

THE DEPARTMENT OF PUBLIC WORKS

BUREAU OF ENGINEERING

HOWARD COUNTY, MARYLAND

HOWARD COUNTY DESIGN MANUAL

VOLUME III

ROADS AND BRIDGES

**Howard County Council
Resolution No. 136-2006
October, 2006**

HOWARD COUNTY DESIGN MANUAL

VOLUME III

ROADS AND BRIDGES

CHAPTER 1	INTRODUCTION AND GENERAL INFORMATION
CHAPTER 2	DESIGN OF ROADS
CHAPTER 3	DESIGN OF BRIDGES, RETAINING WALLS AND SMALL STRUCTURES
CHAPTER 4	ADEQUATE ROAD FACILITIES TEST EVALUTION REQUIREMENTS
CHAPTER 5	TRAFFIC STUDIES

CHAPTER 1

INTRODUCTION AND GENERAL INFORMATION

CHAPTER 1
INTRODUCTION AND GENERAL INFORMATION

	<u>PAGE NO.</u>
1.1 <u>INTRODUCTION</u>	1-1
A. Preface	1-1
B. Authorization	1-1
C. Purpose of Manual	1-1
D. Waivers	1-2
1.2 <u>ABBREVIATIONS</u>	1-2
1.3 <u>DEFINITIONS</u>	1-4
1.4 <u>PROJECTS DEFINED</u>	1-4
A. Capital Projects	1-4
B. Land Development Projects	1-5
1.5 <u>HIGHWAY CLASSIFICATION SYSTEM AND GENERAL PLANS OF HIGHWAY</u>	1-5
A. General	1-5
B. General Design Criteria	1-7
1.6 <u>PROJECT DEVELOPMENT</u>	1-7
A. Land Development Projects	1-7
B. Capital Projects	1-8
1.7 <u>ENGINEERING REPORTS</u>	1-9
A. Purpose of Report	1-9
B. Content of Report	1-9
C. Submission for Review	1-9
D. Public Meetings	1-10
1.8 <u>SURVEYS</u>	1-10
A. Control Surveys	1-10
B. Topographic Surveys	1-11
1.9 <u>PREPARATION OF CONSTRUCTION PLANS</u>	1-14
A. General	1-14
B. Purpose	1-14
C. Drafting and Graphic Standards	1-14
D. Computer Applications	1-18
E. Standards for Depicting Existing Conditions	1-18

	<u>PAGE NO.</u>
1.10 <u>PREPARATION OF CONSTRUCTION SPECIFICATIONS</u>	1-19
A. General	1-19
B. Standard Format	1-20
C. Special Provisions/Technical Specifications	1-20
D. Proposals	1-20
1.11 <u>RECORD DRAWINGS</u>	1-21
A. General	1-21
B. Electronic Files	1-21
C. Replacement Drawings	1-21

CHAPTER 1

INTRODUCTION AND GENERAL INFORMATION

1.1 Introduction

A. Preface

The transportation system is the major structural element of the rural-suburban-urban community and it dictates, in many instances, the shapes and locations of various land uses in the community. Roads are the principal elements of the transportation system and it is extremely important that they be planned and coordinated in conjunction with the land use plan for a given area. Roads are permanent improvements and are expensive to construct and maintain; therefore, the greatest care and foresight are needed in the development of the plans for them, in order that they will be adequate to meet the demands of the developing community, at an acceptable level of service, and be economical to construct and maintain.

B. Authorization

The Road and Bridge Design Manual is Volume III of four volumes of the Howard County Design Manual authorized and required to be promulgated under the Howard County Subdivision and Land Development Regulations as formulated in Council Bill Number 41, enacted November 24, 1975. The other volumes so authorized are:

- Volume I, Storm Drainage Design Manual
- Volume II, Water and Sewer Design Manual
- Volume IV, Standard Specifications and Details for Construction

The Design Manual is to provide, " ... the master technical standards required by Howard County for design, construction and inspection ..." of the various public facilities associated with land development activities. Although the Design Manual is mandated through the land development regulations, it is nonetheless applicable to all other public works projects undertaken by the County.

C. Purpose of the Manual

The purpose of the Road and Bridge Design Manual is to provide criteria and standards for the design of safe, efficient, and coordinated road systems. The requirements set forth herein represent an acceptable standard to Howard County. The criteria and standards contained in this manual are generally compatible with those of the American Association of State Highway and Transportation Officials (AASHTO) and the Maryland State Highway Administration. References are made to documents and criteria published by these and other agencies where appropriate. This manual is a supplement to those

documents and is intended to substantially conform to AASHTO criteria. The criteria and standards have also been formulated with consideration for planning, environmental, bicyclist, pedestrian and related issues, especially for roadways servicing residential areas.

The engineering requirements included in this manual are intended to assist land developers and engineers with designing and building road and bridge facilities within Howard County. Developer Projects and Capital Projects, sponsored by private Developers and the County administration, respectively, shall conform to the procedures, requirements and criteria set forth in this manual.

The manual is not intended to restrict the Design Professionals opportunity to create innovative, practical and economical designs for road and bridge improvements. Rather, it is intended to assist the Design Professional in completing the projects efficiently and economically within the framework of design parameters established herein.

D. Waivers

1. Capital Projects

If the Design Professional for any reason finds it necessary or desirable to use procedures, standards or criteria other than those included in this manual, the Design Professional must apply to the County for a waiver of the design requirements. A request for a waiver is to be addressed to the Chief of the Bureau of Engineering and shall, at a minimum, contain a narrative indicating the design objective and the justification for the request. Approval or denial of the waiver request will be by return letter signed by the Chief of the Bureau of Engineering.

2. Land Development Projects

Requests for approval of design deviations for roads to be approved or constructed as part of a development project are to be submitted to the Department of Planning and Zoning. Satisfactory written justification must accompany the submittal. The Department of Planning and Zoning shall make a decision on any design deviation waiver in writing. The Department of Planning and Zoning may approve any waiver request if it finds that the requesting party has demonstrated the desirability of granting the waiver and that the purpose of the Design manual may be served to an equal or greater extent by the granting of the waiver. Waiver requests that accompany the initial plan submittal will be considered in tandem with the plan review. A fee will be required for waiver requests made with final submissions.

1.2 Abbreviations

Whenever in this chapter or other chapters, the following abbreviations are used, they will represent:

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ACP	Asbestos Cement Pipe
ADA	Americans with Disabilities Act
ADT	Average Daily Traffic
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASHE	American Society of Highway Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BOCA	Building Officials Conference of America
CAD	Computer-aided Drafting
CADD	Computer-aided Design & Drafting
CIP	Cast Iron Pipe
COMAR	Annotated Code of Maryland
DILP	Department of Inspections, Licenses and Permits
DIP	Ductile Iron Pipe
DIPRA	Ductile Iron Pipe Research Association
DPZ	Department of Planning and Zoning
DPW	Department of Public Works
ENR	Engineering News Record
FCP	Forest Conservation Plan
FGCC	Federal Geodetic Control Committee
FHWA	Federal Highway Administration
FSD	Forest Stand Delineation
GPS	Global Positioning System
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
HGL	Hydraulic Grade Line
HLSD	Headlight Sight Distance
HSCD	Howard Soil Conservation District
HS-20, H-20	Truck Loading Designations
LRFD	Load and Resistance Factor Design
MDE	Maryland Department of the Environment
MSHA	Maryland State Highway Administration
MTBM	Micro-tunnel Boring Machine
NAD	North American Datum
NAVD	North American Vertical Datum
NGS	North Geodetic Survey
NOI	Notice of Intent
OSHA	Occupational Safety and Health Administration
PC	Point of Curvature
PCA	Portland Cement Association

PCCP	Pre-stressed Concrete Cylinder Pipe
PCF	Pounds Per Cubic Foot
PGL	Profile Grade Line
PI	Point of Intersection
PSI	Pounds Per Square Inch
PT	Point of Tangency
PVC	Polyvinyl Chloride, Point of Vertical Curve
PVT	Point of Vertical Tangency
RCP	Reinforced Concrete Pipe
ROW	Right of Way
RQD	Rock Quality Designation
SE	Superelevation
SHA	State Highway Administration
SSD	Stopping Sight Distance
SPT	Standard Penetration Test
SWM	Storm Water Management
VCP	Vitrified Clay Pipe
TCP	Traffic Control Plan

1.3 **Definitions**

Designer: A professional engineer, registered in the State of Maryland, who is responsible for the design of the project.

SHA Standard Specifications: Maryland Department of Transportation, State Highway Administration, Standard Specifications for Construction and Materials.

SHA Standard Details: State of Maryland, Department of Transportation, State Highway Administration, Book of Standards, Highway and Incidentals Structures.

Standard Specifications, or Standard Details: Howard County Volume IV Design Manual, Standard Specifications and Details For Construction.

1.4 **Projects Defined**

Road and bridge projects for Howard County are divided into two basic categories: Capital Projects and Land Development Projects.

A. Capital Projects

A Capital Project may arise by any of several administrative means. The common identifying feature distinguishing a Capital Project from a Land Development Project is that funds for implementation of the Capital Project are allocated through the regular budgetary processes within Howard County.

B. Land Development Projects

A Land Development Project arises whenever a land developer engages in the subdivision of land or the development of a parcel of land, either of which fall under the requirements of the Subdivision and Land Development Regulations. When this is the case, the Developer will be required to completely underwrite the cost of construction of these facilities and will cause the preparation of an engineering report, the development of construction plans and specifications, the easement documents and the stakeout and inspection of the construction work. A Developer Project is represented by a signed contract called a Developer Agreement between the Developer and the County.

1.5 Highway Classification Systems

A. General

The basic functions of all roads are the movement of vehicular traffic and provision of access to adjacent land. The Howard County Highway Classification System is exclusively based on these functions and divides the components of the overall road system into seven classifications, each serving the above two basic functions to a different degree. These classifications are based on the general plan guidelines and any more-refined design data that are developed as a result of alignment studies or traffic studies.

The seven classifications of roads and their characteristics are as follows:

Principal Arterial Highway (Freeway)

- A. Provides for efficient and uninterrupted travel between or across states and large metropolitan areas.
- B. Principal arterial include most interstate designated routes.

Intermediate Arterial (Multi-lane Divided or Undivided Highways)

- A. Provides access to principal arterial highway.
- B. Provides efficient but not free or uninterrupted flow between major roads in highly developed areas.
- C. Provides for inter-State, inter-County and inter-regional travel.
- D. Distribute trips to and between freeways or other principal arterials emanating from lesser classified arterials and major collectors.
- E. Provides routes for mass transit system to major towns and communities within the County.
- F. Basic trip length generally exceeds 10 miles.

Minor Arterial Highway

- A. Provides interconnection between principal and intermediate arterial.
- B. Provides a lower level of travel mobility than intermediate arterial to major towns and communities.
- C. Provides routes for mass transit system to major towns and communities within the County.
- D. Primary access to or through communities of high density residential, commercial, retail or industrial land areas.
- E. Provides access to abutting commercial, residential and industrial properties at predetermined locations.
- F. Basic trip length is generally 5-25 miles.

Major Collector

- A. Provides the primary access to an arterial road for one or more neighborhoods or non-residential areas.
- B. Distributes based trips to or from arterial.
- C. Provides a limited amount of travel through neighborhoods and non-residential areas which originates and terminates externally.
- D. Provides direct connections to local roads and minor collectors.
- E. Provides collection and distribution routes for mass transit system.
- F. Basic trip length is generally from 3-10 miles.

Minor Collector

- A. Provides direct access to local roads and direct driveway access to abutting properties.
- B. Internal distribution of trips within a neighborhood or non-residential area or part of a neighborhood or non-residential area.
- C. Connects local roads to one or more major collectors.
- D. Limited amount of through traffic: primarily local in nature.

Local Road (Includes Access Place and Access Street)

- A. Provides direct driveway access to abutting properties.
- B. Distributes traffic generated from a neighborhood or from non-residential areas to collector roadways.
- C. Minimal through traffic, if any.
- D. May be any of the following:
 - (1) A street with a series of cul-de-sacs connecting thereto and ending in a cul-de-sac.
 - (2) A street dead-ending into a cul-de-sac.
 - (3) A connector between two collector roads.

Scenic Roadway

- A. Designated by County Council Resolution in accordance with Section 16.1403 of the Howard County Code.
- B. May be a local, collector or minor arterial road.
- C. Function varies, generally low volume, limited traffic.

A summary of the operating characteristics of each road classification is given in Appendix A.

B. General Design Criteria

Basic geometric criteria for the various road and street classification such as design speed, roadway width, right-of-way, maximum and minimum grades and pavement type are summarized in Chapter 2, Appendix A. Roads and streets having an ADT of less than or equal to 2,000 shall be designed per ADT as referenced in Chapter 2, Appendix A.

1.6 Project Development

As previously indicated, road and bridge projects fall into two categories: Land Development Projects and Capital Projects. How these projects arise and the requirements associated with each are briefly outlined below.

A. Land Development Projects

When a Developer is considering designing a proposed development, the Developer must conform to the Subdivision and Land Development Regulations.

If the project meets the basic requirements, the DPZ will indicate to the Developer the financial requirements that the Developer must satisfy in order to continue with the project. If required by the DPW, the Developer may advance the project by developing an engineering report addressing the considerations set forth in the following chapters of this manual. The report will be used as the basis for a Developer's Agreement, which includes the financial arrangements for both engineering design and construction costs.

Upon the receipt and approval of the engineering report and the preliminary roadway plan, the engineering design of construction plans is authorized. These plans are advanced to the preliminary plan level of completion at which time they are submitted for review to the DPZ, together with a construction cost estimate. The plans are then brought to completion and resubmitted to the DPZ for final review and approval. After approval by the DPZ, and in coordination with other approvals under the subdivision regulations and Section 16.121 of the Howard County Code, the project will advance to the construction phase. The final action under the Developer Agreement is the financial settlement between the County and the Developer in accordance with the terms of the Developer Agreement.

B. Capital Projects

Capital Projects may begin in several ways. Residents may petition the County to undertake projects or to advance projects previously contemplated. Petitions for roadway and bridges are received by the DPW, reviewed by the DPW staff and endorsed with its recommendations, then forwarded to the Director of the DPW. The DPW may originate projects to alleviate existing or projected problems in the overall operation of transportation facilities.

The County Council may request of the County Executive to create a Capital Project. Regardless of who or what the originating cause is for a Capital Project, the County Executive is charged with the responsibility of annually preparing a budget of Capital Projects for adoption by the County Council.

As required by County Charter, public hearings are held prior to action by the Council. This is done for the purpose of reviewing the proposed budget items, publicly displaying all proposals for Capital Projects and receiving relevant citizen comments.

The DPW staff accomplishes most of the preliminary work associated with the identification of Capital Projects. However, after the adoption and funding of Capital Projects are approved, it is normal practice for the County to engage the services of consulting engineers (Designers) to provide the detailed engineering transportation projects. Selection of a Designer is made in accordance with County regulations and policies.

Contracts with Designers on road and bridge projects will stipulate the scope of work, schedule to be followed and arrangements and other details normally associated with contractual procedures. Changes in the Designer's scope of work will be through a change order to the engineering agreement. Unless otherwise accepted by contract, the Designer for Capital Projects will advance a project in the same general manner as described for Developer Projects. All submissions of reports, plans and specifications shall be made directly to the DPW.

The Designer will begin the project by preparing a concise report of the project describing the purpose and extent of the work, providing a preliminary cost estimate and other items of an engineering nature. Review and approval routines as described in this manual will be followed. When engaged in a Capital Project, the Designer's point of contact is with the DPW. The DPW will designate a Project Manager from its staff who will assume responsibility for monitoring the project, coordinating details and reviewing reports, plans, specifications and other data to ensure that the engineering work satisfies the project requirements.

1.7 Engineering Reports

A. Purpose of Report

All capital improvement projects which involve significant expenditure of construction funds will require the preparation of a preliminary engineering report. The purpose of the report is to consider the feasibility of the various alternatives for solving a given problem and establishing the basis for selecting the most feasible solution to the problem and the recommended course of action to effect the solution.

B. Content of Report

Engineering reports vary in their complexity and subject matter based on the type and the particular circumstances of the project being studied. However, all reports shall contain at least the following information:

- Purpose and scope of the study performed
- Description of existing conditions and problems and project history in general
- Establishment of appropriate design criteria on which the study is based
- Description of all feasible alternatives are studied
- Comparison of alternatives including cost estimates, (construction, right-of-way, utility relocation, etc.), environmental impacts, design characteristics, serviceability, impacts to existing traffic and utilities during construction and other pertinent features.
- Conclusions
- Recommendations

Appropriate exhibits such as vicinity and location maps, sketch plan layout of the alternative designs, profiles, typical sections of details and tables shall be included to support and depict the written material in the report.

C. Submission for Review

All reports shall be submitted on 8 1/2 inch by 11 inch bond paper from approved word processor, suitable for reproduction and bound in a booklet with a suitable cover. Maps, plans, profiles, tables, etc. shall be either 8 1/2 inch by 11 inch or folded to that size for binding in the report booklet unless otherwise approved by DPW. The scale of the maps may vary to meet their intended purpose.

Preliminary draft of the report shall be submitted the DPW for review.

After incorporating any modifications or revisions made during the review, the final report shall be signed by a Professional Engineer and submitted to DPW.

D. Public Meetings

The Department of Public Works will schedule all public meetings concerning proposed projects and will coordinate all preparation of exhibits, scripts and brochures and conduct the public meeting presentation. The Designer shall assist in the preparation of the public meeting and the presentation as requested by the DPW.

1.8 Control, Topographic and Construction Surveys

A. Control Surveys

1. All survey controls of capital project for the design and construction of road and bridges shall be established based upon the Howard County DPW Procedures 501.7, "Specifications for Surveying Procedures and Documents," latest edition.
2. Horizontal control shall be established by conventional closed traverse or Global Positioning System (GPS) surveys. All horizontal control shall be tied to the Maryland State Plane Coordinate System, utilizing the monumentation of the National Geodetic Survey (NGS) or the Howard County Geodetic Survey Stations. The State Plane Coordinate System Datum shall be specified, (i.e. NAD. 83 or NAD. 83/91).
3. Conventional traverses shall have a minimum closure ratio of 1:15,000. GPS control points shall be established in accordance with the specifications and requirements of the Federal Geodetic Control Committee (FGCC) for using GPS relative positioning techniques as amended. All control points shall be referenced in detail on the plans to permanently fixed objects that will not be disturbed during construction of the proposed project or other projects. Traverse points shall be clearly identified, and coordinates of each point shall be either shown at the traverse point in a neat manner, or in tabulation form on each plan sheet for which the traverse points occur. Bearings and distances between traverse points shall be shown. The traverse shall be assigned continuous stationing, with stations shown every 100 feet and at traverse points, and equalities shown at each intersecting point for spur lines and loops.
4. Vertical control for all projects shall be referenced to the North American Vertical Datum of 1988 (NAVD 88) as projected by Howard County Geodetic Survey Stations. If NAVD 88 control is not available in a one (1) mile radius the project area, the Designer may contact the DPW for vertical control. The Designer shall clearly indicate on all plans the datum used. Project benchmarks shall be of a permanent nature and shall be spaced at a maximum distance of 1,000 linear feet. All project benchmarks shall be established by traverse as part of a closed vertical control loop. Benchmarks shall be clearly shown and referenced in detail on the plans. A minimum of two (2) benchmarks shall be shown on each plan sheet.

5. Survey baselines shall be extended for the full length of the project and a minimum of 400 linear feet beyond anticipated limits of work. Station equalities shall be shown for all common intersecting control points. Bearings and distances between control points shall be shown. Coordinates of all control points shall be either shown at the control point in a neat manner or in tabulation form on each plan sheet for which the control points occur.

B. Topographic Surveys

1. Limits of Area Covered

The limits of the area to be shown on the plans may vary to some degree on various types of projects, and in general for Capital Projects, the area covered is usually a continuous strip of a minimum of 100 feet outside of the proposed limits of disturbance on each side of the facility and 400 feet beyond the anticipated limits of work (for Developer Projects, limits of work shall be as required on a case by case basis or in accordance with Subdivision and Land Development Regulations).

2. Items to Include in Topographic Surveys

- a. All buildings and other structures within and immediately adjacent to the project limits, together with all improvements, including wells, springs, septic tanks, drain fields, dry wells, etc.
- b. Property and right-of-way lines (proposed and existing) including right-of-way widths and identifying road names.
- c. Property information:
 - 1) Owner Name(s)
 - 2) Front foot distances of each property along the facility
 - 3) Deed and recording references, including parcel number, lot number, subdivision name and record plat reference(s)
 - 4) Property pipes, monuments or markers
 - 5) Street address
- d. Roadway pavements, curb lines, driveway entrances, walkways, fences, walls, etc., including types of materials, widths, heights, and all other descriptive data.
- e. Horizontal and vertical location of all water mains, valves, hydrants, meters, manholes, clean-outs, storm drain inlets and culverts.
- f. Horizontal and vertical location of all existing and proposed overhead, surface and subsurface gas, electric, telephone and cable utilities as determined by field surveys, or other proposed plans, and fully coordinated with existing record drawings and applicable utility companies.

g. Trees:

- 1) Trees 12-inches in diameter and larger within proposed rights-of-way shall be individually located and identified by type. All trees, regardless of size, shall be located and identified by size and type that exist on the landscaped area of the property, including hedges, shrubs, flower beds, etc.
- 2) For trees whose foliage overhangs the right-of-way or construction strip, the extent and diameter of the foliage (fall line) shall also be indicated.
- 3) Tree stands or woods line shall be located and general characteristics of the wooded area given including approximate average size of the trees, density and general type of trees represented.
- 4) Brush and dense undercover areas shall be so noted as applicable.

h. Water courses, such as streams, swales and ditch areas, shall be shown and located including width, depth and water depth data, if applicable. Water courses shall be contoured from field data together with the 100-year flood plain and elevations shown on the plans. Contours shall be shown on both sides of the water course and extended at least 100 feet beyond the parallel alignment of the proposed facility. The flood plain data shall be determined by the Designer with criteria based on existing zoning and full future development of the drainage area.

i. Embankments and other irregularities of terrain including roadside drainage ditches shall be shown and spot elevations of top and bottom of the bank given every 50 feet.

j. Limits of existing wetlands and Waters of the U.S.

k. Vehicular access routes for off road or undeveloped areas shall be identified for use during construction.

l. Identify and reference contract numbers and project numbers of all existing and proposed facilities within and adjacent to the project limits.

m. In new developments where the terrain is being transformed, most of the information shall be obtained directly from approved plans prepared to satisfy proposed improvements including curbs, storm drains, street right-of-ways and lots as taken from the record plat and construction plans and shall show all existing features that are to remain undisturbed.

3. Method of Locating Topography

- a. The method of locating topography shall be by field surveys utilizing the radial survey method, the GPS Real Time Kinematic (RTK) method or the right angle plus offset method. Survey field notes may be kept in the classical method (handwritten notes) or by the electronic data collection method as per the

Section 1.8 Control, Topographic & Construction Reports - Introduction and General Information

Howard County DPW Departmental Procedures 501.7, "Specifications for Surveying Procedures and Documents", latest edition.

- b. Topography may be provided by aerial photogrammetry for engineering studies and drainage area maps. All vertical survey requirements for preliminary and final design shall be acquired by actual field surveys, unless otherwise approved by the DPW.
- c. The Howard County Survey Division will furnish field books for classical methods.

4. Existing and Proposed Contour Lines

If required, existing and proposed contour lines shall be shown on the plans. Sufficient information shall be obtained in order to allow the contours to be shown at 2-foot intervals or less. In areas of steep slopes (greater than 20%), contours may be shown at 5-foot intervals with the approval of the DPW.

5. Cross-sections

Cross-sections shall be taken at fifty (50) foot stations and at intersecting roads, driveways, entrances, rivers, streams, and railroads. Cross-sections shall be at right angles or radial to the proposed alignment and extend a minimum of 100 feet beyond each side of the proposed facility and a minimum of 200 feet beyond anticipated project limits. The minimum distances shown herein shall be extended accordingly in order to provide sufficient information to established profile grade lines beyond the actual project limits or to locate other topography or topographic relief relative to the design or construction of the proposed improvements. Cross sections shall be plotted on standard cross-section sheets of a quality that will provide acceptable prints.

6. Property Corners

Property corners within the construction area shall be referenced such that they may be reset after construction.

7. Howard County Survey Control Stations

Howard County Survey Control Stations that will be affected by the proposed construction shall be noted on the plans as being protected or to be relocated accordingly. Where there is a need to protect or relocate Control Stations, the DPW shall be notified by the Designer in writing prior to the approval of the plans.

1.9 Preparation of Construction Plans

A. General

Contract documents for construction of County or Developer projects in Howard County are commonly comprised of construction plans and the construction specifications. Taken together, these documents form the basis for the construction contract between the Owner and Contractor. Contract documents are prepared by the Designer, who is responsible for a complete description of all work to be performed, in accordance with the Standard Specifications, Volume IV. The Designer remains responsible for adequately designing, detailing, and specifying through the Special Provisions and the Technical Specifications, all contract-specific materials and methods of construction not described in the Standard Specifications, Volume IV.

B. Purpose

1. The primary purpose of construction plans is to show the size, horizontal and vertical location and type of materials and structures to be installed as part of a highway facility. The construction plans must be developed in sufficient detail to depict the improvements and their spatial relationship with both existing conditions and planned future improvements.
2. This section sets forth requirements for information to be placed on construction plans. When completed according to County standards and properly implemented in construction, the original highway facility form a permanent record of the completed work and the materials employed on the project.

C. Drafting and Graphic Standards

1. Sheet Size, Borders and Materials

All highway construction projects shall be prepared on 24" x 36" Mylar drafting film (minimum thickness 0.004 inches, matted both sides). Borders shall be ½-inch on all sides with the exception of the left side, which shall be 1¼ inches, with standard title block. All drafting and lettering shall be performed directly on the original plans and no reproductions, rub-on or adhesive materials shall be used.

2. Computer-aided Drafting (CAD)

Computer-aided drafting may be used on any project if the Designer so desires. All requirements of this section, "Drafting and Graphic Standards," must be met. Plotters used for CAD must be equipped with technical ballpoint pens or standard drafting pens or any electronic printer device. Electronic deliverables to the County (i.e. CAD disks, CDs, etc.) must be in software formatting compatible with existing County systems. The format to be used will be decided at the pre-design meeting.

3. Scale

Highway plans shall be drawn on a scale of 1" = 50'. Roadway profiles are typically drawn to accompany the plan layout and shall be shown below the applicable plan layout on each sheet. Profiles shall be drawn to a horizontal scale of 1" = 50' and a vertical scale of 1" = 5'. The scale to be used for details on any one set of drawings shall be 1/4", 3/8", 1/2", 3/4", 1", or 1 1/2" = 1' - 0".

4. Use of Standard Symbols and Abbreviations

The "Standard Symbols and Abbreviations" shown in the Standard Specifications, Volume IV shall be used wherever possible. Non-standard symbols and abbreviations deemed necessary shall be clearly defined in a legend on the title sheet.

5. Lettering

Vertical lettering shall be used throughout. Lettering shall be uniform, neat in appearance, free of stylization, and large enough to be read when reduced for County filing. Lettering for titles, sub-titles and notes placed on the drawings shall be the size approved by the DPW and as shown in the "General Drafting Standards" in the Standard Specifications, Volume IV. All notes, descriptions, etc. shall be minimum of No. 4 (4/32-inch) in size and shall be either all upper case or all lower case. Proper names only shall be capitalized. Construction notes shall not be placed in shaded areas. Crowding of notes into a small space shall be avoided. Leaders shall be used to identify the object to which each note refers. All lettering in the same contract shall be of the same style.

6. Vicinity Map and Initial Drawing

- a. The first sheet of all projects shall include a 1" = 600' scale vicinity map with three unique sets of grid coordinates, sufficient road names and other features to allow easy recognition of the site. When a set of contract plans contain only one or two sheets the vicinity map shall be placed at the upper right portion of the first plan sheet in a space measuring 8½-inches vertically by 11-inches horizontally. If the vicinity map cannot fit in the 8½ x 11-inch space or whenever there are three (3) or more sheets to the contract, then the first sheet shall be designed as a title sheet with the vicinity map centered on the plan. When the 1" = 600' scale location map exceeds the size of the sheet, the map shall be drawn at a scale of 1" = 1,000'.
- b. In addition to the vicinity map, the initial plan shall show the contract title, contract number and project number. If the project is divided into two or more contracts, each associated contract shall be identified on the vicinity map. Likewise, the plan coverage of each sheet of the construction plans shall be shown on the vicinity map with its corresponding sheet number for ready reference. For projects with more

than three plans (total), a complete sheet index shall also be provided on the title sheet indicating the data shown on each sheet.

- c. When space permits, the first plan of a set shall also show the General Notes pertaining to the contract. If the notes cannot be placed on the initial sheet, a note shall be included on the initial sheet indicating on which sheet the General Notes appear.

7. Information Required on Each Construction Plan

a. General

The purpose of the contract plans is to portray graphically to the review agencies, project engineer and contractor the nature and extent of the proposed work and the conditions under which the work is to be performed. All information that can best be shown by plans and their accompanying dimensions and notes should be shown on the contract plans or appropriate reference to the County's Standard Details, Volume IV made where applicable. Lengthy written descriptions or requirements regarding the work are best included in the specifications, and therefore, shall not be repeated on the plans.

b. Title Block

Each sheet shall have a title block along the lower border of the sheet. The title block shall show the project name, sheet title, contract number, scale, 1" = 600' scale reference map number and block numbers, date, sheet number and signature blocks for the DPW and/or the DPZ. Sheets shall be numbered sequentially 1 through X, where X is the total number of sheets in the contract. Each discipline shall also number each sheet in its group sequentially and prefix the sheet number with a letter abbreviation representing the discipline, e.g. C1 through CX for Civil, where X is the number of plan sheets in the discipline. See Appendix B, "Standard Reference Plan," for specific format.

c. Seal and Signature

The professional engineer's seal, original signature and registration number belonging to the Designer responsible for the design, registered in the State of Maryland, shall be shown on the title block of the first sheet and each finished sheet of the set of plans. The date on which seal and signature were affixed to the plans shall be shown in the same location on all the sheets.

The Designer's seal, signature, registration number and date of signature shall also be shown on the first page of the project specifications.

d. Revision Box

Each sheet shall have a revision box in the title block. The revision box shall document all revisions after the Designer's seal and signature has been affixed to the plan. See Appendix B, "Standard Reference Plan", for location of revision box.

e. Benchmarks and Traverse points

A tabulation of benchmark descriptions and elevations shall be shown on the sheet that the benchmark occurs. A minimum of two benchmarks shall be shown on each plan sheet. Traverse point recovery diagrams with dimensions shall be shown for each traverse point on the sheet where the traverse point occurs. Traverse referencing shall be made to permanently fixed objects that will not be disturbed during construction of the proposed project or other projects. Where ever possible, permanently fixed objects used to locate traverse points shall appear on the plan. Traverse points shall be clearly identified and coordinates of each point shall be either shown at the traverse point in a neat manner, or in tabulation form, on each plan sheet for which the traverse points occur. Bearings and distances between traverse points shall be shown. The traverse shall be assigned continuous stationing, with stations shown every 100 feet and at traverse points, and equalities shown at each intersecting point for spur lines and loops.

f. North Arrow and Grid Ticks

Each plan sheet and location map shall have a north arrow. Plan sheets shall be oriented so that the north arrow points toward the top or toward the right side of the sheet, or toward the upper right quadrant of the sheet.

Each plan sheet shall show a minimum of three coordinated grid ticks based on the Maryland State Plane Coordinate System and all bearings shall be related to grid north. Two of these grid ticks shall be on the same N-S or E-W line, forming a right angle arrangement. The coordinated grid ticks shall be at multiples of 250 feet.

g. Contract Limits

The limits of the contract shall be clearly shown on all plans.

h. Match Lines and Cross-references

All plans in the same contract shall be cross-referenced by ascending numbers. Match lines with a minimum length of 4 inches shall be used wherever the plan is to be continued on the same or another sheet. Data shall be cut off at the match line; duplication of data on matching sheets is not permitted.

i. Sediment and Erosion Control Sheets

1) Approval and Certificate Blocks

Sediment and erosion control sheets shall contain Developer's and Engineer's certifications. The Designer shall contact the Howard Soil Conservation District for current certification blocks.

- 2) All road and bridge construction projects that require sediment control shall have detail sheets with required notes dedicated exclusively to sediment control. Existing and proposed contour lines shall be shown on the erosion and sediment control plans in accordance with the requirements of the Howard Soil Conservation District. Contours shall be displayed as required on separate erosion and sediment control plans. If approved by the DPW/DPZ, the contours may be screened to a 50% level. All sediment and erosion control plans and specifications are reviewed and approved by the Howard Soil Conservation District.

j. Checklists

The Designer shall fully complete the "Preliminary Plan" and "Final Construction Plans" checklist(s). The Designer shall verify that all information detailed on the checklist is shown on the plans. A copy of the checklists may be provided to the Designer together with his notice to proceed, or the Designer may request a copy from the County, as applicable. The appropriate checklist shall be completed and attached to each set of plans submitted for review. This shall apply to all Capital Projects as well as Developer Projects. Land development checklists are also available on the County Internet Site.

D. Computer Applications

Computer programs in the public domain and proprietary computer programs may be used by the Designer with the approval of the appropriate County department. Submittal of the programs to be used shall be made at the pre-design meeting. The currently approved computer programs may be identified by contacting the County. To secure approval for the use of additional computer programs, program documentation, especially computational methodology, must be submitted to the County for review prior to the use of the program in design.

E. Standards for Depicting Existing Conditions

All construction plans shall be drawn to scale and must clearly and completely depict all existing topography and man-made features. In order to develop the required information to scale, the Designer is required to conduct field surveys to accurately establish horizontal and vertical control points along the route of the project based on the system of coordinates adopted by the County. This coordinate system is, in fact, based on the

Maryland State system and is represented with sufficient accuracy in most cases by monuments and benchmarks interposed by the DPW through its aerial and ground mapping program.

Maps based on aerial photogrammetry may not be used for the preparation of construction plans unless sufficient fieldwork is done to make any necessary adjustments to obtain satisfactory accuracy in both the horizontal and vertical planes.

In surveying, plotting and drafting of existing features onto the construction plans, the inclusion or elimination of information must be carefully evaluated in the interest of efficiency of work, clarification of plans and sufficiency of representative information. A complete listing of required survey and as-built information to be included on the base plans is given elsewhere in this chapter. On projects requiring more detailed information, it is the responsibility of the Designer to recognize the extent and detail of information necessary to show a complete picture of the project area. However, in no case shall the Designer show less than the requirements given elsewhere in this chapter.

Instructions for conducting and coordinating field surveys together with the requirements for accuracy, note keeping, placing of monuments and benchmarks and other details are set forth in the Department Procedures 501.7, "Specifications for Surveying Procedures and Documents", latest edition.

As previously indicated, existing natural and man-made topographical features as developed through field survey activities are drawn onto the construction plans using standard notes, symbols and established drafting techniques to present a clear representation of the area.

1.10 Preparation of Construction Specifications

A. General

1. Howard County's Standard Specifications are set forth in Volume IV of the Design Manual. "Standard Specifications and Details for Construction." Non-standard specifications, special provisions, proposal form, contract and bond forms and other designated items shall be developed by the Designer specifically for each project and shall be published in booklet form. These requirements apply to Capital Projects only.
2. Upon completion of the construction plans, the Designer is required to provide the necessary non-standard specifications to accompany the plans. A draft of the project specifications shall be submitted with each set of the final plans for review by the County. At this stage of the project, the Designer should be able to finalize most of the non-standard portions of the specification. When all details of the specifications are completed, the Designer shall submit three completed copies of the non-standard portions of the specifications for Developer Projects and the stipulated number of

copies of the complete and bound specifications for Capital Projects. The final specification shall have the Designer's Professional Engineer's seal, signature and date of signature on the title page.

B. Standard Format

Howard County Design Manual Volume IV, Standard Specifications format is to be used in the preparation of the non-standard portions of the specifications.

C. Special Provisions/Technical Specifications

This section is vitally important to the contract as it contains additions and/or modifications to the Standard Specifications, Volume IV as applicable to each particular contract. The Designer is to contact the DPW for advice on those items normally placed in the Special Provisions and/or Technical Specifications. However, it is incumbent on the Designer to include in this section all conditions to the contract and the work required not otherwise covered, such as special construction methods, materials, measurement and payment, etc., so as to provide a complete contract document.

D. Proposals

1. The proposal form may be designed for a single lump sum payment, a series of unit priced items or a combination of the two. Howard County employs a combination type of proposal where some items of work are bid and paid without regard to measurement. Other items are bid and paid on the basis of a unit of actual measurement multiplied by the corresponding unit price bid by the Contractor or fixed by the contract. The basis of measurement and payment is described in the Standard Specifications, Volume IV and/or in the project specifications.
2. Proposals are often divided into parts to facilitate cost accounting procedures required to allocate costs by projects, administer charges and account for cost participation by various parties involved in the financing.
3. The period of time in calendar days (to be determined by the Designer) permitted for the Contractor to complete the work is stated on the form. The amount of liquidated damages to be charged per day, in the event the work is not completed within the prescribed time period, shall also be given.
4. There are a number of contingent items of work or materials to be employed, which may develop during the course of construction that cannot always be anticipated or that can be anticipated without being qualified. To facilitate the employment of additional materials and the authorization of incidental items of work, all contracts contain a list of fixed price contingent items which are not bid items, which have an assigned unit price and quantity as applicable. These fixed price items are utilized to

enable the Contractor to be paid an equitable sum of money when the particular item of work or the furnishing of materials is authorized and directed during the course of construction. Modifications of this list or modification of the fixed prices shall not be made by the Designer except with the full concurrence of the DPW.

1.11 Record Drawings

A. General

After the contract plans have been signed by the County, the original contract plans and prints thereof become the property of Howard County. During construction, the Contractor and the County's inspector, acting together, will maintain a set of "as-built" or redlined contract plans. Following construction, the original contract plans shall be revised to reflect the as-built conditions.

By submitting the original contract plans for signature, the Designer agrees to allow the County or its representative to modify the contract plans to reflect the as-built conditions. At the County's option, the County may require the Designer to complete the modifications to the plans to reflect the as-built conditions. The County will hold harmless the Designer for as-built information if added to the drawings by others.

Incorrect information shall be deleted and replaced with the as-built information. The revision block shall be completed, initialed and dated by the individual making the modifications.. Each plan in the set shall bear the words "AS-BUILT" in bold letters above the title block on the lower right-hand corner of the plan along with the date that the as-built modifications were completed. All as-built information and lettering shall be of the same style and quality as the original contract drawing.

B. Electronic Files

If the plans are prepared in electronic format, in addition to the modifications to the original construction plans, the County may require that the electronic files be modified to reflect the as-built conditions and delivered to the County.

C. Replacement Drawings

Plans bearing original signatures and dates of approval are important for the DPW's historical records. However, there may be rare instances where extensive modifications to a plan may render the plan illegible. In order to insure that the plans are clear and legible, the DPW may require that a completely new plan with modifications be developed for the as-built plan. The plan shall be noted as "AS-BUILT Replacement Sheet" above the title block on the lower right-hand corner of the plan and dated. Each new plan sheet shall be circulated for all required signatures.

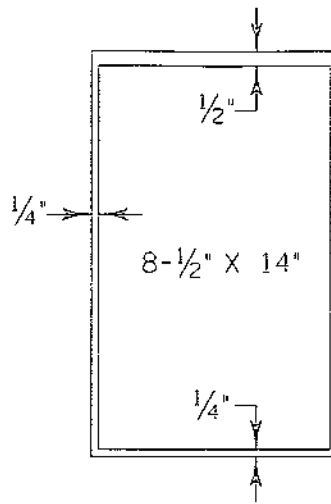
HIGHWAY CLASSIFICATION CHARACTERISTICS

CLASSIFICATION	VOLUME CHARACTERISTICS (ADT)	SERVICE FUNCTION MOVEMENT	SERVICE FUNCTION ACCESS	INTERSECTING ROAD TRAFFIC CONTROL	PUBLIC AND PRIVATE ACCESS CONTROL (1)
Principal Arterial (Freeways)	20,000-100,000 and above	Primary	None	Interchange	Full Control (2)
Intermediate Arterial (Multi-Lane Divided or Un-Divided)	5,000-42,000	Primary	Secondary	Interchange, Signals, Stop Sign, Roundabout	Full (2) or Partial Control (3)
Minor Arterial	2,500-15,000	Primary	Secondary	Signals, Stop Sign, Roundabout	Partial Control (3)
Major Collector	1,500-6,000	Primary	Secondary	Signals, Stop Sign, Roundabout	Partial Control (3)
Minor Collector	1,000-2,000	Secondary	Primary	Stop Sign, Roundabout	None
Local Road (4)	1,000 or Less	Secondary	Primary	Stop Sign, Roundabout	None
Scenic Roadway	Varies	Varies	Varies	Stop Sign, Roundabout	Partial or No Control

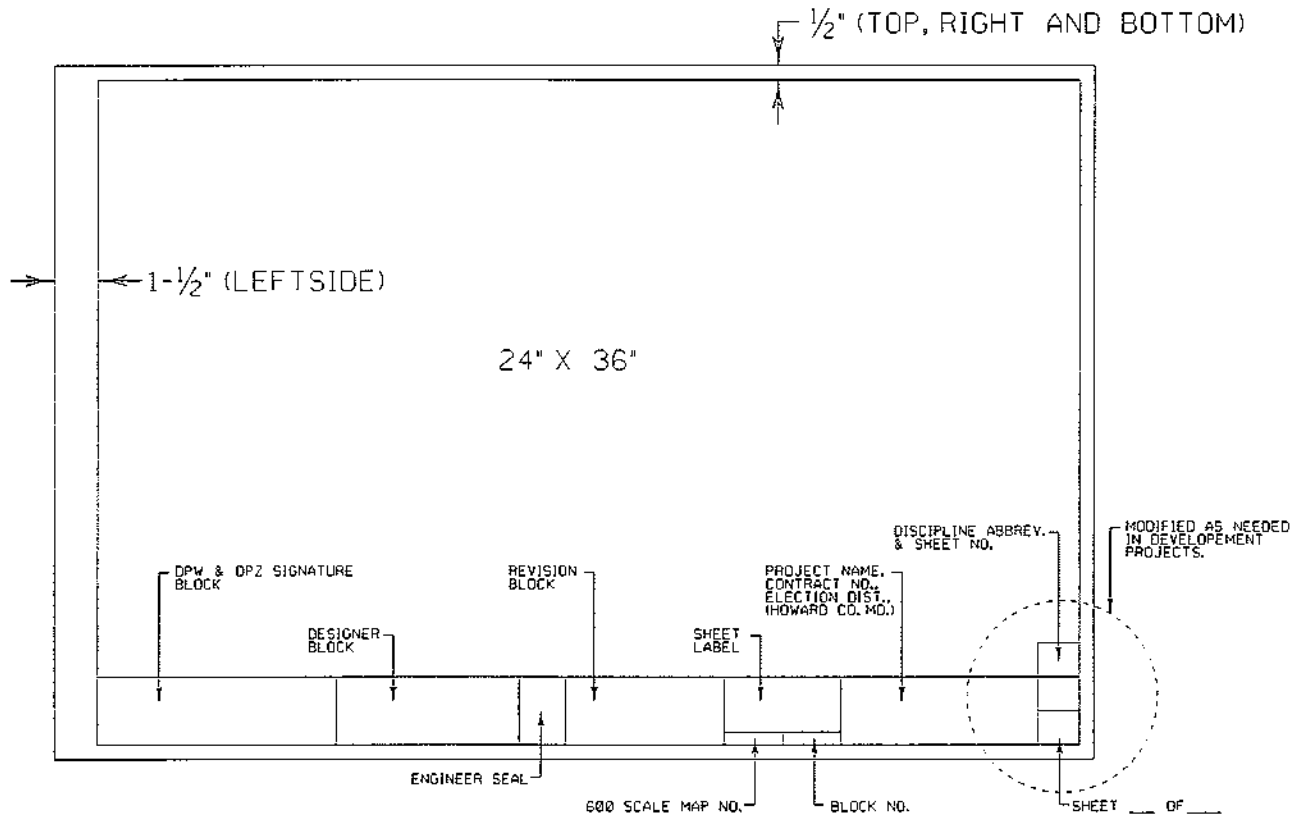
Notes:

- (1) Control of Access – The condition where the right of abutting owners to access in connection with a highway is fully or partially controlled by public authority.
- (2) Full Access Control – The authority is exercised to give preference to through traffic by providing access connections with selected public roads only by prohibiting crossing at grade or direct private driveway connections.
- (3) Partial Access Control – The authority to control access is exercised to give preference to through traffic to a degree that, in connections with selected public roads there may be some crossings at grade and some private driveway connections. A highway with partial access control has the same characteristics but includes some control of access along all or most of the length but lacks the complete grade separation treatment.
- (4) Local Roads consist of Access Place, Access Street, or Cul-de-sac Roads.

