<td>1.98</td>
<td>4”</td>
<td></td>
</tr>
<tr>
<td>Collector</td>
<td>1.75</td>
<td>3”</td>
<td></td>
</tr>
<tr>
<td>Local Street</td>
<td>1.49</td>
<td>2.5”</td>
<td>4” to 6”</td>
</tr>
<tr>
<td>Cul-de-Sac</td>
<td>1.75</td>
<td>3”</td>
<td></td>
</tr>
<tr>
<td>Driveway</td>
<td>1.35</td>
<td>2.5” (Mix 2) TL / FL</td>
<td></td>
</tr>
</tbody>
</table>

(1) TL – Top Lift; BL – Bottom Lift; FL – Finish Lift
(2) Refer to PAG Standard Specifications, Section 406 for Mix 1 and 2.

- Roller compacted concrete pavement may be used as a surface course (minimum 5-inch thickness). No grinding or grooving is necessary if the placed finish meets the limiting side friction values per AASHTO A Policy on Geometric Design of Highways and Streets (1) for 25 mph. If roller compacted concrete is utilized, a geotechnical report is required to provide the material specifications and acceptance criteria that is not part of Pima County standard specifications.

- The ratio of AB to AC for pavement sections should be 1:1 to 1.75:1 for an AC thickness between 2.5” and 3.5” and 1:1 to 1.3:1 when greater than 3.5”.
• Minimum structural numbers in Table 6-2 are not to be used as a substitute for soil sampling and calculating a structural number per step three. The developed pavement structure should be based on the greater of the calculated SN and minimum values in Table 6-2.

• When an existing roadway is widened, appropriate soil sampling within the area of new pavement shall be conducted.

• Minimum pavement sections per roadway classification are provided in Table 6-2. If the combined minimum thickness of the AC and AB courses does not provide the necessary SN, increasing the thickness of AC is preferable to specifying thicker sections of AB.

• For County capital improvement projects, alternative pavement sections for R-values less than R-mean are to be evaluated to insure that the recommended pavement section is the most cost effective section.

B. SUBDIVISION AND DEVELOPMENT PAVEMENT DESIGN

In addition to the design requirements and methodologies outlined in Section A, subdivision and development pavement standards shall adhere to the following requirements:

• The minimum structural numbers (SN) and pavement sections by roadway classification are shown in Table 6-2.

<table>
<thead>
<tr>
<th>20 year AADT</th>
<th>ESAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;500</td>
<td>40,000</td>
</tr>
<tr>
<td>500-1000</td>
<td>70,000</td>
</tr>
<tr>
<td>1000-1500</td>
<td>100,000</td>
</tr>
<tr>
<td>1500-2500</td>
<td>150,000</td>
</tr>
<tr>
<td>Cul-de-sacs</td>
<td>100,000</td>
</tr>
</tbody>
</table>

• When the projected 20 year AADT exceeds 2500, or when the engineer desires to calculate their own ESAL’s, complete calculations, including a breakdown of the traffic by vehicle type shall be included in the pavement design report. The ESAL calculations is to be based on a 20-year design period.

• Using the 20 year projected AADT, the equivalent single axial loads (ESAL) in Table 6-3 are acceptable for pavement design of local and collector subdivision streets.

• When a street is widened the new pavement section shall either match the existing pavement section or meet the applicable minimum thickness as specified in Table 6-2 whichever is greater. The County may request further
evaluation of the new pavement section when warranted by field conditions such as an increase in truck traffic or AADT.

- When a street is widened the complete cross section will be subject to pavement replacement and/or surface treatment in accordance with the Pima County Procedures for the Issuance of Right-of-Way Permits and Regulations of Work Under Permit (6).

- When through streets are designed which may ultimately connect to future developments, pavement design and ESAL calculations shall accommodate future wheel loads to account for all future loading.

- New public subdivision local and minor collector streets constructed of asphaltic concrete shall be surfaced with a slurry seal or treatment that would:
  - be appropriate for the expected traffic load and volume
  - have an expected performance timeframe of at least 5 years
  - conform to PAG Standard Specifications for Public Improvements (4) and Pima County Department of Transportation, Supplemental Specifications (5) for material requirements and specifications;
  - be on an approved list posted to the Pima County website (products believed to meet these criteria should be submitted to Pima County Transportation for approval and inclusion on the approved list), and
  - be applied following the construction completion of at least 75 percent of homes impacting the street system in a given development phase or block per manufacturer recommended timeframe following pavement construction and prior to County acceptance into maintenance. Alternatively, a performance bond may be provided prior to County acceptance, for an amount 10% greater than the seal or treatment cost estimate. The work covered by the performance bond shall be completed a maximum of 10 months following acceptance into maintenance.

