DAVE MORRIS

DESIGN MANUAL

Issued By

GOVERNOR'S
HIGHWAY SAFETY PROGRAM

MISSISSIPPI
STATE HIGHWAY DEPARTMENT

FEDERAL
HIGHWAY ADMINISTRATION

29

FOREWORD

This manual has been developed to provide guidance and assistance to Roadway Design and other Department personnel in the practices and procedures for the detailed design of highways and the preparation of contract plans.

The principal objectives of the manual are:

- to document Department policies with regard to standards of design and procedures for development of contract plans,
- to define criteria to guide judgments and decisions made by Roadway Design personnel,
- to describe the most current and effective design techniques and procedures, and present charts, tables and other information found to be useful by designers, and
- to assure that highway traffic safety factors are adequately considered in the design processes.

Although the manual is directed principally to personnel of the Missisippi State Highway Department, and often reflects specific policies and procedures of the Department, a large portion of the basic information is directly applicable for use by counties and cities. Frequent comments are included to identify variations in standards and procedures adopted by the State Aid Division.

The material in the manual has been reviewed and edited by a committee of Department personnel who are knowledgeable of current design requirements and procedures. A representative of the State Aid Division was included on the committee.

In this first edition, emphasis has been placed principally on compiling and documenting policies and procedures currently being followed as a result of various memoranda and verbal instructions. New and improved procedures were incorporated in the manual when it was evident that they would be more effective and would contribute to increased traffic safety.

Those persons who use the manual can contribute to its continuing improvement by submitting to their supervisor suggestions for ways in which the manual can be made more useful and practical. A committee of persons capable of acting on these suggestions will assemble periodically to review the suggestions and develop recommendations for the Roadway Design Engineer, who will designate the improvements to be incorporated in the manual.

DESIGN MANUAL ORDER

WHEREAS, this Commission proposed to develop and publish a Design Manual which will incorporate in one document safety criteria and design standards or reference to such standards recommended for use in highway design; and

WHEREAS, the Commission has considered and determined and now confirms that the publication and adoption of the Design Manual is proper and necessary.

NOW, THEREFORE, Be It Ordered by this Commission that the Design Manual is an official document of this Commission and that design of highways shall conform to policies, procedures, and standards promulgated by such Design Manual.

ORDERED, This the 27th day of April 1976.

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BOOK 99

PAGE 97

Certified a true and correct copy of the original on file in the offices of the Mississippi State Highway Department, this the 4th day of May 1976.

John R. Tabb

Secretary

TABLE OF CONTENTS

Revisions by Commission Order, Dated July 25, 1978 BOOK 100 PAGE 911

Sheet Nos.	Table of Contents				
Sheet Nos.	2- 3	&	2- 4	
Sheet Nos.	2- 7	&	2- 8	
Sheet Nos.	2- 9	&	2-10	
Sheet Nos.	2-11	&	2-12	
Sheet Nos.	2-13	&	2-14	(2-14 New Sheet)
Sheet Nos.	2-15			(Same as Previous Sheet 2-14)
Sheet Nos.	3- 7	&	3- 8	

Chapter 1

GENERAL DESIGN CONSIDERATIONS

Each year Mississippi makes a large investment in highway construction. The effectiveness of this investment is determined largely by the way in which projects are planned and designed. The purpose of this manual is to provide designers with uniform design criteria and procedures. Specific guides and instructions are presented in the following chapters. This chapter provides an overview of basic objectives, responsibilities and procedures. Special considerations for the Division of State Aid Road Construction are set forth in Chapter 11.

BASIC OBJECTIVE

The basic objective of the road design function is to provide the best possible level of service for highway users--along with maximum safety and economy. Determinations as to levels of service are a part of the overall planning process, where improvement needs are identified, priorities are established and improvement programs are defined. Design standards are adopted which consider all three factors--level of service, safety and economy.

But standards often cannot be sufficiently explicit to assure the best design. Designers must do more than "go by the book." They must exercise good judgment--and frequently they must be innovative.

In addition to assuring adherance to established standards, there is need continually:

- to avoid design details which may inadvertently create traffic hazards.
- to avoid design details which will create maintenance problems and high maintenance costs.
- to be aware of improved design details which may provide equal or better service at less cost.

Above all other responsibilities, designers should continually keep safety in mind.

SAFETY CONSIDERATIONS

For quite some time it had been assumed that most accidents were attributable to some type of driver error. And to some extent this may be true. It is difficult to blame highway design for the single-car accident on a long tangent section of wide modern highway.

But recent research has shown that quite often we inadvertently build in hazards in our highways that contribute to accidents or increase their severity. The "driver's error" may sometimes be caused by the fact that he has been misled by some roadway design feature.

We do not know all the answers yet--but we are learning. Publications of AASHTO and other agencies provide in-depth discussions of highway design practices as related to highway safety. Some of the more significant findings are presented in the following sections. Designers should make certain our past mistakes are not repeated in new construction. All elements of design should be reviewed to ensure that any feature likely to be associated with injury or accident is eliminated or minimized in its effect.

Roadside Design

Special attention must be directed to the safety characteristics of the roadside to ensure deliberate design rather than an unpredictable by-product of construction.

- Slopes. Embankment and cut slopes should be as flat as possible so that a vehicle leaving the roadway will have some chance for recovery. Where economically feasible, 6:1 or flatter slopes should be provided.

- Obstructions. An area adjacent to and 30 feet from the edge of traveled way should be kept free of physical obstructions which might prevent safe vehicle recovery.

- Gore Areas. Avoid heavy structures and unyielding sign supports in the area at the divergence of two roadways.

- Signs. Avoid unnecessary signs. Use breakaway supports. Review signing locations to assure maximum effectiveness and safety.

- Guardrail. The objective of guardrail is to lessen the hazard to highway users, and not to protect any part of the roadway. Guardrail should be used only when the result of striking an object or leaving the roadway would be more severe than striking the rail.

