PROPOSED MODEL LAND DEVELOPMENT STANDARDS AND ACCOMPANYING MODEL STATE ENABLING LEGISLATION

1993 Edition

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Notice

Contributors and Acknowledgements

These proposed Model Land Development Standards and accompanying Model State Enabling Legislation were authored by the NAHB Research Center, with assistance on the statutes provided by the National Conference of States on Building Codes and Standards. The Expert Group, representing both the public and private sectors, met several times throughout the preparation of this document to review and provide guidance on the standards. These standards draw from the most innovative and cost-effective land development standards currently applied by municipalities across the country. Acknowledgment of the Expert Group does not imply the group's endorsement of this document or endorsement by the organizations represented by the group or by the U.S. Department of Housing and Urban Development.

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Foreword

After hearing the testimony of builders, developers, state and local officials, housing and community development advocacy groups, building code officials, planners, and home buyers across the United States on the problems of housing affordability, the President's Advisory Commission on Regulatory Barriers to Affordable Housing developed recommendations to guide city, county, state, and federal government agencies in efforts to increase the production of affordable housing. Recommendation 7-6 of the commission's report responds to testimony regarding excessive residential land development requirements as follows:

> The Commission recommends that States either enact a statewide subdivision ordinance and mandatory land development standards or, alternatively, formulate a model land development code for use by localities. Land development standards should be based on supportable data and research regarding traffic usage, density, and similar criteria. Standards could either be mandatory or serve as a model ordinance for use by localities.*

In response to this recommendation, the U.S. Department of Housing and Urban Development sponsored production of this **1993 Edition of the Proposed Model Land Development Standards and Accompanying Model State Enabling Legislation**. The standards are designed as the minimum requirements necessary to produce quality residential development with reasonable protection for the health and safety of residents, without adding unnecessary costs. It is expected that each state will find it necessary to modify the standards to meet their unique needs and to address issues of local discretion. The standards will be updated as required to reflect users' comments and continuing land development research. Following the standards are three model statutes designed as aides for drafting state preemptive legislation, state legislation for voluntary adoption by local governments, or local legislation. These statutes will also require some modification to meet state and local needs.

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*Advisory Commission on Regulatory Barriers to Affordable Housing. *Not In My Backyard - Removing Barriers to Affordable Housing*. Report to President Bush and Secretary Kemp, U.S. Department of Housing and Urban Development (Washington, DC), 1991, pp. 7-11.

INTRODUCTION

This manual presents model minimum design and construction standards for residential land development that respond to the nationwide need for affordable housing. The model standards are designed to promote quality residential development while striking a reasonable balance between excessive requirements that add unnecessary costs to a home and permissive requirements that may threaten public health and safety. Model legislation to facilitate adoption of the standards is presented following the standards in the form of state preemptive statutes, state voluntary statutes, and local government ordinances. Both the standards and statutes may require modification to meet unique conditions of individual states and localities.

Land development standards provide for the orderly platting and improvement of raw land into building lots and developed sites. Introduced in the 1920s, these regulations have been used by local governments to assure adequate vehicular access to building sites, good drainage, safe drinking water and sanitary systems, and protection of the environment. Although there are many factors that contribute to the cost of a unit of housing, the cost of meeting excessive or unnecessary development regulations is a factor that is sometimes overlooked. The result has been an increase in the cost of housing and a subsequent exclusion of greater numbers of Americans from home ownership opportunities.

Excessive site development requirements are a proven barrier to affordable housing. In the U.S. Department of Housing and Urban Development (HUD)-sponsored Joint Venture for Affordable Housing demonstration, reducing the cost of the developed lot was the single greatest factor in achieving housing affordability. Reducing excessively wide streets and rights-of-way and installing sidewalks only where necessary, for example, bring down material and labor costs and increase the land available for homes. The resulting higher-density community allows land development costs to be spread over a larger number of homes.* (Figure 1 shows the average proportional cost of components of a single-family developed lot.)

Land development requirements are not the only barriers to affordable housing. Other factors that critically influence the cost of housing include the availability and cost of raw land, local zoning provisions, market supply and demand of land and housing, interest cost to the developer and home owner, the cost of materials and labor, development and construction fees, permitting and other administrative procedures, the effects of NIMBY ("Not In My Backyard") attitudes, historic preservation, wetlands protection, endangered species protection, and other environmental regulations imposed at the local, state, and federal levels.

Although the importance of these factors is not to be underestimated, this manual addresses only land development standards. The model standards represent minimum requirements needed to

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*In the Joint Venture for Affordable Housing demonstration, Boise, Idaho, waived requirements for sidewalks on both sides of the street and limited sidewalks to one side in the Lakewood Meadows subdivision, eliminating 2,696 linear feet of sidewalk at $8,000, or $216 per unit. Everett, Washington, reduced street and right-of-way requirements from 50 and 60 feet, respectively, to 24 and 26 feet, respectively, in the Sunridge Development and gained an additional lot for every 133 linear feet of street. For additional cost savings information, see *Affordable Housing: Challenge and Response Volume I: Affordable Land Development*, U.S. Department of Housing and Urban Development, 1987.

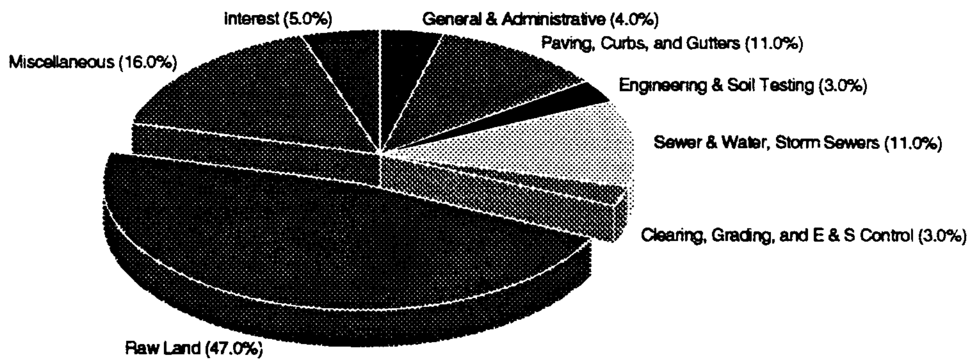


Figure 1. Cost Components of a Single-Family Development Lot
(Source: National Association of Home Builders, *NAHB Backgrounder*, 1990)

produce quality housing development, particularly subdivisions, at a reasonable cost. Developers would have the option to exceed these standards, but they would not be required to do so. Local governments may relax the standards as specific conditions dictate.

The standards include a mix of both performance and prescriptive measures. Performance standards set the level of desired results to ensure sound engineering (e.g., street pavements shall be designed to support the loads from a traffic service volume of an anticipated number of vehicles per day). Prescriptive standards offer a method of meeting the performance requirements (e.g., street pavements shall be constructed with a 2-inch asphalt layer over a 6-inch base). The combination of performance and prescriptive measures allows for the flexibility and innovation needed to address the unique character of specific development sites. Alternative methods that meet the performance standard are accepted and even encouraged if accompanied by sound proof of their reliability and suitability.

The standards developed in this manual apply to all housing development and, if implemented, will ensure consistency across communities, thereby permitting builders to anticipate development costs with greater predictability. Flexibility in the standards enables both local jurisdictions and developers to use discretion in responding to local site conditions. Further, the flexibility accorded local jurisdictions allows developers to take advantage of design opportunities that increase density and to implement accepted cost-saving techniques otherwise prohibited by rigid requirements.

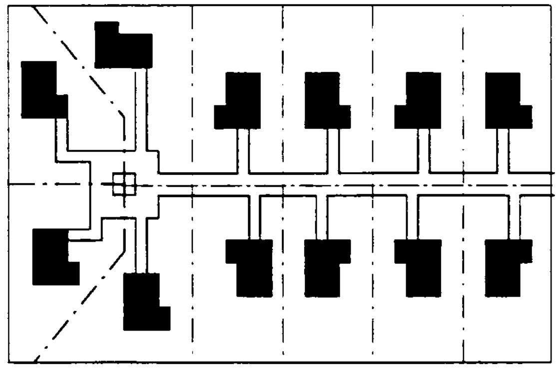
ZONING

Although recommendations for improving zoning regulations and land classification systems are beyond the scope of this manual, it is important to recognize zoning regulations in most jurisdictions determine land use and density and prescribe minimum lot size, floor/area ratio, frontage, setbacks, and space between units. Certain nontraditional zoning classes may, however, eliminate these prescriptive requirements. For example, subdivisions conceived as planned unit developments (PUDs), planned residential developments (PRDs), comprehensive residential developments (CRDs), or community unit plans (CUPs) typically include cluster designs. Houses "clustered" in closely related groups around cul-de-sacs or short loop streets help preserve natural land amenities and open space. Developers can average the density of the clustered housing across the entire development tract instead of measuring density on a per lot basis, which is a hallmark of traditional zoning requirements. Lot sizes can be reduced, costs of developed lots lowered, and open space increased--even as the development conforms to the master plan's zoning designation. Figure 2 compares conventional and cluster development designs for 12 single-family homes on a six-acre parcel of land. Table 1 shows a potential 34 percent savings in land development costs from a cluster concept plan versus a conventional plan for a subdivision in Canton, Ohio, in 1986.

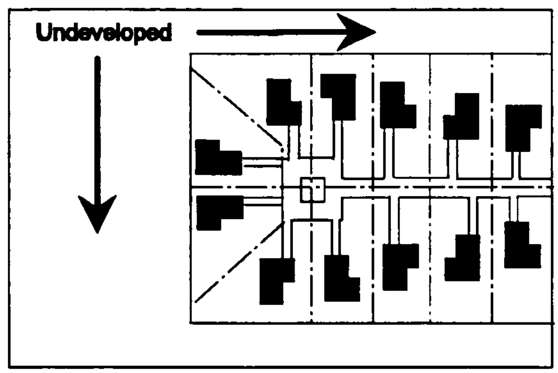
Table 1
CONVENTIONAL VERSUS CLUSTER SINGLE-FAMILY DESIGN SITE DEVELOPMENT COSTS*

	Conventional		Cluster	
SITE IMPROVEMENT	TOTAL COSTS	COSTS/DU	TOTAL COSTS	COSTS/DU
Street Pavement	$ 862,165	$ 1,827	$ 540,569	$1,145
Curbs and Gutters	433,872	919	--	--
Street Trees	412,496	874	374,640	794
Driveways	743,400	1,575	527,715	1,213
Storm Drainage	696,464	1,476	278,295	590
Water Distribution	746,044	1,581	492,792	1,044
Sanitary Sewer	1,142,647	2,421	1,009,601	2,139
Grading	332,044	703	220,755	468
Clearing/Grubbing	156,915	332	109,785	233
Sidewalks	209,250	443	197,775	419
Subtotal	$5,735,297	$12,151	$3,751,927	$8,045
Engineering Fees	$ 332,647	$ 705	$ 217,612	$ 467
TOTAL	**$6,067,945**	**$12,856**	**$3,969,539**	**$8,512**
Actual Difference on a per Lot Basis		$ 4,344		
Percent of Convention Lot Cost		100%		66%

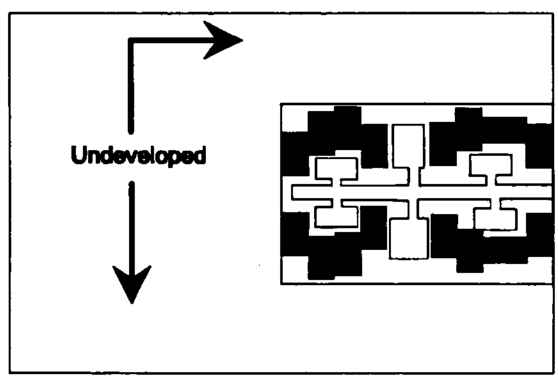
*Comparative costs of developing 166-acre subdivision on the outskirts of Canton, Ohio, in 1986, using a conventional plan concept and a cluster plan concept. *Cost Effective Site Planning*, National Association of Home Builders, 1986, pp. 113-120.



2 DU/AC Gross
2 DU/AC Net
12 Dwelling Units Total
6 acres



2 DU/AC Gross
4 DU/AC Net
12 Dwelling Units Total
3 Acres



2 DU/AC Gross
8 DU/AC Net
12 Dweeling Units Total
1.5 Acres

Figure 2. Conventional and Cluster Single-Family Development Designs
(Source: National Association of Home Builders, *Cost Effective Site Planning*, 1982)

Cluster development planning techniques can be applied to smaller, less complex developments as well as to large planned communities. Local governments may also allow a variety of lot sizes, setbacks, frontage requirements, and yard sizes in conventional developments to promote flexibility, affordability, and sound environmental design. Overall density for the area is maintained, but the minimum lot size can be reduced. The leftover land takes the form of open space either developed or left in its natural state. Local jurisdictions are encouraged to examine their zoning regulations and to revise them as needed to accommodate clustering and other innovative planning techniques.

HOW TO USE THIS MANUAL

The proposed model land development standards are written in code language. Commentary on the standards is provided as needed to clarify the intent of the standards, to suggest alternative ways to meet the standards, and/or to provide additional reference materials. This is an evolving document and will be updated as needed to reflect users' comments, suggestions, and continuing land development research. Comments on this edition of the standards will be accepted through January 1994, by the NAHB Research Center, 400 Prince George's Boulevard, Upper Marlboro, MD 20772-8731, attention Carol B. Schaake.

Model enabling legislation that facilitates the adoption of the standards at the state level is presented in three forms: first, as a model state preemptive statute for uniform land development standards; second, as a model state statute for adoption by reference by political subdivisions; and third, as a model ordinance for adoption by local governments (see Model State Enabling Legislation Section). The standards and statutes can be modified to meet unique state and local political, geographic, climatological, or social conditions.

The standards and statutes do not preempt the enforcement, inspection, and other administrative responsibilities of local jurisdictions as they relate to the residential development process, although the Appendix offers state and local governments guidance on streamlining the residential land development approval process.

The manual does not address land development requirements that result from broader planning considerations such as the provision of off-site facilities, the extension of existing public water and sewer systems to serve proposed development, and the installation of infrastructure to meet future needs. The model standards are, however, designed to allow for extension of all systems as needed to accommodate future growth.

Finally, zoning, aesthetics, and architectural style are local issues beyond the scope of this manual.

PART I

STANDARDS

STREET STANDARDS

Street standards differ from highway standards. While highway standards are intended to expedite traffic movement and limit access to principal arterials, street standards are aimed at providing a transition from fast-moving traffic to local residences. In other words, residential street standards provide the basis for safe, efficient, and economical access to residential areas (Ref. 1, p. 3). Safe residential streets are attained by specifying street geometries that discourage excessive speeds and emphasize access. Because of the short travel distances within subdivisions and residential developments, a reduction in travel speed is not considered an inconvenience. Residential houses are efficiently accessed with lower travel speeds on streets that are safer for bicyclists and pedestrians.

This standard is written to the minimum requirements necessary to meet these goals. In recognizing the many types of residential streets, the American Association of State Highway and Transportation Officials (AASHTO) recommends (as the first step in the design process) that each street should be defined in terms of its specific function within the community (Ref. 2, p. 17). Section 2 adopts and modifies the functional classification system. Each street in the subdivision can then be designed appropriately. Street volume and desired travel speed are given in Section 3, parking requirements in Section 4, and street geometry in Section 5. Remaining appurtenances such as sidewalks and utilities follow in the other sections. Minimum requirements necessary to provide safe, efficient, and economical streets are given in each section of the standard with the ultimate goal of making more land available for homes and reducing housing costs.

While careful consideration was given to each section of this standard, a locality may, based on sound engineering practices, waive any part of these standards to meet unique needs or provide equivalent alternatives.

CONTENTS

STANDARDS / COMMENTARY

1.0 - PURPOSE/STRATEGY

1.1 - Purpose. The purpose of residential streets is to serve the land that abuts them (Ref. 3 p. 1). In doing so, residential streets shall promote (Ref. 4, p. 1)

1. safe and efficient movement of vehicular and pedestrian traffic; and
2. cost-effective streets that take into consideration land use, construction, and future maintenance.

Residential streets are commonly used for purposes other than efficient traffic movement. They should be designed to ensure that such functions as visual settings, entryways for each house, parking, drainage, utility easements, pedestrian circulation systems, and emergency access are safely and effectively accommodated.

1.2 - Strategy. The design and planning of residential streets shall (Ref. 5, pp. 20-21)

1. consider a community or subdivision master plan and use the functional classification system (Section 2);
2. follow natural contours and preserve natural features whenever practical;

   Where cut or fill is required, it is important to balance the requirements to reduce the amount of needed fill or borrow material.

3. minimize traffic speed and volume, noise, congestion, and hazards to pedestrians;

   Sound residential street design should limit access points along major arterial streets and discourage through traffic.

4. minimize the amount of paved area to reduce storm water runoff and thereby protect water resources and reduce costs; and
5. provide an affordable street system that serves the residents in the community.

2.0 - FUNCTIONAL CLASSIFICATION SYSTEM

Each street shall be designed to reflect the overall purpose it is intended to serve. Proposed or existing streets shall be classified according to their function. The function of the street shall provide the basis for residential street design.

Different types of residential streets have different characteristics with regard to density and types of land use. Consequently, a single design for a typical residential street is not practical. A functional classification system is required to differentiate between the various types of residential streets in order to provide a design that best meets the needs of the community.

STANDARDS

2.1 - The following classification system shall be used to identify street function:

COMMENTARY

This classification system is based on the functional categories presented in *A Policy on Geometric Design of Highways and Streets* by AASHTO (Ref. 2), the U.S. Department of Transportation's "Highway Functional Classification: Concepts, Criteria and Procedures" (Ref. 6), and *Residential Streets* by ASCE, ULI, and NAHB (Ref. 5). Some definitions have been revised for clarity.

The concept of function is important to the designer. Even though many of the geometric standards could be determined without reference to the functional classification, the designer must keep in mind the overall purpose that the street is intended to serve. This concept is consistent with a systematic approach to highway planning and provides a rational and cost-effective basis for design (Ref. 2, p. 17).

Local discretion should be used in the review and upgrade of existing streets. If a street that was formerly designed as a subcollector assumes the function of a collector, it may be neither desirable nor practical to upgrade the existing street.

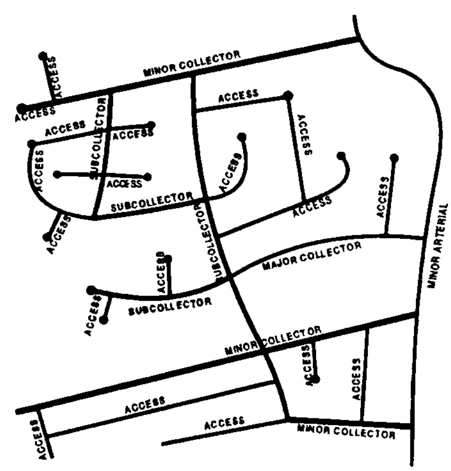


Figure 1. Typical Subdivision Using the Functional Classification System.

STANDARDS	COMMENTARY
2.1.1 - Major Collectors. Major collectors provide access to principal arterials and distribute traffic to the subdivision collectors. More than arterials, they underscore the importance of land access and accommodate lower travel speeds. Some housing may exist along major collectors. New residences should not, however, be sited with direct access to major collectors. Commercial businesses can be accommodated.	Not all subdivisions have major collectors. Depending on their size, some subdivisions have only collector streets instead of both major collectors and collectors.
2.1.2 - Collectors. Collectors penetrate residential areas and distribute trips from the arterials or major collectors to the final destinations. They also accommodate pedestrian and bicycle traffic. Minor businesses may be located along collector streets. Some residences may be located along collectors. However, most residences should be located on subcollector or access streets. In larger subdivisions, collectors provide for movement of traffic between major collector routes.	The collector class provides a balance between land access service to residential neighborhoods and traffic circulation in business areas.
2.1.3 - Subcollectors. Subcollectors distribute traffic from the collectors to the smaller access streets or to residences located on subcollector streets. Conversely, subcollectors connect the smaller access streets and residences to the higher-volume collector streets. While pedestrian and bicycle traffic is present, it may not be as intense as it is on collectors. Through traffic is discouraged.	Given that subcollector streets accommodate residences, it is important to minimize design speeds. Rather than relying on signs to regulate speed, the street geometry itself should encourage safe driving by decreasing pavement widths and using curved sections. Streets with speed bumps that have been added to reduce driving speeds have been improperly designed.
2.1.4 - Access Streets. Access streets provide direct access to residences on abutting land and access to the higher-order system. Access streets offer the lowest level of service, low design speeds, and short trip routes. Through traffic on these streets is deliberately discouraged. Access streets include loop streets and cul-de-sacs.	Access streets normally serve only those residences located on the street. Traffic needs are at a minimum. Street geometry can be designed to provide minimum street dimensions without inducing delays or causing inconvenience. Cul-de-sacs are access streets that are open at one end and have a special turning area at the closed end. Loop streets have two entrances from the same subcollector or collector street.
2.2 - Special Purpose Streets	
2.2.1 - Alleys. Alleys are service ways that provide a secondary means of access to abutting property. They are not intended for general traffic circulation (Ref. 7, p. 25).	
2.2.2 - Divided or One-Way Streets. These are streets that separate traffic into one-way flow.	

STANDARDS

3.0 - STREET DESIGN PARAMETERS

3.1 - Residential street volume and design speed shall follow Table 1 (Ref. 5, p. 28 and Ref. 8, p. 44).

Table 1
DESIGN PARAMETERS

Street Type	Volume (ADT)	Maximum Design Speed (mph)
Major Collectors	3000+	30
Collectors	1000-3000	30
Subcollectors	250-1000	25
Access	0-250*	20

* Loop streets shall have a maximum ADT of 500.

3.2 - **Trip Generation Rates.** Average Daily Traffic (ADT) shall be estimated based on average weekday vehicle trip rates and density. Trip generation rates shall be obtained either from simplified Table 2, the more detailed Institute of Transportation Engineers' (ITE) *Trip Generation* (Ref. 9), or local trip rate studies.

Table 2
TRIP GENERATION RATES (ITE)

Type of Dwelling	Average Daily Traffic*
Single-Family Detached House	9.6
Low-Rise Apartment	6.6
Townhouse	5.9

* Expressed in trips per dwelling unit.

4.0 - PARKING

There shall be sufficient and convenient parking for all residents. Temporary parking shall be provided for visitors and vehicles that serve the community (e.g., delivery and emergency vehicles). Off- and on-street parking are both acceptable means of accommodating vehicles. Total parking requirements (on-street, off-street, or a combination of on- and off-street parking) shall follow Table 3 (Ref. 10, p. 185).

COMMENTARY

After defining the function that the street is to serve, street volume and design speed are determined. These parameters influence street geometry and serve as the basis for the tables in Section 5.

Design speed is not a major factor in the design of residential streets. Design speeds exceeding 30 mph in residential areas are contrary to the basic function of a street, produce increased curve radii, and pose a danger to pedestrians. Because residential streets have relatively short trip lengths and mainly provide access to property, there is little need for high operating speeds (Ref. 2, p. 434).

Based on the trip rates in Table 2 and the density of residential dwellings, the ADT should fall into the ranges shown in Table 1 for the different types of residential streets.

Example: If 20 single-family detached houses are planned to be built on a proposed street, the ADT will be 9.6 trips x 20 houses = 192 ADT. In this case, the street is designed as an access street because the volume is less than 250 ADT.

Trip generation rates may be reduced where mixed use developments, integrated housing, compact design, and convenient transit stops are used. Mixed use developments allow residents to have access to basic services in their own neighborhood. Shuttle services between residential neighborhoods and public transportation access points also reduce vehicle trips.

On-street, off-street, and a combination of on- and off-street parking alternatives should be considered to determine the most cost-effective design.

Other considerations should be taken into account in the design process. The availability of public transportation may decrease the amount of vehicular traffic and thus the need for parking within a subdivision yet increase pedestrian traffic.

STANDARDS

Table 3 PARKING REQUIREMENTS	
Housing Unit Type/Size	Total Parking Spaces
Single-Family Detached	2.0
Multifamily Dwellings	
3 or more bedrooms	2.0
1 or 2 bedrooms	1.5
Efficiency	1.0

4.1 - Off-Street Parking. Off-street parking includes driveways, carports, garages, and parking lots. For multifamily dwellings, parking requirements shall be provided for the physically disabled and be accessible to the building according to the American National Standards Institute (ANSI) A117.1-1986 (Ref. 11, Section 4), the Fair Housing Accessibility Guidelines (Ref. 12, p. 68), or a local or state code.

4.1.1 - Minimum dimensions for an off-street parking space for a standard or mid-sized automobile shall be 8-feet-wide by 18-feet-long. Minimum dimensions for a compact automobile parking space shall be 7-feet-wide by 16½-feet-long. Where curb overhang is allowed, the length of space may be deceased by 2½ feet (Ref. 10, pp. 191-198).

COMMENTARY

Single-family detached (SFD) housing parking is accommodated with either on- or off-street parking. When off-street parking or a combination of on- and off-street parking is used for SFD housing, it is assumed that the street will handle overflow parking.

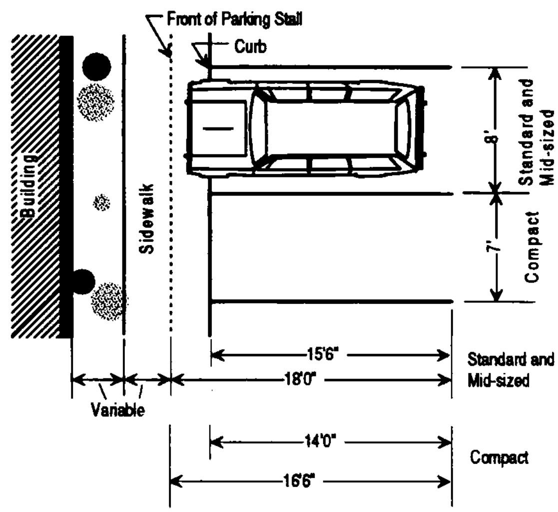


Figure 2. Off-Street Parking Dimensions with Curb Overhang.

The proportion of compact cars varies with region. The local area should be evaluated to determine the appropriate mix of standard and compact spaces to be used for off-street parking (Ref. 10, p. 197).

STANDARDS

4.1.2 - Access aisles shall be provided for off-street parking for the physically disabled. Aisles shall be a minimum 5 feet in width and comply with ANSI 117.1 (Ref. 11, Section 4.6).

COMMENTARY

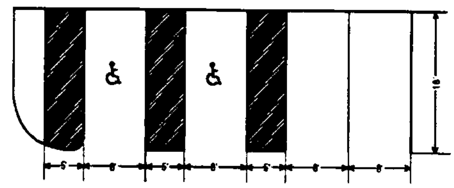


Figure 3. Accessible Parking Spaces.

Two accessible parking spaces may share a common access aisle.

4.1.3 - Aisle width behind parking spaces varies with parking angle. Aisle widths in off-street parking areas shall be designed according to Table 4 (Ref. 13, p. 70).

Table 4
AISLE WIDTH

Parking Angle (degrees)	Aisle Width (feet)
30	12
45	13
60	18
90	20

4.2 - On-Street Parking. On-street parking shall be provided in accordance with the minimum street width requirements of Section 5 and Table 5.

5.0 - STREET GEOMETRY

5.1 - Width of Traveled Way. The width of the traveled way of a residential street shall be based on the function of the street as defined in Section 2, the design parameters outlined in Section 3, the parking requirements given in Section 4, and Table 5.

The width of the traveled way is determined by street function and the degree of on-street parking. Providing wider streets for potential future needs is not necessary in properly planned communities because through traffic is not routed onto residential streets.

STANDARDS

Table 5
WIDTHS OF TRAVELED WAY

Street Type	Minimum Width of Traveled Way (ft): Both On- and Off-Street Parking[1]	Minimum Width of Traveled Way (ft): One-Way Street[2]
Major Collector	20[3]	10
Collector	36[4]	26
Subcollector	26-28[4,5]	26
Access	18-22[5]	18

[1] Where no off-street parking is provided, the minimum width of traveled way for collector streets shall be 36 feet, and 34 feet for subcollector and access streets (two 9- or 10-foot travel lanes and two 8-foot parking lanes). Major collectors do not typically accommodate on-street parking. Access street width can be reduced to 26 feet if parking needs are met on one side of the street and restricted to that side only.

[2] Where on-street parking is not permitted, the one-way street width may be reduced to 10 feet.

[3] Parking is not allowed on major collector streets. Travel lanes may be added in accordance with traffic requirements.

[4] Width can be reduced to 20 feet if on-street parking is not permitted.

[5] Minimum street width shall be selected by taking into consideration the size of fire and emergency equipment that will serve the development.

COMMENTARY

For collectors, the 36-foot width of the traveled way includes two 10-foot travel lanes and two 8-foot parking lanes. The minimum width for a subcollector with both on- and off-street parking is 26 to 28 feet. This assumes a minimum of one 10-foot travel lane and two 8-foot parking lanes. The traveled way may be enlarged to 12 feet if emergency vehicles cannot be accommodated on a 26-foot-wide street. If on-street parking is not permitted, the width may be reduced to 20 feet. The minimum width of the traveled way for an access street with both on- and off-street parking is 18 to 22 feet. This assumes one 10-foot travel lane and one 8-foot parking lane. The traveled way may be enlarged to 14 feet for emergency vehicles if deemed necessary.

Streets should be designed to allow emergency access to all residences. A review of community emergency services and equipment can help ensure the most balanced solution for residential developments. Smaller emergency vehicles that have recently been developed may be preferable for housing subdivisions (Ref. 3, p. 21). Oversized equipment such as hook-and-ladder trucks do not typically respond to single-family fire calls. Communities are beginning to purchase emergency vehicles that fit the streets rather than continuing to design streets to meet the needs of the vehicles (Ref. 8, p. 55).

One-way streets are generally used to reduce congestion and thus decrease travel time and to increase the capacity of a street. They also increase safety by reducing accidents. The one-way street "pair" should preferably comprise adjacent streets (Ref. 14, pp. 807-810).

AASHTO states that the level of user inconvenience occasioned by the lack of two moving lanes is remarkably low in areas where single-family units prevail. Local residential street patterns are such that travel distances are less than 0.5 mile between trip origin and a collector street. Infrequent opposing traffic will yield and pause in the parking lane area until there is sufficient width to pass (Ref. 2, p. 436).

Based on local needs, some communities may want to decrease the requirements for the minimum width of the traveled way. Factors that may contribute to a decrease would be one-way street patterns, parking accommodations, turn-outs, etc.

STANDARDS

COMMENTARY

5.2 - Access and Special-Purpose Streets

5.2.1 - Cul-de-Sacs and Loop Streets. Circular turning areas shall have a minimum turning area radius of 30 feet (Ref. 2, p. 476). "T-," "L-," and "Y-" shaped turnarounds shall be a minimum of 60 feet by 20 feet or be able to accommodate a single unit (SU) design truck as specified by AASHTO (Ref. 2, pp. 438-440).

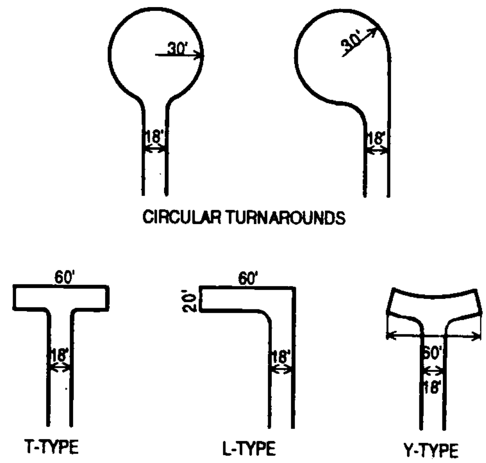


Figure 4. Turnaround Areas.

With a 30-foot outer radius, passenger vehicles can make the customary U-turn and SU design trucks can turn by backing once (Ref. 2, p. 440).

5.2.2 - Alleys. Where used, alleys shall be a minimum of 10 feet in width.

5.2.3 - Divided Streets. Where used, divided streets shall be designed with the street function and volume identified as with other residential streets.

5.2.4 - Private Streets. Private streets shall be designed to the same standards as publicly owned streets.

Private streets are owned and maintained by an individual or a home owners association. Where low-density houses are served by a common driveway, local discretion may be used to allow unpaved surfaces for private streets.

5.3 - Pavement Crown or Cross-Slope. The pavement crown or cross-slope shall be adequate to provide proper drainage. Depending on local site conditions, pavement shall be sloped as a normal crown, inverted crown, or cross-slope. The crown or cross-slope rate shall range between 1.5 and 3 percent (¼-inch per foot is typical) except in transition sections where superelevation is used (Ref. 2, p. 423, 435).

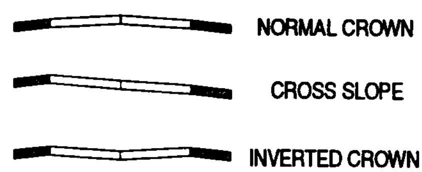


Figure 5. Pavement Crown or Cross-Slope.

Inverted crown pavements with drainage flowing down the center of the street should be used only in areas of little precipitation and where icing is not a problem (Ref. 8, p. 51).

5.4 - Street Grade or Profile. The minimum grade and profile for residential streets shall be 0.2 percent. The maximum grade and profile shall be 15 percent (Ref. 2, p. 435). The street profile shall follow the natural contours whenever practical. Wherever cut or fill is required, the quantities should be balanced.

Where grades of 4 percent or steeper are necessary, the drainage design may become critical. Special care should be taken to prevent erosion on slopes and open drainage facilities (Ref. 2, p. 435).

Where steep slopes result from cut or fill, an easement may be required to provide for slope maintenance (see Section 9.4).

STANDARDS

5.5 - Stopping Sight Distance. The minimum stopping sight distance available on the street shall be sufficiently long to enable a vehicle traveling at or near design speed to stop before reaching a stationary object in its path (Ref. 2, pp. 117-118).

5.5.1 - Minimum Stopping Sight Distance. The minimum stopping sight distance a driver may have on a residential street shall follow Table 6 (Ref. 2, p. 120).

Table 6
STOPPING SIGHT DISTANCE
(for wet, level surface pavements)

Street Type	Design Speed (mph)	Coef. of Friction[1]	Minimum Stopping Sight Distance (ft)
Access	20	0.40	125
Subcollector	25	0.38	150
Collector and Major Collector	30	0.35	200

[1] May vary depending on vehicle and street conditions.

5.5.2 - Corrections Due to Grade. When a street is on a grade, the stopping sight distance (S) shall be adjusted according to Equation 1 (derived from the AASHTO equations in Ref. 2, pp. 119, 124):

$$x=\frac{V^2}{30}\left(\frac{1}{(f\pm G)}-\frac{1}{f}\right), \qquad \text{Eq. 1}$$

where: x = stopping sight distance adjustment (feet);
V = design speed (mph);
f = coefficient of friction between tires and roadway; and
G = percent of grade divided by 100 (+ for upgrade, - for downgrade).

5.6 - Alignment

COMMENTARY

Sight distance is the length of street ahead visible to the driver. Stopping sight distance is the distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied plus the distance required to stop the vehicle from the instant brake application begins. Stopping sight distance is based on a driver's eye height of 3.5 feet and an observed object height of 6 inches (Ref. 2, pp. 117-118, 136).

Table 6 is based on AASHTO's Table III-1 (Ref. 2, p. 120), which takes into consideration reaction time and braking distance. Coefficient of friction values are also taken from AASHTO and account for wet pavements and tire conditions. Corrections due to grade should be considered in Section 5.5.2.

In general, the stopping sight distance is shorter for upgrades and longer for downgrades (Ref. 2, p. 124).

Example: Find the stopping sight distance for a subcollector street with a downhill grade of 6 percent. Assume that the coefficient of friction between tires and roadway is 0.38.

Using Equation 1, the correction due to grade is

$$x=\frac{25^2}{30}\left(\frac{1}{0.38-0.06}-\frac{1}{0.38}\right)$$

$$x=10\ \textit{feet.}$$

The stopping sight distance (from Table 6) is then adjusted accordingly:

$$S=150+10$$

$$S=160\ \textit{feet.}$$

The horizontal and vertical alignments in residential areas should fit closely with the existing topography to minimize the need for cut or fill without sacrificing safety. There is an advantage in residential areas to arranging the alignment purposely to discourage through traffic (Ref. 2, p. 435).

STANDARDS

5.6.1 - Horizontal Alignment. Unless superelevation is provided, the minimum horizontal radius of curve for residential streets shall follow Table 7 (Ref. 2, p. 193).

Table 7
HORIZONTAL ALIGNMENT

Street Type	Design Speed (mph)	Minimum Radius of Curve (ft)
Access	20	90
Subcollector	25	165
Collector and Major Collector	30	275

5.6.2 - Vertical Alignment. Vertical curves shall be simple in application and shall result in a design that is safe, comfortable in operation, pleasing in appearance, and adequate for drainage (Ref. 2, p. 281). Minimum lengths of crest and sag vertical curves shall be determined by Equations 2, 3, 4, and 5 (Ref. 2, pp. 283, 289; Ref. 16, p. 16-6):

	CREST	*SAG*	
for S<L:	$L=\frac{(G_1-G_2)S^2}{1329}$	$\frac{(G_2-G_1)S^2}{400+3.5S}$	Eqs. 2&3
for S>L:	$L=2S-\frac{1329}{G_1-G_2}$	$2S-\frac{400-3.5S}{G_2-G_1}$	Eqs. 4&5

where: L = length of crest or sag curve (ft);
S = sight distance (ft) [not less than stopping sight distance values from Section 5.4];
G_1 = grade entering curve (percent); and
G_2 = grade exiting curve (percent) [grades are positive uphill and negative downhill].

COMMENTARY

Superelevation is usually impractical in residential areas (Ref. 2, p. 436) and therefore is not covered by this standard. Horizontal curves in residential areas are frequently designed without superelevation and thus counteract the centrifugal force solely with side friction. Drivers have developed higher thresholds of discomfort (Ref. 2, p. 186). Lack of superelevation tends to keep the speed of drivers down (Ref. 15, p. 4).

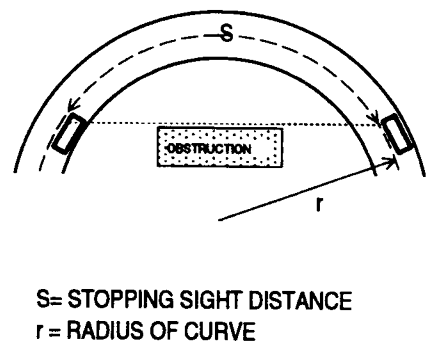


Figure 6. Horizontal Stopping Site Distance.

Sight distance may be limited by a crest or sag curve. The criteria for the minimum length of a crest vertical curve are based on the sight distance over the hill (Ref. 2, p. 283). Equations 2 and 4 use these criteria.

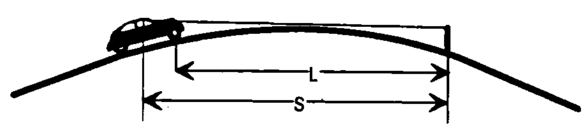


Figure 7. Crest Vertical Curve.

The criterion for minimum sag vertical curve length is based on the headlight beam distance (Ref. 2, p. 289). Equations 3 and 5 use the headlight beam distance criterion.