C. PAVEMENT SECTION SELECTION

In choosing the optimal design for the pavement structure, the following should be considered:

1. Continuity of Pavement Type - To maintain uniform driving conditions for the motoring public, consideration should be given to continuing the same type of existing pavements. This is especially important for relatively short projects.

2. Local Conditions and Subgrade Material - Typically there are multiple pavement structural sections that will meet the requirements of the design equation. Local conditions, such as shallow underground utilities, very heavy slow-moving truck traffic, poor drainage, etc., may make one pavement alternative preferable over the others. A significant change in quality of subgrade material along the length of a roadway may justify more than one pavement structural section. Feasibility of using a geogrid, removing or treating of poor subgrade material, or importing of good material should be considered in the selection of a final pavement section. Refer to Section 1.7 and 2.1.5.2 of ADOT Pavement Design Manual (2) for additional information.
3. **Conservation of Natural Resources** - Conservation of natural resources should be considered in the evaluation of the pavement design alternatives, particularly in areas where aggregates or other materials are scarce.

4. **Anticipated Construction Problems** - Consideration should be given to the feasibility of the proposed design in regard to standard construction methods.

5. **Cost** - A life cycle cost analysis (LCCA) should be performed to determine the most cost-effective structural design. *RealCost software* (7) developed by the Federal Highway Administration, or a similar method, should be used for the LCCA. Unless specified otherwise, pavement service life shall be 20 years.

Normally, the pavement design that satisfies the structural requirements and represents the least cost would be selected. However, there may be times when the least cost design would not necessarily be the most appropriate design. Alternative designs for further review may be appropriate in a situation where no one design seems capable of satisfying all of the constraints. For additional information on design considerations, refer to the latest edition of *AASHTO Guide for Design of Pavement Structures*.

**D. PARKING LOT PAVEMENT**

- In order to control particulate matter, parking areas shall be paved. Parking areas with up to 10 spaces can use a double chip seal or brick pavers as dust control treatments, provided that there is no significant truck traffic.

- For parking areas with ten or more spaces, a minimum structural number (SN) of 1.35 shall be required. This structural number can be obtained by using two inches of asphaltic concrete (AC) on four inches of compacted aggregate base (AB). Depending upon the expected traffic conditions, Pima County may request a pavement design report prepared by a Registered Professional Engineer, to determine if a pavement section with a greater SN is needed.

- Other types of surfacing, including permeable pavements, may be used with the concurrence of the County provided that the pavement structural requirements are met and a registered professional engineer certifies the design.

- Pavement may not be required in historic structures parking areas and in certain vehicle-accessible areas such as contractor yards or storage areas that are access controlled. However, those areas shall still use surface treatments such as gravel or decomposed granite to ensure dust control.

**E. PAVEMENT REPORT**

The data, procedures, and design recommendations are to be documented in a pavement design report which contains the following sections:

*Introduction*
Describe the location and limits of the project, and the proposed improvements with emphasis on the pavement design aspects.

**Geotechnical Data**

Summarize the general geotechnical characteristics of the soils on which the roadway will be constructed. Provide in tabular form the geotechnical data used in designing the pavement structure including the subgrade acceptance chart. The seasonal variation factor should be identified along with figures and equations used in the calculations. Limits of unsuitable subgrade material including soils susceptible to collapse or swelling are to be identified.

**Traffic Data**

State the traffic data used in developing the pavement structure such as current and design year traffic volumes, percentage of vehicle types, percentage of total traffic in the design lane, reliability factors, and so forth. Include the projected annual average daily traffic (AADT) and number of 18-kip equivalent single axle loads (ESAL).

**Pavement Structure Design and Subgrade Acceptance**

Discuss the results of the pavement structure design. Provide in tabular or other appropriate form the calculations used to determine the structural number for the various portions of the project.

Provide pavement section design(s) based on the required structural number(s). Present the data and calculations in a manner that is straight forward and easily repeated for checking.

The subgrade acceptance chart in Appendix C is based on the Pima County correlated R-values. If a project specific correlated R-value is used, a subgrade acceptance chart based on the project specific correlated R-value is to be prepared and included in the report.