Roadway Geometrics

Minimum geometric criteria for most roadway elements are set forth in the design standards for particular types of highways--criteria for items such as widths, slopes, grades, curvature, clearances, etc. However, the designer must exercise individual judgment for specific applications. And these judgments frequently affect highway safety.

- Design Standards. Design standards more liberal than the minimums prescribed will often increase safety and in some instances may not significantly increase the cost.

- Consistency. Geometric consistency is important to safety. A sharp curve at the end of a long tangent or between two relatively flat curves can be hazardous. This is discussed further in the chapter on horizontal alignment.

- Sight Distance. Adequate sight distance is critical to safety. Check out each vertical curve, intersection, median cross-over, and driveway to make certain that sight distance is not restricted below the standard.

- Critical Areas. Particular attention should be given to the geometric adequacy of certain critical areas--locations such as weaving areas, exit and entrance ramps, at-grade intersections, transitions from new facilities to lower-standard old facilities, and any locations where there is potential for wrong-way travel on a one-way facility.

Driver Expectancy

During recent years highways have become more complex, traffic speeds have risen and traffic streams have become more dense. Existing communication systems between the highway and the driver are sometimes inadequate for one or more of the following reasons: (1) failure to command the driver's attention when it is necessary for him to make a vehicular control decision, (2) failure to convey a clear message, thus leading the driver to make an incorrect decision resulting in improper maneuvers and possibly the loss of vehicular control, (3) provision of too many messages for driver comprehension and proper response, and (4) failure to provide sufficient time for the driver to respond with the correct decision.

The results of research point strongly to the fact that good driver communication is only achieved by proper coordination among all roadway and terrain features and the devices used to guide, warn, regulate or control traffic operation. It has been shown that driver expectancy plays a very important role in driver communication. The driver uses the geometric configuration, delineation, markings, railings, intersections and other roadway elements to develop an expectancy as to what lies ahead and how he should react to the situation. When the condition exists as expected, the road has communicated well with the driver.

AASHTO has published a "Driver Expectancy Checklist", copyright 1972, for use as a design review tool. Designers should become familiar with the checklist and develop an awareness of those critical areas of design where effective driver communication will contribute to safety.

Portions of the checklist will be included in subsequent chapters dealing with specific areas of design, along with guidelines for safety considerations.

DESIGN RESPONSIBILITIES

The Roadway Design Division has basic responsibility for detailed design of roads and preparation of contract plans. Individual projects are assigned to specific squad leaders who perform and coordinate the design and development of plans.

Supplementary expertise is provided within the Roadway Design Division by specialists in photogrammetry, roadside development, environmental considerations, pavement design, roadway lighting, hydraulics and geometric design. During the design process the Roadway Design Division exchanges information with other divisions of the Department, as illustrated in the chart on page 1-4.

Each squad leader is responsible for the development of individual projects assigned to him. A principal purpose of this manual is to guide designers in the use of uniform standards and procedures that consistently will result in good quality road design and contract plans.

SOURCES OF INFORMATION

Many different kinds of information must be available to the highway designer. Some information is related to specific projects--other information is of a general nature related to all projects.

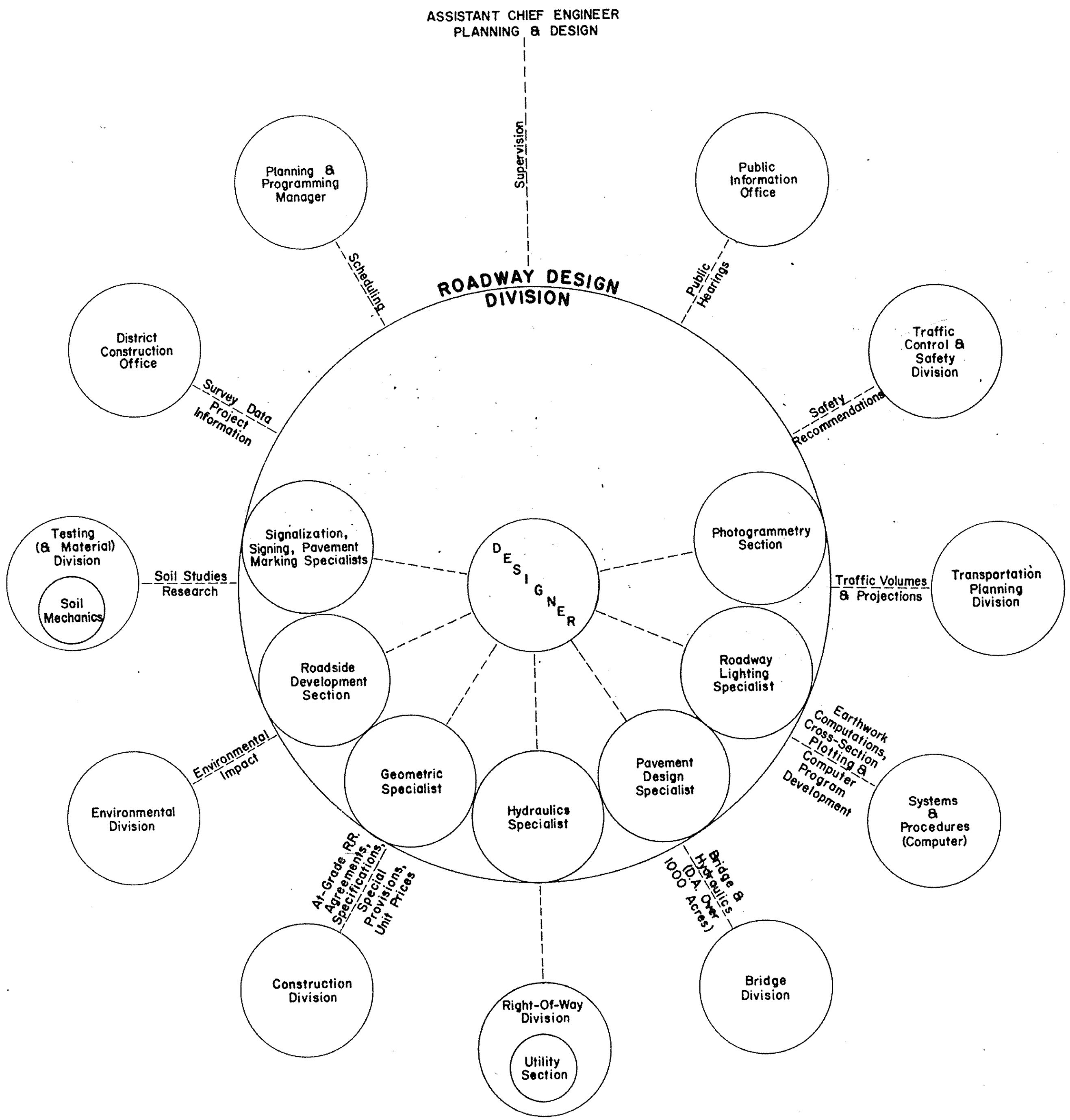
This manual is a principal source of information for designers. Other sources are set forth below.