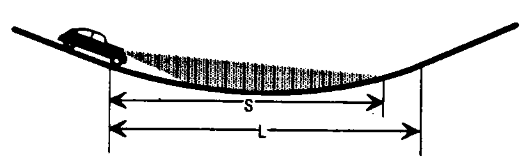


Figure 8. Sag Vertical Curve.

STANDARDS

COMMENTARY

5.7 - Horizontal Clearance to Obstructions. On all streets, a minimum of 1.5 feet shall be provided between the pavement edge (measured from the curb face or shoulder) and obstructions such as utility poles, lighting poles, fire hydrants, and trees (Ref. 2, p. 443).

Design speeds on residential streets are low; therefore, utility and lighting poles, fire hydrants, and trees are considered minimal hazards and may be located within 1.5 feet from the edge of the pavement (Ref. 2, p. 443).

5.8 - Vertical Clearance. Vertical clearance at underpasses should be at least 14 feet over the entire street width plus an allowance for future resurfacing (Ref. 2, p. 428).

5.9 - Structures. Design of bridges, culverts, walls, tunnels, and other structures shall be in accordance with the current *Standard Specifications for Highway Bridges* (Ref. 17). The minimum design loading for new bridges should be HS-20. For bridges to remain in place, see AASHTO-1990 (Ref. 2, pp. 426-427).

6.0 - INTERSECTIONS

Intersections shall be carefully situated to avoid steep profile grades and to ensure adequate approach site distance (Ref. 2, p. 431).

Wherever possible, an intersection should not be situated on or just beyond a short-crest vertical curve or a sharp horizontal curve (Ref. 2, p. 431).

6.1 - Intersection Sight Distance. The driver stopped at a minor street at an intersection shall have sufficient intersection sight distance to be able to drive through the intersection safely or to turn and enter the traffic flow on the major street. The minimum intersection sight distance shall follow Table 8 (Ref. 14, p. 592).

Table 8
INTERSECTION SIGHT DISTANCE
(required along major street with minor street stopped)

Principal Street Design Speed (mph)	Intersection Sight Distance (ft)
20	200
25	250
30	300
35	350
40	400
45	450
50	500
55	550

Intersection sight distance is measured from a point on the minor street of at least 15 feet from the edge of the major street pavement, and from an eye height of 3.50 feet on the minor street to an object height of 4.25 feet on the major street. The intersection sight distances in Table 8 are based on the sufficient time needed to allow a passenger car to pass through an intersection safely or to turn and enter the traffic flow (Ref. 14, p. 592).

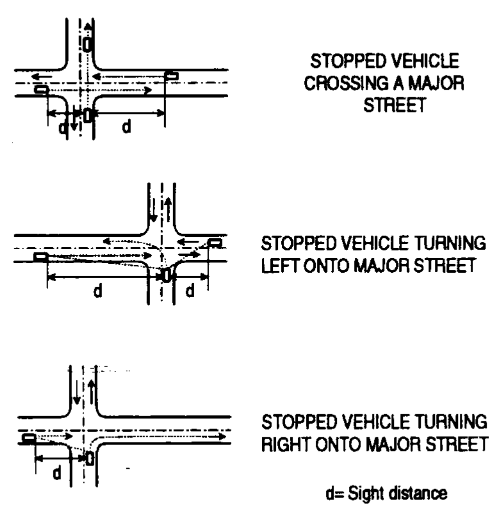


Figure 9. Intersection Site Distance.

STANDARDS

6.2 - Sight Triangle. Embankments, buildings, fences, landscaping, crops, parking, tree overhangs, signs, etc., shall not be designed to interfere with the sight distance anywhere within the sight triangle from an elevation of 3 to 8 feet above the surface of the pavement (Ref. 2, p. 445).

6.3 - Alignment and Profile

6.3.1 - Intersection Angles. Intersecting streets shall meet at as close to a right angle as possible. Intersecting streets shall not meet at angles less than 60 degrees (Ref. 2, p. 445).

6.3.2 - Intersection Spacing. The centerlines of streets shall coincide with the centerlines of streets on the opposite side of the intersection whenever possible. When this is not practical, centerline offsets shall be a minimum of 125 feet (Ref. 4, p. 14).

6.3.3 - Curb (or Edge of Pavement) Radii. Curb or edge of pavement radii at intersections shall accommodate the expected amount and type of traffic and allow for safe turning speeds. Table 9 shall be used to determine minimum curb radii (Ref. 2, p. 706).

Table 9
MINIMUM CURB RADII

Street Type	Curb Radii (ft)
Access and Subcollector	10-15
Collector and Major Collector	15-25

COMMENTARY

The sight triangle is bounded by the sight distance along the traveled portion of the street for each vehicle and the intersection sight distance. The line of sight for the vehicle on the minor street is taken 15 feet back from the edge of the pavement of the major street (Ref. 2, p. 432).

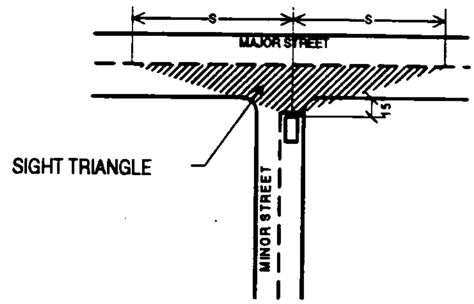


Figure 10. Sight Triangle.

Intersections are points of conflict between vehicles, pedestrians, and facilities and therefore are potentially dangerous. The alignment and profile of the intersecting streets should permit users to discern and perform readily the maneuvers necessary to pass through the intersection safely with a minimum of interference by other users (Ref. 2, p. 685).

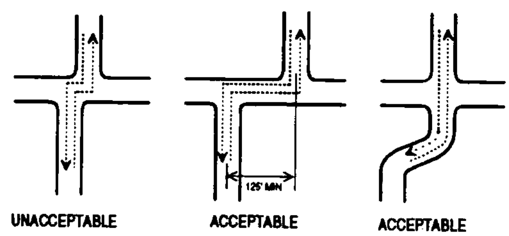


Figure 11. Intersection Spacing.

When they do not coincide, intersections should be spaced far enough apart so that the traffic stopped to make left turns at one intersection does not back up and interfere with traffic movements at the next intersection (Ref. 5, p. 71).

On streets with heavy pedestrian movements, the minimum radius of curb or edge of pavement should be no larger than 15 feet (Ref. 2, p. 445).

STANDARDS

6.3.4 - Profile. The intersection and approach areas where vehicles store while waiting to enter an intersection shall be designed with a relatively flat grade. The maximum grade on the approach leg should not exceed 5 percent where practical. Where ice and snow create hazardous conditions, the maximum grade on the approach leg should not exceed 2 percent wherever practical (Ref. 2, p. 445). These grades shall be maintained for a minimum of 50 feet from the intersection (Ref. 5, p. 73).

6.4 - Railroad Crossings. Grade-crossing warning devices shall be installed at all railroad-residential street grade crossings according to the *Manual on Uniform Traffic Control Devices* (MUTCD) (Ref. 2, p. 445; Ref. 18).

7.0 - PAVEMENTS

Pavements for residential streets shall provide (Ref. 1, p. 54)

1. suitable, smooth surfaces for vehicles;
2. dust-free surfaces to reduce nuisance to properties and maintain visibility for street users; and
3. free-draining surfaces to avoid ponding of water.

7.1 - Types of Pavement. The developer shall select the pavement type based on local climate, soil conditions, and available construction materials. Pavement types include but are not limited to rigid (usually Portland cement) concrete, prestressed concrete, flexible asphalt concrete, full-depth asphalt, deep-lift asphalt, concrete pavers, and brick (Ref. 16, pp. 16-13 to 16-14; Ref. 19; Ref. 20; Ref. 21).

7.2 - Pavement Design. An approved method of pavement design shall be used to design residential streets. Such method shall be a locally approved practice or one of the following: AASHTO Method of Flexible Pavement Design, Caltrans Method of Flexible Pavement Design, Asphalt Institute Method, AASHTO Method of Rigid Pavement Design, Fatigue Strength Method of Design, Multilayer Elastic Analysis, the National Crushed Stone Association Design, or an equivalent method.

COMMENTARY

(6.4) There should be sufficient sight distance on the street for the driver to recognize the crossing, perceive the warning device and the train, and, if necessary, stop (Ref. 2, pp. 445-446).

(7.1) Available construction materials should be evaluated in terms of construction and long-term maintenance costs.

(7.2) Traffic loading, subsoil strength, climate, grade, and construction methods should all be considered in good pavement design.

While these design methods are written primarily for highways and major arterials, design guides such as the AASHTO *Guide for the Design of Pavement Structures* include a chapter on low-volume road design that applies to residential street pavement design (Ref. 20).

STANDARDS

7.2.1 - Subgrade material is defined as the foundation layer of the street (Ref. 5, p. 89), and may be native or imported depending on the suitability of existing material. Except where native materials have already been approved for local use, the subgrade material shall be tested to determine its suitability in terms of both its load-bearing capacity and permeability. Most of the design methods in Section 7.2 provide tests to determine soil suitability.

7.2.2 - Base course material is defined as the layer of material that lies immediately below the wearing surface of a pavement. Base courses may be constructed of approved native materials, graded aggregates, slag, soil-aggregate mixtures, cement-treated granular materials, or bituminous aggregate mixtures. The base course material shall protect against frost action, provide drainage, prevent erosion of the subgrade, and provide increased structural capacity (Ref. 5, p. 90). Base course material shall meet the criteria outlined in the design method chosen in Section 7.2.

8.0 - CURBS AND GUTTERS

8.1 - Curb Type. Curbs are required unless the developer can show that shoulders and/or drainage swales will control storm water runoff. Gutters shall be required if necessary to protect pavement edge. Curb type shall be selected in the best interests of the community with both aesthetics and economics in mind. Some of the types of curbs available are vertical and mountable concrete, asphalt, Belgian block, and granite block.

COMMENTARY

Soil testing includes a sieve analysis to determine the gradation of the material and its suitability for use under load.

Using recycled paving materials is an economical way of providing a subgrade material.

The main functional reason for installing curbs and gutters is to handle storm water runoff. Pavement unravelling is not a reason for installing curbs, if the pavement is installed properly with the base course placed wider than the wearing course (Ref. 22). Other reasons usually involve aesthetics.

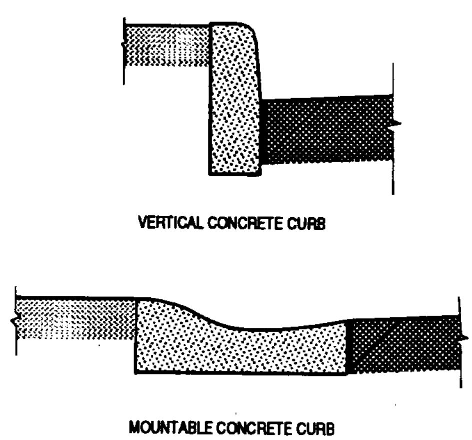


Figure 12. Concrete Curb Types.

STANDARDS	COMMENTARY
8.2 - Curb Ramps. To accommodate wheelchair and bicycle users, curb ramps shall be provided wherever an accessible route crosses a curb. Curb ramps shall comply with ANSI A117.1 (Ref. 11, Section 4.7).	Key points of the ANSI A117.1 Section 3.7 for curb ramps are summarized below: 1. Flared sides shall be constructed in areas where pedestrians will cross ramp. 2. Curb ramps must be a minimum of 3 feet in width (not including flared sides). 3. Slopes must be 1:12 for the ramp, 1:10 for the flares, and 1:20 for adjoining gutters and street surfaces immediately adjacent to ramp. 4. Curb ramp surfaces must be stable, firm, and slip-resistant with warning textures. 5. Ramps must be fully contained in any marked street crossing.
8.3 - Curb Size. The curb size shall be determined by drainage requirements and shall consider the safety of pedestrians.	Curb heights range from 4 to 9 inches (Ref. 2, p. 437).
8.4 - Curb Cuts. Curb cuts for vertical curbs at vehicle entrances shall be a minimum 8-feet-wide.	
9.0 - SHOULDERS AND DRAINAGE SWALES	
9.1 - Shoulders and/or drainage swales may be specified instead of curbs and gutters when the soil or topography make the use of shoulders and/or drainage swales acceptable for control of runoff (Ref. 13, p. 55). **9.2** - Shoulders and/or drainage swales shall consist of stabilized turf, compacted stone or gravel, concrete, asphalt, or other suitable material (Ref. 13, p. 55).	Curbs and gutters and associated impervious storm water piping or channels may cause environmental damage to neighboring streams and ponds due to the rapid channeling of rain water. Whenever possible, residential street design should minimize the area of impervious surfaces and maximize the retention of rain water on site where it can infiltrate and recharge the groundwater.
9.3 - Drainage swale geometry shall meet the requirements of Section 4.0 of Storm Water Management for open channel flow.	Swale size is dependent on anticipated storm water volume.
9.4 - Foreslopes shall be as gentle as feasible and not steeper than 2:1. Cut sections should be designed with adequate ditches (Ref. 2, p. 429).	The foreslope is the slope that starts at the traffic shoulder and extends to the ditch bottom or to the natural grade. An easement may be required for slope maintenance (see Section 12.1). The maximum rate of foreslope depends on the stability of local soils as determined by soil investigation and local experience.

STANDARDS

10.0 - PEDESTRIAN AND BICYCLE ACCESS

10.1 - Sidewalks. The local jurisdiction should determine the need for sidewalks based on a case-by-case study of the anticipated pedestrian traffic. Where sidewalks are required, they shall be a minimum 4-feet-wide (Ref. 11, Section 4.3).

COMMENTARY

Sidewalks link facilities and services with homes and are appropriate only in situations where people walk to destinations. Three (3) feet is the minimum width necessary to accommodate a wheelchair (Ref. 11, Section 4.3).

Consideration should be given to designing alternative pedestrian systems, including pathways and walkways that direct pedestrian and bicycle traffic away from streets and minimize the width of street rights-of-way. Where alternative pedestrian systems are used, attention should be given to provide safe walkways and to minimize potential security problems (Ref. 5, pp. 59-60).

Special consideration should be given to sidewalks planned in neotraditional neighborhoods or in high-density developments where the increased housing density leads to greater pedestrian traffic (e.g., the location of schools within walking distance to residential developments).

Table 10 provides guidelines for sidewalks in residential developments.

Table 10
TYPICAL SIDEWALK REQUIREMENTS

Street Type	Typical Sidewalk Requirements
Major Collectors	None
Collectors	Both Sides
Subcollectors	One Side
Access	None

Major collectors do not typically require sidewalks because houses are not located on these streets.

Collectors connect residences on subcollector streets and small businesses on major collectors. Pedestrian and bicycle traffic is greatest on collector streets; therefore, sidewalks are usually required on both sides of the street.

Subcollectors are low-volume streets. Unless houses front directly on the street (no front yard), sidewalks need to be located only on one side of the street.

Access streets, which typically accommodate a maximum of 25 houses, have even lower volumes. Because of the low density of housing on these streets, sidewalks are rarely required.

STANDARDS

COMMENTARY

10.2 - Pathways and Walkways. Pathways and walkways are alternative pedestrian systems located away from street traffic areas. They shall be considered for construction in medium- and high-density subdivisions and communities. Pathways and walkways shall be a minimum 3-feet-wide.

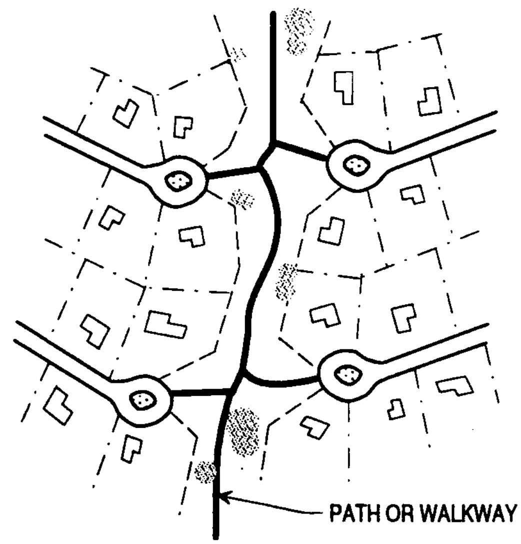


Figure 13. Path or Walkway System.

10.3 - Bicycle Paths. Where there is no community bikeway system, the developer has the option to include bicycle paths in the new development. Where a planned bikeway system exists, new bike paths should tie into that system. Bicycle paths may be located away from traffic areas or in a designated street lane. Bicycle paths shall be a minimum 6- or 8-feet-wide where heavy use and high speeds are projected.

Bicycle paths are designed to link residents' destinations and to provide opportunities for active recreation within the development or between developments.

10.4 - Pavement Types. The developer shall select the pavement type for sidewalks, walkways, pathways, and bicycle paths based on local climate, soil conditions, and available construction materials. Pavement types include but are not limited to concrete, asphalt, and brick. Pavement selected shall provide a smooth surface for small-tire traffic such as bicycles and wheelchairs. Concrete sidewalks shall have a nominal thickness of 4 inches in nontraffic areas (Ref. 13, p. 97).

11.0 - DRIVEWAYS

11.1 - Orientation. The driveway angle with the street shall be a minimum 60 degrees. Driveway returns shall have a minimum 3-foot radius. Flared driveway entrances are acceptable (Ref. 2, p. 442).

The driveway angle with the street should be as close to 90 degrees as possible.

STANDARDS

11.2 - Grades. Driveway grades shall not exceed 12.5 percent for the first 18 feet from the edge of the pavement (Ref. 2, p. 442).

11.3 - Materials. At a minimum, the traveled wheel paths of driveways shall consist of asphalt, concrete, gravel, crushed stone, brick, or other acceptable stabilized ground surface. Where a smooth, paved surface is not used in driveway construction, a stabilized surface shall be provided from the street to the right-of-way or for a distance not less than 5 feet in length, whichever is greater.

12.0 - EASEMENTS AND RIGHTS-OF-WAY

12.1 - Easements grant rights of passage through and/or use of privately owned property. Easements provide the same access to utilities as do rights-of-way (Ref. 8, p. 62). Easements may be used whenever possible to economize on the use of land in lieu of rights-of-way except in the case of streets, curbs, gutters, and storm drains.

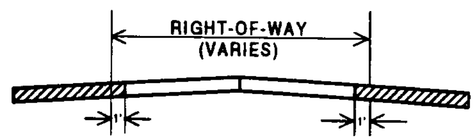
12.2 - Rights-of-way are land areas set aside and managed by a local jurisdiction for the construction of streets, shoulders, swales, curbs, and gutters. They may accommodate utilities such as water, sewer, and electrical service; foreslopes; and sidewalks; otherwise, these utilities shall be located in an easement (Ref. 8, p. 61). Rights-of-way shall be measured from lot line to lot line. The minimum right-of-way width shall exceed by 1 foot on each side of the street the area needed to contain the traveled way, curbs (if required), utilities, and sidewalks (if not located in an easement) (Ref. 5, p. 39).

COMMENTARY

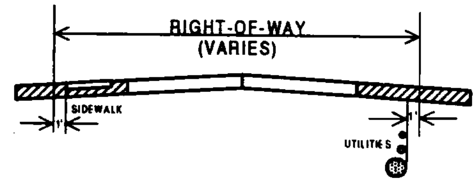
An 18-foot area provides vehicles with a transitional area to negotiate a sag or crest curve as well as with adequate sight distance at the driveway entrance. On driveways with steep slopes, the transition area allows a vehicle room to park safely off the street when inclement weather prevents the vehicle from driving the remaining length of the driveway.

The use of easements may allow the placement of a utility line along the shortest path, thereby decreasing both the overall length of the line and the associated costs. Legal rights to easement land are assigned to the community, utility, and home owners. Home owners use and maintain easement areas, which ostensibly adds to their acreage and saves upkeep funds for the community.

In considering the use of rights-of-way, allowances for future residential street widening are unnecessary in well-planned communities that are designed to discourage through traffic (Ref. 8, p. 62).



RIGHT-OF-WAY WIDTH FOR RESIDENTIAL STREET WITH UTILITIES LOCATED IN EASEMENT



RIGHT-OF-WAY WIDTH FOR RESIDENTIAL STREET WITH UTILITIES AND SIDEWALK

Figure 14. Right-of-Way Widths.

Rights-of-way used for utilities should be subjected to review to ensure that the minimum required width does not contribute to increased housing costs (Ref. 8, p. 61). In colder climates, consideration should be given to allow for temporary snow storage areas.

STANDARDS	COMMENTARY
13.0 - LIGHTING Residential street lighting shall be required where there is a concern for public safety.	Residential street lighting, where used, does not serve the same purpose as highway lighting. Vehicles traveling at slow speeds can easily maneuver residential streets at night without external lighting. Where deemed necessary, illumination can be provided attractively with residential-type lantern lights.
14.0 - TRAFFIC CONTROL DEVICES AND SIGNS 14.1 - Design and placement of traffic control devices and signs shall follow state regulations or the requirements specified in the *MUTCD* (Ref. 18). 14.2 - Street name signs shall be placed at intersections and shall be of a consistent design, style appropriate to the community, and uniform size and color (Ref. 13, p. 65). Street name signs shall be easily visible to vehicular and pedestrian traffic as well as to emergency vehicles.	
15.0 - STORM WATER AND EROSION CONTROL 15.1 - Residential streets shall be designed to take into consideration storm water runoff and to ensure the lowest possible risk to traffic interruption and property damage due to flooding (Ref. 2, p. 306). The Storm Water Management Standards shall apply to residential streets. The appropriate above- or below-ground systems (open channel or closed conduit) shall be designed to handle storm water runoff when necessary.	
15.2 - Erosion prevention shall be a part of the street and storm water design (Ref. 2, p. 308). The Temporary Sediment and Erosion Control and Storm Water Management Standards shall apply to residential streets to prevent erosion.	Erosion can be minimized by using one of the following methods (Ref. 2, p. 308): 1. using flat side slopes; 2. blending with the natural terrain; 3. using drainage channels, inlets, and culverts designed to minimize erosion; and 4. providing ground covers and plantings.

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STORM WATER MANAGEMENT STANDARDS

This section sets forth minimum standards for storm water management in subdivisions and residential developments. The principal design consideration in these standards is the prevention of major property damage and loss of life resulting from storm water runoff. In addition, the standards protect on- and off-site properties from nuisance flooding, excessive erosion, and sedimentation.

While careful consideration was given to each section of this standard, a locality may, based on sound engineering practices, waive any part of these standards to meet unique needs or provide equivalent alternatives.

CONTENTS

STANDARDS	COMMENTARY

1.0 - PURPOSE/STRATEGY

1.1 - Purpose. The storm water management system shall prevent or mitigate major property damage and loss of life resulting from flooding associated with design storm events and shall inhibit the deterioration of waters and water-ways where increased runoff or sedimentation is generated by new development.

Storm water quality, quantity, and flow rate are the fundamental issues of the storm water management plan. Communities have many options for managing storm water--from complete reliance on individual on-site controls to developing a fully integrated regional plan. A regional storm water management plan provides the best solution to watershed resource management.

1.2 - Strategy. Storm water drainage systems shall be designed to

1. protect natural waterways;
2. convey upstream and on-site storm water runoff to a natural watercourse or to a storm drainage facility (Ref. 1, pp. 6-7); and
3. provide protection from the minor storm event and address the major storm so as to prevent major property damage and loss of life.

The use of natural systems that combine natural storage, percolation, and channeling techniques is encouraged. Such systems reduce costs and replenish local water sources by reducing and delaying the release of surface water runoff. Some examples of natural systems include grassed waterways, infiltration beds, and open space storage.

Designers are encouraged always to seek better solutions when addressing storm water drainage systems (Ref. 1, p. 6-6).

2.0 - DESIGN CRITERIA

2.1 - General

2.1.1 - The discharge of storm water shall conform to an applicable regional storm water management plan. In the absence of a regional plan, the discharge of storm water shall conform to these standards.

A regional storm water management plan should specify the quantity of runoff and where it may be discharged. Options include direct discharge to an existing natural or manmade drainageway, on-site detention or retention, or a combination of the two.

A regional plan should be based on local conditions. Decision makers should evaluate the potential effects of alternative management strategies so that the most cost-effective solutions can be selected (Ref. 2, p. IV-6). Opportunities for sharing the cost of storm water management programs for different developments should be considered.

STANDARDS | COMMENTARY

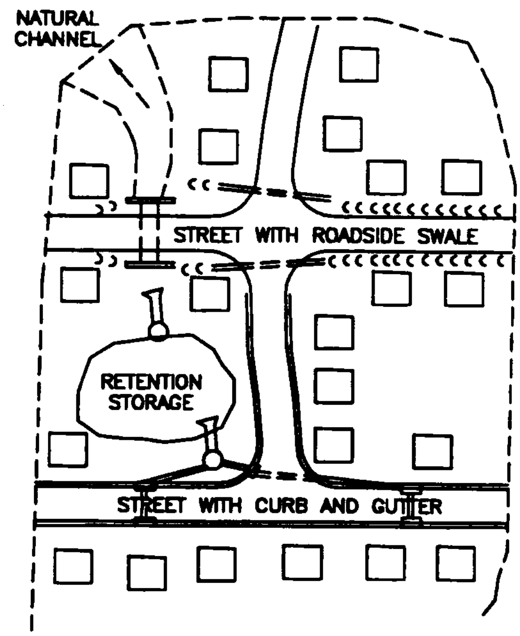

Figure 1. Components of a Storm Water Management System.

2.1.2 - Functional drainage systems consist of major and minor systems (Ref. 1, p. 6-5; Ref. 3, pp. SW-4 to SW-5).

A storm water management system has various objectives that require separate consideration for the respective design events. Although each system and component must have a threshold of hydraulic integrity to perform its intended function, it is economically impractical to design for the worst-case event. For most small developments, consideration of the major system may simply be the provision of adequate overland relief to an acceptable drainage channel.

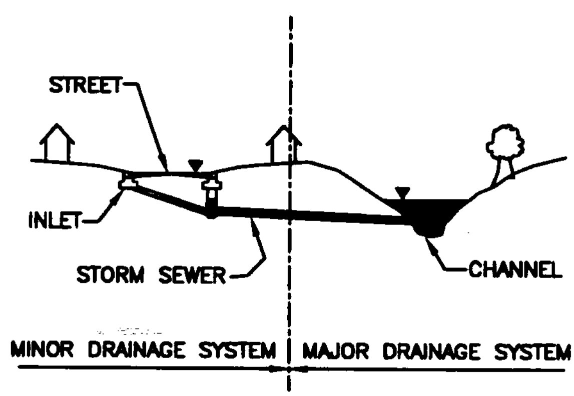

Figure 2. Minor and Major Drainage Systems.

STANDARDS

1. *The major drainage system* takes into consideration the less frequent 100-year (major) storm and is designed to prevent major property damage and loss of life from storm runoff expected from the major storm.

2. *The minor drainage system* is designed to handle the two- and ten-year (minor) storm and to protect development, streams, drainageways, and streets from erosion, sedimentation, and increased runoff.

2.2 - Runoff Discharge

2.2.1 - Major Drainage System Discharge. For the major drainage system discharge, there shall be no increased threat to downstream property considering the 100-year design storm under fully developed conditions.

2.2.2 - Minor Drainage System Discharge. Either of the following criteria shall be met for both the two- and ten-year design storms at all points along the development boundary in order to be able to discharge storm water into downstream drainageways for the minor drainage system:

1. The peak rate of flow shall not be greater than the predevelopment value, or

2. The increase in peak rate of flow or volume created by the development does not cause adverse impacts or aggravate an existing drainage problem downstream for a reach equal to the development site drainage area times 100 (Ref. 1, pp. 6-7, 6-10).

Storm water discharged for the minor storm shall be released at nonerosive energy levels.

2.3 - Easements

Easements shall be required for the discharge of concentrated flows onto adjacent properties and for off-site improvements needed to obtain an adequate outfall. Easements shall also be provided for publicly owned or maintained components of the storm water management system unless such components are located within the public right-of-way.

COMMENTARY

Overland relief swales, natural waterways, water impoundments, retention or detention ponds, soil percolation, and large manmade piping may function as part of the major drainage system.

Typically, the minor drainage system conveys runoff within a site to a major natural or manmade drainageway. The minor system may include underground piping, overland swales, natural drainageways, soil percolation, and other required appurtenances.

The two- and ten-year design events are recommended to ensure that the drainage system is capable of sustaining a range of expected events. Greater protection is then provided for frequent and infrequent events.

It is common practice to combine several utilities in one easement, usually adjacent to road rights-of-way.

STANDARDS

2.4 - Construction

Storm water runoff and erosion shall be controlled during construction according to the requirements of the Temporary Erosion and Sediment Control Standards.

2.5 - Water Quality

Where applicable, projects shall comply with the National Pollutant Discharge Elimination System (NPDES) requirements and permitting process and any state or local water quality standards or Best Management Practices (BMPs).

2.6 - Maintenance

Storm water management plans shall describe maintenance requirements and responsibilities to ensure the operation of the system. Drainage structures shall be constructed to facilitate maintenance requirements. Slopes on access ways for maintenance vehicles shall not exceed 3:1 (3 horizontal to 1 vertical). Adequate easements for maintenance and operation shall be provided as required in Section 2.3.

COMMENTARY

The potential for soil deposition is at its peak during the construction phase of a development. However, with properly planned construction and controls, adverse soil erosion during the construction period can be limited.

The purpose of the NPDES program is to identify potential sources of erosion and pollution from storm water discharge and to provide mechanisms to reduce pollutants. Construction activities that disturb five or more acres of land area are targeted by the plan. Nondelegated states must comply directly with the EPA's NPDES program while delegated states independently issue and administer NPDES model programs. Current nondelegated states are Alaska, Arizona, Florida, Idaho, Louisiana, Maine, Massachusetts, New Hampshire, New Mexico, Oklahoma, South Dakota, and Texas.

Best Management Practices (BMPs) are techniques that improve the quality of storm water runoff by reducing the potential for erosion, promoting infiltration, or promoting the filtering or settling of particulates. These techniques may be used as temporary measures during construction or permanent measures that remain in place indefinitely. Some examples of BMPs include porous pavement, percolation trenches, parking lot storage, infiltration beds, vegetative strips, and measures described in the Temporary Sediment and Erosion Control Standards.

Unless assumed by a private, government, or other public agency, the responsibility for operation and maintenance of storm water management facilities shall remain with the owner(s) of such facilities and be transferred to any successive owner(s). The type and frequency of required inspection and maintenance of storm water facilities should be specified and documented during the design phase. A fundamental requirement is safe and easy access and adequate working space for personnel and equipment performing the work. Some examples of inspection and maintenance procedures that require consideration are (Ref. 4, pp. 438-444)

1. removal of sediment, debris, and other obstructions;
2. control of brush and weeds;
3. repair or replacement of fences, rails, and other safety features or the planting of vegetation;

STANDARDS	COMMENTARY

4. periodic investigation of spillways, earthen dams, and berms for erosion, slumping, excessive seepage, woody growth, instability, and rodent damage; and
5. examination and cleaning or repair of flow-regulation grates or grills installed in catch basins, inlets, or other works.

2.7 - Safety

Safety shall be considered in the design and hydraulics of all storm water structures to prevent injury and accidents.

Storm water structures such as storm sewers, swales, channels, and detention and retention (D/R) facilities may pose hazards to residents, particularly children. Some examples of safety provisions to consider are (Ref. 4, pp. 438-444)

1. removable safety cages or grates mounted on the entrance to open sewers, culverts, and D/R outlet pipes;
2. foot or hand rungs along the channel walls to provide for escape and rescue from flowing waters;
3. drop structures installed intermittently along channels to reduce flow velocity to safer levels (subcritical flow); and
4. use of gradual slopes, e.g., 7:1 around the periphery of a D/R facility.

3.0 - CALCULATION OF RUNOFF (DESIGN HYDROLOGY)

The method of calculating and routing storm water runoff shall be a generally accepted storm water management practice. Runoff calculations shall be based on the design storm event probabilities for runoff discharge given in Section 2.2.

3.1 - Hydrologic Data

3.1.1 - Local rainfall/weather data shall be the basis of design calculations, where available.

3.1.2 - Acceptable types of rainfall data for the calculation of runoff are

1. intensity-duration-frequency (I-D-F) curves;
2. design storm hyetographs;
3. chronologic rainfall records;
4. historical storm events; and
5. other sources as locally approved.

Several sources for hydrologic data are available to the designer. Some of these are

1. the National Oceanic and Atmospheric Administration (NOAA);
2. the National Weather Service (formerly U.S. Weather Bureau);
3. the USDA Soil Conservation Service (SCS);
4. regional planning agencies; and
5. professional publications and research.

A hyetograph is a map or chart displaying temporal or aerial distribution of precipitation.

STANDARDS

3.2 - Time of Concentration, T_c

Time of concentration is an estimate of the time of surface water flow from the hydraulically most remote part of the drainage area to the outlet. A recognized formula and method along with sound professional judgment shall be used to estimate the time of concentration (T_c).

3.3 - Watershed Delineation, Tributary Area, and Hydrologic Condition

3.3.1 - Drainage areas shall be determined from field run topography, verified U.S. Geological Survey quadrangle sheets, aerial photography, surveys drawn to scale, or other approved sources.

3.3.2 - The drainage area shall consider all on- and off-site lands contributing to the proposed development's drainage system.

3.3.3 - For the purpose of calculating and comparing runoff discharge amounts, the predevelopment land use condition, if not completely natural and undisturbed, shall be considered to be under environmentally sound management practices that are reasonable for the current land use. The postdevelopment site condition shall reflect a reasonable assessment of the mature site's condition.

3.3.4 - Pre- and postdevelopment drainage divides shall be delineated to reflect the division of the site for design and calculation purposes and to show any modification of natural divides.

COMMENTARY

Some of the recognized formulas for calculating time of concentration are listed below. The formulas are given in Table 6 in the appendix to this standard.

1. Kirpich (1940);
2. Izzard (1946);
3. Federal Aviation Agency (1970);
4. Kinematic Wave Formula (1965);
5. SCS Lag Equations (1975, 1986);
6. Manning's Equation; and
7. others as locally accepted.

Some typical sources of geologic and land use data follow:

1. the state department of natural resources (vegetation and environmental sensitivity);
2. the USDA SCS Soil Surveys (soil conditions);
3. the U.S. Geological Survey (topography); and
4. regional planning agencies.

Changes in the time of concentration due to development shall be accurately considered in the comparison of runoff before and after development. Off-site contributions to runoff should be based on the current actual land use condition of the off-site drainage area.

STANDARDS

3.4 - Runoff Calculation Methods

Appropriate calculation methods shall incorporate the important hydrologic characteristics of each site. Designers shall use the Rational Method, SCS TR-55, or other recognized methods. The Rational Method and SCS TR-55 are described in Sections 3.4.1 and 3.4.2.

3.4.1 - Rational Method (Ref. 4, pp. 100-105; Ref. 5, p. 9-60). The Rational Method for calculating storm water runoff may be used for developments up to 200 acres in area. Equation 1 is used in the Rational Method

$$Q_T = Ci_TA \quad , \qquad \text{Eq. 1}$$

COMMENTARY

Some acceptable rainfall runoff methods for calculating runoff are listed in Table 1.

Table 1
COMMON RAINFALL RUNOFF CALCULATION METHODS

1. Rational Method (including Modified and Universal)
2. Graphical Peak Discharge Method (SCS TR-55)
3. Tabular Method (SCS TR-55)
4. Synthetic Unit Hydrograph Method (SCS-NEH Section 4)

Application of Methods

Required Output	Drainage Area	Methods
Peak Discharge	≤ 200 acres	1,2,3,4
	≤ 2000 acres	2,3,4
	≤ 20 sq. mi.	3,4
	> 20 sq. mi.	4*
Peak Discharge and Total Volume	≤ 2000 acres	2,3,4
	≤ 20 sq. mi.	3,4
	> 20 sq. mi.	4*
Runoff Hydrograph	≤ 20 sq. mi.	3,4
	> 20 sq. mi.	4*

*Computer models should be considered for large drainage areas.

Common sources for design aids or procedures for runoff calculations follow:

1. the USDA Soil Conservation Service;
2. the U.S. Army Corps of Engineers;
3. the U.S. Bureau of Reclamation;
4. the U.S. Department of Transportation/Federal Highway Administration;
5. universities;
6. professional publications; and
7. regional planning agencies.

A hydrograph is a graphic representation of the stage, flow, velocity, or other characteristics of water at a given point as a function of time.

STANDARDS

where: Q_T = peak rate of runoff (or discharge) for the recurrence interval "T" in cubic feet per second;
C = runoff coefficient, an empirical coefficient representing a relationship between rainfall and runoff. Where surfaces vary in a drainage area, a weighted average shall be used;
i_T = average rainfall intensity during a period of time equal to the time of concentration for the recurrence interval "T" in inches per hour; and
A = tributary area in acres.

3.4.1.1 - Runoff Coefficient (C). The runoff coefficient for the type of soil/cover and land use in the drainage area shall be determined from Table 2.

Table 2
RUNOFF COEFFICIENTS (C)
.FOR THE RATIONAL METHOD
(Ref. 5, p. 9-87)

Character of Surface	Runoff Coefficients
Pavement	
Asphalt and Concrete	0.70 to 0.95
Brick	0.70 to 0.85
Roofs	0.75 to 0.95
Lawns, Sandy Soil	
Flat, 2 Percent	0.05 to 0.10
Average, 2 to 7 Percent	0.10 to 0.15
Steep, 7 Percent	0.15 to 0.20
Lawns, Heavy Soil	
Flat, 2 Percent	0.13 to 0.17
Average, 2 to 7 Percent	0.18 to 0.22
Steep, 7 Percent	0.25 to 0.35
Water Impoundment	1.00

3.4.1.2 - Rainfall Intensity. The average rainfall intensity shall be found by using local hydrologic data such as I-D-F curves (or other types of rainfall data listed in Section 3.1.2) and the time of concentration found in Section 3.2. Where subbasins are part of the design, the flow path involving the longest flow time shall be used in defining the time of concentration for the combined area of subbasins.

COMMENTARY

Where subsequent subbasins are located downstream in the same development, the first time of concentration is added to the travel time in the channel or pipe to the midpoint of the subsequent subbasin. The result is then compared to the local inlet time of the subsequent subbasin. The larger of the two figures is used as the new time of concentration for the channel/pipe serving the subsequent subbasin. This process is repeated for each successively lower subbasin.

STANDARDS	COMMENTARY

3.4.2 - Graphical Peak Discharge Method (SCS TR-55) (Ref. 6). The Graphical Peak Discharge Method, which was developed by the USDA Soil Conservation Service in Technical Release No. 55 (TR-55), may be used to determine storm water runoff, peak discharge, and total volume for developments up to 2,000 acres in area. The peak discharge equation is

$$q_p = q_u A_m Q F_p \quad , \qquad \text{Eq. 2}$$

where:
q_p = peak discharge (cfs);
q_u = unit peak discharge (csm/in);
A_m = drainage area of watershed (mi^2);
Q = runoff (in); and
F_p = pond and swamp adjustment factor.

$$csm = \frac{ft^3}{sec(mi^2)}$$

3.4.2.1 - Runoff (Q) is determined by using the 24-hour rainfall (P), the curve number (CN); Table 1, and Figure 1 in the appendix to this standard.