**Recommendations**

Discuss the recommended structural sections, including sub-base and subgrade treatment, and any alternatives that were considered. Include life-cycle cost analysis, construction, and other factors taken into account in developing the recommendations.
REFERENCES

1. AASHTO. A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Washington, DC, 2018. May be purchased at https://store.transportation.org/Item/CollectionDetail?ID=180&gclid=EAIaIQobChMI1tcnaorWq3wIVkMhkCh23oAJxEAAAYASAAEglL3A_D_BwE


5. Pima County Department of Transportation. Supplemental Specifications. Pima County, AZ. Available at http://webcms.pima.gov/cms/one.aspx?portalId=169&pageId=63368


7. Administration

The responsibility to administer, manage, implement, coordinate, interpret, and enforce the provisions and standards in this manual shall be as follows:

- The County Engineer or their designee shall have responsibility over all elements within the present and future street right-of-way, whether public or private, including areas having a direct safety, capacity or maintenance impact thereon.

- The Development Services Deputy Director of Building and Site Development or their designee shall have responsibility over development areas outside street right-of-way.

The due-process appeal route regarding interpretation or request for modification to these standards shall be as follows:

- Elements within direct impact to present or future right-of-way: staff interpretation, SDSS Modification Committee, County Engineer.

- Elements within development areas other than right-of-way: staff interpretation, SDSS Modification Committee, Development Services Deputy Director of Building and Site Development, Board of Adjustment, Superior Court.

A. INTERPRETATION AND MODIFICATION

County staff are empowered to interpret and approve minor modifications to these standards in alignment with the principles reflected herein or through referenced nationally recognized standards or methodologies.

If the designer believes that a provision of these standards is vague or unclear, a formal interpretation may be requested from Pima County. In other cases, strict compliance with these standards may not be feasible due to unusual site conditions. Pima County may grant a modification of these standards if the following criteria are met:

- The strict application of the provision(s) in question would create an extraordinary and unnecessary hardship due to topographic or other pre-existing physical conditions of the land. The hardship shall not arise from a condition created by an action of the owner of the property.

- The modification is consistent with the general intent and purpose of the standards and the provision(s) from which the modification is requested.
• The modification does not violate State law or other provisions of Pima County ordinances or policies.

• The modification will not cause injury to the rights of surrounding property owners and residents.

• The modification will not reduce traffic safety, capacity, speed, and functional utility of the street system or negatively impact maintenance.

• The modification makes a clear and definable contribution to Pima County’s economic development priorities.

B. SUBDIVISION AND DEVELOPMENT MODIFICATION COMMITTEE

The County Engineer shall appoint and coordinate the activities of a subdivision and development street standards committee, here-in-after referred to as the “Committee” for modifications related to development. The composition and operation of the Committee are as follows:

Number of members: The Committee shall be composed of six persons.

Affiliation and qualifications of members:

• Three members shall be from the Pima County Department of Transportation.

• Three members shall be employed in the private sector.

• Four of the members shall be registered Professional Engineers in the State of Arizona.

• All members shall have knowledge and experience in subdivision design and have a good understanding of the development process.

Appointing Authority: All Committee appointments shall be made by the County Engineer. The County Engineer may also approve an alternate for each member that may serve in the event of an absence.

Term: Committee members serve at the pleasure of the County Engineer.

Transaction of Business:

• Procedures: The Committee may adopt policies and standard operating procedures, subject to the approval of the County Engineer, to assure the
efficient, predictable, fair and balanced administration of the Committee’s work.

- **Meeting frequency:** The Committee shall meet as necessary to conduct the Committee’s business.

- **Quorum:** The Committee shall be considered to be duly assembled at meetings where at least three members or alternates are present. If fewer than three members or alternates are present the meeting shall be re-scheduled.

- **Voting:** Each member of the Committee shall have one vote in all decisions requiring a vote. A request to the committee for an interpretation or a modification requires a vote.

- **Minutes:** A recording secretary shall prepare meeting minutes which shall include all agenda and discussion items and all votes and consensus actions by the committee. Minority opinions shall be included in the meeting minutes when requested by the member(s) casting the minority vote(s).

- **Responsibility:** The Committee shall not approve or deny any request for modification or interpretation, but shall only provide a recommendation for approval or denial to the County Engineer or Development Services Deputy Director of Building and Site Development.

### C. INTERPRETATION AND MODIFICATION REQUESTS

Modification and interpretation requests related to transportation public improvements and residential, commercial/industrial development roadway standards shall be directed to the Department of Transportation and Development Services Department, respectively. Refer to each department’s website for submittal and procedural information.

### D. RESPONSE TO REQUESTS

The County Engineer or Development Services Deputy Director of Building and Site Development may seek the recommendation of the Committee for interpretations and modifications of the standards in this manual.