* This table is to be used as a guide for design purposes but not as a means for classifying roads. Classification shall be established by function as defined in the General Plan. Reference Table 2.01 for related design criteria.



8- $\frac{1}{2}$ " X 14" SHEET FOR RIGHT-OF-WAY AND EASEMENT PLATS ONLY.



24" X 36" STANDARD SHEET SIZE FOR ALL DRAWINGS

NOTES:

ALL DESIGN DRAWINGS COVERED IN THESE STANDARDS SHALL BE ORIGINAL DRAWINGS SUBMITTED ON POLYESTER DRAFTING FILM (MINIMUM THICKNESS 0.004 INCHES) OF THE SIZES INDICATED ABOVE. THE DIMENSIONS SHOWN ARE THE OVERALL DIMENSIONS OF THE DRAWINGS. MATERIAL NOT FURNISHED BY DEPARTMENT OF PUBLIC WORKS. TITLE BLOCK SHALL BE SHOWN IN AREA AS OUTLINED ABOVE.

APPENDIX B

HOWARD COUNTY, MARYLAND
DEPARTMENT OF PUBLIC WORKS

STANDARD REFERENCE
PLAN

DRAWN BY	WR&A
CHECKED BY	WR&A
NO SCALE	
	10/2006

CHAPTER 2

DESIGN OF ROADS

CHAPTER 2 DESIGN OF ROADS

	<u>PAGE NO.</u>
2.1 <u>GENERAL</u>	2-1
A. Introduction	2-1
B. Residential Street Classification and Functions	2-1
C. Traditional Neighborhood Design	2-2
D. Design Controls	2-2
2.2 <u>ROADWAY DESIGN</u>	2-4
A. Introduction	2-4
B. Determination of Typical Section	2-4
C. Modification of Typical Section or Design Criteria	2-4
D. Sight Distance	2-4
E. Permanent Non-Through Streets/Temporary Non-Through Streets	2-6
F. Alleys	2-6
G. Bus Stops	2-6
H. Maintenance of Traffic	2-7
2.3 <u>GEOMETRIC DESIGN</u>	2-7
A. Horizontal Alignment	2-7
B. Vertical Alignment	2-13
2.4 <u>TYPICAL SECTION</u>	2-20
A. General	2-20
B. Pavement And Right-Of-Way Width	2-20
C. Paving Section	2-20
D. Curb And Gutter	2-22
E. Shoulders	2-22
F. Medians	2-22
G. Sidewalks/Sidewalk Ramps	2-23
H. Side Slopes	2-23
I. Traffic Barrier	2-23
J. Pathways And Bikeways	2-24
K. Utility Location	2-25
L. Minimum Edge Distance To Any Roadside Appurtenance	2-26
M. Crossings Locations	2-26
N. Underdrain	2-26
O. Ditches	2-27
P. Staged Construction	2-27
2.5 <u>INTERSECTION DESIGN</u>	2-27
A. Staged Construction	2-27
B. Geometric Design	2-27

	<u>PAGE NO.</u>
C. Right-Of-Way	2-36
D. Minor Intersection Design Procedures	2-36
E. Major Intersection Design Procedures	2-36
F. Intersection With State Highways	2-38
G. Intersection With Existing Roads	2-38
2.6 <u>DRIVEWAYS</u>	2-38
A. General	2-38
B. Residential	2-38
C. Commercial	2-39
D. Spacing and Corner Clearance	2-39
E. Sight Distance	2-40
F. Grade	2-41
G. Auxiliary Lanes	2-41
2.7 <u>ALLEYS</u>	2-41
2.8 <u>PRIVATE ROADS</u>	2-41
2.9 <u>PARKING REQUIREMENTS AND OFF-STREET PARKING LOTS</u>	2-41
A. General	2-41
B. Residential Parking	2-42
C. Off-Street Parking Lots	2-42
D. Perpendicular Parking	2-43
2.10 <u>SOLID WASTE CONTAINERIZATION</u>	2-43
A. General	2-43
B. Definitions	2-43
C. Bulk Container Service Pad	2-44
D. Maneuver Space Requirements	2-44
E. Design Unit Size And Location	2-44
2.11 <u>ROAD TREES</u>	2-45
2.12 <u>SIGNALS, SIGNS AND PAVEMENT MARKINGS</u>	2-45
2.13 <u>ROADWAY LIGHTING</u>	2-45
2.14 <u>SPEED CONTROL DEVICES</u>	2-46
A. General	2-46
B. Definition	2-46
C. Designer Characteristics	2-46
D. Major Street Element Use	2-48

CHAPTER 2 DESIGN OF ROADS

2.1 General

A. Introduction

This chapter presents criteria and guidelines for the design of roads, driveways, entrances, parking, and solid waste container pads. The criteria have been developed considering the intended role of the road in relation to service function, land use, traffic demand, quality of service, vehicular and pedestrian safety, economy and the environment. Basic design criteria are included in Appendix A, "Roadway Design Criteria". For scenic roads, deviations from the basic design criteria set forth in this chapter may be warranted in order to preserve the scenic features of the roadway.

For residential streets including minor collectors, the design should consider the needs of all users, i.e., motorists, pedestrians and cyclists to travel calmly, safely and without inconvenience or delay. Residential street design standards permit roads to be designed so as to reduce speeds and allow for ease of maneuvering at those reduced speeds, while providing opportunities for greater flexibility and creativity for subdivision development.

The opportunities to enhance design relate to: improved pedestrian/bike safety and ambiance; reduced impacts on sensitive environmental features (streams, wetlands, floodplains, steep slopes, forests); preservation of site amenities like specimen trees, vistas, historic features; and creation of meaningful community open spaces and visual focal points that will help define a unique, attractive neighborhood. Residential streets are to be designed to incorporate their primary functions which include discouraging the use as a through traffic route from externally generated traffic. At the same time, the design should limit the length of time local drivers spend in a low speed environment. The maximum travel time should not exceed 2 minutes from any driveway to a collector or existing roadway at the design speed. Speed is controlled by changes to alignment, maximum tangent length and/or speed control devices. Speed control devices are introduced into the street design to encourage appropriate driver behavior.

B. Residential Street Classifications and Functions

The Public Access Place is a very low speed environment with narrow pavement widths serving a maximum of twenty (20) dwelling units. The residential environment is dominant and traffic is completely subservient. The low speed allows for pedestrians to share the travelway. The vehicle speed is controlled by alignment and/or speed control devices. The length should be kept to a minimum.

The Access Street is a low speed environment with narrow pavement widths serving up to 50 dwellings in RR and RC zoning district and 100 dwellings in others. Two-way traffic movement may be interrupted where on-street parking is permitted. The residential environment is dominant and traffic is subservient. Pedestrian movement may share the

roadway, however, a sidewalk is typically provided on at least one side of a closed section roadway to facilitate that use in accordance with the latest edition of the Subdivision and Land Development Regulations. This classification of road generally acts as a road link between the smaller Public Access Place to a Collector Road.

The Minor Collector collects traffic from Public Access Places and Access Streets and carries higher volumes of traffic. A reasonable level of residential amenity and safety is to be maintained by restricting traffic volumes and speeds. Vehicle speeds should be controlled by street alignment and intersection design. In the RC and RR zoning districts all roadways containing traffic volumes between 500 ADT and 1,000 ADT shall be designed to this standard.

C. Traditional Neighborhood Design

The Traditional Neighborhood uses a grid system of roadways with multiple routes which residents can access. The road widths and other parameters can be customized with the permission of both DPZ and DPW. However, the design has many aspects that make up the whole. The resultant layout and templates must work together. The basic objectives of the Design Manual Volume III must still be met, including safety, on-street parking, speed control, access, fire and rescue access, and trash pick-up.

D. Design Controls

The principal features controlling design of roads are design hourly traffic volumes, average daily traffic, design speed, design vehicles, future traffic volumes, roadway location and impacts to adjacent land. These features form the basis for the selection of the geometric elements that are required to accommodate the anticipated traffic at a desired level of service.

1. Design Hourly Volume

Design hourly volume is a volume determined for use in design representing traffic expected to use the roadway. DHV is discussed in Chapter 5 and the designer is referred thereto for its determination and use.

2. Design Speed

Design speed is a selected speed used to determine the various geometric design features of a highway. The design speed should be an appropriate one with respect to the topography, anticipated operating running speed, the adjacent land use, and the functional classification of highway. Once the design speed has been selected, all elements related to highway features should be in balance. Horizontal and vertical alignments, stopping sight distance and super elevation are among the highway elements that are controlled by design speed. For roadway classifications of major collectors and higher, above-minimum design values should be used, where practical. However, on local residential roads, including scenic roads designated by the County

Council, the designer should develop a road design that encourages vehicles to operate at or below design speeds.

3. Design Vehicle

Vehicles have been divided into four general classes, including (1) passenger cars, (2) buses, (3) trucks, and (4) recreational vehicles. The passenger-car classes include passenger cars of all sizes, minivans, vans, sport utility vehicles of all sizes, pick-up trucks of all sizes. Buses include motor coaches, city transit including articulated, and school buses. Trucks includes single-unit trucks, tractor-semitrailer combinations, and tractors with semitrailers in combination with full trailers. Recreational vehicles include passenger cars with camp trailers, passenger cars with boat trailers, motor homes, motor homes with boat trailers, and motor homes towing a car.

Typical design vehicles have been developed for each of the classes. The respective design vehicles have dimensions and a minimum turning radius larger than most vehicles in its class.

The design vehicles designations are as follows:

P	(passenger car)
SU	(single unit truck)
BUS-40 & BUS-45	(motor coaches)
CITY-BUS	(city transit bus)
S-BUS 36	(school bus 65 passenger)
S-BUS 40	(school bus 84 passenger)
A-BUS	(articulated bus)
WB-40	(medium tractor-semitrailer combination)
WB-50	(large tractor-semitrailer combination)
WB-62	(tractor- full trailer combination)
WB-67	(tractor-semitrailer-semitrailer combination)
WB-109	(tractor-full trailer-full trailer combination)
MH	(motorhome)
P/T	(passenger car-camp trailer)
P/B	(passenger car-boat trailer)
MH/B	(motor home with boat trailer)

Dimensions and turning characteristics of each design vehicles can be found in AASHTO, "A Policy on Geometric Design of Highways and Streets, 2004" or latest edition.

In the design of roadways, the Designer should consider the largest design vehicle will most likely use the facility or a design vehicle that will use a specific feature in the facility such as turning movements at an intersection.

For residential developments, the design vehicle shall be BUS-40 which will represent a fire department emergency vehicle. For commercial developments, the design vehicle shall be a WB-50 except in areas where trucks are prohibited.

2.2 Roadway Design

A. Introduction

The design of roadways includes the combination of several features to meet the needs of the community with an acceptable level of service and to be economical to construct and maintained with acceptable impacts to the adjacent land. Features include the general layout of the roadway, horizontal geometry, grades, grading, pavement widths, shoulders, pedestrian access, bicycle compatibility, pavement material, drainage facilities, etc.

B. Determination of Typical Section

The typical section shall be determined by Howard County Department of Public Works Bureau of Engineering based on the Highway Classification System of Howard County and the General Plan, Transportation Map.

C. Modification of Typical Section or Design Criteria

Each project is unique and may require variability in typical section including lane width, cross-slope, sidewalk, etc., horizontal and vertical geometry, inclusion of traffic calming devices. To incorporate modifications to design standards or modifications to typical sections will require approval from the Chief, Bureau of Engineering.

D. Sight Distance

Sight distance is the length of visible roadway ahead of the driver. There are three types of sight distance considered in design and include stopping sight distance, passing sight distance and intersection sight distance. Sight distance shall be made as long as feasible, but never less than the stopping sight distance.

1. Stopping Sight Distance

Stopping sight distance (SSD) is the distance required for a vehicle to stop before reaching an object in its path. It is the sum of the distance traveled from the moment the object is first visible to the driver to the moment the brakes are applied, and the distance required to stop after the brakes are applied.

Stopping sight distance is measured between an eye height of 3.5 feet and an object height of 2.0 feet.

The equation for stopping sight distance:

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

Where V = initial speed (mph)
 t = brake reaction time, 2.5 s
 a = deceleration rate, ft/s², 11.2 ft/s²
 G = percent of grade divided by 100

Table 2.01 consists of computed distances for wet pavements for various speeds and grades.

TABLE 2.01
STOPPING SIGHT DISTANCE

Design Speed (mph)	Downgrades				Upgrades		
	Level (ft)	3% (ft)	6% (ft)	9% (ft)	3% (ft)	6% (ft)	9% (ft)
15	80	80	82	85	75	74	73
20	115	116	120	126	109	107	104
25	155	158	165	173	147	143	140
30	200	205	215	227	200	184	179
35	250	257	271	287	237	229	222
40	305	315	333	354	289	278	269
45	360	378	400	427	344	331	320
50	425	446	474	507	405	388	375
55	495	520	553	593	469	450	433
60	570	598	638	686	538	515	495
65	645	682	728	785	612	584	561
70	730	771	825	891	690	658	631

Reference: A Policy on Geometric Design of Highways and Streets, 2004, Exhibit 3-1, *Stopping Sight Distance* and Exhibit 3-2, *Stopping Sight Distance on Grades*

The relationships between horizontal curvature and sight distance, and vertical curvature and sight distance, are given in Sections 2.3.

2. Passing Sight Distance

Passing sight distance (PSD) is the distance required for a vehicle to pass another before meeting an opposing vehicle which might appear after the pass began. It is applicable only to two-lane, two-way rural major collectors and minor arterial. Passing sight distance is measured between an eye height of 3.5 feet and an object height of 3.5 feet.

The minimum passing sight distance as reflected in Table 2.02 shall be provided at least once per mile.

TABLE 2.02
MINIMUM PASSING SIGHT DISTANCE

Design Speed (mph)	Passed Vehicle (mph)	Passing Vehicle (mph)	Minimum Passing Sight Distance (ft)
20	18	28	710
25	22	32	900
30	26	36	1,090
35	30	40	1,280
40	34	44	1,470
45	37	47	1,625
50	41	51	1,835
55	44	54	1,984
60	47	57	2,135
65	50	60	2,285
70	54	64	2,480

Reference: A Policy on Geometric Design of Highways and Streets, 2004, Exhibit 3-7, *Passing Sight Distance for Design of Two-Lane Highways*

3. Intersection Sight Distance

The sight distance required at intersections is presented in Section 2.5.

E. Permanent Non-Through Streets/Temporary Non-Through Streets

Permanent Non-Through Streets and Temporary Non-Through Streets Design criteria are discussed in Section 2.3.

F. Alleys

Alley Design criteria is discussed in Section 2.7.

G. Bus Stops

For existing or proposed public transit service routes, a bus turnout lane shall be provided where directed by the Department of Public Works or Department of Planning and Zoning. The turnout lane shall be 12 feet wide by 50 feet long with 75 foot transition to existing pavement edge on each end.

A 5 foot sidewalk shall be adjacent to the bus turn out lane. If required by Department of Public Works, a bus shelter pad shall be provided.

H. Maintenance of Traffic

Maintenance of traffic plan shall be in accordance the Federal Highway Administration's Manual on Uniform Traffic Control Devices 2003 or latest edition, Maryland Department of Transportation State Highway Administration Standards for Highways and Incidental Structures, and Howard County Standard Details and Specifications.

2.3 Geometric Design

A. Horizontal Alignment

1. Horizontal Curves

Horizontal curves are used to change direction at a safe rate and shall be used whenever the roadway centerline changes direction.

The relationship of the design speed, curvature and superelevation, which must be established to provide a balanced design, is developed in Section 2.3.2.C. Also, see Appendix A for Roadway Design Criteria.

Reverse curves and compound curves are combinations of simple curves, and criteria governing their use are included in the following section.

a. Design Speed/Minimum Radii

The design speed and minimum radii of horizontal curves for a selected roadway classification, shall be limited as shown in Appendix A.

b. Curve Data

A simple circular curve is a circular arc joining two tangents. A typical curve, along with the pertinent definitions and the formulas needed to calculate the various parts of the curve is shown in Appendix B. Horizontal Circular Curve and are based on the arc definition of a circular curve.

c. Minimum Curve Length

The minimum length of horizontal curves, not used for speed control, shall be 100' on Public Access Place and Access Street, 150' on minor collectors, 300' on major collectors and 500' on arterials. In no case shall the length of curve be less than the minimum superelevation runoff.

d. Reverse Curve

Where reverse curves are used, an abrupt reversal in alignment shall be avoided and length of tangent sufficient for superelevation runoff, but in no case less than 100 feet, shall be provided between the curves, except Public Access Place and Access Street..

e. Compound Curves

In compound circular curves, the radius of the flatter curve should not be more than 1.5 times greater than the radius of the sharper curve.

f. Horizontal Sight Distance

Another control on horizontal alignment is the sight distance across the inside of curves. Where there are sight obstructions such as buildings, trees, hedges, walls, traffic barrier, or cut slopes, efforts shall be made to provide as long sight distance as feasible, but never less than the stopping sight distance.

The relationship between horizontal curvature, distance to obstruction, and sight distance for those cases in which the curve is longer than the pertinent sight distance can be found in A Policy on Geometric Design of Highways and Street AASHTO, 2004, Exhibit 3-54, *Diagram Illustrating Components for Determining Horizontal Sight Distance*. Where this exhibit will not apply, a check for sight distance should be made by scaling dimensions on the plans and profiles.

A height of 2.0 feet above the pavement shall be used as the height of cut slope at which sight is obstructed. This height shall be either the height of the cut slope itself, or, where there is expected to be vegetative cover, the height of such cover (normally 1 foot).

Where there are no sight obstructions within the right-of-way, the right-of-way line shall be used as the sight obstruction or alternately by the inclusion of an easement on a record plat to maintain a clear line of sight zone.

g. General Controls of Horizontal Alignment

In addition to the specific criteria presented in previous sections, the following general controls shall be utilized:

- 1) In selecting the alignment for a given design speed, use of the maximum curvature for that speed should be avoided.
- 2) Consideration shall be given to the alignment and its effect on operating speed. The speed at the bottom of a long downgrade, for example, will be higher than on a level grade, and this shall be considered when introducing a horizontal curve.

- 3) Sharp curvature should not be used at the ends of a long tangent. A series of curves should be used to introduce a sharp curvature.
- 4) Sharp curvature shall be avoided on long, high fills. The absence of reference items such as slopes, trees and buildings makes it difficult for the driver to judge horizontal curvature.
- 5) Broken back curves that is, two curves in the same direction separated by a short tangent, should be avoided. Such an arrangement can usually be replaced by a series of compound curves or a single larger radius curve.

2. Intersection Geometry

Intersection Design criteria is discussed in Section 2.5.

3. Special Design Elements

If the Department of Public Works requires or the designer requests to incorporate any of the following features, the following criteria shall be met:

a. Roundabouts – Rural and Urban, Including Lighting and Landscaping

A roundabout is an unsignalized intersection with a center island with traffic circulating in counter clockwise direction. Traffic entering the roundabout must yield to circulating traffic. Roundabout Design criteria is discussed in Section 2.14.

b. Monumental Entrances

Monumental entrances are divided roadways constructed at a community main entrance. The median width shall be a minimum 8 feet wide, the entrance lane width shall be a minimum 18 feet wide and the exit lane width shall be a minimum 18 feet wide unless the traffic analysis requires a two lane exit in which the minimum width shall be 24 feet wide. The radii of the curb return shall conform to criteria set forth in the section entitled Intersection Design.

The length of the entrance shall be a minimum of 100 feet long and transition back to the standard road width with a transition rate of 15:1.

Monumental entrances that feature gateway signing, plantings, etc. shall not block sight distance.

c. Divided Roadways

Generally, divided roadways may be constructed for roads with Highway Classification of intermediate arterials or higher. The median width shall be 16 feet minimum and 50 feet maximum with 36 feet desirable. A wide median may be planted except plantings shall not reduce intersection sight distance. The plantings shall be located outside the clear zone.

d. Grade Separated Interchange

Although any of several factors may warrant the construction of a grade separated interchange, the most common warrants are high traffic volumes and safety considerations. When an intersection level of service analysis indicates a low level of service or the need for more lanes than can be feasibly provided, a grade separated interchange should be considered.

Interchange design criteria can be found in AASHTO, "A Policy on Geometric Design of Highways and Streets, 2004" or latest edition. In addition, interchange ramps shall conform to the criteria set forth for turning roadways in Section 2.5. Limiting value of grades are given in Section 2.3.

The design procedure for interchanges is similar to that set forth previously for major intersections. The development of alternates and the selection of the optimum plan proceed in a similar fashion. More careful attention, however, must be paid to profiles for interchanges than for at-grade intersections, even when preparing study sketches.

The intersection of interchange ramps with the crossroad should be designed as any at-grade intersection, including provision of adequate sight distance and storage. Special consideration should be given to bridge piers, abutments, and railings which can restrict sight distance if not properly located, and to the high speed of vehicles on exit ramps which might result in rear-end accidents at the terminal with the crossroad if the ramp is not properly designed.

e. Permanent Non-Through Streets

The maximum length of cul-de-sac roads is 1,200 feet. The minimum radius of the paved circular portion shall be 45' in 55' right-of-way in residential area and 47' in 60' right-of-way in non-residential area. The length of a cul-de-sac shall be measured from the flow line of the nearest intersection to the furthest extreme edge of pavement and along the cul-de sac's longitudinal axis. A second access shall be provided when traffic volume exceed 1,000 ADT.

Residential roads which are permanently designed with only one (1) end open to vehicular traffic shall be terminated with a cul-de-sac turnaround. Low volume roads, however, of less than 200 ADT may terminate in a tee or a y-turnaround. Non-residential roads shall be terminated with a cul-de-sac. The design shall be per Standard Details Volume IV and shall permit driveway connection(s) at the head of the tee or y-turn around. The legs of the tee or y-turnaround shall not extend into driveway access. Warning devices at the end of the tee or y-turnaround are required for safety reasons in accordance with Volume IV.

The following shall be the minimum acceptable radii for cul-de-sac bulbs:

Without Island:

45 feet for residential

47 feet for non-residential

With Island:

52 feet for residential

52 feet for non-residential

Note: Islands are permitted within cul-de-sac bulbs in conformance with Standard Details Volume IV and parking is prohibited in accordance with the Howard County Code along the island. Islands are required within cul-de-sac bulbs if the public road is continued by a use in common driveway.

f. Temporary non-Through Streets

In the event a road may be extended in the future, a temporary tee turnaround shall be provided. The legs of the tee or y-turnaround shall not extend into an existing or future driveway access.

4. Superelevation and Transitioning

The relationship between design speed, curvature and superelevation is:

$$R = \frac{V^2}{15(0.01e + f)}$$

Where: e = rate of superelevation in percent
 f = side friction factor
 V = vehicle speed, mph
 R = radius of curve, feet

The vehicle speed shall be the design speed set forth in Appendix A.

Roads with design speeds of 30 mph or greater may be superelevated.

Maximum superelevation rates are dependent upon the type of roadway, the effect of the superelevation upon vehicles operating at less than the design speed and drainage considerations. Vehicles operating at low speeds may have to steer against the curve to overcome the effect of superelevation, and erratic operation can result. On ice and snow, slow moving vehicles may slide to the inside of the curve if the superelevation rate is too high. In urban areas, the close spacing of intersections and driveways limits the superelevation development. The superelevation rates to be used in the various roads based on design speeds are given in Table 2.03. Also included are minimum radius of curvature.

TABLE 2.03
MINIMUM RADIUS USING LIMITED VALUES OF
SUPERELEVATION RATES (e) AND SIDE FRICTION FACTOR (f)

Design Speed (mph)	f	Maximum e %	Minimum Radius (ft)
30	0.20	4	250
40	0.16	4	533
50	0.14	4	926
55	0.13	4	1,190
60	0.12	4	1,500
30	0.20	6	231
40	0.16	6	485
50	0.14	6	833
55	0.13	6	1,060
60	0.12	6	1,330

Reference: A Policy on Geometric Design of Highways and Streets, 2004, Exhibit 3-15, *Minimum Radius Using Limiting Values of e and f* .

On curves, values of superelevation and side friction must be distributed to produce a balanced design. The method used is to increase both superelevation and the side friction factor to the maximum values at the sharpest allowable curvature.

The means of transitioning from a normal crown section to a fully superelevated section and then back to a normal crown section is the tangent runoff and superelevation runoff. The runoff must be sufficiently long to provide a smooth transition and not appear distorted to the driver. The length of tangent runoff shall be such that the outside edge of pavement has the same slope relative to the centerline as that through the superelevation runoff. Two-thirds of the superelevation runoff shall be placed on the tangent and one-third on the curve. Lengths of Superelevation Runoff are shown on Exhibit 3-32, *Superelevation Runoff for Horizontal Curves*, of AASHTO "A Policy on Geometric Design of Highways and Streets, 2004".

Methods of obtaining superelevation are shown in Appendix E1 and E2. Though the means of changing cross slopes are presented in terms of straight lines, the angular breaks shall be rounded in final design to produce smooth pavement edge profiles. Superelevation tables shall be shown on the construction drawings for all subdivision and capital projects and reference all critical stations (P.C., P.T., P.I., full superelevation, etc.).

B. Vertical Alignment

Vertical alignment shall be designed considering the design speed and road classification in order to provide a balance between all geometric elements of the road.

The two components of vertical alignment are grades and vertical curves. Minimum grades are established to assure adequate drainage, and maximum grades are established considering the operational characteristics of the design vehicle. Vertical curves must be at least long enough to provide the required stopping sight distance.

Vertical alignment is controlled by a profile grade line (PGL) shown on the contract plans. The PGL shall coincide with the roadway centerline. For divided roadways, the PGL shall be the centerline of each travel way.

5. Grades

a. Minimum

The minimum grade shall be 1.0%. Where a closed section is used, the spacing of inlets must be carefully studied when utilizing the minimum grade to avoid the spreading of storm water across the pavement. Criteria limiting drainage encroachment upon the roadway are given in the Design Manual, Volume I, Storm Drainage.

b. Maximum

The maximum grade for Local Roads, Minor Collectors, Access Street, Public Access Place and Non-Through streets shall be 10%. The approach to the cul-de-sac bulb, y- or t-turnaround shall not exceed 8% for the 200 feet just prior to the bulb's linear profile or the y- or t-turnaround. A vertical curve may be used to lower the approach grade to the maximum required within the 200 feet specified in this section. The maximum pavement cross-slope measured radially through the bulb shall be 6%. The minimum grade for the linear profile shall be 2%.

With the above approach grade requirement, the 10% limit may be extended to an absolute maximum of 12% on Local Roads, Cul-de-Sacs, Access Street and Access Place under the following conditions:

- 1) Sufficient justification is presented. Justification should focus on grading, clearing and environmental impact reduction.
- 2) No parking is permitted along this length. Coordination is required with the Department of Planning and Zoning to affirm adequate off-road parking is available.
- 3) Landing grade and related criteria are satisfied.
- 4) Tangent length maximum 450 feet.

- 5) The length of grades may not exceed 450 ft. along the tangent section, and the intersection landing grades must meet AASHTO requirements. The 12% maximum grade may be used in townhouse or apartment developments if no driveway access is required.

The maximum grade for Major Collectors and Arterials shall be the following:

<u>Design Speed (MPH)</u>	<u>Desirable</u>	<u>Absolute</u>
40	6%	8%
50	5%	7%
60	4%	6%

For interchange ramps, the maximum upgrade shall be 6% and maximum downgrade shall be 7%.

6. Vertical Curves

The vertical curve, which is a parabola, is the means by which transitions are made between vertical tangents. A typical curve with the major elements identified is shown in Appendix C. Vertical Curve.

The elevation of any point on the curve may be computed by using the following formula:

$$Y = ax^2 + bx + c$$

Where:

Y = Elevation of the desired point on the curve

$$a = \frac{G_2 - G_1}{2L}$$

b = G₁

c = Elevation of PVC

x = Distance from PVC to point on curve (in stations)

G₁ = Grade tangent from the PVC (percent)

G₂ = Grade tangent from the PVT (percent)

L = Length of the curve (in stations)

The vertical offset between the tangent and any point on the curve can be determined by the following formulas:

1. Between PVC and PVI: $y = ax^2$
2. Between PVI and PVT: $y = a(L - x)(L - x)$

The high or low point of a vertical curve can be found by the following formula:

$$x = \frac{(L)(G_1)}{(G_1 - G_2)}$$

The grade G , at any point on the vertical curve can be determined by the following formula:

$$G = \frac{(G_2 - G_1)(x)}{L} + G_1$$

The six possible types of vertical curves are shown in Appendix D, Types of Vertical Curves. Types I through III are crest vertical curves, meaning the PVI is above the curve, and Types IV through VI are sag vertical curves, meaning the PVI is below the curve.

Whenever vertical tangents change grade, they shall be connected by a vertical curve. On special circumstances such as critical clearance, the use of asymmetrical vertical curves may be appropriate. These curves are used infrequently and thus the curve data equations have not been included in this manual. Geometrical curve data can be found in numerous highway engineering texts. The use of these curves will require approval from the Department of Public Works or Department of Planning and Zoning.

a. Crest Vertical Curves

Minimum lengths of crest vertical curves are based on stopping sight distance criteria as shown in Table 2.04 when the height of eye is 3.5 feet and the height of object is 2.0 feet.

The formulas for minimum length of crest vertical curves are:

When $S < L$

When $S > L$

$$L = \frac{AS^2}{2158}$$

$$L = 2S - \frac{2158}{A}$$

L = Length of crest vertical curve, in feet

S = Stopping sight distance, in feet

A = Algebraic difference in grades, in percent

A graphical relationship between length of the crest curve, algebraic difference in grades and design speed is shown on Exhibit 3-71, *Design Controls for Crest Vertical Curves* of AASHTO, "A Policy on Geometric Design of Highways and Streets, 2004".

TABLE 2.04
DESIGN CONTROLS FOR STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

Design Speed (mph)	Stopping Sight Distance	Rate of Vertical Curvature, K*
15	80	3
20	115	7
25	155	12
30	200	19
35	250	29
40	305	44
45	360	61
50	425	84
55	495	114
60	570	151
65	645	193
70	730	247

* Rate of vertical curvature, K, is the length of curve per percent algebraic difference in intersecting grades (A). $K=L/A$

Reference: A Policy on Geometric Design of Highways and Streets, 2004. Exhibit 3-72, *Design Controls for Stopping Sight Distance and for Crest Vertical Curves*.

Passing Sight Distance

Design values for crest vertical curves for passing sight distance will be different than those for a stopping sight distance based upon a different object height. The passing sight distance height uses an object height of 3.5 feet.

The formulas for minimum passing sight distance of crest vertical curves are:

When $S < L$

$$L = \frac{AS^2}{2800}$$

When $S > L$

$$L = 2S - \frac{2800}{A}$$

L = Length of crest vertical curve, in feet

S = Stopping sight distance, in feet

A = Algebraic difference in grades, in percent

The design controls for crest vertical curves based on passing sight distance are presented in Table 2.05 Comparing these values with design controls for stopping

sight distance, these lengths are generally 7 to 10 times greater and are normally impractical to include in a project. Therefore, passing sight distance is generally provided at locations where roadway alignments do not require crest vertical curves.

TABLE 2.05
DESIGN CONTROLS FOR CREST VERTICAL CURVES BASED ON PASSING SIGHT DISTANCE

Design Speed (mph)	Passing Sight Distance (ft)	Rate of Vertical Curvature, K*
20	710	180
25	900	289
30	1090	424
35	1280	585
40	1470	772
45	1625	943
50	1835	1203
55	1985	1407
60	2135	1628
65	2285	1865
70	2480	2197

* Rate of vertical curvature, K, is the length of curve per percent algebraic difference in intersecting grades (A). $K=L/A$

Reference: A Policy on Geometric Design of Highways and Streets, 2004, Exhibit 3-73, *Design Controls for Crest Vertical Curves Based on Passing Sight Distance*.

b. Sag Vertical Curves

Headlight sight distance (HLSD) is used to determine the length of sag vertical curves. When a vehicle enters a sag vertical curve at night, the roadway lighted ahead of the driver depends on the height of the headlight and direction of the headlight beam.

Headlight sight distance is measured with a headlight height of 2 feet and a 1-degree upward divergence of the light beam.

Minimum lengths of sag vertical curves shall therefore be based upon a headlight sight distance equal to the stopping sight distance.

The formulas for minimum length of sag vertical curves, based upon this criterion, are:

For $S < L$

$$L = \frac{AS^2}{400 + 3.5S}$$

For $S > L$

$$L = 2S - \frac{400 + 3.5S}{A}$$

L = Length of sag vertical curve, in feet

S = Stopping sight distance, in feet

A = Algebraic difference in grades, in percent

The design controls for sag vertical curves are presented in Table 2.06.

TABLE 2.06
DESIGN CONTROLS FOR SAG VERTICAL CURVES

Design Speed (mph)	Stopping Sight Distance (ft)	Rate of Vertical Curvature, K*
15	80	10
20	115	17
25	155	26
30	200	37
35	250	49
40	305	64
45	360	79
50	425	96
55	495	115
60	570	136
65	645	157
70	730	181

* Rate of vertical curvature, K, is the length of curve per percent algebraic difference in intersecting grades (A). $K=L/A$

Reference: A Policy on Geometric Design of Highways and Streets, 2004, Exhibit 3-75, *Design Controls for Sag Vertical Curves*.

A graphical relationship between length of the crest curve, algebraic difference in grades and design speed is shown on Exhibit 3-74, *Design Controls for Sag Vertical Curves* of AASHTO "A Policy on Geometric Design of Highways and Streets, 2004".

7. Critical Length of Grade

It is necessary to consider, in addition to maximum grade, the effect of length of grade upon vehicle operation. Though most passenger cars can climb fairly steep long grades with little difficulty, trucks generally undergo a substantial reduction in speed which can result in a reduced level of service and increased accident potential. The maximum length of designated upgrade that a loaded truck can travel without an unreasonable reduction in speed is termed the "critical length of grade." Major collectors in commercial or industrial areas and all arterials shall be checked for critical length of grade.

The maximum permissible speed reduction shall normally be 15 mph. Where the upgrade is preceded by a substantial downgrade, vehicle speeds are likely to be higher at the bottom of the upgrade, and the maximum permissible speed reduction may then be as great as 20 mph.

A relationship between speed reduction, percent of grade, and length of grade is shown on Exhibit 3-59, *Critical Length of Grade for Design* of AASHTO "A Policy on Geometric Design of Highways and Streets, 2004". Whenever a design exceeds the critical length of grade, the grade shall be reduced, the length reduced, or a climbing lane added.

For grades steeper than shown on Exhibit 3-59 but within allowable criteria, the critical length of grade shall be 450'.

Factors to be considered in designing the end of a climbing lane include average running speed, topography and sight distance. In no case shall the climbing lane be ended prior to a point at which the truck can attain a speed of at least 30 mph.

8. General Controls for Vertical Alignment

In addition to the specific criteria presented in previous sections, there are a number of general controls applicable to vertical alignment.

- a. In selecting the vertical alignment based on a given design speed, use of the maximum gradient and minimum length of curve for that speed should be avoided.
- b. The length of a vertical curve shall not be less than three times the design speed in mph.
- c. A smooth profile grade, consistent with the topography, shall be strived for in preference to a grade with numerous breaks and short lengths of tangent.
- d. The profile shall be such that hidden dips, hazardous to passing maneuvers, are avoided.
- e. Short tangents between vertical curves should be avoided. A more pleasing alignment can be attained by lengthening the curves to eliminate the tangent.

- f. Where there is an at-grade intersection on a highway with a steep grade, the gradient should be reduced through the intersection to aid turning vehicles and reduce hazards.

2.4 Typical Sections

A. General

Typical sections for the various functional road classifications are shown in the Standard Details of Volume IV of the Design Manual and include:

Residential Streets - Access Place,
Access Street, Minor Collector (Closed Section)
Residential Streets - Access Place,
Access Street, Minor Collector (Open Section)
Non-Residential Streets - Local Road,
Minor Collector, Major Collector
Minor Arterial
Undivided Intermediate Arterial
Divided Intermediate Arterial

Typical sections for principal arterial freeways shall be developed specifically for each project and submitted to the Department of Public Works for review and approval.

B. Pavement and Right-of-Way Width

1. Roadway Right of Way

Roadway right-of-way widths shall be as shown on the typical sections.

2. Pavement Widths and Cross Slope

Roadway pavement widths shall be as shown on the typical sections. Turning lanes shall be 12 feet wide. In closed sections, this width shall be measured to flowline. The designer must consider the presence of parked vehicles, sight distance and the presence of pedestrians where no sidewalk is provided. The pavement cross-slope shall be as shown on the typical sections. All pavement widths are flowline to flowline and not back of curb. Where sidewalks are not present, a minimum of 3' shoulders shall be provided on both sides. Outside lanes on curbed roadways on major collectors or above shall be a minimum of 14' wide to facilitate bicycle use.

C. Paving Section

The Designer or Developer shall obtain the services of a consultant Registered Professional Geotechnical Engineer to prepare a Soils Evaluation and Pavement Design Report. The Geotechnical Engineer shall be licensed to practice in the State of Maryland, and shall sign

and seal the report. The report shall be submitted to the Department of Public Works, and must be approved prior to base paving.

The Designer or Developer shall submit, for approval, the Final Road Construction Plans, which specify the road classification, zoning district, and pavement section, as shown in the Typical Sections in the Standard Details Volume IV of the Design Manual. It is preferred that the Soils Evaluation and Pavement Design Report is performed during the design phase of the project, using the DPW "Geotechnical Data Required for Water, Sewer, Storm Drain and Road Design and Construction Guideline, and is submitted with the plans. If the soils evaluation and report is to be performed after construction begins, the plans shall include the following note:

"Construction of road base pavement is not permitted until DPW approves the pavement design recommendations submitted in the Soils Evaluation and Pavement Design Report required in Section 2.4 of the Design Manual Volume III."

The report shall contain the results of the following required tests that the Geotechnical Engineer has performed on each of the predominant soil types to be used in the road construction:

1. California Bearing Ratio (CBR) Test (AASHTO T-193)
2. Sieve Analysis (AASHTO T-88)
3. Liquid Limit & Plasticity Index of Soils (AASHTO T-89 & T-90)
4. Modified Proctor (AASHTO T-180)
5. Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM-D-2488-84)

The report shall identify the CBR used for the pavement design. The maximum CBR value for subgrade soils used in the design of pavement sections is 7. The CBR test shall be the soaked test at 95% compaction.

The report shall identify micaceous soils used for the pavement subgrade. The description and identification of soils shall include the estimated percentage of mica content. Soils estimated to have a mica content in excess of five percent (trace amount) of the total volume, shall be considered to be micaceous. Micaceous soil subgrades require the use of aggregate base in the pavement section.

The report shall include pavement design recommendations, based on the results of the soils analyses, based on an assumed 20-year pavement life expectancy, and based on the expected Equivalent Single Axle Loads (ESALs). The ESALs used for design shall account for construction loading and phase construction. The Geotechnical Engineer may recommend a pavement design based on one of the following:

1. If the top 2 feet of subgrade soil has a CBR greater than 3, and meets the material requirements for unit weight and plasticity indices, the Geotechnical Engineer may recommend a pavement section by selecting from the Standard Details.

2. If the top 2 feet of subgrade soil has a CBR less than 3, or does not meet the material requirements for unit weight and plasticity indices, the Geotechnical Engineer may recommend removing the unsuitable material and replacing it with suitable material, and may recommend a pavement section by selecting from the Standard Details.
3. If the top 2 feet of subgrade soil has a CBR less than 3, or does not meet the material requirements for unit weight and plasticity indices, the Geotechnical Engineer may recommend improving the unsuitable material using Cement Modified Soil, and may recommend a pavement section by selecting from the Standard Details.
4. If his reasons are indicated in the report, the Geotechnical Engineer may recommend an alternate pavement section of his own design.

D. Curb and Gutter

Curb and gutter shall be in accordance with the Standard Details as shown in Volume IV.

The following are the permitted uses for the various types of curb:

Standard Combination Curb and Gutter: Any road.

Modified Combination Curb and Gutter: Cul-de-sac bulb, local roads, and minor collectors in residential areas.

Bituminous Curb: Shall only be used for temporary installation.

Flush Curb: Shall be used on the inside of all open section curves with a radius of 1,000 feet or less unless an alternative edge treatment is approved by the Department of Public Works.

Monolithic Curb: Private parking area only.

E. Shoulders

Shoulders shall be as shown on the typical sections.

F. Medians

Medians shall be as shown on the Standard Details. Raised medians 6 feet or less in width should have a paved surface, while those greater than 6 feet in width shall be seeded and mulched or landscaped with low maintenance vegetation. For special consideration of emergency vehicle movements, mountable medians or mountable median noses may be considered on a case-to-case basis. For divided roads, future widening shall be planned in the median area.

G. Sidewalks/Sidewalk Ramps

Regulations governing the placement of sidewalks are contained in the "Subdivision and Land Development Regulations". Those areas normally requiring sidewalks are so indicated on the typical sections.

Adjacent to the curb the minimum sidewalk width shall be 5 feet. Sidewalks located two feet or more from the curb may be 4' in width. Sidewalk ramps must be in compliance with current ADA requirements.

Where there will be a large number of pedestrians, such as near schools and in some commercial areas, the sidewalks shall be made sufficiently wide to accommodate the anticipated pedestrian demand. Sidewalks shall be constructed in concrete as shown in the Standard Details, Volume IV.