1. *24-Hour Rainfall (P)* is obtained from local precipitation maps, SCS synthetic 24-hour rainfall distribution maps, or National Weather Service duration-frequency data for the selected design storm (frequency).

2. *Curve Number (CN)* is determined by using Table 2 in the appendix to this standard based on soil type and land cover. If land use or soil type is not homogeneous over the watershed, a composite CN value can be determined by computing a weighted average based on using Equation 3:

$$CN\ (weighted) = \frac{\Sigma(CN \times Subarea)}{Total\ Area} \quad , \qquad \text{Eq. 3}$$

The Curve Number is determined by soil type and land cover. Similar to the runoff coefficient of the Rational Method, the Curve Number indicates the relationship between rainfall and runoff.

A list of hydrologic soil groups for U.S. soils is found in SCS TR-55. For general classifications of these groups, refer to Table 2 in the appendix to this standard.

3.4.2.2 - Unit Peak Discharge (q_u) is obtained by using the time of concentration (T_c), the initial abstraction (I_a), rainfall (P), and Figure 2 from the appendix to this standard for the appropriate rainfall distribution type.

1. *Initial Abstraction (I_a)* is obtained by using the Curve Number and Table 4 from the appendix to this standard.

STANDARDS | COMMENTARY

2. *Time of Concentration (T_c)* is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. T_c is the sum of the travel times (T_t) for the various consecutive flow segments according to Equation 4:

$$T_c = T_{t1} + T_{t2} + \ldots T_{tm} \quad , \qquad \text{Eq. 4}$$

where: m = number of flow segments.

3. *Travel Time (T_t)* is the time it takes water to travel from one location to another in a watershed as sheet flow, shallow concentrated flow, open channel flow, or a combination of these.

   a. For *sheet flow* (of less than 300 feet), T_t is calculated by Equation 5:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} S^{0.4}} \quad , \qquad \text{Eq. 5}$$

   where: T_t = travel time (hr);
   n = Manning's roughness coefficient (Table 3 in the appendix to this standard);
   L = flow length (ft);
   P_2 = 2-year, 24-hour rainfall (in)--consult precipitation maps; and
   S = slope of hydraulic grade line (land slope, ft/ft).

   After a maximum of 300 feet, sheet flow is considered as shallow concentrated flow.

   b. *Shallow concentrated flow* is calculated by using Figure 3 in the appendix to this standard and Equation 6 as follows

$$T_t = \frac{L}{3600\ V} \quad , \qquad \textit{Eq.6}$$

   where: T_t = travel time (hr);
   L = flow length (ft); and
   V = average velocity (ft/s)--Figure 3 in the appendix to this standard.

   For slopes less than 0.005 ft/ft, consult Appendix F from SCS TR-55.

STANDARDS	COMMENTARY

c. For *open channel flow*, travel time (T_t) is also calculated by using Equation 6. However, the average velocity (V) is calculated by using water surface profile information or the following form of Manning's Equation expressed in Equation 7:

Open channels are assumed to begin where surveyed cross-section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on U.S. Geological Survey (USGS) quadrangle sheets.

$$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}, \qquad \text{Eq. 7}$$

Manning's n values for open channel flow can be obtained from standard textbooks such as Chow (1959) or Linsley et al. (1982).

where: V = average velocity (ft/s);
r = hydraulic radius (ft) equal to a/p_w;
a = cross-sectional flow area (ft^2);
p_w = wetted perimeter (ft);
s = slope of the hydraulic grade line (channel slope, ft/ft); and
n = Manning's roughness coefficient for open channel flow.

3.4.2.3 - Pond and Swamp Adjustment Factor (F_p) is derived from Table 5 in the appendix to this standard.

4.0 - OPEN CHANNELS

Open channels consist of swales, ditches, or depressions, both natural and manmade, that convey surface water.

Grass channels or surfaces reduce runoff velocities, enhance infiltration, and remove runoff contaminants.

4.1 - Channels shall have the hydraulic capacity to carry the 10-year design storm runoff within the channel bed and banks. Out-of-bank flow may be permitted on land slopes parallel to the channel where it can be shown that no erosion damage or serious property damage will result. Channels function as part of the major drainage system and shall be evaluated for the 100-year design storm to determine the impacts of runoff on adjacent property. The channel's hydraulic capacity shall be increased where adjustments to channel geometry provide significant protection to adjacent properties during the 100-year event.

It is preferable to rely on adequate existing natural channels whenever possible. Manning's Equation may be used to compute the depth and velocity of flow in channels where uniform flow is expected to occur. The Standard Step or Direct Step method should be used where there is no appreciable length of constant section and grade and there is no opportunity for conditions of uniform flow to exist. Uniform flow rarely occurs in natural streams because of changes in depth, width, and slope along the channel.

STANDARDS

4.2 - Channels that are not designed as detention or infiltration facilities shall minimize standing water or wetness problems by maintaining minimum longitudinal slopes. Vegetative channel linings shall maintain minimum slopes of 2 percent, or 0.5 percent where necessitated by topographical conditions. Concrete or paved channel linings shall maintain minimum slopes of 0.3 percent.

4.3 - Channels shall be protected from scour and erosion by providing a channel lining adequate to sustain the velocity of the 10-year design storm. Permissible velocities for grass-lined channels are given in the following table (Ref. 7, p. 7-14):

Table 3
PERMISSIBLE VELOCITIES FOR SWALES, OPEN CHANNELS, AND DITCHES WITH UNIFORM STANDS OF VARIOUS WELL-MAINTAINED GRASS COVERS

		Permissible Velocity on	
Ground Cover	Slope Range (percent)	Erosion-Resistant Soils (fps*)	Easily Eroded Soils (fps*)
	0-5	8	6
Bermudagrass	5-10	7	5
	Over 10	6	4
Bahia, Buffalograss,	0-5	7	5
Kentucky Bluegrass,	5-10	6	4
Smooth Brome, Blue Grama, Tall Fescue	Over 10	5	3
Grass Mixture	0-5	5	4
Reed Canarygrass	5-10	4	3
Lespedeza Sericea, Weeping Lovegrass, Yellow Bluestem, Redtop, Alfalfa, Red Fescue	0-5	3.5	2.5
Common Lespedeza Sudangrass	0-5	3.5	2.5

*Feet per second.

4.4 - Channel geometry shall inhibit erosion and shall not exceed the allowable side slopes for the material used according to Table 4 (Ref. 8, p. 5-17):

COMMENTARY

Channel linings are used to protect the entire channel surface. Vegetation is the most commonly used protection for channels with infrequent flow, relatively low velocities, and where a good stand can be established and maintained. Channels should be located outside fill areas when possible to reduce the risk of erosion.

The slope of channel banks is dependent on the required maintenance as well as on the stability of the soil and channel lining. Channels should be maintained to function at the level to which they were designed. Banks that require mowing should be placed at 3:1 slopes or flatter.

STANDARDS

COMMENTARY

Table 4
MAXIMUM SIDE SLOPES FOR OPEN CHANNELS

Type of Channel	(horizontal:vertical)
firm rock	vertical to ¼ : 1
concrete lined stiff clay	½ : 1
fissured rock	½ : 1
firm earth with stone lining	1 : 1
firm earth, large channels	1 : 1
firm earth, small channels	1½ : 1
loose, sandy earth	2 : 1
sandy, porous loam	3 : 1

4.5 - Maintenance personnel shall have access via easements to maintain and repair public drainage channels in areas outside the public right-of-way. The easement shall be such that the 10-year design storm flow is contained within the easement.

5.0 - CLOSED CONDUIT STORM SEWERS

Closed conduit storm sewers consist of inlets, manholes, and pipes that capture and convey storm runoff.

The use of a closed conduit storm sewer is generally costly, accelerates the rate of runoff, and prohibits infiltration into the ground.

5.1 - System Design

5.1.1 - Pipe sizes for closed conduit flow shall be based on the 10-year design storm runoff and minimum allowable velocities. Pipe sizes less than 12 inches in diameter shall be fed through inlets that prohibit potential blockage of these smaller pipe diameters. The system shall provide for the cleaning of sediment and other deposits by maintaining a minimum velocity of 2 fps during the 10-year storm.

Manning's Equation is the most common method of estimating the capacity and flow resistance in closed conduits, although the Kutter, Hazen-Williams, and Darcy Weisbach formulas are also acceptable. Manning's Equation assumes uniform flow; Equation 7 is a version of this. Roughness coefficients can be found in textbooks such as Chow (1959) and Linsley et al. (1982).

5.1.2 - Closed conduit storm sewer systems shall convey the 10-year design storm to a point of discharge by gravity or pressure flow. In pressure flow conditions, the hydraulic grade line shall be calculated to reflect losses in pipes and structures and shall not rise to an elevation greater than the sewer structure tops during the design storm.

Generally, gravity flow occurs where the capacity of pipe run exceeds the design flow and the outfall point does not control discharge. Storm sewer systems may be designed for pressure flow when the hydraulic grade line is above the crown of the pipe. The decision to design a pressure flow system may be based on aesthetics, the need to submerge outfalls, economics, limitations associated with reduced pipe sizes, or grade constraints in outfalling the system.

STANDARDS	COMMENTARY
5.2 - Pipe Materials	
5.2.1 - Acceptable pipe and end section materials shall conform to the standards in Section 9 and include vitrified clay, concrete, corrugated aluminum, corrugated metal, ductile iron, and plastic.	Asbestos cement pipe is on the EPA list of products to be banned and is not recommended for use.
5.2.2 - Storm sewer systems shall be capable of withstanding anticipated loads. Pipes located under roadways or travelways shall be capable of withstanding the live loads imposed by passing vehicles and shall sustain AASHTO H-20 loading. Pipes located in open areas with vegetative cover shall be protected from accidental damage by burial at minimum depths of 2 feet. The maximum burial depth allowed shall not exceed pipe manufacturers' recommended depth for the material used unless an engineering calculation shows the pipe material to be adequate.	Protective sleeves or alternative materials in the loaded area can provide economical benefits in some situations.
5.3. - Pipe Placement	
5.3.1 - Maintenance personnel shall have access via easements to maintain the public system located outside the public right-of-way. The easement shall be wide enough to allow access to maintain and perform general repair on all parts of the system. The minimum easement width shall be 10 feet. Pipes may be offset from the center of the easement, and easements of separate utilities may overlap.	
5.3.2 - Storm pipes shall be protected from excessive bearing pressures by placing them outside the 45 degree influence zone of building structures unless an engineering calculation shows the pipe material or soil condition to be adequate for the subjected load.	
5.3.3 - To maintain joint integrity, pipe runs designed as curves between structures shall follow manufacturers' allowable deflections for the type and size of pipe.	The practice of installing pipes along vertical and horizontal curves, as opposed to along conventional straight alignments, allows cost savings by reducing the number of structures and permitting the system to follow the terrain more closely. Curved lines can be constructed by using both rigid and flexible pipe. Rigid pipe is installed by deflecting the pipe joint from a straight position, while flexible pipe is deflected by bending the pipe itself.
5.3.4 - Where steep grade makes possible the use of a reduced pipe size, the pipe size may be reduced at a manhole, but hydraulic allowances shall be made for head loss of entry, increased velocity, and the effect of velocity retardation at the lower end where the flow traverses a flatter slope.	Pipe size along a run should be reduced when substantial savings on construction costs can be derived.

STANDARDS

5.4 - Installation

5.4.1 - Pipes or structures constructed on fill shall be stable and protected against settlement by compacting fill material to 95 percent of the modified Proctor (ASTM D1557-78) maximum dry density.

5.4.2 - Pipes on 20 percent slopes or greater shall be anchored securely with concrete anchors or equal to prevent the pipe from creeping downhill.

5.4.3 - Proper trenching, bedding, and backfill are required for pipe performance. Bedding shall conform to the standards of Section 9.3.1. The width of the trench shall allow the pipe to be laid and properly jointed and to permit the backfill to be placed and compacted as needed. Debris, frozen material, large stones, organic matter, or other unstable materials shall not be used for backfill within 2 feet of the top of the pipe.

5.4.4 - The receiving surface where pipes discharge shall be protected from erosion by evaluating the discharge velocity for the 10-year design storm. The use of energy-dissipating devices may be necessary to reduce the velocity to acceptable levels for the receiving surface.

5.5 - Inlet Design

Inlets allow surface runoff to enter the closed conduit system. They convey water into the system while preventing entry of large debris.

5.5.1 - A storm sewer inlet shall be located in all sump locations not designed as detention or infiltration facilities. Inlets at low points on sag vertical curves shall evaluate the spread and depth at the point of 2 percent longitudinal slope.

COMMENTARY

Anchors or collars are devices placed around pipes to increase resistance to movement or to decrease the susceptibility of groundwater or seepage flow along the pipe. The size and spacing of collars should be based on soil conditions and the slope and type of pipe.

There are three basic types of inlets: gutter or grated inlets located in the gutter surface near a curb or in depressions, curb opening inlets located in the vertical face of a curb, or combination inlets used in a street or roadway with curb and gutter.

STANDARDS

5.5.2 - Street inlets and inlets in parking areas shall reduce the spread and depth of flow to acceptable levels during the 10-year design storm. The acceptable level of flow on residential streets shall be as specified in Table 5. Inlets located on continuous grades may be designed to permit a portion of flow to bypass the structure; however, calculations for the downstream structure must consider the bypass.

Table 5
ACCEPTABLE LEVEL OF FLOW

Inlet Location	Acceptable Level of Flow
Access Street	Maintain 8-foot travel lane with maximum 1-inch depth
Subcollector Street	Maintain one clear 10-foot travel lane
Collector and Major Collector Street	Maintain two clear 10-foot travel lanes*

* Reduce to one clear 10-foot travel lane for one-way street.

5.5.3 - Any area inundated by water ponding at an inlet during the 10-year design storm event shall be located within an easement or right-of-way.

5.5.4 - Inlets located in sump locations need to be considered with respect to the major drainage system. The 100-year design event shall not cause buildings to flood in the event that a single inlet becomes blocked. Overland relief to another inlet or surface channel shall be provided to protect property.

5.5.5 - Inlet grates and frames shall be sufficiently durable to sustain traffic loads, resist corrosion due to road salt and other contaminants, and resist scour due to sand and grit. Inlet grates and frames shall be constructed of cast iron, ductile iron, galvanized steel, or other suitable material.

5.5.6 - Storm inlets shall be designed to minimize risk to motorists, pedestrians, and cyclists. Grate inlets with horizontal openings parallel to the curb shall prohibit bicycle tires from passing through the openings. Inlets located in travel-ways shall be flush with the surface and equipped with traffic-graded tops. Inlets shall be designed to prohibit the entrance of children by restricting any opening from passing a 6-inch-diameter sphere.

COMMENTARY

Generally, the spread of storm water on residential streets and in sump locations is a minor inconvenience and lasts for only short periods after significant storm events. The spread of flow on streets and the performance of inlets may be determined by various formulas, nomographs, and computer models. HEC-12 is a computer application that allows input of street and flow characteristics to model inlet performance, including depth, spread, interception, carryover, and efficiency. Manipulation of Manning's Equation as expressed by Izzard allows calculation of the hydraulic capacity of a street section as follows in Equation 8:

$$Q = 0.56\frac{Z}{n}d^{8/3}S^{1/2} \quad \text{Eq. 8}$$

where:
- Q = flow (cfs);
- Z = $1/S_x$;
- S_x = cross-slope of the pavement (ft/ft);
- d = depth of water at face of curb (ft);
- S = longitudinal grade of street (ft/ft); and
- n = Manning's roughness coefficient.

STANDARDS	COMMENTARY
5.6 - Manholes	
Access for inspection and maintenance shall be provided through the use of manholes.	
5.6.1 - A manhole or inlet with access shall be placed at maximum distances of 800 feet (Ref. 9, p. 20). A manhole shall be located at changes in pipe size, grade, or alignment on straight runs and at all storm pipe intersections except roof drains.	Access openings for storm sewer systems can be placed at greater distances than formerly allowed due to advances in construction practices, inspection and cleaning equipment, and techniques for repair of damaged pipes.
5.6.2 - Manholes shall be constructed of the materials and to the specifications outlined in Section 9.	The most widely used manholes today are precast concrete, although brick, cast-in-place concrete, and premolded fiberglass plastic are acceptable options. Judgment should be used in selecting the most economical and functional material for each application.
5.6.3 - Manholes shall be designed to convey the flow adequately from influent to effluent pipes. The angle between influent and effluent pipes shall be not less than 90 degrees, and the drop between inverts shall be not less than 0.1 foot, except where calculations show that the design has no negative effects on the system due to loss of energy in the manhole.	The drop between the influent and effluent shall be adequate to convey the flow hydraulically in view of the angle of deflection and the velocity of influent and effluent, thereby ensuring hydraulic efficiency.
5.6.4 - Manholes shall be accessible and safe for maintenance personnel. Manhole steps shall be provided in accordance with ASTM C 478-88, or ladders shall be provided in conformance to OSHA standards (1910.27, 1910.268).	
5.6.5 - Manhole and inlet castings located in travelways shall be capable of withstanding traffic loads and shall meet the standards listed in Section 9. Manholes located in travelways shall be constructed flush with the finished surface so as not to pose a hazard to pedestrians or motorists.	Manhole covers are generally cast iron, but any structurally adequate material with appropriate durability is acceptable.
6.0 - CULVERTS	
Culverts provide for the passage of surface water beneath highways, streets, or other obstructions.	Driveways crossing properly designed street swales may not require culverts if the storm flow does not pose a hazard to motorists or damage the driveway surface. Pipes under driveways should be sized to maintain acceptable flow levels on streets according to Table 5 or to carry the 10-year flow when pipes are part of a major stream channel.

STANDARDS	COMMENTARY
6.1 - Allowable culvert materials include all allowable pipe materials outlined in Section 5.2.1. The selected material shall sustain the anticipated loads as required for a closed conduit system.	Culverts are available as circular, arch, oval, or box culverts. The selection of appropriate culvert shape should consider economy, clearances, and hydraulics.
6.2 - Culverts shall carry the 10-year design storm. The culvert size shall be selected to convey the design storm without overtopping embankments. Culverts less than 12 inches in diameter shall be equipped with a screen or grate on the upstream end to prohibit blockage. Culverts shall be sized according to the U.S. Department of Transportation "Hydraulic Charts for the Selection of Highway Culverts" (Ref. 10) or other appropriate method.	Culverts control either inlet or outlet flow, both of which are affected by headwater depth, the type of inlet, and the cross-sectional area of the culvert. Outlet control flow is further affected by the slope, roughness, length, and tailwater depth of the culvert. Considerable savings may be realized for inlet control culverts by designing improved inlets that allow for reduced culvert diameters.
6.3 - Where the culvert discharge velocity for the 10-year design storm reaches erosive levels for the receiving surface, an energy-dissipating device shall be provided to reduce velocities to acceptable levels.	Energy dissipation devices may include riprap, gabions, concrete slabs, or headwalls and wingwalls with a stilling basin.
7.0 - DETENTION AND RETENTION FACILITIES	
Detention and retention facilities control the release of runoff and sediment from a drainage system. The primary purpose of detention and retention facilities is to reduce the peak rate of storm water release and thereby control downstream flooding. The volume of storm water discharge as well as water-borne pollutants can be reduced by these structures.	Storm water detention may alleviate existing downstream drainage problems by reducing upstream release rates. Equitable cost-sharing incentives should be established to promote the use of these types of proactive storm water management projects at the scale of the individual development. Detention facilities also increase the aesthetic and recreational qualities of a development and can be used as part of a development's open space system.
7.1 - General **7.1.1** - Detention and retention facilities are defined as follows:	Assuming that they do not pose a threat to the health and safety of the community, detention/retention facilities may be located in the recreation area of a residential development. They may take the form of a pond in a park or a dry depressed area used for recreation.

STANDARDS	COMMENTARY

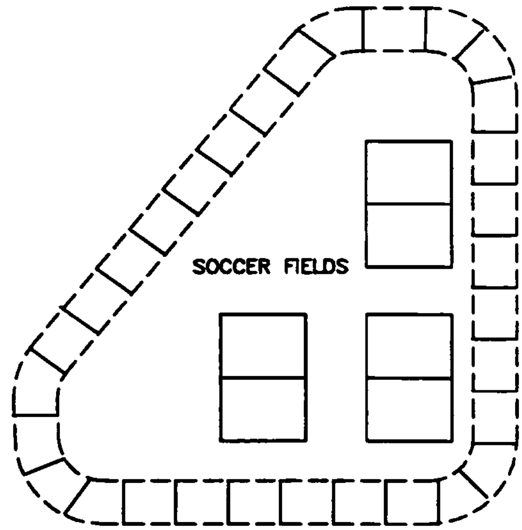

Figure 3. 100-Year Storm Detention Facility Designed for Use as a Recreation Area.

1. *Detention Facility.* A surface water runoff storage facility that is normally dry but is designed to hold (detain) surface water temporarily during and immediately after a runoff event (Ref. 4, p. 246).

Examples of detention facilities are natural swales provided with crosswise earthen berms that function as control structures; constructed or natural surface depressions; subsurface tanks or reservoirs; and infiltration or filtration basins.

2. *Retention Facility.* A surface water runoff storage facility always contains (retains) a substantial volume of water to serve recreational, aesthetic, water supply, or other functions. Surface water is temporarily stored above the normal stage during and immediately after runoff events (Ref. 4, p. 246).

Examples of retention storage facilities include ponds, wetlands, and small lakes in residential and commercial developments and public areas.

7.1.2 - Storm water detention shall comply with existing watershedwide requirements regarding acceptable discharge rates and volumes.

The discharge rates and volumes of detention facilities should be checked to see that frequent flood events do not increase damage to downstream areas.

STANDARDS

7.2 - Detention and Retention Facility Design

7.2.1 - The following table for storm events shall be used to design detention and retention facilities:

Table 6
STORM EVENT RETURN PERIOD FOR D/R FACILITIES

Component	Return Period
Discharge Flow Regulation for the Primary Spillway	2- and 10-year
Storage Capacity[1]	10-year
Emergency Spillway[2]	100-year

[1] Storage capacity shall be based on a minimum storm duration of 6 hours.
[2] Emergency spillways shall be designed for a storm duration of 24 hours.

7.2.2 - Detention and retention facilities shall be designed to meet the discharge requirements of Section 2.

7.2.3 - Routing of storm water through the pond shall be done by approved methodology.

7.2.4 - Overflow relief or emergency spillways for ponds shall be designed to pass flows estimated from the 100-year storm event without damaging the structure or severely damaging the spillway.

7.2.5 - The design of berms, dams, and appurtenances shall provide for all necessary engineering considerations associated with embankment construction, seepage control, earth fill and compaction, inlet and outlet construction and operation, hydrology and hydraulics, downstream hazard analysis, maintenance, safety, and stability.

7.2.6 - Maximum berm side slopes shall be 2:1. Side slopes shall be protected with grass, stone, or other adequate methods to prevent erosion and to stabilize the slope.

7.2.7 - Structural earth fills for retaining water shall be compacted to at least 90 percent of the standard Proctor density at optimum moisture content as provided in ASTM D 698.

COMMENTARY

D/R facilities are probably the most commonly used methods to control runoff rates. For safety reasons, the detailed design of these facilities becomes progressively important as both facility size and the potential hazard to downstream life and property increase. Larger facilities require the involvement of several government agencies, professionals, and the public in an expensive and time-consuming planning and design endeavor. Many small ponds common to residential development require less involvement but require many of the same engineering considerations.

Some approved methods of routing storm water through storage facilities include the following:

1. SCS TR-55
2. Puls
3. Modified Puls
4. Muskingom Method

Side slopes should reflect the structure's recreational purposes, if any, and thereby permit safe access and use. Lower side slopes should be considered where access is needed and high soil erodibility or instability exists. Slopes along D/R facilities or along channels that are to be maintained by power mowing should consider maximum slopes of 3:1.

STANDARDS	COMMENTARY
7.2.8 - Detention ponds (dry ponds) shall be designed with minimum bottom slopes of 2 percent or 0.5 percent where necessitated by topographical conditions. Trickle flow channels of concrete or other approved material shall be included in the design when continuous flows are expected or smaller bottom slopes are desired.	Piped underdrains are acceptable alternatives to trickle trenches. When detention ponds provide both recreational and storm water management functions, drainageways should be constructed to permit the removal of stored water within an acceptable time, thereby protecting vegetation and restoring recreational use after only minimal disruption.
7.2.9 - Retention ponds (wet ponds) shall be designed with a low drain valve or acceptable method to remove retained water for maintenance and dredging without releasing trapped sediment.	The design should consider available construction practices for draining the reservoir, diverting the base flow, and removing the sediment. The larger the expected sediment yield, the more important are maintenance operations to the design formulation.
7.2.10 - Retention pond design shall consider the effect of sedimentation on the required permanent storage volume.	Sediment yield and sediment storage capacity should be balanced to provide a reasonable period of service before bottom cleaning is required. The layout of the pond should promote sedimentation.
7.2.11 - Hydraulic control structures, appurtenances, and components shall be designed by using approved hydraulic calculation techniques and data. Outfalls must be designed to prevent erosion by incorporating energy dissipators and protective measures as necessary.	
7.2.12 - The minimum outlet pipe diameter shall be 6 inches. The minimum riser pipe diameter shall be 8 inches (Ref. 11, p. 122). Orifices or inlets subject to clogging shall be designed with a trash rack that adequately prevents clogging yet allows ease of maintenance. Designs shall inhibit unauthorized access to hazardous components of the drainage structure.	Trash rack openings should be sized to allow materials to pass safely through the protected orifice or pipe. The trash rack area should be 10 times the cross-sectional area of the protected orifice, pipe, gate, or valve (Ref. 4, p. 312).
8.0 - FLOODPLAIN MANAGEMENT	
Floodplain management is the extension of storm water management to address prevention of damage from anticipated catastrophic flooding events.	The major federal agency involved in floodplain management is the Federal Emergency Management Agency (FEMA).
8.1 - The 100-year base flood elevation (BFE) shall be the basis for establishing a floodplain area. **8.2** - The 100-year floodplain and the 100-year major system floodplain shall be delineated on the development plans.	The base flood or 100-year flood affects all land inundated by the flood. The base flood has a 1 percent chance of being equalled or exceeded in any given year.

STANDARDS

8.3 - The 100-year floodplain elevation shall be established by an approved method or source such as a Flood Hazard Boundary Map (FHBM), Flood Insurance Rate Map (FIRM), or Flood Insurance Studies (FIS) as approved by the Federal Emergency Management Agency (FEMA), the Federal Insurance Administration (FIA), or the National Flood Insurance Program (NFIP). In all cases, the most current information shall be used. Independent studies shall rely heavily on available local historical flood records, actual floodplain surveys, stream flow records, and approved backwater calculation methods. The impacts of potential development on the floodplain shall be adequately considered.

8.4 - Residential buildings located within the floodplain shall comply with FEMA requirements. The lowest floor of residential buildings, including basements, shall be above the base flood elevation. Within FEMA-designated coastal V-zones, residential buildings shall be designed to sustain high velocity waters. The bottom of the lowest horizontal structural members of the lowest floor, excluding pilings and columns, shall be at or above the base flood elevation (Ref. 12, p. 1-4).

COMMENTARY

The floodplain studies prepared by the federal government insurance programs neglect the potential impact of future development on the floodplain (Ref. 4, p. 45). Again, these issues are perhaps best resolved by careful regional planning. However, the literature does not identify a single, preferred method for adjusting a flood record to account for the effect of urbanization (Ref. 5, pp. 9-1 and 9-10).

Encroachment into the floodplain should be avoided for obvious safety and long-term economic reasons. Structures that are situated in the floodplain should consider flood-proof construction methods. The potential for the structure to impede riverine flood flow and increase the severity of flooding through backwater effects should also be considered (Ref. 12).

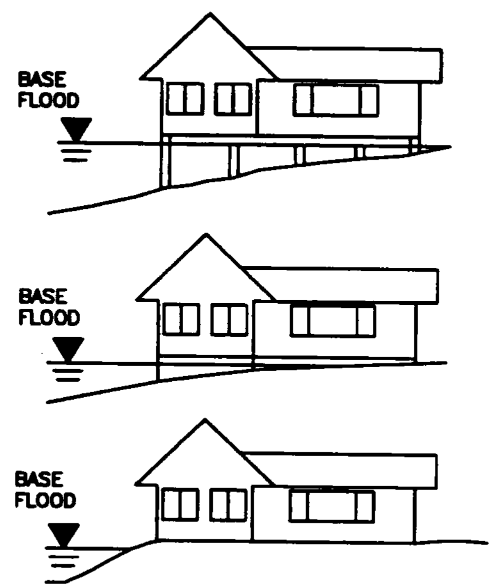

Figure 4. Base Flood Elevations for Residential Structures.

STANDARDS | COMMENTARY

9.0 - MATERIAL STANDARDS

All materials and appurtenances for storm water management systems shall conform to current standards of the American Society for Testing and Materials (ASTM), the American Standards Association (ASA), the American Water Works Association (AWWA), the American National Standards Institute (ANSI), or the General Services Administration (federal specifications) for the material type and its intended use. All installations shall be in accordance with manufacturers' recommendations where not governed by these standards.

The following specifications are applicable:

9.1 - Pipe and Joints

9.1.1 - Reinforced concrete pipe shall meet all requirements of ASTM C-76-89. Joints shall meet ASTM C443-85 requirements.

9.1.2 - PVC pipe and fittings shall conform to ASTM D-3034-89. Pipe shall be installed in accordance with ASTM D-2321-89. Pipe shall be free from defects, bubbles, and other imperfections in accordance with accepted commercial practice.

9.1.3 - Ductile iron and grey iron pipe, fittings, and joints shall be cement-lined and sealcoated and meet the requirements of Section 10 of the Water Supply Standards.

9.1.4 - Vitrified clay pipe shall meet ASTM C-700-89 and be installed in accordance with ASTM C-12-86. Vitrified clay joints shall conform to the requirements of ASTM C-425-88.

9.2 - Manholes

9.2.1 - Manholes shall be precast or cast-in-place concrete, brick, concrete block, or fiberglass.

9.2.2 - Precast reinforced concrete manholes shall conform to the requirements of ASTM C-478-88.

9.2.3 - Brick for manhole construction shall be dense, hard-burned clay brick conforming to ASTM C-62-89.

9.2.4 - Manhole frames and cover castings shall be iron conforming to ASTM A-48-83.

STANDARDS	COMMENTARY
9.3 - Installation and Testing **9.3.1** - Bedding classes A, B, or C as described in ASTM C12-86 (ANSI A106.2) shall be used for all rigid pipe. In addition, bedding classes I, II, or III as described in ASTM D2321-89 (ANSI K65.171) shall be used for all flexible pipe provided that pipe of the proper strength is used to support the anticipated load. **9.3.2** - Pressure systems shall be tested in accordance with AWWA C-600-87 and the provisions of the Water Supply Standards.	

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STORM WATER MANAGEMENT STANDARDS

APPENDIX

Table 1
RUNOFF DEPTH FOR SELECTED CNs AND RAINFALL AMOUNTS[1]

	Runoff Depth for Curve Number of												
Rainfall	40	45	50	55	60	65	70	75	80	85	90	95	98
						inches							
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

[1]Interpolate the values shown to obtain runoff depths for CNs or rainfall amounts not shown.

Source: *Urban Hydrology for Small Watersheds 2nd Edition (TR No. 55).* U.S. Department of Agriculture, Soil Conservation Service, 1986.

Table 2
RUNOFF CURVE NUMBERS

Soil Groups

A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type and Hydrologic Condition		A	B	C	D
Open Space (lawns, parks, golf courses, cemeteries, etc.)					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious Areas					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and Roads					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved, open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Residential Districts by Average Lot Size					
1/8 acre or less (townhouses)		77	85	90	92
1/4 acre		61	75	83	87
1/3 acre		57	72	81	86
1/2 acre		54	70	80	85
1 acre		51	68	79	84
2 acres		46	65	77	82
Newly Graded Areas (pervious areas only, no vegetation)		77	86	91	94
Meadow (continuous grass, protected from grazing and generally mowed for hay)		30	58	71	78
Brush (brush-weed-grass mixture with brush the major element)	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads (buildings, lanes, driveways, and surrounding lots)		59	74	82	86

Source: *Urban Hydrology for Small Watersheds 2nd Edition (TR No. 55).* U.S. Department of Agriculture, Soil Conservation Service, 1986.

Table 3
ROUGHNESS COEFFICIENTS (MANNING'S n) FOR SHEET FLOW

Surface Description	n[1]
Smooth Surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated Soils	
Residue cover ≤20	0.06
Residue cover >20%	0.17
Grass	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).

[2]Includes species such as weeping lovegrass, bluegrass, buffalograss, blue grama grass, and native grass mixtures.

[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

Source: *Urban Hydrology for Small Watersheds 2nd Edition (TR No. 55).* U.S. Department of Agriculture, Soil Conservation Service, 1986.

Table 4
I_a VALUES FOR RUNOFF CURVE NUMBERS

Curve Number	I_a (n)	Curve Number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Source: *Urban Hydrology for Small Watersheds 2nd Edition (TR No. 55).* U.S. Department of Agriculture, Soil Conservation Service, 1986.

Table 5
ADJUSTMENT FACTOR (F_p) FOR POND AND SWAMP AREAS SPREAD THROUGHOUT WATERSHED

Percent of Pond and Swamp Areas	F_p
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Source: *Urban Hydrology for Small Watersheds 2nd Edition (TR No. 55).* U.S. Department of Agriculture, Soil Conservation Service, 1986.

Table 6
SUMMARY OF TIME OF CONCENTRATION METHODS

Method and Date	Formula for T_c (minutes)	Remarks
Kirpich (1940)	$T_c = 0.0078\ (\frac{L^2}{S})\ 0.385$ L = length of channel/ditch from headwater to outlet (ft) S = average gully slope (ft/ft)	Developed from SCS data for seven rural basins in Tennessee with well-defined channel and steep slopes (3% to 10%). For overland flow on concrete or asphalt surfaces, multiply T_c by 0.4. For concrete channels, multiply by 0.2. No adjustment for overland flow on bare soil or flow in roadside ditches. Reference: *Civil Engineering*, Vol. 10, No. 6, June 1940.
Izzard (1946)	$T_c = \frac{41.025\ (0.0007\ i + c)L^{0.33}}{S^{0.333}\ i^{0.667}}$ i = rainfall intensity (in/hr) c = retardance coefficient L = length of flow path (ft) S = slope of flow path (ft/ft)	Developed in laboratory experiments by Bureau of Public Roads for overland flow on roadway and turf surfaces. Values of the retardance coefficient range from 0.0070 for very smooth pavement; to c = 0.012 for concrete pavement; to c = 0.06 for dense turf. Solution is extremely tedious and requires iteration. Product i times L should be < 500. Reference: *Proc. Highway Research Board*, Vol. 26, pp. 129-146, 1946.
Federal Aviation Agency (1970)	$T_c = \frac{1.8\ (1.1-C)L^{0.50}}{S^{0.333}}$ C = rational method runoff coefficient L = length of overland flow (ft) S = average overland slope (%)	Developed from air field drainage data assembled by the U.S. Army Corps of Engineers. Method is intended for use on airfield drainage problems but has been used frequently for overland flow in urban basins. Reference: "Airport Drainage," Federal Aviation Agency, Department of Transportation Advisory Circular, A/C 150-5320-5B, Washington, D. C., 1970.
Kinematic Wave Formulas Morgali (1965)	$T_c = \frac{0.94\ L^{0.6}\ n^{0.6}}{i^{0.4}\ S^{0.3}}$ L = length of overland flow (ft) n = Manning roughness coefficient i = rainfall intensity (in/hr) S = average overland slope (ft/ft)	Overland flow equation developed from kinematic wave analysis of surface runoff from developed surfaces. Method requires iteration since both i (rainfall intensity) and T_c are unknown. References: Morgali and R.K. Linsley, "Computer Simulation of Overland Flow," *J. Hyd. Div.* American Society of Civil Engineers, Vol. 91, No. 81, May 1965.
Old SCS Lag Equation (1975)	$T_c = \frac{L^{0.8}\left[\frac{1000}{CN} - 9\right]^{0.7}}{190\ S^{0.5}}$ L = hydraulic length of watershed (longest flow path) (ft) CN= SCS runoff Curve Number S = average watershed slope (ft/ft)	Equation developed by SCS from agricultural watershed data. It has been adapted to small urban basins under 2,000 acres. Generally a good equation where area is completely paved. For mixed areas, it tends to overestimate. Adjustment factors are applied to correct for channel improvement and impervious area. The equation assumes that T_c = 1.67 x basin lag. Reference: Soil Conservation Service Tech. Release No. 55, U.S. Department of Agriculture, January 1975.
New SCS Sheet Flow Equation	$T_c = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ S^{0.4}}$ L = overland flow length (ft) n = Manning n for sheet flow P_2 = 2 yr. - 24 hr. rainfall (in) S = overland slope (ft/ft)	Equation developed by SCS for Revised TR-55, June 1986.

Source: *ASCE Hydrology Manual No. 28 (Revised), Chapter 9: Urban Hydrology (Draft Copy).* Task Committee on Chapter 9, American Society of Civil Engineers, 1992.