Contingent on the above listed scope of responsibility, the County Engineer, Development Services Deputy Director of Building and Site Development or their
designee may accept or reject the Committee’s recommendation and provide the
applicant a decision in writing three working days of the Committee meeting. The
request shall include the reason why the Committee’s decision is accepted or
rejected.

Per statutory authority, the decision of the County Engineer over the street right-of-
way is final and cannot be appealed. However, if the applicant is not satisfied with
the decision of the Development Services Deputy Director of Building and Site
Development, the decision may be appealed to the County Board of Adjustment
by notifying the project Site Review Manager of the request within thirty calendar
days of the Committee decision. Appeals to the Board of Adjustment shall be
scheduled within three working days of request for the next available Board of
Adjustment meeting date, in accordance with County policy.

E. MODIFICATIONS TO STANDARDS

Standards that are repeatedly modified through the County modification process
or no longer align with County policies, procedures, regulations and guidelines or
do not reflect recognized innovations and developments in the profession may be
modified and incorporated into the manual upon approval of the County Engineer
or Development Services Deputy Director of Building and Site Development,
contingent on area of responsibility. Once incorporated herein, these modifications,
in accordance with the limitations attached thereto, become part of the standards
and may be used without invoking the modification process.
8. Sections and Details

Roadways in Pima County are to be constructed in accordance with the most recent version of PAG Standards Specifications and Details for Public Improvements (1) and Pima County Department of Transportation Specifications and Details (2).

REFERENCES

   http://apps.pagnet.org/standardspecifications/

2. Pima County. Standard Details. Department of Transportation, Tucson, AZ.
Chapter 8 - Roadway Sections

WEDGE CURB

VERTICAL CURB

NOTES:

1. Clear Zone. Refer to latest edition of AASHTO Roadside Design Guide. Grade at +2% from hinge point to back of curb.

2. Profile grade, axis of rolloff and roadway storm are to be located at centerline of pavement with 0 - 2% pavement across slope.

3. Concrete vertical curb. PAG Std. 200 Type 2 (+6 inch).

4. Concrete wedge curb. PAG Std. 200 (h=6 inch).

5. Sidewalk, 5 ft. wide, concrete sidewalk per PAG Std. 200. 3 in. x 8 ft. wide when culverting back of curb. Curbway required with wedge curb.

6. 6 inch min depth roadbed ditch.

7. Landscaping and stormwater harvesting.

8. Strip pavement where applicable. Must extend 5 ft. beyond catch point.

9. 10 ft. utility easement or as required by utility companies.

STANDARD TYPICAL SECTION

LOCAL STREET
(URBAN RESIDENTIAL SUBDIVISION)

ISSUED:
Mar. 2019

REVISED:

PIMA COUNTY
(URBAN RESIDENTIAL SUBDIVISION)
Chapter 8 – Roadway Sections

Standard Typical Section

Local Street (Commercial and Industrial Subdivision)
Chapter 8 - Roadway Sections

2020 Pima County Roadway and Development Street Standards Manual

ISSUED: Mar. 2019
REVISED: 2020

STANDARD TYPICAL SECTION

MINOR COLLECTOR
(RURAL 2-LANE)

NO. S-4

NOTES:


2. Profile grade, axis of rotation and roadway crown are to be located at centerline of pavement with -2% pavement and shoulder cross slope.

3. 6 inch min depth roadside ditch.

4. Landscaping and stormwater harvesting.

5. Pavement width may be reduced to 24' with the installation of traffic calming alternatives. Only applies to arterial within a subdivision.

6. Slope pavement where applicable. Must extend 5' from beyond edge paint.

7. Utility easement area required by utility companies. Only applies to subdivision streets.
Chapter 8 – Roadway Sections

NOTES:

1. Curb Zone. Refer to latest edition of AASHTO Roadside Design Guide. Grade at +2% from hinge point to back of curb.

2. Profile grade, aids of rotation and roadway crown are to be located at centerline of pavement with a −2% pavement cross slope.

3. Concrete vertical curb. PAG Std. DTU 296 Type 1 (H=6 in.)


5. 6 inch min depth roadway ditch.


7. Pavement width may be reduced to 24’ with the integrated of traffic calming alternatives. Only applies to streets within a subdivision.

8. Slope easement where applicable. Must extend 5 ft. beyond catch point.

9. 10 ft. Utility easement or as required by utility companies. Only applies to subdivisions streets

10. 48” R/W if direct access to individual property is not permitted. 60” R/W if direct access to individual property is permitted.