Technical Assistance

The District Engineers furnish designers with field survey notes and sketches, soils information and recommendations related to the design of specific projects.

Designers will receive guidance and assistance from persons with training and competence in specialized fields as indicated by the relationships shown on the next page.

ROAD DESIGN ORGANIZATION AND RELATIONSHIPS



Department Publications

Designers will have frequent need to refer to the following materials published by the Department.

- **Standard Specifications**

  The book of Mississippi Standard Specifications for Road and Bridge Construction describes the various construction work items and Department relationships with contractors.

- **Special Provisions**

  A file of Special Provisions is maintained to identify current amendments (additions, deletions and revisions) to the Standard Specifications.

- **Standard Roadway Design Drawings and Bridge Design Drawings**

  These are drawings of standardized details suitable for use in contract plans. For reference purposes, they have been bound in two separate volumes.

- **Standard Operating Procedures**

  These volumes set forth official Department policies and operating procedures for all functions. Roadway Design Division procedures are found in the section entitled "RWD."

- Policy Memorandums

  Designers will receive copies of memorandums defining new or revised policies and procedures. Periodically the policies will be incorporated in revisions to the Design Manual.

AASHTO Publications

Mississippi standards and policies adhere closely to policies established by AASHTO. Numerous AASHTO publications provide background on accepted highway design practices in greater detail than is appropriate in this manual. Designers should be thoroughly familiar with the three comprehensive publications listed below. These sources are to be used as guides on details not covered in this manual--and for in-depth explanation of the concepts which serve as bases for policies and procedures.

- A Policy on the Geometric Design of Rural Highways, 1965 (commonly known as the "Blue Book").

- A Policy on Arterial Highways in Urban Areas, 1973 (commonly known as the "Red Book").

- Highway Design and Operational Practices Related to Highway Safety, 1974 (commonly known as the "Yellow Book").

Over fifty other AASHTO publications are available to provide authoritative guides and policies in specific areas--such as pavement design, drainage design, landscaping, rest area, lighting, utility, etc. A complete listing of these materials is available in the Roadway Design Division office.

FHWA Publications

This Manual contains all FHWA program directives impacting on State Highway Departments which were formerly issued as Policy and Procedure Memorandums (PPM's), Instructional Memorandums (IM's), Notices, Orders, etc. In addition, it contains all program directives relative to administration of the Direct Federal Construction Program.

Information on the varieties and types of traffic signs and other traffic control devices approved by FHWA for highway use is found in the:

- Manual on Uniform Traffic Control Devices for Streets and Highways, 1971.

TRB and NCHRP Reports

The National Cooperative Highway Research Program (NCHRP) reports, and various Transportation Research Board (TRB) publications--among them, the Highway Capacity Manual--cover the entire field of highway and traffic engineering. TRB publications prior to 1974 are identified as Highway Research Board (HRB) reports.

Copies of these reports are available in the Department library.

Supplier Publications

Literature on special design problems may be available from suppliers of construction materials. Such literature may be useful in the design of special culverts, retaining walls and other items.

PROJECT FILE

Squad leaders will maintain a complete file of all information relative to each project for which they are responsible.

When a project is assigned to a squad leader, he will be given a file folder containing pertinent project information compiled to date. Usually this will consist of:

- Form RWD-200, "Field Notes and Sketches"

  This sheet documents the inventory of all field data transmitted by the District--including field survey notes, right-of-way notes, incidental notes and miscellaneous maps, plans and sketches.

- Soils Data

  A report on the testing of soil samples and a graphical sketch of the soil profile throughout the proposed project--prepared and submitted by the District.

- Form RWD-600, "Project Design Data"

  This sheet documents basic design data instructions for the project, as prepared by the District Engineer and approved by the Roadway Design Engineer.

- Special Location and Design Recommendations

  Sometimes there is need for special consideration of problems unique to a particular project. The designer will be advised of the problem, and recommended procedures and solutions will be documented.

- Justification for Deviations from Standards

  Designers are obligated to adhere to established standards. Any proposed design element which is less than the established standard must be documented and approved by the Roadway Design Engineer.

After receiving the initial file package, the squad leader should maintain a current project record file with the following types of information:

- plan progress record
- field inspection reports
- miscellaneous project memorandums,

and should maintain a project estimate file for:

- quantity calculations.

On completion of the design and contract plans, the project record file shall be retained in the Roadway Design Division for later transfer to Central File. The project estimate file may be discarded after final contract payment.

QUANTITY ESTIMATES

The quantity of all contract bid items shall be estimated in terms of the units of measurement set forth in the Standard Specifications. Uniform criteria for degree of accuracy and rounding of computations are shown on the next page.

All computations should be documented with quantity calculations in the project estimate file.