Figure 1. Solution of Runoff Equation

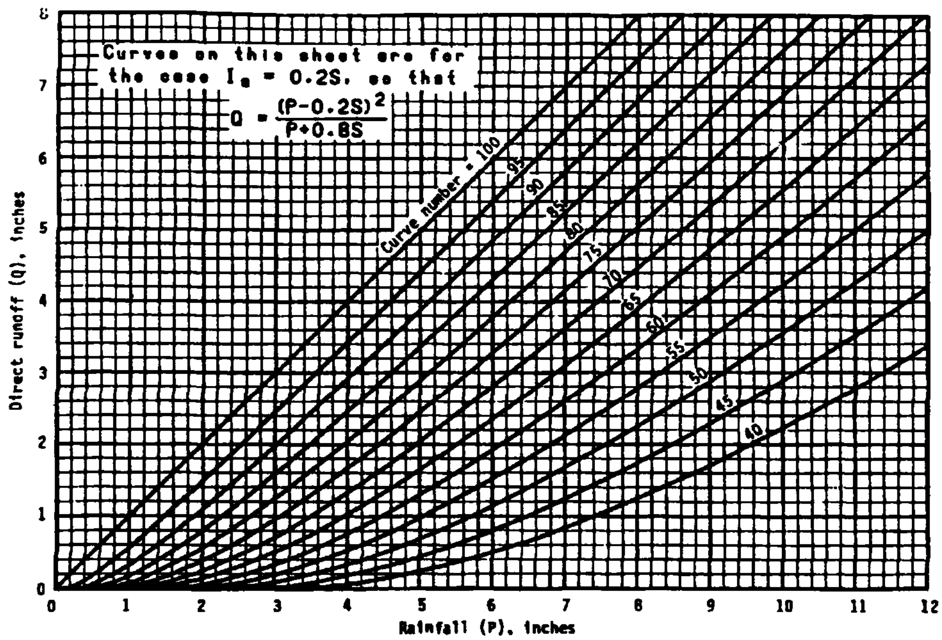
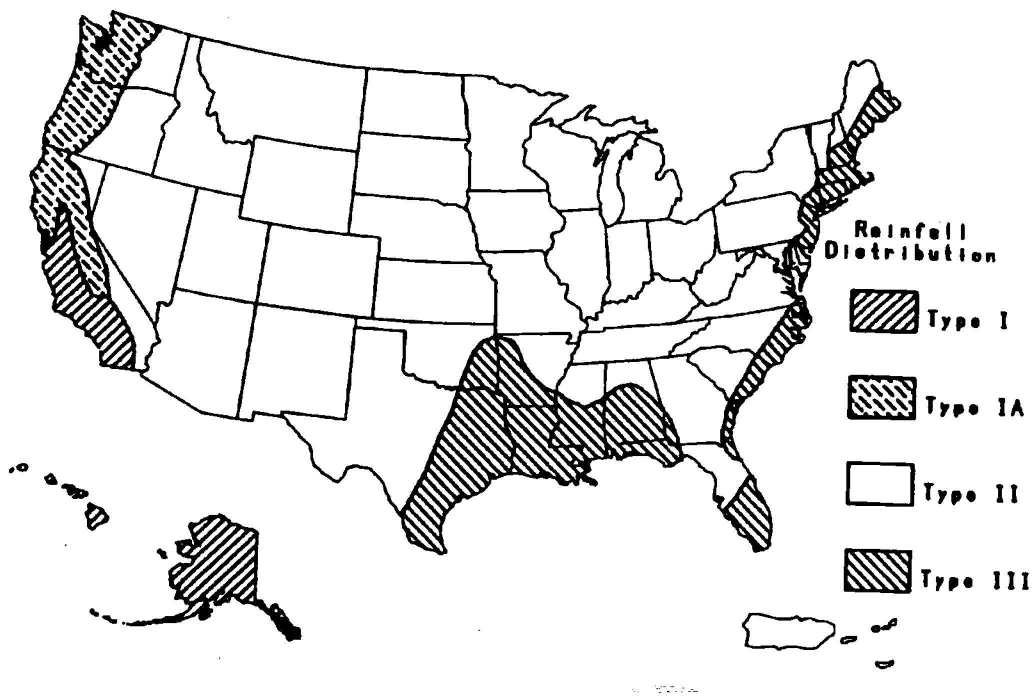


Figure 2. Approximate Geographic Boundaries for SCS Rainfall Distributions



Source (both figures): *Urban Hydrology for Small Watersheds 2nd Edition (TR No. 55).* U.S. Department of Agriculture, Soil Conservation Service, 1986.

Figure 2-I. Unit Peak Discharge (q_u) for SCS Type I Rainfall Distribution.

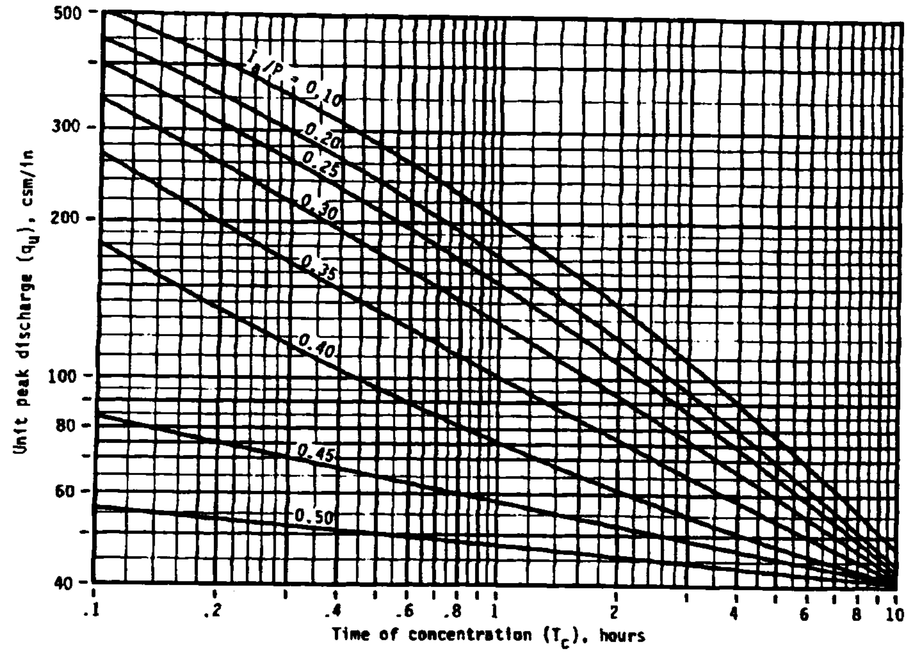
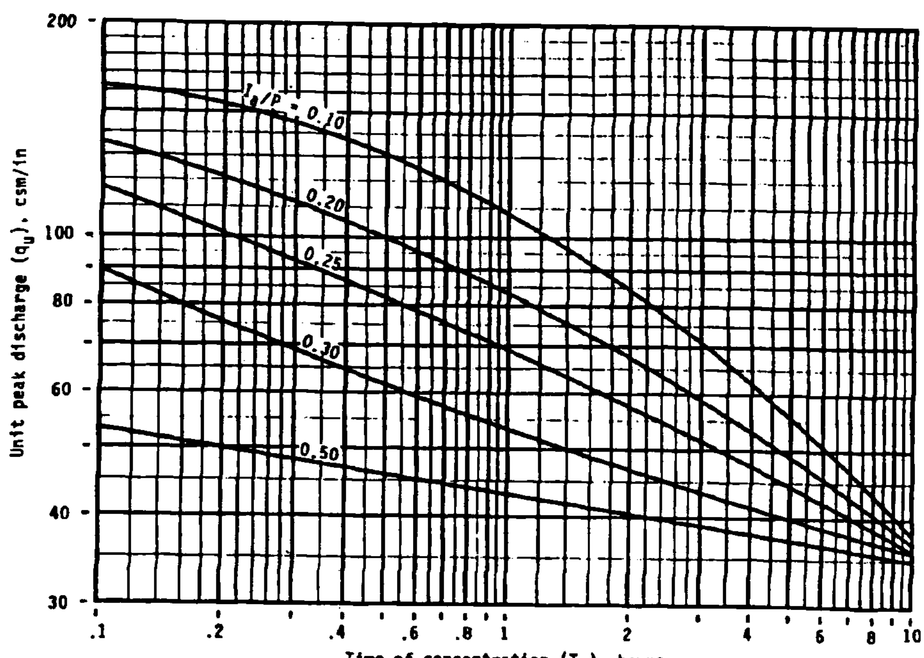


Figure 2-IA. Unit Peak Discharge (q_u) for SCS Type IA Rainfall Distribution



Source (both figures): *Urban Hydrology for Small Watersheds 2nd Edition (TR No. 55).* U.S. Department of Agriculture, Soil Conservation Service, 1986.

Figure 2-II. Unit Peak Discharge (q_u) for SCS Type II Rainfall Distribution

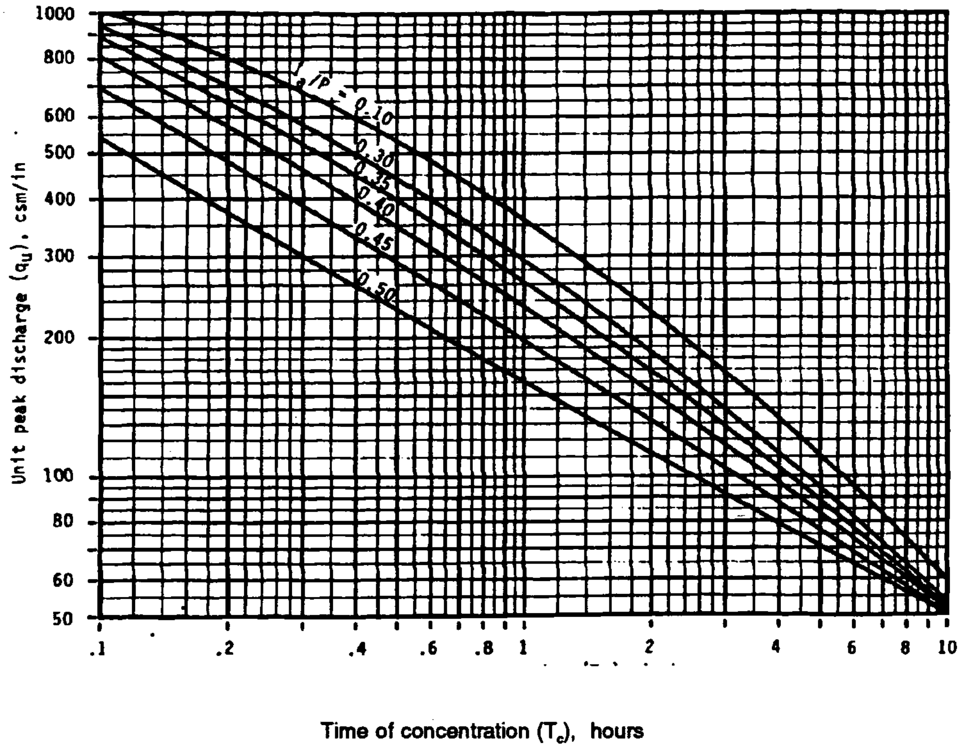
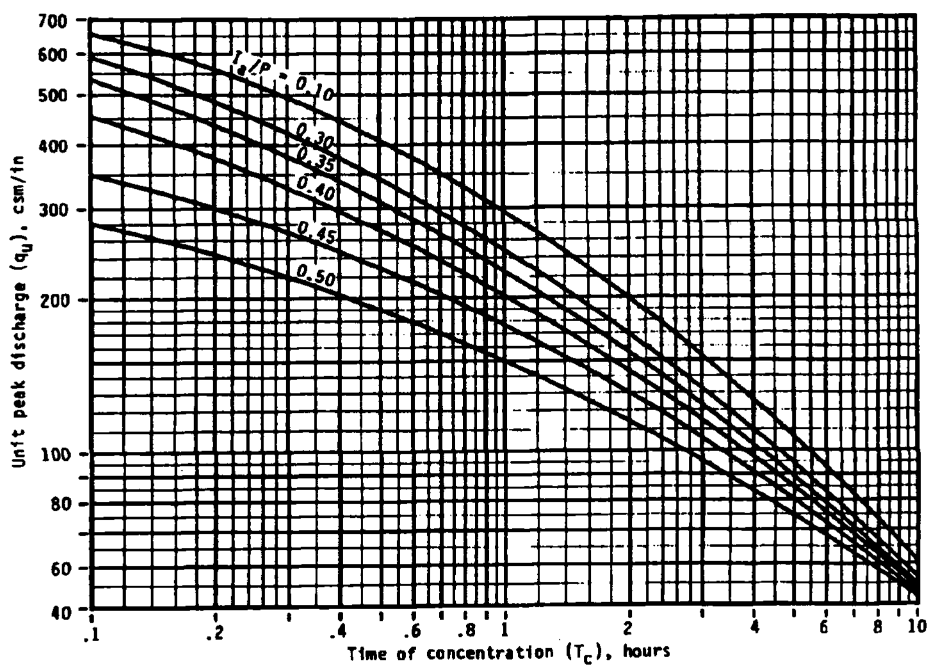
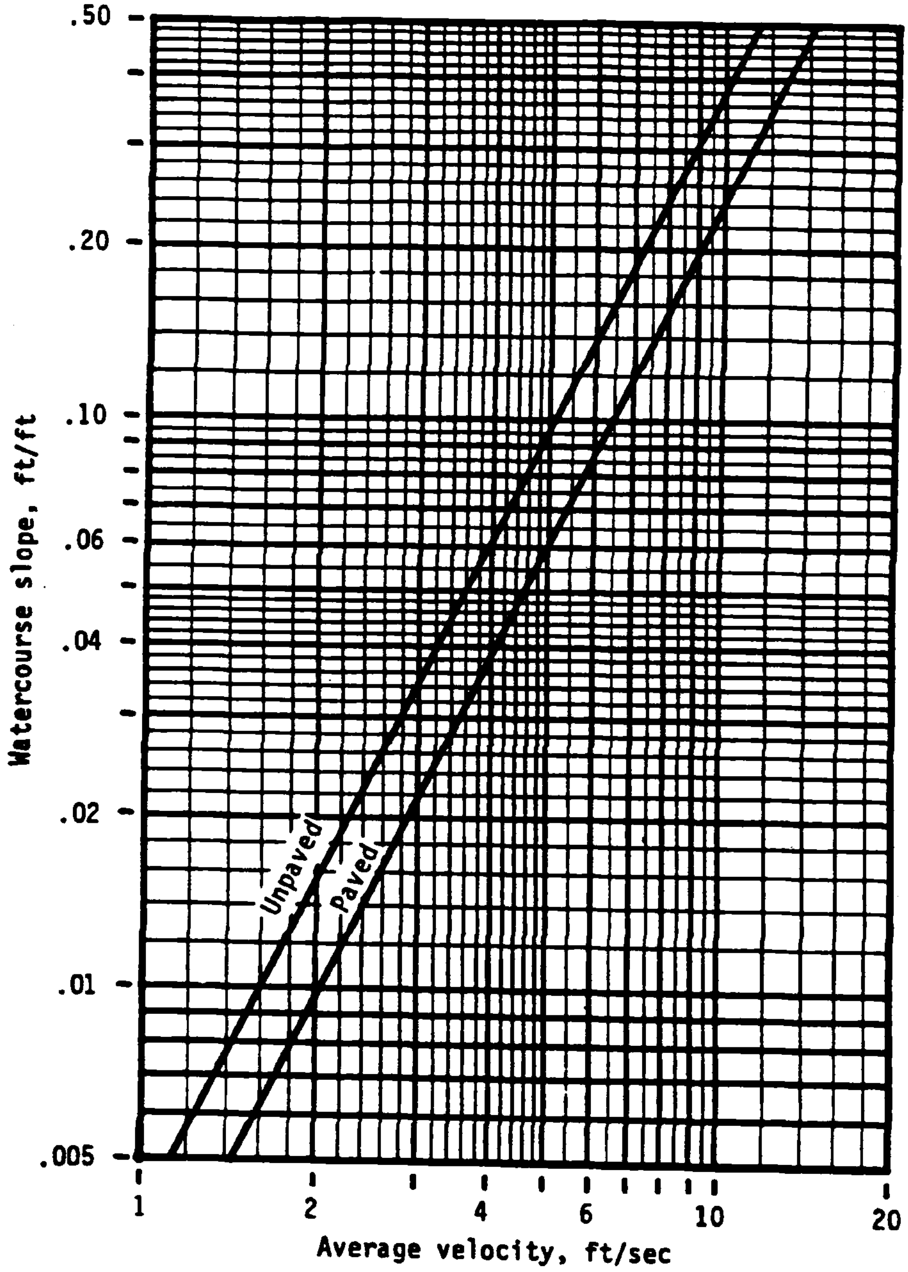


Figure 2-III. Unit Peak Discharge (q_u) for SCS Type III Rainfall Distribution



Source (both figures): *Urban Hydrology for Small Watersheds 2nd Edition (TR No. 55).* U.S. Department of Agriculture, Soil Conservation Service, 1986.

Figure 3. Average Velocities for Estimating Travel Time for Shallow Concentrated Flow



Source: *Urban Hydrology for Small Watersheds 2nd Edition (TR No. 55)*. U.S. Department of Agriculture, Soil Conservation Service, 1986.

TEMPORARY SEDIMENT AND EROSION CONTROL STANDARDS

Sediment and erosion control practices protect development sites, adjacent properties, and downstream waterways from excessive sediment deposition and erosion. This is accomplished by applying conservation practices that reduce the potential for erosion and sediment transport while capturing and retaining excessive sedimentation. These measures are considered Best Management Practices (BMPs) because they prevent or reduce nonpoint source water pollution.

Sediment and erosion control is especially important during construction when the ground is susceptible to the effects of wind, water, ice, and gravity. Conservation measures inhibit these effects. Measures may be temporary and remain in place until the construction project is completed, or they may be permanent and remain in place indefinitely.

While careful consideration was given to each section of this standard, a locality may, based on sound engineering practices, waive any part of these standards to meet unique needs or provide equivalent alternatives.

CONTENTS

STANDARDS	COMMENTARY
1.0 - GENERAL CRITERIA	
1.1 - Standard vegetative control and structural practices shall be selected, designed, and constructed as specified in Sections 3 and 4. Controls that filter, divert, or promote the settlement of sediment particles from storm runoff shall be provided in the following situations: 1. to prevent sediment-laden runoff from leaving disturbed areas; 2. to isolate disturbed areas from erosive surface runoff associated with significant undisturbed areas; 3. to protect storm drainage conveyance systems at operable inlets that collect untreated runoff from denuded areas.	Control practices use trapping, filtering, or diversion techniques to protect adjacent properties from land disturbance activities.
1.2 - All conservation measures shall possess the structural integrity to withstand the effects of the two-year return storm.	
1.3 - The limits of construction disturbance and vegetation to be protected shall be clearly delineated on plans. The corresponding locations shall be physically marked at the construction site before the start of construction operations.	Disturbed areas shall be minimized and natural vegetation shall be protected and retained during design and construction to the greatest extent possible. The limits of construction disturbance should extend only to those areas required to accommodate the proposed construction. Consideration should be given to valuable tree stands and easily eroded areas with critical soils or slopes that "necessitate the installation of more costly control measures" (Ref. 1). Flagging, signs, or otherwise physically marking the limits of construction inhibits the inadvertent disturbance of areas during construction.
1.4 - Where applicable, projects shall comply with the National Pollutant Discharge Elimination System (NPDES) requirements and permitting process. 1.5 - The requirements of the Storm Water Management Standard regarding allowable discharges, velocities, and adequate outfalls shall apply to all conservation measures.	The purpose of the NPDES program is to identify potential sources of erosion and pollution from storm water discharge and to provide mechanisms to reduce pollutants. Construction activities that disturb five acres or more of land area are targeted by the plan. Nondelegated states must comply directly with the EPA's NPDES program while delegated states independently issue and administer NPDES model programs. Current nondelegated states are Alaska, Arizona, Florida, Idaho, Louisiana, Maine, Massachusetts, New Hampshire, New Mexico, Oklahoma, South Dakota, and Texas.

STANDARDS

2.0 - CONSERVATION PROVISIONS

2.1 - Conservation measures for major grading operations shall be installed as soon as practical to address the changing landscape of the construction site.

2.2 - Stabilization measures shall be initiated on disturbed areas as soon as practical but no more than 14 days after construction activity on a particular portion of the site has temporarily or permanently ceased. Exceptions to the requirement are

1. where permanent controls at all points of runoff have been provided;
2. where construction activities will resume on a portion of the site within 21 days from when the construction activities ceased;
3. where the initiation of stabilization measures is precluded by snow cover or frozen ground; or
4. in arid areas (areas with an average annual rainfall of 0 to 10 inches) and semi-arid areas (areas with an average annual rainfall of 10 to 20 inches) where the initiation of stabilization measures is precluded by seasonal arid conditions.

2.3 - Off-site vehicle tracking of sediment and the generation of dust from the construction site shall be minimized. This shall be accomplished by providing a construction entrance or undertaking street sweeping as necessary.

2.4 - The disturbance of watercourses shall be avoided to the greatest extent possible due to the watercourses' potential for sediment transport. Channels shall be stabilized immediately after any in-channel work is completed. Where existing or proposed permanent ponds are used as sediment basins during the construction process, the trapped sediment shall be removed after all upstream areas are permanently stabilized. The pond shall be cleaned to its original or design invert.

COMMENTARY

A conservation plan should be prepared to coordinate efforts and define the responsibilities of designers, construction superintendents, and inspectors. Plans should detail the schedule of operations and where and when various erosion and sediment control practices should be installed. Efforts to plan development to fit a site's particular topography, soils, drainage patterns, and natural vegetation are critical in controlling erosion and sedimentation. When possible, land-disturbing activities should be avoided on large or critical areas during months of intense erosive rainfall.

Soil stabilization refers to establishing ground covers that protect soil from the erosive forces of raindrop impact and flowing water. "Stabilization measures are often the most important measures taken to prevent offsite sediment movement and can provide large reductions of suspended sediment levels in discharges and receiving waters" (Ref. 2). Applicable practices include vegetative establishment, mulching, and the early application of a gravel base on areas to be paved. Soil stabilization practices should be selected for their appropriateness for the time of year, site conditions, and estimated duration of use. These stabilization standards are modifications of the EPA's NPDES requirements.

Construction traffic and access routes required for a project should be addressed in the planning stage. The least disruptive route practical for the type and amount of expected traffic should be chosen. Temporary access and haul roads should be clearly designated.

Although some amount of stream channel nourishment by sedimentation is beneficial, the stream should be protected during construction operations from excessive amounts, which can be damaging. Where a flowing stream must be crossed frequently by construction vehicles, a temporary stream crossing as described in Section 4.11 should be employed.

STANDARDS	COMMENTARY
2.5 - On linear projects, areas shall be protected from sediment deposition by limiting the exposed trench length. The exposed trench length shall be limited to that which can be opened and filled in one working day.	Linear projects are those that involve a narrow path of disturbance. Construction such as sewer or waterline projects progresses along the path.
2.6 - Sedimentation shall be minimized by the responsible placement of excavated material. Excavated material shall be placed in protected areas clear of ditch or erosive flows. Material shall be placed on the uphill side of trenches on linear projects where consistent with safety and space considerations. Where excavated material is stockpiled, the stockpile shall be adequately protected with structural or vegetative measures due to the material's erosion potential.	
2.7 - Permanent and temporary cut-and-fill slopes shall be designed and constructed to maintain stability and minimize erosion and, if necessary, be equipped with special stabilization measures. Slopes found to be eroding excessively shall be provided with additional slope-stabilizing measures until the problem is corrected.	The type of slope protection provided, if any, should consider the length and steepness of the slope, the soil type, the upslope drainage area, groundwater conditions, and other specific site conditions. Soil roughening and diversions as described in Section 4 are two acceptable methods to improve slope stabilization.
2.8 - All conservation measures shall be inspected and maintained at regular intervals and after significant rainfall events to ensure their function and effectiveness. Sediment trapping devices shall be cleaned as required in Section 4.6 and in the appendix to this standard for each specific device. Vegetation planted on excessive slopes of 2:1 or greater shall be of the type able to flourish with limited maintenance.	Maintenance of vegetation should include measures necessary to establish and sustain growth, including watering or fertilization as required.
2.9 - At the completion of the project when final site stabilization is achieved, all temporary conservation measures shall be removed and any trapped sediment removed from the site or permanently stabilized.	

3.0 - VEGETATIVE PRACTICES

The following vegetative practices are acceptable methods of minimizing erosion and sedimentation. These may be temporary or permanent practices. Persons engaged in planning, designing, installing, and maintaining sediment control measures may use these or other generally accepted standard engineering and agricultural practices.

STANDARDS / **COMMENTARY**

3.1 - Topsoiling. Topsoiling involves techniques for preserving and using topsoil to enhance final site stabilization with vegetation. Stockpiling of topsoil shall be done in such a manner that natural drainage is not obstructed and no off-site sediment damage results.

3.2 - Seeding. Seeding permits the establishment of a permanent or temporary vegetative cover on disturbed areas by planting seed. Seed shall be evenly applied. Areas that fail to establish vegetative cover shall be reseeded as soon as such areas are identified.

Seeding provides stabilization to reduce erosion and sedimentation and problems associated with mud and dust production from bare soil surfaces.

3.3 - Sodding. Sodding establishes permanent turf immediately through the placement of sod. Sod strips laid in drainageways shall consist of plant materials able to withstand the designed velocity and shall be secured with pegs, staples, or wire netting as necessary.

Sod limits erosion, sedimentation, mud, and dust problems and can be used to stabilize drainageways where concentrated overland flow will occur.

3.4 - Mulching. Mulching is the application of grass, hay, wood chips, wood fibers, straw, gravel, or other suitable materials to the soil surface. Seeded and planted areas where slopes are steeper than 2:1 shall be stabilized with mulch.

Mulching protects the soil surface from raindrop impact and reduces the velocity of overland flow. Mulching fosters the growth of vegetation by holding the seeds, fertilizers, and topsoil in place; by helping to retain moisture; and by providing insulation against extreme heat or cold. Mulching is often used alone in areas where temporary seeding is not feasible because of season or climate. A binder, netting, or the tacking of mulch to the ground may or may not be required depending on the area of application.

4.0 - STRUCTURAL PRACTICES

The following temporary structural practices are acceptable methods of minimizing erosion and sedimentation. Persons engaged in planning, designing, installing, and maintaining sediment control measures may use these or other generally accepted standard engineering and agricultural practices.

Depending on the specific construction activities, adequate conservation provisions for a site may be provided by one or any combination of the practices in this section or by stabilization measures alone. Modifications to standard practices or innovative conservation practices may be employed but should be thoroughly described and detailed before application.

4.1 - Construction Entrance. Construction entrances shall comply with the design, construction, and maintenance requirements given in the appendix to this standard.

A construction entrance is a stone stabilized pad located at points of vehicular ingress and egress on a construction site. The pad reduces the amount of mud and sediment transported onto public roads by vehicles or runoff. A diagram of a typical stabilized construction entrance is shown in the appendix to this standard.

STANDARDS

COMMENTARY

4.2 - Straw Bale Barrier. Where used, straw bale barriers shall be placed on downslope areas to intercept sediment or to reduce flow velocity. Straw bale barriers shall not be constructed in streams or swales where there is the possibility of a washout.

A straw bale barrier involves the use of baled straw or hay placed in various combinations to reduce flow velocities and intercept sediment. A straw bale barrier may also be used to divert or direct runoff to a slope drain, sediment trap, or other control measure.

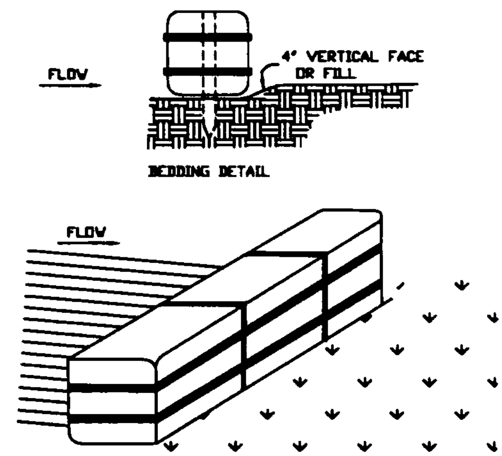


Figure 1. Typical straw bale barrier.
(Source: Commonwealth of Virginia. *Virginia Erosion and Sediment Control Handbook: Second Edition.* 1980)

4.3 - Silt Fence. Silt fences shall comply with the design, construction, and maintenance requirements given in the appendix to this standard. Silt fences shall not be constructed in streams or swales.

A silt fence is a vertical barrier with wood or metal fenceposts to which a filter fabric is attached. The fence traps sediment before it leaves the construction area. It detains construction runoff but permits sedimentation while filtering the water. An example sketch of a silt fence is shown in the appendix to this standard.

4.4 - Storm Drain Inlet Protection. Filter fabric, excavated gravel, straw bale, and block and gravel inlet protections shall comply with the design, construction, and maintenance requirements given in the appendix to this standard. Storm drain inlet protection alone shall not be used below disturbed drainage areas greater than one acre.

An inlet protection is either an excavated impounding area around a storm drain drop inlet or curb inlet or a sediment filter constructed of straw bales, filter fabric, block and gravel, wire mesh and gravel, or sod. It reduces the sediment entering the storm drainage system before stabilization of disturbed areas.

4.5 - Diversion Swale or Dike. Diversion swales and dikes shall meet stabilization requirements given in Section 2.2 and shall comply with the design, construction, and maintenance requirements given in the appendix to this standard.

A diversion swale is a small excavated channel. A dike is a ridge of compacted soil. Each is used to intercept runoff and divert it to a sediment control device around a disturbed area or to an area where it can be safely released. A diagram of a typical earth dike is shown in the appendix to this standard.

STANDARDS	COMMENTARY
4.6 - Sediment Trap. Sediment traps shall comply with the design, construction, and maintenance requirements given in the appendix to this standard.	A sediment trap is a small storage or detention area constructed by excavating a depression, using a natural depression, or creating an impoundment with a low head dam. Sediment traps are used to detain construction runoff long enough to allow the larger-sized sediment particles to settle out before the runoff is released to downstream areas. A diagram of a typical sediment trap is shown in the appendix to this standard.
4.7 - Temporary Sediment Basin. Temporary sediment basins shall be engineered based on an analysis of the expected storm runoff. They shall be sized to provide a minimum volume of 3,600 cubic feet (Ref. 2, p. 3-62) per disturbed acre draining to the facility.	A sediment basin performs the same function as a sediment trap, although it has a greater volume and is located below disturbed areas generally greater than five acres.

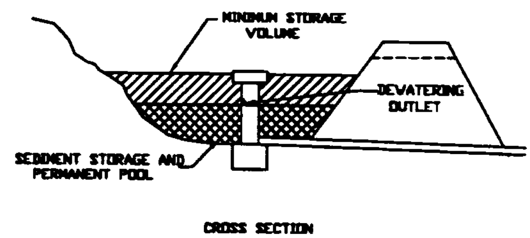


Figure 2. Typical Temporary Sediment Basin.
(Source: U.S. Environmental Protection Agency. *Storm Water Management for Construction Activities.* 1992)

STANDARDS	COMMENTARY
4.8 - Temporary Slope Drain. Pipe slope drains shall comply with the design, construction, and maintenance requirements given in the appendix to this standard. Pipe slope drains shall release flow at nonerosive energy levels for the receiving surface as required for pipe and culvert discharges in the appendix to the Storm Water Management Standards.	A temporary slope drain is a device used to carry runoff from one elevation to a lower elevation without excessive erosion of the slope. Slope drains may be plastic sheets, metal or flexible pipe, stone gutter, fiber mats, concrete or asphalt ditches, or half-round pipe.
4.9 - Check Dam. Check dams shall comply with the design, construction, and maintenance requirements given in the appendix to this standard.	A check dam is a small dam constructed of logs or stone across a swale or drainage ditch to reduce the water's velocity and to trap small amounts of sediment.

STANDARDS

4.10 - Level Spreader. Level spreaders shall be located at the outlets of dikes or diversions. Level spreaders shall not be constructed on fill material.

COMMENTARY

A level spreader is an excavated depression constructed at zero grade across a slope. It converts a concentrated flow to a sheet flow, allowing water to be released at less erosive levels.

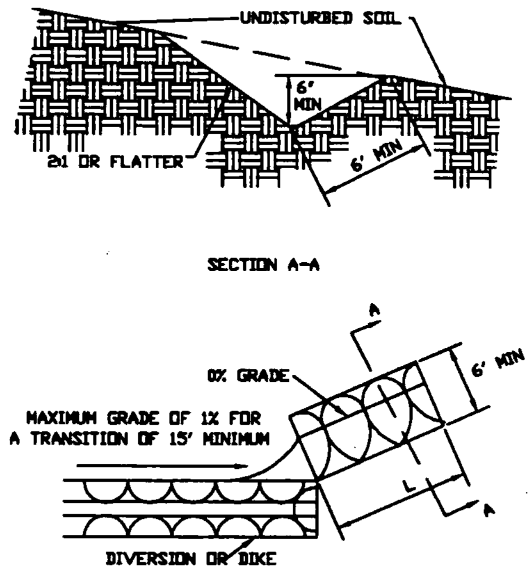


Figure 3. Typical Level Spreader.
(Source: Commonwealth of Virginia. *Virginia Erosion and Sediment Control Handbook: Second Edition.* 1980)

4.11 - Temporary Stream Crossing. When construction traffic must frequently cross a flowing watercourse, a temporary stream crossing shall be constructed.

A temporary stream crossing is a structural span installed across a flowing watercourse for use by construction traffic. It may consist of bridges, round pipes, or pipe arches, all of which provide a means of both crossing streams without damaging the channel or banks and keeping sediment generated by construction traffic out of the stream.

REFERENCES

1. Commonwealth of Virginia. *Virginia Erosion and Sediment Control Handbook: Second Edition.* Virginia Department of Conservation and Historical Preservation, Division of Soil and Water Conservation. 1980.

2. U.S. Environmental Protection Agency. *Storm Water Management for Construction Activities.* 1992.

TEMPORARY SEDIMENT AND EROSION CONTROL STANDARDS

APPENDIX

SILT FENCE

Application

Silt fences are appropriate at the following general locations:

- Immediately upstream of the point(s) of runoff discharge from a site before flow becomes concentrated (maximum design flow rate should not exceed 0.5 cubic feet per second).
- Below disturbed areas where runoff may occur in the form of overland flow.

Materials

Allowable materials include the following:

- Burlap of 10 ounces per square yard of fabric.
- Synthetic filter fabric fabricated of a pervious sheet of polypropylene, nylon, polyester, or polyethylene yarn conforming to the requirements in Table 1 below.

Table 1
SYNTHETIC FILTER FABRIC REQUIREMENTS

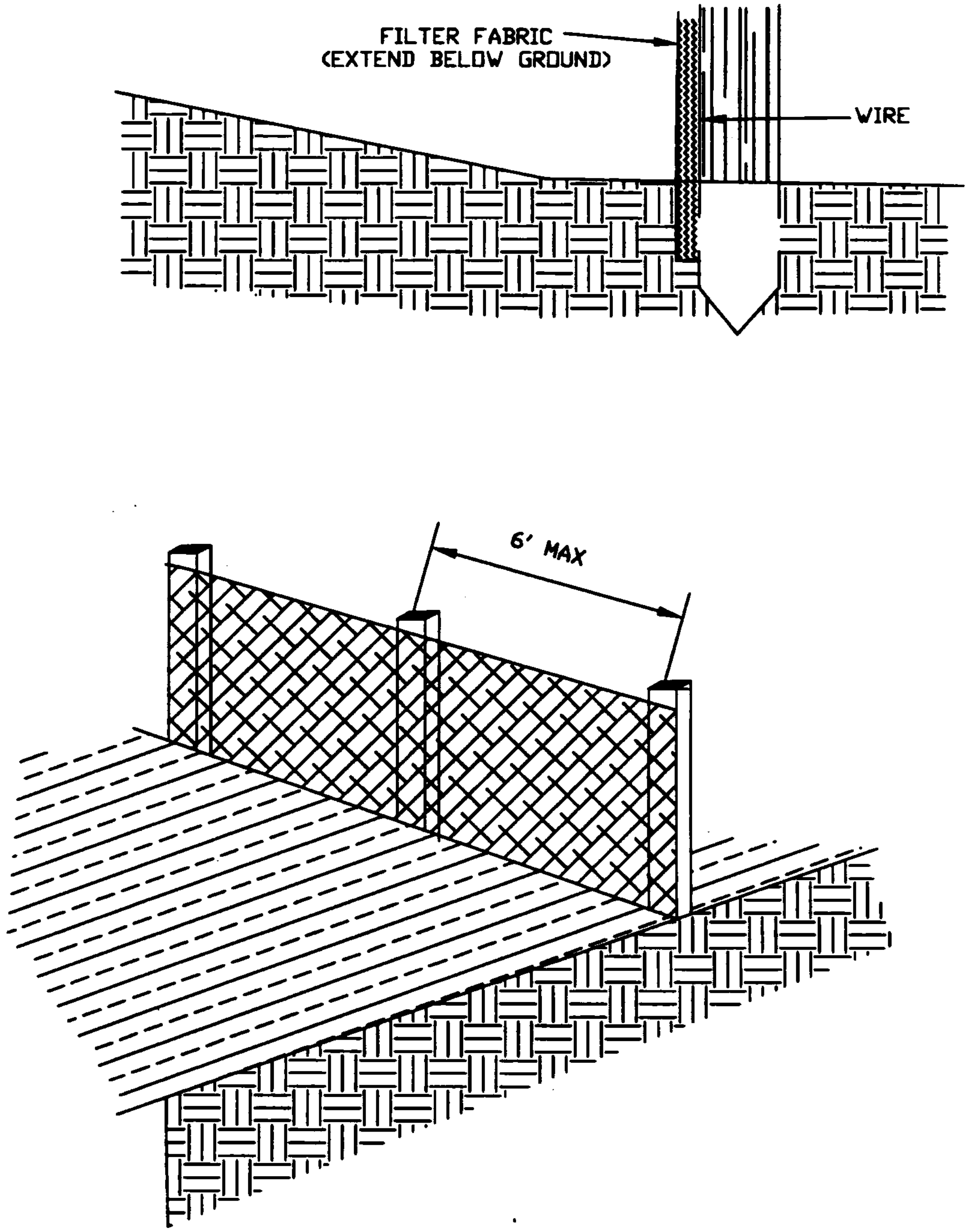
Physical Property	Requirements
Filtering Efficiency	75 to 85 percent (minimum)
Tensile Strength at 20 percent (maximum) Elongation	Standard Strength--30 lb/linear inch (minimum) Extra Strength--50 lb/linear inch (minimum)
Slurry Flow Rate	0.3 gal/ft^2/min (minimum)

- Synthetic filter fabric should contain ultraviolet ray inhibitors and stabilizers to provide a minimum of six months of expected usable construction life at a temperature range of 0°F to 120°F.

Maintenance and Inspection

- Inspect filter fences daily during periods of prolonged rainfall, immediately after each rainfall event, and weekly during periods of no rainfall. Make any required repairs immediately.
- Remove sediment when it reaches one-third to one-half the height of the filter fence.

TYPICAL SILT FENCE



SOURCE: MODIFIED FROM STATE OF NORTH CAROLINA, 1980,
AND STATE OF WISCONSIN, 1980.

PIPE SLOPE DRAIN

Application

Pipe slope drains (PSD) are appropriate in the following general locations:

- On cut or fill slopes before permanent storm water drainage structures are installed.
- Where earth dikes or other diversion measures have been used to concentrate flows.
- On any slope where concentrated runoff that crosses the face of the slope may cause gullies, channel erosion, or saturation of slide-prone soils.
- As an outlet for a natural drainageway.

Construction Specifications

- Place the PSD on undisturbed or well-compacted soil.
- Place filter cloth under the inlet and extend it 5 feet in front of the inlet and key and 6 inches on all sides to prevent erosion. A 6-inch metal toe plate may also be used to prevent erosion.
- Ensure firm contact between the pipe and the soil at all points.
- Securely stake the PSD to the slope at intervals of 10 feet or less.
- Ensure that all slope drain sections are securely fastened together and have watertight fittings.
- Extend the pipe beyond the toe of the slope and discharge at a nonerosive velocity into a stabilized area (e.g., rock outlet protection may be used) or to a sedimentation trap or pond.

Maintenance and Inspection

- Inspect after every storm. Make any necessary repairs.
- Check to see that water is not bypassing the inlet and undercutting the inlet or pipe. If necessary, install a headwall or sandbags.
- Check for erosion at the outlet point and check the pipe for breaks or clogs. Install additional outlet protection if needed and immediately repair breaks and clean any clogs.

CONSTRUCTION ENTRANCE

Application

A construction entrance is appropriate wherever vehicles are leaving a construction site and entering a public road.