Standard sidewalk locations are shown on the typical sections. The designer may have the option to place a sidewalk at variable distances from the curb such as in a landscaped serpentine walk, or move the sidewalk close to the curb for some special reason such as the preservation of an existing stand of trees.

Where sidewalks are not provided, a concrete pad will be provided per Howard County School Board requirements at anticipated school bus stops to allow students to assemble while waiting for the bus.

H. Side Slopes

Side slopes for excavations and embankments should be as flat as feasible considering earthwork and right-of-way requirements. The normal maximum slope shall be 2:1. Where poor soil conditions exist, soil tests and a slope stability analysis shall be conducted to determine an acceptable slope.

Reference shall be made to "Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas" for regulations concerning the treatment of slopes to provide erosion control.

The intersection of a cut slope and the existing ground shall be rounded as shown in the Standard Details, Volume IV.

All slopes shall be covered with topsoil and seeded and mulched. Other stabilization materials beside grass may be used subject to Department of Public Works.

I. Traffic Barrier

Traffic barrier is needed at certain roadside obstacles and along some embankments to reduce the severity of run-off-the-road type accidents. It should only be installed where the

severity of a collision with the traffic barrier will be less than that which would occur were the traffic barrier not present.

Combinations of embankment slope and height warranting traffic barrier are shown in Appendix F. Wherever feasible, the embankment should be adjusted to eliminate the need for traffic barrier. Where traffic barrier is warranted, it shall be placed as shown in SHA Standard Details.

Factors to be considered when determining the need for traffic barrier at fixed roadside objects include design speed, roadway functional classification, type of obstacle and distance from pavement edge to the obstacle. Traffic barrier shall conform to the standard details, except that scenic roads and along cul-de-sac roads, access place, access street and minor collectors in residential areas, weathered steel traffic barrier may be used.

Traffic barrier W-beam shall normally be extended from the fill into the cut as shown in SHA Standard Details. Where a long low fill not requiring traffic barrier is adjacent to a fill that does warrant traffic barrier, the traffic barrier may be started or ended on the low fill in accordance with SHA Standard Details.

Placement of traffic barrier guardrail adjacent to a closed section roadway shall be evaluated on a case-by-case basis when there is a roadside obstacle, a hazardous embankment, or as indicated in the typical sections. If any of these conditions warrant a traffic barrier, it shall be placed in accordance with the, SHA Standard Details.

Rail rider reflectors shall be installed on all traffic barrier W-beam at a spacing of two times the design speed.

Concrete Barrier may be used as an alternate to traffic barrier W-beam subject to the review and approval of the Department of Public Works.

J. Pathways and Bikeways

Pathways shall be constructed in subdivisions where directed by the Department of Planning and Zoning or under capital project implementation by the Department of Public Works or the Department of Education.

Residential areas, school and open space areas and short routes connecting residential and employment centers typically warrant provisions for pedestrians and/or bicyclists.

Bikeways may be separated from the roadway but within the road right-of-way such as through open areas.

Cul-de-Sac roads and local roads will not normally have designated bikeways because of the low traffic volumes and speeds.

The location of all bikeway systems should be compatible with the General Plan for Howard County. Bikeways may be incorporated as part of a combined bikeway/pedestrian pathway system where they can be accommodated with adequate safety.

When planning a bikeway, the Department of Planning and Zoning shall be consulted to provide coordination between the planned bikeway and those in surrounding areas.

The Department of Public Works shall be consulted when planning a bikeway within or adjacent to a road right-of-way.

The design of bikeways shall be in conformance with the AASHTO Criteria for Bikeways.

K. Utility Location

The normal locations for the placement of utilities within the road right-of-way are shown in the Standard Details of Volume IV of the Design Manual. Where conditions are such that the use of the normal location arrangements would be infeasible or for scenic roads, would have an adverse impact on scenic features such as roadside vegetation, embankments, wetlands and streams, an alternate arrangement shall be developed and submitted to the Department of Public Works for review and approval. All utility owners shall have their utility installation plans approved before any construction is initiated in accordance with the agreement executed between the County and utility company.

Requirements for telephone, gas, electric and cable television submittals:

1. All drawings must be accompanied by a transmittal letter that includes the following information:
 - a. Name of Development
 - b. Location
 - c. Election District
 - d. Project Number
 - e. Water and Sewer Contract Numbers
 - f. Type of Construction
 - g. Alexandria Drafting Company (ADC) Map Number and Grid
2. All existing and proposed sewer lines, water lines, house connections, fire hydrants, storm drains, manholes, related appurtenances and sidewalks must be shown on all drawings submitted for approval.
3. All existing and proposed water and sewer lines must be identified by contract number.
4. The diameter of all water lines, sewer lines and storm drains must be shown.
5. All plans submitted must be to scale, using a minimum scale of 1" = 50'.

6. The following information is to be noted on all drawings:
 - a. "Maintain a 5-foot horizontal clearance and a 1-foot vertical clearance from all existing and proposed water lines, sewer lines, fire hydrants, storm drains and related appurtenances when installing cable, transformer pedestals, gas lines, utility poles, and guide wires."
 - b. "Any pedestal placed in conflict with sidewalk or county owned/maintained utility will be moved at the company's expense."
 - c. Indicated at all fire hydrants "Do Not Disturb Butress".
7. Transformers and/or pedestals should be located on property lines without twin water/sewer house connections. In those areas where a transformer and/or pedestal is required at a property line adjacent to a water or sewer house connection, the unit shall be set back six to ten feet from the front of the property line. The drawing shall clearly indicate the potential conflict and a note referencing the setback shall be provided.
8. Transformers and/or pedestals shall not be placed in storm water management access easements.
9. Transformers, pedestals or other box-like equipment should not be visible from scenic roads. Use depressions, berms, or vegetation to screen.
10. The location of all road trees shall be shown on all drawings. Trees damaged or destroyed will be replaced at the utility company's expense.
11. An application for a utility permit must be submitted concurrent with the design submission.

L. Minimum Edge Distance to Any Roadside Appurtenance

The distance from the face of curb or edge of shoulder to any roadside appurtenance shall not be less than 3-feet.

M. Crossings Locations

The crossing locations within the private or public right-of-way for golf cart paths shall be reviewed and approved by the Department of Public Works or Department of Planning and Zoning.

N. Underdrain

Longitudinal underdrain shall be used to drain the pavement section. Longitudinal underdrain shall be located at the outside edge of shoulder in open section and behind curb in closed section.

Underdrain is generally placed at low points along the roadway profile and along the low side of the superelevation.

Underdrain shall outlet into side ditches or drainage inlet structures

O. Ditches

Roadside ditches shall conform to the Typical Sections of Volume IV and Volume I, Storm Drainage Design Manual.

P. Staged Construction

Consideration should be given to staged construction when it is determined by traffic analysis that a given road will initially require a much smaller section than the ultimate. A typical example of this condition is a four-lane divided intermediate arterial. Four lanes may be needed in the design year but the construction of only one of the two-lane roadways might be sufficient for a number of years beyond initial construction.

Factors to be considered include level of service provided by the initial construction, time until widening is required, cost of initial and ultimate construction, ease with which the ultimate section can be added to the initial section and maintenance of traffic problems which may occur during the ultimate construction.

Care must be exercised that the change from the initial to the ultimate section will not result in an undue amount of reconstruction. An example is a road over passing another road being built under staged construction. In such a case, the ultimate section, not just the initial, shall be spanned.

As a guideline, staged construction should be considered only when the time between initial and ultimate construction would be greater than five years.

2.5 Intersection Design

A. Staged Construction

To assure that an intersection is designed to safely and efficiently accommodate the traffic desiring to use it, certain procedures and analyses must be performed. This section contains the geometric design elements applicable to intersections, the procedures to be followed in developing the best possible design layout and the information required on the construction drawings. A roundabout may be required at an intersection with three (3) or more legs

B. Geometric Design

1. Location and Spacing

Roads should be so located that sufficient length is provided between intersections for weaving, storage and associated land uses. The minimum intersection spacing, measured along the through roadway between centerline of intersecting roadways, shall be as indicated in Table 2.07.

TABLE 2.07
MINIMUM INTERSECTION SPACING

Functional Classification of Through Road	Minimum Intersection Spacing (Centerline to Centerline)
Principal Arterial	To be in accordance with MSHA Criteria
Intermediate Arterial	
Divided	Median Crossover: 1600' Tee Intersection: 750'
Undivided	750'
Minor Arterial:	750'
Major Collector	500'
Minor Collector	250'
Access Street	250'
Public Access Place	N.A.

Notes:

1. Intersection spacing is the distance between any two public or private roads as located on the specified through road
2. Skew Angle and Horizontal Curvature

Roadway centerlines shall intersect between 80 degrees and 100 degrees and continue through the intersection without offset or break.

In order to prevent drainage problems along the fillets of two intersecting roadways from being created, spot elevations and flow arrows should be provided to ensure positive drainage along the fillet.

3. Design Vehicles and Turning Paths

Many intersection design details, such as curb radii and island locations, depend upon the choice of the design vehicle. The larger design vehicles require larger curb radii and wider lane widths between islands than do the smaller vehicles. Selection of the design vehicle depends upon the functional classifications of the intersecting roads, adjacent land use, and volume and type of vehicles that will use the intersection. Turning paths for the various design vehicles are shown in AASHTO, "A Policy on Geometric Design of Highways and Streets 2004", or latest edition.. For non-standard intersections or road terminus, a turning template showing adequate turning radius of the design vehicle shall be provided.

4. Minimum Curvature for turning Movements

The minimum fillet radius (either curb or edge of roadway) which will permit a design vehicle to make a 90 degree turn shall be consistent with those specified in Exhibit 9-19, *Edge-of-Traveled-Way Design for Turns at Intersections* and 9-20, *Edge of Traveled Way for Turns at Intersections* of AASHTO, "A Policy on Geometric Design of Highways and Streets 2004".

It must be remembered that these radii specified in AASHTO, "A Policy on Geometric Design of Highways and Streets 2004", are minimums and result in turns being made at extremely slow speeds. Though provision of larger radii is desirable for improved traffic movement, it should be weighed against the resulting increase in pedestrian walking distance across the intersection roadways.

In the absence of specific knowledge of the type of vehicles making a turn, the radii listed in Table 2.08 shall be used at 90 degree intersections.

TABLE 2.08
MINIMUM CURB FILLET RADIUS in FEET

Functional Classification Intersection Roads	Residential Area	Non-Residential Area
Cul-de-Sac, Local, Access Place, Access Street	25	-
Cul-de-Sac – Minor Collector	25	35
Local-Local	25	35
Local-Minor Collector	30	35
Local-Major Collector	35	40
Minor Collector-Minor Collector	35	40
Minor Collector-Major Collector	35	50
Major Collector-Major Collector	35	50
Collector-Minor or Intermediate Arterial	35	60
Minor or Intermediate Arterial- Minor or Intermediate Arterial	35	60
Principal Arterial-Any Classification	Consult D.P.W.	

The above radii are based on a 90 degree turning angle. Reference shall be made to Exhibit 9-19 and 9-20 of AASHTO, "A Policy on Geometric Design of Highways and Streets 2004", for information concerning skewed intersections.

Some vehicles turning from higher classification roads with wider pavement sections onto Access Place and Access Street roadways, may find it difficult to stay in the appropriate lane without crossing the centerline, due to the relatively narrow residential

road standards. It is expected that the driver will use caution when making these maneuvers and wait until there is a sufficient gap in traffic to safely negotiate the turn.

Curbing shall be provided at intersections in which the design vehicle must encroach upon adjacent lanes when making turning maneuvers.

With the relatively low volume and local nature of the traffic associated with Access Place and Access Street roadways, there should be sufficient gaps to safely allow this type of turning maneuver. In some instances, the intersections shall be required to flare the pavement width for a short distance in order to allow the design vehicle to make the turn and stay on the pavement. The designer shall demonstrate that there is sufficient pavement width where encroachment into adjacent lanes occur. Roadways with classifications of minor collector and above should have sufficient pavement width to prevent encroachments into adjacent lanes from occurring.

5. Auxiliary Lanes

Auxiliary lanes at intersections are used to increase capacity of the through movement, provide storage for turning vehicles and provide sufficient space for vehicles to decelerate from the design speed of a new roadway or 85th percentile operating speed of an existing roadway to either a stop or the safe speed for the turn.

Auxiliary lanes shall be required under any of the following conditions:

- a. Auxiliary acceleration lanes are not recommended unless needed to maintain intersection capacity as indicated in Chapter 4.
- b. The design speed of a new roadway or 85th percentile operating speed of an existing roadway is 40 mph or more and vehicles waiting to turn left or right would pose a hazard to through traffic. Either a channelized additional lane or a lane within a raised protective median may be required.
- c. At bus stops or where a large number of passengers load or unload from passenger cars.
- d. For warrants for auxiliary lanes at driveways, see Section 2.6.

In any of these cases, a free right turn with a directional island combined with an acceleration lane or left turn lane are desirable and may be required by the Department of Public Works or the Department of Planning and Zoning.

Auxiliary lanes shall be 12 feet wide. In closed sections, this width shall be measured to flowline.

The length of an auxiliary lane is composed of three parts: entering taper, deceleration lane and storage length. Though the total length should be the sum of the lengths. The

minimum length for acceleration and deceleration lanes shall be in accordance with AASHTO, "Policy on Geometric Design of Highways and Streets 2004", Exhibit 10-70 *Minimum Acceleration Lengths for Entrance Terminals with Flat Grades of Two Percent or Less* and 10-73, *Minimum Deceleration Lengths for Exit Terminals with Flat Grades of Two Percent or Less*, respectively.

On closed sections, the taper of an auxiliary lane shall be consistent with AASHTO. The taper shall consist of reverse symmetrical curves and be approximately the length required by AASHTO. The design speed of the entrance or exit curve shall be 15 mph.

The minimum length of auxiliary lane required for storage depends upon traffic volumes, type of vehicles, speed and signalization. To be fully effective, the turning lane must be sufficiently long to assure that vehicles in it do not block the through lanes and at signalized intersections, a line of stored through vehicles does not block its entrance. The length shall be consistent with the traffic study evaluation.

At unsignalized intersections where turning traffic cannot make a free turn, the length of storage in right-turning lanes shall be sufficient to accommodate the average number of vehicles arriving during a two-minute period within the design hour, and the length of storage in left turning lanes shall be sufficient to accommodate the average number of vehicles arriving in a 5 minute period within the design hour.

At signalized intersections, the minimum length of storage of right-turning lanes shall be that required to accommodate the average number of turning vehicles arriving per cycle and the minimum length of storage of left-turning lanes shall be that required to accommodate twice the average number of turning vehicles arriving per cycle. In the absence of definite knowledge of the cycle length, it shall be assumed to be 75 seconds.

Also, at signalized intersections, to ensure that the entrance of an auxiliary lane is not blocked by stopped through vehicles, the length required to store 1.5 times the average number of through vehicles arriving per cycle shall be determined, and if it is greater than the length of auxiliary lane otherwise required, it should be used as the minimum length. The taper shall be in addition to this length requirement.

The results of a detailed queue analysis may be substituted for the above length requirements.

The length required to store each passenger car is 20 feet and each truck and bus 50 feet. Traffic volumes shall be determined by methods contained in Chapter 5.

6. Turning Roadways

The main controls on the design of turning roadways (connecting roadways for traffic turning between two intersection legs) are radius of the inside edge of pavement and width of roadway. The relationship between roadway width, curvature and design

vehicles is specified in AASHTO "A Policy on Geometric Design of Highways and Streets 2004", Exhibit 3-51, *Design Widths of Pavements for Turning Roadways*.

Widths of turning roadways shall be based on A Policy on AASHTO "Geometric Design of Highways and Streets 2004", Exhibit 3-51 in accordance with the following:

1. Traffic condition B shall normally govern design.
2. Case 1 may be used to determine the width of turning roadway only where the island formed by the roadway is less than 25 feet long.

The minimum sight distance on turning roadways shall be equal to the stopping sight distance.

The length of crest and sag vertical curves needed to satisfy this sight distance requirement shall be in accordance with Section 2.3.

7. Median Lanes and Openings

A median lane is a left-turning auxiliary lane located within the median, and the determination of its need, as well as its geometric, such as length and width, shall be as for any auxiliary lane.

Where the turning volume is sufficiently high, as determined by a level of service analysis, queue analysis, and if the median width is large enough, two left-turn lanes may be provided, each being the width of a normal turning lane. The receiving leg of the double left-turn shall be sufficiently wide to receive the two turning lanes of traffic without undue hazard. This width is dependent upon type of turning vehicles and angle of the turn, but shall not be less than 30 feet.

Barriers shall not be used to separate the through and left-turn lanes.

Though median openings should usually be located at intersections with cross roads and major traffic generators, such factors as close intersection spacing or long left-turn lanes may make this infeasible. An analysis of the projected traffic volumes and the road network shall be conducted to determine the recommended location of median openings.

The design of the median opening shall normally be based upon a 50 foot radius which is tangent to the median edge and cross road centerline. The median opening width shall be as defined by AASHTO "A Policy on Geometric Design of Highways and Streets 2004", Exhibit 9-79 and 9-81, *Minimum Design of Median Openings*.

The median opening design should be checked to assure that opposing left turns can be made without conflict.

A semicircular end shall be used on all median islands 6 feet or less in width.

For widths greater than 6 feet, a bullet nose shape, as shown in AASHTO "A Policy on Geometric Design of Highways and Streets 2004", Exhibit 9-87, *Above-Minimum Design of Median Openings*, shall be used.

The ends of median islands shall be depressed to 2 inches above the pavement using the Maryland SHA details and shall have a radius equal to $M \times 15$, where M is the median width. In no case shall the minimum length of the median opening be less than the cross street width plus 8 feet.

8. Traffic Islands

Traffic islands are areas between traffic lanes used for controlling vehicle movements or for pedestrian refuge. All islands with an area of at least 75 square feet shall be raised and bounded by a standard curb or combination curb and gutter. Islands with areas less than 75 square feet shall have a normal pavement section and be marked by paint.

Divisional islands, which are islands separating opposing traffic flows within the intersection area, shall be a minimum of 4 feet wide. The offset from the edge of travel lane to the approach nose shall be at least 3 feet.

The approach noses of traffic islands shall be depressed to 2 inches above the pavement.

On islands adjacent to turning roadways, the approach nose shall be offset at least 4 feet from the edge of the adjacent through lane and a minimum of 2 feet from the edge of the turning roadway.

The nose radii of triangular islands shall be 2 feet, except the right-angle corner, which shall have a 5 foot radius. The approach nose of divisional islands shall have a 1-foot radius, offset as discussed above. The end of a divisional island shall be in accordance with median openings.

All divisional islands, six feet or less in width, as well as triangular islands of less than approximately 150 square feet, shall be paved or planted with low maintenance landscaping evergreens, provided that the ultimate height does not conflict with line of sight and ultimate spread does not conflict with gutter drainage.

Divisional islands wider than six feet, and triangular islands greater than 150 square feet in area shall be seeded and mulched or sidewalks shall be included where directed by the Department of Planning and Zoning or deemed necessary for a safe pedestrian crossing by the Department of Public Works.

All roadways separated by islands shall provide a clear turning radius for the design vehicle or shall have mountable payers at noses for emergency vehicle access.

Traffic circles at intersections shall provide a minimum radius for the design vehicle.

9. Intersection Sight Distance

The maneuvers occurring at an intersection are different from those occurring at other points along a highway and sight distance needed to ensure safety at intersection is consequently different.

Areas along the intersection approach should be cleared of obstructions which could interfere with the driver's view. These areas are called clear sight triangles. In intersection design, two types of clear sight triangles are used, approach sight triangle and departure sight triangle.

The approach sight triangle pertains to vehicles approaching an uncontrolled or yield-controlled intersection. The triangular area at each quadrant should be clear of obstructions so that drivers approaching the intersection can see a potential conflicting vehicle and have adequate time to slow down or stop.

The departure sight triangle provides sight distance for stopped vehicles on the minor-road to depart the intersection and enter or cross the major road. Departure sight triangles should be provided in each quadrant of each intersection approach controlled by yield or stop sign.

The sight triangles vary with the different type of traffic control. AASHTO, A Policy on Geometric Design of Highways and Streets have categorized intersections with the following different type of traffic control.

Case A – Intersection with no control

Case B – Intersection with stop control on minor street

Case B1 – Left Turn from minor street

Case B2 – Right turn from minor street

Case B3 – Crossing maneuver from the minor street

Case C – Intersections with yield control on minor street

Case C1 – Crossing maneuver from the minor road

Case C2 – Left or right turn from the minor road

Case D – Intersections with traffic signal control

Case E – Intersections with all-way stop control

Case F – Left turns from the major street

Procedures to determine sight distances at the various types of intersections can be found in AASHTO, "A Policy on Geometric Design of Highways and Streets, 2004" or latest edition. Operating speed (85th percentile) along the existing road shall be utilized for the analysis.

For residential area, stopping sight distance may be used up to a point where the road being entered or crossed is a minor collector or below. Sight distance is measured from

an eye height of 3.5 feet at a point on the centerline of the access 10 feet back from the edge of travel way of the intersecting roadway where a point 2 feet above the roadway surface is visible. For all other intersections, intersection sight distance must be met.

Where a roadway can not meet intersection sight distance, a request to waive intersection sight distance may be submitted. The request shall include stopping sight distance computations showing the proposed intersection located at the optimum location to achieve maximum sight distance and meet the requirement of Section 2.3. The request shall also include a measurement at which point the driver stopped at the intersection and the approaching driver can see each other.

Intersection sight distance is measured using a height of eye of 3.5 feet and height of object of 4.5 feet. The distance is measured from a point 10 feet back from the edge of paving.

10. Intersection Vertical Alignment

Typical section pavement slopes of the road with the higher functional classification shall be carried through the intersection without deviation. The pavement slopes of the road with the lower classification shall be warped to meet the pavement edge of the through road. Where two roads of the same classification intersect, they shall be connected by transitioning both roadways.

As discussed above, one of the intersecting roads shall be determined to be the more important and its grade carried through the intersection without interruption. The grade of the other road as it descends to the through road shall be considered a landing grade. Landing grade shall meet the criteria in Table 2.09.

TABLE 2.09
MAXIMUM INTERSECTION LANDING GRADES AND DISTANCES

<u>Functional Classification</u>	<u>Maximum Landing Grade</u>	<u>Distance From Intersection*</u>
Arterial	+3.0%	200'
Collector	+3.0%	175'
Local. Cul-de-sacs	+4.0%	40'**
Access Street. Access Place		

*Distance measured from pavement edge of intersection road to the PVC of the vertical curve

**No landing grade is required if the tangent is not greater than 4%

The vertical alignment of roads intersecting with State highways is discussed in Section 2.5.F.

11. Pedestrian Facilities

Provisions shall be made in the intersection design for the pedestrian needs as discussed in Chapter 5.

Pedestrian ramps shall be provided at all locations having sidewalks. Pedestrian ramps shall include a detectable warning surface. Typical ramps and detectable warning surface details are contained in the Standard Details, Volume IV.

C. Right-of-Way

The right-of-way lines at intersections shall be adequate to accommodate all the required design features but shall not be less than that required by the latest "Subdivision and Land Development Regulations".

D. Minor Intersection Design Procedures

All intersections not requiring a level of service analysis as indicated in Chapter 4 are considered to be minor intersections. They are the intersection of Access Place or Access Street and any other road, and the intersection of two minor collectors or roadways whose projected volumes do not exceed 3,000 ADT on each road. All others are considered to be major intersections.

The design procedure for minor intersections is similar to that for major intersections but with some modifications. No level of service analysis is required because continuation of the typical section through the intersection will ensure adequate traffic operation. Fewer alternates will have to be developed than for major intersections because volumes will be lighter and channelization and turning roadways will seldom be warranted.

The same elements of geometric design and evaluation of alternate designs that apply to major intersections also apply to minor intersections.

E. Major Intersection Design Procedures

1. General

The following procedure is intended to be used as a guide for the design of major intersections. It provides a framework within which the traffic and geometric design elements, as well as any other pertinent factors, can be studied in an orderly fashion.

The major steps are:

1. Collection of data
2. Establishment of applicable design criteria
3. Traffic studies
4. Development of alternates
5. Selection of optimum plan
6. Final design

2. Collection of Data

a. Traffic Data

The types of traffic data required, and the methods by which they are to be obtained are included in Chapter 4.

b. Existing Physical Conditions

Existing field run topography, road conditions, utilities and right-of-way limits should be shown on an up-to-date map of the site. Information regarding flood levels, drainage problems, and soil conditions should also be obtained. Any buildings, walls, or other features which might conflict with the proposed intersection should be carefully noted on the plan.

c. Future Highway and Land Development

The Department of Planning and Zoning, the Department of Public Works, and the State Highway Administration should be contacted to determine what land development is planned for the area as well as any planned road or utility improvements.

3. Establishment of Applicable Design Criteria

Prior to the development and analysis of various layouts, certain design criteria must be established to assure all alternates are designed on the same basis. The functional classification is to be used as a guide for design, however, specific design hour volumes shall be used for the actual roadway design, right-of-way and pavement width. These design criteria shall include:

1. Design year and ultimate projected traffic volumes.
2. Design speed of each intersecting road.
3. Acceptable level of service
4. Design vehicle
5. Design speed of turning movements
6. Special features (such as need to accommodate the handicapped or provisions for bus stops)

4. Traffic Studies

The traffic studies required and the methods by which they are to be conducted are presented in Chapter 5

F. Intersection with State Highways

Criteria for design and information related to acquisition of permits for intersections with State Highways are contained in “Rules and Regulations for Commercial, Subdivision, Industrial, and Residential Entrances to State Highways”.

Information regarding traffic signals at intersections with State Highways is included in Chapter 5 of this Design Manual.

G. Intersection with Existing Roads

A sight distance analysis shall be required for intersecting roadways with existing roadways and includes proposed driveways access to existing roadways.

2.6 Driveways**A. General**

Control of driveway location and design is essential in assuring that a road will be capable of performing its intended role through and even beyond the design year. Driveways must be so located as to minimize impact on traffic flow and still provide access consistent with the road's classification and projected volumes.

The control of access shall be in accordance with the functional classification of the road and refined traffic studies.

There are three types of driveways: residential, commercial and industrial, and high volume. Residential and use-in-common driveways are those serving single-family houses with no more than six (6) dwelling units. Commercial and industrial driveways serve primarily employment and shopping areas, and are consequently used by more trucks and larger number of vehicles than residential driveways. High volume driveways are those with anticipated volumes exceeding 200 peak hour vehicles (total volume for both directions for a two-way entrance or the total volume for a one-way entrance).

The design of residential and commercial and industrial driveways is discussed herein. High volume driveways shall be designed in accordance with intersection design criteria. High volume driveways must be analyzed in the same manner as roadways. Depending on the movements that the high volume driveway supports (i.e., 1-way or 2-way) the analysis may require an examination of queuing acceleration/deceleration criteria, level of service, signal warrants or all of these factors.

B. Residential

The desired width of residential driveways and easements, when required, is as shown in Table 2.10

TABLE 2.10
REQUIRED MINIMUM DRIVEWAY WIDTHS

Lots Served	Driveway Width (ft)	Corresponding Easement (min) (ft)
1	12	N/A
2 to 6	16	24*

*If a shared residential driveway crosses a 100-year floodplain as defined by Volume 1 of the Howard County Design Manual, then a Public Access Place shall be required

Residential driveway entrances shall be in accordance with the Standard Details, Volume IV.

Driveways serving one residential lot or shared driveways for up to six (6) lots shall consist of a minimum standard of six (6) inches of crusher run base with tar and chip coating. All others refer to the Standard Details, Volume IV.

Drainage elements (e.g. culverts, bridges) shall be provided at all driveways where the waterway discharge meets or exceeds 5 cubic feet per second for a 10-year storm. The drainage element within a 100-year floodplain shall be designed to pass the 100 year storm with no more than 1 foot of water over the driveway.

C. Commercial – Industrial and Multi-family

Entrance openings and curb radii shall be in accordance with the Standard Details, Volume IV. The angle of intersection shall be radial or 90 degree unless otherwise approved by the Department of Public Works or Department of Planning and Zoning.

Commercial entrances shall be designed for WB vehicles and be constructed in accordance with the Standard Details, Volume IV.

D. Spacing and Corner Clearance

In designing driveways near intersections, the effects on through traffic of vehicles entering and leaving the driveway must be considered. Volumes, flow patterns, signalization, channelization, and sight distance are among the factors involved.

Each driveway shall be designed considering anticipated traffic conditions and the driveway's effect upon the traffic operation. The clearances shall not be less than shown in the following:

Minimum Corner Clearance

Driveway to Intersection	Distance
Residential	25'
Commercial and Industrial	
Minor Arterial	75'
Major Collector	75'
Minor Collector	50'
Local	50'
High Volume	Treated as an Intersecting Road

Note: Driveway clearance measured from edge of entrance opening to the PC of the curb circle of the intersecting road

For driveway spacing between driveways of different classifications, the higher spacing of the different categories shall be used.

The normal minimum distance between any driveway and property line shall be 2 feet measured at the right-of-way line. This does not apply to two adjoining driveways serving pipe stem lots.

Distance Required between Driveways

Distance Between Driveways (Min.)

Residential	4'*
Commercial and Industrial	
Minor Arterial	350'
Major Collector	250'
Minor Collector	110'
Local	110'
High Volume	Treated as an Intersecting Road

*Measured between edges of driveways at right-of-way lines.

E. Sight Distance

The sight distance shall be provided at all driveways per Section 2.5.9. The choice of design vehicle is dependent upon the type of land use to be served by the driveway.

F. Grade

Maximum grade of single-family residential driveways shall be 15% and minimum turning centerline radius shall be 45 feet. Overhead clearance shall be a minimum of 12 ft. Maximum grade of multi-family residential driveways (travel ways) shall be 12%, and limited to 6% when parking is adjacent thereto.

The grades for commercial and industrial and high volume multi-family residential driveways (200 vph) shall be a maximum of ten (10) percent. The vertical and horizontal alignment for these types of driveways shall be designed using a minimum design speed of twenty-five (25) miles per hour. Overhead clearances shall be a minimum of 16 ft.

Recommended driveway profiles are included in the Standard Details, Volume IV.

G. Auxiliary Lanes

An auxiliary lane may be required at high volume driveways (>200 vph) along major collector roads with a pavement width less than 40 ft. or along any major collector roads because of high traffic volumes, unusual conditions or for safety purposes, or related to truck use and the percent and length of grade.

All auxiliary lanes shall be designed in accordance with Section 2.5.

2.7 Alleys

Alleys shall generally follow the pattern of adjoining roads. Alleys in all residential areas shall have a minimum width of 16 feet and in all commercial or industrial areas, a minimum width of 25 feet. Alleys shall have a maximum grade of 10 percent with vertical clearance of 13.5 feet and have a minimum stopping sight distance of 120 feet. The elevation of the outside edges of the alley shall be two inches lower than the finished grade of the adjoining property. The angle of intersection between an alley entrance and a road, measured between the alley centerline and the road edge of pavement, shall be 90 degrees unless otherwise approved per Section 2.5.

2.8 Private Roads

Where allowed by subdivision regulations, private roads may be utilized. They shall be constructed to public road standards.

2.9 Parking Requirements and Off-Street Parking lots**A. General**

The need to provide sufficient parking space is critical to the effective use of these roadway design standards. This parking needs to be provided at locations that are consistent with

these design standards and the provisions of the Zoning Regulations and the Subdivision and Land Development Regulations.

B. Residential Parking

The provision of adequate parking space is a function of zoning density, minimum lot size, and the availability of front yard setback areas. These elements should be evaluated to develop the design mix between off-street (i.e., on lot) and on-street parking. Where possible, effort should be made to create side by side driveways on adjacent lots to maximize on-street parking.

To meet zoning requirements, 2.0 spaces per unit off-street parking shall be provided which can be accommodated by garage space, driveway spaces, parking pads, and courts. Garages count as a full space. For the Access Place and Access Street standards to be effective, additional overflow and guest parking shall be required. This can be accommodated on or off- street, with on-street treated according to Table 2.11.

TABLE 2.11
OVERFLOW/GUEST PARKING

Zoning Classification	Overflow/Unit	Access Place	Access Street & Minor Collector
SFD:RC,RR,R-20	0.5	No Restriction	No Restriction
SFD: Other Districts Except R-MH	0.5	Parking one side	Indented*
R-MH, SFA, Apts.	0.3	Indented*	Indented*

* Indented parking is not required when the road width is increased to 28 feet for access place and access street

C. Off-Street Parking Lots

Off-street parking lots must be designed to accommodate the anticipated demand, provide parking stalls of sufficient size to accommodate the vehicles and provide a circulation system which will minimize the delay within the parking lot and prevent overflow congestion onto the adjacent roads. The factors involved in projecting parking demand are discussed in Chapter 5 and the minimum requirements for various land uses are given in the Zoning Regulations. Dimensions of the various components of a parking lot shall be in accordance with current Institute of Transportation Engineers (ITE) guidelines. The basic dimension of a standard size parking stall shall be 9' by 18'. Adjustments to this size can be made for designated compact car parking spaces (8.5' by 16') and other designated parking conditions. The minimum aisle widths between rows of parking shall be 24 feet. See Appendix G, Parking Stall Layout elements for aisle and stall dimensions for various parking arrangements.

The parking lot design shall discourage random movements and, through the use of traffic engineering aids such as signs and islands, provide positive guidance to the motorist and shall be made to minimize vehicular and pedestrian conflicts. Parking lot islands, landscaped with deciduous trees are desired to provide shade in warm weather and reduce the temperature of the roadway's storm water runoff. It is also recommended to channel pedestrian access and ensure that any ornamental landscaping does not limit incidental surveillance and become a detriment to safety. Lighting of the medians is also important to enhance the safety of both pedestrians and vehicles. Efforts shall be made to minimize vehicular and pedestrian conflicts.

Reserved parking for persons with disabilities shall be provided in all off-street parking areas in accordance with current Maryland Accessibility Code Guidelines for Building and Facilities requirements. One in every four of the reserved spaces, but not less than one, shall be designated "Van Accessible". The reserved parking spaces and access aisles shall be level with surface slopes not exceeding 2% in all directions. Refer to the Americans with Disabilities Act Accessibility Guidelines (ADAAG) for further details. The number of off-street parking spaces reserved for persons with disabilities shall be provided in accordance with the Howard County Zoning Regulations.

Pedestrian ramps should be located so as to provide easy and direct access between the reserved parking spaces for persons with disabilities and the building entrance.

The paving section of parking lots shall be in accordance with the Standard Details, Volume IV.

D. Perpendicular Parking

In single family semi-detached or single family attached developments, perpendicular parking along public roads will only be allowed on roads where the ADT is 1,000 or less.

2.10 Solid Waste Containerization

A. General

To adequately accommodate the storage, collection, and removal of refuse at commercial, industrial or institutional development, multi-family residential complexes, single family detached residential on a common driveway and mobile home parks, the following criteria must be met.

B. Definition

1. Refuse Storage Area is defined as that space on the premises where refuse is deposited by occupants and stored until it is transferred to a collection or processing vehicle and removed from the premises.

2. Maneuver Space is defined as that portion of the premises upon which the collection vehicle must travel on its trip from the road to the refuse storage area(s) and exit.

C. Bulk Container Service Pad

Where required, the container must be placed on a level area easily accessible to a front end loader to allow for uninterrupted service access at any time. The location and alignment shall be approved by the Department of Public Works or Department of Planning and Zoning.

Each bulk container shall be placed on a concrete pad with concrete apron, see Standard Details, Volume IV.

D. Maneuver Space Requirements

Minimum overhead clearance: 24 feet unobstructed. Minimum width: 15 feet, unobstructed straight approach for tender truck.

Minimum length: 42 feet, unobstructed straight approach for tender truck.

The maneuver space shall accommodate a truck with a 300 inch wheel base and 38 foot turning radius with an access drive not to exceed 8 percent. The area shall be designed to avoid backing the truck into a traffic lane of a public thoroughfare.

Where multiple containers are grouped a minimum space of two (2) feet must be maintained between adjacent containers. Visual screens are not required; however, if used, at least three (3) feet of clearance space on the sides and rear is required.

E. Design Unit Size and Location

Each individual dwelling unit in a multi-family residential area or mobile home park shall be provided either with an individual or centralized refuse storage area within approximately 200 feet of the dwelling unit or occupancy it serves. For a single family detached residential on a Private Access Place or use in a common driveway, a collection area that is screened from adjacent properties by landscaping shall be provided along the public road.

Residential complex units consisting of more than ten (10) individual residential units shall obtain and use bulk containers for refuse within approximately 200 feet of the dwelling unit or occupancy it serves.

Only six (6) cubic yard and eight (8) cubic yard gravity type, stationary containers will be approved by the County. (One (1) six cubic yard container will serve approximately fifteen (15) dwelling units and one (1) eight (8) cubic yard container will serve approximately 20

dwelling units. However, it must be taken into consideration whether the units are 1, 2, or 3 bedrooms and whether trash compactors are used.)

Each container shall be of a design that can be serviced by Howard County Contractor's Container Tender Truck. Bulk containers shall have sliding metal doors in lieu of swinging doors with spring latches.

2.11 Road Trees

See the Howard County Landscape Manual for requirements.

2.12 Signals, Signs and Pavement Markings

A plan(s) shall be included with final design submittals for all capital and land development projects addressing required signals, signs and pavement markings. The plan shall be consistent with the operational intent of the roadway, applicable chapters in this manual and current acceptable traffic engineering practice such as outlined in the Manual of Uniform Traffic Control Devices. All such elements are to be installed in a timely fashion following final paving and prior to dedication and shall be so specified by a note on the plan(s). For scenic roads, signs should be kept to the minimum necessary for safety and consolidated whenever possible to minimize visual clutter. The cost of traffic signals, signage and pavement markings shall be the responsibility of the developer. Traffic Signal plans shall be drawn on a scale of 1" = 20'. Traffic signals, traffic signs and pavement markings design are discussed in Chapter 5.

2.13 Roadway Lighting

Street lights shall be incorporated into the design as per the following:

County Intersections:

Street lights shall be installed at every County intersection. Street lights shall also be installed at 500 foot intervals along roadways with intersections spacing exceeding 1,000 feet and lights shall be installed midway between intersections with spacing between 800 feet and 1,000 feet. Street lights shall be installed at the terminus of dead end streets longer than 500 feet.

Street lights for all intersections shall have luminaries units consisting of 150 Watt High Pressure Sodium Vapor. All other installations shall have luminaries of 100 Watt High Pressure Sodium Vapor.

Street lighting design is discussed in Chapter 5.

2.14 Speed Control Devices

A. General

The introduction of speed control devices should be part of the total street environment. Isolated devices, especially in streets where there is general expectation of higher speeds can cause accidents. The use of speed control devices should be carefully considered because of the potentially negative impacts to property access and the availability of on street parking and the potential for vehicles to collide with them.

It is the intent of these road standards to design roadways that do not encourage speeding. Typical past practices that encouraged long tangent sections of road, long sweeping curves and wide pavement only serve to invite speeding. These standards require the use of short tangent sections, tight curves and narrow pavements to keep speeds down to design levels. This design also encourages vehicles to travel the roadways at almost constant speeds.

Speed control devices are placed at predictable spacing with appropriate signage and generally should reduce speeds to the design speed. It is up to the design professional to place a variety of speed control options within the site that best suit the layout and topography of the development. The design professional should use judgement concerning the placement of all calming devices as not to impede driveway and intersection access or conflict with sight distance requirements. It is recommended that the design professional meet with the Department of Planning and Zoning.

B. Definitions

Speed control devices can be classified into categories according to their geometry and horizontal deflection. These horizontal deflection devices include such things as:

1. Roundabouts
2. Lateral Shifts
3. Center median islands
4. Chicane

Each type of device has different engineering design criteria which helps to determine when it is appropriate. The designer needs to be aware that the type and placement of speed control devices will have a significant impact on the visual character of both the streetscape and subdivision layout. Some combinations will create a more formal streetscape that is generally appropriate for higher density developments. Other combinations will appear more informal and be suitable for rural and low density developments.

C. Design Characteristics

Properly located and designed horizontal deflection devices are highly visible, and alert the driver from some distance away to slow down. They have less physical effect on traffic and

contribute to the generation of less traffic noise and residential complaints than vertical devices. They need to be illuminated for safety.

1. Roundabouts

Roundabouts are primarily used at intersections to reduce the number of conflict points in turning movements. Due to their symmetry, roundabouts create a more formal character to the streetscape. Roundabouts interrupt the line of vision and prepare a driver to reduce speed. Roundabout design shall be based on criteria set forth in the US Department of Transportation, Federal Highway Administration Publications. Howard County may require other design consideration for roundabouts.

2. Lateral Shift

This type of speed control device utilizes a single curve meeting the Minimum Curve Radii shown in Appendix A, or a reverse curve with minimum deflection angles of 30 degrees. It can be designed so a small open space will be developed. The open space can be streetscape and used for directional signing. Street lighting on the outside is required for safety.

3. Center Median Islands

Center median islands offer great flexibility. They can be designed to perform different functions and to create either very formal or informal streetscapes. Large islands can be landscaped, thereby restricting visibility of the street beyond them promoting driver caution. Small islands can be used but need directional signing to increase their visibility. Street lights are required for safety.

Central medians and median islands are generally located to control speeds along tangent of roadway by visually interrupting the pavement surface.

Center Median Islands shall be minimum 8 feet in width. Entrance and exit fillets shall not be designed below a minimum radius of 45 feet. Travel lane width through the device shall be maintained at 12 feet and 14 feet

4. Chicane

This type of speed control device utilizes a critical bend or a series of reverse curves into the horizontal alignment of a roadway. If used in series in conjunction with small open space areas, the streetscape effect can be very formal. If chicane occurs around stands of trees, rock outcrops or other natural features, a very informal natural streetscape can be created.

5. Street Narrowing

This strategy is reserved for retrofit situations on existing roadways where problems may exist such as vehicles speeding near pedestrian crossings. There is no general design for this type of retrofit. Each street narrowing must be evaluated on a case by case basis. In those cases where this is a developer plan strategy, a Traffic Study shall be submitted to the Department of Public Works addressing the existing conditions and the impact of the modifications.

D. Major Street Element Use

The use of the major street elements such as directional changes in the horizontal alignment to create slow points is the preferable use of speed control devices. For each type of traffic calming or speed control device or method used, turning templates must be provide depicting the movements required. It must be shown that the design vehicle can make all turning movements without adversely impacting the roadway or other vehicles. These templates shall be provided at the preliminary design stage to insure that the road layout will function adequately. Parking may be restricted along these areas of control if needed to insure adequate vehicle movements.