UNIT ROUNDING
OF PRELIMINARY QUANTITY ESTIMATES

MEASUREMENT UNIT	DESCRIPTION	NEAREST UNIT	
		QUANTITY SHEETS	SUMMARY OF QUANTITIES
Acre	All items	0.01 acre	1 acre*
Barrel	All items	0.1 barrel	1 barrel
CWT	All items	0.1 hundredweight	1 hundredweight
C.Y.	All items	1 cubic yard	1 cubic yard
	Except:		
	Structure Excavation	0.01 cubic yard	1 cubic yard
	Concrete	0.01 cubic yard	1 cubic yard
Each	All items	1 unit	1 unit
Gal.	All items	1 gallon	1 gallon
Lb.	All items	1 pound	1 pound
L.F.	All items	1 lineal foot	1 lineal foot
	Except:		
	Pipe Culverts	4-foot increment	4-foot increment
	Guardrail	12.5-foot increment	12.5-foot increment
M.	All items	1 thousand	1 thousand
M.B.M.	All items	0.01 thousand board measure	1 thousand board measure
M. Gals	All items	1 thousand gallons	1 thousand gallons
Mile	All items	0.001 mile	0.001 mile
S.F.	All items	1 square foot	1 square foot
S.Y.	All items	1 square yard	1 square yard
Sta.	All items	1 station	1 station
Sta. Yd.	All items	1 station yard	1 station yard
Ton	All items	0.1 ton	1 ton*

*When quantities are smaller than one unit, round to one decimal place.

Detailed analyses of estimated quantities are included in the contract plans for certain pay items. Examples are shown in the model plans in Chapter 12. The Summary of Quantities in the contract plans shall include all pay items to be included in the contract.

CONTRACT PLANS

To assure accurate and consistent interpretation of contract plans, it is important that the format, content and placement of information be consistent for all projects.

Model contract plans are described and illustrated in Chapter 12. Designers should adhere to this format when preparing the drawings and assembling the plans.

The Department has a self-instructional Plan Reading Course which should be administered to new employees for orientation and training in plan preparation.

To minimize detailing and drafting work, Standard Drawings are used extensively for those design features which may be common to many projects. Each squad leader is provided with a bound set of currently available "Roadway Design Standard Drawings." Applicable Standard Drawings should be selected during the design process, and identified in the plan index so they may be printed and bound with each set of contract plans.

Chapter 2
DESIGN STANDARDS

Without some form of established criteria, individual designers would be called on to make personal judgments as to the appropriate geometric characteristics of proposed highways. These decisions can have very significant impact on the level of traffic service, safety and cost effectiveness of the highway investment.

Design standards provide a framework to guide decisions uniformly with consideration of those factors which influence level of service, safety and economy.

Although this manual is directed principally to the design of state highways and to procedures to be followed by the State Highway Department, many of the guides and criteria are equally applicable to local roads and streets. In the case of design standards, there are significant differences between the criteria for state highways and the design guides for local roads and streets adopted by the Division of State-Aid Road Construction. The established geometric criteria for both types of facilities will be identified separately in this chapter.

SOURCE OF STANDARDS

The American Association of State Highway and Transportation Officials (AASHTO) is the recognized authority on highway design policies and standards. Since 1938, AASHTO has been developing and publishing design policies for use by highway agencies--and continues to update policies and standards to reflect new findings and the current state of knowledge.

The AASHTO publication, "A Policy on Geometric Design of Rural Highways," 1965, along with several smaller publications on specific elements of highway design, provide the principal sources of information and criteria contained in this manual.

A similar AASHTO publication, "Geometric Design Guide for Local Roads and Streets," is the principal source of criteria for design of state aid projects.

APPLICATION IN MISSISSIPPI

Many of the AASHTO design criteria are expressed as minimum values or ranges of values for particular conditions. The Mississippi State Highway Department adheres to the basic framework of AASHTO design policies. But, the specific standards adopted herein by the Department reflect judgments as to appropriate applications in Mississippi--often higher than suggested minimum standards.

Fixed Standards

Some standards are defined in terms of fixed values--standards for elements such as lane width, shoulder width and bridge width. Widths less than standard would not provide adequate levels of service and safety--and widths greater than standard usually would not be an economical investment.

Rates of superelevation are fixed rates based on physical laws relating to forces of motion and friction.

Minimum Standards

Many standards will be expressed in terms of minimum values--criteria for elements such as sight distance, degree of curvature, median width, vertical and lateral clearances, and slopes. Design higher than minimum values is encouraged when there will not be a significant increase in cost.

Departure from Standards

Occasionally there may be unusual conditions which warrant departure from standards. Any proposed design which does not assure at least the minimum prescribed standards must be documented and approved by the Roadway Design Engineer.

BASIC DESIGN CONTROLS

Several factors influence decisions as to the geometric characteristics of highways. Consideration should be given to:

- traffic volumes
- design speeds
- predicted operating speeds
- highway capacity
- systems
- control of access.

Traffic Volumes

The amount and characteristics of traffic are perhaps the most significant bases for highway design criteria. Highways normally will be designed to accommodate traffic expected for a particular design year--usually about twenty years in the future.

The Transportation Planning Division of the Department maintains current records on traffic data and develops projections of expected future traffic. This information is made available to designers and is expressed in the following terms:

- Average Daily Traffic (ADT)--the total traffic for the year divided by 365, or the average volume per day. The total CURRENT ADT reflects existing traffic plus expected attracted traffic upon completion.

- Design Hourly Volume (DHV)--the peak hour traffic (30th highest hourly volume) expected during the future year chosen for design

- Directional Distribution (D)--a measure of the highest traffic volume in one direction during peak hours, expressed as a percentage of the DHV

- Composition (T)--a measure of the proportionate number of trucks in the traffic stream, expressed as a percentage of total traffic during the DHV.

For most highways, the DHV is used for design criteria. On minor low-volume roads the CURRENT ADT is sufficient.

The design traffic data to be shown on plans are:

ADT -- current (year specified)
ADT -- future (year specified)
DHV -- future
D -- directional distribution in predominant direction expressed as a percentage of total DHV
T -- trucks, expressed as a percentage of DHV.

Design Speeds

For each proposed highway improvement, a design speed is selected which establishes basic criteria for certain design elements such as curvature, superelevation, sight distance and critical length of grades. It is the maximum safe speed that can be maintained over a specified section when design features reflect minimum values for that speed.