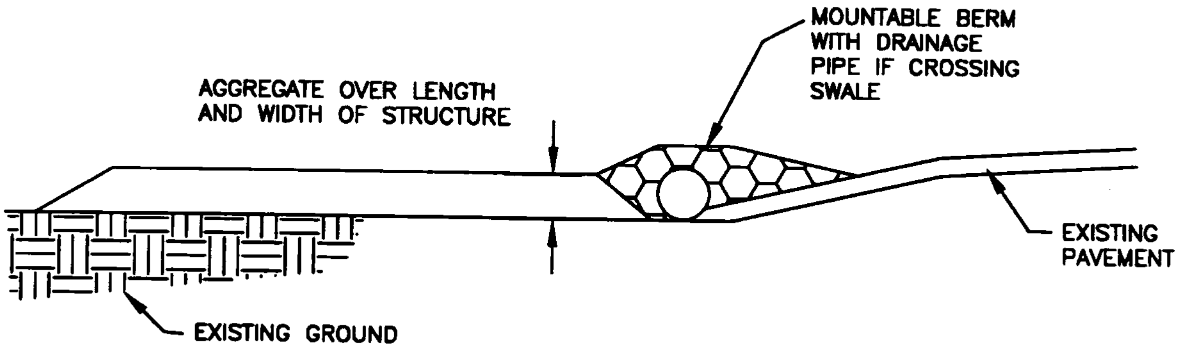
Construction Specifications

- Clear all vegetation, roots, and other obstructions in preparation for grading.
- Place stone to a depth of 6 inches or greater for the entire width and length of the construction entrance.
- Provide at least a 10-foot width.
- Flare the entrance where it meets the existing road to provide a turning radius.

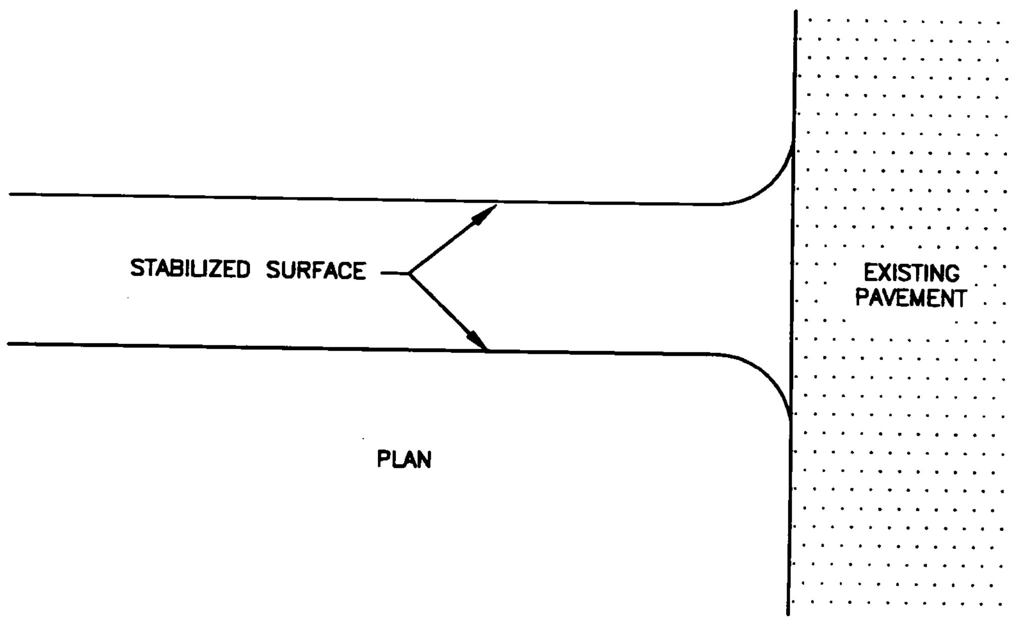
Maintenance and Inspection

- Inspect the measure after a high volume of traffic uses the construction entrance or after a storm event.
- Apply additional stone periodically and when repair is required.

TYPICAL STABILIZED CONSTRUCTION ENTRANCE



PROFILE



PLAN

SOURCE: MODIFIED FROM MARYLAND DEPARTMENT OF THE ENVIRONMENT, 1991.

FILTER FABRIC INLET PROTECTION

Application

Inlet protection is appropriate in the following locations:

- Small drainage areas (less than 1 acre) where the storm drain inlet is functional before the drainage area has been permanently stabilized.
- Where there is danger of sediment silting in an inlet that is in place before permanent stabilization.
- In drainage areas with slopes of 5 percent or less. The slope of the area immediately surrounding the inlet should not exceed 1 percent. This type of inlet protection is not appropriate for use in paved areas because the filter fabric requires staking.

Materials

- Filter fabric
- Wooden stakes 2 inches by 2 inches or 2 inches by 4 inches
- Washed gravel

Construction Specifications

- To avoid failure caused by pressure against the fabric when overtopping occurs, limit the height of the filter fabric to 1.5 feet above the crest of the drop inlet.
- Place a stake at each corner of the inlet and around the edges at no more than 3 feet apart.
- For stability, install a framework of wood strips around the stakes at the crest of the overflow area 1.5 feet above the crest of the drop inlet.
- Excavate a trench 8 inches in depth around the outside perimeter of the stakes. If a sediment trapping sump is to be provided, the excavation may be as deep as 2 feet.
- Staple the filter fabric to the wooden stakes with heavy-duty staples, overlapping the joints to the next stake. Allow 12 to 32 inches of filter fabric to extend beyond the bottom of the stakes for formation into the trench.
- Place the bottom of the fabric in the trench and backfill the trench all the way around with washed gravel to a minimum depth of 4 inches.

Maintenance and Inspection

- Inspect after every storm and make any necessary repairs.
- Remove sediment and restore the trap to its original dimensions when sediment accumulates to one-half the design depth of the trap.

EXCAVATED GRAVEL INLET PROTECTION

Application

Inlet protection is appropriate in the following locations:

- Small drainage areas (less than 1 acre) where the storm drain inlet is functional before the drainage area has been permanently stabilized.
- Where there is danger of sediment silting in an inlet that is in place before permanent stabilization.
- Where ponding around the inlet structure could be a problem to on-site traffic.

Materials

- Hardware cloth or wire mesh
- Filter fabric
- Washed gravel

Construction Specifications

- Excavated gravel and mesh inlet protection may be used with most inlets where overflow capability is needed and in areas of heavy flows of 0.5 cfs or greater.
- The trap should have a sediment trapping sump of 1 to 2 feet measured from the crest of the inlet.
- To achieve maximum trapping efficiency, the longest dimension of the basin should be oriented toward the longest inflow area.
- Remove any obstructions to excavating and grading. Excavate sump area, grade slopes, and properly dispose of soil.
- Secure the inlet grate to prevent seepage of sediment-laden water.
- Place wire mesh over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Overlap the strips of mesh if more than a single strip is needed.
- Place filter fabric over the mesh and extend it at least 18 inches beyond the inlet opening on all sides. Ensure that weep holes in the inlet structure are protected by filter fabric and gravel.

Maintenance and Inspection

- Place stone/gravel over the fabric/wire mesh to a depth of at least 1 foot.
- Inspect after every storm and make any necessary repairs.
- Remove the sediment and restore the trap to its original dimensions when sediment accumulates to one-half the depth of the trap.

BLOCK AND GRAVEL INLET PROTECTION

Application

Block and gravel inlet protection is appropriate in the following locations:

- Small drainage areas (less than 1 acre) where the storm drain inlet is functional before the drainage area has been permanently stabilized.
- Where there is danger of sediment silting in an inlet that is in place before permanent stabilization.

Materials

- Hardware cloth or wire mesh
- Filter fabric
- Concrete block
- Washed gravel

Construction Specifications

- Block and gravel inlet protection may be used with most types of inlets where overflow capability is needed and in areas of heavy flows of 0.5 cfs or greater.
- To achieve maximum trapping efficiency, the longest dimension of the basin should be oriented toward the longest inflow area.
- Secure the inlet grate to prevent seepage of sediment-laden water.
- Place wire mesh over the drop inlet so that the wire extends a minimum of 12 to 18 inches beyond each side of the inlet structure. Overlap the strips of mesh if more than a single strip is needed.
- Place concrete blocks in a single row lengthwise on their sides along the sides of the inlet. The foundation should be excavated a minimum of 2 inches below the crest of the inlet, and the bottom row of blocks should be placed against the edge of the structure for lateral support.
- Place the concrete blocks such that the open ends of the blocks face outward not upward and the ends of adjacent blocks abut. Lay one block on its side on each side of the structure to allow for dewatering of the pool.
- Construct the block barrier to at least 12 inches in depth depending on the size of block.
- Before backfilling, place wire mesh over the outside vertical end of the blocks to prevent stone from washing down the inlet.
- Place gravel against the wire mesh to the top of the blocks.

Maintenance and Inspection

- Inspect after every storm and make any necessary repairs.
- Remove the sediment and restore the trap to its original dimensions when sediment accumulates to one-half the design depth of the trap.

CHECK DAMS

Application

Check dams are appropriate for use in the following locations:

- Across swales or drainage ditches to reduce the velocity of flow.
- Where velocity must be reduced because a vegetated channel lining has not yet been established.

Materials

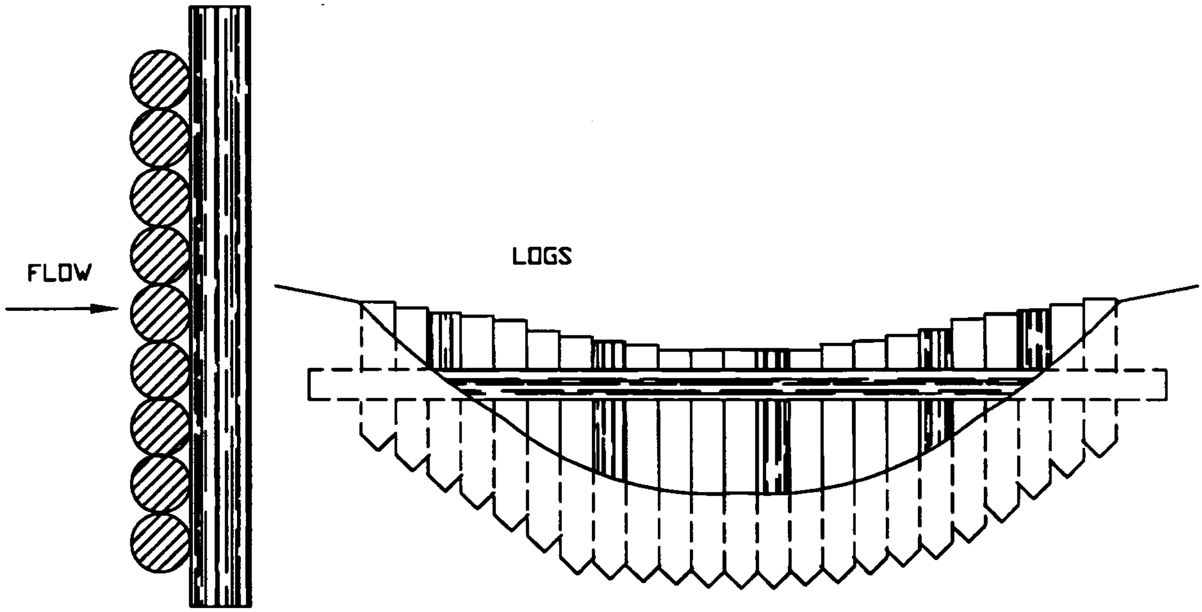
- Stone 2 to 15 inches in diameter
- Logs 6 to 8 inches in diameter
- Sandbags filled with pea gravel
- Filter fabric

Construction Specifications

- The drainage area above the check dam should be between 2 and 10 acres.
- The center of the check dam must be 6 to 9 inches lower than either edge, and the maximum height of the dam should be 24 inches.
- The check dam should be as much as 18 inches wider than the banks of the channel to prevent undercutting when overflow water re-enters the channel.
- For rock check dams, place the stone on the filter fabric, extend the stone 18 inches beyond the banks, and keep the side slopes 2:1 or flatter.
- For log check dams, firmly embed the logs in the ground to a minimum 18 inches in depth.
- For sandbag check dams, securely seal and place bags by hand or use appropriate machinery.

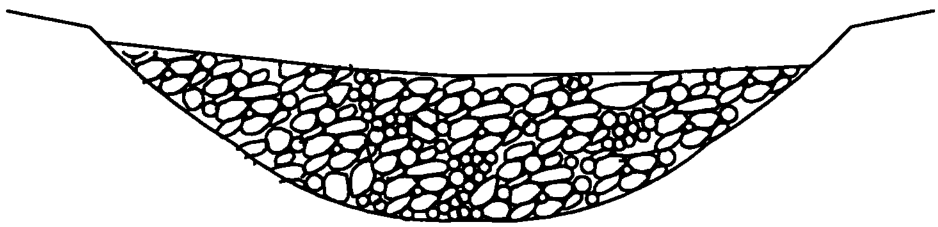
Maintenance and Inspection

- Inspect after every storm and make any necessary repairs.
- Remove accumulated sediment and leaves from behind the dam and repair any erosive damage to the channel after each storm or when one-half the original height of the dam is reached.
- If sandbags are used, inspect the fabric of the bags for signs of deterioration.

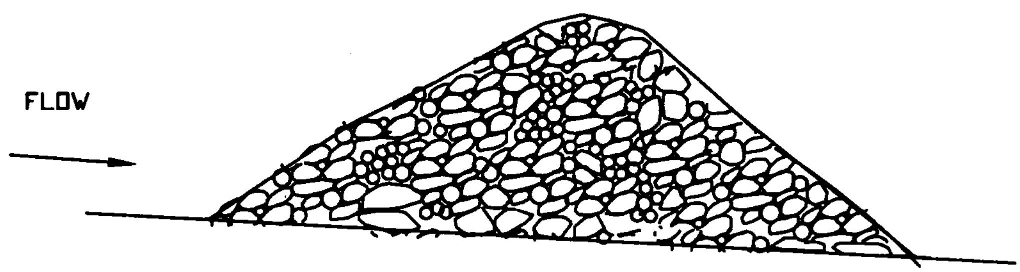


PLAN VIEW

LOG CHECK DAM



SECTION ROCK CHECK DAM



SECTION ROCK CHECK DAM

SOURCE: U.S. ENVIRONMENTAL PROTECTION AGENCY, 'STORM WATER MANAGEMENT FOR CONSTRUCTION ACTIVITIES,' 1992.

EARTH DIKE

Application

Earth dikes are appropriate in the following situations:

- To divert upslope flows away from disturbed areas such as cut or fill slopes and to divert runoff.
- To reduce the length of slope crossed by runoff.
- At the perimeter of the construction site, to prevent sediment-laden runoff from leaving the site.

Materials

- Compacted soil
- Coarse aggregate

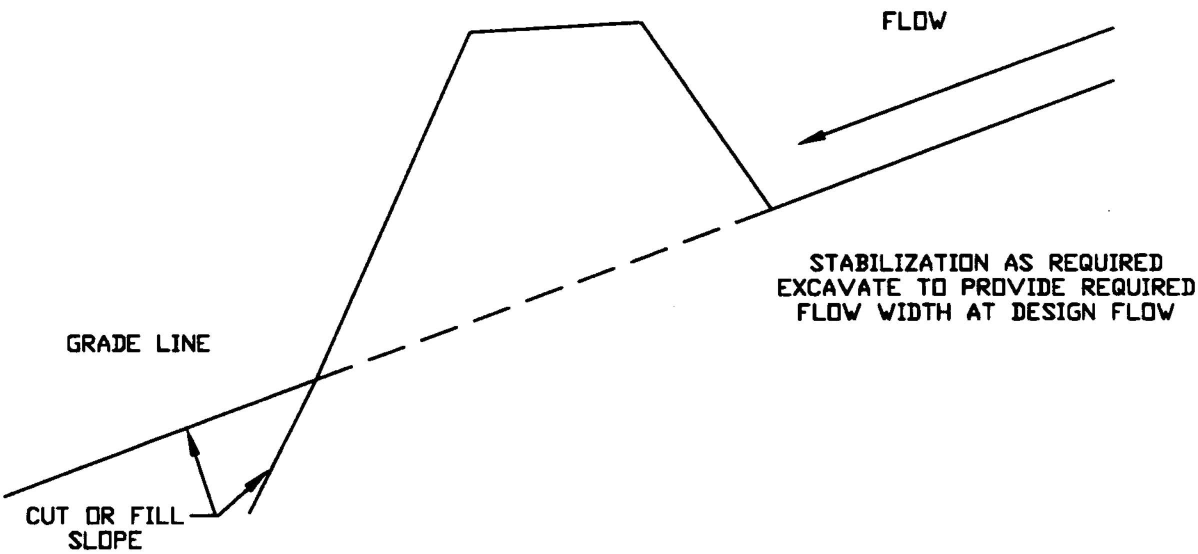
Construction Specifications

- Direct sediment-laden runoff to a sediment-trapping device.
- The base for a dike 18-inches-high and 24-inches-wide at the top should be between 6 and 8 feet. The height of the dike is measured on the upslope side.
- If the dike is constructed of coarse aggregate, the side slopes should be 3:1 or flatter.
- The channel formed behind the dike should have a positive grade to a stabilized outlet. The channel should be stabilized with vegetation or other stabilization measures.

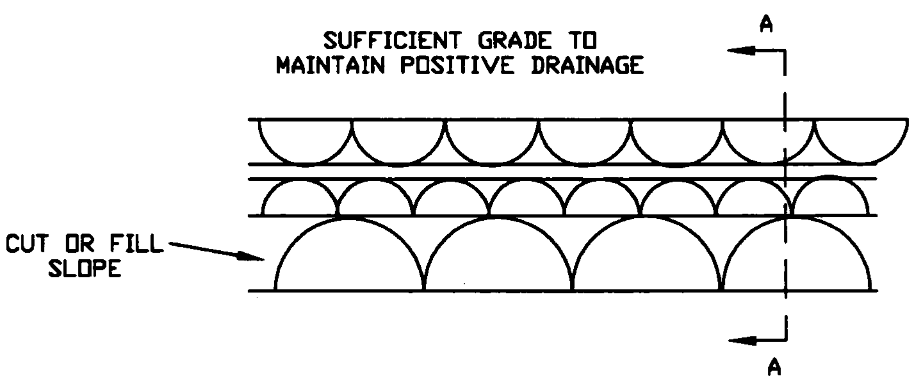
Maintenance and Inspection

- Inspect after every storm and make any necessary repairs.
- Inspect the dike, flow channel, and outlet for deficiencies or signs of erosion.
- Reseed or stabilize the dike as needed to maintain its stability.

TYPICAL EARTH DIKE



CROSS SECTION A-A



PLAN VIEW

SOURCE: MODIFIED FROM MARYLAND DEPARTMENT OF THE ENVIRONMENT, 1991.

SWALE

Application

Temporary diversion swales are appropriate in the following situations:

- To divert upslope flows away from disturbed areas such as cut or fill slopes and to divert runoff to a stabilized outlet.
- At the perimeter of the construction site to prevent sediment-laden runoff from leaving the site.
- To direct sediment-laden runoff to a sediment trapping device.

Materials

- Grass seed for temporary or permanent stabilization
- Sod
- Coarse aggregate or riprap

Construction Specifications

- The channel should have a uniform positive grade.
- The channel should be stabilized with temporary or permanent stabilization measures.
- Runoff must discharge to a stabilized outlet.

Maintenance and Inspection

- Inspect after every storm and make any necessary repairs.
- Inspect the flow channel and outlet for deficiencies or signs of erosion.
- Reseed or stabilize the channel as needed to prevent erosion during a storm event.

TEMPORARY SEDIMENT TRAP

Application

Temporary sediment traps are appropriate in the following locations:

- At the outlet of the perimeter controls installed during the first stage of construction.
- At the outlet of any structure that concentrates sediment-laden runoff, e.g., at the discharge point of diversions, channels, slope drains, or other runoff conveyances.
- Above a storm water inlet that is in line to receive sediment-laden runoff.

Materials

- Filter fabric
- Coarse aggregate or riprap 2 to 14 inches in diameter
- Washed gravel
- Seed and mulch for stabilization

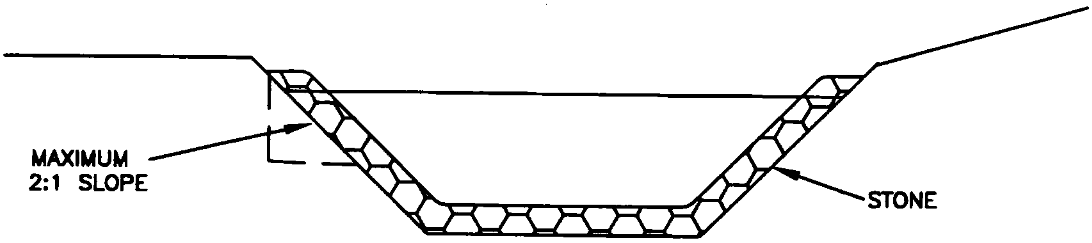
Construction Specifications

- Temporary sediment traps may be constructed by excavation alone or by excavation in combination with an embankment.
- The drainage area for the sediment trap should not exceed 5 disturbed acres.
- Sediment traps are temporary measures and should not be left in place longer than 18 to 24 months.
- The capacity of the sedimentation pool should provide storage volume for 3,600 cubic feet/acre drainage area.
- The embankment may not exceed 5 feet in height.

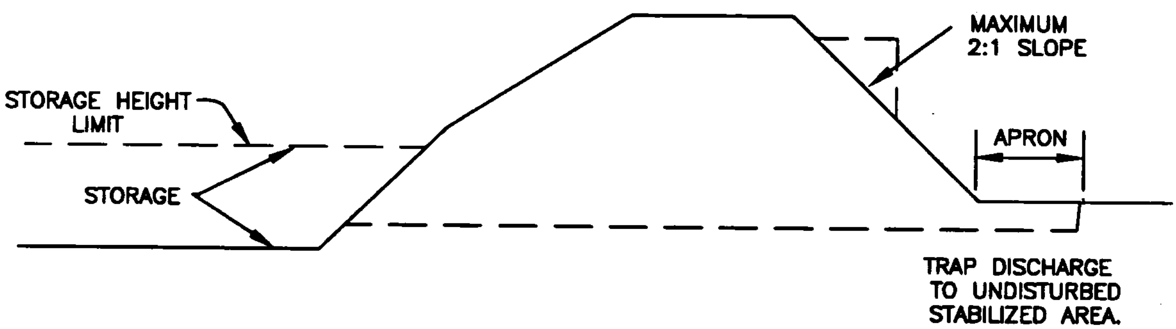
Maintenance and Inspection

- Inspect after every storm and make any necessary repairs.
- Frequent removal of sediments is critical to the functioning of this measure. At a minimum, remove the sediment and restore the trap to its original volume when sediment reaches one-eighth of its original volume.

TYPICAL SEDIMENT TRAP



CROSS SECTION



PROFILE

SOURCE: MODIFIED FROM STATE OF MARYLAND, "STANDARDS AND SPECIFICATIONS FOR SOIL AND EROSION AND SEDIMENT CONTROL", 1983.

SOURCES

The material in this appendix was extracted and modified from *Storm Water Management for Construction Activities*, U.S. Environmental Protection Agency, 1992. The following sources are cited extensively in this reference.

- Commonwealth of Virginia, County of Fairfax. *1987 Check List for Erosion nd Sediment Control.* Fairfax County, Virginia. 1987.

- State of North Carolina. *Erosion and Sediment Control Planning and Design Manual.* North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development. 1988.

- Maryland Department of the Environment. *1991 Maryland Standards and Specifications for Soil Erosion and Sediment Control* (draft). 1991.

- State of Washington. *Storm Water Management Manual for the Puget Sound Basin.* Department of Ecology. 1991.

SITE UTILITIES STANDARDS

This section provides minimum standards for the safe installation of gas, electric, cable television, and telephone facilities. Where used, street lighting, signal wiring, irrigation systems, district heating, and other utility systems shall also comply with these standards.

These systems are, for the most part, provided by privately owned utility companies that are also responsible for system maintenance and service. Cost, aesthetics, and safety should be considered in utility placement. Critical economic factors to consider in above-ground or underground placement are subsurface conditions, the number of poles required, and the possibility of joint trenching.

While careful consideration was given to each section of this standard, a locality may, based on sound engineering practices, waive any part of these standards to meet unique needs or provide equivalent alternatives.

CONTENTS

STANDARDS

1.0 - GENERAL

1.1 - Utilities and/or their related facilities that are not the maintenance responsibility of individual home owners shall be accessible by placement within an easement or right-of-way.

COMMENTARY

Rather than dedicating additional right-of-way, utilities may be placed in easements whenever possible to economize on the use of land. Easement widths may be reduced by using joint trenches, which limit clearing and disturbance and preserve natural areas. An example of joint trench utility locations is shown in Figure 1.

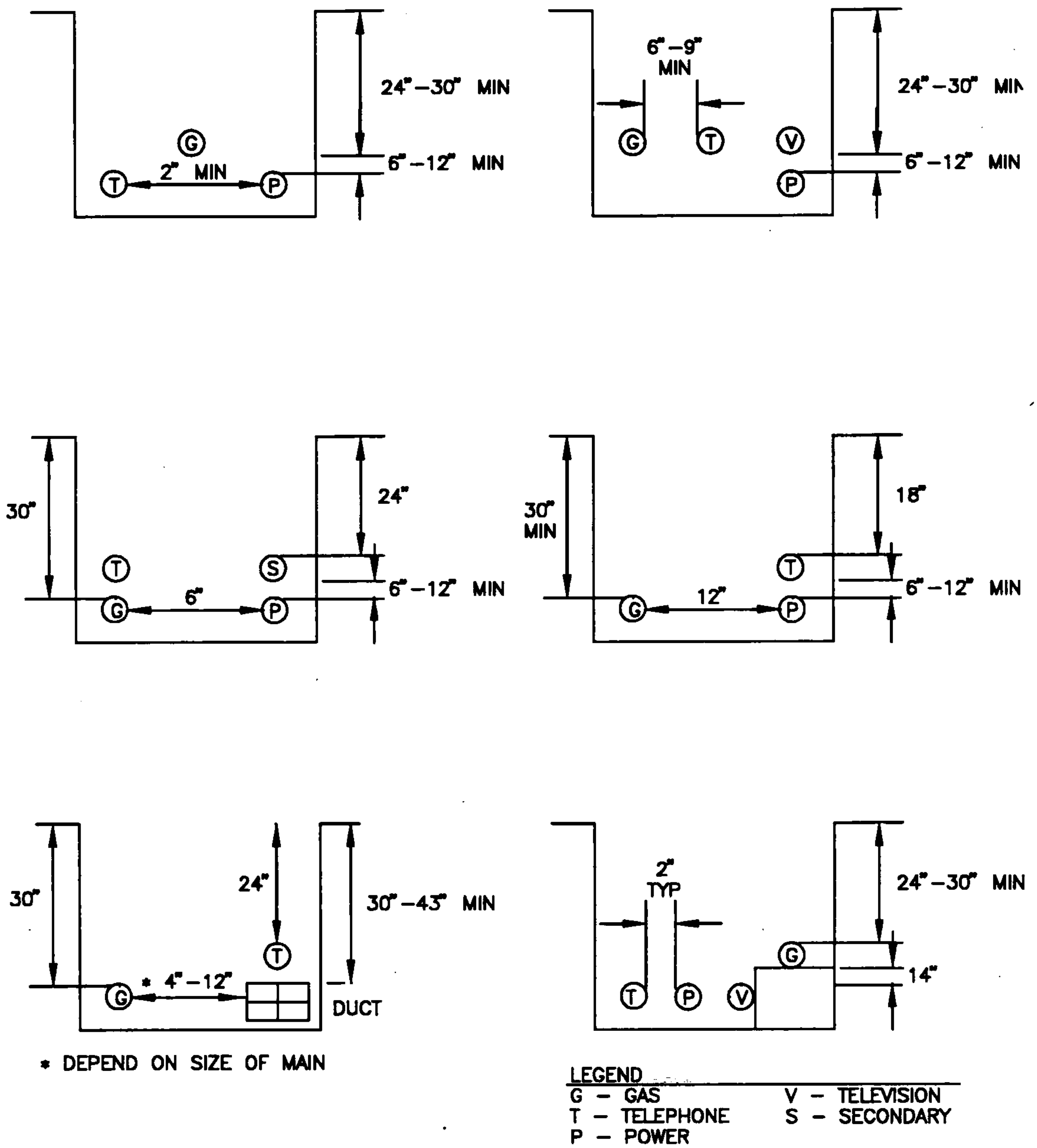


Figure 1. Typical Joint Trench Cross Sections.
(Source: U.S. Dept. of Housing and Urban Development. *Innovative Site Utility Installations*. 1983)

STANDARDS	COMMENTARY
1.2 - All electric supply and communication lines and equipment shall comply with requirements of the 1993 National Electric Safety Code (Ref. 1) or local utility company requirements regarding grounding, materials, clearances, protection, and cover.	The National Electric Safety Code covers the basic provisions for safeguarding persons from hazards arising from the installation, operation, or maintenance of electric currents. The code applies to all electric supply and communication facilities, including cable television and telephone.
1.3 - All gas installations on consumer's premises shall comply with requirements of the 1992 National Fuel Gas Code (Ref. 2) or local building code requirements regarding materials, clearances, protection, and cover. All gas transmission and distribution piping systems shall comply with ANSI Standard B31.8-1982 or local utility company requirements.	The National Fuel Gas Code offers general criteria for the installation and operation of gas piping and gas equipment from the point of delivery, which is generally the outlet of the service meter, to the connections with each gas utilization device. ANSI Standard B31.8 provides criteria for the gas piping distribution system and should be followed for portions of the system not covered by the National Fuel Gas Code.
2.0 - ABOVE-GROUND FACILITIES When above-ground utility facilities are used, they shall be safely set back from the roadway as specified in Section 5.7 of the Street Standards.	The rigidity of utility obstructions placed along roadways should consider the density of development and the potential hazard to pedestrians, opposing traffic, adjacent buildings, and the impacting vehicle.
3.0 - SUBSURFACE FACILITIES	
3.1 - Utility companies shall allow for the future location of facilities and prevent accidental damage to buried facilities by physically marking their location, documenting their as-built location, and/or uniformly aligning them with streets or other physical features.	A common method of marking nonmetallic utility lines is by installing tracer tape. The tracer tape is placed approximately 1 foot above the top of the line and allows detectors on the surface to locate the utility.
3.2 - Conduit placed beneath roadways shall be capable of withstanding the anticipated load and shall meet requirements for AASHTO H-20 loading.	By placing conduit beneath roadways, maintenance or future installation of buried utilities can be accomplished without expensive destruction of pavement and interruption of traffic.

REFERENCES

1. Institute of Electrical and Electronics Engineers. *1993 National Electric Safety Code (ANSI C2-1993).* 1992.

2. American Gas Association and National Fire Protection Association. *National Fuel Gas Code (ANSI Z223.1-1992, NFPA 54-1992).* 1992.

SANITARY SEWAGE SYSTEMS STANDARDS

The purpose of the sanitary sewage system is to dispose of domestic sewage safely. Both public and private treatment and disposal systems are acceptable.

While careful consideration was given to each section of this standard, a locality may, based on sound engineering practices, waive any part of these standards to meet unique needs or provide equivalent alternatives.

CONTENTS

STANDARDS

1.0 - SANITARY SEWER DESIGN-GRAVITY SYSTEMS

The sanitary sewage system shall safely collect and deliver sewage to its treatment location or to an existing collection system. Gravity systems shall be designed with the hydraulic grade line below the crown of the pipe. Since domestic sewage flows are often concentrated at particular times of the day, the sewage system shall be designed to carry the peak flow. The system shall be separate from and resistant to surface- and groundwater infiltration and inflow. Future ultimate development shall be considered in design of the system where adjacent areas have no other available means for sewage disposal. An easement shall be provided to allow access for future connections of public systems.

1.1 - The sewer pipe capacity of the proposed and existing system shall be adequate to carry the peak design flow in a nonpressure condition. The quantity of sewage from residential communities shall be based on an average daily design flow of 75 gpcd, with a peak flow factor of 2.5. The design population shall be based on values in Table 1 (Ref. 1, p. 19). The amount of groundwater infiltration shall be limited to 500 gallons per inch of pipe diameter per mile per day. Design values based on local experience or records of existing similar systems in the area may be substituted for the above values when warranted.

Table 1
DESIGN VALUES:
PERSONS PER DWELLING UNIT

Dwelling Unit Type	Design Values Persons/D.U.
Single-Family	3.5
Townhouse	3.1
Low-Rise Apartments	2.9
Medium- or High-Rise Apartments	2.7

COMMENTARY

Although many communities operate combined storm and sanitary systems, these standards separate the two systems in new residential development as a means of reducing treatment costs. It is not necessary to install sewers for future development unless sewage studies have been conducted and a community agrees to pay for oversized facilities to handle future growth. However, access for future extension of the system must be provided.

The values for determining sewer flow are based on the National Association of Home Builders' *Sanitary Sewer Systems Land Development Standards*, which, in turn, were derived from the results of a national survey of practices in 92 communities in 37 states.

STANDARDS

1.2 - Pipe sizes shall be determined from the peak design flow and the minimum and maximum allowable velocities. The system shall be placed at grades that maintain adequate velocities, thereby preventing solids from settling out of the sewage. A minimum full flow velocity of 2.0 fps shall be maintained (Ref. 2, p. 122). Erosion of the pipe materials shall be prevented by allowing a maximum velocity of 15 fps at average flow (Ref. 2, p. 22). The engineer shall use either manufacturer-recommended roughness coefficients or the values shown in Table 2. For flow in the lines less than one-fourth full, increased values for the roughness coefficient shall be used in determining flow velocity.

Table 2
PIPE MATERIAL VALUES OF *n* FOR USE IN MANNING'S EQUATION

Pipe Material	Use in Design From	To
Clean Cast Iron	0.013	0.015
Dirty or Tuberculated Cast Iron	0.015	0.035
Riveted Steel	0.015	0.017
Welded Steel	0.012	0.013
Galvanized Iron	0.015	0.017
Wood Stave	0.012	0.013
Concrete		
Good workmanship	0.012	0.014
Poor workmanship	0.016	0.017
Plastic	0.011	0.015
Vitrified Clay	0.011	0.017

COMMENTARY

Hydraulically, the use of smaller and more economical pipes for low-flow areas increases the velocity and depth of flow and thus provides a better, self-cleansing system. Due to its simplicity, Manning's Equation is the most common method for estimating the capacity and flow resistance in closed conduits. The Kutter, Hazen-Williams, and Darcy Weisbach formulas are also acceptable.

Manning's Equation

$$Q = VA = \frac{1.49}{n} R^{2/3} S^{1/2} A$$

Q = flow rate
V = velocity
A = cross-sectional area
n = roughness coefficient
R = hydraulic radius
S = slope

2.0 - PIPE MATERIALS

2.1 - Acceptable pipe materials shall conform to the standards in Section 10 and include concrete, ductile and cast iron, plastic, steel, and vitrified clay.

The use of watertight materials and joints should limit the amount of water that infiltrates the system as well as inhibit root intrusion, thereby reducing treatment costs and limiting damage.

Asbestos cement pipe is on the EPA list of products to be banned and is not recommended for use.

2.2 - Sanitary systems shall be capable of withstanding anticipated loads. Pipes located under roadways or travelways shall be capable of withstanding the live loads imposed by passing vehicles and shall sustain AASHTO H-20 loading. The maximum burial depth shall not exceed the pipe manufacturer's recommended depth for the material used unless engineering calculations show the pipe material to be adequate.

The use of protective sleeves or alternative materials in the loaded area is acceptable to protect the pipe.

STANDARDS

3.0 - PIPE PLACEMENT

3.1 - Maintenance personnel shall have access via easements to maintain the public system located outside the public right-of-way. The easement shall be wide enough to allow personnel and equipment access to maintain and perform general repair on all parts of the system. The minimum easement width shall be 10 feet. Pipes may be offset from the center of the easement. Easements of separate utilities may overlap.

3.2 - Sewer pipes shall be protected from excessive bearing pressures by placing them outside the influence zone of building structures unless engineering calculations show the pipe material or soil condition to be adequate for the subjected load.

3.3 - Precautions shall be taken when sewer pipes approach, cross, or run parallel to water pipes to avoid possible contamination of the water supply. A water pipe shall not pass through or come in contact with a sewer manhole. The water pipe shall be protected by one of the following:

1. providing a 10-foot horizontal separation between water pipes and the sewer;
2. placing water pipes 18 inches above the sewer and on a separate shelf; or
3. constructing both the water pipe and sewer with watertight joints and then pressure testing each to ensure water tightness.

3.4 - Sewer pipes that cross surface waters shall be protected against damage and anchored to prevent movement. For aerial crossings, support shall be provided at all joints and precautions shall be taken against freezing. For underwater crossings, the top of the sewer shall be at least 1 foot below the natural bottom of the stream bed when the sewer is located in rock, 3 feet below the natural bottom of the stream bed when the sewer is located in other material, or below the channel pavement when stream channels are paved (Ref. 4). The trench shall be backfilled with stone, coarse aggregate, washed gravel, or other materials that resist scour and prevent siltation.

COMMENTARY

(3.2) An example sketch of the building influence zone is given in the appendix to this standard.

(3.3) These measures to protect the water supply from contamination are based on common construction practices used across the country. The option of placing the water pipe on a separate shelf in a common trench is allowed by the BOCA code as well as the Great Lakes Recommended Standards for Water Works (10 State Standards, Ref. 3). A detail of a common sewer and water trench with the water pipe on a separate shelf is shown in the appendix to this standard.

(3.4) Sewer systems should be designed to minimize the number of stream crossings and to cross as nearly perpendicular to the stream flow as possible. Precautions against freezing for aerial crossings may include insulation, increased pipe slope, or any other practice that provides protection.

STANDARDS / **COMMENTARY**

3.5 - Sewer pipes shall be protected against freezing by providing adequate burial depths or other insulating arrangements. The top of the gravity or pressure sewer pipe shall be located below the lowest established frost depth.

The use of insulating material around sewer pipes is an alternative protection measure against freezing and capitalizes on the internal heat in the system. The soil type and surface cover may also be considered in resisting frost depth.

3.6 - To maintain joint integrity, pipe runs designed as curves between manholes shall follow manufacturers' allowable deflections for the type and size of pipe.

The practice of installing sewer lines along vertical and horizontal curves as opposed to following a conventional straight alignment allows cost savings by reducing the number of manholes and permitting the system to follow the terrain. Curved sewers can be constructed by using both rigid and flexible pipe. Rigid pipe is installed by deflecting the pipe joint from a straight position, while flexible pipe is deflected by bending the pipe itself. A curvilinear gravity sewer layout is compared to a conventional layout in the appendix to this standard.

4.0 - INSTALLATION

4.1 - Pipes or structures constructed on fill shall be stable and protected against settlement by compacting fill material to 95 percent of the modified Proctor (ASTM D 1557-78) maximum dry density.

4.2 - Where steep ground makes possible the use of a reduced pipe size, the pipe size may be reduced at a manhole, but necessary hydraulic allowances shall be made for head loss of entry, increased velocity, and the effect of velocity retardation at the lower end where the flow moves across a flatter slope.

Pipe size along a sewer run should be reduced when substantial savings on construction costs can be derived.

4.3 - Sewers on 20 percent slopes or greater shall be anchored securely with concrete anchors or equal (Ref. 4) protection to prevent the pipe from creeping downhill.

Anchors or collars are devices placed around pipes to increase resistance to movement or decrease susceptibility of groundwater flow along the pipe. The size and spacing of required collars should be based on soil conditions and the slope and type of pipe.

