An Introduction to Stormwater Drainage and Site Development

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An Introduction to Stormwater Drainage and Site Development

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1. DESIGN CRITERIA.

Design surface drainage, underground drainage systems, stormwater management facilities, and erosion and sediment control in accordance with the applicable requirements of the local regulatory authority. The design of the storm drainage system and stormwater management must address the following:

- **THE STORMWATER MANAGEMENT PLAN** must comply with federal, state, and local regulatory requirements including regional or site-specific stormwater management agreements.

- **THE TEMPORARY AND PERMANENT** erosion and sediment control practices must be provided in accordance with local regulatory requirements during both the construction and operational phases of the project.

- **THE GRADING** must complement the features and functions of the natural drainage system and the existing contours. Also consider the high and seasonal groundwater table elevations in the siting and sizing of stormwater management facilities.

- **UTILIZE OVERLAND FLOW** and natural site features where stormwater drainage will not impact site function. Drainage systems must prevent erosion of existing soils, prevent ponding, and convey flow to a suitable outfall location. Use pump stations and transmission mains only with explicit authorization by the Owner.

- **CULVERTS, DITCHES, AND OTHER DRAINAGE STRUCTURES** constructed along or tributary to fish streams must be designed to minimize adverse environmental effects.

1.1 DESIGN METHODS. Time of concentration must be calculated using the TR-55 method or as approved by the TR-55 Curve Number method. The Rational Method may also be used for drainage areas smaller than 200 acres. Regional intensity-duration-frequency (IDF) curves are available in most state or local regulatory agency drainage manuals or from the National Oceanic and Atmospheric Administration (NOAA).

1.2 DESIGN STORM FREQUENCY AND SPREAD. For design of the drainage system, use a minimum 10-year storm frequency, the facility type minimum, or the minimum required by the local governing authority, whichever is more stringent. Maximum spread for many roads is ½ driving lane using a minimum of 5-year storm frequency.

2. ROOF DRAINAGE.

Where roof drainage is discharged to grade, provide splash blocks/paved channels to direct the flow away from the structure. Eliminate safety hazards from ice, ponding, flooding, etc., in pedestrian and vehicular traffic areas. Where underground collection of roof drainage is used, provide an air break between the downspouts and underground piping. Size underground piping in accordance with the latest edition of the International Plumbing Code (IPC) or a minimum of 6 inches (150 mm) interior diameter, whichever is greater. No more than three downspouts shall be collected in a single outlet before connecting to a storm drainage structure, and the length of pipe from the most distant downspout to a drainage structure shall not exceed 150 feet (45.7 m). Provide a cleanout for each downspout connection and collection header; provide distances between cleanouts not greater than 100 feet; and provide cleanouts at changes in direction.

3. SURFACE STORM DRAINAGE.

3.1 GRADING. Determine the appropriate requirements for site grading and accessibility. Ensure that the grading and associated stormwater runoff do not adversely affect surrounding sites. Acceptable ranges of transverse and longitudinal slopes are indicated in Table 1. Grading criteria is also indicated in the American Association of State Highway and Transportation Officials' (AASHTO) *A Policy on Geometric Design of Highways and Streets*.

Item No.	Item Description	Requirement	Best Practices
1	Longitudinal grades of roadways	Min. 0.3%	Min. 0.5%
2	Transverse grades of roadways	Min. 2.0%	
3	Concrete pavement in parking areas	Min. 1.0%	Min. 1.5% Max. 5%
4	Curb & gutter Valley gutter	Min. 0.3%	Min. 0.5%
5	Bituminous pavement in parking areas	Min. 1.5%	Min. 2.0% Max. 5.0%
6	Permeable pavements in parking areas	Min. 1.0%	Max. 5.0%
7	Walks, transverse	Max. 2.0%	
8	Walks, longitudinal		Max. 5.0%
9	Concrete landings	Max. 2.0%	
10.	Paved concrete ditches, longitudinal	Min. 0.3%	
11	Unpaved ditches, longitudinal	Min. 0.5%	
12	Pervious surfaces (grass/turf/landscape)*	Min. 2.0%	