The selected design speed should be a logical one with respect to the character of the terrain and the type of highway. Every effort should be made to use as high a design speed as practicable.

A highway in level terrain justifies a higher design speed than one in rolling or mountainous terrain. And a highway in open country justifies a higher design speed than one in an urban area.

A highway carrying a large volume of traffic may justify a higher design speed than a less important facility in similar topography. However, a low design speed should not be assumed for a low traffic volume road where the topography is such that drivers are likely to travel at high speeds. Drivers do not adjust their speeds to the importance of the highway, but to the physical limitations and traffic thereon.

The table below provides a general guide to the ranges of design speeds considered appropriate for various categories of highways in Mississippi.

HIGHWAY TYPE		Design Speed (MPH)
Multilane Highways	- Rural	70
	- Urban	50-70
2-Lane Rural State Highways	- Arterial	60
	- Local & Collector	*30-60
Rural State Aid County Roads		*30-50

* 40 MPH is recommended minimum.

Predicted Operating Speeds

There is need to recognize conditions where actual operating speeds typically may exceed the design speed. For example, terrain conditions may limit the overall design speed to 50 MPH, but several long tangents within the section may encourage much higher speeds. This situation should be recognized, and those curves at each end of the tangent should be somewhat flatter than minimum standards for 50 MPH so as to permit transition back to the design speed. (Reference, page 3-13)

A danger also exists in the above situation if vertical curves on the tangent section are designed for 50 MPH stopping sight distance when operating speeds may be 65 MPH or higher.

Highway Capacity

Highways must be designed to accommodate the traffic volumes expected in the design year. The number of lanes to be provided is the principal design element affected. In Mississippi, decisions as to number of lanes normally are made during the planning process before projects are assigned to individual squad leaders.

However, there are several significant factors related to highway capacity with which the designer must be concerned--factors such as:

- Passing Sight Distance. The theoretical capacity of a 2-lane road is greatly reduced when there is limited opportunity for overtaking and passing slower moving vehicles. In terrain where it is impractical to provide an adequate amount of passing sight distance, additional lanes may be required.

- Auxiliary Climbing Lanes. The capacity of a 2-lane road is significantly affected by long, steep grades with slow moving trucks. An auxiliary climbing lane may be warranted.

- Signalized Intersections. Installation of signals at an intersection may reduce capacity to the point that additional lanes may be required at the intersection.

- Urban Area Conflicts. Roadside conflicts associated with urban area developments should be considered in assuring adequate highway capacity.

- Lateral Clearance. It is found that restricted clearance between the edge of traveled way and roadside obstructions will reduce capacity.

- Interchanges. Capacity in the vicinity of interchanges can be affected by the design of ramps, ramp terminals and weaving sections.

Throughout the design process, the design volume and design capacity must be compared--and where capacity is not equal to or greater than expected volume, some other alternate must be considered.

Some guides for the need of capacity analyses are presented in subsequent chapters. More detailed guides and instructions are in the Highway Capacity Manual. Designers should be familiar with the Capacity Manual and the factors to be considered. Traffic engineering assistance may be requested for unusual or complex capacity analysis situations.

Highway Systems

Some design policies and standards are related to established highway systems and levels of service. Three such systems are recognized in Mississippi:

- Interstate highways
- Other designated state highways
- State aid county roads.

Uniformly consistent nationwide standards have been established for the Interstate System--standards generally higher than those used for other state highways.

Standards for other multilane state highways are similar to, but generally somewhat lower than standards for the Interstate System.

Design standards for 2-lane designated state highways vary according to the functional classification and traffic volume.

A somewhat lower level of design standards is applicable to county road improvement projects financed in whole or in part by funds allocated by law to the counties and administered by the State Aid Division.

Tables of design standards for these systems are shown at the end of this chapter.

Control of Access

Design policies and standards will be affected by the type of access for specific highways. The four types of access control are:

- Type 1 - Freeways. Full control of access, with no access to through traffic lanes except at interchanges.

- Type 2A - Partially Controlled Access Highways. Access to through traffic lanes permitted only at designated exits and entrances. Frontage roads may be provided for abutting property owners.

- Type 2B - Partially Controlled Access Highways. Access to through traffic lanes permitted only at designated exits and entrances.

- Type 3 - Conventional Highways. Access to traffic lanes permitted directly from abutting property. Special permits are required for additional new access points after initial construction is completed.

Designers will be advised of the type of access to be employed on each individual project.

STANDARDS BASED ON DESIGN SPEEDS

Two design standard considerations are related directly to the selected design speed:

- curvature and superelevation
- required sight distances.

At least the minimum values for these standards must always be provided--regardless of traffic volumes, highway systems or any other consideration. These design elements are very closely related to traffic safety and cannot be compromised.

Standards for gradients also are closely related to design speeds, although some variations may be permitted for low traffic volumes or rough terrain.

These critical standards are discussed in the following paragraphs, and established values related to design speeds are shown in the table on page 2-10 at the end of this chapter.

Curvature and Superelevation

In the design of highway curves, it is necessary to establish the proper relation between design speed and curvature and also their joint relations with superelevation. While these relations stem from laws of mechanics (speed, centrifugal force and side friction factor), the actual values for use in design depend on practical limits and factors determined more or less empirically over a range of variables.

The maximum permissible rate of superelevation is an example of practical limitations. Race tracks can accommodate high speeds with relatively sharp curvature because of very steep superelevation. Highways must serve vehicles traveling at a wide range of speeds. Slow-moving vehicles or stopped vehicles would be adversely affected with excessively steep superelevation, particularly in areas subject to ice and snow. AASHTO suggests maximum superelevation rates in the range of 0.06 to 0.12 foot per foot (6 to 12%). The Department has adopted a maximum rate of 0.10 foot per foot for state highways.

Complete tables of superelevation rates for various combinations of design speed and curvature are shown in Chapter 3. For a particular design speed, very little superelevation is needed for flat curves. As the degree of curvature increases, the rate of superelevation must also increase. When the required superelevation reaches 0.10, the maximum permissible degree of curvature is identified for that particular design speed. Similarly, a maximum degree of curvature is established for each design speed.