PUBLIC ROADWAY DESIGN CRITERIA

1. RESIDENTIAL STREETS DESIGN CRITERIA SUMMARY - OPEN CROSS SECTION

Classification	Maximum Volume Avg. Daily Traffic (ADT)	Design Speed (mph)	Pavement Width (ft.)	Max. Dist. Between Speed Control Devices (ft.)	Minimum Curve Radius	Sidewalk	Curb	Right of Way Width (ft.)
Use-in-Common	60	15	16	N/A	45	N/A	N/A	24
Access Place	200	25	22	N/A	210	N/A	N/A	50
Access Street	500	30	24	510	350	N/A	N/A	50
Minor Collector	1,000	35	28	600	550	N/A	N/A	50

2. RESIDENTIAL STREETS DESIGN CRITERIA SUMMARY - CLOSED CROSS SECTION

Classification	Maximum Volume Avg. Daily Traffic (ADT)	Design Speed (mph)	Pavement Width (ft.)	Max. Dist. Between Speed Control Devices (ft.)	Minimum Curve Radius	Sidewalk	Curb	Right of Way Width (ft.)
Access Place	200	25	24	N/A	210	Sub. Regs. Sec. 16.134	Modified	50
Access Street	1,000	30	24	510	350	Sub. Regs. Sec. 16.134	Modified	50
Minor Collector	2,000	35	28	600	550	Sub. Regs. Sec. 16.134	Standard	50

3. NON-RESIDENTIAL STREETS DESIGN CRITERIA SUMMARY

Classification	Maximum Volume Avg. Daily Traffic (ADT)	Design Speed (mph)	Pavement Width (ft.)	Max. Dist. Between Speed Control Devices (ft.)	Minimum Curve Radius	Sidewalk	Curb	Right of Way Width (ft.)
Local Roads & Cul-de-sacs	1,000	30	Closed 40	N/A	350	Sub. Regs. Sec. 16.134	Standard	60
Minor Collector	2,000	35	Closed 40	N/A	550	Sub. Regs. Sec. 16.134	Standard	60
Major Collector	-	40	Closed 40	N/A	See Table 2.03	Sub. Regs. Sec. 16.134	Standard	60
Arterial	-	40	Varies	N/A	See Table 2.03	As Required	Standard	100
Minor	-	50						100
Intermediate	-	50						100
Divided	-	50						150

Notes:

1. Residential Streets Design Criteria Summary - Open Cross Section

a. Flush curb on inside of all curves.

b. Standard curb required at all street intersections.

c. Roads leading to cluster development areas may be designed as a Minor Collector with a traffic calming feature at the beginning of an access street.

2. Assume residential dwelling = 10 ADT. For a more accurate definition see ITE Trip Generation Manual, Latest Edition.

3. Pavement width shall be increased at intersections as needed per turning template of design vehicle.

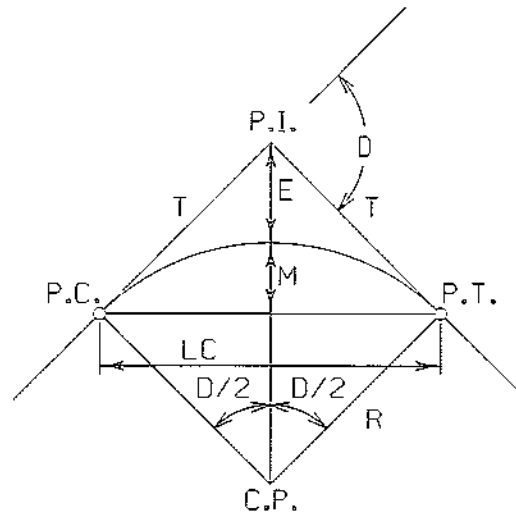
4. Maximum Distance Between Speed Control Devices

a. Speed control devices are not required on roadways less than 1,200' long.

b. Speed control devices are not required on portions of roadways with less than 1,200' between intersection control stop signs, yield signs, roundabouts, traffic signals.

c. Roadways and portions of roadways not meeting item 4a. or 4b. shall adhere to the Maximum Distance between Speed Control Devices requirements.

5. Any Access Place and/or Access Street in townhouse, condominium/apartment development will require 26' of pavement width.



DEFINITIONS AND SYMBOLS

P.I. - POINT OF INTERSECTION

THE POINT AT WHICH TWO TANGENTS TO THE CURVE INTERSECT.

P.C. - POINT OF CURVATURE

THE POINT AT WHICH THE TANGENT ENDS AND THE CURVE BEGINS.

P.T. - POINT OF TANGENCY

THE POINT AT WHICH THE CURVE ENDS AND THE TANGENT BEGINS.

D - DELTA OR INTERSECTION ANGLE ($D = D_c \cdot L / 100$)

THE DEFLECTION ANGLE BETWEEN THE TANGENTS AT THE P.I. THIS IS EQUAL TO THE CENTRAL ANGLE SUBTENDED BY THE CURVE.

D_c - DEGREE OF CURVE ($D_c = 100 \cdot D / L$)

THE CENTRAL ANGLE SUBTENDED BY AN ARC OF 100 FEET. THIS IS THE ARC DEFINITION OF A CURVE AND SHALL BE USED FOR ALL ROAD AND STREET PROJECTS.

R - RADIUS ($R = 5729.578 / D_c$)

THE DISTANCE BETWEEN THE CENTERPOINT AND ANY POINT ON THE CURVE.

T - TANGENT DISTANCE ($T = R \cdot \tan(D/2)$)

THE DISTANCE BETWEEN THE P.C. AND THE P.I. OR BETWEEN THE P.I. AND THE P.C.

L - LENGTH OF CURVE ($L = 100 \cdot D / D_c$)

THE ARC DISTANCE BETWEEN THE P.C. AND THE P.T.

LC - LONG CHORD ($LC = 2 \cdot R \cdot \sin(D/2)$)

THE STRAIGHT LINE DISTANCE BETWEEN THE P.C. AND THE P.T.

E - EXTERNAL DISTANCE ($E = T \cdot \tan(D/4)$)

THE DISTANCE BETWEEN THE P.I. AND THE MIDDLE OF THE CURVE.

M - MIDDLE ORDINATE ($M = R \cdot (1 - \cos(D/2))$)

THE DISTANCE BETWEEN THE MIDDLE OF THE CURVE AND THE MIDDLE OF THE LONG CHORD.

C.P. - CENTER POINT OF THE CURVE

APPENDIX B

HOWARD COUNTY, MARYLAND
DEPARTMENT OF PUBLIC WORKS

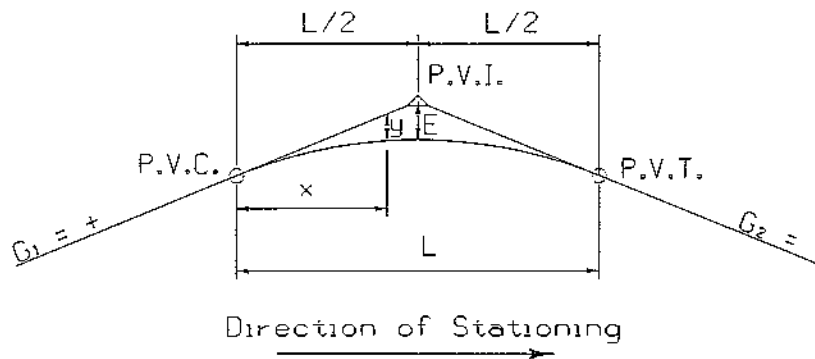
HORIZONTAL CIRCULAR CURVE

DRAWN BY WR&A

CHECKED BY WR&A

NO SCALE

10/2006



DEFINITIONS

P.V.I. - POINT OF VERTICAL INTERSECTION

P.V.C. - POINT OF VERTICAL CURVATURE

P.V.T. - POINT OF VERTICAL TANGENCY

G_1 & G_2 - GRADE OF TANGENTS, IN PERCENT, WITH UPGRADES IN DIRECTION OF STATIONING BEING POSITIVE AND DOWNGRADES BEING NEGATIVE

L - TOTAL LENGTH OF VERTICAL CURVE, IN STATIONS

E - VERTICAL OFFSET FROM P.V.I. TO THE MIDDLE OF THE CURVE, IN FEET

y - VERTICAL OFFSET IN FEET FROM A POINT ON THE TANGENT TO AN INTERMEDIATE POINT ON THE CURVE

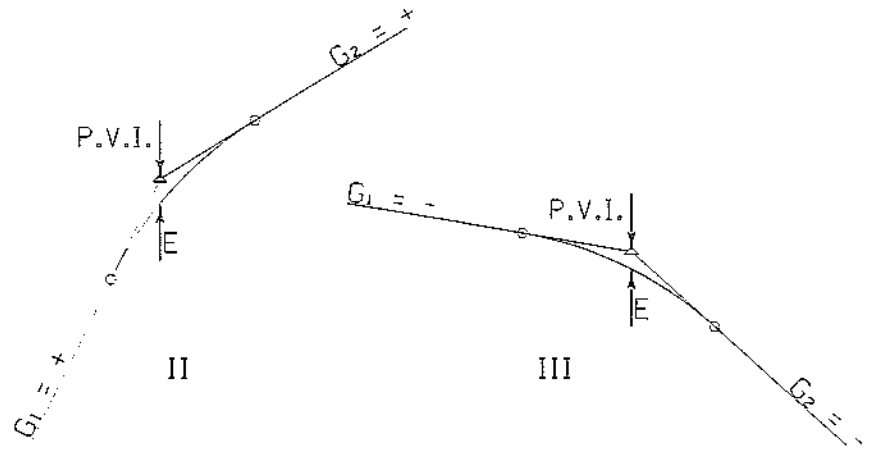
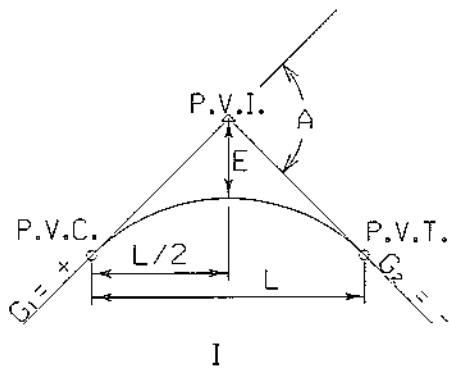
x - HORIZONTAL DISTANCE FROM THE P.V.C. TO ANY POINT ON THE CURVE, IN STATIONS

APPENDIX C

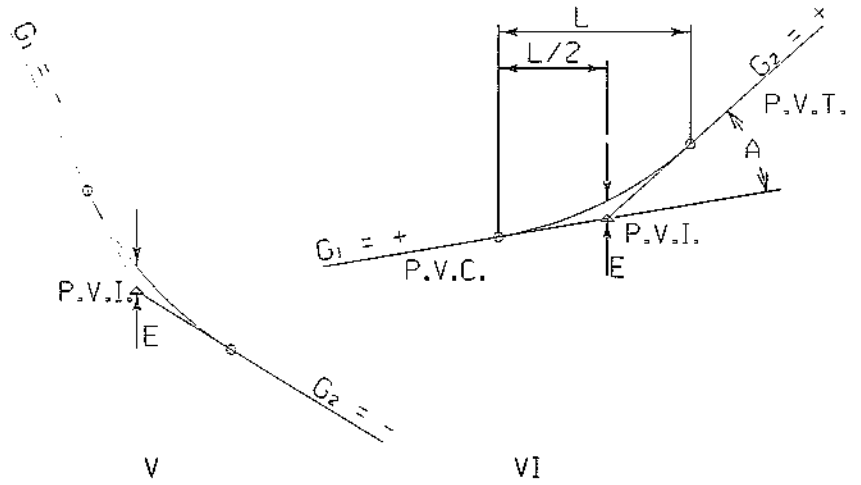
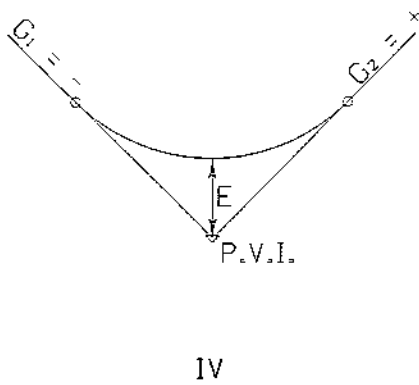
HOWARD COUNTY, MARYLAND
DEPARTMENT OF PUBLIC WORKS

VERTICAL CURVE

DRAWN BY	WR&A
CHECKED BY	WR&A
NO SCALE	
	10/2006



CREST VERTICAL CURVES



SAG VERTICAL CURVES

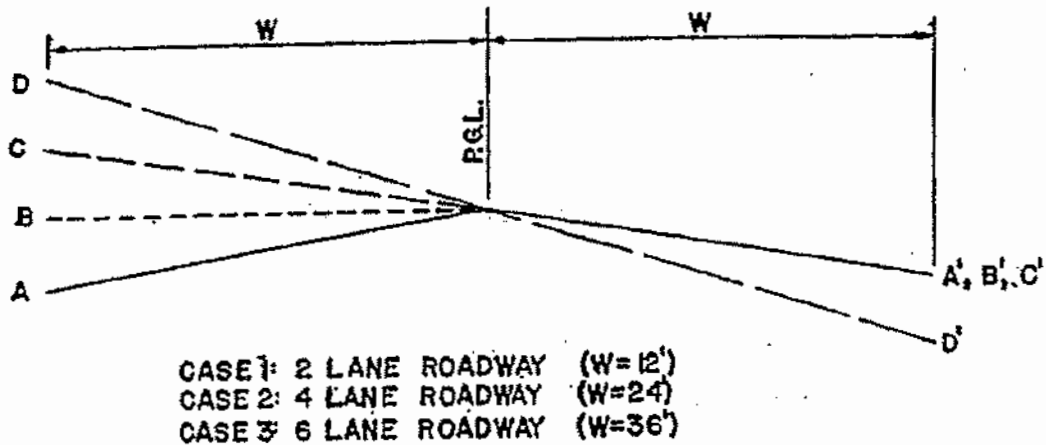
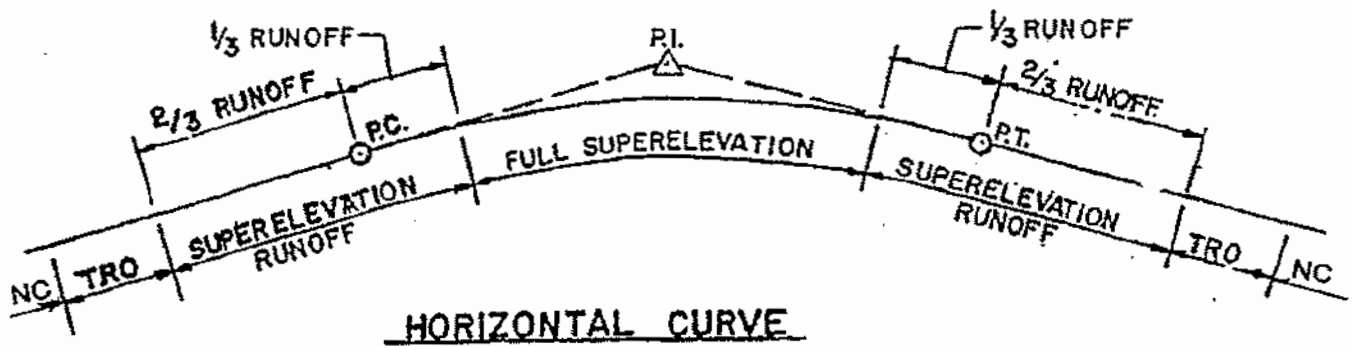
G_1 & G_2 - GRADE OF TANGENTS, IN PERCENT
 A - ALGEBRAIC DIFFERENCE IN GRADE
 L - LENGTH OF VERTICAL CURVE

APPENDIX D

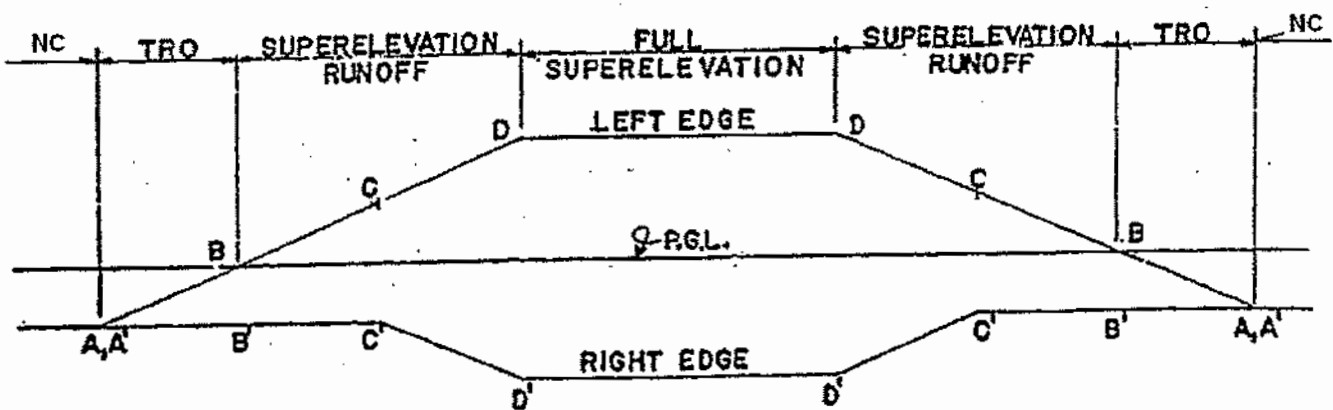
HOWARD COUNTY, MARYLAND
 DEPARTMENT OF PUBLIC WORKS

TYPES OF
 VERTICAL CURVES

DRAWN BY	WR&A
CHECKED BY	WR&A
NO SCALE	
	10/2006



CROSS SECTION



EDGE PROFILES

LEGEND

P.C. - POINT OF CURVATURE
 P.T. - POINT OF TANGENCY
 TRO - TANGENT RUNOUT
 P.G.L. - PROFILE GRADE LINE

NC - NORMAL CROWN

APPENDIX E.1

HOWARD COUNTY, MARYLAND
 DEPARTMENT OF PUBLIC WORKS

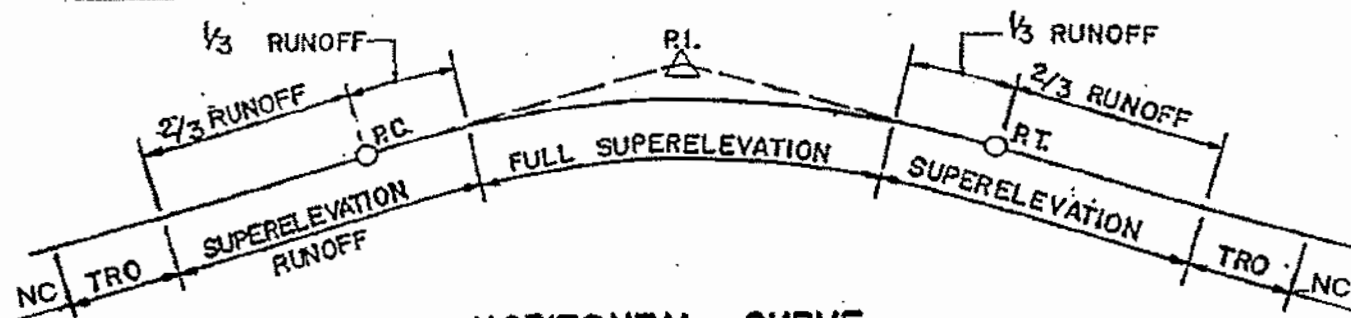
METHOD OF ATTAINING
 SUPERELEVATION
 (CASE 1, 2 & 3)

DRAWN BY WR&A

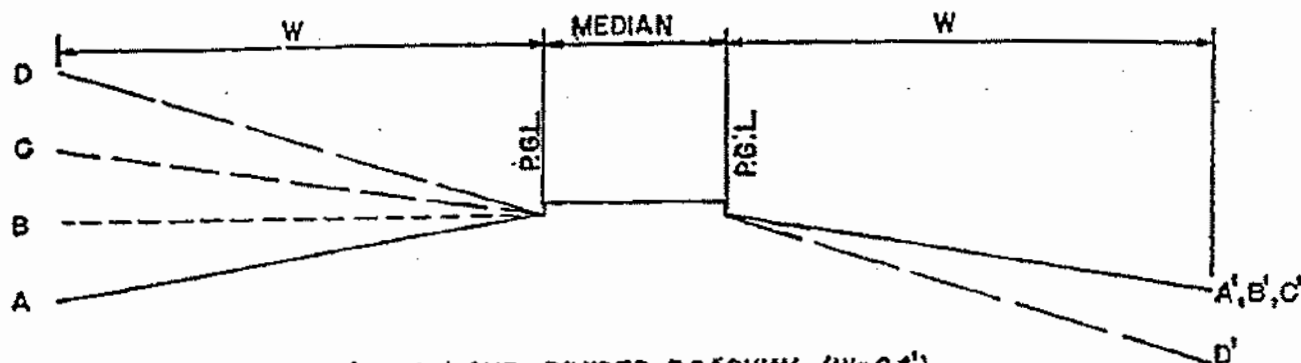
CHECKED BY WR&A

NO SCALE

10/2006

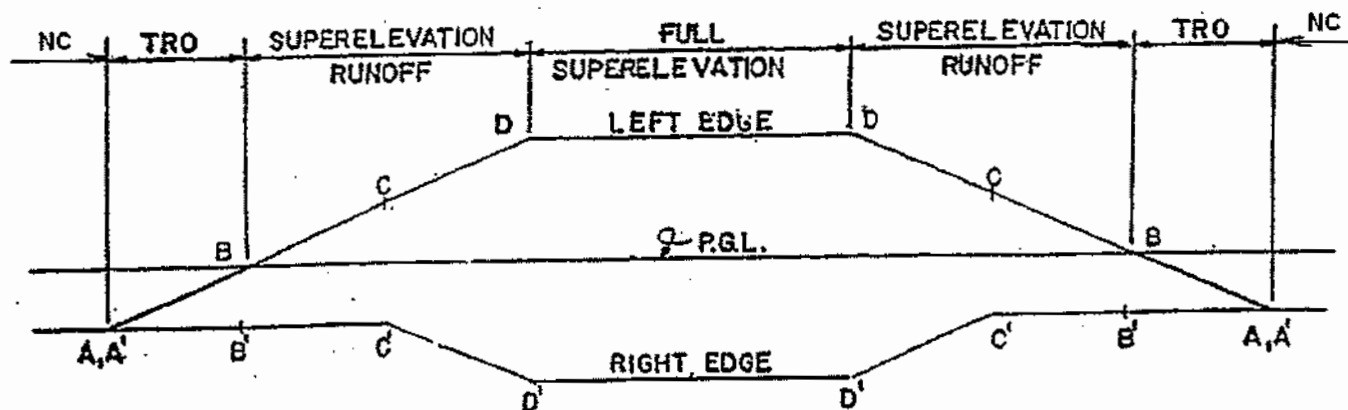


HORIZONTAL CURVE



CASE 4: 4 LANE DIVIDED ROADWAY (W=24')
CASE 5: 6 LANE DIVIDED ROADWAY (W=36')

CROSS SECTION



EDGE PROFILE

LEGEND

RC.— POINT OF CURVATURE
RT.— POINT OF TANGENCY
TRO— TANGENT RUNOUT
P.G.L.— PROFILE GRADE LINE

NC - NORMAL CROWN

APPENDIX E.2

HOWARD COUNTY, MARYLAND
DEPARTMENT OF PUBLIC WORKS

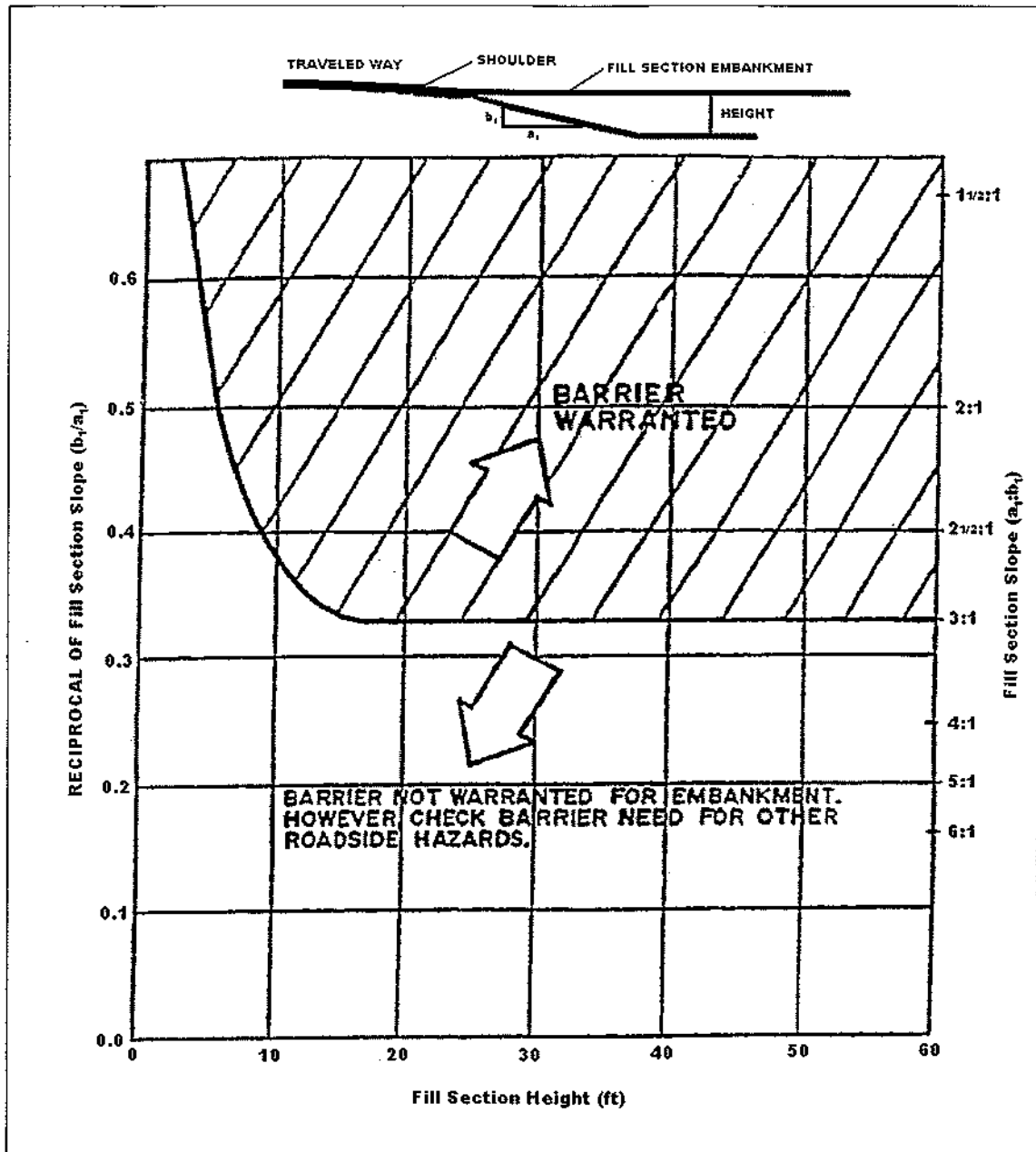
METHOD OF ATTAINING
SUPERELEVATION
(CASE 4 & 5)

DRAWN BY WR&A

CHECKED BY WR&A

NO SCALE

10/2006

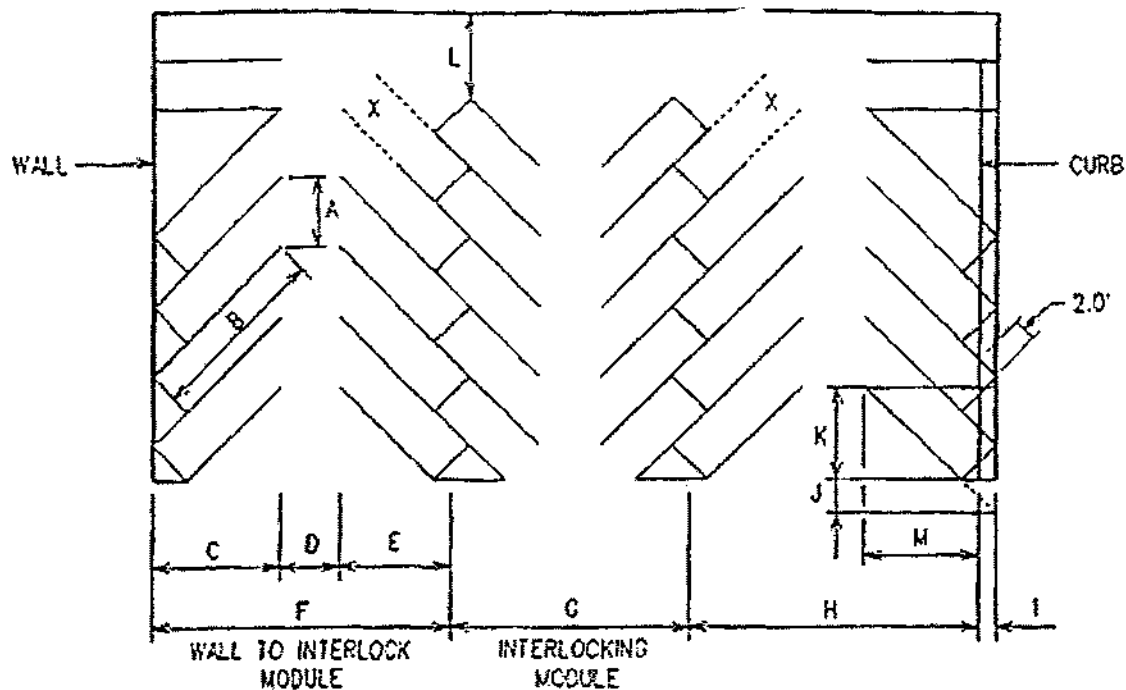


APPENDIX F

HOWARD COUNTY, MARYLAND
DEPARTMENT OF PUBLIC WORKS

TRAFFIC BARRIER REQUIRED FOR
EMBANKMENT GEOMETRY

DRAWN BY	WR&A
CHECKED BY	WR&A
NO SCALE	
	10/2006



X - STALL NOT ACCESSIBLE IN CERTAIN LAYOUTS

DIMENSION	ON DIAGRAM	45°	60°	75°	90°
STALL WIDTH, PARALLEL TO AISLE	A	12.7	10.4	9.3	9.0
STALL LENGTH OF LINE	B	27.0	23.2	20.4	18.0
STALL DEPTH TO WALL	C	19.1	20.1	19.7	18.0
AISLE WIDTH BETWEEN STALL LINES	D	15.0	18.0	23.0	24.0
MODULE, WALL TO INTERLOCK	E	15.9	17.8	18.6	18.0
MODULE, INTERLOCKING	F	51.0	55.9	61.3	60.0
MODULE, INTERLOCK TO CURB FACE	G	47.8	53.7	60.1	60.0
BUMPER OVERHANG (TYPICAL)	H	49.6	54.2	59.3	58.0
OFFSET	I	1.4	1.8	1.9	2.0
SETBACK	J	6.4	2.6	0.6	0.0
CROSS AISLE, ONE-WAY	K	12.7	9.0	4.7	0.0
CROSS AISLE, TWO-WAY	L	16.0	16.0	16.0	16.0
STALL DEPTH (OVERHANG ALLOWED)	M	17.7	18.4	17.8	16.0

NOTES :

1. THE MINIMUM REQUIREMENTS AS SET FORTH IN THE ZONING REGULATIONS SHALL BE COMPLIED WITH.
2. SEE SECTION 2.8 FOR REQUIREMENTS RELATING TO PARKING SPACE DESIGN FOR THE HANDICAPPED.
3. PARALLEL PARKING STALLS SHALL BE A MINIMUM OF 8'x22' WITH A MINIMUM ADJACENT AISLE WIDTH OF 12 FEET, (24 FEET IF TWO-WAY).
4. THIS FIGURE BASED UPON A STALL WIDTH OF 9 FEET.
5. THE ABOVE DIMENSIONS MAY VARY AS PROVIDED IN A RECORDED FINAL DEVELOPMENT PLAN FOR A NEW TOWN DISTRICT.

APPENDIX G

HOWARD COUNTY, MARYLAND
DEPARTMENT OF PUBLIC WORKS

PARKING STALL
LAYOUT ELEMENTS

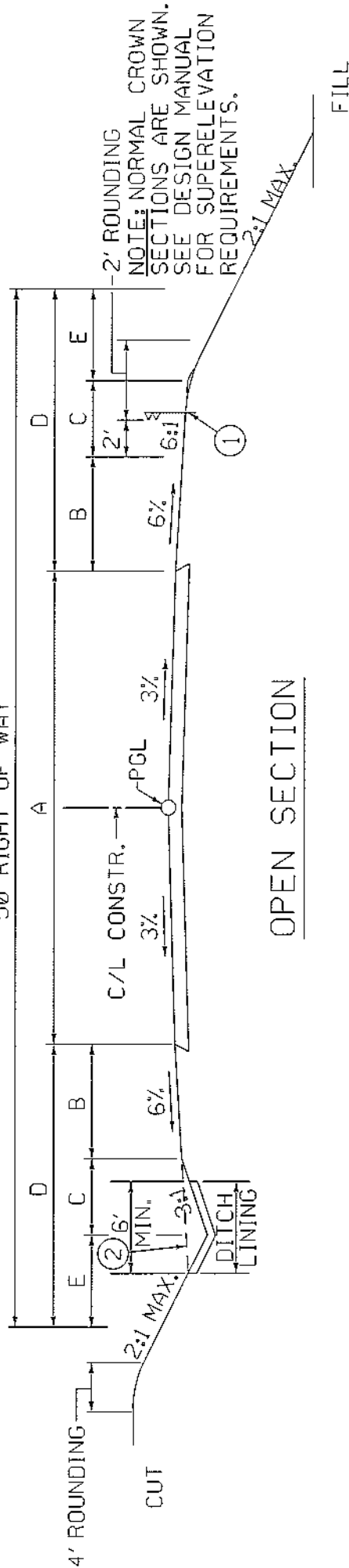
DRAWN BY WR&A

CHECKED BY WR&A

NO SCALE

10/2006

50' RIGHT OF WAY



① TRAFFIC BARRIER W-BEAM AS REQUIRED. SEE DESIGN MANUAL.

② DITCH CROSS SECTION SLOPE MAY BE FLATTENED TO PROVIDE A SWALE AT OR NEAR THE CREST OF VERTICAL CURVES WHERE QUANTITY OF SWALE FLOW IS SMALL, AS APPROVED BY DPW.

NOTE: PROVIDE CURB AT INTERSECTION. SEE DESIGN MANUAL.

CLASSIFICATION	A	B	C	D	E	PAVING SECTION
MINOR COLLECTOR 1000 A.D.T.	28' 4"	4'	4'	11'	3'	P-3
ACCESS STREET 500 A.D.T.	24' 4"	4'	4'	13'	5'	P-2
ACCESS PLACE 200 A.D.T.	22' 4"	4'	4'	14'	6'	P-2

FOR REFERENCE PURPOSE ONLY

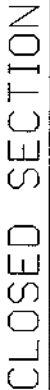
TYPICAL SECTION - Residential Streets
Access Place, Access Street, Minor Collector
Open Section (Outside Planned Service Area Only)

DRAWN BY

CHECKED BY

NO SCALE

R-1.01



- ① TYPE OF CURB VARIES (MOD. COMB. CURB & CUTTER OR ST'D. COMB. CURB & CUTTER - SEE DESIGN MANUAL).
- ② 4" CONCRETE SIDEWALK AS REQUIRED BY SUB-DIVISION REGULATIONS.

CLASSIFICATION	A	B	C	D	PAVING SECTION
MINOR COLLECTOR 2000 A.D.T.	28'	6'	4'	11'	P-3
ACCESS STREET 1000 A.D.T.	*24'	8'	4'	13'	P-2
ACCESS PLACE 200 A.D.T.	*24'	8'	4'	13'	P-2

* TOWNHOUSE, CONDOMINIUM/APARTMENT DEVELOPMENTS REQUIRE 26' MINIMUM PAVING (WITH P-2 PAVING SECTION).

FOR REFERENCE PURPOSE ONLY

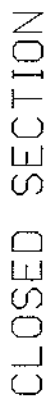
TYPICAL SECTION - Residential Streets
Access Place, Access Street, Minor Collector
(Closed Section)

DRAWN BY

CHECKED BY

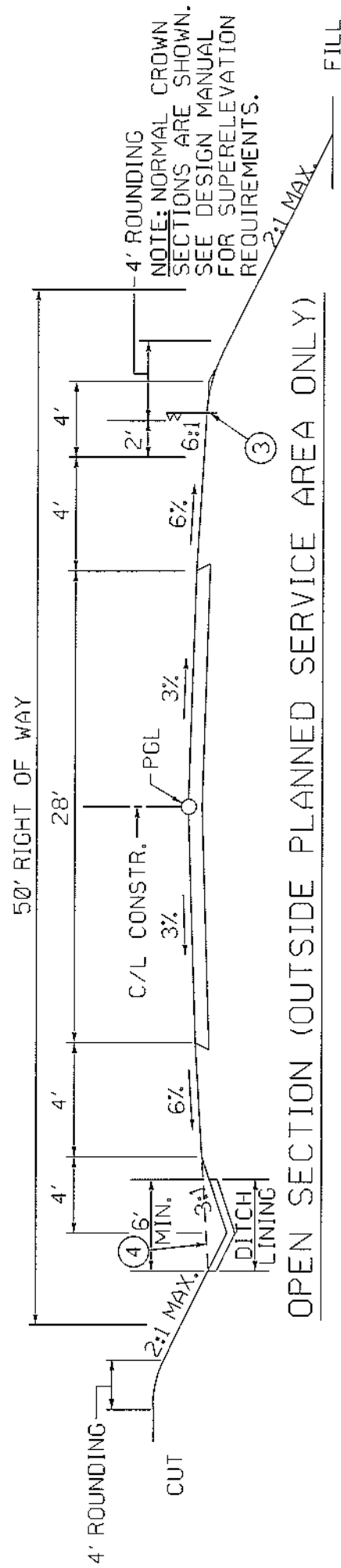
NO SCALE

R-1.02



- ① TYPE OF CURB VARIES (MOD. COMB. CURB & GUTTER OR ST'D. COMB. CURB & GUTTER-SEE DESIGN MANUAL).
- ② 4" CONCRETE SIDEWALK AS REQUIRED BY SUB-DIVISION REGULATIONS.
- ③ TRAFFIC BARRIER W-BEAM AS REQUIRED. SEE DESIGN MANUAL.
- ④ DITCH CROSS SECTION SLOPE MAY BE FLATTENED TO PROVIDE A SWALE AT OR NEAR THE CREST OF VERTICAL CURVES WHERE QUANTITY OF SWALE FLOW IS SMALL, AS APPROVED BY DPW.

CLASSIFICATION	PAVING SECTION
MAJOR COLLECTOR	P-4
MINOR COLLECTOR 2000 A.D.T.	P-4
LOCAL ROADS & CUL-DE-SACS 1000 A.D.T.	P-3



OPEN SECTION (OUTSIDE PLANNED SERVICE AREA ONLY)

TYPICAL SECTION - Non-Residential Streets

FOR REFERENCE PURPOSE ONLY

Local Roads,
Minor Collector, Major Collector

DRAWN BY

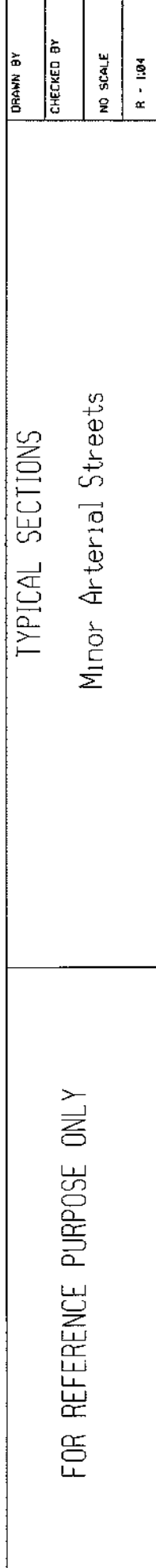
ЧЕШКЕВ АУ

NO SCALE

8-1.03

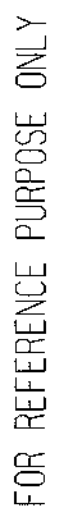


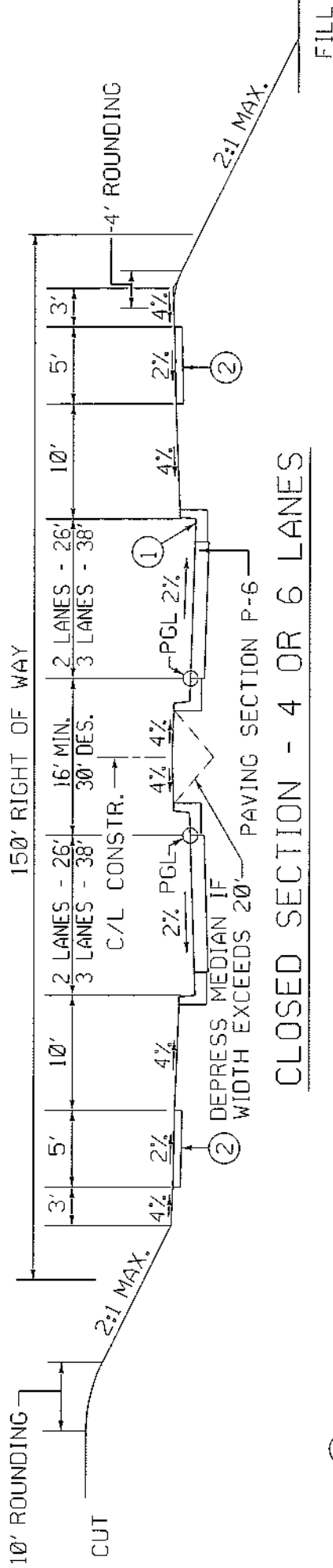
④ DITCH CROSS SECTION SLOPE MAY BE FLATTENED TO PROVIDE A SWALE AT OR NEAR THE CREST OF VERTICAL CURVES WHERE QUANTITY OF SWALE FLOW IS SMALL, AS APPROVED BY DPW.



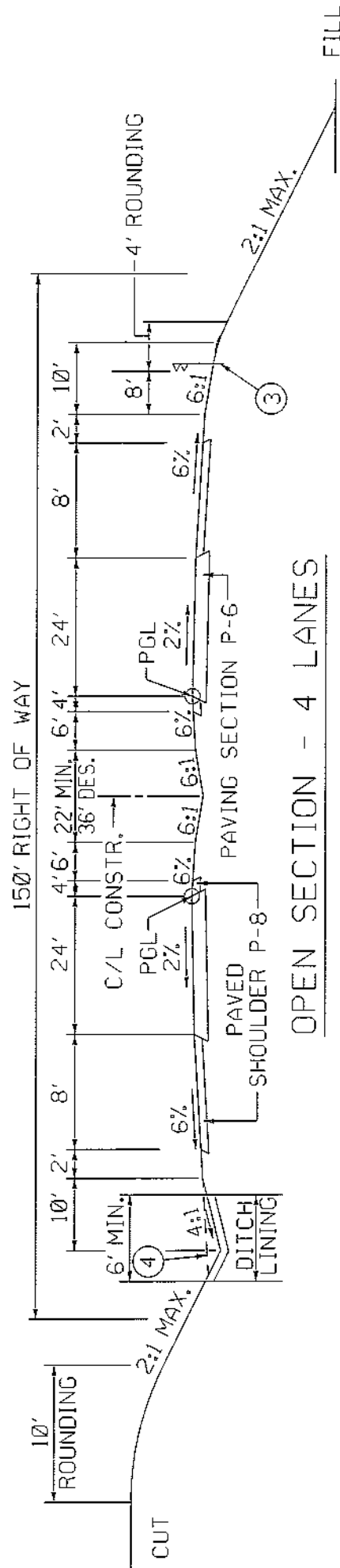
TYPICAL SECTIONS

Minor Arterial Streets





- ① ST'D. COMB. CURB & GUTTER.
- ② 4" CONCRETE SIDEWALK AS REQUIRED BY SUB-DIVISION REGULATIONS.
- ③ TRAFFIC BARRIER W-BEAM AS REQUIRED. SEE DESIGN MANUAL.
- ④ DITCH CROSS SECTION SLOPE MAY BE FLATTENED TO PROVIDE A SWALE AT OR NEAR THE CREST OF VERTICAL CURVES WHERE QUANTITY OF SWALE FLOW IS SMALL, AS APPROVED BY DPW.
- ⑤ NORMAL CROWN SECTIONS ARE SHOWN. SEE DESIGN MANUAL FOR SUPERELEVATION REQUIREMENTS.
- ⑥ THE CURB AND GUTTER ALONG THE MEDIAN SHALL HAVE THE STANDARD GUTTER SLOPE TO PREVENT SNOW MELT IN THE MEDIAN FROM DRAINING ONTO ROADWAY.