ISSUED:  Mar. 2019

REVISED:  PIMA COUNTY

STANDARD TYPICAL SECTION

MINOR COLLECTOR
(URBAN 2-LANE)

NO.   S-5
NOTES:

1. Clear Zone. Refer to latest edition of AASHTO Roadside Design Guide. Grade at +2% from high point to back of curb.

2. Profile grades, ends of sidewalk and roadway crown are to be located at centerline of pavement with a 0.2% pavement cross slope.

3. Concrete vertical curb, PAG Std. Dtl. 205 Type 2 (4-6 inch.)

4. 5 ft. wide concrete sidewalk per PAG Std Dtl. 200. Use 8 ft. when shutting back of curb.

5. 10 ft. utility easement or as required by utility companies.

6. 6 inch mix depth roadside ditch.

7. Landscaping and stormwater harvesting.

8. Slope pavement where applicable Must extend 5 ft. beyond catch point.

STANDARD TYPICAL SECTION

MINOR COLLECTOR
(COMMERCIAL AND INDUSTRIAL SUBDIVISION)
Chapter 8 – Roadway Sections

STANDARD TYPICAL SECTION

ISSUED: Mar. 2019
REvised: [Pima County Transportation]

NO. S-7

Major Collector (Rural 2-Lane)

Notes:
2. Profile grade, edge of shoulder and roadway crown area to be located at centerline of pavement with a -2% pavement and shoulder cross slopes.
3. 5 inch min. depth roadside ditch.
4. Landscaping and stormwater harvesting.
5. Edge of pavement 15 ft. utility easement or as required by utility companies. Only applies to subdivision streets.
6. Slope easement where applicable. Must exceed 6 ft. beyond each point.

See Safety Edge Detail
Chapter 8 – Roadway Sections

STANDARD TYPICAL SECTION

MAJOR COLLECTOR (RURAL 3-LANE)

ISSUED: Mar. 2019

NOTES:

2. Profile grade, set of rotation, and roadway crown are to be located at centerline of pavement with ±2% pavement and shoulder cross slopes.
3. 6 inch min depth roadway ditch
4. Landscaping and stormwater harvesting.
5. Slope easement where applicable. Must extend 5 ft. beyond center point.
6. 10 ft. utility easement or as required by utility companies. Only applies to subdivision streets.
Chapter 8 – Roadway Sections

NOTES:

1. Clear Zone. Refer to latest edition of AASHTO Roadside Design Guide. Grade at +2% from hinge point to back of curb.

2. Profile grade, axis of rotation and roadway crown are to be located at centerline of pavement with a -2% pavement cross slope.

3. Concrete vertical curb, FAA Std. Bc. 209 Type 1 (H=5 inch).

4. Median/median barrier, 5 ft min. concrete sidewalk per PAG Std. DIN 200, use 6 ft width when abutting back of curb.

5. 6 inch min. depth roadsides ditch.


7. 10 ft. utility easement or as required by utility companies. Only applies to subdivision streets.

ISSUED: Mar. 2019

REVISED:

PIMA COUNTY TRANSFERTATION

STANDARD TYPICAL SECTION

MAJOR COLLECTOR (URBAN 3-LANE)

NO. S-9
Chapter 8 - Roadway Sections

2020 Pima County Roadway and Development Street Standards Manual

Chapter 8 – Roadway Sections - 100

NOTES:

2. Profil e grade, size of rotation and roadway crown are to be located at centerline of pavement with 0 - 1/2% pavement and shoulder area slope.
3. 6 inch min depth recessed ditch.
4. Landscaping and stormwater harvesting.

ISSUED: Mar. 2019

REvised:

STANDARD TYPICAL SECTION

MINOR ARTERIAL (RURAL 3-LANE)

NO. S-10
Chapter 8 – Roadway Sections

Notes:

1. Clear Zone. Refer to latest edition of AASHTO Roadside Design Guide. Grade at +2% from hinge point to back of curb.

2. Profile grade, axis of rotation and roadway crown are to be located at centerline of pavement with a -2% pavement cross slope.

3. Concrete vertical curb. PAV std. Dil. 200 Type 1 (1-6 in.)

4. Landscaping and stormwater harvesting

5. Sidewalk 5 ft. min. concrete sidewalk per PAV std. Dil.

6. Use 6 ft. widths when abutting back of curb.

5. 6 inch min depth roadway ditch.