** Regulatory agency's stormwater management criteria may govern for items used as stormwater management features.*

Table 1

Grading

3.2 EROSION AND SEDIMENT CONTROL. Design erosion and sediment controls that minimize the discharge of pollutants from earth disturbing activities in conformance with the applicable requirements of the regulatory agency with jurisdiction over the installation regarding erosion and sediment control. Where requirements do not exist, provide an erosion and sediment control plan in accordance with the requirements of the Environmental Protection Agency's (EPA's) 2003 Construction General Permit (which is also the referenced standard for LEED Sustainable Site Prerequisite 1).

4. UNDERGROUND GRAVITY STORM DRAINAGE SYSTEM.

For drainage system design comply with the following criteria:

- **PROVIDE STRAIGHT ALIGNMENTS** for piping between storm drainage structures. Use of curvilinear alignment is not allowed for pipes with a diameter of 48 inches (1200 mm) or less. For pipes with a diameter greater than 48 inches (1200 mm) use of curvilinear alignment may be allowed with explicit authorization by the regulatory authority. Deflection at structures must not be less than 90 degrees for main line flows and not less than 60 degrees for contributory flows, as measured from the centerline of the mainline discharge.

- **STORM DRAINAGE PIPING** must not pass under buildings and must be a parallel distance of at least 10 feet (3.05 m) from building foundations.

- **AVOID CONFLICTS** with other utilities.

- **CONFLICT STRUCTURES** will not be allowed without Owner approval.

- **COMPLY WITH STATE OR APPLICABLE REGULATORY AGENCY'S REQUIREMENTS** for separation distances between utilities and other public health and safety issues.

- **PROVIDE A STRUCTURE** at collection and inlet points, at changes in horizontal or vertical alignment, at pipe junctions and with minimum spacing of a pipe run according to Table 2. Provide a discharge structure wherever flow changes from piped flow to open channel flow.

Pipe Diameter		Maximum Spacing	
Inches	mm	Feet	Meters
12-24	300-600	300	91.44
27-36	675-900	400	121.92
42-54	1050-1350	500	152.4
60 and up	1500 and up	1000	304.8

Table 2

Storm structure spacing criteria

- **IN THE DESIGN OF CULVERTS** and storm drains, consider headwater and tailwater and their effects on hydraulic grade line and capacity. The following upstream controls may limit the headwater elevation:

  - **NOT HIGHER THAN** an elevation that is 18 inches (450 mm) below the outer edge of the shoulder at its lowest point in the grade.

  - **UPSTREAM PROPERTY DAMAGE**.

  - **ELEVATIONS ESTABLISHED** to delineate the National Flood Insurance Program or other floodplain zoning.

  - **HW/D IS AT LEAST** 1.0 and not to exceed 1.5 or the local requirement where HW is the headwater depth from the culvert inlet invert and D is the height of the barrel.

- **LOW POINT IN THE ROAD GRADE** which is not necessarily at the culvert location.

- **ELEVATION OF TERRAIN** and ditches that will permit flow to divert around the culvert. The tailwater elevation in the storm drain outfall must be either the average of the critical depth and the height of the storm drain conduit, (dc + D)/2, or the mean high tide if tidal conditions are present, whichever is greater. Storm drains must be designed for open channel flow. The hydraulic grade line for the storm sewer system must not exceed the pipe crown elevation unless the outfall is submerged. If the controlling tailwater elevation is above the crown elevation of the outfall, the hydraulic grade line for the storm sewer system must not exceed one foot (300 mm) above the crown, or one foot (300 mm) below the structure rim or gutter flow line at inlets, whichever is the lower elevation at each structure. At structures, consider setting the inlet pipe crown elevation equal to or greater than the outlet pipe crown elevation to minimize the hydraulic turbulence at the junction. Consider setting the invert elevation of the outflow pipe at least 0.1 feet (30 mm) lower than the lowest inflow pipe invert elevation to accommodate the hydraulic losses through the structure.