Stopping Sight Distance

Sight distance is the length of highway ahead visible to the driver. The minimum sight distance available must be sufficient to enable a vehicle traveling at or near the likely top speed to stop before reaching an object in its path.

Reference should be made to the AASHTO Policy on Geometric Design of Rural Highways for a thorough explanation of the concepts and procedures for defining required stopping sight distance. It is sufficient for this manual to identify the sight distance requirements for various design speeds, and to recognize those conditions which should be thoroughly investigated to assure that adequate sight distance is provided.

Sight distance can be restricted by vertical curvature, horizontal curvature, roadside obstructions or any combination of these elements. Procedures for checking sight distance are described in subsequent chapters.

Established minimum and desirable stopping sight distances are shown at the end of this chapter. Designers should always try to provide the desirable sight distance. Minimum values should be used only for unusually restrictive conditions.

Passing Sight Distance

Consideration of passing sight distance is limited to 2-lane two-way highways on which vehicles frequently overtake slower moving vehicles and the passing must be accomplished on a lane used by opposing traffic. Passing sight distance for use in design is determined on the basis of the length needed to safely complete a normal passing maneuver.

Sight distance adequate for passing should be provided frequently on 2-lane highways, and the length of each passing section should be as long as feasible.

There are no fixed criteria for the frequency of passing sections. However, experience shows that highway capacity is measurably reduced when a significant percentage of a particular section of highway is restricted to sight distances of less than 1,500 feet. Highways with high traffic volumes will require a higher proportion of passing sight distances than those with low volumes. Analysis of capacity related to percentage of length with sight distance greater than the passing minimum would indicate whether or not alignment and profile adjustments, or additional lanes, are necessary to accommodate the traffic.

Established minimum passing sight distances are shown at the end of this chapter. These distances for design should not be confused with other distances used as warrants for placing no-passing zone pavement markings on completed highways. Values shown in the Manual on Uniform Traffic Control Devices are substantially less than design distances and are derived for traffic operating control needs which are based on assumptions different from those for design.

Grades

Establishment of criteria for grades has not been as objective as for other geometric elements of highways. AASHTO has established recommended maximum grades, based principally on analysis of vehicle operating characteristics and common practice among highway agencies.

Criteria for maximum grades are related principally to design speed--with some permissible variations when considering terrain and traffic volume.

General guidelines for maximum grades are shown at the end of this chapter. The maximum design grades should be used infrequently, only as dictated by terrain conditions.

More detailed guides and criteria for design of grades are presented in Chapter 4.

STANDARDS BASED ON TRAFFIC VOLUMES

Most of the standards defining the geometric characteristics of highway cross-section elements are related to traffic volumes. Geometric standards adopted for use in Mississippi are summarized in tabular form at the end of this chapter. Also included is a typical cross section defining standard nomenclature for the individual design elements--as well as identifying the basis for measurement of values referred to in the standards.

Each of the design elements shown in the tables is discussed on the following pages.

Number of Lanes

The required number of lanes depends principally on traffic volumes and highway capacity. Normally, the number of lanes will be determined during the planning process. Designers will be concerned primarily with analyzing the need for auxiliary lanes at specific locations, and for evaluating the overall effect of design features, such as restricted passing sight distance, on capacity.

Surfaced Lane Width

The traveled way designated for vehicle operation (excluding shoulders) normally consists of two or more surfaced traffic lanes. The lane width depends principally on traffic volumes--and ranges from 10 feet for very low volumes to 12 feet for most major highways.

Total Shoulder Width

Well designed and maintained shoulders are necessary on rural highways with any appreciable traffic volume. Shoulders provide a refuge when a driver makes an emergency or parking stop. Also, they provide a recovery area for vehicles inadvertently leaving the traffic lane.

Surfaced Shoulder Width

The surface width of a shoulder is that part constructed to provide better all-weather load support than afforded by natural soils or stabilized materials.

Median Width

Medians on rural highways preferably should be of sufficient width to provide freedom from interference by opposing traffic, to minimize headlight glare, and to assure safe operation of vehicles at intersections and crossovers.

Median width is the distance between edges of traffic lanes of the separated roadways. The minimum permissible median width on any rural multilane state highway is 64 feet. Wider separation with independent grade design of each roadway is desirable.

In urban areas with severe right-of-way restrictions, the median width of state highways may be reduced to 30 feet. The median width of both Interstate and other fully controlled access multilane highways may be reduced to 9 feet when a concrete median barrier is installed.

Vertical Clearance

Vertical clearance is measured between overhead structures and the finished roadway surface. The designated clearance must be provided over the entire usable roadway width, including shoulders.

On all state highways, the minimum vertical clearance shall be designed for 16'3". This will assure a minimum clearance of 16 feet after future resurfacing.

The required vertical clearance for design of state-aid county roads is 14'6".

Where highway structures cross over railroads, the vertical clearance between the top of rail and bottom of highway structure shall be at least 23 feet.

Lateral Clearance

Adequate lateral clearance between the edge of traffic lanes and roadside obstructions has been shown to be a very important traffic safety factor. Vehicles leaving the roadway should have reasonable opportunity to recover control and return to the roadway without overturning or colliding with roadside objects such as trees, poles, headwalls or other large objects.

The minimum lateral clearance for rural interstate, multilane and arterial state highways is 30 feet. For local and collector roads and for state aid county roads, the required lateral clearance is less, as listed in the appropriate design standards and guides.

Breakaway-type light poles and sign posts are permitted in the lateral clearance zones. Slopes in these clearance zones should be as flat as practical.

In situations where guardrail is installed, the lateral clearance shall equal or exceed the full shoulder width.

Bridge Width

The bridge width dimensions in the design standard tables refer to the clear width between curbs or between rails, whichever is less.

Two conditions are set forth in the tables. The first entry applies to all new bridge construction and widening of existing bridges.