Issued: Mar. 2019

Revised:

Standard Typical Section

Minor Arterial (Urban 3-Lane)

No. S-11
Chapter 8 – Roadway Sections

NOTES:

1. Clear Zone. Refer to latest edition of AASHTO Roadside Design Guide. Grade at -2% from hinge point to back of curb.
2. Roadway pavement cross slope -2% from median curb (typ).
3. Concrete vertical curb. PAG Std. Dtl. 278 Type 1 (+/− 6 inch).
4. Walkway: 5 ft. min. concrete sidewalk per PAG Std. Dtl. 200. Use 6 ft. width when adjoining back of curb.
5. 6 inch min depth roadside ditch.
7. Median control profile grade and axis of rotation. Location may vary.

ISSUED: Mar. 2019

REvised:

STANDARD TYPICAL SECTION

MINOR ARTERIAL
(URBAN 4-LANE DIVIDED)

NO. S-12
Chapter 8 – Roadway Sections

NOTES:

3) Concrete vertical curb. PAG Std. D11. 209 Type 1 (4-8 inch).
4) Catch basin, PAG Std. D51.

ISSUED: Mar. 2019
REVISED: 2020

STANDARD DETAIL

PAVEMENT DRAINAGE
(CATCH BASIN LOCATIONS)

NO. S-15
APPENDIX A

Figure A-1. Right-Turn Lanes Traffic Volume Warrants at unsignalized intersections for Two-Lane Roadways
Figure A-2. Right-Turn Lanes Traffic Volume Warrants at unsignalized intersections for Four-Lane Roadways

Note: Existing roadway constraints may restrict the ability or need to install turning lanes. Traffic Engineering may require engineering analysis to support alternative recommendations for the installation of turning lanes.
EXHIBIT A-1. Auxiliary Lane Design Standards and Layout

**Left-Turn Lane Taper Length**

**Symmetrical Widening** - The preferred way of creating a left-turn lane is by widening the roadway on both sides equally as shown in Figure 1. This minimizes the amount of lateral shifting for through traffic. Taper lengths will be reduced by a proportional amount based on the proportion of widening of each side, e.g., by ½ for symmetrical widening.

The taper length is determined by the formula:

\[ T = \frac{W \times S}{2} \]

for speeds of 45 mph or greater

and by

\[ T = \frac{(W \times S^2)/60}{2} \]

for speeds under 45 mph

where:

- \( T \) = length of taper in feet
- \( W \) = width of lane in feet
- \( S \) = posted speed for existing roadways, or design speed for new or reconstructed roadways.

![Figure 1. Symmetrical Widening](image-url)
**Non-Symmetrical Widening** - In some instances it may be necessary to add the required widening to only one side of the roadway as shown in Figure 2. When widening to only one side, the taper length is determined by the formula:

\[ T = W \times S \text{ for speeds of 45 mph of greater} \]

and by

\[ T = \frac{W \times S^2}{60} \text{ for speeds under 45 mph} \]

where:

- \( T \) = length of taper in feet
- \( W \) = width of lane in feet
- \( S \) = posted speed for existing roadways, or design speed for new or reconstructed roadways.

**Table: Non-Symmetrical Widening**

<table>
<thead>
<tr>
<th>POSTED or DESIGN SPEED (MPH)</th>
<th>GAP (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 40</td>
<td>60</td>
</tr>
<tr>
<td>40 – 50</td>
<td>90</td>
</tr>
<tr>
<td>&gt; 50</td>
<td>140</td>
</tr>
</tbody>
</table>
Right-Turn Lane Taper Length

Lengthy tapers are generally not required for right turn lanes, since the lane may be simply added to the outside of the traveled way, however a shorter taper equal in length to the gap is provide to transition the edge line from the normal pavement cross section to the edge of the turn lane.

Figure 3. Right-Turn Lane Taper

<table>
<thead>
<tr>
<th>POSTED or DESIGN SPEED (MPH)</th>
<th>GAP (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 40</td>
<td>60</td>
</tr>
<tr>
<td>40 – 50</td>
<td>90</td>
</tr>
<tr>
<td>&gt; 50</td>
<td>140</td>
</tr>
</tbody>
</table>
**Left- and Right-Turn Lane Storage Length**

A 95th percentile queue analysis should be used to determine right and left-turn storage lengths. If values other than the 95th percentile are used, a justification shall be provided in the Traffic Study or a letter shall be submitted to the County Engineer, or designee, for approval. Minimum storage lengths are 110 feet (≤ 40 mph) and 150 feet (≥ 45 mph).