- **THE DOWNSTREAM PIPE** configuration, slope and size must have capacity for the upstream hydraulic peak flow. The pipe size must not decrease downstream in the direction of flow.

- **LOCATE DRAINAGE STRUCTURES** out of paved areas wherever possible. Adjust structure locations to avoid primary wheel tracks when structures must be located in roadways.

- o **DURING DESIGN** evaluate the potential for infiltration of fine soils into drainage pipe joints and, if it is a known maintenance issue at the Installation, specify watertight joints to mitigate the possibility.

4.1 MINIMUM PIPE SIZE.

Use a minimum inside diameter of 12 inches (300 mm) for storm drainage piping (not including roof drainage piping) for runs 50 feet (15.2 m) or less and where the existing downstream pipe is a 12-inch (300 mm) inside diameter with sufficient capacity; otherwise, use a minimum inside diameter of 15 inches (375 mm).

4.2 MINIMUM AND MAXIMUM COVER.

Provide minimum cover for all pipes sufficient to support imposed dead and live loads for the pipe materials used: 24 inches (600 mm), ½ of the pipe diameter, or greater than frost penetration according to UFC 3-301-01, whichever is greater. For pipes in non-paved areas, account for loads from expected maintenance equipment. Increase depth of cover, pipe material strength, or bedding requirements to accommodate the imposed loads during and after construction. For pipes under rigid pavement, the minimum cover may be reduced to 12 inches (300 mm) from the top of pipe to the finished grade and to 6 inches (150 mm) from the top of the pipe to the bottom of the concrete pavement if:

- Reinforced concrete pipe (ASTM C76, Class V) is used.
- Design assumptions and calculations are approved by the Owner

Determine the maximum cover for all individual pipe and culvert installations underlying roads, streets, and open storage areas subject to H-20 live loads. See Chapter 9 of the Federal Aviation Administration (FAA) document AC 150/5320-5C for additional design guidance on minimum and maximum cover.

4.3 DESIGN VELOCITY. Provide a minimum full flow velocity as indicated in Table 3. Determine full flow velocity using the Manning equation under no surcharge at peak flow conditions. Consider a minimum slope of 0.2 percent for constructability.

Item Description	Requirement	Best Practices
Full flow velocity	Min. 2 feet/sec	Min. 3 feet/sec

Table 3

Design velocity

4.4 MANNING'S ROUGHNESS COEFFICIENT. Use Manning's roughness coefficient, "n" of 0.013 for smooth concrete pipe. For other drainage materials, see state or local regulatory agency's requirement.

4.5 MATERIAL SELECTION. Provide storm drain system materials in conformance with the Unified Facilities Guide Specifications (UFGS) to meet specific site conditions and soil characteristics. Consider thermal expansion of pipe material based on pipe location and temperatures of stormwater.

4.6 CULVERTS AND OUTFALLS. Culverts and outfalls must have headwalls, endwalls, wingwalls, flared or mitered end sections at free outlets. In areas of seasonal freezing, the structure must also be designed to preclude detrimental heave or lateral displacement caused by frost action. The most satisfactory method of preventing such damage is to restrict frost penetration beneath and behind the wall to non-frost-susceptible materials. Positive drainage behind the wall is also essential. Outlets and endwalls must be protected against undermining, bottom scour, damaging lateral erosion, and degradation of the downstream channel.

4.7 STORM STRUCTURES. Storm structures for roads and site drainage must be in accordance with the UFGS, or the State Department of Transportation's (DOT) Standards and Specifications where the project is located, or the requirements of the applicable local regulatory agency that governs stormwater management, whichever is more stringent. Structures must provide access for maintenance. Internal dimensions must not be less than 2 feet (600 mm) in any one direction. Ensure that catch basins, curb inlets, and manholes are of adequate size to accommodate inlet and outlet pipes. Provide structures of cast-in-place or precast concrete. Masonry structures are allowed for shallow installations less than 5 feet (1.52 m) in depth. Design structure frames, covers and grates to withstand traffic loadings and meet any additional requirements set forth in the using agency criteria for the particular application. Select grate type based on such factors as hydraulic efficiency, debris handling characteristics, pedestrian and bicycle safety, and loading conditions. Grates in traffic areas must be able to withstand traffic loads. Require fixed ladders on all structures over 12 feet (3.66 m) in depth.