The second entry applies when a highway is to be reconstructed. Existing bridges which fit the proposed alignment and profile may remain in place if the structural capacity and the clear roadway width are at least equal to the values shown in the tables. However, each existing structure with less than desirable width should be evaluated in accordance with criteria in the "Yellow Book."

For design speeds of 50 MPH or less on minor roads with few trucks, existing bridges with widths 2 feet less than indicated in the table may remain in place. In no case shall the minimum clear width be less than the approach traveled way (surfaced lanes).

Roadway Width at Bridge Ends

It is Department policy to install guardrail protection at all bridge ends on state highways and on state-aid projects financed with federal funds. In some instances, it will be necessary to widen the embankment at the bridge ends to facilitate guardrail installation.

The approach roadway width at bridge ends shall be at least 4 feet wider than the clear width of the bridge. The transition between normal roadway width and the roadway width at bridge ends should be in accordance with the design of the guardrail installation.

Right-of-Way Border Width

The right-of-way border width is defined as the distance between right-of-way lines and the toe of fill slopes or top of cut slopes.

There is no fixed rule for designing right-of-way widths. Each situation must be evaluated individually with consideration of existing conditions and economic factors. As a general rule, the right-of-way design for state highways should provide at least the border widths shown in the design standard tables.

State law requires that right-of-way for state-aid projects be furnished by the county. Sufficient right-of-way should be acquired to accommodate the proposed roadway section.

Surface and Shoulder Slopes

The pavement surface must be sloped sufficiently to ensure proper drainage, yet not so steeply as to adversely affect vehicle operation. For state highways the surface slopes on tangent sections shall be 1.50 percent for concrete and hot bituminous pavements and 2.0 percent for double bituminous surface treatment. All shoulder slopes shall be 4.00 percent.

For state-aid projects, the ranges of permissible surface slopes are shown in the design tables.

Side Slopes

Roadway excavation and embankment slopes should be reasonably flat in the interest of safety, appearance and economy of maintenance. Four types of cross-section slopes are identified on the typical section nomenclature drawing:

In cut sections,

- Foreslope--the slope extending outward and downward from the shoulder point to the ditch line.
- Backslope--the slope extending upward and outward from the ditch line to intersect the natural ground line.

In fill sections,

- Safety slope--the slope extending outward and downward from the shoulder point for a horizontal distance to meet the minimum lateral clearance requirements set forth in the design standard tables.
- Fill slope--the embankment slope extending outward and downward from the outer limit of the safety slope to intersect the natural ground.

Factors which affect the rates of slope are type of highway, traffic volume, depth of cut, and height of fill as shown in the slope schedules.

Liberal warping and rounding of the cross section should be provided at the ditch bottoms and tops of backslopes.

DESIGN STANDARDS AND GUIDES

- GEOMETRIC DESIGN STANDARDS BASED ON DESIGN SPEED
- TYPICAL SECTION NOMENCLATURE
- GEOMETRIC DESIGN STANDARDS FOR MULTILANE STATE HIGHWAYS
- GEOMETRIC DESIGN STANDARDS FOR RURAL 2-LANE ARTERIAL STATE HIGHWAYS
- GEOMETRIC DESIGN STANDARDS FOR RURAL 2-LANE LOCAL ROADS AND COLLECTOR ROADS
- GEOMETRIC DESIGN GUIDES FOR RURAL STATE AID COUNTY ROADS

GEOMETRIC DESIGN STANDARDS 1/
BASED ON DESIGN SPEED

DESIGN CRITERIA	DESIGN SPEED — MPH					
	30	40	50	60	65	70
Maximum Horizontal Curvature 2/ (Degrees)	25.0	13.5	8.5	5.5	4.5	4.0
Stopping Sight Distance (Feet)						
Minimum	200	275	350	475	550	600
Desirable	200	300	450	650	750	850
Passing Sight Distance (Feet)	1100	1500	1800	2100	2300	2500
Maximum Grades (Percent)						
State Highways: 3/						
Level Terrain	6	5	4	3	3	3
Rolling Terrain	7	6	5	4	4	4
Mountainous Terrain	9	8	7	6	6	5
State-Aid County Roads: 4/						
Level Terrain	7	7	6	5	-	-
Rolling Terrain	9	8	7	6	-	-
Mountainous Terrain	10	10	9	-	-	-

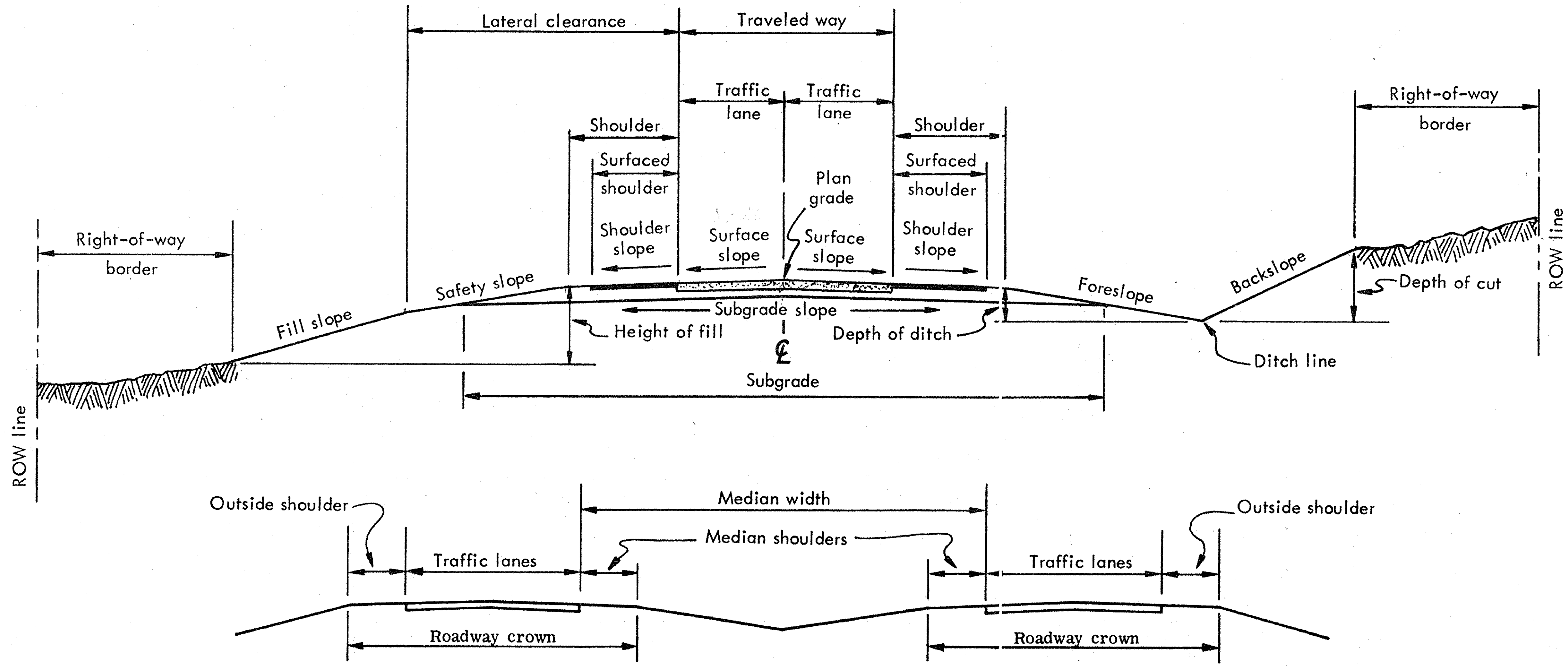
1/ Applicable to all road systems.