FOR REFERENCE PURPOSE ONLY	TYPICAL SECTIONS	DRAWN BY
		CHECKED BY
		NO SCALE
		R - 1.06

Divided Intermediate Arterial Streets

CHAPTER 3

DESIGN OF BRIDGES, RETAINING WALLS AND SMALL STRUCTURES

CHAPTER 3
DESIGN OF BRIDGES, RETAINING WALLS AND SMALL STRUCTURES

	<u>PAGE NO.</u>
3.1 <u>INTRODUCTION</u>	3-1
A. Responsibility of the Designer	3-1
B. Limitation of Topics Presented in the Design Manual	3-1
C. Abbreviations	3-1
D. Definitions	3-2
3.2 <u>GENERAL FEATURES OF DESIGN</u>	3-2
A. Coordination With Road and Street Planning	3-2
B. Design Specifications	3-2
C. Technical Reference for Design	3-3
D. Basic Information Required for Design	3-3
E. Selection of Retaining Wall Type	3-4
F. Selection of Bridge Type	3-5
G. Selection of Culverts	3-7
H. Structures Over Waterways	3-8
I. Clearances	3-9
J. Bridge Roadway Section	3-10
K. Horizontal and Vertical Alignment	3-11
L. Subsurface Investigations	3-12
M. Foundation Reports	3-12
N. Scour Reports	3-13
O. Bridge Inspection	3-14
3.3 <u>DESIGN LOADING – HIGHWAY STRUCTURES</u>	3-14
A. General	3-14
B. Dead Load	3-15
C. Live Load	3-15
D. Wind Loads	3-15
E. Thermal Forces	3-16
F. Force of Stream Flow	3-16
G. Earth Pressure	3-16
H. Earthquake Forces	3-17
I. Pedestrian Bridge Loading	3-17
J. Distribution of Loads	3-17
3.4 <u>SUBSTRUCTURES AND RETAINING WALLS</u>	3-17
A. Retaining Walls	3-17
B. Abutments	3-30
C. Piers	3-33
D. Foundations	3-34
E. Substructure Protection	3-36
F. Slope and Bank Protection	3-36

	<u>PAGE NO.</u>
3.5 <u>BRIDGE SUPERSTRUCTURE</u>	3-36
A. Slab on Beams or Girders	3-37
B. Beams and Girders	3-38
C. Steel Beams and Girders	3-38
D. Prestressed Concrete Beams	3-39
E. Bridge Drainage	3-39
F. Expansion Joints	3-39
G. Bearings	3-39
H. Drainage Troughs	3-40
I. Elevations	3-40
 3.6 <u>BOX CULVERTS</u>	3-40
A. Analysis	3-40
B. Design Guidelines	3-41
C. Bottomless Box Culverts (Rigid Frames)	3-42
 3.7 <u>PIPE CULVERTS</u>	3-42
A. Geometry	3-43
B. End Treatment	3-43
C. Foundation Requirements	3-45
 3.8 <u>UTILITIES ON BRIDGES</u>	3-46
A. Telephone Lines & Cable	3-46
B. All Other Utilities	3-46
 3.9 <u>REHABILITATION OF EXISTING STRUCTURES</u>	3-46
A. Introduction	3-46
B. Superstructure Repairs	3-46
C. Substructure Repairs	3-51
D. Retaining Walls	3-53
E. Maintenance of Traffic	3-54
 3.10 <u>LOAD RATINGS</u>	3-54
A. Introduction	3-54
B. Methodology	3-54
C. Posting	3-55
 3.11 <u>PLAN PREPARATION GUIDELINES</u>	3-55
A. Introduction	3-55
B. Sheet Layout and Order	3-55
 3.12 <u>REFERENCES</u>	3-56

CHAPTER 3

DESIGN OF BRIDGES, RETAINING WALLS AND SMALL STRUCTURES

3.1 Introduction

A. Responsibility of the Designer

This chapter addresses the selection and use of design and evaluation criteria and practices applicable to the design and maintenance of Public Works structures including bridges, retaining walls and small structures in Howard County. The subject matter presented herein includes specifications and guidelines for the selection, analysis and design of Public Works structures and their individual subcomponents. While the requirements described for the various aspects of design will include and cover the majority of conditions encountered, there is no intention to relieve the Designer of the responsibility to recognize when conditions are not favorable for the application of these design guidelines. The Designer shall be continually alert to those conditions that cannot be satisfied by the application of these design guidelines.

The design specifications to be used for various types of Public Works structures are identified and referenced herein. Guidance and interpretations of the design specifications and specific standard design requirements of the Bureau of Engineering are also presented in this Chapter.

B. Limitations of Topics Presented in the Design Manual

It is not possible to include in this manual all features and topics of design and drafting necessary to accomplish the development of structure designs and construction documents for all projects incorporating bridges, retaining walls and small structures. The topics addressed herein are limited to those that will assist the Designer in performing most engineering design tasks in an efficient manner and comply with currently accepted engineering practice as well as Howard County practice. Although it is the Designer's responsibility to exercise professional judgment in the acceptance and/or use of the design guidelines included herein, the Designer shall recognize that they are being provided to assist in the development of the project in the manner preferred by Howard County. However, projects that are funded by Federal and/or State Aid may require compliance with the design criteria and standards set forth by the funding agency. Any deviations from these design guidelines shall be brought to the attention of Howard County immediately. Any waivers of this design manual shall be justified to Howard County in writing, from an engineering evaluation, and shall include relevant considerations of life cycle costs and/or maintenance requirements. Approval or denial of the waiver requests will be by return letter signed by the Chief of the Bureau of Engineering.

C. Abbreviations

For standard abbreviations, refer to Section 1.2, "Abbreviations", of this design manual.

D. Definitions

Bridge: A structure designed to carry vehicular, pedestrian and/or bicycle traffic having a roadway surface comprised of a structural element such as reinforced concrete or timber.

Culvert: A structure designed to carry vehicular, pedestrian and/or bicycle traffic having a roadway surface placed atop earthen fill and/or a structure designed as a continuous unit between the superstructure and substructure.

Small Structure: Any bridge or culver structure that measures less than 20' clear between abutments (measured parallel to the roadway centerline).

Retaining Wall: Any structure that is built to retain a fill section or a roadway as a means to eliminate or minimize impacts to adjacent properties or structures.

3.2 General Features of Design**A. Coordination with Road and Street Planning**

Bridges, small structures and retaining walls are required for grade separations, stream crossings and earth retention usually as elements of a road or street facility. Planning and design of these structures must be coordinated with the road or street planning for overall project purpose as well as agreement in alignment, grade and, typical section. For structures in historic districts and along scenic roads, aesthetics is also an important design consideration.

B. Design Specifications**1. A.A.S.H.T.O.**

For highway and pedestrian bridges, retaining walls and small structures, the basic design specifications to be used are those of the latest edition of the "Standard Specifications for Highway Bridges" of the Association of State Highway and Transportation Officials (A.A.S.H.T.O., Ref. 1), including subsequent interim specifications.

The design method to be used shall be that which is customarily used by the Maryland State Highway Administration, i.e. Service Load Design Method.

2. A.R.E.M.A.

The basic specifications to be followed in the design of railroad bridges or walls retaining railroad embankments are the current specifications of the American Railway Engineering and Maintenance-of Way Association (A.R.E.M.A., Ref. 2).

3. Howard County Storm Drainage Design Manual

Hydrologic and hydraulic design of structures shall be in accordance with the "Howard County Storm Drainage Design Manual Volume I" (Ref. 7).

C. Technical References for Design

1. Capital Projects

Capital projects will be designed using Maryland State Highway Administration Office of Bridge Development Policy and Procedure Manual (Ref. 10) and Structural Standards Manual (Ref. 11).

2. Other Projects

Other projects shall be designed similarly as Capital Projects unless written authorization is granted by the Chief of the Bureau of Engineering.

D. Basic Information Required for Design

1. General Information

To determine the overall configuration of a structure, the designer must obtain or establish the project alignment, profile and typical section and impose them on the existing physical topography.

2. Studies and Reports

Previous studies, engineering reports and preliminary plans, if any, shall be reviewed before beginning any new work on the project.

3. Record Plans

Records of utilities, existing structures, stream flow, and subsurface investigations at or near the proposed structure must be obtained.

4. Topography

Existing topographic maps such as those available from the United States Coast and Geodetic Survey and the Howard County Department of Public Works may be used for preliminary studies. Hydrologic studies shall be based upon the best available topographic mapping. Existing mapping must be supplemented by aerial photogrammetry and/or ground surveys to provide adequate detailed topography at the project site.

E. Selection of Retaining Wall Type

The type of retaining wall to be constructed usually is determined by the cost of construction. However, some other factors such as critical clearances or right-of-way cost may affect the decision. The most economical type of wall to construct is primarily a function of the height of the wall. A gravity type wall is the most economical for low walls, a cantilever type wall for intermediate heights and a counterfort type for high walls. Other factors that shall be considered in the comparison of alternate wall types are the lateral earth pressure, the type of foundation, the depth of piles, and the allowable bearing pressure. The simplicity of construction and the durability of a gravity wall must also be considered in the final decision. See Section 3.4.A.1 for a description of retaining wall types.

In the historic districts and on scenic roads the aesthetics of a stone facing, colored and impressed concrete brick or wood trim may merit consideration. The approval of aesthetic amenities and/or special landscaping shall be subject to the review and approval by Chief of the Bureau of Engineering.

1. Proprietary Walls

Proprietary walls are patented systems for retaining soil. Depending on conditions, they can be more economical when compared to conventional retaining wall types. These walls are often more economical for long abutments and where high wall heights are dictated by field conditions. This type of wall construction can also save on bridge superstructure costs by reducing span lengths.

The detailed design and associated drawings are the responsibility of the proprietary wall firm, and wall products are typically provided through licensed regional manufacturers. The Maryland State Highway Administration requires that proprietary walls considered for use on capital projects must be on the list of Approved Proprietary Retaining Walls provided in the SHA Policy and Procedure Manual (Ref. 10).

a. MSE

Mechanically stabilized earth (MSE) walls are comprised of a reinforced soil mass and modular precast concrete facing panels which are vertical or near vertical. MSE walls may be used where conventional gravity, cantilever, or counterforted walls are considered, and are well suited for supporting fills and where substantial total and differential settlements are anticipated. The precast facing panels are adaptable to a variety of architectural finishes. MSE walls should not be used where utilities other than highway drainage would be constructed in the reinforced soil zone, where erosion or scour may undermine the reinforced soil zone, or where galvanized reinforcements may be exposed to surface or ground water contaminated by pollutants characterized by low pH and high chlorides or sulfates.

b. Precast Gravity

Precast gravity walls, also known as segmental or modular retaining walls, consist of interlocking, soil-filled concrete units, and depend on dead weight for stability. The precast units can also be used with soil reinforcements to construct taller walls than those that resist loads by gravity alone. The stacked prefabricated units offer fast, easy installation, with the flexibility of curved and corner alignments and terraced walls. The concrete units may be colored and the wall face fabricated in a variety of shapes and textures.

Precast gravity walls should not be used on curves with a radius of less than 800 ft unless the curve can be substituted as a series of chords, or where the longitudinal differential settlement along the face of the wall is greater than 1/200.

c. Gabions

Gabions are stacked, stone-filled wire baskets that are interconnected to form gravity-type walls. Gabion walls are simple to install and are well suited for use as channel linings, slope protection, and low-height retaining walls. They are permeable, which allows for backfill drainage and also permits the growth of natural vegetation. Once vegetation has been established, these walls blend well into the natural environment. Gabion walls are inherently flexible and are able to tolerate differential settlement that may result from unstable foundation soils or undermining due to erosion or scour.

F. Selection of Bridge Type

1. Site Conditions

Since no two bridge sites are exactly equivalent, the designer must develop a particular span arrangement and bridge type for each individual site. Conditions at the proposed site such as existing grading, type of crossing and subsurface conditions must be taken into consideration. The constraints of limited right-of-way are relevant to some sites. Bridges in historic districts and on scenic roads should be designed to preserve or enhance the appearance of the road and to afford passengers views from the bridge.

2. Materials

The type of material to be used in construction will depend on a variety of factors including suitability of material to load requirements, availability of material, construction procedures, maintenance of traffic, construction time, unusual site conditions and relative life cycle cost of the various types of materials. The County precludes the use of prestressed concrete box beams and planks without the expressed written permission of the Chief of the Bureau of Engineering due to the difficulty in maintaining these types of structures. Wooden bridges in County park property may be acceptable subject to the review and approval by both the Chief of the Bureau of

Engineering and Director of the Department of Recreation and Parks.

3. Cost

Since the relative economy of structure types cannot be generalized, it will be necessary to prepare economic comparisons of alternate bridge types suitable for a given situation in order to determine which type is most suitable from a cost standpoint. Future maintenance costs should be considered in addition to initial costs to insure that the structure with the lowest life cycle cost is used.

To prepare these economic comparisons, it is first necessary to determine the structure quantities that are associated with each type of bridge. These may be obtained from preliminary designs, from quantity charts, from historical data, or by a combination of these methods.

Unit prices for application to the estimated quantities should be determined based on recent bid tabulations for comparable projects in the Howard County area. These unit prices must be adjusted by judgment on the basis of project size, location and construction difficulties.

4. Safety and Aesthetics

Important considerations are safety and aesthetics. Maximum traffic safety is provided by deck type overpass structures with adequately designed safety barriers and open span underpass structures without piers or other structural elements adjacent to the roadway.

Bridges on scenic roads or in historic districts merit special design consideration. The width of the deck should be consistent with the adjacent roadway. Barrier parapet walls should incorporate open railings at passenger eye level to permit views of the river crossing and adjacent scenery. Abutment embankments/slopes and piers shall be positioned to retain the natural stream channel adjacent to the bridge. If erosion is of concern, consider bio-engineering rather than rip-rap, gabions or a concrete channel.

Architectural treatment and other embellishments such as wider sidewalks for pedestrian use, bicycle lanes, open railing and special lighting should be considered where it is appropriate to improve the appearance and utility of the bridge to make it more compatible with the other elements of the surrounding community especially in historic districts along a scenic road. Modest use of special treatment can be done without a significant increase in cost, but such aesthetic requirements as an increase in span lengths, special finishes and special structural shapes can result in significant cost increases. The added cost resulting from special treatment must be evaluated to determine that the improved aesthetics are worthy of the increased cost.

5. Maintenance Requirements

Future maintenance is another important consideration in the design of new bridges and existing bridge rehabilitations. All bridge components must be accessible for routine biennial inspection as well as maintenance, either by a snooper or some other means. Designs should provide for superstructure jacking to facilitate servicing, repair, or replacement of bridge bearings.

Key items to minimize future maintenance include:

- Minimize the number of expansion joints.
- Design sealed joints to prevent deck runoff from draining onto the bearings and beam seats below.
- Provide joint components that can be maintained.
- Avoid unusual joint details.
- Avoid details that trap dirt in splices, joints or other components.
- Locate scupper outlets below the bottom flange of beams to prevent water damage from splash-back.
- Provide downspouts and/or splash blocks where scupper outlets would cause erosion or dump water on roadways from overpasses.
- Eliminate or minimize the existence of deck drainage systems. If required, design deck drainage systems with sufficient size and adequate slope to prevent clogging and ponding. Provide clean-outs and avoid sharp bends in piping.
- Protect stream channels from erosion and piers and abutments from scour.
- Provide roadway drainage at abutments and wing walls to prevent erosion.
- Provide adequate vertical and horizontal clearances to prevent vehicle damage.
- Consider the feasibility of painting structural steel, and evaluate the suitability of weathering steel.
- Consider using precast prestressed concrete structural members.
- Investigate the feasibility of using integral or semi-integral abutment construction.

G. Selection of Culverts

1. General

Culverts are generally cost effective solutions for relatively small stream crossings. A single culvert can be used for the smallest crossing. Larger stream crossings can utilize multiple cell box culverts or a battery of pipe culverts. In each case, all factors of hydraulics, topography, economics and environmental factors must be considered before a culvert alternative is selected. It will be necessary to comply with the policies of all permitting agencies concerning the need for permits and the maintenance of the natural environment. Design of culverts shall meet all the requirements of bridges, including those for foundation design and scour design. For small culverts with inverts, subsurface borings taken for the roadway will usually be sufficient for the foundation design.

Box culverts are generally made of concrete with mild reinforcing. These can be cast in the field or precast at a factory in units which are then shipped and placed in the field. When precast concrete box culverts are used, the box culvert ends and all wing walls, headwalls and toe walls shall be cast in place; refer to Volume IV Design Manual.

Pipe culverts are available in a large range of shapes, sizes and materials. Steel pipes can consist of pipes rolled at the mill such as corrugated metal pipes (CMP's, etc.) or pipes made from steel plates assembled at the job site such as structural steel plate pipes (SPP's, etc.). Steel pipes less than 4' in diameter may be either the CMP or the SPP type. Steel pipes larger than 4' in diameter must be of the SPP type.

Culverts without paved inverts, such as structural plate pipe arches and precast concrete arches, are also commonly available. These types of structures are very dependant on the foundation conditions and their use may require extensive foundation and scour investigation work.

Refer to Volume I Design Manual for additional information concerning culverts.

2. Advantages

For streams of a size within the hydraulic capacity of a culvert, the culvert is usually less costly to design, construct and maintain than a bridge. A culvert structure is less susceptible than a bridge to structural defects due to differential settlement, undermining and scour.

3. Disadvantages

In most cases, culverts tend to have the following disadvantages:

- The design opening is wider than the existing channel requiring undesirable channel modifications
- Silting occurs during low flow.
- Multiple cells tend to obstruct flow and accumulate debris during flood flow.
- Water velocity increases in the culvert causing downstream scour.

H. Structures over Waterways

1. Hydrologic Studies

Hydrologic studies shall be performed for all structures crossing waterways. Stream flow for these studies shall be calculated in accordance with procedures described in the "Howard County Storm Drainage Design Manual", Vol. I (Ref. 7). Existing stream gauging data, observed high water marks and observations of local residents shall be used to check the hydrological calculations based on empirical methods.

2. Hydraulic Studies

a. Bridges

Analysis of the effect of the bridge on the stream flow and establishment of the design high water at the bridge site or at other critical points shall be in accordance with the procedures described in the Federal Highway Administration booklet "Hydraulics of Bridge Waterways" (Ref. 6).

A freeboard of one (1) foot from the design high water to the underside of the superstructure shall be maintained. Refer to the "Howard County Storm Drainage Design Manual" (Ref. 7) for specific freeboard requirements.

b. Box Culverts

The effects of flow in the design of box culverts shall be analyzed in accordance with the procedures described in the Federal Highway Administration Circular "Hydraulic Design of Highway Culverts" (HDS - 5) (Ref. 8) or similar publications. Due consideration shall be given to both inlet control and outlet control.

3. Hydraulic Design Criteria

a. Highwater Elevation

A stream crossing structure shall be designed to interfere as little as possible with the natural stream channel and shall conform to the "Howard County Storm Drainage Design Manual", Vol. I (Ref. 7) and other State and Federal requirements.

b. Maximum Velocities

Discharge velocity shall be consistent with channel materials. For maximum and minimum velocities, refer to the "Howard County Storm Drainage Design Manual", Vol I (Ref. 7).

I. Clearances

1. Horizontal Clearances - Highways

a. Bridge Roadway Width

The roadway width of bridges shall preferably be the full width of the approach roadway section including the shoulders. Minimum bridge roadway widths are discussed in the MSHA "Policy and Procedure Manual" (Ref. 10) for various classifications of highways. If the approach roadway section includes a sidewalk,

the sidewalk shall be carried across the bridge.

b. Underpass Clearance

For an open section roadway or a bridge, the piers or abutments shall be set to provide clearance for the full shoulder plus a guardrail or concrete barrier. The roadway face of the guardrail shall be at least 5'-0" from the face of the pier or abutment. The face of the guardrail or barrier shall be at least 2'-0" outside of the normal shoulder line. For closed section roadways, the face of pier or abutment shall be set a minimum of 8'-0" back of the curb line. Piers and abutments shall be protected by guardrail or crash walls.

2. Horizontal Clearances - Railroads

Horizontal clearances from railroad tracks to piers, abutments or walls of an overpass structure shall be in accordance with the requirements of A.R.E.M.A. (Ref. 2) and the policy of the particular railroad for the class of track involved. In the case of privately owned spurs, the clearances shall be at least equal to the requirements of the Maryland Public Safety Laws and meet the approval of the railroad operating over the spur.

3. Vertical Clearance

a. Highways

Vertical clearance to highway or railroad structures over highways shall be 16'-0" minimum over any usable portion of the roadway and shoulder.

b. Railroad

Vertical clearance over railroads shall be 24'-3" (top of rail to underclearance) for electrified railroads, and 23'-0" for all others. Clearance shall be approved by the railroad owner.

c. Pedestrian

Vertical under clearances for pedestrian bridges shall be: 16'-0" over streets or highways; 24'-3" over electrified railroads; and 23'-0" over other railroads.

J. Bridge Roadway Section

1. Curbed (Closed) Section

The flow line of a curbed roadway section shall be continuous across the bridge. If the approach roadway section includes sidewalks, the sidewalks shall be carried across the bridge. If the approach roadway section does not include sidewalks and there is 3' minimum between the curb and edge of traffic lane, then a traffic barrier shall be

located at the flow line. If the approach roadway section does not include sidewalks and there is less than 3' between the curb and edge of traffic lane, then a sidewalk shall be carried across the bridge.

2. Rural (Open) Section

The shoulder of a rural section shall be carried across the bridge. The cross slope configuration shall conform to that of the approach roadway except that the cross slope in the shoulder area on the bridge shall be an extension of the adjacent traffic lane (i.e., no shoulder breaks on bridge). The approach roadway shoulder slope shall be transitioned to meet the shoulder slope of the structure beginning at a minimum distance of fifty (50) feet from the ends of the structure.

3. Barriers

All barriers on bridges and approaches, including transitions, shall meet or exceed Maryland State Highway Administration and A.A.S.H.T.O. specifications, including crash testing requirements. Selection of the appropriate barrier, with or without metal railing, should be made with consideration given to the type of roadway facility (controlled access or non-controlled access), whether pedestrians and/or cyclists are expected to use the bridge, and whether sidewalks are required on bridge. Safety fence shall be provided in accordance with SHA requirements. Decorative barriers/railings or bridge lighting appurtenances shall be subject to the approval of the Chief of the Bureau of Engineering.

Careful attention shall be given to the treatment of railing at the bridge ends. Exposed rail ends, posts and sharp changes in the geometry of the railing shall be avoided. A smooth transition by means of a continuation of the bridge barrier, flared end posts, roadway guardrail anchored to the bridge barrier, continuation of bridge guardrail, or other effective means shall be provided to protect the traffic from direct collision with the bridge rail ends. Guidelines for these transitions are specified in the MSHA "Book of Standards for Highway and Incidental Structures" (Ref. 15).

K. Horizontal and Vertical Alignment

1. Bridges

The horizontal and vertical alignment of the bridge must be coordinated with the overall plan and profile of the approach roadway. Geometric design requirements concerning sight distances, minimum curve radii, superelevation, etc., shall be in accordance with Chapter 2, "Design of Roads". Methods and criteria for maintenance of traffic are contained in Chapter 5, "Traffic Studies".

2. Horizontal Alignment of Box Culverts

a. Alignment with Waterway and Road

Culverts shall generally be located and aligned as closely as possible to the natural drainage course for which they are being designed. The skew angle shall be kept as close to 0 degrees as possible, while providing a minimum stream relocation, if any.

b. Maintenance of Flow

The designer must consider the requirements for maintaining stream flow during construction. It may be necessary to provide a temporary channel in order to provide for maintenance of flow. Maintenance of stream flow plans shall be prepared in accordance with the latest edition of the MDE "Maryland Waterway Construction Guidelines" (Ref. 9).

L. Subsurface Investigations

In order to determine the type of foundation and allowable bearing pressures, borings will be required at the proposed locations of walls, culverts and bridge foundations. The information obtained should include elevation of the existing ground at the boring, a description and depth of the material encountered, number of blows per six (6) inches on the sampling spoon, recovery of cored rock, total depth of boring, the water table level and the time of observation. For small culverts with inverts, subsurface borings taken for the roadway will usually suffice for the foundation design.

Split spoon samples shall be taken at every change in material at intervals not exceeding five (5) feet. All borings should be drilled to refusal and cored a minimum of 5 feet into rock.

Foundation borings shall generally be located as follows: one boring at each end of each substructure unit for multibeam bridges; one boring at each end minimum with intermediate borings as required to maintain 100' maximum c/c spacing for culvert type structures and retaining walls.

All of the boring log information must be shown on the plans.

M. Foundation Reports

A formal Foundation Report is required for all retaining walls 3' or greater in height measured from the top of wall to the ground line at the front face of wall; all box culverts; all pipe culverts with individual spans greater than 8' measured perpendicular to the pipe; all hydraulic structures without inverts; and all bridges. For structures not meeting these requirements the designer shall perform sufficient subsurface investigations and analysis to insure the stability of the structure.

The formal foundation report shall provide all information and calculations documenting that the subsurface investigations and foundation design have been made in accordance with the requirements of this Volume III Design Manual and A.A.S.H.T.O. In addition, the

foundation report shall address the settlement of approach fill embankment on bridge foundation design as well as pertinent foundation construction considerations. The Foundation Report shall be accompanied by boring logs plotted on a plan sheet and preliminary structure plans.

For all new or replacement bridges, detailed Foundation Reports shall be prepared for review and approval by the Chief of the Bureau of Engineering. Foundation Reports shall include copies of all boring and laboratory testing information including a project map noting the location of all test borings. For Capital Projects, Foundation Reports shall be prepared in accordance with applicable sections of the MSHA Policy and Procedure Manual” (Ref. 10).

N. Scour Reports

Current regulations require that the construction, replacement or rehabilitation of any bridge structure which uses either full or partial funding from the Federal Government be accompanied by an approved Scour Analysis Report. Reports for such projects will be reviewed by the Maryland State Highway Administration Office of Bridge Development (OBD). All scour reports shall be developed in accordance with the OBD “Interim Manual of Hydrologic and Hydraulic Design” (the Interim Manual) (Ref. 12), and in particular, Chapters 9 and 11.

All scour reports shall be prepared and sealed by a registered professional engineer in the state of Maryland. Personnel involved in the evaluation of scour need to possess the technical qualifications, including practical experience, education and professional judgment, to perform the individual tasks assigned. Interpretation of results and conclusions of scour analyses shall be accomplished by registered engineers qualified in the appropriate disciplines. Because of the complexity of bridge scour, the evaluations shall be performed by an interdisciplinary team of engineers with the requisite knowledge in structural, hydraulic, river mechanics and geotechnical engineering.

For non-federally funded projects, scour reports may not be required if any of the following criteria applies:

- The project scope is limited to the rehabilitation of the bridge superstructure and/or minor rehabilitation of the substructure. Minor rehabilitation of the substructure shall be limited to abutment (or pier) repair and shall not include any changes to the overall geometry of the substructure units, with the exception of minor fascia treatments that do not reduce the total waterway opening by more than 10%.
- The project is a replacement or rehabilitation of a bridge or bottomless culvert where evidence of scour is minimal either through inspection or previous inspection reports and where the proposed abutment footings, or deep foundations such as piles, are founded in non-erodible rock. Rock where borings indicate a Rock Quality Designation less than 50% shall be assumed to be erodible (FHWA Memorandum on Scourability of Rock – June 19, 1991).

- The project is a new, replacement or rehabilitated bridge or culvert along a private road or drive not governed by any county, state or local municipality easements, right-of-way or right-of-entry.

The county reserves the right to request that a formal scour report be prepared in accordance with MSHA standards for any project within county right-of-way or along a roadway maintained by the county by virtue of easement, right-of-entry or prior agreement. A formal Scour Report shall be required for all bridges and small structures without integral paved inverts and which carry waterways. A formal Scour Report shall also be required for retaining walls which could be subject to stream action and which require a formal Foundation Report. The Scour Report shall be submitted in conjunction with the Foundation Report. The county may also request that a scour report be prepared for a structure for the purpose of re-evaluating the Structure Inventory and Appraisal Item 113. If a scour report is not requested by the county, the engineer of record shall still have the responsibility of ensuring that the bridge or culvert is designed in adequate consideration of the effects of scour.

Contraction, abutment and pier scour depths resulting from scour analyses shall be used in the assessment of the bridge stability in accordance with Chapter 11 of the Interim Manual. For the Design Flood for scour, the material in the resulting scour prism shall be assumed to be removed, and the bridge shall be analyzed with stability factors as dictated by the A.A.S.H.T.O. "Standards Specifications for Highway Bridges" (Ref. 1). For the Check Flood for scour, the material in the resulting scour prism shall be assumed to be removed and the bridge shall be analyzed with a stability factor of 1.0.

O. Bridge Inspection

Howard County maintains an inventory of bridges and the larger "small structures". To assist the County, designers are required to provide the following information for culverts with spans greater than 10' and for all bridges:

- Design Year Storm
- Run-Off Q in cfs
- Drainage area in acres
- High Water Elevation for the Design Storm
- Year of Maryland State Highway Specification used
- Year of A.A.S.H.T.O. Specification used.

3.3 Design Loading – Highway Structures

A. General

Loads, loading combinations and adjustments to the allowable stresses for loading conditions shall be in accordance with the provisions of A.A.S.H.T.O. (Ref. 1).

B. Dead Load

1. Future Wearing Surface

In addition to the dead load of the structure, an allowance shall be made in the design analysis for a future wearing surface. This shall be 25 lbs./sq. ft. for all except moveable spans and exceptionally long spans. The additional deck load for these spans shall be determined on an individual basis depending on the type of construction.

2. Unit Loads on Culverts

The dead load on culverts shall include the dead load of the box and the weight of earth above the box. Loads shall be calculated in accordance with A.A.S.H.T.O. Specifications, (Ref. 1). Except for box culverts on piles, the dead load of the bottom slab and water within the box should be neglected in design of slabs and walls. These dead loads shall, however, be included when determining foundation pressures. In the absence of more exact information, the density of the soil shall be taken as 120 lbs./cu. ft. and 150 lbs./cu. ft. shall be used for the weight of the concrete.

3. SIP Forms

An additional allowance shall be made in the design analysis when the use of steel stay in place forms is required. This loading shall be 15 lbs./sq. ft. of deck form plan area. This value includes the weight of the forms plus concrete in the corrugation valleys of the forms.

C. Live Load

1. Design Loadings

For all bridges 35 feet and over in span length, and all other structures, an HS 25 loading shall be used. For all bridges less than 35 feet in span length an HS 27 loading shall be used. The concrete bridge deck portion of bridges with longitudinal stringers shall be designed with HS 25 loading. For additional information concerning Design Loadings, see the MSHA "Policy and Procedures Manual" (Ref. 10). The loading for temporary structures will be determined by the Department of Public Works on the basis of the duration of time the temporary structure is expected to be in place and the anticipated traffic characteristics during that period. It shall not be less than H-15 with standard over-load provisions, as specified in the A.A.S.H.T.O. Specifications (Ref. 1).

D. Wind Loads

Wind loads calculated in accordance with A.A.S.H.T.O. Specifications (Ref. 1) shall be applied to the bridge substructure and superstructure as indicated therein.

E. Thermal Forces

Thermal forces shall be as specified by A.A.S.H.T.O. (Ref.1) for moderate climate.

F. Force of Stream Flow

The effect of flowing water on piers shall be calculated in accordance with A.A.S.H.T.O. (Ref. 1).

No static or dynamic pressures shall be applied for ice-floes, ice-sheets or ice-jams except under special circumstances for public structures such as pedestrian bridges in public parks. The consideration of occasional cost and safety must be considered in the structure's life cycle cost and this determination shall be made by the Chief of the Bureau of Engineering

G. Earth Pressure

Structures which retain earth shall be proportioned to withstand pressure as given by Rankine's formula. In the absence of more specific information, an equivalent fluid pressure of 35 lbs./cu. ft. shall be used. This pressure is based on the assumption that a layer of porous backfill and a drainage system with weep holes will be provided to insure a low ground water elevation at the rear face of the structure.

If conditions are such that it is not possible to control the water table behind the structure, the structure shall be designed taking into account, below the water level, the full hydraulic pressure in conjunction with pressures of the submerged soil.

A sloping finished grade line behind the structure may be accounted for by computing the pressure on the basis of the depth of earth in a vertical plane at the heel of the footing.

1. Water Pressure

If conditions are such that it is not possible to control the water table behind the structure, the structure shall be designed taking into account, below the water table, the full hydraulic pressure in conjunction with pressures of the submerged soil. Below the water table the unit weight of the retained soil is reduced to its submerged or buoyant value. As a result, the lateral earth pressure below the water table is reduced, while the retained water exerts a horizontal hydrostatic pressure.

When ground water levels differ on opposite sides of a retaining wall, the upward buoyant force beneath the wall foundation tends to overturn the wall. Unequal ground water levels also result in seepage beneath the wall. The effect of seepage forces is to increase the load on the back of the wall (and decrease any passive resistance in front of the wall). Pore pressures in the backfill soil can be approximated through the development of a flow net or other analytical methods, and then added to the horizontal earth pressures acting on the wall.

H. Earthquake Forces

Structures shall not be designed to resist earthquake forces.

I. Pedestrian Bridge Loading

Pedestrian bridges shall be designed for the same loads as highway bridges except for live load and impact. For pedestrian bridges, live load shall be in accordance with A.A.S.H.T.O. (Ref. 1).

J. Distribution of Loads

For distribution of loads refer to A.A.S.H.T.O. (Ref. 1)

3.4 Substructures and Retaining Walls

A. Retaining Walls

The primary structural function of a retaining wall is to counteract the lateral forces caused by earth pressure. These forces have two principle effects on the wall. First, they tend to overturn the wall and secondly, these forces tend to push or slide the wall. Before designing specific parts of the wall, such as the footing, stem, etc., overall stability of the wall and the earth mass must be satisfied. The total earth mass containing the wall and its foundation must be in equilibrium. A subsurface investigation should be made to determine the possibility of a slip plane failure that would affect the stability of the entire installation. The overturning moment about the toe of the footing, caused by the earth pressure and surcharge, must be resisted by the stabilizing moments of the dead load forces. Unless a structure is keyed into rock or is restrained by an adjacent structure, the horizontal earth pressure force must be resisted by friction between the footing and the foundation. Retaining walls used in subdivisions and site development plans shall use the retaining wall checklist when submitting designs.

Reinforced fills and proprietary retaining walls will be considered on a case by case basis. No consideration for use shall be given unless the system has been approved for use by the Maryland State Highway Administration.

1. Types

There are five principal types of retaining walls: gravity walls, semi-gravity walls, cantilever walls, counterfort walls and buttress walls.

a. Gravity Walls

Gravity Walls resist sliding and overturning by means of their mass, the resultant of all forces being within the middle third of any horizontal section through the wall.

Reinforcing is required only to resist shrinkage and temperature forces and shall be the minimum required by the governing design specification.

As a guide for initial design, the width of the base of the wall should be approximately 0.45 times the total height. The final size used varies with the type of material, the slope of the backfill surface, the surcharge and the allowable bearing pressure.

Gravity walls may be used under any condition where foundation material is reasonably good, and are often the most economical type for use where the wall is quite low. Because of its massive construction, this type of wall is more resistant to destructive agents and partial disintegration of the concrete is not as serious as for the heavily reinforced types.

b. Semi-Gravity Walls

By introducing a relatively small amount of reinforcing steel in the back face of a gravity wall, a more slender stem can be used. This type of wall is commonly known as a semi-gravity wall. The semi-gravity wall is more economical than the solid gravity wall and has the same advantage of durability due to massive construction, although to a lesser extent.

c. Cantilever Walls

Cantilever walls consist of a continuous stem supported on a continuous footing. Resistance to overturning results from the stabilizing action of the weight of concrete in the wall and the block of earth supported directly over the heel of the footing. The stem, the heel of the footing and the toe of the footing act as cantilever slabs resisting the applied loads.

The stem shall be designed to resist the moments and shears caused by the earth pressure above the top of footing and the surcharge applied to it. The weight of the stem itself shall be taken into account and the critical sections designed for direct stress and bending.

The heel of the footing shall be designed to resist its own weight and the total weight of the earth supported directly on it, with or without a reduction for upward foundation pressures.

The toe shall be designed to resist the foundation pressure acting on it, less its own weight, but no reduction is to be made for backfill over the toe.

Cantilever walls are the most widely used type and can be used in heights to approximately 30 feet. This type of wall is by nature more flexible than the other types, and considerable deflection can be expected at the top of the higher walls. Consequently, cantilever walls should not be tied to other types of walls with shear

keys. Rather, architectural offsets or pilasters should be incorporated into the design at such junctures so that differential deflection will not be noticeable.

For the most economical arrangement, a cantilever wall stem should be located over the point where the resultant of the loads pierces the plane of the footing. This means the toe of the footing for the typical wall should be about one-third the total width of the footing. However, the stem may be located anywhere on the footing as required by right-of-way requirements, conflict with structures and utilities, or for other reasons.

As a guide for initial design, the footing width normally ranges between 0.5 and 0.7 the total height of the wall, depending on allowable bearing pressures, desirable bearing differentials and superimposed loads.

d. Counterfort Walls

Counterfort walls consist of a face wall spanning continuously between counterforts which extend into the backfill. Counterforts are spaced at some constant interval, usually in the range of from 8 feet to 16 feet and are supported on either individual or continuous footings.

The face wall may be either full height or, in the case of deep footings, extend only $2 \pm$ feet below finished grade at the front of the wall.

Face walls shall be designed as continuous slabs in increments of height. Each increment shall have the proper thickness and/or reinforcement to resist the average earth pressure over that increment. If the face wall is tied to the footing, the bottom increment can be designed for vertical and horizontal bending.

The heel portion of continuous footings shall also be designed as continuous slabs. The toe, which commonly is rather short, shall be designed as a cantilever as previously described. Counterforts shall be designed as tee- beams to resist the overturning forces for the full counterfort interval.

Counterfort walls are usually most economical for heights over 30 feet and in instances where the footing must be placed very deep.

Widths of counterfort footings to satisfy stability requirements are usually at least 0.5 the height of the wall. The heel dimension is normally governed by the counterfort design.

It is necessary that counterforts be of sufficient size to permit proper placing and vibrating of the concrete and to permit proper cleaning prior to placing the concrete. They should not be less than 2 feet in thickness.

e. Buttress Walls

A variation of the counterfort wall is the buttress wall. This type of wall resembles the counterfort wall except that the members supporting the face slab are on the exposed face of the wall and are called buttresses rather than counterforts. The face slab is designed in the same manner as a counterfort wall and the buttresses are designed as rectangular beams. Since the buttresses are exposed and therefore reduce the clearance in front of the wall, the buttress wall is rarely used.

f. MSE

Mechanically stabilized earth (MSE) walls resist lateral loads through the dead weight of the reinforced soil mass behind the wall facing. Wall heights of up to 40 ft can be constructed. MSE walls are often used at bridge abutments, with a stub abutment supported on piles behind the wall.

MSE wall systems are designed to meet the requirements for overall stability, including overturning and sliding, bearing capacity, and deep stability, as well as the internal stability requirements of the reinforced soil mass. Lateral pressures are determined from active earth pressure acting on the back of the reinforced soil mass.

The reinforced soil mass consists of select granular backfill placed in layers between reinforcement, which is comprised of either metal or geosynthetic strip or grid systems. Steel soil reinforcements and connection hardware shall be galvanized. Generally, the soil reinforcement length is about 70 percent of the overall wall height, and is uniform throughout the entire height of the wall.

Facing elements are designed to resist the horizontal force of the reinforcement. Typically precast concrete facing panels are used, but cast-in-place, shotcrete (i.e., pneumatically applied mortar), or metal mesh panels are also used. Typically the panels are set onto a cast-in-place leveling pad at foundation level.

Internal drainage must be provided to prevent saturation of the reinforced backfill and infiltration of damaging elements from the surface. In cut areas, drainage blankets are provided behind and below the reinforced soil mass. For roadways subject to chemical deicing agents, an impervious membrane above the first layer of reinforcement may be necessary.

g. Precast Gravity

Prefabricated modular wall systems are designed to resist lateral earth loads as a gravity retaining wall. Two systems are generally used: interlocking soil filled concrete bins and segmental masonry concrete units. Soil filled bin systems can be used to construct walls up to 45 ft high. Segmental wall systems may be used to construct walls four to six feet high without soil reinforcements. They can also be

used with soil reinforcements, typically metal or geosynthetic meshes, for wall heights up to 45 ft.

For overall stability against sliding and overturning, the modular units are considered to act as a rigid body. For overturning, 80 percent of the soil-fill unit weight within the modules is effective in resisting overturning moments, as not all of the soil can be expected to arch within the module. The full weight of the soil-fill may be considered to resist sliding. Stability shall be evaluated at every module level.

Modular units are installed on either concrete or gravel leveling pads, depending on soil conditions. Soil shall be sloped away from the wall base to prevent erosion and eliminate water from running along the wall base. Where groundwater behind the wall is expected, the backfill is typically drained with a continuous drainage blanket consisting of crushed stone immediately behind the wall and a continuous perforated drain pipe near the footing level. Additional subsurface drainage may be required behind reinforced soils. It is also important to provide adequate grading or drainage systems at the top of the wall to direct surface flows away from walls.

h. Gabions

Gabion walls are constructed from stone filled wire mesh boxes, which are stacked and wired together. The backfill can be placed behind the wall as each level of boxes is installed. Gabion walls can be economically constructed to about 30 feet in height. Gabions can also be used as a wall facing with soil reinforcements, typically galvanized wire mesh, for wall heights up to 45 feet.

Gabion boxes are constructed from hexagonal mesh woven from soft galvanized wire. The wire may be PVC coated to protect from acidic soils or marine environments. The nominal size of the mesh openings is three to four inches. The boxes are usually constructed with internal wire mesh diaphragms or wire cross-ties for increased strength. Standard gabions are available with the following dimensions:

Nominal Length – 6, 9, or 12 feet
Nominal Width – 3 feet
Nominal Height – 1, 1.5, or 3 feet.