5. STORMWATER MANAGEMENT FACILITIES.

Design stormwater management facilities in accordance with applicable regulations of the regulatory authority.

6. STORMWATER PUMP STATIONS.

Use of stormwater pump stations is generally not allowed except with explicit authorization by the Owner. Design stormwater pump stations in accordance with the criteria referenced in the paragraph entitled, "Design Criteria".

6.1 UPGRADES TO EXISTING PUMP STATIONS. Existing pump stations may be upgraded where a complete hydraulic analysis shows that the pump station can operate at the proposed capacity in conformance with the jurisdictional requirements for a new pump station of equal capacity. Include effects on the existing force main to its point of discharge in the hydraulic analysis, and if networked, the effects on all other pump stations connected to the system. This analysis is required whenever additional flow is added to a pump station, even if physical changes to the station are not proposed.

7. SAFETY AND STORM DRAINAGE SYSTEM COMPONENTS.

Provide protective measures for stormwater management facilities, such as detention/retention ponds, in residential housing areas and other areas frequented by children, in accordance with the applicable requirements of the locality or equivalent. Protective measures include, but are not limited to, appropriate site selection for the storm water management facility and/or providing a fenced enclosure surrounding the facility. When provided, the fence must be a minimum of 4 feet (1.22 m) high with locking access gates.

8. SECURITY AND STORM DRAINAGE SYSTEM COMPONENTS.

Provide security barriers at all locations where security fences must cross drainage ditches or swales to ensure that intruders are prevented from passing under the fence. Pipes larger than 10 inches (250 mm) in diameter that cross under security fences require protective measures. Designs must comply with the appropriate physical security criteria.

9. AIRFIELD DRAINAGE

9.1 DESIGN STORM FREQUENCY AND SPREAD. For the design of drainage systems for airfields and heliports, use the minimum required by the local governing authority for airfield and heliports or the minimum required as follows, whichever is more stringent:

- Runways and Taxiway Pavements – 2 year storm frequency.

- Apron Pavements – for 2 year or 5 year storm frequency as directed by the Owner.

Ponding is not allowed on taxiway and runway pavements including paved shoulders. Ponding around apron inlets must not exceed 4 inches (100 mm). The center 50 percent of runways; the center 50 percent of taxiways serving these runways; and helipad surfaces along the centerline must be free from ponding resulting from storms of a 10-year frequency.

9.2 SURFACE STORM DRAINAGE FOR AIRFIELDS

9.2.1 GRADING. Use accepted practices for the grading criteria for airfields.

9.2.2 CURBS AND GUTTERS. Curbs and gutters are not permitted to interrupt surface runoff along a taxiway or runway. The runoff must be allowed unimpeded travel transversely off the runway and then directed to the area inlets. Inlets spaced throughout the paved apron construction must be placed at proper intervals and in well-drained depressed locations.

9.2.3 OPEN CHANNELS. Open channels or natural water courses are permitted only at the periphery of an airfield or heliport facility and must be well removed from the landing strips and traffic areas.

9.3 UNDERGROUND GRAVITY STORM DRAINAGE SYSTEM FOR AIRFIELDS. Avoid drainage patterns consisting of closely spaced interior inlets in pavements with intervening ridges for airfields. Such grading may cause taxiing problems, including bumping or scraping of wing tanks. Crowned sections are the standard cross sections for roadways, runways, taxiways, and safety areas. Crowned sections generally slope each way from the center line of the runway on a transverse grade to the pavement. If there is a long, gradually sloping swale between a runway and its parallel taxiway (in which the longitudinal grade, for instance, is all in one direction), additional inlets should be placed at regular intervals down this swale. Should this be required, ridges may be provided to protect the area around the inlet, prevent bypassing, and facilitate the entry of the water into the structure. If the ridge area is within the runway safety area, the grades and grade changes will need to conform to the limitations established for runway safety areas in other pertinent publications. Watertight joints are recommended under airfield pavements.