4.4 - Proper trenching, bedding, and backfill are required for pipe performance. Bedding shall conform to the standards of Section 10.3.1. The width of the trench shall allow the pipe to be properly laid and jointed and to permit the backfill to be placed and compacted as needed. Backfill shall be of a suitable material removed from excavation except where other material is specified. Debris, frozen material, large stones, organic matter, or other unstable materials shall not be used for backfill within 2 feet of the top of the pipe (Ref. 4).

4.5 - Inverted siphons shall be allowed when a standard gravity line is not economically or physically feasible.

An inverted siphon refers to a depressed sewer that stands full even with no flow. Its purpose is to carry the flow under an obstruction and regain as much elevation as possible after the obstruction has been passed.

STANDARDS	COMMENTARY
5.0 - SERVICES/LATERALS	
5.1 - Gravity laterals shall be sized and sloped to carry the peak design flow from the building or buildings served while meeting the minimum size and slope requirements of locally adopted building codes.	
5.2 - Service lines serving more than one building shall be located in an easement or in a common area. The service shall separate before entering individual dwelling units.	The use of multiple connections to a single service line allows for an economical and functional system as long as the pipe is sized to serve all buildings connected to it. Multiple connections reduce the cost of trenching and pipe.
5.3 - Sewer laterals shall provide access for cleaning by placing cleanouts on 4-inch and smaller lines not more than 75 feet apart or as required by locally adopted building codes. For lateral lines greater than 4 inches, the requirements for access points shall comply with the requirements for mains in consideration of the fact that cleaning equipment is available to service these larger sizes.	
5.4 - A positive direction of flow from sewer laterals shall be maintained by means of a tee or wye connection to the main.	
6.0 - MANHOLES/CLEANOUTS	
Access for inspection and maintenance shall be provided through the use of manholes and cleanouts.	In some cases, cleanouts can be used as replacements for manholes to reduce construction costs without sacrificing system integrity.
6.1 - A manhole or cleanout shall be placed at the terminal end of a pipe main. A manhole shall be located on the main at changes in pipe size, at changes in grade or alignment on runs not designed as curves, at all sewer main intersections, and at maximum distances of 800 feet measured along the pipe (Ref. 5, p. 20). A standard detail for a cleanout is included in the appendix to this standard.	Manholes can be placed at greater distances than previously allowed due to advances in construction practices, inspection and cleaning equipment, and techniques for repair of damaged pipes. Modern sewer television inspection and sealing equipment has become commonplace. Many localities have the capability to pinpoint leaks in sewer lines with a television camera and then immediately seal the crack or leaking joint with pressure grout. This equipment can reach up to 750 feet in one direction (Ref. 5, p. 20).
6.2 - Manholes shall be constructed of the materials and to the specifications outlined in Section 10.2. Manholes shall be watertight to prevent infiltration of groundwater. Manholes located within flood zones, detention facilities, or areas of storm water gutter, swale, or channel flow shall be equipped with a watertight frame and cover.	The most widely used manholes today are precast concrete, although brick, cast-in-place concrete, and premolded fiberglass plastic are acceptable options. The design engineer should use judgment in selecting the most economical and functional material for each application.

STANDARDS	COMMENTARY
6.3 - Manholes shall be coved to convey the flow adequately from influent to effluent lines. The drop between the influent and effluent shall be adequate to convey the flow hydraulically given the angle of deflection and the velocity of influent and effluent. To ensure hydraulic efficiency, the angle between influent and effluent pipes shall be not less than 90 degrees and the drop between inverts shall be not less than 0.1 foot. In designs where these requirements are not met, the engineer shall submit calculations that show that the design has no negative effects on the system due to loss of energy in the manhole.	Improvements in construction practices, especially the use of lasers for setting sewer grades and inverts, eliminates the need for incorporating allowances into the design of sewer slopes and inverts due to limitations of field construction.
6.4 - Manholes shall be accessible. They shall be designed to be safe for maintenance personnel. Either manhole steps in accordance with ASTM C 478-88 or manhole ladders conforming to OSHA standards (1910.27, 1910.268) shall be provided.	
6.5 - An inside or outside drop connection shall be provided when the vertical distance between pipe inverts exceeds 3 feet in the manhole. In addition, sewer laterals shall not connect directly to a manhole more than 3 feet above the lowest invert.	A drop connection conveys flow from a high influent invert to a lower effluent invert without splashing sewage on maintenance personnel who may enter the manhole.
6.6 - Manhole castings located in travelways shall be capable of withstanding traffic loads and shall meet the standards outlined in Section 10. Manholes located in travelways shall be constructed flush with the finished surface so as not to pose a hazard to pedestrians or motorists.	Manhole covers are generally fabricated of cast iron, but any structurally adequate material with appropriate durability is acceptable.

7.0 - TESTING

After backfilling, the mains of the gravity system shall be cleaned and tested to detect any defects or damage in materials or construction.

7.1 - Deflection tests shall be performed on all flexible pipe runs. If the deflection test is run using a rigid ball or mandrel, the object shall have a diameter equal to 95 percent of the inside diameter of the pipe. No pipe shall exceed a deflection of 5 percent (Ref. 4).

7.2 - A leakage test, either infiltration or exfiltration, shall be performed on all pipe runs. The leakage, outward or inward, shall not exceed 200 gallons per inch of pipe diameter per mile per day for any section of the system. An exfiltration or infiltration test shall be performed with a minimum positive head of 2 feet. The air test, if used, shall at minimum conform to the test procedure described in ASTM C-828-88 (Ref 4).

STANDARDS | COMMENTARY

8.0 - ALTERNATIVES TO GRAVITY-FLOW SYSTEMS

This section addresses acceptable alternatives to the standard gravity system for sewage disposal, including pressure systems, septic tank effluent pump (STEP) systems, vacuum sewers, and main line pump stations.

8.1 - All pipe fittings, valves, and pieces for conveying or transmitting raw sewage under pressure shall conform to the requirements for water mains outlined in Section 10 of the Water Supply Standards. In no case shall the operating pressure of the system exceed the maximum pressure rating of the pipe or fittings.

8.2 - Publicly owned and maintained easements shall be provided for pressure systems to allow maintenance personnel to gain access to all pipes, valves, pumps, and equipment.

Pressure systems and pump stations are used where gravity collection is not physically or economically feasible. Pressure systems and pump stations follow flat terrain and use small-diameter pipe. Both alternatives permit cost savings by eliminating the trenching and rock excavation otherwise required of deep gravity sewers. In addition, pressure systems eliminate the need for manholes by relying on cleanouts for maintenance.

8.3 - Main line pumping stations shall be protected from sewage back-up in the event of mechanical or electrical failures. They shall be equipped with two pumps, each of which shall be capable of carrying the peak flow in the event the other pump should fail. A liquid level warning device shall be provided to alert maintenance personnel of pump failure or stoppage. Additional tank capacity, a separate overflow tank, or an emergency generator shall be provided in case of a power failure.

Main line pump stations collect sewage by gravity flow and raise it to a higher elevation by pumping. The sewage is often pumped through a pressure line. The main line pump station is often an expensive facility but permits centralized collection and eliminates multiple pumps and locations that require maintenance.

8.4 - Individual grinder pumps and STEP units that serve up to three dwelling units shall be equipped with an alarm to warn of a mechanical breakdown or power failure.

Grinder pumps transmit raw waste from a single home or a small group of homes through a pressure line to either a gravity collection sewer or a treatment facility. The grinder pump macerates the raw waste, allowing it to be transmitted through small-diameter pressurized pipes that follow the terrain. No septic tank is required with a grinder pump. STEP systems pump waste that has been pretreated by a septic tank to a final treatment facility. The pumps and pressure lines in a STEP system are sized to handle septage rather than raw sewage as in the case of a grinder pump.

8.5 - Vacuum sewers shall require a vacuum interface valve at each home connection. The valve breaks the vacuum long enough to allow a certain volume of sewage to enter the line and then closes to maintain a vacuum in the line. The central vacuum shall be equipped with a standby generator for protection in the event of a power failure.

Vacuum sewers draw sewage from homes to a common collection point. A vacuum valve at each home requires less maintenance than a pump, allows sewage to enter the pressure line, and prohibits backflow.

STANDARDS	COMMENTARY
8.6 - An easement shall be provided for STEP systems, small-diameter gravity systems, and other public systems that use individual septic tanks for pretreatment to allow for maintenance of the septic tank.	
8.7 - Pressure lines shall be accessible for maintenance and inspection by providing a cleanout every 800 feet.	
9.0 - ON-SITE WASTEWATER TREATMENT/DISPOSAL	
This section covers the design and construction of on-site wastewater treatment and disposal systems, including septic systems, mounds, recirculating sand filters, evapotranspiration, and package systems. Other systems that meet the requirements of local health authorities shall also be acceptable, provided that they are designed in accordance with accepted engineering practices.	These standards for on-site wastewater treatment/ disposal are based largely on recommendations and requirements set forth in EPA's *Design Manual On-Site Treatment and Disposal Systems* (1980) (Ref. 6). On-site systems have historically been viewed as temporary disposal systems. Advances in technology and extensive research on the operation and maintenance of on-site systems have shown, however, that on-site systems can be properly designed for permanent sewage disposal.
9.1 - Septic Tank--Soil Absorption Systems	
9.1.1 - **Septic tanks** shall be made of concrete, plastic, fiberglass, or other materials that meet the following requirements:	Septic tanks are used to pretreat effluent by retaining solids and scum that can otherwise quickly clog soils.
1. Septic tanks shall be watertight to prevent sewage leaks and infiltration of groundwater. Inlet and outlet devices shall be designed to prevent the discharge of sludge or scum. Access shall be provided for periodic pumping of septage.	
2. Minimum tank volume shall be in accordance with Table 3 or shall otherwise be designed for a 24-hour retention time based on 45 gallons per capita per day (Ref. 6, p. 101).	Twenty-four-hour retention is required to allow settling to occur.
3. The length-to-width ratio of rectangular septic tanks shall be at least 2:1 but not more than 3:1 to prevent high-velocity discharges.	
4. Septic tanks shall be designed to resist soil pressures and buoyancy forces to which they are exposed. They shall be installed to be level on undisturbed soil, gravel, or compacted fill.	Septic tanks installed below the seasonal high groundwater table may need to be secured to prohibit movement.
5. All septic tanks shall be resistant to corrosion.	

STANDARDS

6. Septic tanks shall be vented to the atmosphere to release hydrogen sulfide and methane gases through at least one minimum 3-inch vent.

Table 3
MINIMUM SEPTIC TANK VOLUME*

Dwelling Unit Type	Gallons
1-2 Bedrooms	750
3 Bedrooms	900
4 Bedrooms	1,000
5 Bedrooms	1,250
Each Additional Bedroom	250

* EPA *Design Manual On-Site Wastewater Treatment and Disposal Systems*, based on U.S. Public Health Service and Federal Housing Authority recommendations.

9.1.2 - Soil absorption systems shall consist of trenches, beds, pits, or mounds that meet the requirements of this section. All influent shall be pretreated by sedimentation in a septic tank or equivalent as specified in Section 9.1.1. Absorption systems shall be located outside construction traffic areas.

Septic tank effluent may flow to the absorption area by gravity flow, or mechanical pumps may be used to dose the absorption area. Pumps shall be installed in a holding tank sized to store a minimum 24 hours of sewage flow.

Minimum horizontal separation distances from the absorption area shall be maintained in accordance with Table 4.

Table 4
MINIMUM HORIZONTAL SEPARATION DISTANCE

Item	Distance in Feet
Up Gradient Deep Drill Well	50
Down or Cross-Gradient Well	100
Dug Well	100
Cuts, Escarpments	10
Property Line	5
Building Foundation	10

COMMENTARY

The vent for the septic tank may be located at the tank or along the service line before it enters the house.

Construction activity can compact and/or smear soils and reduce their infiltration capacity.

Dosing systems require additional maintenance of the pump and chamber. However, the systems have been shown to be effective in reducing soil clogging.

STANDARDS	COMMENTARY

9.1.2.1 - *Trenches, Beds, and Pits*

Trench and bed systems shall not be located on sites with excessive slopes. Trench systems shall be located on slopes of 0 to 25 percent. Bed systems shall be located on slopes of 0 to 10 percent. Trench, bed, and pit absorption systems shall maintain a minimum 2 feet of unsaturated soil between the bottom of the system and the seasonally high water table or an impervious layer.

Commentary: Trenches and beds are long, shallow absorption areas. Trenches are usually 12- to 18-inches-wide, whereas beds are several feet or more in width. There are no "correct" standard dimensions--dimensions should be based on the infiltration rate of the soil. Pits are deep excavations, they have limited application in areas with high groundwater tables or shallow obstructions. In trenches, beds, and pits, 2 to 4 feet of unsaturated soil is necessary to treat effluent before it enters the groundwater. Further treatment occurs as contaminants move through the groundwater.

Trench, bed, and pit systems shall be located in soil suitable for absorption as determined by examination of the soil profile by an engineer or soil scientist experienced with soil absorption systems. Recommended application rates for septic tank effluent are provided in Table 5. Bottom and sidewall areas may be counted as infiltration surfaces. The size of the absorption area shall be based on a 45 gpcd wastewater flow.

Commentary: Percolation test results have often been used to determine application rates of septic tank effluent. However, percolation tests demonstrate a high variability of up to 90 percent (Ref. 6, p. 39). Further, they measure saturated flow as opposed to the unsaturated flow below a mature drainfield. As a result, a soil texture evaluation is recommended to determine application rates.

Table 5
RECOMMENDED RATES OF WASTEWATER APPLICATION FOR TRENCH AND BED BOTTOM AREAS

Soil Texture	Application Rate (gpd/ft^2)
Gravel, Coarse Sand	Not suitable
Coarse to Medium Sand	1.2
Fine Sand, Loamy Sand	0.8
Sandy Loam, Loam	0.6
Loam, Porous Silt Loam	0.45
Silty Clay Loam, Clay Loam	0.2

Notes

Rates are based on septic tank effluent from a domestic waste source. A factor of safety may be desirable for wastes of significantly different character.

Soils with gravel and coarse sand textures can be used if the soil is replaced with a suitably thick (>2 ft) layer of loamy sand or sand.

A reserve land area equal to 100 percent of the absorption area as required by Table 5 (Ref. 6, p. 217) shall be provided. Reserve areas can be located between original trenches where the sidewall-to-sidewall distance is at least 6 feet.

Commentary: A reserve area is required because of the high potential for failure associated with poor maintenance of septic tanks. If a failure occurs, the reserve area can be used to install another absorption field. Reserve areas may not be necessary where strict maintenance is ensured.

STANDARDS

Trenches and beds shall be gravel-filled systems, or gravelless systems installed in accordance with manufacturers' recommendations. Trenches and beds shall be no closer than 18 inches to an adjacent trench (Ref. 6, p. 221) and shall be at least 1 foot in width.

9.1.2.2 - *Mound Systems*

The mound system consists of a suitable fill material, an absorption area, a distribution network, a cap, and topsoil. Table 6 presents commonly used fill materials and their respective design infiltration rates (Ref. 6, p. 245).

Table 6
COMMONLY USED FILL MATERIALS AND THEIR DESIGN INFILTRATION RATES (PER EPA)

Fill Material	Characteristics (percent by weight)	Design Infiltration Rate (gpd/ft^2)
Medium Sand	>25% between 0.25-2.0 mm <30-35% between 0.05-0.25 mm < 5-10% between 0.002-0.05 mm	1.2
Sandy Loam	5-15% Clay content	0.6
Sand/Sandy Loam Mixture	88-93% Sand 7-12% Finer-grained material	1.2
Bottom Ash	-- --	1.2

Mound geometry shall comply with the minimum dimensions given in Table 7. Sideslope and upslope surfaces shall maintain minimum setbacks of 10 feet from the edge of the absorption bed. The downslope setback is dependent on the permeability of the natural soil and the required mound base area.

COMMENTARY

Mound systems are usually suitable where a conventional absorption field is limited by the shallow depth of permeable soils or a high groundwater table. Mounds are also beneficial with slowly permeable soils that are easily smeared or compacted (Ref. 6, p. 241).

The required absorption bed area is determined by dividing the peak design flow by the design infiltration rate of the fill material. The absorption bed area is the area of the rock bed (A x B in Figure 1).

The dimensions of the mound are larger than the required absorption area of the field to prevent wastewater discharge at the perimeter or from the sides of the mound.

STANDARDS

Table 7 MOUND DIMENSIONS	
Item	Dimension
Sand Fill Depth	1-foot Minimum
Rock Bed Depth	9-inch Minimum
Cap at Bed Edge	1-foot Minimum*
Cap at Bed Center	1.5-foot Minimum*

* Includes topsoil depth.

The base area of the mound shall be sufficiently large to absorb the wastewater before it reaches the perimeter of the mound to avoid surface seepage. Mound base areas shall be determined by using Table 8 (Ref. 6, p. 249).

Table 8
INFILTRATION RATES FOR DETERMINING MOUND BASE AREA

Natural Soil Texture	Percolation Rate (min/in)	Infiltration Rate (gpd/ft²)
Sand, Sandy Loam	0-30	1.2
Loams, Silt Loams	31-45	0.75
Silt Loams, Silty Clay Loams	46-60	0.5
Clay Loams, Clay	61-120	0.25

On level sites, the entire base area (L x W in Figure 1) shall be considered as the effective area. On sloping sites, only the area below and downslope from the absorption bed shall be considered ([(B) x (A+I)] in Figure 1).

Sand mounds shall maintain a minimum distance of 20 inches from the original ground surface to the seasonal high groundwater table and at least 3 feet to an impermeable barrier.

A reserve area equal to 100 percent of the required original area shall be provided. A maximum 3:1 sideslope shall be maintained on mounds.

9.2 - Evapotranspiration Systems

Evaporation and evapotranspiration (ET) systems shall be designed in accordance with the EPA *Design Manual On-site Wastewater Treatment and Disposal Systems.*

COMMENTARY

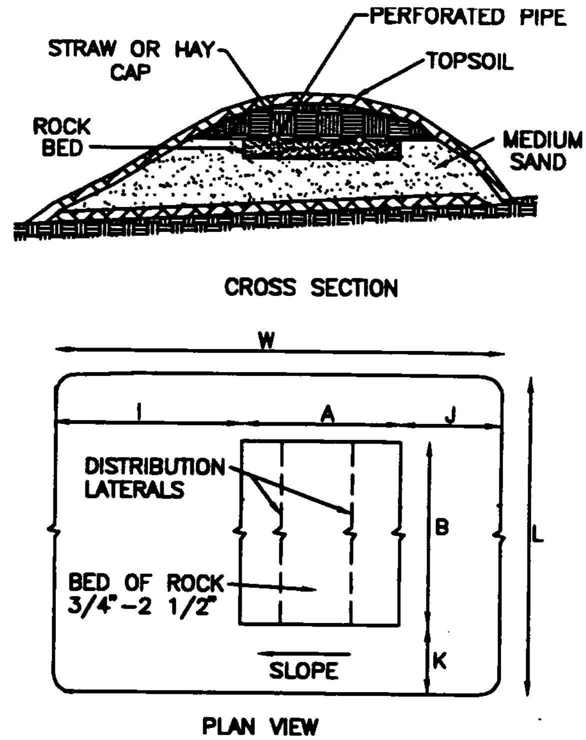


Figure 1. Mound Dimensions.

A = Width of rock bed
B = Length of rock bed
K = Sideslope setback distance from rock bed to edge of mound
I = Downslope setback distance from rock bed to edge of mound
J = Upslope setback distance from rock bed to edge of mound
L = Length of sand mound
W = Width of sand mound

The required effective base area is determined by dividing the peak design flow by the infiltration rate of the natural soil.

ET systems rely on evaporation and transpiration to eliminate or reduce the effluent flowing to an absorption area.

STANDARDS

9.3 - Recirculating Sand Filters

Influent to a sand filter system shall be pretreated by a septic tank as specified in Section 9.1.1.

A hydraulic loading rate of 3.0 to 5.0 gpd/ft^2 shall be maintained, not including recirculated wastewater. The recirculation ratio shall be between 3:1 and 5:1 (Ref. 6, p. 128). Recirculation tanks shall have a minimum volume of at least one day's wastewater flow based on 45 gpcd.

Filters shall be vented on their upstream end. Filters shall have a filter medium depth of at least 24 inches and underdrains of gravel or crushed stone that slope at least 0.5 percent toward the outlet. Filters with surface discharges shall comply with Section 9.4.

Filter media shall have an effective size between 0.3 and 1.5 mm and a uniformity coefficient no greater than 4.0.

Filters discharging to soil absorption fields shall comply with Section 9.1.2 except that application rates shall be multiplied by a factor determined by the authority with jurisdiction over sewage treatment and disposal.

9.4 - Package Systems and Surface Discharge Systems

Effluent from package systems and other systems that discharge to surface ditches or waters shall comply with state health department standards for water quality. These systems shall be designed and installed in accordance with manufacturers' recommendations and meet applicable state and federal regulations.

10.0 - MATERIAL STANDARDS

All materials and appurtenances for sanitary systems shall conform to currently dated standards of the American Society for Testing and Materials (ASTM), the American Standards Association (ASA), the American Water Works Association (AWWA), the American National Standards Institute (ANSI), or the General Services Administration (federal specifications) for the material type and use intended. All installations shall be in accordance with manufacturers' recommendations where not governed by these standards.

COMMENTARY

Recirculating sand filters provide advanced treatment of septic tank effluent. Their main advantages include improved treatment, especially nitrogen reduction. In addition, effluent can be disposed of in a much smaller area compared to that required for disposal of septic tank effluent.

Research has shown that soils can receive 7.5 to 8 times the wastewater flow from recirculating sand filters as compared to septic tank effluent [(1) T.L. Loudon and G.L. Burnie, "Performance of Trenches Receiving Sand Filter Effluent in Slowly Permeable Soils," 6th National Symposium on Individual and Small Community Sewage Systems, ASCE (Chicago, IL), December 1991; and (2) R. Siegrist, "Hydraulic Loading Rates for Soil Absorption Systems Based on Wastewater Quality," 5th National Symposium on Individual and Small Community Sewage Systems, ASCE (Chicago, IL), December 1987].

STANDARDS

The following are applicable specifications:

10.1 - Pipe and Joints

10.1.1 - Reinforced concrete pipe shall meet all requirements of ASTM C-76-89. Joints shall meet ASTM C443-85 requirements.

10.1.2 - PVC pipe and fittings shall conform to ASTM D-3034-89. Pipe shall be installed in accordance with ASTM D-2321-89. Pipe shall be free from defects, bubbles, and other imperfections in accordance with accepted commercial practice. Allowable minimum radii for bending PVC pipe are included in the appendix to this standard.

10.1.3 - Ductile iron and grey iron pipe, fittings, and joints shall be cement-lined and sealcoated and meet the requirements of Section 10 of the Water Supply Standards.

10.1.4 - Vitrified clay pipe shall meet ASTM C-700-89 and be installed in accordance with ASTM C-12-86. Vitrified clay joints shall conform to the requirements of ASTM C-425-88.

10.2 - Manholes

10.2.1 - Manholes shall be precast or cast-in-place concrete, brick, concrete block, or fiberglass.

10.2.2 - Precast reinforced concrete manholes shall conform to the requirements of ASTM C-478-88.

10.2.3 - Brick for manhole construction shall be dense, hard-burned clay brick conforming to ASTM C-62-89.

10.2.4 - Manhole frames and cover castings shall be iron conforming to ASTM A-48-83.

10.3 - Installation and Testing

10.3.1 - Bedding classes A, B, or C as described in ASTM C12-86 (ANSI A106.2) shall be used for all rigid pipe. Bedding classes I, II, or III as described in ASTM D2321-89 (ANSI K65.171) shall be used for all flexible pipe, provided the proper strength pipe is used to support the anticipated load.

10.3.2 - Pressure systems shall be tested in accordance with AWWA C-600-87 and the provisions of the Water Supply Standards.

COMMENTARY

DEFINITIONS

Inverted Siphon. A depressed sewer that stands full even with no flow. Its purpose is to carry the flow under an obstruction and regain as much elevation as possible after the obstruction has been passed.

Flexible Pipe. A pipe that derives its load-carrying capacity from the interaction of the flexible pipe and the embedment soil (Ref. 2, p. 157). Flexible pipe materials include ductile iron (DIP), steel, thermoset plastic, and thermoplastic. Thermoplastic includes acrylonitrile-blitadiene-styrene (ABS), polyethylene (PE), and polyvinyl chloride (PVC).

Rigid Pipe. A pipe that derives a substantial part of its basic earth-load carrying capacity from the structural strength inherent in the rigid pipe wall (Ref. 2, p. 154). Rigid pipe materials include cast iron (CIP), concrete, and vitrified clay (VCP).

Lateral. A pipe that conveys sewage flow from one or more buildings to the sewer main.

Sewer Main. The principal pipe artery that collects sewage flow from branches and building connections.

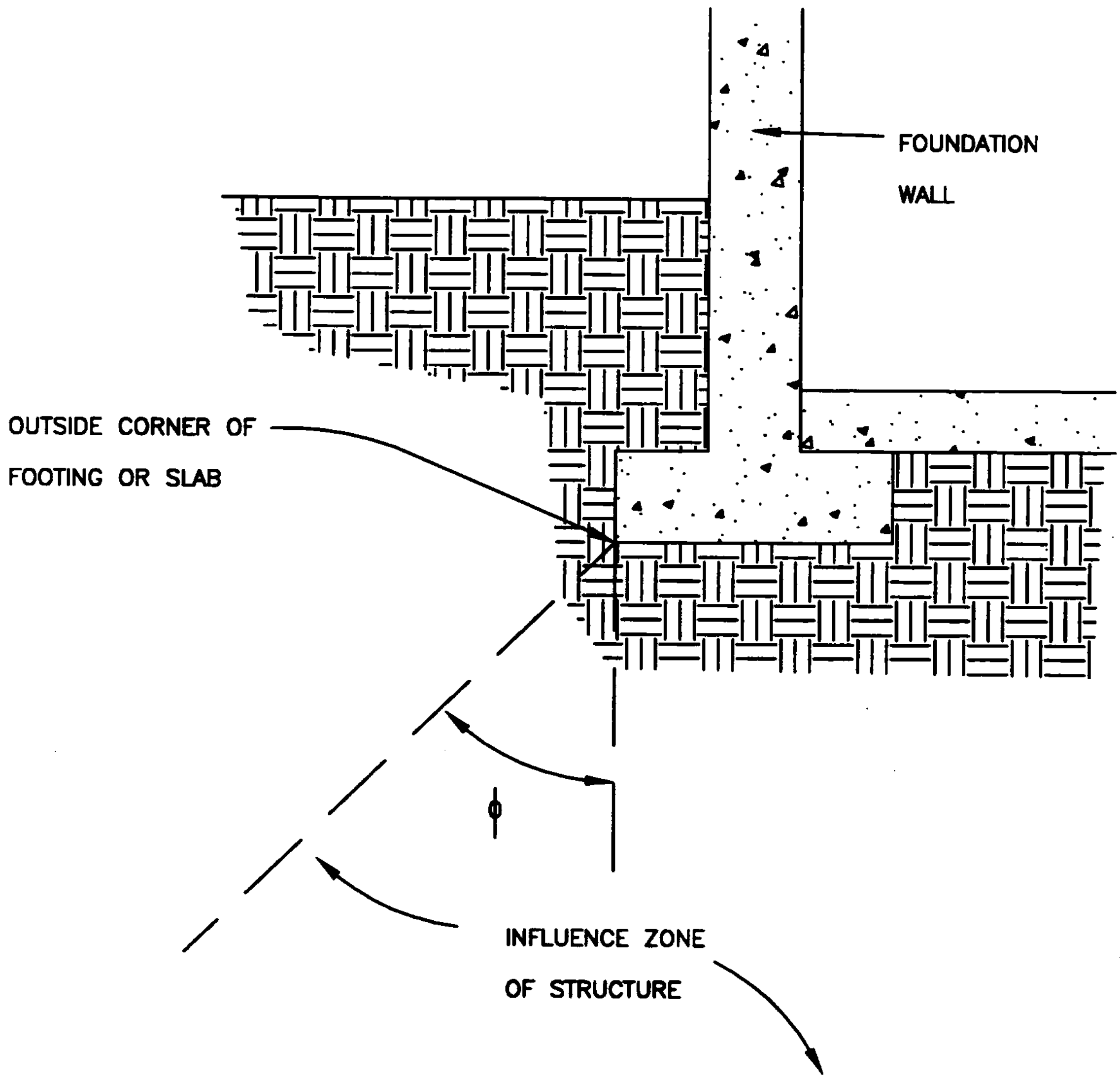
REFERENCES

1. NAHB Research Center. *Manual on Residential Sanitary Sewer Systems Land Development Standards.* 1974.
2. American Society of Civil Engineers and the Water Pollution Control Federation. *Gravity Sanitary Sewer Design and Construction.* 1982.
3. Great Lakes Upper Mississippi River Board of State Sanitary Engineers. *Recommended Standards for Water Works.* 1978.
4. Great Lakes Upper Mississippi River Board of State Sanitary Engineers. *Recommended Standards for Sewage Works.* 1978.
5. U.S. Department of Housing and Urban Development, Office of Policy Development and Research. *Innovative Site Utility Installations.* 1983.
6. U.S. Environmental Protection Agency, Office of Water Program Operations and Office of Research and Development Municipal Environmental Research Laboratory. *Design Manual Onsite Wastewater Treatment and Disposal Systems.* 1980.

SANITARY SEWAGE SYSTEMS STANDARDS

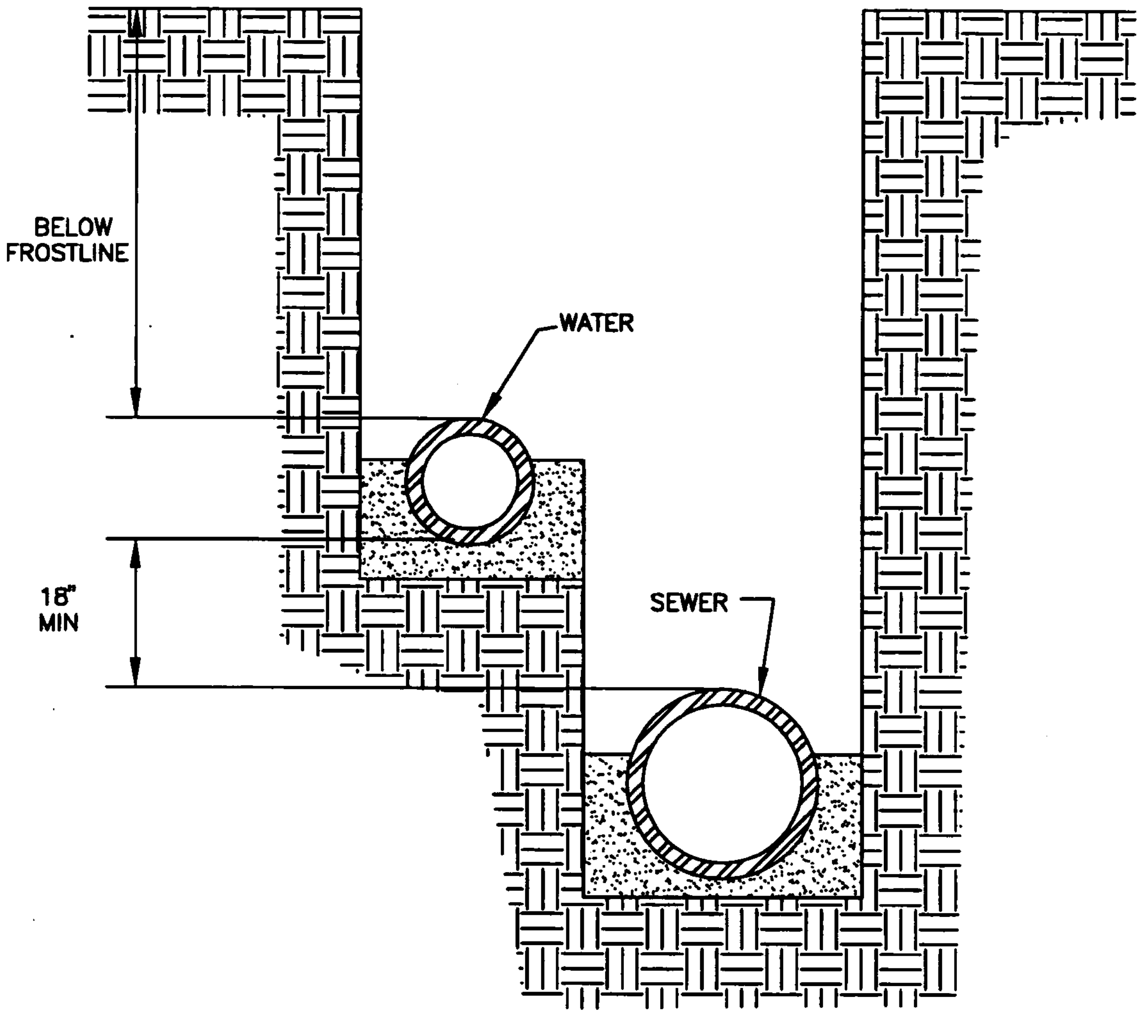
APPENDIX

DIAGRAM OF BUILDING INFLUENCE ZONE

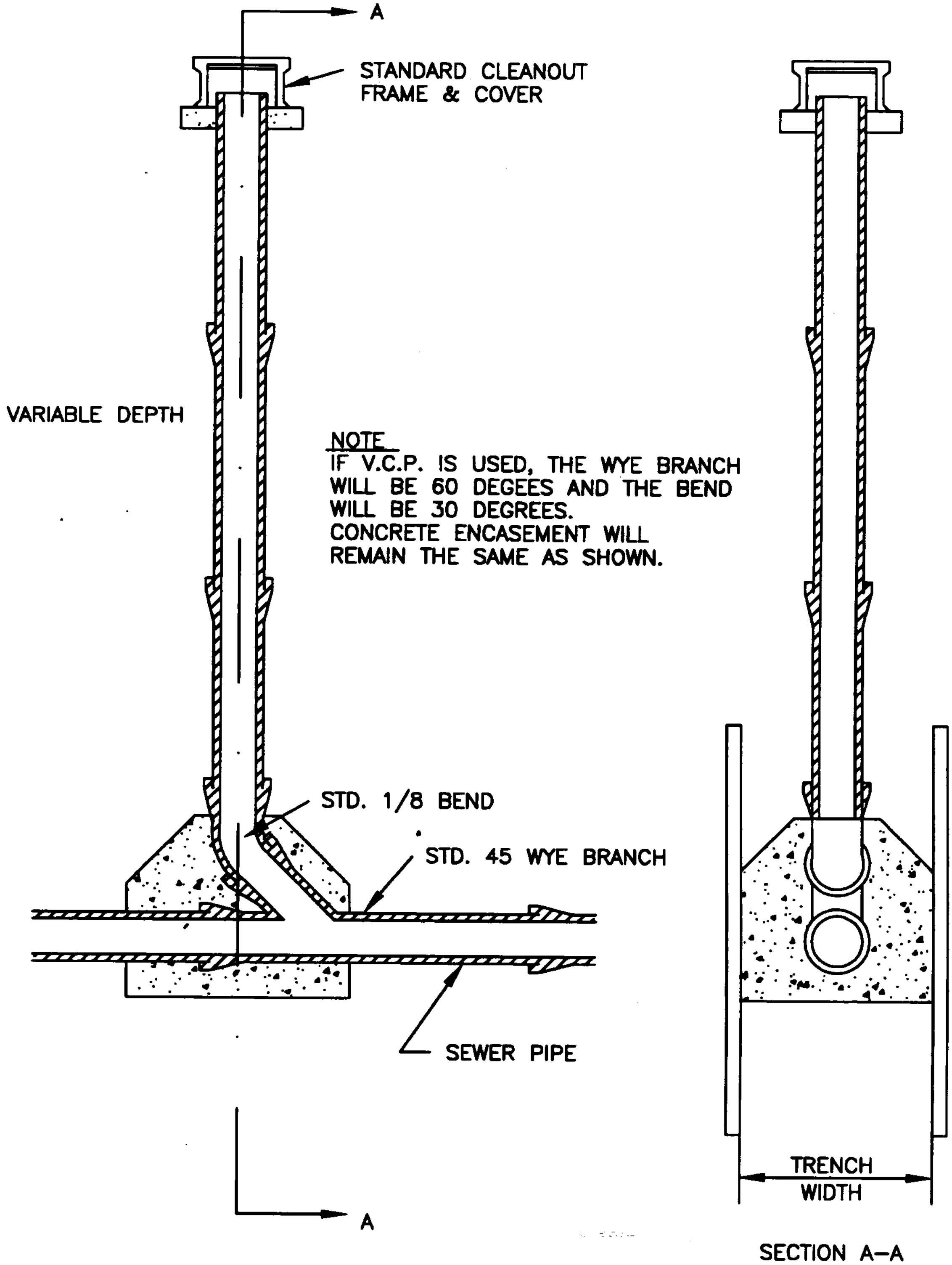


ϕ = 45 DEGREES TYPICALLY, BUT DEPENDENT ON SOIL CONDITIONS

TYPICAL DITCH SECTION FOR
COMMON TRENCHING OF WATER AND SEWER LINES

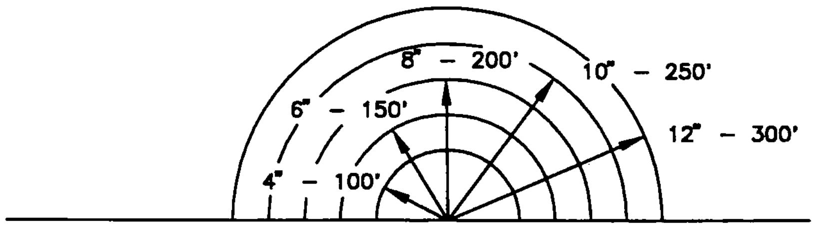


STANDARD DETAIL OF CLEANOUT

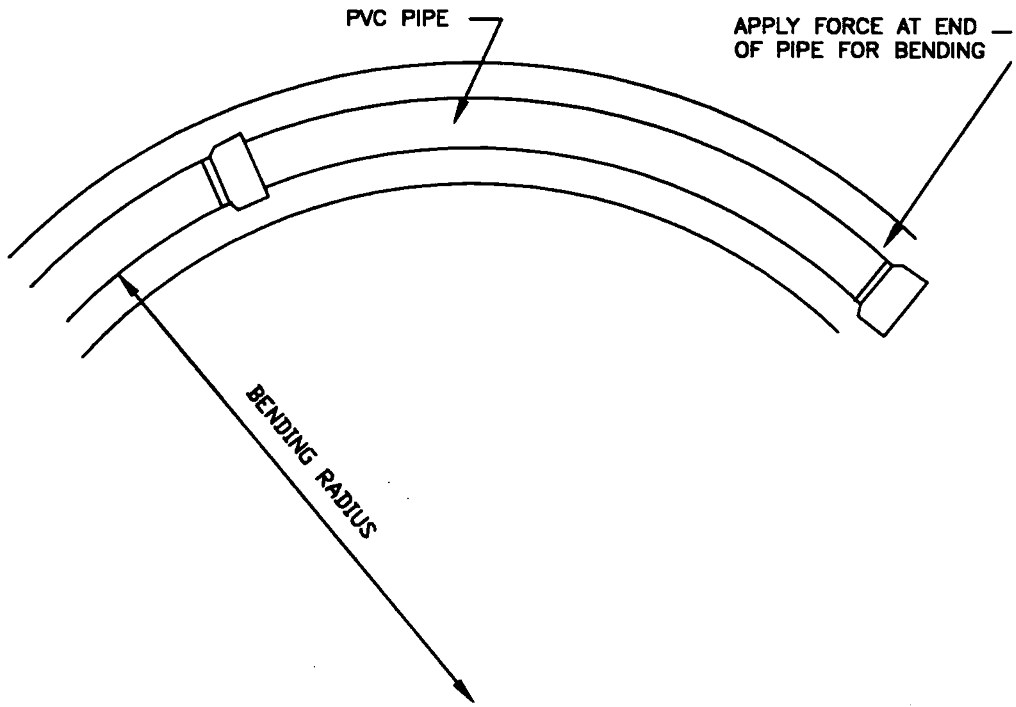


SOURCE: U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, "INNOVATIVE SITE UTILITY INSTALLATIONS."