**Channelized Right-Turn Lanes**

Channelized right turn lanes shall be designed with a flat angle as shown below. Channelized right turn lanes should only be installed when a performance based analysis warrants their installation or with the approval of the County Engineer.
APPENDIX B

GEOTECHNICAL INVESTIGATION

Purpose
The purpose of the geotechnical investigation is to determine the pavement structure, trench backfill requirements, foundation designs, and other geotechnical information needed for design of the various elements of the roadway project.

Process
The designer shall undertake the investigations described below as appropriate for the particular project. The designer shall arrange a geotechnical investigation coordination meeting with the County to discuss proposed test boring locations and potential geotechnical issues related to the project. Prior to beginning any investigation, testing or sampling, the designer shall develop plans outlining proposed test boring and sampling locations, and shall request Blue Stake to locate utilities.

Upon completion of the geotechnical investigations, the report is to be submitted to Pima County for review. The Materials Section will be responsible for evaluating the appropriateness of the existing soils for various uses on the project. This information will be provided to the designer for inclusion in the final Geotechnical Report and preparation of the project’s Special Provisions.

Roadway Soil Investigation

The roadway soil investigation for pavement design shall be performed in accordance with the requirements in the current edition of the Arizona Department of Transportation Materials Preliminary Engineering and Design Manual and the following additional provisions. Field exploration shall be performed only after the initial roadway profile grade and alignment have been established.

- The minimum number of borings and test samples shall be in conformance with the Materials Preliminary Engineering and Design Manual. Each boring shall extend a minimum of 5 feet below the final finished grade of the pavement and borings shall be located at significant features of the design such as drainage crossings, walls, etc. Sampling frequency shall be based on the specific needs of the project and the engineer shall ensure that all soil types encountered are adequately sampled and tested.

- Split-spoon and ring samples shall be obtained by performance of standard penetration tests (SPTs) at intervals of 2.5 feet and 5 feet below the anticipated finished grade of pavement. If a split-spoon sample is collected at 2.5 feet then ring sample shall be collected at 5 feet. This sampling pattern shall be alternated in adjacent pavement borings along the corridor. For example, if one boring has a split-spoon sample at 2.5 feet and ring sample at 5 feet then the next boring shall have ring sample at 2.5 feet and split-spoon sample at 5 feet. The ring samples shall be obtained in set of 6 rings at a minimum.

The in situ dry density and moisture content shall be determined from a suitable ring within the set of six (6) rings. If the in situ dry density is less than 100 pcf or is described as “loose”, a one-dimensional collapse test shall be performed on another suitable ring sample from the same set of six (6) rings in accordance with ASTM D5333. This test is to determine the need for subgrade modifications to mitigate the detrimental effects of soil collapse on pavement structure.

- For samples with PI>15 and percent fines (passing #200) >20%, swell tests shall be performed on in situ as well as remolded compacted soils in accordance ASTM D4546 Part B to determine swell potential. The surcharge (seating pressure) during the swell test shall be 125 psf. Swell tests on in situ samples shall be performed using undisturbed ring samples. The swell tests on remolded compacted soils shall be performed by remolding the soils to 95% of maximum dry density and at 3% below optimum moisture content. The maximum dry density and optimum moisture content shall be determined in accordance with ASTM D698 (Standard Proctor).
• Sampling existing pavements is required to produce an accurate representation of existing pavement structure. The location of test holes in existing pavements shall be varied to yield samples in the paved shoulder (if present), inside and outside lanes and from lanes in both directions. This is especially important in providing design recommendations for rehabilitation or widening projects where the existing pavement may be incorporated into the new structural pavement section.

**Trench Backfill Investigation**

The trench backfill soil investigation shall be conducted at the plan development stage when the storm drain system and cross drainage structures are fairly well defined. Sampling locations and test bores shall be taken at enough locations to be considered representative of the materials in the area. The sampling depth shall be to the pipe or cross drainage structure invert elevation, plus the thickness of the structure, plus 6 inches. Test boring locations shall be marked and numbered consecutively on 11”x17” project plan sheets and included in the appendix of the Geotechnical Report.

**Channel Soil Investigation**

For channel improvements, the wash bottom and banks shall be sampled a minimum of every 500 feet. At least one test boring shall be taken at each proposed grade-control structure location. These borings shall extend a minimum of 25 feet below the existing flow line unless an impenetrable substratum is encountered. For bank protection design, tests shall be conducted a minimum of every 500 feet along both sides of the proposed bank protection alignment. Testing alternate sides of the channel is permissible if the results demonstrate uniformity between the sides.