9.3.1 MINIMUM AND MAXIMUM COVER. Use cover tables included in Chapter 9 of the FAA document AC 150/5320-5C provided project specific loads and conditions do not deviate from those indicated.

9.3.2 MATERIAL SELECTION FOR AIRFIELDS. The use of plastic pipes is not approved under any type of airfield pavement except for subsurface water collection and disposal.

9.3.3 STORM STRUCTURES FOR AIRFIELDS. Design structure frames, covers and grates to withstand airfield traffic loadings and to meet any additional requirements set forth in the using agency criteria. Isolate airfield structures from the pavement section. Provide structures of cast-in-place or precast concrete; do not use masonry structures in airfield construction. Use ductile iron or steel grates and covers. Inlet grating and frames must be designed to withstand maximum aircraft wheel loads, considering the gear configuration of the largest aircraft using or expected to use the facility. Commercially manufactured grates and frames have been designed specifically for airport loadings. Provide hold-down devices to prevent grate displacement by aircraft traffic. If manufactured grates are used, the vendor must certify the design load capacity. For structures that will be required to support both in-line and directional traffic lanes, such as diagonal taxiways or apron taxi routes, do not consider load transfer at expansion joints in the design process; however, if specific knowledge about the long-term load transfer characteristics of a particular feature supports the use of load transfer in the design of a particular drainage structure, then an exception can be allowed and load transfer considered.

9.4 SAFETY. Avoid attracting wildlife to the facility; avoid a Bird/Animal Aircraft Strike Hazard (BASH) issue.

10. SITE DEVELOPMENT

10.1 PRELIMINARY SITE ANALYSIS. Conduct a preliminary site visit and obtain photographs of the site. Research and obtain the installation's master plan, utility maps and as-built record drawings for information related to topography, utility and storm drainage availability, including design approaches used in the project vicinity. Evaluate the potential for abandoned or unmapped utilities. Research and review available subsurface investigation data and reports in order to evaluate subsurface conditions. Identify flood hazard areas in accordance with the International Building Code (IBC) Section 1612, Flood Loads. Research and obtain explosive safety requirements. Consult with the regulatory authorities to determine if the site has any environmental concerns, such as radon, pesticides, or known contamination. If required, provide a radon mitigation system design. Evaluate the need for additional analysis based on project requirements and site conditions. Conduct detailed consultations with the regulatory authority in order to clearly define requirements and preferences.

10.2 EXISTING CONDITIONS

10.2.1 GEOTECHNICAL SITE INVESTIGATION. Obtain soil exploration, testing and evaluation from a professional geotechnical engineer. Determine the extent of exploration and testing based on recommendations with the geotechnical engineer, structural engineer (for foundations), civil engineer (for LID, pavements, wells, septic systems, etc.), local stormwater permitting agency (for detention ponds), and regulatory authority reviewers. Indicate the results of the subsurface investigation, including boring locations, boring logs, groundwater observations, a summary of laboratory test results, and any details required to convey requirements for site preparation on the contract documents.

10.2.2 SURVEYING. A licensed or certified professional must seal all surveys in accordance with the applicable requirements of the local regulatory agency or overseas equivalent having jurisdiction over the installation. Where overseas equivalent requirements do not include an accuracy standard, provide surveys at a minimum third order in accordance with the Federal Geodetic Control Committee's *Standards and Specifications for Geodetic Control Networks*. Consult with the owner to establish contact with the owner's real estate personnel prior to entering the property. Notify and obtain authorization from all public and private landowners for a right of entry and trespass, over, across and through all lands necessary to perform the required field survey work. Consult with the owner to establish contact with the appropriate environmental personnel before entering the area with regards to any restrictions concerning vegetation cutting/clearing, natural resources, endangered species, etc.