ALLOWABLE MINIMUM RADII FOR BENDING PVC PIPE

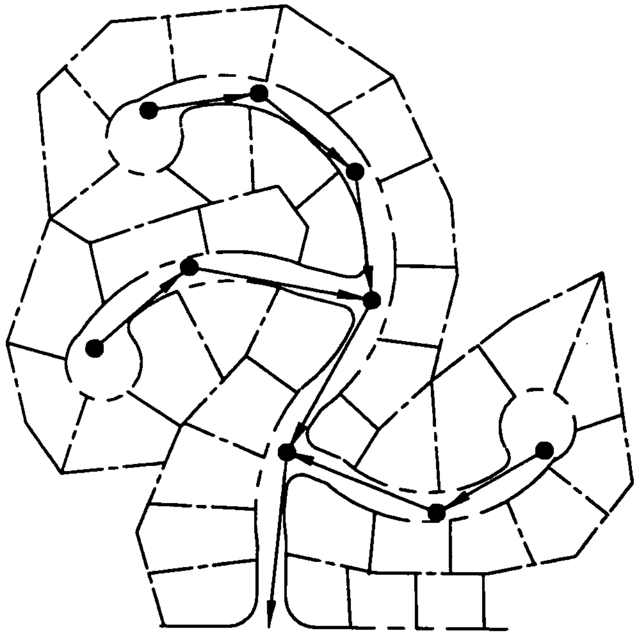


PIPE SIZE (IN)	SECTION LENGTH (FT)	APPROXIMATE LINEAR OFFSET AT MINIMUM RADII (IN)	CANTILEVER FORCE AT END OF PIPE TO ACCOMPLISH MINIMUM RADII (LBS)
4	20	24	6
6	20	16	20
8	20	12	48
10	20	12	95

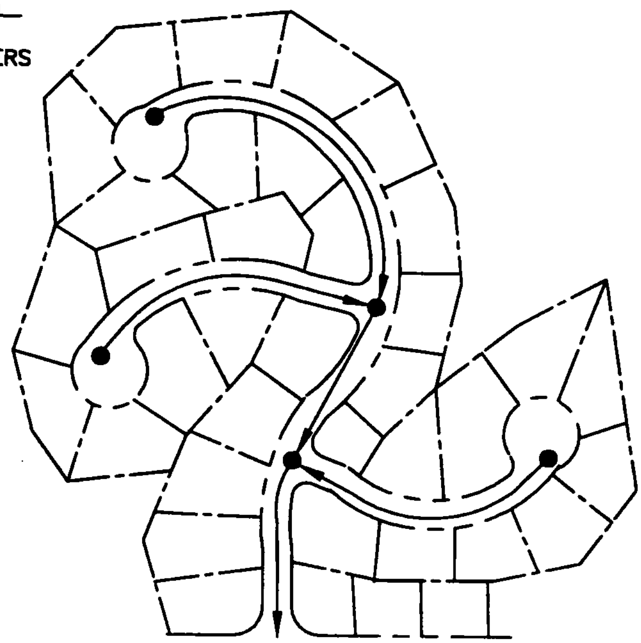


SOURCE: U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, "INNOVATIVE SITE UTILITY INSTALLATIONS."

CONVENTIONAL GRAVITY SEWER LAYOUT
VERSUS CURVILINEAR DESIGN



CONVENTIONAL LAYOUT OF GRAVITY SEWERS
(9 MANHOLES)



CURVILINEAR LAYOUT OF GRAVITY SEWERS
(5 MANHOLES)

SOURCE: U.S. DEPARTMENT OF HOUSING AND URBAN DEV.,
"INNOVATIVE SITE UTILITY INSTALLATIONS."

WATER SUPPLY STANDARDS

The primary purpose of a residential water supply system is to deliver potable water to meet domestic needs. Potable water for the system shall be provided by a public water supply or a private well. Public systems also provide fire protection for the community.

While careful consideration was given to each section of this standard, a locality may, based on sound engineering practices, waive any part of these standards to meet unique needs or provide equivalent alternatives.

CONTENTS

STANDARDS

1.0 - SUPPLY SYSTEM DESIGN-GENERAL

The supply system shall provide an adequate water supply and pressure for domestic needs. The system shall be evaluated for the period of peak hourly consumption. The public supply system shall be capable of providing the required fire flows in addition to the peak domestic demands. The system shall be designed to supply these domestic and fire needs without creating adverse velocities or pressures in new or existing systems. Future development shall be considered in system design where adjacent undeveloped areas have no alternative water source. Easements or public access areas for future connections shall be provided.

1.1 - Domestic flows required for residential use shall be based on estimated occupancy and per capita water use according to Tables 1 and 2.

Table 1
WATER CONSUMPTION RATES

Dwelling Unit Type	Average Day Consumption	Factor for Peak Hour Consumption
Single-Family*	100 gpcd	5.5
Single-Family w/Extensive Water Requirements*	125 gpcd	6.0
Apartments*	75 gpcd	5.0

*Values based on a metered water system.

The above values shall be reduced by 20 percent for single-family residences with septic tanks and increased by 200 percent or more, based on local judgment, for unmetered services. Design values based on local experience or records of existing similar systems in the area may be substituted for the above values when warranted.

The design population shall be based on values in Table 2 (Ref. 2, p. 43).

COMMENTARY

The period of peak hourly consumption is evaluated to account for domestic water use, which is often concentrated at particular times of the day. It is not necessary to provide active water service to future developments, although access to allow for extension of the system must be provided.

Private water supply systems are not required to provide flow for fire protection, although NFPA 1231 Standard on Water Supplies for Suburban and Rural Fire Fighting (Ref. 1) is a standard communities could use for guidance in this area. A higher level of fire protection could result in lower insurance premiums for the home owner.

These values for determining residential water demand are based on the National Association of Home Builders *Water Distribution Systems Land Development Standards.* These standards represent data from a national survey of 92 communities in 37 states and a review of available literature and research on residential water use. Since water use varies with climatic and other conditions, local water use information may be substituted for the values in the tables where warranted. Table 1 gives values for average day water use and a factor to determine peak-hour consumption.

STANDARDS

Table 2
DESIGN VALUES:
PERSONS PER DWELLING UNIT

Dwelling Unit Type	Design Value Persons/D.U.
Single-Family	3.5
Townhouse	3.1
Low-Rise Apartment	2.9
Medium- or High-Rise Apartment	2.7

1.2 - The water system shall be designed to provide satisfactory pressure at fixtures during the peak hourly demand. For residential buildings less than four stories, a minimum design pressure of 30 psi at the service connections shall be provided during the period of peak hourly demand (Ref. 2, p. 29). Alternatively, the system shall be designed to provide adequate pressure during the period of peak hourly demand at the most remote fixture in a dwelling.

1.3 - The required fire flow is based on exposure from and to adjacent structures. For residential one- and two-family dwellings not exceeding two stories in height, Table 3 shall be used to calculate needed fire flows of two-hour duration (Ref. 3, p. 17-36). In recognition of the value and effectiveness of automatic sprinklers, the required fire flow for buildings with sprinklers shall be that needed for the sprinkler system plus 500 gpm hydrant flow (Ref. 3).

Table 3
REQUIRED RESIDENTIAL FIRE FLOWS

Distance Between Buildings	Required Fire Flow (gpm)
Over 100 Feet	500
31-100 Feet	750
11-30 Feet	1,000
10 Feet or Less	1,500

Add 500 gpm to the required fire flow for wood-shingle roof coverings on the subject dwelling or adjacent buildings.

1.4 - The water system design shall protect against negative backflow due to pressures in the main by maintaining a minimum allowable residual pressure of 20 psi during the period of peak hourly demand (Ref. 3, p. 17-35).

COMMENTARY

Pressures lower than 30 psi are acceptable when it can be shown that such pressures will be adequate to serve the most remote fixture. Lower pressures will require finished fixture information and shall take into account the type of fixture and head loss through meters, service connections, valves, dwelling piping, and differences in elevation.

In areas where local building codes require sprinkler systems, the fire flow requirements do not need to meet the same standards as for nonsprinklered buildings. In any case, fire protection should not be redundant. Water mains not designed to carry fire flows should not be connected to fire hydrants unless an evaluation is performed to determine the effect of the connection on the system.

STANDARDS / COMMENTARY

1.5 - Excessive internal pressures that lead to leaks or ruptures of pipe materials and fittings shall be avoided in the system. When static pressures exceed 100 psi, pressure-reducing devices shall be provided on mains (Ref. 4). In no case shall the design pressure exceed the maximum working pressure of the pipe materials and fittings.

1.6 - Excessive velocities in the system; resulting in large head losses, pipe erosion, and water hammer; create the potential for breaks and connection failures and shall be prohibited. The maximum allowable design velocities in the system shall not exceed those recommended by the manufacturer of the pipe and fittings.

1.7 - The pipes in the system shall be sized to provide the design pressures and flows at the acceptable velocities outlined in this section. Fire hydrants shall be served by minimum 6-inch-diameter pipes or by larger pipes, if calculations warrant.

1.8 - In many communities, the existing water distribution infrastructure provides an acceptable level of service but does not meet the minimum requirements of these standards. In these situations, where reasonable layout and sizing of a development's water system are not the cause of inadequate pressures or flows according to these standards, the system shall be evaluated by the community on a case-by-case basis. An analysis shall be submitted to the community to demonstrate the performance of the proposed design.

2.0 - PIPE MATERIALS

2.1 - Acceptable pipe materials include concrete, ductile and cast iron, plastic, steel, and vitrified clay that meet the requirements of the standards listed in Section 10. The engineer shall use manufacturers' or other appropriate roughness coefficients in the design calculations.

Commentary: Asbestos cement pipe is on the EPA list of products to be banned and is not recommended for use.

2.2 - Water systems shall be capable of withstanding anticipated loads. Pipes located under roadways or travelways shall be able to sustain the live loads imposed from passing vehicles and shall meet design requirements for AASHTO H-20 loading. The maximum depth of burial shall not exceed pipe manufacturers' recommended depth for the material used unless calculations show the material to be adequate.

Commentary: The use of protective sleeves or alternative pipe material for the loaded area is acceptable to protect the pipe.

STANDARDS

3.0 - PIPE PLACEMENT

The system shall be placed to deliver water adequately to its distribution points in accordance with this section.

3.1 - Maintenance personnel shall have access via easements to maintain the public system located outside the public right-of-way. The easement shall be wide enough to allow personnel and equipment access to maintain and perform general repair on all parts of the system. The minimum easement width shall be 10 feet. Pipes may be offset from the center of the easement. Easements of separate utilities may overlap.

3.2 - Water pipes shall be protected from excessive bearing pressures by placing them outside the influence zone of building structures unless engineering calculations show the pipe material or soil condition is capable of sustaining the applied load.

3.3 - Precautions shall be taken when water pipes approach, cross, or run parallel to sewers to avoid possible contamination. A water pipe shall not pass through or come in contact with a sewer manhole. The water pipe shall be protected by one of the following:

1. providing a 10-foot horizontal separation between water pipes and the sewer;
2. placing the water pipe 18 inches above the sewer and on a separate shelf; or
3. constructing both the water pipe and sewer with watertight joints and pressure testing each to ensure watertightness.

3.4 - Water pipes that cross surface waters shall be protected against damage, anchored to prevent movement, and provided with easily accessible shutoff valves located outside the floodway at each end of the water crossing. For aerial crossings, the pipe shall be supported and protected from damage or freezing. For underwater crossings, the top of the water pipe shall be at least 1 foot below the natural bottom of the stream bed when the pipe is located in rock or 3 feet below the natural bottom of the stream bed when the pipe is located in other material. The trench shall be backfilled with crushed rock or gravel (Ref. 4).

COMMENTARY

Engineering judgment should be used in selecting the optimal location of the water system. The location should be compatible with the site layout and not dictate or limit design or land use alternatives. Placing the system under the pavement, along the streets, or behind the units in an easement are options to consider.

A diagram of the building influence zone is given in the appendix to this standard.

These measures to protect the water supply from contamination are based on common construction practices used across the country. The option of placing the water pipe on a separate shelf in a common trench is allowed by the BOCA code as well as the Great Lakes Recommended Standards for Water Works (10 State Standards, Ref. 5). A detail of a common sewer and water trench with the water pipe on a separate shelf is shown in the appendix to the Sanitary Sewage Systems Standards.

STANDARDS	COMMENTARY
3.5 - Water supply pipes shall be protected against freezing by providing adequate burial depths or other insulating arrangements. The top of the water pipe shall be located below the lowest established frost depth.	
3.6 - Proper trenching, bedding, and backfill are required for pipe performance. Bedding shall conform to the standards of Section 10. The width of the trench shall allow the pipe to be properly laid and jointed and to permit the backfill to be placed and compacted as needed. Backfill shall be of a suitable material removed from excavation except where other material is specified. Debris, frozen material, large stones, organic matter, or other unstable materials shall not be used for backfill within 2 feet of the top of the pipe.	
3.7 - Pipes constructed on fill shall be stable and protected against settlement by compacting fill material to 95 percent of the modified Proctor (ASTM D1557-78) maximum dry density.	
3.8 - Metal water pipe shall be protected from corrosion due to local conditions through the installation of cathodic protection, application of protective coatings, treatment of water, or avoidance of corrosive soils.	Corrosion in steel and iron water mains is sometimes caused by contact of two dissimilar metals with water or soil, stray electrical currents, impurities or strains in metals, contacts between acids and metals, bacteria in the water, or soil-producing compounds that react with metal. When corrosive soils are unavoidable, exterior slip-on plastic liners, polyrap, or similar protection should be considered.
4.0 - SERVICE CONNECTIONS	
The function of a service connection is to convey potable water from the main to the building at an adequate pressure and flow rate.	The use of multiple connections to a single service line allows for an economical and functional system if the line is sized to serve all connected buildings. The costs of trenching and pipe will be reduced. Likewise, by combining service and fire lines where required, development costs are reduced.
4.1 - Service lines that serve more than one building shall be located in an easement or in a common area and meet requirements of locally adopted building codes for installation and placement. The service shall separate before entering a dwelling unit.	
4.2 - Service line valves, fittings, and materials shall conform to the standards outlined in Section 10.	Components of a typical water service connection are shown in the appendix to this standard.
4.3 - Service line size shall provide adequate water quantities and pressures to the buildings served yet meet minimum size requirements of locally adopted building codes.	

STANDARDS	COMMENTARY
5.0 - APPURTENANCES	
Appurtenances are accessories to the water system, including fittings to accommodate system geometry and controls for the protection and maintenance of the system.	
5.1 - Sufficient valves shall be provided on water mains to minimize any inconvenience or sanitary hazards during repairs. At minimum, valves shall be located to reduce the length of pipe shut down during service to 800 feet (Ref. 3, p. 17-35). Where systems serve widely scattered customers and future development is not expected, the valve spacing shall not exceed one mile (Ref. 4).	
5.2 - The system shall be designed to prevent failure at fittings by selecting fittings with the same range of working pressure as the pipe with which they are used. Fitting materials shall be compatible with pipe materials and standards outlined in Section 10.	
5.3 - All tees, bends, plugs, and hydrants shall be provided with thrust blocking, tie rods, or joints designed to prevent movement (Ref. 3, p. 17-47).	Typical examples of thrust block placement are shown in the appendix to this standard.
5.4 - The system shall be designed to allow for the removal of sediment and air by placing air releases or hydrants at high points and blowoffs or hydrants at low points. A blowoff or fire hydrant shall be located on dead-end lines to provide a means of flushing these lines. No flushing device shall be directly connected to a sewer. Automatic air relief valves shall not be used in situations where flooding of the manhole or chamber may occur.	Flushing devices should be sized to provide flows with a velocity of at least 2.5 fps in the water main being flushed (Ref. 4).
5.5 - Where meters are required, they shall be located in an accessible area and be of minimal size to deliver adequate flows. Meters shall be placed so they are protected from damage or freezing.	
5.6 - There shall be no connection between the distribution system and any pipes, pumps, hydrants, or tanks whereby unsafe water or other contaminating materials may be discharged or drawn into the system (Ref. 4). Backflow prevention devices shall be required on hydrants that use pumps interconnected with an auxiliary water supply.	

STANDARDS	COMMENTARY
6.0 - FIRE HYDRANTS	
Fire hydrants shall be placed to provide adequate coverage and convenient access in an emergency.	
6.1 - Fire hydrants shall be able to deliver adequate flows from the system to the hose and shall meet the applicable standards outlined in Section 10.3.	
6.2 - Hydrants located within the pavement of a travelway or parking area shall be protected from vehicular damage with bollards or similar physical barriers that must not interfere with the operation of or connection to the hydrant.	The decision to use bollards or protective posts and other physical barriers such as guardrails calls for site-specific judgments about protecting the hydrant while allowing access for emergency personnel. An example of fire hydrant protection is given in the appendix to this standard.
6.3 - Hydrants shall be located within a 500-foot hose reach of all building areas. The available equipment of the protecting agency may allow adjustments in required hydrant locations.	The hose reach should be measured with respect to obstructions that might inhibit emergency personnel from extending hoses from a given hydrant to the most distant building.
6.4 - Hydrants protecting multistory residential or commercial buildings shall be located such that a burning structure will not impair connection to the hydrant. The hydrants protecting these structures shall be placed at a minimum of 40 feet from the protected structure.	
6.5 - Hydrants shall allow for convenient connections in an emergency and facilitate emergency repairs. Hydrants shall be located with the hydrant flange 2.5 inches from the ground surface as shown in the appendix to this standard.	
6.6 - Hydrants shall be located outside areas of constant or frequent ditch flows to protect them from surface water erosion.	A figure of typical fire hydrant placement is shown in the appendix to this standard.
7.0 - TESTING AND DISINFECTION	
Flushing, testing, and disinfecting the water system shall be conducted to prepare the newly constructed system for service and to locate installation problems.	

STANDARDS

7.1 - The system shall be flushed before connection to the public water supply to remove foreign materials. The system shall also be pressure tested and leakage tested in accordance with AWWA Standard C600-87. The system shall meet minimum leakage requirements of AWWA C600-87, which requires leakage to be less than the number of gallons per hour determined by the following formula:

$$L = \frac{ND\sqrt{P}}{J}$$

where: L= minimum allowable leakage (gph);
J= 1,850 for bell and spigot joints;
J= 3,700 for mechanical and push-on joints;
N= number of joints in tested length;
D= nominal diameter of pipe (in.); and
P= average test pressure (psi gauge).

7.2 - All new, cleaned, or repaired water mains shall be disinfected in accordance with AWWA Standard C651-86 (Ref. 4) to remove harmful bacteria.

8.0 - PRIVATE WELLS

A private water supply system or well may serve as an alternative to a public system for water supply needs. Where used, wells shall comply with the requirements of this section.

8.1 - To protect public supply systems from contamination by a private well, cross connections between private and public water systems shall be prohibited.

COMMENTARY

The EPA considers a private water supply system to be one that serves less than 15 connections and less than 25 users. State and local health authorities regulate private wells used as potable water supplies. Specific regulations vary considerably by state and county and should be consulted in the design and construction of a private well.

A developer and jurisdiction must consider several factors in selecting and approving construction of a well or wells in favor of connection to an existing water supply. These factors extend to the cost of the connection versus the cost of the private well, including the number of units and the distance to the connection; any long-term public financial commitments to water supply infrastructure, including anticipated revenue from future connections; and ground water availability and quality at the site.

STANDARDS | COMMENTARY

8.2 - The private well and system shall be designed, tested, and maintained to supply adequate water quantities while complying with local or state water quality standards or, in the absence of such standards, with relevant EPA standards required by the Safe Drinking Water Act.

8.3 - The well shall be protected from possible sources of contamination by conforming to the minimum offset distances in Table 4.

The separation distances given in Table 4 are based on recommendations by EPA (Ref. 6, p. 36) and HUD (Ref. 7, p. 19). The separation distance from the property line should consider identifiable septic or drain fields on adjoining property.

Table 4
MINIMUM WELL SEPARATION DISTANCES

Distance From	To Well
Property Line	5 Feet
Down Gradient Septic Tank or Drain Field with Deep Drilled Well	50 Feet
Up or Cross-Gradient Septic Tank or Drain Field	100 Feet
Septic Tank or Drain Field with Dug Well	100 Feet
Sewer Lines	10 Feet

8.4 - Pressure shall be retained in artesian wells by sealing the casing into the overlying impermeable formation.

Artesian wells are those in which the ground water is under pressure because it is confined beneath an impermeable layer of material below the recharge area of the aquifer (Ref. 7, p. 9).

8.5 - Surface water shall be prevented from entering the well by filling the open space outside the casing with a watertight cement grout or puddled clay from a point just below the frost line or at the deepest level of excavation near the well to the necessary depth. Contaminated water or other objectionable material shall be prevented from entering the well by installing a sanitary well seal with an approved cap at the top of the well casing.

9.0 - COMMUNITY WELLS

Passage of the 1974 Safe Drinking Water Act and its 1986 amendments resulted in the promulgation of national drinking water regulations for public and private water systems. A community well serving at least 15 connections or at least 25 users is regulated under the act and shall adhere to EPA levels of water quality.

EPA has set numeric standards referred to as maximum contaminant levels and secondary maximum contaminant levels for contaminants that pose potential health risks in drinking water. EPA maximum contaminant levels and secondary maximum contaminant levels are given in Table 1 in the appendix to this standard.

STANDARDS

COMMENTARY

9.1 - A community well distribution system shall meet the minimum requirements of these standards with respect to materials, pipe placement, service connections, appurtenances, fire hydrants, and testing.

9.2 - Community wells shall be protected from contamination and shall comply with Section 8.0, Private Wells.

10.0 - MATERIAL STANDARDS

All materials and appurtenances shall be specified in the design, shall be suitable to accomplish the objective of the water supply system, and shall conform to currently dated standards of the American Society for Testing and Materials (ASTM), the American Standards Association (ASA), the American Water Works Association (AWWA), the American National Standards Institute (ANSI), or the General Services Administration (federal specifications) for the material type and intended use. All installations shall be in accordance with manufacturers' recommendations where not governed by these standards. The following are applicable specifications:

10.1 - Pipe and Fittings

10.1.1 - Ductile iron pipe shall conform to ANSI/ AWWA Standard C151/A21.51-86. Ductile iron pipe fittings and grey iron pipe fittings 3 inches through 48 inches shall conform to ANSI/AWWA Standard C110/A21.10-87. Rubber-gasket joints for grey iron pipe or ductile iron pipe and fittings shall be as specified in ANSI/AWWA Standard C111/A21.10-90. Joints for ductile iron pipe with threaded flanges shall conform to ANSI/AWWA Standard C115/A21.15-88.

10.1.2 - Reinforced concrete water pipe shall conform to ANSI/AWWA Standards C300-89, C301-84, C302-87, and C303-87. Joints for reinforced concrete pipe shall be as specified in AWWA Standard C301-84.

10.1.3 - PVC pressure pipe and fittings 4 inches through 12 inches shall conform to ANSI/AWWA Standard C900-89. PVC pipe sizes 14 inches through 36 inches shall conform to AWWA Standard C905-88. Installation shall be in accordance with ASTM D-2321-89 and ASTM D-2274-88.

STANDARDS

COMMENTARY

10.1.4 - Polyethylene tubing for water mains or connections 1/2-inch through 3 inches shall comply with AWWA Standard C901-88 and conform to ASTM specification D-1248-89. Polybutylene tubing 1/2-inch through 3 inches shall conform to AWWA Standard C902-88 and ASTM specification D-2581-91. Tubing dimensions and tolerances shall conform to ASTM D-2737-89.

10.2 - Valves

10.2.1 - Service line valves and fittings shall comply with AWWA Standard C800-89.

10.2.2 - Gate valves shall comply with ANSI/AWWA Standard C500-86 or AWWA C509-87.

10.2.3 - Butterfly valves shall be designed and manufactured in accordance with ANSI/AWWA Standard C504-87.

10.2.4 - Ball valves shall conform to AWWA Standard C507-85.

10.2.5 - Check valves 2 inches through 24 inches shall comply with ANSI/AWWA Standard C508-82.

10.3 - Hydrants

10.3.1 - Dry barrel fire hydrants shall conform to AWWA Standard C502-85. Wet barrel hydrants shall conform to AWWA Standard C503-88.

10.3.2 - Fire hydrant outlets shall be equipped with American National Fire Hose Connection Screw Threads and shall be equipped with thread adapters when the local fire department thread is different (Ref. 8).

10.4 - Installation and testing of all new water mains and their appurtenances shall comply with AWWA Standard C600-87.

10.5 - Water mains shall be disinfected according to AWWA Standard C651-86. Wells shall be disinfected according to AWWA Standard C654-87.

ABBREVIATIONS AND DEFINITIONS

AASHTO. American Association of State Highway and Transportation Officials, Room 341, National Press Building, Washington, DC 20045; (202) 624-5800.

ANSI. American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036; (212) 642-4900.

ASTM. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103; (215) 299-5400.

Average Day Consumption. The daily average of water consumption used during a one-year period (see Table 1).

AWWA. American Water Works Association, 6666 West Quincy Avenue, Denver CO 80235; (303) 794-7711.

Fixture. A device that is either temporarily or permanently connected to the water distribution system and demands a supply of water.

Main. The principle water pipe to which service connections are made.

Maximum Day Consumption. The amount of water used in the 24-hour period during which the highest consumption total is expected in a three-year period.

Multistory Residential. A building greater than four stories in height and intended for multifamily occupancy.

NFPA. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269; (617) 770-4543.

Peak Hourly Consumption. The maximum amount of water used in any given hour of a day. It is calculated by multiplying the average day consumption by the peak factor in Table 1.

Potable Water. Water free from impurities in amounts sufficient to cause disease or harmful physiological effects and conforming to the standards or regulations of the public health authority with jurisdiction over the water supply.

Residual Pressure. The resultant pressure in the system during periods of demand flows.

Service Connection. The appurtenances and pipe from the municipal main to any building receiving water.

REFERENCES

1. National Fire Protection Association. *NFPA 1231-1984, Standard on Water Supplies for Suburban and Rural Fire Fighting.*
2. NAHB Research Center. *Manual on Water Distribution Systems Land Development Standards.* 1974.
3. National Fire Protection Association. *Fire Protection Handbook.* 1986.
4. Great Lakes Upper Mississippi River Board of State Sanitary Engineers. *Recommended Standards for Sewage Works.* 1978.
5. Great Lakes Upper Mississippi River Board of State Sanitary Engineers. *Recommended Standards for Water Works.* 1978.
6. U.S. Environmental Protection Agency. *Manual of Small Public Water Supply Systems.* 1991.
7. U.S. Department of Housing and Urban Development. *Minimum Design Standards for Community Water Supply Systems* (4940.2 Rev. 1). 1992.
8. National Fire Protection Association. *NFPA 1963-1979, Standard for Screw Threads and Gaskets for Fire Hose Connections.*

WATER SUPPLY

APPENDIX

Table 1
MAXIMUM CONTAMINANT LEVELS (MCLs)[1]

Inorganic Contaminants

Parameter	MCL	Parameter	MCL
Arsenic	0.05	Fluoride	4.0
Asbestos (fibers/L)	7 million	Lead	0.015[2]
Barium	1	Mercury	0.002
Cadmium	0.005	Nitrate (as N)	10
Chromium	0.1	Nitrate + Nitrite (as N)	1
Copper	1.3[2]	Selenium	0.01
Fluoride	4.0		

Organic Contaminants

Parameter	MCL	Parameter	MCL
Alachlor	0.002	Ethylene dibromide	0.00005
Atrazine	0.003	Heptachlor	0.0004
Benzene	0.005	Heptachlor epoxide	0.0002
Carbofuran	0.04	Lindane	0.0002
Carbon Tetrachloride	0.005	Methoxychlor	0.04
Chlordane	0.002	Monochlorobenzene	0.1
2,4-Dichlorophenoxyacetic	0.07	Polychlorinated biphenyls	0.0005
Dibromochloropropane	0.0002	Styrene	0.1
o-Dichlorobenzene	0.6	Tetrachloroethylene	0.005
para-Dichloroethane	0.075	Toluene	1
1,2-Dichloroethane	0.005	Toxaphene	0.003
1,1-Dichloroethylene	0.007	Total Trihalomethanes	0.010
cis-1,2-Dichloroethylene	0.07	2,4,5-TP (Silvex)	0.05
trans-1,2-Dichloroethylene	0.1	Trichloroethane	0.005
1,2-Dichloropropane	0.005	1,1,1-Trichloroethane	0.020
Endrin	0.0002	Vinyl Chloride	0.002
Ethylbenzene	0.7	Xylenes	0.10

Radiological Contaminants

Parameter	MCL
Total radium (radium 226 + radkum-228)(pCi/L)	5
Gross alpha activity (pCi/L)	15
Beta particle and photon activity (millirem/year)	4

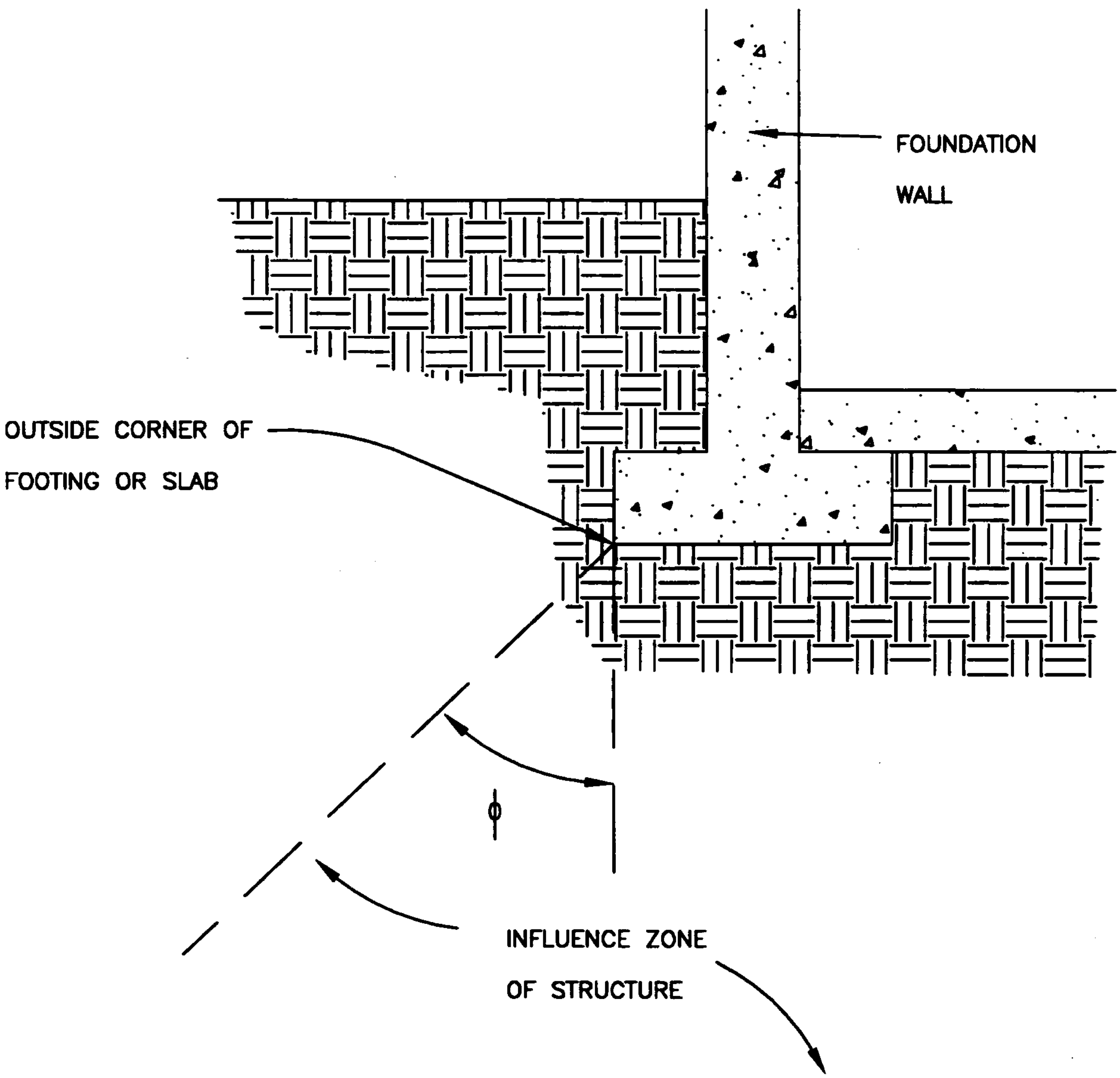
Secondary Maximum Contaminant Levels (SMCL)[1]

Parameters	MCL	Parameter	MCL
Aluminum	0.05 to 0.2	Manganese	0.05
Chloride	250	Odor (TON)	3.0
Color (ptCo units)	15	pH	6.5 to 8.5
Copper	1.0	Silver	0.1
Corrosivity	Noncorrosive	Sulfate	250
Fluoride	2.0	Total dissolved solids	500
Foaming Agents	0.5	Zinc	5.0
Iron	0.3		

[1]Unit in mg/L unless otherwise noted.

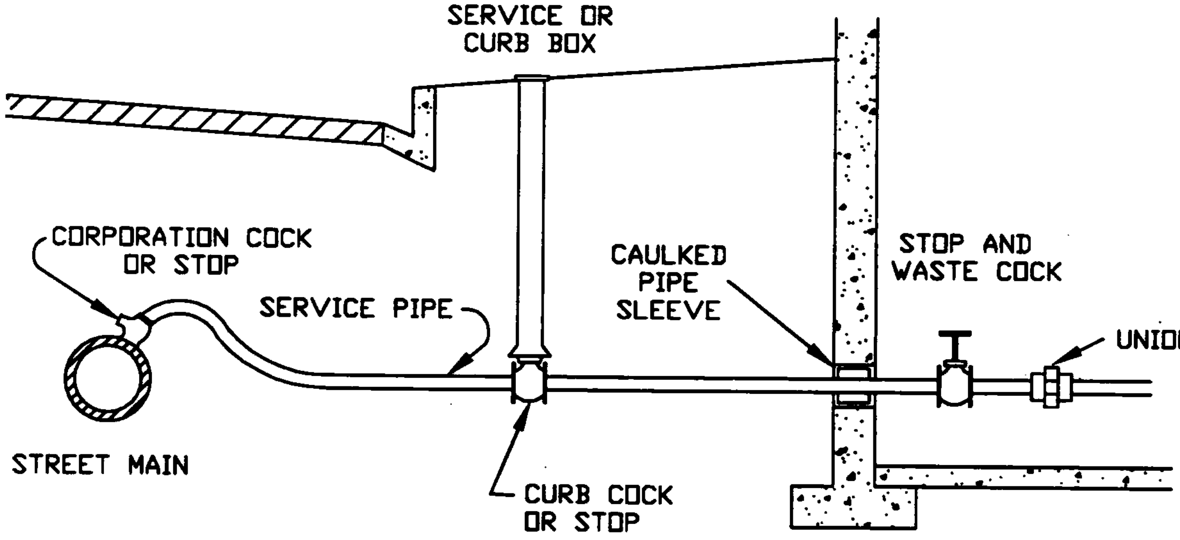
[2]USEPA has set "action levels" for copper and lead in public drinking water.