The stone used to fill the gabion baskets should be non-friable, weather resistant, and preferably high density. Gabions may be filled by hand or machinery, but in either case it is important that they be filled carefully to maintain the box shape to ensure proper alignment of the wall.

Gabion walls are designed to resist lateral earth loads as a mass gravity structure, in which the additional tensile resistance of the wire mesh is ignored. Gabion structures are permeable, allowing for free drainage, and are not designed for water

pressure loads. While gabion walls are self draining, it is advisable to provide a backfill drain above footing level to collect drainage and protect the wall foundation. Smaller height gabions are used at the base of walls, and the boxes are arranged such that the longest dimension is perpendicular to the wall to reduce shear deformation. The front wall face may be either stepped or flush, but a stepped front face is preferable, especially for taller walls. Gabion walls are constructed tilted back toward the retained soil at about a 6 degree angle for stability.

i. Noise Abatement Walls

Noise Abatement Walls shall be designed and constructed in accordance with the MSHA Sound Barrier Policy and Noise Program Guidelines. All components shall meet or exceed the requirements set forth in these policies and guidelines and will be subject to the same level of review and design standard. General design guidelines and references for noise abatement walls are as follows:

FHWA Guidelines for Noise Abatement Walls:

- FHWA Highway Noise Fundamentals, 1980
- FHWA Highway Traffic Noise Sources, 1980
- FHWA Traffic Noise Model Technical Manual, 1998
- FHWA Measurement of Highway-Related Noise, 1996
- FHWA Highway Construction Noise: Measurement, Prediction, and Mitigation, 1977
- AASHTO Guide on Evaluation and Abatement of Traffic Noise, 1993
- FHWA Highway Traffic Noise Analysis and Abatement Policy and Guidance, 1995
- FHWA A Guide to Visual Quality in Noise Barrier Design, 1976
- FHWA Noise Barrier Design Handbook, 1975
- COM624P (Caisson Analysis), Latest Version
- AASHTO Guide Specifications for Structural Design of Sound Barriers
- AASHTO Standard Specifications for Highway Bridges
- FHWA Traffic Noise Model (TNM), Latest Version

MSHA Guidelines for Noise Abatement Walls:

- MSHA Statewide Highway Noise Program Guidelines and Procedures for Program Administration and Technical Analysis and Reporting
- Sound Barrier Policy, 1998
- Structural Standard Details for Noise Abatement Wall Posts, Panels, Caissons, Access Doors, and Fire Department Connections

2. Retaining Wall Design Guidelines

a. General Items

The purpose of these guidelines is to establish the minimum requirements necessary to provide plans and details for the construction of retaining walls in Howard County.

These guidelines shall be adhered to when practical and applicable, but the responsibility of providing a complete design ultimately belongs to the design engineer. Innovative designs are not meant to be discouraged by these guidelines. Common sense and good engineering judgment are essential elements of any good design.

In order to facilitate the review process, these guidelines are intended to promote consistency and expediency by standardizing the requirements that are necessary in order to provide acceptable retaining wall construction documents.

If a retaining wall exceeds three feet in height at any point, the following criteria will apply, otherwise it is exempt from review by the Development Engineering Division and only the Department of Inspections, Licenses, and Permits (DILP) and the Division of Land Development (DLD) regulations apply. The height of a retaining wall for this purpose is measured from the finished grade at the front of the wall to the top of the wall. Grades above or below the wall shall not exceed a 2:1 slope.

All horizontal dimensions in the plan view shall be taken from the bottom face of the wall at the proposed grade.

Retaining walls shall not be constructed upon fill materials. Exceptions may be granted via the Design Manual Waiver Request process.

All retaining walls, regardless of height, shall not be constructed within a Howard County Right of Way or Easement. The only exception is if written permission has been granted by the Director of Public Works.

All construction documents for retaining walls three feet in height or higher shall be designed, signed, and sealed by a Registered Professional Engineer.

b. Construction Drawings – Plan Views

All retaining walls shall be shown in plan view showing all of the proposed conditions at a maximum scale of 1" = 50'.

Show enough grading around the retaining wall to clearly demonstrate all flow patterns in the vicinity of the retaining wall. Provide spot elevations every 50 feet along the length of the wall at the top and bottom of the wall.

Provide flow arrows along the top of the wall to indicate flow paths along the length of the wall. It is not desirable for run-off to be allowed to cascade over the top of retaining walls. This will be permitted if run-off approaching the wall is sheet flow and adequate scour protection is provided.

For all walls, a minimum ten foot wide construction easement/setback shall be required from the face of the wall. If the wall is greater than ten feet in height the width of the easement shall be equivalent to the height of the wall. This easement shall be clear of floodplains, buffers, wetlands, property boundaries, structures and/or other environmentally sensitive areas. 4:1 is the maximum slope allowed within this easement in front of the wall.

A permanent wall maintenance easement shall be provided behind each wall that is equivalent in width to the height of the wall plus the length of the geogrid. No structures may be placed within this easement.

For "CRITICAL" walls ten feet or more in height, the design engineer shall appropriately address the issue of global stability for the slope and provide an acceptable maintenance easement based upon the conclusions of the analysis.

For all block and timber retaining walls, a ten foot wide "NO TREE" planting zone shall be delineated behind the top of the wall.

Under no circumstances shall the maintenance easement for any wall encroach upon the building envelope of any residential lot.

c. Construction Drawings – Elevations

The elevation, or front view, of the proposed retaining wall is considered to be the most important detail for the purposes of constructing the wall.

The following scales are recommended, but good judgment is necessary to ensure that this detail is readable and reasonably drawn.

VERTICAL: 1" = 1' to 1" = 5' : 1" = 2' preferred

HORIZONTAL: 1" = 5' for lengths up to 50'

1" = 10' or as appropriate over 50' in length

Provide a vertical scale bar and horizontal stationing across the bottom of the elevation.

For the purpose of constructability, the front view shall have each typical section identified by a letter or a number. Provide section breaks shown as heavy vertical lines indicating where each section begins and ends. Variation from one section to the next should be minimized in order to reduce the number of typical sections.

Essential elements of the elevation are as follows:

- A complete outline of the wall
- Show the finished grade line superimposed over the wall at the top and at the bottom
- Show the locations of the weep holes (40' on center) and other utilities in proximity to the wall
- The vertical placement of the geogrid must be identified by which block layers the geogrid is to be inserted between
- Indicate the required allowable bearing strength for each typical section or as it varies
- Show with a dimension the maximum height allowed by design for each typical section

d. Construction Drawings – Cross Sections

Show a typical cross sectional detail for each section of the wall as it varies by height and geogrid placement and/or other significant design features. The maximum vertical scale is 1" = 5'; 1" = 2' is preferred.

Show the maximum height of the wall for each typical section.

For block or timber walls, show the number of blocks or timbers, vertically placed, graphically.

For reinforced concrete walls, show the typical reinforcement design including notes to indicate proper horizontal spacing along the length of the wall.

Indicate the maximum slope above or below allowed by the design. The maximum slope allowed is 2: 1.

For each typical section show the allowable bearing strength that is required for the soil beneath the base of the wall

Show the drain placement behind the base of the wall, entrenched in stone for at least one foot of depth, then covered with filter fabric to prevent clogging. More stone should then be placed in a one foot wide vertical layer to 90% of the walls height to facilitate water flow to the drain. Weep holes must daylight through the wall every 40 feet.

Geogrid placement by layers and length for manufactured block walls must be shown in the cross sectional detail

e. Construction Details – Fences/Guardrails

Retaining walls that exceed thirty inches in height at any point and present an inherent falling hazard require a fence along the entire length of the wall.

The fence must be a minimum of thirty-six inches in height, and the openings in the fence or rail must be small enough to prevent the passage of a four inch sphere.

Fences must be stable enough to withstand 200 lbs of concentrated loading applied horizontally at any point.

A typical footing detail shall be provided.

If the fence is set back from the face of the wall, the fence shall be tapered at the ends of the wall to prevent children from accessing the ledge.

If the fence is not directly above the wall, show its location in the plan view.

For walls in proximity to vehicular traffic, guardrails, per the Howard County standard guardrail details are required.

For roadways and parking lots, the face of the curb must be a minimum of two feet in front of the face of the guardrail or the retaining wall. The Howard County standard 7" curb is required.

The location of a guardrail, if required shall be three feet from the face at the top of the wall to the side of the guardrail facing the wall.

f. Design Calculations / Failure Analysis

All retaining walls shall be designed to resist the three possible modes of failure: sliding, overturning, and bearing failure. Sufficient analysis shall be provided to confirm that the appropriate factors of safety have been achieved.

2.0 for sliding failure (1.5 for manufactured block)

2.0 for overturning failure

2.0 for bearing failure - block or timber walls 3.0 for bearing failure - concrete walls

Any likely or anticipated surcharge loads shall be included in the failure analysis. If none are included in the design, add a note to the cross sectional details stating "this wall is not designed for surcharge loads".

For manufactured block walls, supplemental design booklets may be submitted to satisfy the failure analysis requirement but they may not be considered as part of the construction drawings. The plans shall contain all of the relevant information required to construct the wall.

For reinforced concrete walls, provide a complete set of design calculations for the wall, including the placement and spacing of steel reinforcement.

g. Construction Drawings -- Required Notes

"Retaining walls shall only be constructed under the observation of a Registered Professional Engineer and a (NICET, W ACEL or equivalent) certified soils technician."

"The required bearing pressure beneath the footing of the wall shall be verified in the field by a certified soils technician. Testing documentation must be provided to the Howard County Inspector prior to the start of construction." The required test procedure shall be the Dynamic Cone Penetrometer Test ASTM STP-399."

"The suitability of fill material shall be confirmed by the on-site soils technician. Each eight inch lift must be compacted to a minimum of 95% Standard Proctor Density and the testing report shall be made available to the Howard County Inspector upon completion of construction. "

"For "CRITICAL" walls, one soil boring is required every 100 feet along the length of the wall. copies of the boring reports shall be provided to the Howard County Inspector upon completion of construction."

All other miscellaneous information required for the construction of the retaining wall shall be included somewhere on the construction drawings. Items may include: material specifications, recommendations from the manufacturer of block wall systems, notes from the design engineer, specific instructions for non-typical designs, etc.

Each design package shall include the designer's seal and signature on the cover page along with the name, address, and telephone number of the consulting firm he represents. Also provide the name, address, and telephone number of the owner/developer.

h. Policy On Retaining Walls In Storm Water Management Facilities

The Howard County Design Manual Volume I requires under section 5.2.4.1. that "A pond buffer shall be provided in accordance with the criteria set forth in the Maryland Stormwater Design Manual, Volumes I and II. The minimum distance from the end of the outlet structure, including the rip-rap exit channel, to the downstream property line shall not be less than 25 feet. Along other parts of the facility, the minimum distance from the toe of the embankment or top of cut to the property lines, rights-of-way, and structures shall be 25'. For structures adjacent to the facility, the distance from the 1 DO-year water surface elevation within the facility shall be 25 feet minimum horizontal and two feet minimum vertical to the lowest floor elevation of a habitable structure."

This specification applies for all new retaining wall construction plans to be submitted for review. Through the Alternative Compliance request procedure the following provisions will govern.

In general the Department of Public Works discourages the use of retaining walls in storm water management facilities due to the increased maintenance costs and long term liability of the structures. The Department recognizes, however, that in some instances retaining walls may be required as other viable alternatives may not be available. If the Department or its designee deems that retaining walls are the only viable solution within a storm water management facility, the following criteria shall govern:

- 1) For all facilities, both public and private, retaining walls shall not be allowed within the embankment area, either inside or outside the facility, unless the toe of the retaining wall and any tie-backs are beyond the phreatic line of the facility. These walls shall have a height not to exceed three feet. Tiered walls shall not be allowed unless they are designed so that the influences of the upper walls do not impact the lower walls.
- 2) For publicly owned and maintained facilities or privately owned and jointly maintained facilities, minor retaining walls, less than three feet in height, measured from the top of the wall to the ground along the face, shall be allowed on cut slopes above the uppermost maintenance bench of any storm water management facility. These walls shall not be located in the ponding area of the facility. These walls shall be privately owned and maintained. The construction and maintenance of these walls shall be made part of a developer agreement for the facility.
- 3) For privately owned and maintained facilities, the maximum height of any wall, whether single or tiered, shall not exceed ten feet. These walls may be located in or adjacent to pooling areas provided the walls are reinforced concrete and shall be designed to withstand the hydrostatic pressure and saturated ground conditions on the footing of a flooded condition.

- 4) All retaining walls in excess of thirty inches in height shall have an appropriate safety railing or fence.

- i. Tiered Walls

For tiered walls where the total cumulative height of the tiers is ten feet in height or greater, the provisions for "CRITICAL" walls apply.

The set back from one wall to the next in a series of tiers shall be equivalent to the height of the lower wall or greater.

The slope between tiered walls shall not exceed 4: 1.

3. Wall Thickness

The thickness of the top of a wall shall be sufficient to accommodate any railing or appurtenance to be placed on it. However, for ease in placing concrete, it shall not be less than 1 foot.

4. Passive Pressure

Passive pressures on the front face of a wall are unpredictable and shall be neglected for normal wall footing depths. Shear keys shall be similarly avoided. Passive earth pressure shall not be considered in any case if the cover in front of the wall may be subject to scour or if the ground slopes at more than 4:1 rate.

5. Wall Elevations

Top of wall elevations shall be computed at joints and alignment breaks and at vertical curve control points. The elevation shall be tied to Howard County control where available within one mile.

6. Batter

For walls over 15 feet in height, consideration shall be given to provide a batter on the front face of wall. The back face of the wall shall be battered if required for the stem design.

7. Joints

Walls shall be detailed with expansion points through the portion above the footing at approximately 90 ft. intervals. Gravity, semi-gravity and cantilever walls shall have two equally spaced contraction joints located between the expansion joints. The face walls of counterfort and buttress walls are designed as continuous beams and they cannot have contraction joints within a continuous unit. Counterfort and buttress walls shall be

designed in continuous units not over 60 feet in length with expansion joints between units.

8. Drainage and Weep Holes

Drainage systems should be provided behind retaining walls to reduce hydraulic pressures, which could result in failure of the wall. Retaining walls are typically drained by means of either continuous back drains or weep holes, along with porous backfill, which allows water to flow behind the wall. Weep holes extending through the wall stem with a pocket of gravel backfill on the back, are inexpensive, but often become clogged. Continuous back drains are preferable to weep holes and may be outlet into nearby storm drainage systems, if available, to minimize aesthetic impacts.

For retaining walls and larger wing walls, sloped perforated PVC pipe drains shall be placed along the back face of walls. The perforated pipe drains are placed below a full height porous backfill blanket and are supported on a continuous concrete ledge extending from the back of the wall. Drain outlets, consisting of 4 in. non-perforated PVC pipe, spaced at no more than 15 ft along the wall, are located 1 ft above the finished groundline at the front of wall. Outlet drain pipes are to be extended 3 in. from the face of wall, where visible to the public, to minimize staining. Where sidewalk areas are located along the front of walls, outlet drain pipes are to be placed below the sidewalk and outlet into the adjacent gutter.

For box culvert wing walls and wing walls less than 30 ft. long and 16 ft. tall, use weep drains with 2 cu. ft. of porous backfill behind each drain. The requirements for outlet drain pipes are the same as for the continuous back drains.

B. Abutments

Abutments support the ends of the bridge beams and provide for the transition from the bridge structure to the approach roadway pavement. All abutments retain the earth of the adjacent roadway and are subject to live load surcharge. Some types of abutments retain substantial amounts of fill. The abutment design must satisfy the requirements of a retaining wall. In addition, the overall stability and the foundation loads must be checked both with and without the dead and live loads from the superstructure. Provision shall be made for surcharge due to construction loads.

1. Types of Abutments

a. Gravity Abutments

As with gravity retaining walls, gravity abutments resist loads imposed on them by means of their mass. The resultant of forces must be within the middle third of any horizontal section through the abutment, both with and without the loads imposed by the superstructure.

b. Spill-Through Abutments

This type of abutment is designed with openings between the supporting legs to allow the embankment material to spill through and form a slope in front of the abutment. The abutment must be designed for the earth pressure on the backwall and cap and on the fill face of the supporting legs. The area of the legs shall be multiplied by a shape factor, usually 2.0, to allow for arching of the soil. If the embankment slope in front of the abutment is not subject to scour, passive earth pressure may be considered on the front face of the legs. The legs and cap shall be designed as a frame to support the loads imposed by the superstructure.

c. Stub Abutment on Piles

This type of abutment is similar to a spill-through abutment except that the piles are very flexible compared to the stiffness of the concrete stub. The piles shall be considered pinned at the footing and shall be designed for axial load only. Batter piles shall be provided to resist horizontal forces. The lateral resistance of the soil surrounding the piles will provide lateral stability and can resist an unbalanced shear which will depend on the nature of the soil.

d. Cantilever and Counterfort Abutments

Cantilever and counterfort abutments resist loads in a manner similar to their retaining wall counterparts.

e. Integral and Semi-Integral Abutments

Integral abutments eliminate the need for abutment roadway joints and hence provide a structure that will require minimal, if any, maintenance to the abutments and associated bearings. Integral abutments should be considered for new bridges when the project site conditions and geometry are suitable for these types of elements. Key considerations to be evaluated include soil type and profile, span alignment, length and skew, superstructure type and the presence of utilities on the bridge. In general, for integral abutment design to be considered, the soil type shall be a reasonably graded cohesionless soil with no defined rock line. Soil profiles suitable for driven pile foundations are also suitable for the installation of integral abutments. Integral abutments shall not be used when there is the possibility of pile downdrag forces. Integral abutments shall only be considered for use on tangent superstructure alignment with a change in vertical grade less than 5% between abutments. Maximum span length for use with integral abutments is 200' and maximum skew (measured as the angle between the centerline of beam and a line normal to the centerline of bearing) is 30 degrees. Superstructure types that may be used with integral abutments include concrete slab supported by a redundant steel beam system or adjacent or spread prestressed concrete I-beams, box beams or slab beams. The use of timber superstructure components shall not be used with integral abutments. Normally, integral abutments are discouraged when the bridge carries

utilities due to the required opening in the abutment stem to facilitate utility conduit expansion. This opening is a potential source of future deterioration and should be avoided, if possible.

Only cast-in-place concrete piles or steel H-piles shall be considered for use with integral abutments. If steel H-piles are selected, they shall be installed with the weak axis parallel to the centerline of bearing (i.e., driven to allow bending from thermal movements to be about the weak axis). Depending on the soil type and profile, consideration shall be given to pre-auguring a hole that extends a minimum of 10 feet below the bottom of abutment. The pre-augured hole shall be at least two times the pile diameter and filled with well-graded sand or a bentonite slurry mix. Piles shall extend to a sufficient depth to provide adequate structural stability (i.e., no “stilting” effect) and end fixity even when the adverse effects of scour are considered. A minimum of one pile per steel girder or spread prestressed concrete beam member shall be used.

Bearings shall be selected to resist the temporary loading imposed by the superstructure prior to encapsulating the ends of the beams and bearings with the deck closure pour. Minimalist bearings such as plain elastomeric pads should be considered.

Concrete approach slabs shall be used with all integral abutment designs and shall be structurally tied to the bridge deck slab and abutment stem via hinge reinforcement. If the end of the approach slab abuts rigid roadway approach pavement, provisions for expansion shall be implemented at this location. If the roadway approach pavement is flexible, the ends of the approach slabs may butt up against the section without expansion provisions being provided. The ends of approach slabs adjacent to flexible pavement shall be protected by steel angle armoring embedded in the slab with studs. Approach slabs shall be poured atop well graded aggregate and dual layers of polyethylene curing sheeting.

Semi-integral abutments also eliminate the need for abutment roadway joints, but since they are founded on a rigid foundation (e.g., spread footing, multiple rows of piles, etc.), expansion bearings will be required. Criteria for the use of semi-integral abutments are similar for that specified for integral abutments. Semi-integral abutments should be considered when the soil profile is not favorable (i.e., presence of rock, clayey soils, etc.) or if span lengths, geometry or alignment issues preclude the use of integral abutments.

2. Design Guidelines

a. Lateral Earth Pressure

The lateral earth pressure shall be computed in the same manner as for a retaining wall.

b. Other Loads

In addition to lateral earth pressure, the abutment shall be designed to withstand the dead load of the abutment and superstructure, live load over any portion of the superstructure or approach fill, wind forces, longitudinal forces from the superstructure when the bearings are fixed and longitudinal forces due to friction or shear resistance of the bearings when the bearings are not fixed. The design shall be investigated for all combinations of these forces which may produce the most severe loading case.

c. Drainage

It is not necessary to provide drainage behind the stems of perched abutments when they are placed atop granular fill.

C. Piers

1. Types of Piers

a. Rigid Frame Piers

Rigid frame piers consist of a continuous pier cap, columns and a continuous footing or independent footings. Rigid frame piers are generally used on bridges spanning highways and railroads.

b. Single Column Piers

Single column piers, or hammer head piers, consist of a pier cap supported by a single column. Single column piers are generally used for bridges spanning rivers or streams or where they are necessitated by space requirements.

c. Solid Stem Piers

The cap and column of a solid stem pier is a single unit supported by a continuous footing. They are used for short or narrow piers.

d. Pile Bents

Pile bent type piers consist of a single or double row of piles driven to act as both foundation and substructure elements. Superstructure loads are distributed to the piles via a rigid structural pile cap. Pile types normally considered in a pile bent type pier include timber, steel H-pile and cast-in-place concrete. A structural cap, normally constructed of reinforced concrete, encases the top portion of the piles to distribute superstructure loads. Pile bent piers shall be designed to account for the adverse effects of scour as it may create a longer unbraced pile length. Pile bents

shall be checked against the ultimate scour condition. Both structural stability and pile stresses should be investigated.

Pile bent piers are normally utilized for stream crossings to minimize the impacts to the waterway during and after construction as well as minimize the reduction in the available hydraulic opening. Appropriate scour countermeasures shall be incorporated into the detailing of this pier type as required by the existing or proposed conditions.

2. Design Guidelines

a. Loads

Piers shall be designed to withstand the dead and live loads super-imposed thereon; wind pressures acting on the pier, the superstructure and on the moving live loads; shrinkage and temperature forces; forces due to stream current; and longitudinal traffic traction forces. These various forces shall be divided into components that are normal to and parallel to the centerline of the pier.

b. Application of Loads

Longitudinal forces are transferred to the substructure mainly through the fixed bearings acting at the hinge of the bearing. However, some longitudinal force will be transferred through the expansion bearings by virtue of friction. The maximum longitudinal force, due to superimposed loads or temperature effect, which is transferred to the pier at an expansion bearing, is equal to the bearing friction.

Transverse force may also be assumed to act at the hinge of the bearing. The total transverse force on the superstructure will be transferred to the piers and abutments in proportion to the length of the adjacent spans.

c. Columns

Rigid frame column spacing shall be in the range of from 12 feet to 20 feet. The spacing shall be set so that positive and negative movements in the pier cap are approximately equal. All columns shall be designed using Load Factor Design as specified in the A.A.S.H.T.O. Specifications (Ref. 1). Service load design may not be used for columns. Circular pier columns whose diameter is 5'-0" or less shall be designed using spiral reinforcing.

D. Foundations

1. Depth

Footings of all piers in the floodplain shall be founded on rock or on piles driven to rock, except as approved by the Chief of the Bureau of Engineering.

All other footings in the floodplains, including those for abutments, wing walls, and culverts shall be founded below the estimated depths of scour, or 3' below the thalweg, whichever is lower.

Footings outside the floodplain shall be founded on a suitable uniform foundation below the frost line and not less than 3'-0" below finish grade. Refer to the A.A.S.H.T.O. Specifications (Ref. 1) for footings on slopes.

Footings on rock shall be keyed into the bedrock a depth of 12 inches when they are designed to transfer lateral forces. When a bedrock foundation is required for scour protection or design bearing pressure, footings shall be carried into bedrock a minimum of six inches. Spread footings on soil shall have the lower 1' in depth poured against undisturbed earth.

Plan sheets on which footings are shown shall include a note giving the allowable soil pressure or pile loads.

2. Loads

Footings shall be designed to transmit to underlying stratum all forces transmitted to and acting on the substructure component.

3. Pile Foundations

a. Types

Available pile types that may be considered for use include timber, cast-in-place concrete and steel H-pile. Each pile shall be evaluated for the project site conditions based on the available soil information, drivability, loading and structure location.

4. Drilled Shafts

Allowable stress design (ASD) methods shall be used to size and evaluate drilled shafts. Design of concrete drilled shaft foundations shall be done in accordance with AASHTO "Standard Specifications for Highway Bridges" (Ref. 1) and utilizing COM624P or another industry acceptable drilled shaft design program.

5. Design Guidelines

a. Location of Resultant Loads on Spread Footings

Footings founded on materials other than bedrock shall be proportioned so that the resultant intersects the bottom of the footing within the middle third. The resultant force on footings founded in bedrock may be outside of the middle third provided that the maximum allowable bearing pressure is not exceeded.

b. Pile Foundations

Pile foundations shall be so proportioned that no pile receives more than the maximum allowable pile load and no pile is subjected to uplift under any combination of design loads. All pile foundations shall have batter piles to resist horizontal forces transmitted to the foundation and to increase the rigidity of the entire structure. Plumb piles may be assumed to resist 2 kips of lateral load per pile.

E. Substructure Protection

The selection and design of substructure protection to resist the effects of scour shall be in accordance with MSHA guidelines and FHWA circulars and memorandums associated with scour countermeasure design. FHWA Hydraulic Engineering Circular 23 (HEC-23) (Ref. 18) shall be used in the design of countermeasures at piers and abutments.

Class II riprap is the preferred material for scour countermeasures. The D_{50} of the riprap shall be confirmed in accordance with HEC-23. Velocities used in the design of countermeasures shall be based upon the 100-year or incipient overtopping storm event, whichever yields a higher velocity, and shall be derived by using the hydraulic modeling techniques described in the MSHA "Interim Manual of Hydrologic and Hydraulic Design" (Ref. 12). Configuration of the riprap blankets, including depth, distance from abutments/piers, toe dimensions, etc., shall be in accordance with MSHA memorandum "Scour Countermeasures at Bridges" (November 25, 1992).

F. Slope and Bank Protection

Slope and bank protection (revetments) for roadway approach embankments, retaining walls and stream channel banks shall be selected and designed in accordance with FHWA Hydraulic Engineering Circular 11 (HEC-11) (Ref. 19). Class II riprap is the preferred material for revetments.

Where applicable, revetments shall be designed to accommodate wave height and wave run-up as described in HEC-11. For the purpose of determining the total height of the revetment, the engineer should assume that the maximum wave height occurs coincidentally with the maximum water surface elevation generated by the design storm.

3.5 Bridge Superstructure

The bridge superstructure includes the slab, beams or girders and bearings. The function of the superstructure is to distribute and transmit loads to the substructure. Bridge superstructure shall be designed in accordance with A.A.S.H.T.O. Specifications (Ref. 1).

A. Slab on Beams and Girders**1. Concrete**

All superstructure concrete including parapets, abutment backwalls and parapet portion of wingwalls but excluding concrete overlay shall be air entrained concrete with a minimum 28 day compressive strength of 4500 p.s.i. Slab concrete shall be low slump concrete.

2. Wearing Surface

Concrete slabs shall have an extra 1/2 inch concrete which will serve as a wearing surface. This wearing surface shall be considered sacrificial and shall not be included when determining member strength.

3. Reinforcing

Epoxy coated reinforcing bars shall be used for the entire superstructure, including top and bottom mats of slabs, abutment backwalls and parapet portion of wingwalls.

4. Forms

Concrete slabs shall be poured on stay-in-place metal forms.

5. Concrete Cover

Slabs shall have 2 1/2 inches of cover over the top reinforcing mat (which includes a 1/2 inch concrete wearing surface) or 1 inch of cover between the bottom reinforcing mat and the stay-in-place forms. Parapets and backwalls shall have 2 inches of cover.

6. Slab Thickness

Slabs shall be designed to carry the dead and live load loading in accordance with the A.A.S.H.T.O. Specifications (Ref. 1) with an allowable working stress f_c equal to 1350 p.s.i. The minimum slab thickness including the concrete overlay shall be 7-1/2 inches.

7. Deck Pour Sequence

Construction plans shall include a suggested pouring sequence including the order and limits of each pour. For conventional superstructures (i.e., non-integral or non-jointless), positive moment regions of the superstructure shall be poured first followed by the pours in the negative moment region(s). For integral abutment bridges, the pouring sequence shall be configured to minimize dead load rotation at the abutment to prevent unwanted transverse deck cracking.

In developing the pour sequence, consideration shall be given to accounting for the temporary stresses on the in place portions of the structure that may not have been considered such as lateral flange buckling of the longitudinal girders supporting the wet concrete. Individual concrete pours shall not exceed 100 cubic yard per day without written authorization of the Chief of the Bureau of Engineering.

B. Beams and Girders

1. Composite and Non-Composite Design

In superstructures consisting of concrete slabs supported on prestressed concrete beams or steel beams or girders, composite designs shall be used for simple spans exceeding 35 feet, and generally for continuous spans exceeding 50 feet. Because of the effect of span ratios, no specific limits for composite design can be established for continuous construction.

Continuous steel beam or girder spans shall be designed as composite for positive movement regions only; however, shear connectors shall be provided at maximum allowable spacing through the negative movement regions even though composite action is not considered.

2. Camber

a. Spans Less than 50 Feet

Steel beams with a span of less than 50 feet shall not be cambered for dead load deflection or vertical curve corrections. If the beams are not rolled exactly true, they shall be fabricated and erected with their natural camber up.

b. Spans 50 Feet or More

Steel beams and girders with spans of 50 feet or more shall be cambered to compensate for dead load deflection and vertical curve correction. Camber tolerance shall be zero (0) inches under to one-half (1/2) inch over.

3. Bearing Stiffeners

Stiffeners shall be placed at all bearings. The stiffeners shall be designed to carry the total reaction acting as a column.

C. Steel Beams and Girders

Steel plate girders shall be designed, where economically feasible, to eliminate transverse and longitudinal web stiffeners. The use of A.A.S.H.T.O. M270 Grade 50W steel must be approved on a case by case basis by the Chief of the Bureau of Engineering.

D. Prestressed Concrete Beams

In lieu of steel beams or girders, precast prestressed concrete beams may be used for simple spans. The length and weight of any prestressed concrete member shall not exceed the State of Maryland limitations for highway shipment without permits.

E. Bridge Drainage

Scuppers on bridges shall be avoided if possible. On closed systems inlets shall be placed immediately off the bridge at the upgrade end of the bridge to prevent accumulated gutter flow from entering the structure. On open section roadways inlets shall be placed immediately off the bridge at the downgrade end to control water accumulated on the bridge. On closed section roadways, inlets shall be placed downgrade from the bridge as required by the gutter flow design.

Scuppers shall be placed on the bridge only if the ponding encroachment exceeds the limit permitted by the Howard County Storm Drain Design Manual, (Ref. 8). Where required, scuppers shall be MSHA standard scuppers. Scuppers shall be a minimum of 10' from any substructure unit. Downspouts shall extend 8" below adjacent stringers and shall outlet into streams, slope protection or splash blocks.

F. Expansion Joints

Watertight roadway expansion joints shall be provided at all abutments and at all piers supporting simple spans. These joints shall provide for the total thermal movement for a temperature range of 0 F to 120 F.

Abutments integral with the superstructure should be considered where appropriate in lieu of expansion joints.

G. Bearings

The selection of bearings shall consider length of span contributing to expansion, superstructure material type, applied loading, bridge skew and degree of curvature (if applicable). Consideration should be given to selecting bearings that require minimal maintenance including plain and steel laminated elastomeric pad bearings with or without polytetrafluoroethylene (PTFE) – stainless steel sliding surfaces. Bronze sliding bearings shall be considered for steel structures. Refer to the MSHA "Structural Standards Manual" (Ref. 11) for suggested bronze sliding bearings. The use of steel rocker bearings is prohibited.

Elastomeric bearings are generally used to support precast prestressed concrete slabs or beams. Plain pads are preferred unless structure rotation and thermal translation require steel laminated bearings. Elastomeric bearing shall be adequately attached to the bearing seat via an appropriate epoxy bonding compound. Provisions shall also be considered to prevent the elastomeric pads from "walking" by using restrainer bars, plates or angles or by

inserting an anchor dowel through the ends of the precast prestressed concrete member and embedded into the beam seat.

H. Drainage Troughs

Drainage troughs shall be investigated for use on new structures or rehabilitated structures where open joints (e.g., finger joints) are located in the bridge deck. Troughs shall also be considered as a way of providing a redundant system to protect specific bridge elements if the roadway joints begin leaking. Fiberglass drainage troughs shall be used underneath all open joint systems and shall be installed using a cross slope no less than 1" per foot. Adequately sized catch basins shall be incorporated into the system to collect all drainage water and efficiently disperse it away from the structure by means of downspout piping. Suitable caulking material shall be used along the interface between the structure and the trough to prevent water seepage.

Neoprene drainage trough material may be used in other locales assuming that the anticipated drainage flow will not exceed the capacity of the trough. Troughs placed underneath closed joint systems shall be installed at a cross slope of no less than ¼" per foot. Stiffening bars shall be incorporated into the system to keep the neoprene material flush up against the structure to prevent water seepage.

Stainless steel hardware shall be used to affix the drainage trough to the structure. Downspout piping shall be incorporated into the drainage trough systems when necessary to convey drainage away from the structure. PVC conduit shall be used for the piping material and it shall be adequately attached/braced against the structure to maintain the integrity of the system. Stainless steel hardware shall also be used to brace the downspout piping. Discharge from any downspout piping shall be directed away from structure foundations and/or adjacent roadway surfaces. Refer to the MSHA Structural Standards Manual (Ref. 11) for suggested drainage trough details.

I. Elevations

Bridge deck elevations shall be computed and indicated on the plans at each girder centerline, PG/L of the roadway, at any roadway break lines and along the gutter flow lines. Elevations shall be provided at 1/8th points.

3.6 Box Culverts

A. Analysis

Box culverts shall be analyzed as closed rigid frames. The dead and superimposed earth loads, the lateral earth pressures and the live and impact loads are to be analyzed separately. The results of these separate loading conditions shall be assembled in various combinations to give maximum moments and shears at the critical points; i.e., the corners, and the positive moment areas. Appropriate live load positions shall be used to produce maximum positive or negative moments. A maximum of one-half of the moment caused by

lateral earth pressure, including any live load surcharge, may be used to reduce the positive moment in the top and bottom slabs. The weight of the bottom slab of a box culvert will be resisted by an equal and opposite soil pressure and the weight of the slab will cause no bending in the structure. The structure should therefore be analyzed for a net soil reaction, excluding the reaction to the weight of the bottom slab.

B. Design Guidelines

1. Minimum Thickness

The thickness of walls and slabs of a box culvert shall be not less than 8 inches for members with single reinforcing and not less than 12 inches for members with reinforcing in both faces.

2. Minimum Reinforcing Cover

The minimum cover shall be as follows:

- a) Bottom of bottom slab - 3 inches
- b) Top slab used as riding surface - 2 1/2 inches (including 1/2 inch concrete wearing surface)
- c) All other faces — 2 inches

a. Epoxy Coated Reinforcing

When the distance from the riding surface to the top slab is less than 2', all reinforcing in, or extending in, the top mat of reinforcing steel for the entire length of the culvert shall be epoxy coated.

3. Wearing Surface

If the top slab is to be used as a roadway riding surface, it shall have a 1/2" integral concrete wearing surface. This wearing surface shall be considered sacrificial and shall not be included when determining member strength. When the top slab is not the riding surface, the earth cover provided shall be no less than 9 inches (in addition to paving) at the minimum point.

4. Contraction and Expansion Joints

Contraction joints shall be provided at a spacing of approximately thirty (30) feet. Expansion joints shall be provided at approximately ninety (90) foot intervals. Reinforcement shall be stopped two (2) inches clear of joints.

5. Headwalls

Headwalls shall be provided at the exposed ends of box culverts, to retain the earth cover and to act as edge distribution beams on skewed alignments. The headwall shall be constant height.

6. Cut-Off Walls

In order to provide for effects of scour, cut-off walls, a minimum of three (3) feet deep, shall be provided at the exposed ends of the culverts. Wing wall footings shall be set at the elevations of the bottom of the cut-off walls and securely tied to them with reinforcement.

7. Provisions for Future Extension

If the culvert is to be placed under a roadway which could be widened in the foreseeable future, provisions shall be made for extension of the culvert by placement of appropriate joint keys on the exposed inlet and outlet faces.

C. Bottomless Box Culverts (Rigid Frames)

Bottomless culverts should be considered when it is desirable from a permitting standpoint to put in a culvert with a natural channel and the span length is such that using a structural plate pipe arch is uneconomical. Since the foundation loads on a bottomless culvert are relatively higher than a four-sided box, the existing subsurface information must be closely analyzed to determine if the culvert can be supported by spread footings. If the resultant bearing pressure is too high when compared to the allowable, or the adverse affects of settlement is a possibility, placing the structure on piles should be considered. Regardless of the foundation system, the bottom of footing for any rigid frame shall be placed a minimum of 3 feet below proposed groundline.

Bottomless culverts shall be analyzed for scour in accordance with current MSHA guidelines. The Designer should consult with the MSHA Office of Bridge Development for guidance on the selection of bottomless culverts and the preferred analysis and countermeasure design procedures.

3.7 Pipe Culverts

The hydraulic design and analysis of roadway cross culverts should be performed in accordance with the guidelines contained in the Howard County Storm Drainage Design Manual, FHWA HDS-5, Chapter 13 of the MSHA Interim Manual and applicable MDE and ASACE regulations. This section deals specifically with larger culvert crossings of waterways with base flow.

A. Geometry

Pipe culverts shall be designed to carry the full ultimate roadway section including safety grading, guardrail backing, etc.

The layout of any pipe culvert shall be configured primarily to preserve existing drainage patterns and watercourses, while integrating the overall geometry of the roadway embankment. Significant guidance is available in Chapter 13 of the Interim Manual and in HDS-5 regarding the optimal configuration of the culvert to accommodate different channel types.

When culverts are used singularly at crossings, the pipe invert shall be set 1' below the planned bottom of stream bed. When multiple pipe culverts are used in a single crossing, one pipe shall be considered the low flow cell and have its invert set 1' below the planned bottom of stream bed; the remaining pipes shall have their inverts set 1' above the low flow invert. Natural siltation will fill the bottom of the pipe to the planned stream bed level.

For pipe culvert crossings of Non-tidal Wetlands and Waterways, including Water of the U.S., the Designer shall be thoroughly familiar with the regulations of COMAR Section 26.17.04.06, Bridges and Culverts. The engineer should be aware that, for any such crossing, culvert lengths are typically limited to 150 feet by COMAR 26.17.04.06.B.3. In addition, this section of COMAR also requires that culverts conveying such waters have inverts buried by at least 1 foot. For any such crossing, the Designer shall coordinate with regulating agencies at the concept stage in order to confirm the basic type, size and location of the culvert prior to proceeding with final design.

B. End Treatment

Steel pipe culverts derive their strength from the interaction of the soil with the pipe. At pipe ends, this interaction no longer applies and the end treatment must be detailed to stiffen the pipe as well as to protect against hydraulic and erosion forces.

1. Headwalls

For culverts with greater than 5' of fill measured at the start of the fill slope, headwalls shall generally be the minimum height possible. There shall be 9" of cover from the top of the pipe to the ground line at the back face of headwall and there shall be 9" freeboard from the ground line to the top of headwall at the back face of wall. Regardless of whether the headwall is perpendicular to the culvert or parallel to the roadway, the top of the headwall shall be level.

For culverts with less than 5' of fill measured at the start of the fill slope, the headwall shall generally be placed so that the barrier on the headwall lines up with the traffic barrier on the approach roadway.

The front and back faces of the headwall shall extend a minimum of 1' horizontally beyond the pipe prior to the start of the wingwall. The portion of the headwall over the pipe shall be designed as a horizontal beam carrying the horizontal loads to either side of the pipe. The portions of the headwall immediately beside the pipe shall be designed as a cantilever, fixed at the footing, and shall carry the horizontal loads from the area over the pipe as well as loads placed on it directly. The pipe shall be attached to the headwall by J bolts at 18" c/c around the perimeter. No load from the headwall shall be assumed to be carried by the pipe.

Details of the headwall shall include a plan view drawn to a scale of $3/8"=1'-0"$ or larger depicting placement of the headwall reinforcing.

The bottom of the headwall and wing wall footings shall be a minimum of 3' below the low flow pipe invert elevation. A toe wall may be placed below this if required but a bottom of footing less than 3' below the low flow pipe invert in conjunction with a toe wall shall not be acceptable. Shear keys and/or passive pressure to increase the sliding resistance shall not be considered.

Headwalls on large pipe culverts should generally be oriented parallel with the roadway embankment. For smaller culverts and headwalls not visible from the roadway, headwalls may be oriented perpendicular to the centerline of the pipe.

Headwalls for large culverts should have the edges beveled at a minimum angle of 45 degrees around the entire pipe circumference. The use of flared wingwalls may be required to reduce erosion at culvert inlets and outlets. In general, upstream wingwalls should be flared at 1:1 from parallel with the direction of flow. A 4:1 flare is recommended for downstream wingwalls (4 in the direction of flow to 1 perpendicular to the direction of flow).

Culvert headwalls that are to be used for earth retaining in excess of standard dimensions (i.e. greater than 6 inches above the top of the pipe) will require special design. The concept of using a standard headwall in conjunction with a smaller diameter pipe, such as a 36-inch pipe used with a standard headwall for a 48-inch pipe, will not be acceptable. The Designer shall have the responsibility of designing such retaining-type headwalls in accordance with the A.A.S.H.T.O. "Standard Specifications for Highway Bridges" (Ref. 1).

2. Other End Treatments

End treatments other than head walls are generally allowed if they conform to the pipe manufacturer's recommendations. Step beveled ends are preferred over fully beveled ends for their added stiffness however both require concrete collars/slope protection with J bolts at 18" c/c and toewalls extending 3' below the low flow pipe invert. Particular care must be taken with beveled ends for pipe arches due to their stiffness requirements.

It is structurally preferred for pipe ends to be on an axis perpendicular to the pipe centerline. For pipes not perpendicular to the centerline of the roadway, this may require warping the fill slopes. This structurally preferred solution may entail excessive cost for large culverts, may present aesthetic concerns for culverts with limited fill or may be impractical due to the right of way limitations. Each culvert site shall be examined in terms of end treatment.

Exposed square ends are not permitted except as temporary structures for aesthetic considerations.

Reinforced concrete or corrugated metal end sections are acceptable for use on single pipe culverts up to 36-inches in diameter, depending upon the application. When riprap is specified in conjunction with an end section, the riprap shall extend to the intersection of the end section and the pipe. End sections shall not be substituted for headwalls if the skew of the pipe is greater than 60 degrees to normal or if the pipe carries base flow.

Large-diameter culverts with extremely high outlet velocities (typically in excess of 20 feet per second) may require the design of specialty energy dissipaters. These dissipaters are typically cast-in-place or precast concrete. The methodologies presented in FHWA Hydraulic Engineering Circular 14 (HEC 14) (Ref. 20) shall be used in the design of any such dissipaters. The structural design of these units shall be in accordance with the A.A.S.H.T.O. "Standard Specifications for Highway Bridges" (Ref. 1).