10.2.2.1 TOPOGRAPHIC SURVEYS. Provide a topographic survey of the project site in accordance with each service's requirements as well as the requirements of the state or local authority in which the site is located. If the state or host nation equivalent requirements are not available, use the National Society of Professional Surveyors (NSPS) *Model Standards for Topographic Surveys.*

10.3 DESIGN APPROVALS AND PERMITS. The owner must identify, assist and provide, as applicable, all permits, approvals and fees required for the design and construction of the proposed project from federal, state and local regulatory authorities or overseas equivalent. A Professional Civil Engineer experienced and licensed in the state where the project is located may be required to obtain permits and approvals. Seek out the project National Environmental Policy Act (NEPA) documentation, as applicable, for project specific requirements. Consult with the owner to determine the appropriate signatories for permit applications.

10.4 CLEARING AND DEMOLITION. Identify the following in the construction documents: limits of disturbance; limits of demolition; limits of clearing and grubbing; and isolated trees and shrubs to remain or to be removed. Describe size, density and type of trees to be cleared and grubbed, items to be salvaged or relocated, staging area, as well as temporary storage area and location. Coordinate with the owner concerning clearing options to remove merchantable timber from the project site. During site demolition and preparation, remove existing and abandoned utilities under or within 10 feet (3.05 m) of the proposed building and facility foundations, and reroute existing utilities to remain.

10.5 SITE DEVELOPMENT. Base the location and orientation of facilities on an analysis of activities to be accommodated and on specific requirements for each project, to include all functional, technical and economic factors. Incorporate the following into site the design, as applicable:

10.5.1 LAND USE (existing and future)

10.5.2 CIRCULATION (vehicle and pedestrian)

10.5.3 ORIENTATION AND LOCATION TO INTEGRATE GREEN SPACE. Provide adequate grading and drainage while preserving natural topographic features to minimize cut and fill, impact on existing drainage patterns, and tree removal.

10.5.4 OPERATIONAL AND NATURAL CONSTRAINTS

10.5.4.1 MAINTAIN MANDATED BUFFERS:

- Noise abatement
- Antiterrorism/physical security clearances
- Storage and handling hazardous material clearances
- Separation of incompatible land use or functions
- Building setbacks (if established)
- Fire separation zones per building and fire codes

10.5.4.2 ELIMINATE OR MINIMIZE CONSTRUCTION ACTIVITIES REQUIRING PERMITS, for areas such as archaeological sites, wetlands, utilities, and stormwater management.

10.5.4.3 MINIMIZE SITE OR UTILITY MAINTENANCE AND OPERATING COSTS.

10.5.4.4 ACCOMMODATE SITE constructability and security requirements.

10.5.4.5 MINIMIZE DISTANCE to existing utility connections.

10.5.5 FLOOD HAZARD AREAS. Project sites located in flood hazard areas must be designed in accordance with IBC Section 1612. Ensure proper correlation between vertical datums.

10.6.2 VEHICLE CIRCULATION.

For design of streets and parking for facilities, comply with the American Association of State Highway and Transportation Officials' (AASHTO's) *A Policy on Geometric Design of Highways and Streets;* and AASHTO's *Roadside Design Guide*. Design streets and parking areas (i.e., site entrances and exits, service drives, parking lots and other areas with special requirements, e.g., drive up drop off areas or loading docks) to accommodate the largest vehicle that will use the facility. The design must also address the turning and reverse movements for the vehicles using the facility. Streets, parking areas and structures must conform to current antiterrorism and handicap accessibility requirements. Use Best Practices document, AASHTO's *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)* as applicable.

10.6.2.1 TRAFFIC STUDIES. Provide traffic studies and analysis in accordance with the Surface Deployment and Distribution Command Transportation Engineering Agency's (SDDCTEA) Pamphlet 55-17 which references SDDCTEA's Pamphlet 55-8, *Traffic Engineering Study Reference*.

10.6.2.2 DESIGN VEHICLES. Design vehicle types include:

a. Passenger car, truck, light-delivery truck, bus, and truck combinations are as defined by AASHTO (e.g., moving vans, refuse trucks, school buses, and snow-clearing trucks)

b. Emergency vehicles

c. Specialized military vehicles, such as tracked vehicles

Obtain design information for emergency vehicles and specialized military vehicles from the Government's Project Manager.