The investigation may need to provide structural information necessary to design rigid lining, soil cement mix design if in situ material is to be used, and depth of scour. Borings to determine toe down stability analysis shall extend a minimum of 5 feet below the proposed bottoms of the toe downs.

**Bridge Soil Investigation**

The bridge soil investigation shall be performed in conjunction with the Bridge Structure Selection Report (see Section 3.14). Adequate exploration, testing, and analysis shall be performed to determine the bridge foundation and abutment designs.

If the bridge is a river crossing, sufficient geotechnical information for determining depth of scour must also be obtained. A minimum of one test boring at each proposed bridge pier and abutment location is required. These test borings shall extend a minimum depth of 70 feet unless an impenetrable substratum is encountered. Test borings must also extend at least 20 feet below the ultimate bottom of each pier and abutment.

**Protection of Vegetation**

Vegetation may not be disturbed or damaged during the geotechnical investigation without the prior written approval of the property owner. Pima County will approach the property owner for such permission subsequent to the designer demonstrating the need for vegetative disturbance.

**Protection of Archaeological and Historical Sites**

A geotechnical-boring plan showing any existing roadways and proposed boring locations shall be provided to the Pima County Project Manager in advance of fieldwork. The Project Manager will forward the plan to the Pima County Office of Cultural Resource and Historic Preservation (OCRHP), which will determine if the proposed field work is located in an area of known artifacts. If sufficient concern exists, the OCRHP will provide an archaeologist to observe the boring as it is being conducted.
Note: The discovery of archaeological or historical sites or objects shall be immediately reported to Pima County, and all reasonable steps taken to secure its preservation. Artifacts from historic or prehistoric ruins or archaeological sites may not be disturbed, excavated, or collected.

Restoration of Test Sites

Test sites must be restored to their prior condition unless written permission to leave the site disturbed has been obtained from the affected property owner. Pima County will contact the affected property owner for this permission upon demonstration of the need by the designer.

Report Content

The designer shall document the procedures, findings, and resulting design recommendations in a Geotechnical Report. The report should contain the following information that is pertinent to the project.

Introduction
Describe the location and limits of the project, and the proposed improvements with emphasis on those elements requiring geotechnical consideration.

Site Exploration
Discuss the number and location of borings, boring procedures, and laboratory testing methodology and procedures.

Subsurface Conditions

Describe the types of materials, the depth of impermeable substratum (if encountered) and the general subsurface conditions. Summarize the results of the analyses needed for the particular project. These may include the following:

Pavement Design:
- Sieve Analysis
- Plasticity Index (PI)
- R-values
- pH and Resistivity
- Resilient Modules
- In situ dry density
- In situ moisture content
- Collapse potential
- Swell potential

Trench Backfill:
- Gradation
- Liquid Limit
- Plastic Limit
- Plasticity Index (PI)
- pH and Resistivity
- Soluble salts (chlorides and sulfates)

Retaining Wall, Spread Footing, Drilled Shafts and Other Structures:
- Unit weight of soil
- Allowable bearing pressure
- Active and passive friction coefficients
• Active and passive lateral pressure
• Shear Strength (C)
• Settlement
• Internal friction angle (Ø)
• Swell
• pH and Resistivity
• Soluble salts (chlorides and sulfates)
• Other specific information such as spring constants of soil-structure interaction analysis

The designer shall consult with the pavement design engineer and/or structural engineer to confirm the specific information needed for the project.

Conclusions and Recommendations

Recommendations, which shall also include the information needed for the particular project, typically address the following:

• Maximum cut and fill slopes
• Erosion potential and slope stability
• Special treatment of subgrade
• Treatment of embankment materials
• Collapse and differential settlement
• Swell potential
• Compaction
• Bridge foundation design parameters for drilled shafts, spread footings, and abutment walls
• Retaining wall design parameters
• Need to replace in situ material with engineered backfill
• Possible slope stabilization techniques
• Other geotechnical information needed for the particular project
APPENDIX C

SUBGRADE ACCEPTANCE CHART FOR PIMA COUNTY Rc VALUES

Note: For any chosen Design R-value, if the tested plasticity index and percent fines of a soil plot below that R-value line, the soil is considered to be acceptable. If the plasticity index and percent fines of a soil plot above that R-value line, the soil is considered to be unacceptable and shall not be used as subgrade material. Also, the X-value shown in the legend for each R-value represents the maximum X-value (at 2.80%) of each Design R-value based on the equation, \( Y = \frac{X}{10} \).
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