3. Stream Protection

Where required due to high outlet velocities or stream instability, channel protection shall be designed in accordance with the methodologies of FHWA Hydraulic Engineering Circular HEC 11 (Ref. 19) and HEC-20 (Ref. 21) and the guidance presented in Chapter 10 of the MSHA Interim Manual (Ref. 12).

Severe stream instability at culvert outlets should be assessed by qualified engineers experienced with fluvial geomorphology and Rosgen stream restoration techniques.

C. Foundation Requirements

Large culverts in excess of 48 inches in diameter shall be bedded in a concrete cradle which will support the pipe for at least 10 percent of its overall height.

Multiple-cell pipe culverts shall be spaced so that adjacent outside surfaces are as follows:

- Diameter less than 48 inches: Not less than 2 feet apart.
- Diameter greater than 48 inches: One-half the diameter or 3 feet apart, whichever is less.

This section applies to steel pipe culverts with spans greater than 8' measured perpendicular to the pipe.

A normal foundation report shall be required, refer to Section 3.2.M.

3.8 Utilities on Bridges

A. Telephone Lines & Cable

Galvanized steel conduits will only be allowed to be placed in the sidewalk slab of the bridge.

B. All Other Utilities

No utilities other than telephone conduits will be permitted to be placed on a bridge. No conduit shall be placed closer than ten (10") inches from the face of the curb and three (3") inches from the inside face of the parapet or twelve (12") inches from the edge of the slab if no parapet is provided.

3.9 Rehabilitation of Existing Structures

A. Introduction

This section addresses the rehabilitation of existing structures as part of an overall program to repair various Public Works structures. The goal of rehabilitation is to maintain the safety and structural integrity of the structure as well as extend its useful service life. The focus of any rehabilitation program is to effect repairs to key or critical structure elements in a timely manner to eliminate the need to replace the entire unit.

The rehabilitation design of existing structures shall be performed in accordance with applicable sections of the latest edition of the AASHTO "Standard Specifications for Highway Bridges" (Ref. 1), including subsequent interim specifications. The design methodology shall be based on that customarily used by the Maryland State Highway Administration, i.e., the Service Load Design method. The design of temporary works (e.g., falsework) shall be performed in accordance with applicable sections of the latest edition of the A.A.S.H.T.O. "Guide Design Specifications for Bridge Temporary Works" (Ref. 16) and the A.A.S.H.T.O. "Construction Handbook for Bridge Temporary Works" (Ref. 17).

B. Superstructure Repairs

Superstructure repairs include rehabilitating those bridge elements located above the abutment or pier beam bearing seat. The elements to be addressed include decks, roadway barriers and sidewalks, roadway joints (transverse and longitudinal), drainage devices (including scuppers, troughs and downspout pipes), approach slabs, structural framing systems and bearings.

1. Bridge Decks

In general, the rehabilitation of bridge decks will consist of maintenance repairs of the roadway surface (or soffit), removal of the top portion of the deck and placing a specialized concrete overlay or a complete deck replacement. The scope of rehabilitation should be based on the latest inspection information and all available testing data as appropriate. If inspection and testing information is unavailable, it is desirable to obtain this data through an in-depth inspection of the bridge deck and an adequate testing program. The in-depth inspection should focus on determining areas containing concrete defects that require repair including delaminations, spalling and cracking. All areas shall be thoroughly documented by defect type and location. The in-depth inspection shall include visual and tactile inspection methods including hammer tapping, chain drag and other nondestructive tests to evaluate the deck condition. Based on this information, concrete cores should be taken to evaluate, at a minimum, the compressive strength and chloride ion content of the deck concrete. Cores shall be taken in areas containing observed deterioration as well as areas in relatively good condition (as a control). A minimum of two (2) cores shall be taken for any bridge including a minimum of one (1) per span for multi-span structures. Cores shall not be taken directly over any main longitudinal or transverse structural members. Pending the results of the in-depth inspection and testing, a rehabilitation scheme can be recommended to repair the deck in place, install an overlay or replace the deck.

An estimate of the remaining service life should be made accounting for the current age of the deck, its current strength as compared to the original design strength, chloride ion content, location and extent of any observed structural cracking and the location and extent of concrete deterioration. The remaining service life estimate should be considered in the final decision to rehabilitate or replace the deck.

Concrete deck repairs involve placing an adequate concrete patching material in an area that has been first properly cleaned and prepared. Any area to be repaired shall have all deteriorated and loose concrete removed, exposed reinforcing steel cleaned of all rust (and replaced if it has lost more than 20% of its original section), and the area air blast or water-jet blast cleaned. Concrete patch material shall be chosen based on factors including durability, suitability of the material for the repair location, curing time (as it relates to opening lanes back to traffic) and cost.

If it is determined that the deck has adequate overall strength and some remaining service life left, a specialized concrete overlay may be considered. A concrete overlay will help to protect the remaining portions of the deck as well as extend the remaining service life of the bridge deck. Generally, only 1" to 2" of the existing concrete deck surface is removed (where the potential for delaminations or a high concentration of chloride ions exist) and the surface prepared to receive the overlay material. As part of the surface preparation process, localized concrete repairs may be required to insure that the rehabilitated deck is a sound and integral element. Material(s) used in the patching process discussed previously are suitable for this repair. The overlay material

shall be a dense cementitious type material suitable for placing in relatively thin applications. Materials such as latex modified concrete, micro-silica concrete and very early high strength latex concrete should be considered depending on the application needs. The structural capacity of the deck should be verified if more than 2" of concrete is removed from the top surface.

If the selected rehabilitation alternative is for complete replacement of the concrete deck, several issues shall be evaluated, including, but not limited to, studying and developing stages of construction for maintenance of traffic, maintenance of utilities, checking the existing framing system for the new deck weight including the consideration of the effects of composite action and differential camber in adjacent beams (as a result of staged construction) and the rehabilitation needs for the substructure and those superstructure elements to remain.

Other rehabilitation work associated with the bridge deck will be the repair or replacement of existing roadway joint systems. The failure of transverse (and longitudinal) roadway joints may lead to substructure deterioration, bearing failure and section loss at the ends of the main superstructure supporting members. Depending on the severity of the joint deterioration, only the replacement of the seal may be required. Field measurements of the joint opening should be taken along with the ambient temperature to insure that the correctly sized seal is installed. If the condition of the joint system is such that replacement is required, the existing joint configuration should be confirmed in the field and checked against available plans. If plans are unavailable, field measurements and details of the existing joint system shall be recorded for subsequent use in preparing joint replacement plans. As part of any joint modification scheme, consideration should be given to installing drainage troughs in accordance with Section 3.5.H of this Design Manual. The replacement joint system chosen (armored compression or strip seal, asphaltic plug, silicone, elastomeric, etc.) shall take into consideration such factors as cost, serviceability, durability (i.e., resistance to truck traffic) and constructability.

As part of a deck maintenance program, consideration should be given to eliminating bridge scuppers. If feasible, eliminating scuppers will minimize the deterioration of the deck from standing water/debris resulting from clogged scuppers. An analysis of the scupper(s) shall be performed and if the design spread for a ten-year storm event does not encroach more than 6 feet into the traveled way, Scuppers to be eliminated shall be filled with a lean concrete mix.

2. Barriers

Traffic barriers include railings and parapet systems. Barriers inadequately attached to the superstructure (as a result of deterioration, accident damage or substandard design) shall be rigidly connected to the deck and/or fascia beams to provide sufficient strength to resist vehicular impacts.

3. Girders/Beams/Trusses

These repairs encompass many different types of repairs and will include all work to rehabilitate girders, beams and trusses.

There are many types of repairs that may be performed on steel beams/girders. Rusted webs can be repaired by welding or bolting plates across the deteriorated areas. Deteriorated flanges may be repaired by welding or bolting cover plates across the deteriorated or damaged areas. Care must be taken when welding to ensure that allowable fatigue stresses are not exceeded and that weld quality can be obtained under field conditions.

For bridges with high volumes of truck traffic, repairs may involve the retrofitting of beams/girders at intermediate diaphragms or cross frame connections to prevent and/or mitigate problems at fatigue-sensitive connection details. Cracks in welds, as well as, cracks in the web and connection plates, have resulted from these fatigue-sensitive connection details. Retrofit details to consider include bolting angles or tees to the connection plates and flanges to prevent and/or mitigate out-of-plane bending or high-stress concentrations. In addition to this retrofit, welds may be repaired via grinding, drilling crack ends and replacing any cracked connection plates. Each situation must be carefully studied to ensure that the retrofit detail can be properly constructed in the field and that it will be achieving its intended purpose of eliminating and/or reducing out-of-plane bending or high-stress concentrations.

Although most projects will involve the repair and/or replacement of select members, in some cases, it may be desired to upgrade the load-carrying capacity of a structure. This can be accomplished by several methods, including applying more advanced analysis methods, rating the structure using load and resistance factor design, replacing the deck with lightweight concrete or a different type of lightweight deck (e.g. exodermic, etc.), making multiple simple spans continuous over the piers, post tensioning, or adding shear studs to make non-composite beams composite. When adding studs for the development of composite action, the type of steel being stud welded must be carefully evaluated. Older steels (e.g., A7) are not as ductile as current steel and special care must be utilized when attaching any element via welding.

Trusses often need to be strengthened because of deterioration at the lower chord and connections. Strengthening can be accomplished by the addition of stressing cables or splicing of the chords themselves. Care must be taken in these repairs because of the lack of structural stability when a lower chord member is disconnected. On many trusses, the floorbeam/stringer framing system, including connections, may need rehabilitation and/or upgrading. Many of these repairs can be handled as stated above for steel beams/girders.

Timber beams deteriorating as a result of decaying wood or insect attack can be rehabilitated by replacing individual members or strengthening by thru-bolting galvanized steel channels to each side.

Rehabilitation of concrete tee-beam bridges typically involve beam repairs to address spalling, cracking and any exposed reinforcing steel that has lost cross sectional area. If the extent of deterioration does not compromise the ability of the member to safely carry load, cosmetic repairs using pneumatically applied mortar may be utilized to halt further deterioration. If the extent of corrosion adversely affects the load carrying capacity of the member, and the bridge cannot be load restricted, external reinforcement such as carbon fiber reinforced polymer sheets can be bonded to the sides and bottom of the beam to upgrade the live load capacity.

Prestressed members with concrete spalling can be repaired after cleaning of the strands. Some preloading of the beam may be necessary to prevent future cracking of the concrete patch. If prestressing strands are damaged or severed to a point where the load-carrying capacity of the member is inadequate, the member can be repaired by providing external post-tensioning. This method can also be used to increase the strength of under-designed prestressed beams. In addition, the use of external reinforcement such as carbon fiber reinforced polymer sheets can be bonded to the sides and bottom of the beam to upgrade the live load capacity in shear and/or bending.

4. Bearings

Deteriorated bearings may need to be cleaned and painted, reset or replaced with a similar or better functioning bearing device. To reset or replace bearings, the bearing load must be released through the use of hydraulic jacks and temporary jacking beams supported by the existing girders. Steel columns anchored to the face of the substructure may also support the jack(s). Or, if space allows, the jack(s) can be placed on the beam seat behind the end of a girder. The design plans shall clearly state the limits of the jacking system with respect to load, the amount of girder displacement that can be tolerated and whether traffic can be maintained on the bridge during the jacking operations. The existing structural components must also be checked to confirm their ability to withstand the jacking forces.

For bearings exhibiting extensive and advanced paint deterioration and base metal corrosion, complete cleaning and repainting may be necessary to restore full operational capacity to the bearings. In addition, these bearings may have to be jacked and temporarily supported to facilitate a more thorough cleaning. Reference the following section for the cleaning and painting of steel bearings.

5. Painting

The painting of steel superstructure elements (beams, girders, diaphragms, bearings, etc.) encompasses the cleaning and painting of all exposed surfaces as part of a maintenance or rehabilitation project. Depending on the condition of the paint system, either spot cleaning and painting or complete removal and replacement of the paint system may be required. However, if the paint system condition is relatively good, minor cleaning and overcoating may be a more economically viable alternative to full

removal and coating. Spot cleaning shall extend a minimum of 10' from the beam ends on simple spans and 10' from the centerline of bearing on continuous spans. Steel bearings and associated end diaphragms should be included within these limits. Other areas of additional spot cleaning (e.g., exterior sides of fascia girders) shall be included as necessary.

The existing paint system should be evaluated for adhesion in accordance with ASTM D4541 as well the coating thickness and the compatibility of the existing coating with the new coating. Evaluation of the paint system shall be in accordance with the current edition of the "SSPC Painting Manual, Volume 2" (Ref. 13).

Prior to cleaning and painting, the existing paint system shall be evaluated for the presence of lead paint. If lead paint is present, contract specifications shall be prepared for proper and adequate lead paint removal and containment and worker protection (reference Volume 4 – Specifications for more information). 100 percent containment of blast by-products shall be contained. The design of the containment system shall be borne by the Contractor performing the work.

The new paint system(s) shall be in conformance with the Volume 4 Specifications assuming that it is compatible with the existing paint system.

C. Substructure Repairs

Substructure repairs include rehabilitating those bridge elements located at or below the abutment or pier beam bearing seat. The elements to be addressed include beam seats (and pedestals), abutments and wing walls, piers, slopes and foundation elements.

1. Concrete Repairs

The repair of concrete substructures generally involves both cosmetic and structural rehabilitation. Cosmetic repairs include superficial concrete deterioration such as shallow spalling (defined by no exposed reinforcement) and delaminating concrete (i.e., incipient spalling). Structural repairs include flexural or shear cracking, cracks wider than 1/16" and deep spalling where reinforcement is exposed (regardless of the condition of the reinforcement).

Concrete repair limits shall be based on the latest field inspection documentation. This information shall be field verified if it is older than one year or if the limits of concrete deterioration are not well defined. When determining the limits of repair for both shallow and deep spalling, the outside dimensions of the defect shall be increased by a minimum of 6" on all sides to insure that the deteriorated portion is encapsulated within the repair.

All concrete repairs shall include provisions to remove all loose and deteriorated concrete and thoroughly clean the remaining surfaces prior to placing the repair material. Any exposed reinforcement shall be blast cleaned and inspected for section

loss. Any bar reinforcement that has sustained more than 20% section loss shall be replaced by reinforcement of equal size and adequately lapped/spliced to develop the full strength of the bar.

The material used to repair deteriorated concrete shall be selected based on the location, type and volume of the proposed repair.

2. Pile Repairs

Repairs to piles will consist of a combination of structural enhancement and/or protection. For existing steel piles with section loss resulting from corrosion, steel plates or rolled channel section shall be field bolted to increase the capacity of the pile. Unless the pile has significant section loss, the addition of these steel elements can be affixed under full traffic load. The length of these newly bolted members shall extend well beyond the limits of the deteriorated portions so that the bolted connection is fully developed within the full original section of the pile. For concrete piles, additional concrete section may be added in a similar manner utilizing reinforcement doweled into the existing pile and tremie concrete placed. Repairs to timber piles that have lost section can be accomplished using timber pile splices. Concrete and steel pilings shall be repaired by cleaning the exposed surfaces and placing fiberglass jackets from the channel bottom to up above the splash zone, or just in the vicinity of the splash zone if that distance is prohibitively long. Grout or a specialized concrete mix shall be placed between the existing pile and the jacket, with reinforcement added as needed to provide additional strength. Substantial cross sectional losses can be strengthened by adding material to the pile and extending the concrete pile strut to the mudline. The foundation unit must be analyzed with this additional dead load to insure that none of the piles are being overstressed by this additional weight.

3. Scour and Undermining

Channel degradation and/or scour can advance to the point of exposing the piles. In addition, strong waterway currents or wet/dry cycles can reduce the cross section of the piling at the channel bottom or mudline or water surface (common to timber piles and steel pipe piles). The foundation should be analyzed to determine the pile/soil interaction affects from lateral and vertical loadings and incorporate this information into a structural model to determine the overall structural integrity and/or stability of the foundation unit in question. Inspection observations and measurements or subsequent structural analyses will dictate if pile repairs should be performed in accordance with the previous section.

If scour countermeasures are deemed necessary, scour computations and evaluations shall be performed in accordance with HEC-18. In addition, an underwater inspection (including soundings) should be performed as well as a review of previous underwater inspection reports and other scour evaluation reports. Generally, scour countermeasures for bridges over streams, creeks and rivers will include riprap or grout bag blankets placed around piers and abutments. Stream instability countermeasures, if required,

shall include riprap or gabion bank protection, spur dikes and check dams. Scour countermeasures for bridges over tidal waterways will include riprap aprons around pile bents and riprap revetments around abutments and approach roadways.

During the development of scour countermeasures, all permitting requirements shall be determined and applied for at the Preliminary Design phase.

4. Underpinning

In extreme cases of undermining, a substructure unit may lose sufficient bearing, which could result in the structure collapsing. In the case where a substructure unit has rotated or settled, it may be necessary to jack the substructure unit back into proper position prior to underpinning the foundation. The method used to underpin a foundation depends greatly upon the amount of undermining and whether the underpinning is required to provide structural support. For severely undermined foundations, the underpinning must be performed in such a manner as to provide bearing. This can be accomplished by placing either a temporary form or a permanent fiberglass jacket around the substructure footing and pumping concrete or grout in the void between the substructure footing and the form. Reinforcing steel shall be doveled into the existing foundation or a rock foundation below. The form shall be high enough to provide sufficient head pressure so that the concrete or grout is forced into all voided areas and up against the bottom of the existing foundation. Constructing a cofferdam, dewatering the area, and constructing temporary forms is also another method which may be considered; however, this method results in considerable disturbance within the waterway and is generally more costly and sensitive to permitting regulations.

For foundations where the undermining is minor and it has been determined that the remaining bearing area provides sufficient bearing capacity, pumping grout behind placed grout bags can be performed. The grout bags will prevent future undermining of the foundation while the grout pumped behind the grout bags will fill voids in which the bags could not fill.

D. Retaining Walls

The rehabilitation of retaining walls should consider the material and type of wall. For concrete retaining walls, repairs will generally only be made to the surface areas unless wall alignment is in question. Concrete repairs for retaining walls shall generally follow those stipulated for bridges under Section 3.9.C.1.

For the repair of MSE or other proprietary type precast walls, rehabilitation measures should be discussed with the wall manufacturer prior to implementing repairs. Typical problems involving MSE walls include the failure of the soil reinforcement strap attached to the wall facing panel. Grouted tie-back anchors may be considered to stabilize the wall panel and eliminate future local erosion of the fill.

Since gabion walls can tolerate substantial settlement and/or rotation prior to failure, repairs may only be necessary when the wire basket cages corrode or break. Retying the wires is an acceptable measure to repair the baskets. Gabion walls with substantial settlement and/or rotation shall be analyzed for stability to determine if the wall can remain or if reconstruction is required.

E. Maintenance of Traffic

Maintenance of Traffic (MOT) for the rehabilitation of existing structures shall conform to applicable portions of Section 5.6 as contained later within this volume.

3.10 Load Ratings

A. Introduction

This section addresses the calculation of load ratings for new or existing structures as part of a design project to rehabilitate or replace an existing bridge. Load ratings may also be required for existing structures that have incurred structural deterioration observed during routine biennial inspections. Load ratings shall be calculated for all bridges carrying traffic including culvert type structures covered with less than 8 feet of earthen fill. As part of the final design of new or replacement bridges, the designer shall compute the load ratings for the structure and include these with the Final Plans submittal to the County.

B. Methodology

Load ratings shall be calculated using the load factor design method as outlined in Chapter 6 of the latest edition of the A.A.S.H.T.O. "Manual for Condition Evaluation of Bridges" (Ref. 14). Note that for timber bridges, the service load design method shall be used for load rating purposes. At a minimum, the three standard Maryland legal live load vehicles shall be rated, including the H-15 (15 tons), HS-20 (36 tons) and Type T-3 (33 tons) trucks. The 3S-2 modified (40 tons) truck shall only be rated (for existing structures only) if previous rating calculations included a check of this vehicle. In addition, load ratings may be required for any special vehicles (e.g., school buses, emergency vehicles, special permit vehicles, etc.) as directed by the County.

Both inventory and operating load rating values shall be computed for each truck considered. Material values shall be based on any available record plans or field testing, as applicable. If no plan or testing information is available, material properties shall be estimated based on the provisions contained within Chapter 6 of the latest edition of the A.A.S.H.T.O. "Manual for Condition Evaluation of Bridges" (Ref. 14).

The inventory load rating value shall be considered as the load level that can safely cross the structure for an indefinite time period assuming that the structure remains in its current condition. The operating load rating value shall be considered as the maximum load level that can safely cross the bridge. Allowing this maximum load to cross the bridge indefinitely may compromise the structural integrity and limit the service life of the bridge.

Load ratings shall be computed based on the known section properties of each member accounting for any section loss or member deterioration that could adversely affect the load rating values. Load ratings may be hand-calculated or computed using appropriate computer software written specifically for structural load ratings. For rigid frames and box culvert type structures, structural models based on plane frame analysis methodologies shall be used. In addition to the application of dead and live loads, earth pressure loads (vertical and horizontal) shall be also be applied. Earth pressure loads shall be additive to the dead loads when computing the available member capacity to resist the applied live loads. For paved inverts that are structurally connected to the side walls (e.g., four-sided box culvert), the structural model shall incorporate the effects of the bottom slab loading on the subbase by utilizing spring constants in the model. These spring constants shall be based on an evaluation of the existing soil conditions to determine an appropriate coefficient of subgrade reaction. Each member within a four-sided culvert structure (i.e., walls, top slab and invert slab) shall be analyzed and load rated. Headwalls on rigid frame, four-sided culverts and pipes need not be load rated.

C. Posting

Structures that do not rate out for the minimum vehicle weight at the inventory level (i.e., the rating factor, $RF < 1.0$) shall be recommended for posting to the Chief of the Bureau of Engineering. All postings shall include both the Gross Vehicle Weight (GVW) for the H-15 and Type T-3 trucks and the Gross Combination Weight (GCW) for the HS-20 and Type 3S-2 modified (if applicable) trucks. The acceptance and implementation of the recommended load posting shall be at the discretion of the Chief of the Bureau of Engineering.

3.11 Plan Preparation Guidelines

A. Introduction

This section provides guidance on the proper manner to prepare plans for bridge replacement and/or rehabilitation projects. CADD guidelines related to the production of plan sheets using Microstation is covered under applicable sections of Chapter 1. Plan preparation guidelines for retaining wall projects are covered under Section 3.4.A.

B. Sheet Layout and Order

Bridge plan sheets shall be generated and prepared using commonly accepted engineering and drafting techniques and practices. In general, plan sheet layout shall be developed to include only those views, sections and details pertinent to a particular bridge component. Mixing of various details from different portions of the structure (e.g., substructure and superstructure) shall be avoided wherever possible.

The order of bridge plan sheets for new structures shall conform to the following:

General Plan and Elevation

Hydraulic and Hydrologic Data Sheet (if applicable)
Geometric Layout (for substructure footings or piles)
Substructure Unit Plan and Elevation (for abutments, wing walls and piers)
Substructure Typical Sections (of abutments, wing walls and piers)
Bridge Typical Section(s)
Framing Plan Layout
Beam/Girder Details (includes elevation, camber information, splice details, etc.)
Diaphragm Details (end and intermediate)
Bearings
Deck Elevations
Roadway Joint Details (includes plan layout, sections and any necessary details)
Bridge Railing Details
Approach Slab Layout and Sections (if applicable)
Miscellaneous Details
Boring Logs (including plan layout of locations)

The order of plan sheets for a rehabilitation project will follow this general order as applicable. Highway plan sheets and any necessary maintenance of traffic plan sheets shall be placed ahead of the bridge plans when they are made a part of the project.

3.12 **References**

- (1) "Standard Specifications for Highway Bridges", American Association of State Highway and Transportation Officials (A.A.S.H.T.O.)
- (2) "Manual for Railway Engineering", American Railway Engineering and Maintenance-of-Way Association (A.R.E.M.A.)
- (3) "Manual of Steel Construction", American Institute of Steel Construction (A.I.S.C.)
- (4) "ACI Manual of Concrete Practice", American Concrete Institute (A.C.I.)
- (5) "Structural Welding Code", AWS D1.1, American Welding Society (A.W.S.)
- (6) "Hydraulics of Bridge Waterways", Hydraulic Design Series No. 1, U.S. Department of Transportation, Federal Highway Administration
- (7) "Howard County Storm Drainage Design Manual", Department of Public Works, Bureau of Engineering, Howard County, Maryland
- (8) "Hydraulic Design of Highway Culverts", Hydraulic Design Series No. 5, U.S. Department of Transportation, Federal Highway Administration
- (9) "Maryland Waterways Construction Guidelines", Maryland Department of the Environment

- (10) "Policy and Procedure Manual", Maryland Department of Transportation, State Highway Administration, Office of Bridge Development
- (11) "Structural Standards Manual (Volumes I and II)", Maryland Department of Transportation, State Highway Administration, Office of Bridge Development
- (12) "Interim Manual of Hydrologic and Hydraulic Design", Maryland Department of Transportation, State Highway Administration, Office of Bridge Development
- (13) "SSPC Painting Manual, Volume 2", Society for Protective Coatings
- (14) "Manual for Condition Evaluation of Bridges", American Association of State Highway and Transportation Officials (A.A.S.H.T.O.)
- (15) "Book of Standards for Highway and Incidental Structures", Maryland Department of Transportation, State Highway Administration, Office of Highway Development
- (16) "Guide Design Specifications for Bridge Temporary Works", American Association of State Highway and Transportation Officials (A.A.S.H.T.O.)
- (17) "Construction Handbook for Bridge Temporary Works". American Association of State Highway and Transportation Officials (A.A.S.H.T.O.)
- (18) "Bridge Scour and Stream Instability Countermeasures Experience, Selection, and Design Guidance", Hydraulic Engineering Circulars No. 23. U.S. Department of Transportation, Federal Highway Administration
- (19) "Design of Riprap Revetment", Hydraulic Engineering Circulars No. 11, U.S. Department of Transportation, Federal Highway Administration
- (20) "Hydraulic Design of Energy Dissipators for Culverts and Channels", Hydraulic Engineering Circulars No. 14. U.S. Department of Transportation, Federal Highway Administration
- (21) "Stream Stability at Highway Structures". Hydraulic Engineering Circulars No. 20. U.S. Department of Transportation, Federal Highway Administration

CHAPTER 4

ADEQUATE ROAD FACILITIES TEST EVALUATION REQUIREMENTS

CHAPTER 4
ADEQUATE ROAD FACILITIES TEST EVALUATION REQUIREMENTS

	<u>PAGE NO.</u>
4.1 <u>PURPOSE</u>	4-1
4.2 <u>REQUIREMENTS</u>	4-1
A. Projects Requiring Evaluation/Traffic Study	4-1
B. Level of Service	4-1
C. Study Area	4-1
4.3 <u>TRAFFIC VOLUMES</u>	4-2
A. Existing Traffic Volumes	4-2
B. Projected Site-Generated Traffic Volumes	4-2
C. Projected Background Development	4-3
4.4 <u>ROADWAY CONDITIONS</u>	4-3
A. Existing Roadway Conditions	4-3
B. Proposed Roadway Conditions	4-3
C. Proposed Capital Program Improvements	4-4
4.5 <u>MITIGATION REQUIREMENTS</u>	4-4
A. Project Schedule Deferment	4-4
B. Project Scope Reduction	4-4
C. Roadway/Intersection Mitigation Plan	4-4
4.6 <u>TRANSITIONAL REQUIREMENTS</u>	4-6
4.7 <u>EXEMPTIONS</u>	4-6
A. Exempt Non-Residential Projects	4-6
B. Exempt Residential Projects	4-7
4.8 <u>APPROVAL REQUIREMENTS</u>	4-7
A. Subdivision Approval	4-7
B. Site Development Plan	4-7

CHAPTER 4

ADEQUATE ROAD FACILITIES TEST EVALUATION REQUIREMENTS

4.1 Purpose

This chapter of the Design Manual provides the guidelines for the preparation of the portion of the Traffic Study required pursuant to the Adequate Public Facilities requirements of the Subdivision and Land Development Regulations. The purpose of this portion of the Traffic Study is to determine the level of service of intersections and critical roadway segments within an impact area of a proposed subdivision or land development when the project is phased or completed.

The intent of the Adequate Public Facilities requirements is to direct new development to areas where road facilities are adequate and to require mitigation where deficiencies exist. The developer is required to analyze the intersections and critical links in the vicinity of the proposed development and pass the test for adequate road facilities as a condition of subdivision and land development approval.

4.2 Requirements

A. Projects Requiring Evaluation/Traffic Study

An Adequate Road Facilities Test Evaluation is required in most cases for property going through the subdivision and/or land development process and is to be submitted with the first submission to the County. The development must pass the test or have an approved mitigation plan, if necessary, to proceed through the process. This evaluation will show the traffic conditions on the collector and higher classified highway intersections in the vicinity of the project. The evaluation will be based upon the scheduled phase and/or completion year of the project. All projects that are not classified as comprehensive or phased are classified as Conventional Projects and the analysis time frame will be three years (e.g., 2005 - 2008) from the first submission to the County. Projects that are zoned new town, planned golf course community, mixed use, R-A-15, and any zoning district with a planned development (P.D.) overlay are considered comprehensive projects and/or phased. For comprehensive and phased projects, the developer is required to submit a phasing and completion schedule, which will be the basis for establishing the test years.

B. Level of Service

The intersection level of service (LOS) standard for this evaluation for County-controlled intersections is LOS D and the standard for State-controlled intersections is LOS E. The intersection level of service criteria is for the overall intersection.

C. Study Area

Projects are required to evaluate the designated intersections in the impact area of the site. The impact area of a project is defined as follows:

- **IN PLANNED SERVICE AREA FOR PUBLIC WATER AND SEWER** - In that portion of the County in the Planned Service Area for Public Water and Sewer, an "Impact Area" means an area up to one and one-half road miles in all directions from each project entrance on a County or State road, but not beyond the intersection of a major collector or higher classified road with a major collector or higher classified road. The first intersection in all directions that meets this definition shall be evaluated.
- **IN NO-PLANNED SERVICE AREA FOR PUBLIC WATER AND SEWER** - In that portion of the County in the No-Planned Service Area for Public Water and Sewer, an "Impact Area" means an area up to two road miles in all directions from each project entrance on a County or State road, but not beyond the intersection of a minor collector or higher classified road with a minor collector or higher classified road. The first intersection in all directions that meets this definition shall be evaluated.

When a project's impact area crosses the Planned Service Area Boundary, the boundary limitations and intersection evaluation criteria will change to the applicable standards of the service area entered.

Classifications of the roadway segments in the intersections will be governed by the General Plan Highways Map. The General Plan Highways Map will be used to establish which intersections will be analyzed in the Adequate Road Facilities Test Evaluation except as provided in Section 4.4.

4.3 Traffic Volumes

An Adequate Facilities Test Evaluation will be conducted in accordance with the procedures and technical standards identified in Chapter 5. Each intersection is required to be analyzed for the end of each scheduled phase and/or scheduled completion year of the project. The intersection will be tested with the traffic volumes that consist of the following components:

A. Existing Traffic Volumes

Existing traffic volumes that have been field counted at the intersection as of the date the developer submits the application for approval of the project to the Department of Planning and Zoning.

B. Projected Site-Generated Traffic Volumes

The project's projected site-generated traffic volumes at the intersection in the scheduled phase and/or completion years.

C. Projected Background Development**1. Unrecorded Previously Approved Development**

Traffic volumes projected for the intersection from other proposed subdivisions and site development plans that have passed the test for adequate road facilities prior to the submission of the application for approval of the project but not yet recorded (if not previously counted).

2. Recorded Previously Approved Development

Traffic volumes generated by subdivisions or site development plans that were recorded or approved prior to submission of the application for approval of the project and are scheduled to be completed before or during the scheduled phase and/or completion year of the proposed project (if not previously counted).

3. Background Traffic Growth Rate

Background traffic growth of 3% per year compounded for up to three years or other rate if adequate traffic data exists to support a change. Comprehensive or phased projects will use a background traffic growth of 6% compounded per year beyond year three in the study. The developer may propose or the Department may require different background traffic growth rates if validated field counts and other traffic data about the intersection support a different rate.

4.4 Roadway Conditions

The analysis of the intersections shall be based upon:

A. Existing Roadway Conditions

Actual existing intersection conditions in existence as of the date the developer submits the application for approval to the Department of Planning and Zoning for the project.

B. Proposed Roadway Conditions

New road facilities or improvements to existing road facilities that are included in developer's mitigation plans submitted prior to date of application of the project to the Department of Planning and Zoning. These plans shall be included in the evaluation if they are scheduled to be completed before or during the scheduled phase, and/or completion year of the proposed project.

C. Proposed Capital Program Improvements

New road facilities or improvements to existing road facilities identified in the County's current Capital Program or extended Capital Program as defined in Title 22 of the Howard County Code and/or the Maryland Consolidated Transportation Program for which sufficient funds have been included so that the facilities will be substantially completed before or during the scheduled phase and/or completion year of the project, unless the Director of Public Works determines that such facilities or improvements are not likely to be completed by that time.

4.5 Mitigation Requirements

When the analysis of an intersection indicates that the level of service will be below the adopted level of service standard, the developer shall revise the project with one or more of the following actions:

A. Project Schedule Deferment

Defer the project until a future date when the Adequate Road Facilities Test Evaluation indicates that the level of service standard will not be exceeded.

B. Project Scope Reduction

Reduce the scope of the proposed project to meet the level of service standard.

C. Roadway/Intersection Mitigation Plan

Develop a mitigation plan for the intersection(s) that will increase the capacity on road facilities in the impact area so that the level of service after construction of the project would be equal to the level of service if the project had not been constructed but not more than the minimum level of service. Mitigation means the funding of improvements by the developer, approved by the Department, to off-site road facilities. Mitigation measures may include any intersection capacity improvement except grade-separation of the roadways and ramps within the intersection or improvements to the through lanes of intermediate arterial and higher classified roads. Please note the following:

- Existing Traffic Signal Modification: For existing traffic signal(s), mitigation may initially appear possible by adjustments in the signal phasing and/or timing. In reality, this is rarely possible due to signal coordination, storage of queued vehicles, etc. The developer is required to obtain advance approval from the agency responsible for the existing traffic signal maintenance prior to proposing modification to signal as a mitigation measure.
- Grade Separation: When grade separation of the intersection is the only viable mitigation alternative, full mitigation will not be required. When grade separation of an intersection or improvement to the through lanes is the only feasible alternative to providing mitigation, the County will program these improvements into the Capital Improvement Budget request for consideration of adoption. This request will be based

upon receiving a payment in lieu of the cost of the partial mitigation from the developer.

1. Shared Developer Mitigation Plan

When two or more developers are proposing mitigation plans for the same intersection, the Department will apportion the improvements between the parties based upon their proportion of the critical movements in the intersection. In the event that the timing of the development, technical infeasibility, or other factors do not allow the apportionment of the improvements, the Department shall collect from each developer the proportionate cost of the improvements corresponding to the development's proportion of the critical movements in the intersection. The funds collected will satisfy the developer's obligation for mitigation for the affected intersection. These funds will be collected on the basis that these funds will be programmed into a future Capital Project for the purpose of improving the intersection to mitigate the traffic generated by the multiple projects.

2. Capital Project Impact

When a developer's mitigation plan is proposed with a time frame that shows that a future capital project by the State and/or County will remove or negate the intersection improvements, the Department may waive the improvements and collect the estimated construction costs of the mitigation. These funds will then be programmed into a future Capital Project. Alternately, the improvements may be delayed to a certain date if a major facilities agreement is executed guaranteeing the improvements and the time schedule. If a proposed mitigation plan provides only temporary improvements due to proposed improvement plans for the road facility by others, a waiver may be granted for the improvements if the waiver does not cause traffic safety problems. In the event that a waiver is granted, the developer will be required to enter into a major facilities agreement to pay the cost of mitigation to the County, which will be used to help fund the cost of a Capital Project for future road facility improvements.

3. Constrained Roadway Impact

When a developer is required to evaluate a traffic capacity-constrained road facility, the Adequate Road Facilities Test Evaluation is still required. In the event that the level of service is below the standards in this manual, a mitigation plan is required. However, mitigation will be required to the extent that the mitigation plan improvements do not have a negative impact on the physical and right-of-way characteristics that have caused the constrained road facility to be designated. The developer may obtain the listing of constrained road facilities from the Department. The listing of constrained road facilities will be established by a resolution of the Howard County Council.

4.6 Transitional Requirements

If a project in the submission process has received sketch plan, preliminary plan, or final plan approval prior to the effective date of the Adequate Public Facilities Ordinance, an Adequate Road Facility Test Evaluation is not required provided that the project continues to meet the milestones established in the subdivision regulations.

If a project passes the test but is deferred because it cannot receive a school allocation, the Department may require an update of the data for Adequate Road Facility Test Evaluation and accompanying mitigation plan provided that the changes to the plan do not increase the cost of mitigation.

Once a subdivision has passed the Adequate Road Facilities Test Evaluation, no further approval for adequate road facilities for that project is required provided that the project's milestones are met, the developer executes a developer agreement and/or major facilities agreement for the proposed mitigation plan, the project is recorded, and in the case of site development plans, the traffic volume from the project does not exceed the traffic volume in the traffic study that formed the basis for passing the test during the subdivision plan approval process. If the traffic volume exceeds the volumes in the subdivision traffic study, the site development plan will be tested for the excess traffic.

4.7 Exemptions

Projects which do not generate any traffic are exempt from the requirement of submitting and passing the Adequate Road Facilities Test Evaluation. Site Development Plans which do not increase the traffic beyond what is already generated from the site at the time of application are exempt from submitting and passing the Adequate Road Facilities Test Evaluation. In order to obtain the exemption, an affidavit must be submitted and approved which provides an explanation of why no additional traffic is generated.

The following projects are exempt from the requirements of passing the Adequate Road Facilities Test Evaluation:

A. Exempt Non-Residential Projects

1. Non-Residential Subdivision Plans

- a. A non-residential resubdivision (see subdivision regulations)
- b. An exempt Government Facility, as follows:

- 1) A facility to be owned or operated by the Federal Government, State Government, Howard County Public Schools, or any agency thereof.

- 2) A facility owned by Howard County or any agency thereof where essential County Government services are provided, including police services, fire prevention and suppression services, emergency medical services, highway maintenance, detention facilities, water treatment and supply, sewage disposal and treatment, and solid waste disposal.

2. Non-Residential Site Development Plans

- a. An exempt Government Facility as defined in Section 4.7.A.1.b.2). above.

B. Exempt Residential Projects

1. Parcel Divisions (see Subdivision and Land Development Regulations)
2. Exempt Divisions (see Subdivision and Land Development Regulations)
3. Subdivisions in agricultural preservation districts for dwellings of the owner or the owner's child(ren).
4. Residential Resubdivisions (see Subdivision and Land Development Regulations) that do not increase the unit of housing units allowed.
5. Minor Subdivisions
6. Residential Site Development Plans for single family attached and detached housing.

4.8 Approval Requirements

A. Subdivision Approval

Once a subdivision has been approved for Adequate Road Facilities, no further approval for Adequate Road Facilities for that project is required during the subdivision or site development plan approval process, provided that:

1. The developer continues to meet all required milestones;
2. The developer executes a major facilities agreement for any proposed mitigation;
3. The project proceeds to recordation and is recorded; and,
4. The traffic volume from the project in the site development plan traffic study does not exceed the traffic volume in the projected traffic study that formed the basis for passing the Adequate Road Facilities Test during the subdivision plan approval process. If the traffic volume in the site development plan exceeds the traffic volume in the subdivision traffic study, the site development plan will be tested for the excess traffic only.

B. Site Development Plan

1. Once a site development plan has been approved for Adequate Road Facilities, no further approval for Adequate Road Facilities is required, provided that the developer executes a developer agreement and/or a major facilities agreement for any proposed mitigation.

CHAPTER 5

TRAFFIC STUDIES

**CHAPTER 5
TRAFFIC STUDIES**

	<u>PAGE NO.</u>
5.1 <u>INTRODUCTION</u>	5-1
5.2 <u>TRAFFIC STUDIES</u>	5-1
A. General	5-1
B. Level of Service Studies	5-5
C. Safety Studies	5-9
D. Pedestrian/Bicyclist Studies	5-9
E. Parking/Access Studies	5-11
F. Noise Studies	5-12
5.3 <u>INTERSECTION TRAFFIC CONTROL DEVICES</u>	5-15
A. Traffic Signals	5-15
B. Roundabouts	5-15
C. Alternate Traffic Control Devices	5-16
5.4 <u>TRAFFIC SIGNING AND PAVEMENT MARKING</u>	5-16
A. General	5-16
B. New Subdivisions	5-16
C. Capital Improvement Projects	5-17
5.5 <u>STREET LIGHTING</u>	5-17
A. Street Lighting along Roadways/Streets	5-17
B. Street Lighting at Intersections	5-19
C. Parking Lot/Area Lighting	5-20
5.6 <u>MAINTENANCE OF TRAFFIC DURING CONSTRUCTION</u>	5-20
5.7 <u>AT-GRADE RAILROAD CROSSINGS</u>	5-21

CHAPTER 5

TRAFFIC STUDIES

5.1 Introduction

The prime functions of roads and intersection are the movement of traffic, both vehicular and pedestrian, and the provision of access to adjacent land. If a road or intersection is designed without consideration of these functions and the degree to which it will be required to perform them, it may quickly become obsolete. The purpose of this chapter is to provide principles and guidelines for the design of safe, efficient, and coordinated road and street systems.

The road and street classification system set forth in Chapter 1 contains criteria for classifying roads based on their function and includes information concerning traffic control and typical roadway sections. This chapter presents methods of predicting the traffic volume and the analysis techniques for evaluating the impact on roads and intersections. Roads and intersections are discussed and procedures are outlined for analyzing and designing the intersection to provide safe traffic operations at an acceptable level of service. Guidelines are set forth to assure adequate accommodation for pedestrians and bicyclists, parking facilities, and noise impacts for the intended land use. Requirements for traffic control devices, such as signs and signals, as well as street/highway/intersection lighting and at-grade railroad crossings, are presented. Problems associated with maintenance of traffic during construction are also discussed.

5.2 Traffic Studies

A. General

There are four types of traffic studies: (1) level of service, (2) safety, (3) pedestrian/bicyclist, and (4) parking/access. Level of service studies attempt to balance the traffic supply and demand imposed on road and street intersections. Safety studies are conducted to determine the pattern of past traffic crashes (accidents), identify the cause, and develop means to alleviate the problem. Pedestrian/bicyclist studies are concerned with the number of pedestrians/bicyclists and their safety. Parking/access studies identify the need for parking spaces and parking regulations, both on and off-street, and evaluate access to/from the adjacent roadway.

In combination, when conducted properly, these studies ensure that proposed roadways and intersections, whether designed as part of a capital improvement project or a subdivision, will be capable of performing their intended purpose safely and efficiently and will become a part of a balanced and coordinated transportation system.