10.6.2.3 DESIGN TRAFFIC. Use the Transportation Research Board's (TRB's) *Highway Capacity Manual* to evaluate average daily traffic (ADT) and peak hourly traffic, as applicable. Adjust for vehicles other than passenger cars. In addition to the vehicles indicated in the *Highway Capacity Manual* (e.g., trucks, RV's and buses), add specialized military vehicles as a vehicle type and determine the nearest equivalent AASHTO vehicle type.

10.6.2.4 STREETS AND ROADWAYS. Single-lane streets may be provided for fire lanes and approach drives to buildings within built-up areas. Access roads to unmanned facilities may also be single-lane roads. Where shoulders are not sufficiently stable to permit all-weather use and the distance between intersections is greater than ½-mile (805 m), turnouts must be provided at 1/4-mile (402 m) intervals along single lane roads for use by occasional passing or meeting vehicles.

10.6.2.4.1 FIRE LANE AND EMERGENCY VEHICLE ACCESS. Fire lanes and emergency vehicle access must comply with the requirements of the regulatory authority.

10.6.2.5 PARKING AREAS. Parking areas include on-street parking, off-street parking lots, and parking structures. Conform to existing topography to the greatest extent possible. Refer to the scope of work for the total parking requirement of number of spaces. Provide parking spaces primarily by off-street parking areas or structures. Design parking areas in accordance with SDDCTEA Pamphlet 55-17 *Better Military Traffic Engineering, Chapter 17.* The design must allow for all types of traffic that may be associated with the facility including deliveries, emergencies and garbage pick-up. However, the design must discourage through traffic.

10.6.2.5.1 ON-STREET PARKING. The use of on-street parking is discouraged. On-street parking will not be allowed within 20 feet (6.10 m) of an intersection. The minimum length for the first and last stall is 18 feet (5.49 m). The minimum length for each interior stall is 22 feet (6.71 m). Exception to SDDCTEA Pamphlet 55-17: The minimum width for all stalls is 8 feet (2.44 m).

10.6.2.5.2 OFF-STREET PARKING. Typically 90 degree parking is preferred for off-street parking for ease of traffic flow. If 90 degree parking is not used, the designer must be able to justify by showing that the minimum functional and technical requirements are met while providing an economic benefit. Provide a minimum of 9 feet (2.74 m) wide and 18.5 feet (5.64 m) long parking spaces for 90 degree parking. *Exception to SDDCTEA Pamphlet 55-17:* In areas of limited space, provide a minimum buffer strip of 8 feet (2.44 m).

10.6.2.5.3 MOTORCYCLE PARKING. Motorcycle parking surfaces are typically designed as rigid pavements to prevent kickstands from penetrating the bituminous pavement in warm weather. Motorcycle parking stalls shall be a minimum of 9 feet (2.74 m) long and 4.5 feet (1.37 m) wide.

10.6.3 BRIDGES AND UNDERPASSES. Where applicable, comply with AASHTO's *A Policy on Geometric Design of Highways and Streets* and AASHTO's *Standard Specifications for Highway Bridges*. Use Best Practices document, U.S. Department of Agriculture's (USDA's) *Low-Water Crossings: Geomorphic, Biological, and Engineering Design Considerations* as applicable. For railroad bridges comply also with the American Railway Engineering and Maintenance-of-Way Association (AREMA) publication *Manual for Railway Engineering* as well as the design manual of the relevant railroad company.

10.6.4 SPECIAL CIRCULATION AREAS. Circulation areas for other than normal passenger car traffic have special requirements to maintain traffic safety. These areas require additional space to accommodate unusual traffic patterns and greater turning radii for maneuverability. Special circulation areas include areas such as drop off areas, delivery and service zones, dumpsters, drive-in facilities, emergency vehicle access, and entry control facilities.