DIAGRAM OF BUILDING INFLUENCE ZONE



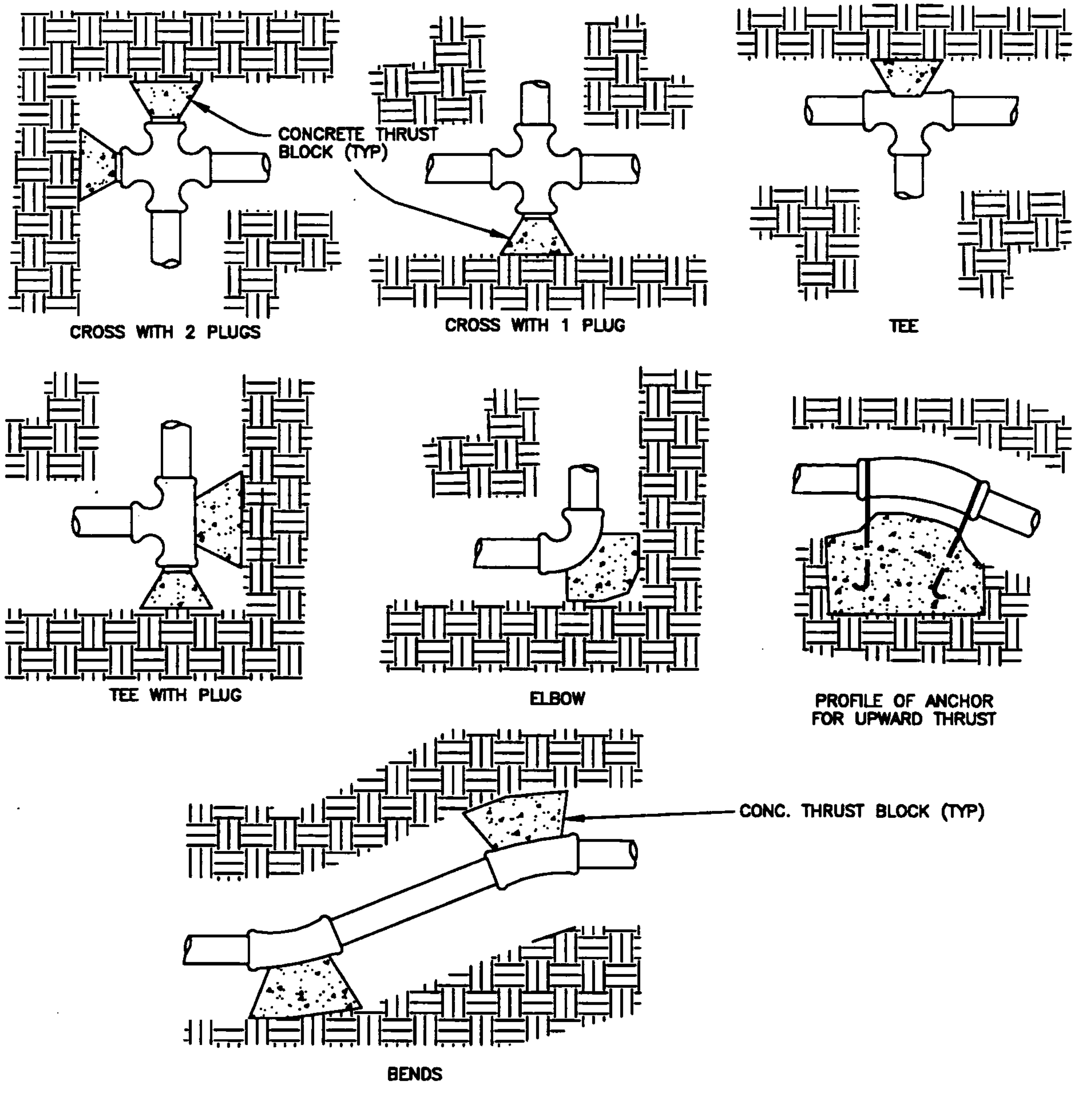
ϕ = 45 DEGREES TYPICALLY, BUT DEPENDENT ON SOIL CONDITIONS

TYPICAL WATER SERVICE CONNECTION
WITH CURB STOP



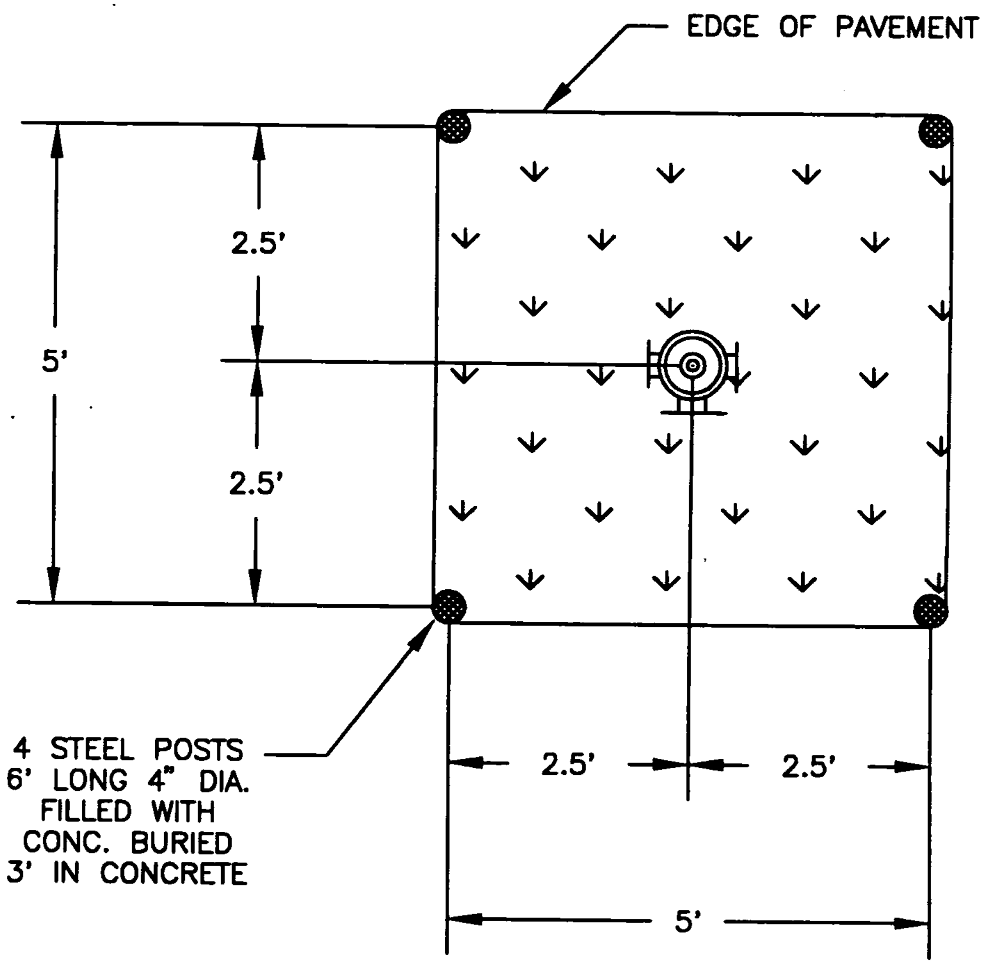
SOURCE: U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, 'INNOVATIVE SITE UTILITY INSTALLATIONS.'

CONDITIONS FOR USING THRUST BLOCKS



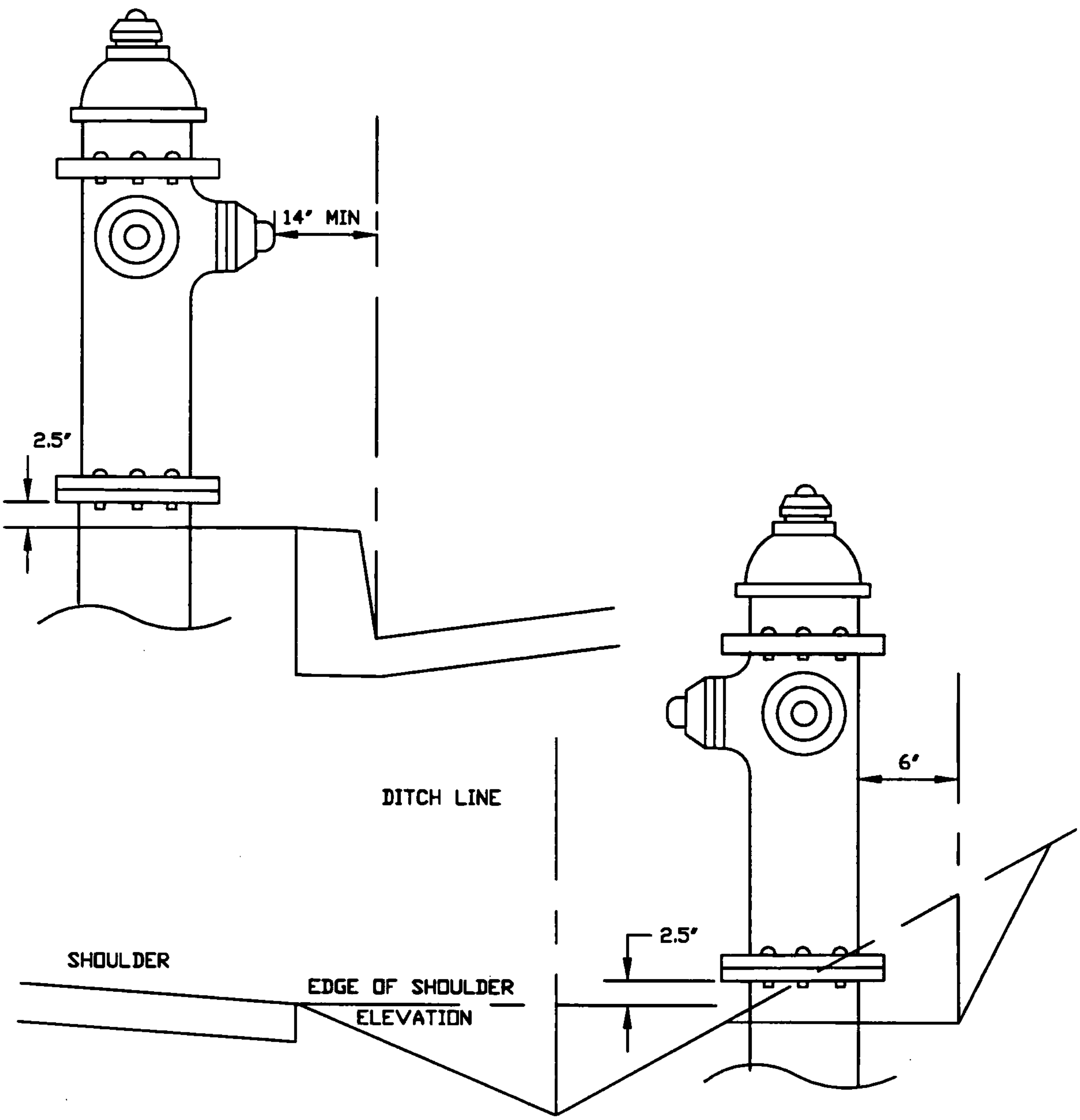
SOURCE: U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, "INNOVATIVE SITE UTILITY INSTALLATIONS."

TYPICAL FIRE HYDRANT PROTECTION IN AREA WHERE ISLAND CANNOT BE CONSTRUCTED



Source: *Fairfax County Public Facilities Manual.* Fairfax County, VA. 1988.

TYPICAL FIRE HYDRANT PLACEMENT



Source: *Fairfax County Public Facilities Manual*. Fairfax County, VA. 1988.

MISCELLANEOUS STANDARDS

Some jurisdictions have extended subdivision authority to include standards concerning open space and landscaping. Although requirements in these areas may sometimes be appropriate in a residential development, such requirements typically add to the cost of housing. Jurisdictions must attempt to establish a reasonable balance between the costs and benefits of these requirements to the residents.

While careful consideration was given to each section of this standard, a locality may, based on sound engineering practices, waive any part of these standards to meet unique needs or provide equivalent alternatives.

CONTENTS

STANDARDS	COMMENTARY

1.0 - OPEN SPACE

1.1 - The developer shall give consideration to open space.

Open space within a development should be designed to perform a function. **Developed open space** provides for active recreation to serve residents. **Undeveloped open space** preserves natural vegetation, site amenities, and environmentally sensitive areas and allows for the passive enjoyment of residents.

Paths and trails, recreational facilities, storm water management, erosion and sediment control facilities, and utility easements can be provided within a development's open space.

1. Storm water can be channeled through grass-lined swales and natural channels in open areas to minimize grading and sodding costs and to allow for groundwater replenishment.

2. Natural and manmade ponds in open space areas can serve as storm water detention areas.

3. Open space can be a buffer between neighborhoods or between the community and other surroundings.

1.2 - There is no minimum requirement for open space.

Factors to consider in determining the need for open space include

1. the age of anticipated residents;
2. population density;
3. area economics;
4. regional and cultural facilities; and
5. topographical features.

Cluster planning techniques allow for smaller lots that share open space (common space). Such common space is owned and maintained by a home owner or community association.

STANDARDS / COMMENTARY

2.0 - LANDSCAPING

Some communities have passed stringent landscaping standards. These may require, for example, street trees, trees of a specific size and species, or a certain number of trees or shrubs per lot. The cost consequences of such requirements deserve recognition. While landscaping and tree preservation may be desirable, competing community goals require consideration.

2.1 - The developer shall give consideration to landscaping.

Well-planned landscaping may serve several functions, such as

1. assisting in soil stabilization and prevention of erosion;
2. improving groundwater recharge;
3. retarding storm water runoff;
4. acting as a noise buffer;
5. screening nuisance areas, trash collection areas, streets, and parking;
6. providing shade and cooling; and
7. increasing privacy.

2.2 - There is no minimum requirement for landscaping.

Although efforts should be taken to minimize needless destruction of natural vegetation during the site planning and development processes, the cost of preservation must be considered. Trees should be removed where they pose a safety hazard to nearby buildings or pedestrian or vehicular traffic, prevent essential grade changes or reasonable utility installation, or interfere with compliance with other regulations. It is important to note that tree removal and disposal are also costly.

PART II

MODEL
STATE ENABLING LEGISLATION

STATE PREEMPTIVE STANDARDS FOR LAND DEVELOPMENT AND SITE IMPROVEMENT

Note: Commentary in brackets ([ ]) in this statute is for informational purposes only.

An Act providing statewide uniform land development standards for subdivisions and, where applicable, site review and not limiting a local authority's power to control use, area, density, bulk, or dimensional or zoning requirements.

Be it enacted by the Legislature of the State of ______________:

1. The Legislature finds and declares that:

   a. The multiplicity of standards for land development, subdivisions, and site improvements that currently exists in this state increases the costs of housing without commensurate gains in the protection of the public health and safety;

   b. All citizens of this state are entitled to safe, decent, affordable housing;

   c. It is in the public interest to avoid unnecessary cost in the construction process, and uniform land development and site improvement standards that are both sound and cost-effective will advance this goal;

   d. Adoption of uniform land development and site improvement standards will satisfy the need to ensure predictability;

   e. The public interest is best served by basing development and site improvement review on sound, objective standards;

   f. The goal of streamlining the development and site improvement approval process by improving the efficiency of the application process is best served by establishing a uniform set of technical standards for land development that represents a consensus of the concerns of informed and interested parties; and

   g. The goal of providing the widest possible range of design freedom and diversity in development can be accomplished when technical requirements are based on sound minimum standards.

2. a. There is established a State Land Development and Site Improvement Advisory Board *[Agency]* to develop and promulgate statewide land development and site improvement standards. The Board shall consist of the Commissioner of Community Affairs (or equivalent) as a nonvoting member, the Director of the Division of Housing (or equivalent), one planner employed by a local government entity, one planner with expertise in private residential development, and one representative each from:

1. the State Society of Professional Engineers;
2. the State Society of Architects;
3. the State Association of County/Municipal Engineers;
4. the State Board on Affordable Housing;
5. the State Builders Association;
6. the State League of Counties or Municipalities; and
7. a State College or University from the field of planning, architecture, engineering, or building construction.

[The intent of this section is to establish a body of professionals with the technical expertise to develop and approve the standards. If an existing state board or agency currently can assume this responsibility, a new board need not be established. It is to everyone's advantage to include the expertise of engineers, planners, builders, etc.]

b. The Commissioner of Community Affairs shall appoint all voting members for a term of ____ years. Vacancies shall be filled for an unexpired term. The Commissioner shall select a Chair from among the Board members. Members may be removed for cause by the Commissioner.

[Use the established administrative procedures for appointments and terms of office for state boards or commissions.]

c. Board members shall serve without compensation but may be entitled to reimbursement for expenses incurred in the performance of their duties.

3. a. The Board shall prepare and submit to the Commissioner, within ____ days of the appointment of its full membership, recommendations for statewide land development and site improvement standards for residential development. The attached XYZ Model Land Development Standards are recommended for use in their entirety. Any changes to the XYZ Standards or any Board-developed standards shall be technically equivalent to the provisions of the XYZ Standards and shall not be more restrictive than the XYZ Standards for enforcement by any government entity within the state.

In addition to the recommended standards, the Board shall develop a model application form for use throughout the State.

b. The Commissioner shall promulgate the recommended land development and site improvement standards and standard application form without any changes. The regulations shall be adopted and become effective within _______ months of their submission to the Commissioner.

c. A political subdivision may seek a waiver of any section of the standard if an equivalent provision is substituted. No waiver shall provide a more stringent requirement. Any application for a waiver shall be submitted in writing to the Commissioner, who shall direct the application to the Board. The Board shall render its decision on the application within ____ days of receipt. Any decision of the Board may be appealed back to the Board for a hearing of all interested parties. The Board shall render any final decision of an appeal within ____ days of the hearing. The decision of the Board on appeal shall be final.

[The number of days required for various decisions and appeal should be based on existing cycles for state boards or agencies. In addition, existing appeals processes and alternative dispute resolution mechanisms should be included herein to hear aggrieved parties.]

d. At a minimum, a developer must meet the State Land Development Standards.

e. The Board shall annually review the regulations adopted and shall recommend to the Commissioner any changes deemed necessary. Any changes made in the regulations pursuant to this subsection shall be made according to the same procedure and subject to the same waiver provisions set forth above.

4. The standards set forth in this Act shall supersede any land development and site improvement standards, including subdivision and site review where applicable, promulgated by any political subdivision. When there is a conflict between local land development standards and the state standards, the state standards shall take precedence. However, the development and site improvement ordinances of any municipality shall govern any project that has been submitted for approval before the effective date of the state land development and site improvement standards. In areas where there is no zoning or subdivision ordinance authority, the state shall have authority.

5. These standards shall apply to all state projects where applicable.

6. Nothing contained in this Act shall in any way limit the zoning power of any political subdivision in regulating use, area, or bulk or in regulating those other land development requirements as part of a site review process that are not addressed by these standards.

7. Nothing in these standards shall limit the implementation or enforcement of state or local building construction codes.

8. If any one section or provision of the State Land Development Standards is ruled invalid, the remainder of the standards remains intact and enforceable.

9. As used in this Act, "land development and site improvement standards" mean any standards regarding construction work on, or improvement in connection with, residential development and shall include streets and circulation, off-street parking, water supply, sanitary sewers, storm water management, erosion and sediment control, and utilities.

10. This Act shall take effect immediately.

STATE LAND DEVELOPMENT AND SITE IMPROVEMENT STANDARDS FOR VOLUNTARY ADOPTION BY POLITICAL SUBDIVISIONS

Note: Commentary in brackets ([ ]) found in this statute is for informational purposes only.

An Act providing state-approved uniform land development and site improvement standards that include subdivisions and site review where applicable for local adoption by reference.

Be it enacted by the Legislature of the State of ______________:

1. The Legislature finds and declares that:

   a. The multiplicity of standards for land development, subdivisions, and site improvements that currently exists in this state increases the costs of housing without commensurate gains in the protection of the public health and safety;

   b. All citizens of this state are entitled to safe, decent, affordable housing;

   c. It is in the public interest to avoid unnecessary cost in the construction process, and uniform land development and site improvement standards used by local governments that are both sound and cost-effective will advance this goal;

   d. Adoption by local jurisdictions of streamlined and consistent land development and site improvement standards will satisfy the need to ensure predictability;

   e. The public interest is best served by basing development and site improvement review on sound, objective standards;

   f. The goal of streamlining the development and site improvement approval process by improving the efficiency of the application process is best served by establishing a uniform set of technical standards for land development that represents a consensus of the concerns of informed and interested parties;

   g. The goal of providing the widest possible range of design freedom and diversity in development can be accomplished when technical requirements are based on sound minimum standards.

2. a. There is established a State Land Development and Site Improvement Advisory Board *[Agency]* to develop and maintain uniform standards for land development and site improvement that may be made available to local governments for adoption by reference. The Board shall consist of the Commissioner of Community Affairs (or equivalent) as a nonvoting member, the Director of the Division of Housing (or equivalent), one planner employed by a local government entity, one planner with expertise in private residential development, and one representative each from:

1. the State Society of Professional Engineers;
2. the State Society of Architects;
3. the State Association of County/Municipal Engineers;
4. the State Board on Affordable Housing;
5. the State Builders Association;
6. the State League of Counties or Municipalities;
7. a State College or University from the field of planning, architecture, engineering, or building construction.

[The intent of this section is to establish a body of professionals with the technical expertise to develop and approve the standards. If an existing state board or agency can assume this responsibility, a new board need not be established. It is to everyone's advantage to include the expertise of engineers, planners, builders, etc.]

b. The Commissioner of Community Affairs shall appoint all voting members for a term of ____ years. Vacancies shall be filled for an unexpired term. The Commissioner shall select a Chair from among the Board members. Members may be removed for cause by the Commissioner.

[Use the established administrative procedures for appointments and terms of office for state boards or commissions.]

c. Board members shall serve without compensation but may be entitled to reimbursement for expenses incurred in the performance of their duties.

3. a. The Board shall prepare and submit to the Commissioner, within ____ days of the appointment of its full membership, recommendations for statewide land development and site improvement standards for residential development. The attached XYZ Model Land Development Standards are recommended for use in their entirety. Any changes to the XYZ Standards or any Board-developed standards shall be technically equivalent to the provisions of the XYZ Standards and shall not be more restrictive than the XYZ Standards for enforcement by any government entity within the state.

In addition, the Board shall develop a model application form for development approval that may be used by local governments that adopt such standards.

b. The Commissioner shall promulgate the recommended land development and site improvement standards and standard application form without any changes. The regulations shall be adopted as state-approved land development and site improvement standards within _____ months of submission to the Commissioner.

c. Any local government that adopts these standards may seek a waiver of any section of the standard if an equivalent provision is substituted. No waiver shall provide a more stringent requirement. Any application for a waiver shall be submitted in writing to the Commissioner, who shall direct the application to the Board. The Board shall render its decision on the application within _____ days of receipt. Any decision of the Board may be appealed back to the Board for a hearing of all interested parties.

The Board shall render any final decision of an appeal within ______ days of the hearing. The decision of the Board on appeal shall be final.

[The number of days required for various decisions and appeals should be based on existing cycles for state boards or agencies. In addition, appeal processes and alternative dispute resolution mechanisms that currently exist should be included herein to hear aggrieved parties.]

d. At a minimum, a developer must meet the State Land Development Standards in any jurisdiction adopting such standards.

   [The State may offer technical and financial assistance or other incentives to local governments to encourage and facilitate the adoption and implementation of these State Land Development Standards. For example, a waiver of state reviews might be offered.]

e. The Board shall annually review the regulations adopted and shall recommend to the Commissioner any changes deemed necessary. Any changes made in the regulations pursuant to this subsection shall be made according to the same procedure and subject to the same waiver provisions set forth above.

4. The standards set forth in this Act shall be deemed state-approved land development and site improvement standards and shall hold the force of law only when adopted by a local government in this state and only in those adopting jurisdictions.

5. These standards shall apply to all state projects where applicable.

6. Nothing contained in this Act shall in any way limit the zoning power of any local government in regulating use, area, or bulk or in regulating those other land development requirements as part of a site review process that are not addressed by these state-approved standards.

7. Nothing in these standards shall limit the implementation or enforcement of state or local building construction codes.

8. If any one section or provision of the State Land Development Standards is ruled invalid, the remainder of the standards remains intact and enforceable.

9. As used in this Act, "land development and site improvement standards" mean any standards regarding construction work on, or improvement in connection with, residential development and shall include streets and circulation, off-street parking, water supply, sanitary sewers, storm water management, erosion and sediment control, and utilities.

10. This Act shall take effect immediately.

LAND DEVELOPMENT AND SITE IMPROVEMENT STANDARDS FOR ADOPTION BY LOCAL GOVERNMENTS

Note: *Commentary in brackets ([ ]) found in this ordinance is for informational purposes only.*

An Ordinance providing local uniform land development and site improvement standards that include subdivisions and site review where applicable.

Be it enacted by the Governing Body of the Jurisdiction of ______________:

1. The Governing Body finds and declares that:

   a. The lack of consistent standards for land development, subdivisions, and site improvements that currently exists in this jurisdiction increases the costs of housing without commensurate gains in the protection of the public health and safety;

   b. All citizens of this jurisdiction are entitled to safe, decent, affordable housing;

   c. It is in the public interest to avoid unnecessary cost in the construction process, and streamlined land development and site improvement standards used by this jurisdiction that are both sound and cost-effective will advance this goal;

   d. Adoption of streamlined and consistent land development and site improvement standards will satisfy the need to ensure predictability;

   e. The public interest is best served by basing development and site improvement review on sound, objective standards;

   f. The goal of streamlining the development and site improvement approval process by improving the efficiency of the application process is best served by establishing a uniform set of technical standards for land development that represents a consensus of the concerns of informed and interested parties; and

   g. The goal of providing the widest possible range of design freedom and diversity in development can be accomplished when technical requirements are based on sound minimum standards.

2. a. There is established by the governing body a Local Land Development and Site Improvement Advisory Board to develop uniform standards for land development and site improvement within the boundaries of _______________. The Board shall consist of the Chair of the Planning Board (or equivalent) as a nonvoting member and five to nine persons that may include the Director of the Building Office, a planner employed by a local government entity, a planner with expertise in private residential

development, a professional engineer or surveyor, a registered architect, a municipal engineer or the Superintendent of Public Works, a representative of the local home builders association, and a private citizen.

[The local Department of Public Works, Planning Board, or Building Office may be the appropriate authoritative body, thereby requiring no new board to be established. The intent of establishing such a body is to ensure that interested and affected parties are represented and that the technical expertise necessary to develop and approve land development standards is available.]

b. The Chair of the Planning Board (or equivalent) shall appoint all voting members for a term of ____ years. Vacancies shall be filled for an unexpired term. The Chair of the Planning Board (or equivalent) shall select a Chair from among the Board members. Members may be removed for cause by the Planning Board Chair, or equivalent.

[Use the established administrative procedures for appointments and terms of office for local boards or commissions.]

c. Board members shall serve without compensation but may be entitled to reimbursement for expenses incurred in the performance of their duties.

3. a. The Board shall prepare and submit to the Chair of the Planning Board (or equivalent) within ___ days of the appointment of its full membership, recommendations for local land development and site improvement standards for residential development. The attached XYZ Model Land Development Standards are recommended for use in their entirety. Any changes shall be technically equivalent to the XYZ Standards and shall not be more restrictive than the XYZ Standards in stringency.

In addition, the Board shall develop a model application form for development approval.

b. The Chair of the Planning Board (or equivalent) shall promulgate the recommended land development and site improvement standards and standard application form without any changes. The regulations shall be adopted as the local land development and site improvement standards within _____ months of submission to the Planning Board Chair (or equivalent).

[The number of days required for various decisions and appeals should be based on existing cycles for local boards or commissions.]

c. At a minimum, a developer must meet the Local Land Development Standards.

d. The Board shall annually review the regulations adopted and shall recommend to the Chair of the Planning Board (or equivalent) any changes deemed necessary. Any changes made in the regulations pursuant to this subsection shall be made according to the same procedure.

[Appeal and/or alternative dispute resolution mechanisms that currently exist should be included herein to hear aggrieved parties.]

4. Nothing contained in this Ordinance shall in any way limit the zoning power of this jurisdiction in regulating use, area, or bulk or in regulating other land development requirements as part of a site review process that are not addressed by these standards.

5. Nothing in these standards shall limit the implementation or enforcement of state or local building construction codes.

6. If any one section or provision of the Local Land Development Standards is ruled invalid, the remainder of the standards remains intact and enforceable.

7. As used in this Ordinance, "land development and site improvement standards" mean any standards regarding construction work on, or improvement in connection with, residential development and shall include streets and circulation, off-street parking, water supply, sanitary sewers, storm water management, erosion and sediment control, and utilities.

8. This Ordinance shall take effect immediately.

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APPENDIX

Land Development Approval Process

APPENDIX
Land Development Approval Process

INTRODUCTION

Over the past 15 years, many public and private organizations have studied the land development approval process at the national, state, or local level. Indeed, a literature review reveals many similar recommendations for improving the quality, efficiency, and timeliness of the process. One notable example is the 1991 report issued by the President's Advisory Commission on Regulatory Barriers to Affordable Housing (Ref.1) entitled "Not in My Back Yard: Removing Barriers to Affordable Housing" (NIMBY). The NIMBY report cites burdensome and uncoordinated approval and permitting systems, multiple reviews by overlapping jurisdictions, and the costs of delays in permit approval systems as factors in housing prices. Previous studies have looked at the development approval process in even more detail. While these studies share the same basic recommendations, many jurisdictions have been unable to implement the recommendations effectively.

In general, the several studies' recommendations can be grouped into five major areas discussed below:

1. Develop Clear and Concise Development Standards, Guidelines, and Submission Requirements

The development standards, guidelines, and submission requirements must be written so that the criteria are clear to developers, their design teams, and the reviewing agencies. Permits required for particular development types should be enumerated and explained on a checklist or other brief summary. There should be adequate information about the reviewing agencies and the regulations they enforce.

2. Use Preapplication Conferences

Preapplication conferences have been shown to be one of the most effective tools in expediting the development approval process. The preapplication conference is an informal, nonbinding meeting of the developer, the developer's design team, and key representatives of the local reviewing agencies. To be completely prepared for the conference, the developer must carefully think through the proposed project. The preparation of a conceptual site plan enhances this process but should be optional. The planning staff and key representatives of other appropriate departments must likewise subject the application to a thorough review. From the conference, the developer should develop a clearer understanding of the requirements for the proposed development before investing in expensive, more detailed plans and studies. Preapplication conferences can help avoid unnecessary delays later in the process.

3. Make the Development Review Process More Efficient

The first step in making the process more efficient is for developers and their design teams to establish a cooperative relationship with reviewing departments. This relationship should be geared to solving problems--not making them. The developer's design team should prepare complete submissions, and the government agency reviews should be of professional quality. There needs to be a clear assignment of responsibilities to the reviewing agencies and duplicate reviews should be eliminated. When preliminary and final reviews are required, each review should narrow the issues. A review committee can resolve interagency disputes.

The approval process can be further streamlined by reducing the reviews of overlapping jurisdictions. One example is the federal delegation of wetlands review to state or local authorities. If delegation to the local level is not possible, then even greater emphasis must be placed on intergovernmental cooperation. The final steps that local governments can take to make the approval process more efficient is similar to the first one--communication. The developer should have ready access to key decision makers and should be informed of problems before public hearings.

4. Compress the Review Process Time Schedule

The most obvious method for compressing the time schedule is to allow concurrent rather than sequential reviews by government agencies. The next step is to improve the certainty of review times and to make deadlines realistic. Local government must require the review agencies to make rapid reviews and prompt decisions. An enforcement mechanism written into local statutes can ensure timely reviews and decisions. Projects should be classified as major or minor, and minor, noncontroversial projects should be "fast-tracked," if appropriate. For major projects, the developer should have the option of combining preliminary and final approvals. Local governments can also speed the process by implementing an automated review tracking system and setting up a "one-stop" processing system in which a specific individual or agency is assigned the role of permit expeditor. The better the management information available to a local government, the more efficient the development process can operate.

5. Improve the Efficiency of Public Hearings

The first step is to combine multiple hearings since the same information is often presented by the developer, staff, and the public at public hearings before several commissions or boards. If the decision making cannot be consolidated within one body, then the various commissions can hear the testimony at one time and recess to separate or even sequential deliberations. The commission or board should also delegate as much as possible to staff. An example is staff rather than planning commission reviews of subdivision. The reviews can then be read into the planning commission minutes (Ref. 2). Boards can also appoint hearing officers and rely on their technical expertise. The cycle for public hearings can sometimes be accelerated to make the process more efficient. The hearing process should provide for a well-defined appeal process. To resolve difficult cases, mediation procedures can be incorporated into the appeals process in lieu of forcing the parties to resort to litigation (Ref. 3). To give more predictability and flexibility to the approval process, a developer should vest for a reasonable period after an approval.

MODEL LAND DEVELOPMENT APPROVAL PROCESS

A model land development approval process that incorporates the above recommendations is presented in the following section and summarized in Figure 1. The process consists of four stages: Preapplication, Application, Preliminary Plan Approval, and Final Plan Approval.

Stage 1: Preapplication Conference (Optional)

A developer may request a preapplication conference through the appropriate lead agency. The developer may submit a concept plan before the preapplication conference to help explain the proposed development strategy. The lead agency should arrange for the participation of the following key departments: Planning, Transportation, Building, Fire, Water and Sewer, Storm Water, Wetlands, Sediment Control and Grading, Landscape, and others as appropriate. The pre-application conference should be scheduled within 15 to 30 days of the developer's request. Six goals of the preapplication conference as described in a Rutgers University report (Ref. 4) follow:

1. Acquaint the applicant with the substantive and procedural requirements of the subdivision and site plan ordinance;
2. Provide for an exchange of information regarding the proposed development plan and applicable elements of the master plan, zoning ordinance, and other development requirements;
3. Advise the applicant of any public sources of information that may aid the application;
4. Otherwise identify policies and regulations that create opportunities or pose significant constraints for the proposed development; and
5. Review any proposed concept plans and consider opportunities to increase development benefits and mitigate undesirable project consequences;
6. Permit input into the general design of the project.

Stage 2: Application

The developer and design team must prepare all necessary submission documents (e.g., plans, specifications, and permit applications). The local jurisdiction will facilitate this design and application process by spelling out clear and concise development standards, guidelines, and submission requirements. A sample checklist is contained in Figure 2. The local jurisdiction will designate a specific department or individual to provide this information and to accept the submission documents for processing ("one-stop processing"). The lead agency will submit complete plans and other submission documents to reviewing agencies within two working days.

Figure 1
Simplified Land Development Approval Process Subdivision and/or Site Plan

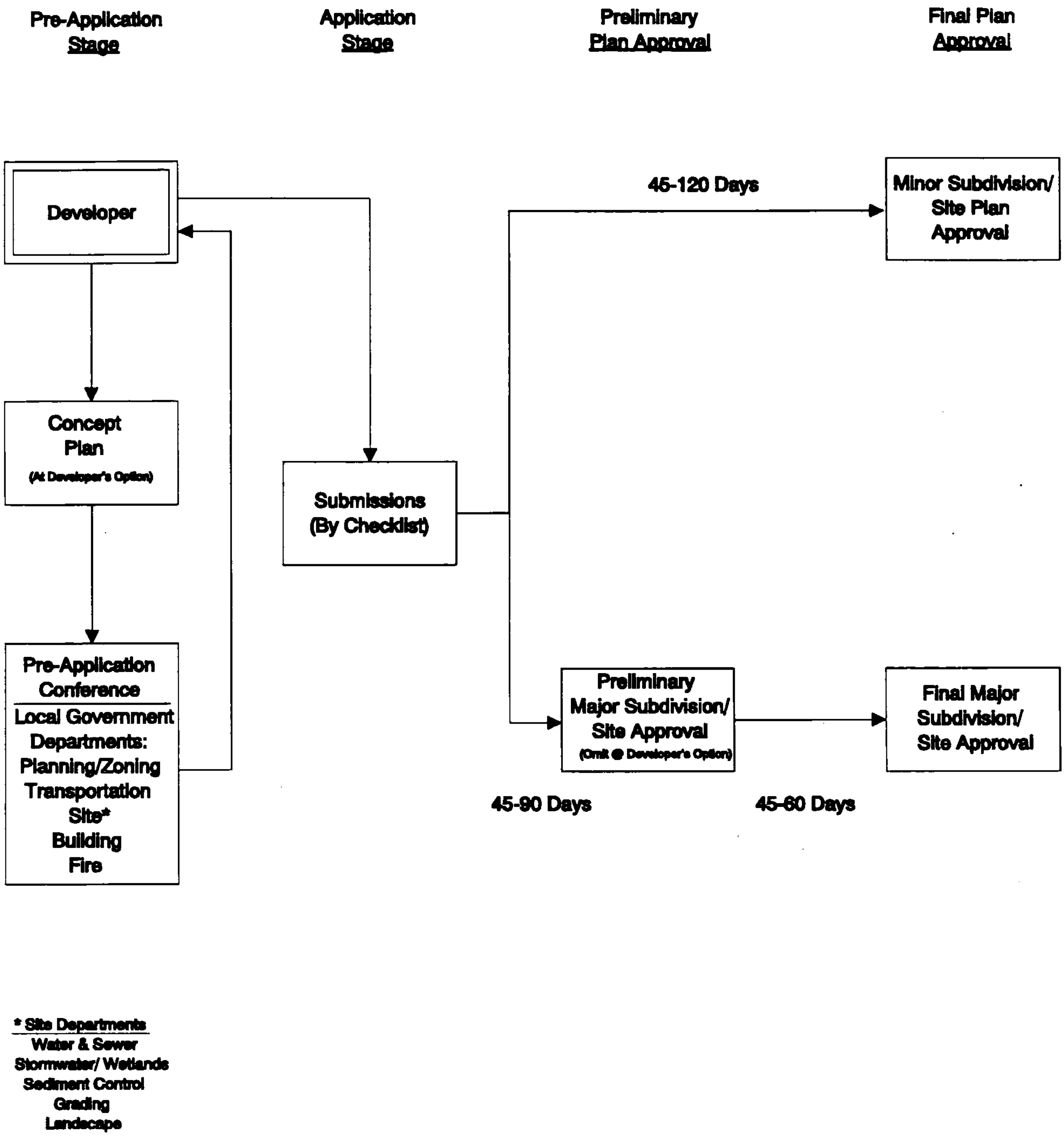

Figure 2
Sample Checklist

Minimum Submission Requirements

General Items--All Sheets

- Complete title (sheet title, plan title, date, county and state, scale, etc.)
- North arrow

Cover Sheet

- Owner's or developer's name, address, and telephone number
- Engineer's name, address, and telephone number
- Vicinity map
- Sheet index
- Legend for standard symbols used

General Items--Site Plan Sheets

- A plan view of the development area at a readable engineer's scale. The plan view should show all proposed and existing streets, buildings, and utilities.
- List net area and gross area in acres and square feet.
- Locate all existing and proposed easements, rights-of-ways, and property lines.
- Show existing natural features shown including contours.
- Note all uses that will occur on-site.
- Note building square footage.
- Label adjacent properties with owner, zoning, and land use.
- Show proposed buildings with finished floor elevations .
- Show building restriction lines.
- Define limits of the construction area.
- Show the design speed and traffic volume for each roadway.
- Note whether streets are to be public or private.
- Describe pavement design.
- Show typical section width of travelways, thickness and type of pavement, typical cross-slopes, and types of curb or shoulder.
- Delineate parking spaces with typical sizes.
- Show number of parking spaces required and number provided.
- Show locations of site lighting.

Figure 2 (continued)

General Items--Profiles

- Show items at a readable horizontal and vertical scale.

Sanitary Sewerage

- Show all lines labeled with size, material, slope, and length.
- Show laterals.
- Show cleanout and manhole locations.
- Show stationing at all manholes.

Storm Water Management

- Describe how storm water will be handled.
- Show structure types and sizes with all invert elevations.
- Label pipes with type, size, and slope.
- Show typical swale and ditch cross-section.
- Complete hydraulics.
- Provide drainage divide map.

Erosion and Sediment Control

- Describe erosion and sediment control narrative.
- Show location of mechanical sediment control measures.

Water Systems

- Show location and type of all connections.
- Show pipe size, type, and profile.
- Locate fire hydrants.
- Show design values for existing fire flows and domestic flows with explanation or calculation.
- Describe effects on system during peak hour use.
- Describe effects on system during maximum day use with fire flows from each proposed hydrant individually.

Stage 3: Preliminary Plan--Review and Approval

For major subdivisions or major site plans, a preliminary submission is necessary. Major subdivisions and major site plans can be defined as those with more than 10 dwelling units. A preliminary submission should be of sufficient detail to permit review and approval of all important design and regulatory issues. A preliminary submission should not, however, be required to include items such as standard details or full project notes. The length of time for review and approval should be 45 to 120 days. This time frame assumes that minor problems in the submission can be resolved informally between the reviewer and the developer's design team. Only when there are major problems with a submission should a reviewer reject it and require the developer to start the process over again.

Stage 4: Final Plan--Submission and Approval

The submission for final approval should contain the level of detail necessary for the local jurisdiction to review and ensure compliance with all regulations. For a plan that has not gone through any preliminary plan approval, the review and approval should be accomplished within 45 to 120 days. For a resubmission of a preliminary plan, review and approval should not exceed 60 days. Final plan approval often requires one or more public hearings before a planning commission or other public boards. When disputes arise during a public hearing, it may be necessary to continue the hearings to allow the parties in the dispute to resolve their differences. Even though this sometimes lengthens the approval schedule, sufficiently flexible local ordinances can avoid some appeals, which could consume even more time.

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1. President's Advisory Commission on Regulatory Barriers to Affordable Housing. *Not in My Back Yard: Removing Barriers to Affordable Housing*. U.S. Department of Housing and Urban Development. Washington, DC. 1991.

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3. NAHB Research Center. *Affordable Residential Land Development: A Guide for Local Government and Developers*. Prepared for the U.S. Department of Housing and Urban Development. Washington, DC. July 1987, p. 15.

4. Listokin, David and Carole Walker. *The Subdivision and Site Plan Handbook*. The Center for Urban Policy Research, Rutgers University, New Brunswick, NJ. 1989.

5. National Association of Home Builders. *Land Use and Construction Regulations: A Builders View*. Washington, DC. 1982.