Project plans shall be consistent with the approved traffic study. If a change in land use or a major revision to the project's plans is made, a revised traffic study is required.

1. Scope of Studies

Not all projects will require a detailed traffic study. Certain capital improvement projects, such as the realignment of a two-lane rural minor arterial, may not require any parking studies. New developments will not generally be concerned with safety studies because the roads are proposed rather than existing, so there will be no crash history to study. Some developments such as small residential subdivisions may require only very limited

studies to evaluate known specific problems. However, all projects are required to conduct an Adequate Road Facilities Test Evaluation as outlined in Chapter 4.

As there is considerable variety in the scope and purpose of capital improvement projects, so will there be considerable variety in the traffic studies required. Resurfacing and minor widening projects will not normally require traffic studies, whereas a thorough analysis may be needed for the relocation or reconstruction of a major existing intersection. Each project should be judged individually and the Department shall have final authority as to the determination of which studies are appropriate and are to be performed.

All projects, regardless of size, require that sufficient provisions are made for pedestrians, bicyclists, and vehicular parking. Compliance with Howard County's "Subdivision and Land Development Regulations" provides requirements for these needs and consequently pedestrian and parking studies are not required to be submitted. However, level of service and accident studies, where appropriate, shall be performed for those projects which will generate sufficient traffic to have a significant impact on existing facilities. These will include, but not be limited to, all subdivision and/or land developments of an ultimate size that generate greater than 100 peak hour trips in the morning or evening. Subdivisions and/or land developments which generate less than 100 peak hour trips may be required to perform a traffic study if the level of service (LOS) of intersections within the study area is below (worse than) LOS D.

Site development plans do not have to provide an additional traffic study if the study approved with the original subdivision is still valid. All traffic studies shall be required to include Level of Service Analysis for intersections within a 1/2 mile radius from the development. Local street intersections generally do not have to be analyzed unless known operational problems exist at those intersections. Low volume intersections with no known operational deficiencies do not have to be analyzed.

2. Study Report Format/Presentation/Content

Though the extent and content of traffic study reports will vary with the needs of the projects being studied, certain guidelines are applicable to all such reports.

The following information, when applicable/appropriate, shall be included in the report:

- Cover Sheet (include name and location of project, developer, Design Professional, date, etc.)
- Table of Contents
- Scope and Purpose
- Summary of Existing Conditions and Description of Proposed Development
- Design Criteria – design data shall be within one (1) year of Sketch Plan submittal with school in session
- Level of Service Study of Intersections and Links- include volumes, level of service and required geometrics (number of lanes, length of turning lanes, etc.)

- Safety Study (if appropriate) - include accident history, analysis, conclusions and proposed improvements
- Pedestrian/Bicyclist Study (if appropriate) - include projected pedestrian needs and methods proposed to provide for them
- Parking Study (if appropriate) - include projected parking demand and proposed accommodations
- Summary of Conclusions and Recommendations - roadway classifications, traffic signals, auxiliary lanes, etc.
- Appendix - include calculations, sketches, backup data, etc.

All reports shall be typewritten and reproduced on 8-1/2" x 11" paper. Maps, charts, tables, diagrams, and other supporting data often help clarify the presentation and should be included as needed. Maps showing existing and proposed streets and traffic data, major traffic generators, accident locations, and parking areas add greatly to the clarity of the report. The scale of maps may vary to meet their intended purpose.

For Capital Projects, five (5) copies of the report shall be submitted to the Department of Public Works. Developers shall submit reports to the Department of Planning and Zoning at the time of the first submission to the County.

All traffic study reports must be signed by a Registered Professional Engineer and are subject to review and approval by the Chief, Bureau of Engineering for Capital Projects and/or Chief, Development Engineering Division for Developer Projects.

The developer's Traffic Engineer should consider the following items during the preparation of the traffic study. If relevant, these items must be discussed, and a remedy to any problem detailed. Items for consideration include but may not be limited to:

- Level of Service Analysis
- Conflict Analysis
- Signalization Analysis
- Additional Right-of-Way Needed
- Additional Pavement
- Acceleration and Deceleration Lanes
- Analysis for Additional Turn Lanes
- Storage Requirements
- Queuing Analysis
- Crash Mitigation

If phased development is involved, each of the above items shall be analyzed for each phase and the twenty (20) year planning horizon. The planning horizon analysis is used for determining and reserving ultimate right-of-way needs.

3. Design Year and Ultimate Development Year

To ensure that a roadway and intersection are able to fulfill their intended purpose, they shall be planned to meet the traffic demand which is expected at various given times in the future. Traffic studies shall evaluate the scheduled phase and/or completion years of the project and the twenty (20) year planning horizon.

Volume characteristics of County road classifications are summarized in Appendix A, Chapter 1. The volume characteristics are provided as a guide for design purposes and should not be used for classifying roads. Classification has been established by function in the General Plan.

Table 5.01 indicates the daily service (average daily traffic) volume that specific classifications of roadway are expected to convey in the ultimate (20-year planning horizon) scenario. LOS D is the general County requirement except for constrained roadways.

The design year for capital improvement projects will be designated by the Department of Public Works.

When appropriate, consideration should also be given to conditions expected to exist at various time intervals between the scheduled phase and/or completion years so the possibility of staged construction can be evaluated.

Table 5.01 – Daily Service Volume for County Roadway Classifications

Roadway Classification – # Lanes			Service Volume (vehicles per day)		
			LOS C	LOS D	LOS E
Urban/Suburban Areas	Principal Arterial & Freeways	4-Lane	47,400	61,600	75,800
		6-Lane	71,000	92,350	113,700
		8-Lane	94,800	123,200	151,600
	Undivided Intermediate & Minor Arterials	2-Lane (10' lanes)	8,100	8,900	9,700
		2-Lane (12' lanes)	9,800	10,800	11,800
		4-Lane (12' lanes)	20,800	22,900	25,000
Rural Areas	Divided Intermediate & Minor Arterials (At-Grade Intersections)	4-Lane	23,900	26,300	28,700
		6-Lane	35,700	39,250	42,800
		8-Lane	46,900	51,600	56,300
	Minor Arterials & Major Collectors (Low standards, no traffic signals; typically 10' lanes, restricted sight distance, poor lateral clearance)	2-Lane	4,700	5,900	7,100
	Minor Arterials & Major Collectors (High standards, no traffic signals; generally more recently constructed with 12' lanes, good passing sight distance, good lateral clearance)	2-Lane	8,200	10,000	11,800
		4-Lane	21,700	32,600	43,500
		6-Lane	32,600	48,950	65,300

Source: Adapted from the 1980 Howard County Network Study with interpolation for LOS D and the addition of more specific classification titles.

The purpose of Table 5.01 is to relate a projected average daily traffic (ADT) volume for the 20-year planning horizon to the cross-section of a representative County classification of roadway which in general can convey the expected traffic flow at a desired level of service. The functional classifications described in the General Plan and the Design Manual serve as a guide for roadway width, lanes, and right-of-way. More specific detail is needed as a foundation for design. Typically, this is presented in Capital Projects' alignment studies and/or approved traffic analyses.

B. Level of Service Studies

1. General Requirements

When analyzing intersections in the study, the latest version of the Maryland State Highway Administration's (MSHA) Critical Lane Volume (CLV) analysis procedures is the method to be used.

Level of Service (LOS) is a qualitative measure of operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and driving comfort and convenience. Six Levels of Service, lettered A through F, have been established to represent a range of operating conditions and the driver's perception of those conditions. Level of Service A is characterized by free-flow speeds and freedom to maneuver, while Level of Service F is characterized by stop-and-go traffic and excessive delay. Safety is not included in the measures that establish service levels.

The minimum level of service to be used in planning of roads and intersections shall be Level of Service D. The standards for design are different from the requirements of the Adequate Road Facilities Test Evaluation as outlined in Chapter 4. When a design is proposed as part of a mitigation plan for passing the test for Adequate Road Facilities Test Evaluations, the applicable provisions of Chapter 4 should be used. The Traffic Engineer should clearly differentiate in the traffic study the separate analysis.

By specifying a level of service and the traffic volumes desiring to use a given road, the geometrics required to provide that level of service can be determined. There are three steps to be conducted in the study as follows: Collection of current data, projection of traffic data, and level of service analysis. When these studies are properly conducted and their results are taken into consideration in design, the road should be capable of serving its intended purpose.

2. Collection of Existing Data

When the project being studied involves an existing road facility, the first step in the level of service study is the determination of existing conditions. This includes not only volumes but, where appropriate, the type of traffic (trucks, buses, cars), directional distribution, turning movements, and roadway data (width, etc.). This information is necessary to determine the existing level of service and the expected level of service in the future if no improvements are made.

Roadway Information Required:

- a. Pavement & Lane Widths
- b. Number of Lanes & Lane Configuration

- c. Presence of Parking
- d. Grades
- e. Distance to Lateral Obstructions
- f. Average Highway Speed
- g. Percent of passing sight distance greater than 1500 feet (on two-lane highways only)
- h. Intersection Signal Timing & Phasing

The above information can be obtained from the Department of Public Works and/or a field inspection.

Traffic Information Required:

- a. ADT (Average Daily Traffic) - total number of vehicles passing a given point on an average day (if needed).
- b. DHV (Design Hourly Volume) - the number of vehicles passing a given point during the peak hour of an average day (or weekday in industrial areas). On two-lane roads, the DHV is the total number of vehicles, bi-directional, whereas on other highways, it is divided into directional flows.
- c. PHF (Peak Hour Factor) - the ratio of the design hourly volume to the peak rate of flow (PRF) expanded to one hour. For intersections, the peak rate of flow is measured in fifteen-minute periods, while on roadways it is measured in five-minute periods; i.e.,

$$\begin{aligned} 15 \text{ minute peak volume} &= 200 \text{ vehicles} \\ \text{PRF} &= 200 \text{ veh.} \times 60 \text{ min./hour} / 15 \text{ min.} = 800 \text{ vehicles/hour} \\ \text{PHF} &= \text{DHV} / \text{PRF} \end{aligned}$$

- d. D (Directional Distribution) - percentage of the DHV oriented in the predominant direction. The directional distribution is needed on all existing intersections and shall be determined by actual counts.
- e. K-Factor = DHV/ADT - this information shall be supplied when appropriate.
- f. T (Truck Percentage) - percentage of trucks in the DHV. The truck percentage shall be applied when appropriate. In residential and other areas not strictly influenced by commercial or industrial land use, the truck percentage shall be assumed to be 5%. In commercial and industrial areas or in any location with a large number of trucks, the truck percentage shall be determined by actual counts.

Sources of traffic information include:

- a. State Highway Administration
- b. Department of Public Works

If traffic data are not available from the above sources, counts will have to be made and converted to an ADT and DHV. A useful source to convert is MSHA Highway Information Services Division's "Maryland Highway Traffic Trends" (go to <http://www.marylandroads.com/traffictrends2>). The factors for the station in

“Maryland Highway Traffic Trends” nearest to the study site should be used (unless the nearest station is on an interstate route).

Though the Department of Public Works will furnish any current data available in its files, the assembly of the data for analysis is the responsibility of the applicant.

3. Projection of Future Traffic Volumes

To ensure that an intersection will be capable of accommodating the demand imposed on it at an acceptable level of service for a number of years beyond its construction, it is necessary to predict future traffic volumes. Changes in the trends of development and income are but a few of the factors that can alter traffic patterns and consequently change projected volumes. Therefore, a necessary requirement is to carefully consider the anticipated future needs in determining traffic volumes for the scheduled phase and/or completion year of the project.

There are three primary components associated with traffic projections: existing traffic volume, background traffic growth, and traffic volume generated by new development. Background growth is that attributable to a generally increasing population and income, overall development, and increased use of the automobile. When considering future volumes, each of these categories must be analyzed individually and then combined for their total impact on a facility.

Existing traffic volumes can be determined by methods set forth in the previous section.

Background traffic growth shall be projected at 3% per year compounded for the first three years of a project. In year four and beyond, background traffic growth shall be projected at 6% per year compounded. Other background traffic growth rates may be proposed by the developer or required by the Bureau of Engineering or Department of Planning and Zoning if validated field counts exist and other traffic data exists to support a different projection.

Traffic volumes generated by new development shall be based upon the median values in the most current edition of the Institute of Transportation Engineers (ITE) publication “Trip Generation” that most closely reflect proposed subdivisions and land development plans. These volumes shall be based on those projects which have been recorded but not yet built and any other projects which have been submitted to the County at the time of submission of the traffic study to the County.

Caution and judgment must be exercised in applying the trip generation rates. The availability of mass transit, extensive carpooling, schools within walking distance of homes, and multiple shift industries may warrant their modifications. In addition, the orientation of trips must be considered.

The use of trip generation rates other than those in ITE’s “Trip Generation” is subject to review and approval by the Chief, Bureau of Engineering or Department of Planning and Zoning.

When projecting traffic from projects, accurate determination of the number and type of generation units (i.e., dwelling units, floor area, etc.) is of the utmost importance though the information is generally readily available, when considering a specific subdivision, there may be a multiplicity of proposed land uses along the road under consideration

which are in various stages of development, and the determination of the number and type of generation units for the scheduled phase and/or completion year of the project is then not such a straight-forward procedure. The Department of Public Works and/or Department of Planning and Zoning shall be consulted when making this projection.

4. Level of Service Analysis

a. General

The level of service analysis can be used in several ways. The existing level of service, the level of service at some future date if no improvements are made, and the geometrics required to provide a desired level of service for a specific volume of traffic can be determined.

A complete level of service analysis may require the study of more than one time period. The peak flow normally occurs twice per day: once in the morning (AM) and once in the evening (PM). The predominant movement during the AM peak is away from residences and toward employment areas, whereas the opposite occurs during the PM peak. Consequently, both of the peak periods should be considered. Normally the hours of peak traffic to and from a development will coincide with the hours of the adjacent peak highway traffic, but cases in which this does not occur are fairly common. An example is a shopping center located along a minor arterial. Though the peak flow on the arterial may occur between 5:00 and 6:00 PM on weekdays, the shopping center's peak may occur on a Saturday afternoon between 2:00 and 3:00 PM. Such a situation may require analysis for several time periods. The normal procedure, however, is to analyze the DHV's developed by traffic projection for the AM and PM peak hours.

b. At-Grade Intersection (Interrupted Flow)

At-grade intersections can be controlled by several means, such as basic right-of-way rule, yield, two-way stop, four-way stop, roundabout, and signalization. The level of service analysis assures signalization, but is also applicable to intersections controlled by other means (e.g., roundabout, continuous flow intersection).

c. Level of Service Studies Results

The primary function of a level of service study is the determination of the intersection geometrics required to provide a desired level of service in the design year.

The number of lanes required on either a through road or at an intersection can be determined and the need for auxiliary lanes as well as their length can be established.

The need for signalization can be determined from the projected traffic volumes and the intersection designed to accommodate it.

When used in conjunction with the parking study, the level of service study indicates where on-street parking will have to be eliminated and thus where additional off-street parking may be needed.

Where a development in a given area is projected to be phased over a long period of time, staged construction should be considered and the level of service study used to

determine when the various stages of construction should be proposed for completion.

C. Safety Studies

Often a proposed project, either subdivision or capital improvement, will be in an area of frequent past crashes, the study of which can help minimize any detrimental effect the proposed development might have, as well as make possible the incorporation of design features which may alleviate the existing hazardous conditions.

Crash records are available from the Howard County Department of Public Works' Traffic Division and the State Highway Administration's Traffic Safety Analysis Division. The records from at least the previous three (3), and preferably five (5), years should be obtained and cover all sections of road that may be directly impacted by the proposed project.

Upon accumulation of the records, the data must be organized in a manner to facilitate analysis. The most common method of presentation is the collision diagram, which includes pertinent roadway characteristics together with sufficient information regarding the crashes to recognize any patterns that may exist.

The collision diagram should be carefully studied to determine the cause or causes of crashes and possible remedies. Crashes involving rear-end collisions with left-turning vehicles or vehicles swerving to avoid left-turning vehicles may indicate the need for a separate left-turn lane. Numerous right angle collisions at a stop-controlled intersection may reflect inadequate sight distance or the need for signalization. Crashes occurring under certain environmental conditions, such as during the night or rain, may indicate the need for lighting or special skid resistance treatment of the pavement.

The results of such an analysis can be used to design safety improvements to be combined with the proposed project. They may indicate a better location for a development's primary access intersection with an existing road than originally planned, or the County may decide to build a left-turn lane on an existing road in conjunction with improvements planned for a development.

When a safety study concludes that significantly high crash rates exist at a project site because of roadway and/or intersection deficiencies, an improvement plan must be submitted to correct the problem as part of the traffic study.

D. Pedestrian/Bicyclist Studies

Safety and general community well-being is greatly enhanced by consideration of and provision for pedestrian and bicyclist needs. Careful planning and design of sidewalks, separate walkways and/or bike/pedestrian paths/trails, and the intersection of pedestrian and vehicular paths benefit not only pedestrians but also motorists due to the removal of pedestrians from the roadway.

In general, all curbed roadways shall be flanked with at least one sidewalk to prevent pedestrians from using a vehicular travel way. For Developer projects, consult the "Subdivision and Land Development Regulations" for sidewalk requirements on Subdivision Roads.

The needs of pedestrians can be determined in several ways. Review of the zoning map and submitted development plans should give insight as to what areas may be subject to heavy

pedestrian activity. Existing problems can be identified by the safety study. Regulations pertaining to sidewalk construction by developers are presented in the "Subdivision and Land Development Regulations".

Sidewalks shall be constructed where required by the "Subdivision and Land Development Regulations". In addition to requiring sidewalks in residential areas, these regulations state that sidewalks may be required within commercial and industrial subdivisions "on advice of the Department of Public Works." Sidewalks in such locations will normally be required because of the substantial number of pedestrians involved and the conflict they experience with vehicular traffic, especially where on-street parking occurs.

Consideration shall also be given to the construction of sidewalks in areas of large pedestrian generators, such as schools, churches, meeting halls, and transit stops.

The "Subdivision and Land Development Regulations" state that consideration shall be given to the provision of pedestrian walkways. Such walkways can improve an area's environment and provide an improved "people" circulation system, especially where facilities along streets are not adequate or where pedestrians can be better accommodated by separated routes. Examples of locations that warrant consideration of walkways are schools where walkways can improve safety and floodplains where they can enhance recreational opportunities. Final determination concerning the land division of a development project with respect to pedestrian walkways will be made by the Department of Planning and Zoning in accordance with the "Subdivision and Land Development Regulations".

The intersection of pedestrian and vehicular paths requires special attention. The intersection should be located so as to maximize the pedestrian sight distance. The crosswalk should normally be located directly in line with the sidewalks on the approach streets. Where there are long radius curbs or flare treatment, the crosswalk should be offset to minimize walking distance within the roadway. For excessively wide streets, medians may be needed to provide pedestrian protection. The crosswalk must be clearly delineated and visible to both driver and pedestrian during both day and night.

Pedestrian overpasses and underpasses are warranted only where there are high pedestrian and/or vehicular volumes, such as at industrial plants, schools, athletic fields, or theaters. Factors to be considered in addition to volumes include age of pedestrians and accident history. As there is a reluctance on the part of pedestrians relative to convenience and security to use these structures unless they are extremely well designed and take advantage of the natural topography, each location must be studied individually.

Though existing pedestrian-vehicle conflicts can normally only be controlled by the means discussed above, the design of new subdivisions offers an excellent opportunity to minimize these conflicts. The provision of walkways, use of cul-de-sacs and looped streets, proper design of street patterns, and judicious location of high pedestrian generators shall be considered in the site planning process.

Consideration shall be given to the disabled in all projects. The intersections of all streets with curb and sidewalk, and all pedestrian overpasses and underpasses, shall be provided with accessible ramps in conformance with the Americans with Disabilities Act (ADA) "Standards for Accessible Design" and Standard Details shown in Volume IV. Rural pedestrian crossing traffic signal indications may be warranted at some locations. Special

problems such as the difficulty of the driver to see a common wheelchair occupant must be recognized and studied.

E. Parking/Access Studies

The provision of adequate and properly located and designed parking is vital to the proper operation of the street network. Poorly designed entrances and exits, or an insufficient supply of parking spaces, can create congestion on what would otherwise be an adequate street, increase crash potential, and lead to reduced sales in business districts.

Off-street parking is often needed to assure an adequate supply of parking, promote traffic flow, and increase safety. Regulations indicating the number of off-street parking spaces and loading facilities needed for various land uses are given in the Zoning Regulations of Howard County.

The design of a parking lot must be such that sufficient off-street reservoir space is provided to store vehicles waiting to enter the facility. Minimum inbound off-street reservoir requirements are given in Table 5.02.

Where refuse containers are required, such as in multi-family developments and industrial areas, sufficient area for them and the trucks serving them shall be included in the parking area.

Principles of off-street parking design (aisle width, stall arrangement, entrance and exit location, etc.) are presented in Chapter 2.

Table 5.02 - Minimum Inbound Off-Street Reservoir Requirements¹

Land Use	Reservoir Requirements ²
Drive-In Bank (ATM)	5 spaces per lane or 8 spaces for first window and 4 for each additional window
Mechanical Car Wash	10 spaces per bay or lane
Fast Food Restaurant	10 spaces per bay or lane
Auto Maintenance/Services	3 spaces per bay or lane
Parking Facility <ul style="list-style-type: none"> • Free-Flow Entry • Ticket Dispenser Entry • Manual Ticket • Attendant Parking 	1 space per entry driveway 2 spaces per entry driveway 8 spaces per entry driveway 10% of that portion of parking capacity served by attendant-controlled driveway

¹ These reservoir requirements may be changed, when deemed necessary, by the Department of Public Works. No vehicle queuing will be allowed on adjacent roadway.

² Each space shall be 22 feet long – Source: Transportation Research Board *Parking Principles*, 1971 Special Report 125.

F. Noise Studies

The health, safety and general community well-being is greatly enhanced by the consideration of and provision for noise abatement or mitigation measures as appropriate in the planning for and development of residential land uses.

1. Noise Level Threshold

An average level of 65 dBA (A-weighted decibels) at the building curtilage is the threshold beyond which the ambient noise level is considered to be unacceptable to the human ear in a noise-sensitive land use environment. It is the responsibility of the developer of any property in Howard County to ascertain that the noise level, based upon ultimate traffic volumes for the General Plan horizon year or 20 years into the future, whichever is more, within and adjacent to the proposed development, shall be below this threshold.

2. Future Noise Level Analysis

The means for projecting future noise levels shall be based upon the Noise Assessment Guidelines published by the U.S. Department of Housing and Urban Development, or Federal Highway Administration's Traffic Noise Model (TNM) as appropriate. Concurrent with submission of a Preliminary Plan, a developer shall be required to submit a noise analysis report to the Department of Planning and Zoning if any of the existing or proposed buildings or their curtilages within or adjacent to the subdivision fall within the following locational guidelines:

1. Located within 1000 feet of an existing right-of-way line of Interstate Route I-95 or that segment of U.S. Route 1 from MD 100 to MD 32 or any other roadway where heavy truck traffic is expected to exceed an ADT of 10,000 vehicles.
2. Located within 500 feet of any other existing or proposed Principal or Intermediate Arterial highway right-of-way line.
3. Located within 250 feet of any existing or proposed Minor Arterial right-of-way line.
4. At the discretion of the Chief, Bureau of Engineering or Department of Planning and Zoning a noise study may be required for any proposed development where, based on unusual conditions, it is determined that noise impacts from an existing or proposed highway or rail line are likely to exceed an average of 65 dBA.
5. Located within 500 feet of an existing or proposed rail line.
6. Located within the approved Airport Noise Zone as established by the Maryland Aviation Administration.

3. Noise Mitigation Requirements

As a prerequisite to Preliminary Plan approval, mitigation measures shall be proposed by the developer to lower the ambient noise level below the 65 dBA threshold within the building curtilage. Building curtilage shall generally be defined as that area of the site which is used for prolonged human activity (see Figure 5.01). The Department of Public Works or Department of Planning and Zoning shall review the noise analysis and mitigation measures to determine their adequacy and appropriateness. Such measures

may include, but not be limited to, noise buffers, noise barriers, building orientation, or the use of acoustical insulation for buildings other than residences.

The following are the noise limit requirements for residential development:

1. The 65 dBA line can come up to the front of the structure;
2. The 65 dBA line can come up to the sides of the structure;
3. The 65 dBA line may not be located on the backyard of a lot with area less than 10,000 square feet;
4. The 65 dBA line may be located at a minimum of 25 feet from the rear building restriction line on lots with area 10,000 square feet or greater. Decks may project 10 feet beyond this envelope; however, applicable zoning restrictions prevail.

In the event that these mitigation measures are not feasible, alternate measures shall be evaluated. Such measures may include increasing unit distances from the noise source, reorienting buildings, their openings, and yards away from the noise source, earth berms, sound walls, heavy evergreen landscaping, etc.

Sound walls shall at a minimum meet construction and product specifications for "Plywall Sound Barrier" by Hoover Treated Wood Products, Inc., or an equivalent. Construction and product specifications shall be included on the appropriate plan for County review and approval.

Building construction materials may be used to reduce interior sound to 45 dBA in residential units if it is agreed by the County that exterior abatement cannot be performed to the 65 dBA standard.

In situations where the Bureau of Engineering or Department of Planning and Zoning determines that lesser setback is allowed, the following standard note shall be added to the record plat or site development plan:

"The contour line drawn on this plan is advisory as required by the Howard County Design Manual, Chapter 5, revised April 2005, and cannot be considered to exactly locate the 65 dBA exposure. The 65 dBA exposure was established by Howard County to alert developers, builders and future residents that areas beyond this threshold may exceed generally accepted noise levels established by the U.S. Department of Housing and Urban Development."

5. All noise evaluation locations shall be measured 5' (average ear level) above the proposed grade or deck elevation at the defined limits found in this section.

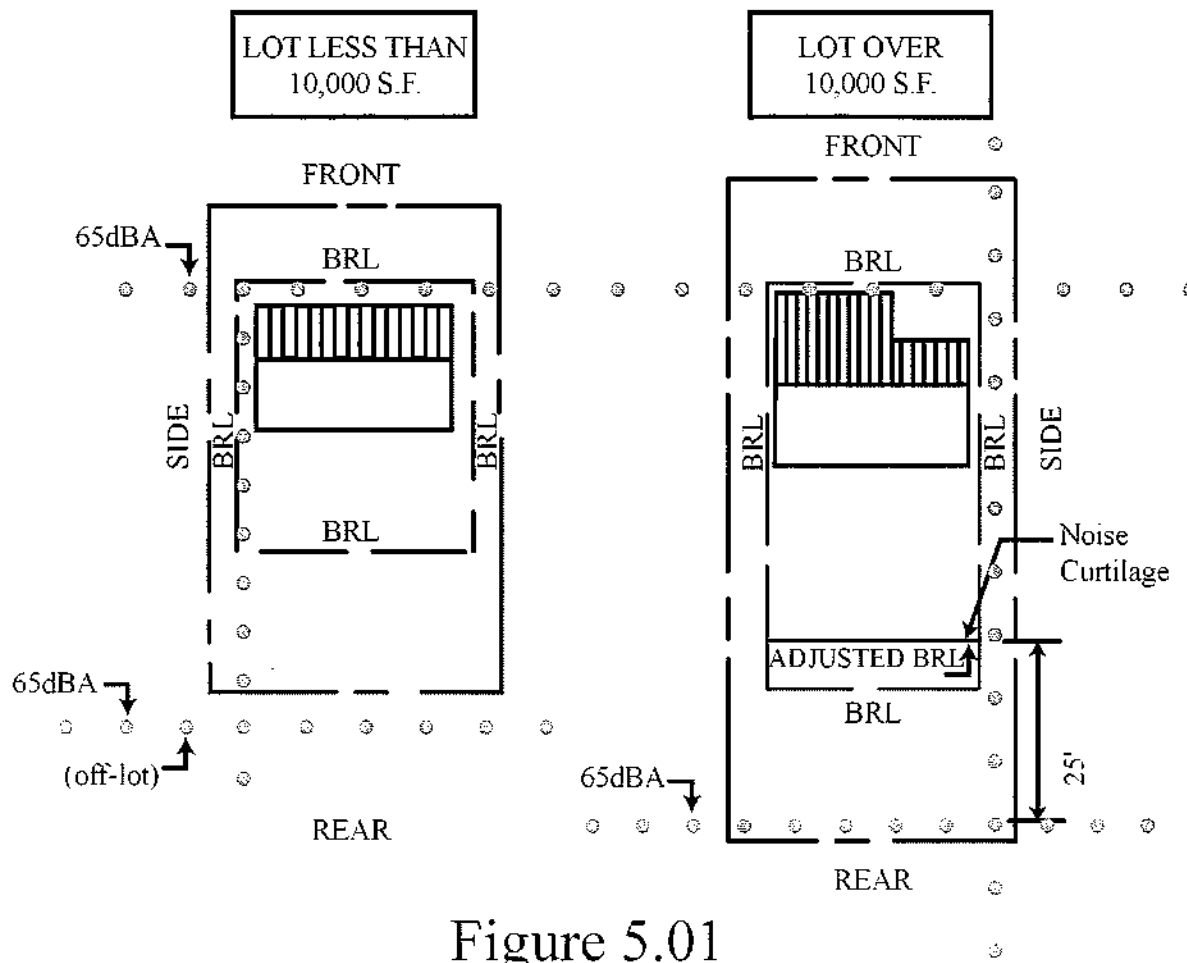


Figure 5.01

5.3 Intersection Traffic Control Devices

A. Traffic Signals

Traffic signals should be installed where it has been clearly demonstrated that they will significantly increase the efficiency of an intersection. The basis for such a determination will be FHWA "Manual on Uniform Traffic Control Devices for Streets and Highways 2003 Edition" or later edition.

Though both the determination of need and design of traffic signals is a function of either the Howard County Department of Public Works or the Maryland State Highway Administration, consideration should be given to their requirements during design of the intersection. The Department of Public Works may require installation of underground conduits and signal supports during the initial construction so as to reduce the cost of and disruption caused by installation of the signal system when it is installed in the future.

Current procedures to be followed and cost responsibility for traffic signals are set forth in the policy directive of the State Highway Administration entitled "Installation and Maintenance of Traffic Signals on the State Highway System" and the latest "Subdivision and Land Development Regulations". The actual cost responsibility for each proposed signal will be determined by the Chief, Traffic Division, Bureau of Highways.

B. Roundabouts

Roundabouts are circular intersections with specific design and traffic control features. These features include Yield control of all entering traffic, channelized approaches, and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 30 mph. The advantages of a properly located and designed roundabout over other intersection traffic control devices include:

- Improved intersection operation – roundabouts can accommodate higher left-turn volumes than other intersection control devices.
- Lower crash rates and crash severity – roundabouts reduce the number of traffic conflict points and vehicle speeds, and provide a clearer indication of the driver's right-of-way compared to other intersection traffic control.
- Cost – roundabouts that do not require significant roadway realignment typically require similar pavement area and right-of-way to a four-legged intersection, while having lower operating costs than a traffic signal.
- Improved Aesthetics – roundabouts also provide an opportunity to improve the aesthetics of an intersection with landscaping in connection with community enhancement projects.

It is important to distinguish that these distinct features of a roundabout are not applicable to other circular intersections, such as rotaries and neighborhood traffic circles. All roundabout studies and design shall be conducted in conformance with MSHA's "Roundabout Design Guidelines June 2004" or latest edition and the Federal Highway Administration's "Roundabouts: An Informational Guide" Publication No. FHWA-RD-00-067.

C. Alternate Traffic Control Devices

Evaluation of alternate traffic control devices (e.g., turn restrictions, channelized left-turn “Florida-T”/half signals, continuous flow intersections) shall be conducted only at the discretion and under the direction of the Howard County Department of Public Works. Traditional intersection traffic control devices such as traffic signals and roundabouts shall be initially studied prior to consideration of any alternate traffic control devices. When considering such alternate traffic control, grade separation shall also be evaluated as an option for comparison purposes.

5.4 Traffic Signing and Pavement Marking**A. General**

Signs and pavement markings, which warn, guide, and regulate traffic, both vehicular and pedestrian, are required to ensure the maximum efficiency of the street system. To do so, however, they must be properly designed and installed. All signs and pavement markings shall be designed according to the FHWA “Manual on Uniform Traffic Control Devices for Streets and Highways 2003 Edition” or latest edition.

B. Standards and Guidelines for Traffic Signs and Pavement Markings in New Subdivisions

These Standards and Guidelines are designed to implement the “Subdivision and Land Development Regulations” that state:

“the developer shall be responsible for... and traffic-control devices.” (Section 16.119, Paragraph 10)

“Traffic Control Devices: Signs, signals, markings, and other devices prescribed to regulate, guide, or warn traffic.” (Section 16.108(b), Paragraph 61).

“The developer shall erect street names signs and traffic-control devices at each street intersection. These signs and devices shall be consistent with this Code and the Design Manual and shall be approved by the Department of Planning and Zoning, after consultation with the Director of Public Works.” (Section 16.137)

The developer shall be responsible for the material and labor costs in connection with installing all traffic signs on new streets within the development. The developer shall also be responsible for all maintenance costs incurred prior to acceptance of the street into the public street system. The cost of installing any traffic signs or pavement markings on existing County roads or streets that may be required as a result of the development will be borne by the developer.

The developer shall submit the signing and pavement marking layouts to the Department of Public Works for review and approval. Upon approval, the developer shall install the traffic signs and markings at his/her own expense. The developer has the option to pay the County to install the traffic signs. The street name signs will be installed by the Department of Public Works, at the expense of the developer.

The following requirements of Howard County shall also be met:

1. All intersections shall be controlled by either stop signs or signals. Traffic entering intersection roundabouts shall be controlled by yield signs, that is, entering traffic shall yield to circulating traffic within roundabout.
2. All pavement markings shall be at least five inches wide.
3. Double-yellow centerline stripes are required on all roadways except local streets and cul-de-sac streets.
4. The minimum R1-1 "STOP" sign size is 30" x 30" and the minimum R2-1 "SPEED LIMIT" sign size is 24" x 30".
5. All sign post used for traffic control signs installed in the County Right-of-Way shall be mounted on 2" galvanized steel, perforated, square tube post (14 gauge) inserted into a 2-1/2" galvanized steel, perforated, square tube sleeve (12 gauge) – 3' long. A galvanized steel pole cap shall be mounted on top of each post.

C. Capital Improvement Projects

The signing and marking of capital improvement projects will be designed by the Department of Public Works unless otherwise directed.

5.5 Street Lighting

Street lighting, where properly designed and installed, can greatly enhance a community's environment. Though lighting is desirable at virtually all locations, economics and concern for energy requirements dictate that it be restricted to those areas which will experience the greatest benefit.

A. Street Lighting along Roadways/Streets

Street lighting installations in new subdivisions shall be in accordance with both the Standards and Guidelines for Street Lighting in New Subdivisions, presented in Section 5.5.A.1 and the current "Subdivision and Land Development Regulations".

When requested, the determination of need for lighting of capital improvement projects shall be made by the Traffic Division, Bureau of Highways. Factors to be considered include roadway width, roadside obstacles, speed, pedestrians, and accident history.

The recommended ratio of average-to-minimum luminance shall not exceed 3 to 1 on arterials, 4 to 1 on collector roadways, and 6 to 1 on all other roadways.

Break-away poles shall be used along arterial roadways. At all other locations, the light poles can be the non-breakaway type.

The street light pole shall be designed to withstand an 80 mph wind. Acceptable street light poles and fixtures for each roadway classification are shown in Table 5.03.

Table 5.03 – Acceptable Street Light Pole and Fixture*

Roadway Classification	Minimum Pole Height (feet)	Pole Type	Fixture	Lamp Size
Residential	14'	Black Fiberglass	Post-top: Premier or Acorn	100w HPS or 150w HPS
Minor Collector	14'	Black Fiberglass	Post-top: Premier or Acorn	150w HPS
Major Collector	30'	Bronze Fiberglass	Pendant: Sag or Cut-off	150w or 250w HPS
	23'	Black Fiberglass	Tear Drop	250w HPS
Arterials	30'	Bronze Fiberglass	Pendant: Sag or Cut-off	250w or 400w HPS
	23'	Black Fiberglass	Tear Drop	250w HPS

* The actual type, spacing and size of lamp will be determined by the Traffic Division/Bureau of Highways/DPW.

The lighting system should be designed in conjunction with the roadway so that the result will be a coordinated facility in which each element complements the other. The relation between lighting and signs and potential obstacles must be carefully considered. Roadside obstacles can often be reduced by the utilization of "joint-use" poles, which can, for example, support both a luminaire and a traffic signal.

1. Standards and Guidelines for Street Lighting in New Subdivisions

These Standards and Guidelines are designed to implement the "Subdivision and Land Development Regulations" that state:

"Unless the Department of Planning and Zoning, after consultation with the Director of Public Works, determines that adequate street lighting already exists, the developer of subdivisions and site developments shall provide street lighting in accordance with the Design Manual..." (ART III, Section 16.135 Street Lighting)

The developer shall be totally responsible for the material and labor costs in connection with installing street light poles and luminaires, including relocations and/or changes made to new or existing lighting systems. The developer shall also be totally responsible for all energy and maintenance costs incurred for a period of two (2) years.

Procedure

- a. After the Road Construction Plan has been approved and signed, the Department of Planning and Zoning, Development Engineering Division (DPZ/DED) shall prepare a cost estimate based on the lighting system designed. The lighting system shall be in compliance with the guidelines set forth herein and shall be selected in accordance with BGE's approved Hardware List.

The cost estimate shall include the following:

- (1) Hardware and Installation costs; and,
 - (2) Energy, Inspection and Maintenance charges for two (2) years (based on the size of the lamp).
 - b. The street lighting layout along with a description of the hardware shall be forwarded to BGE for processing by the Traffic Division, Bureau of Highways.
 - c. The Department of Public Works, Real Estate Services Division upon receipt of a cost estimate from the DPZ/DED, shall begin the Development Agreement process by notifying the developer of all costs associated with the proposed street lighting system.
 - d. Upon receipt of a certified check in the amount of the estimated costs prepared by the DPZ/DED, the Department of Public Works shall authorize the utility company to install the street lighting system in accordance with the street lighting layout.
 - e. When the developer formally petitions the Department of Public Works to accept a roadway(s) and associated improvements into the public system, all damage to any street light pole(s) and fixture(s) as a result of construction or vandalism prior to such acceptance, must be satisfactorily corrected. Personnel of the Department of Public Works shall inspect for damage and correction of same.
2. Street Light Location and Spacing

Along minor collectors and residential roadways street lights shall be installed to provide a lateral clearance of 3 feet from the back of curbs. Along major collector and arterial roadways the lateral set-back shall be a minimum of 4'.

The placement of street lights along County roadways shall be determined by the Traffic Division, Bureau of Highways/DPW based upon the road type, horizontal and vertical alignment, vehicle volume, intersection design, accident history, pedestrian usage, and area zoning (when applicable).

3. Street Light Illumination Levels and Glare

The site plan shall indicate the location and design of outdoor lighting facilities with provision for shading, shielding, or directing lighting fixtures so as not to adversely affect the operation of vehicles or reflect into residential buildings. All lighting facilities shall use standard BGE hardware.

4. Street Lighting at Speed Control Devices

Speed control devices shall have a minimum of one street light as required by the "Subdivision and Land Development Regulations" or as required by the Department of Public Works.

B. Street Lighting at Intersections

All intersections shall have a minimum of one street light. The determination of need for additional lighting, as well as the design of a lighting system, shall be subject to review and approval by the Department of Public Works.

C. Parking Lot/Area Lighting

The minimum illumination levels for all parking areas (public or private) shall comply with the values stipulated in Table 5.04.

Table 5.04 – Parking Areas (Public or Private) - Average Maintained Horizontal Illumination

Commercial			Residential		
Zoning	Minimum Illumination (footcandles)	Uniformity Ratio	Zoning	Minimum Illumination (footcandles)	Uniformity Ratio
H-O	0.9	6:1	R	Not Applicable	Not Applicable
H-C	0.9	6:1	R-ED	Not Applicable	Not Applicable
POR	1.0	6:1	R-20	0.4	6:1
CC	1.2	4:1	R-12	0.4	6:1
B-1	1.2	4:1	R-SC	0.9	6:1
B-2	1.2	4:1	R-SA-8	0.6	4:1
SC	0.9	4:1	R-A-15	0.6	4:1
M-1	0.9	6:1	R-MH	0.9	6:1
M-2	0.9	6:1	R-HR	0.4	6:1
ID	0.6	6:1	R-VH	0.4	6:1
PEC	0.9	6:1			
NT	0.9	4:1			
PGCC	0.6	4:1			

5.6 Maintenance of Traffic During Construction

When designing either an improvement of an existing road or a completely new road, consideration must be given to maintaining traffic during construction. The high traffic volumes often found in areas of construction, coupled with what is normally a long construction period, can result in a complex problem which can make an otherwise acceptable design infeasible. The maintenance of traffic, therefore, must be carefully studied during the design process.

Three methods of maintaining traffic are available. The first is to stage construction so that the existing facility can be used to accommodate traffic during construction. A four-lane highway, for example, can often be reconstructed by marking on no more than two lanes concurrently. During peak periods, it may be necessary to remove equipment and open more than two lanes.

The second means of maintaining traffic is to divert it to adjacent streets over detour routes using existing roadways. One-way patterns, limitation of parking and certain turning movements, rerouting of transit routes and coordinated signals are some of the means by which such a transfer can be successfully accomplished.

Where traffic cannot be satisfactorily accommodated by the first two methods, construction of temporary detour routes will be necessary. An example is the construction of a new bridge over a stream to replace the existing structure with no change in the road alignment. This situation would require a temporary run-around detour road either over other existing roads in the area or via a specially constructed temporary roadway.

As each construction project is somewhat different than any other, no set rules can be given governing the development of the maintenance of traffic plan. Certain principles, however, apply to all situations.

The three means of maintaining traffic should be studied and a plan developed utilizing some combination thereof. Traffic volumes and speeds, capacities of existing roads, the existing street pattern, availability of land for detour routes, and scheduling of construction activities are among the factors that need to be considered.

The roadway, whether in a construction area or a detour, shall be satisfactory to accommodate traffic at a reasonable speed, which is dependent upon speed approaching the roadway and length of project, but normally not less than 30 mph.

Where rail traffic is interrupted, the railroad affected shall be contacted and a maintenance of traffic plan developed which is acceptable to both the railroad and the Department of Public Works.

The signing and marking of all roadways associated with maintenance of traffic shall be in accordance with the FHWA "Manual on Uniform Traffic Control Devices for Streets and Highways 2003 Edition" or latest edition, and shall conform to County or MSHA "Book of Standards Temporary Traffic Control Devices Typical Applications," where possible.

The complete maintenance of traffic plan, including but not limited to the schedule of construction operations as related to traffic maintenance, the number and widths of lanes to be open during various periods of the day, and the alignment, grade, typical section, and construction details of temporary detour roads, shall be included in the contract documents.

Where pedestrians will be affected by road construction, provisions shall be made for them in a manner similar to that for vehicles.

The maintenance of traffic plan is subject to review and approval by the Department of Public Works.

5.7 At-Grade Railroad Crossings

Protective devices at railroad at-grade crossings shall be in accordance with FHWA's "Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)" 2003 Edition or latest edition.