10.6.4.1 ENTRY CONTROL FACILITIES. Use SDDCTEA Pamphlet 55-15, *Traffic and Safety Engineering for Better Entry Control Facilities* for entry control facility criteria.

10.7 SITE APPURTENANCES. Provide site appurtenances in accordance with State or local standards where the project is located.

10.7.1 PEDESTRIAN CIRCULATION. Provide a network of sidewalks, separated from, but connected to vehicular circulation systems, to allow for pedestrian circulation between various new and existing elements of the project. Interface new pedestrian circulation systems with existing pedestrian circulation systems. Provide crosswalks for pedestrian safety as indicated in SDDCTEA's Pamphlet 55-17, Chapter 8. The minimum width for walks is 4 feet (1.22 m). Use Best Practices document, AASHTO's *Guide for the Planning, Design and Operation of Pedestrian Facilities* for additional design guidance. Sidewalks may consist of portland cement concrete (PCC), bituminous concrete (asphalt), solid pavers, permeable pavers, or pervious concrete. The minimum thickness of PCC concrete sidewalks is 4 inches (100 mm). Provide bituminous sidewalks with a minimum 4 inches (102 mm) thick base and a 1 inch (25 mm) thick bituminous surfacing.

10.7.2 CURB/CURB AND GUTTER. Use concrete curb and gutter when overland flow cannot be achieved to extend curb/curb and gutter from an adjacent facility, or to confine traffic. Asphalt-type curbs are only allowed in remote areas where approved by the installation.

10.7.3 WHEELSTOPS. Provide 6 feet (1.83 m) long wheelstops anchored to the pavement at parking spaces adjacent to sidewalks, buildings, stormwater management facilities, areas of extreme slope, and other areas without curb, where a vehicle would likely cause property damage. Locate the front face of the wheelstop 30 inches (762 mm) from the edge of the pavement or sidewalk. Where snow removal equipment is used, wheelstops may not be allowed by the regulatory authority.

10.7.4 BOLLARDS.

10.7.4.1 BOLLARDS AROUND STRUCTURES. Provide bollards around any structure subject to damage from vehicular traffic by incidental contact; such bollards must be at minimum 4 feet (1.22 m) high. For steel bollards, provide a minimum of 4 inch (100 mm) diameter filled with concrete and painted. Bollards on aircraft aprons protecting fire hydrants may not exceed 30 inches (762 mm) aboveground and 24 inches (610 mm) above the load bearing paving.

10.7.5 SIGNAGE AND MARKINGS. Provide signs and associated pavement markings to facilitate proper utilization of the project site. Provide new traffic control devices (i.e. signs, markings, etc.) in accordance with SDDCTEA's Pamphlet 55-17 *Better Military Traffic Engineering* and Pamphlet 55-14, *Traffic Engineering for Better Signs and Markings.* Also use the Federal Highway Administration's (FHWA's) *Manual on Uniform Traffic Control Devices* (MUTCD) and *Standard Highway Signs and Markings* (SHSM).
Provide non-reflectorized pavement markings for paved parking areas, reflectorized pavement markings for paved roads and streets, and fire access markings in accordance with the State Department of Transportation (DOT) or local governing authority's requirements.

10.7.6 TRASH DUMPSTER ENCLOSURES. Where dumpster pads are required in a project, provide a dumpster pad with an enclosure conforming to the Installation Appearance Plan. Provide a concrete pavement pad to support and accommodate the dumpster and front wheels of the service truck.

10.8 UTILITIES. Locate utilities to minimize connection costs. New underground utilities must be at least 10 feet (3.05 m) from the proposed structures, except for building connections. Minimize underground utilities located beneath pavements, except where crossings are required. Locate the required crossings to minimize traffic interference with future maintenance. Obstructions including signs and poles for overhead utilities must be located outside the limits of the usable shoulder on roads designed without barrier curbs. Where practical, roads designed with barrier curbs must have the desirable lateral clearances to obstructions as indicated in AASHTO's, *A Policy on Geometric Design of Highways and Streets* except that fire hydrant clearances must be in accordance with requirements of the regulatory authority.