2/ Based on maximum superelevation rate of 0.10 foot per foot. See tables in Chapter 3 for rates of superelevation and runoff distances.

3/ Low volume rural highways may have grades 2 percent steeper.

4/ Grades for relatively short lengths may be increased 150 percent for highways with ADT less than 250.

TYPICAL SECTION NOMENCLATURE



Revised July 25, 1978

GEOMETRIC DESIGN STANDARDS FOR MULTILANE STATE HIGHWAYS

VOID (SEE 2-12 REV. SEPT. 24, '85

DESIGN CRITERIA		Interstate		Other Multilane	
		Rural	Urban	Rural	Urban
NUMBER OF LANES		4 or more as determined by capacity analysis			
SURFACED LANE WIDTH (Feet)		12			
SHOULDER WIDTH (Feet)	Outside	12		10	
	Median	8		8	
SURFACED SHOULDER WIDTH (Feet)	Outside	10		9	
	Median	4		3	
MINIMUM MEDIAN WIDTH (Feet)		64	40 9 w. conc. med. barrier	64	30 9 w. conc. med. barrier
MINIMUM VERTICAL CLEARANCE		16' 3"			
MINIMUM LATERAL CLEARANCE (Feet)	Obstruction	30			
	Guardrail	12		10	
BRIDGE WIDTH		Width of traffic lanes plus 12' outside shoulder and 6' median shoulder		Width of traffic lanes plus 10' outside shoulder and 6' median shoulder	
MINIMUM ROADWAY WIDTH AT BRIDGE ENDS		Bridge width plus 4'			
DESIRED MINIMUM R.O.W. BORDER WIDTH (Feet)		30	15	30	15
MINIMUM R.O.W. WIDTH (Feet)		300	1/	250	1/

SLOPE SCHEDULE

Highway System	Cut Sections			Fill Slopes	
	Foreslopes		Backslopes	Within 30' of Pave. Edge	Outside 30' of Pave. Edge
	Depth of Ditch (Feet)	Slopes	Slopes	Slopes	Slopes
Interstate	2/ 3'-0"	6:1	3:1	6:1	3:1
Other Multi-Lane	2/ 3'-4"	6:1	3:1	6:1	3:1

1/ Determined by build-up, property value, etc.

2/ Maintain a minimum of 1 foot depth ditch from subgrade shoulder. Adjust foreslope distance as required in cuts when in superelevated sections.

Revised July 25, 1978

GEOMETRIC DESIGN STANDARDS FOR MULTILANE STATE HIGHWAYS

DESIGN CRITERIA		INTERSTATE		OTHER MULTILANE	
		Rural	Urban	Rural	Urban
NUMBER OF LANES		4 or more as determined by capacity analysis			
SURFACED LANE WIDTH (Feet)		12			
SHOULDER WIDTH (Feet)	Outside	12		10	
	Median	8		8	
SURFACED SHOULDER WIDTH (Feet)	Outside	10		4/ 9	
	Median	4		4/ 3	
MINIMUM MEDIAN WIDTH (Feet)		64	40 10' W. Conc. Med. Barrier	64	30 10" W. Conc. Med. Barrier
MINIMUM VERTICAL CLEARANCE 3/		16'6"			
MINIMUM LATERAL CLEARANCE (Feet)	Obstruction	30			
	Guardrail	12		10	
BRIDGE WIDTH		Width of traffic lanes plus 12' outside shoulder and 6' median shoulder		Width of traffic lanes plus 10' outside shoulder and 6' median shoulder	
MINIMUM ROADWAY WIDTH AT BRIDGE ENDS		Bridge width plus 4'			
DESIRED MINIMUM R.O.W. BORDER WIDTH (Feet)		30	15	30	15
MINIMUM R.O.W. WIDTH (Feet)		300	1/	250	1/

S L O P E   S C H E D U L E

Highway System	Cut Sections			Fill Slopes	
	Foreslopes		Backslopes	Within 30' of Pave. Edge	Outside 30' of Pave. Edge
	Depth of Ditch (Feet)	Slopes	Slopes	Slopes	Slopes
Interstate	2/ 4'-0"	4/ 6:1	3:1	4/ 6:1	3:1
Other Multi-Lane	2/ 4'-0"	4/ 6:1	3:1	4/ 6:1	3:1

1/ Determined by build-up, property value, etc.

2/ Maintain a minimum of 1 foot depth ditch from subgrade shoulder. Adjust foreslope distance as required in cuts when in superelevated sections.

3/ 16' Minimum (6" allowed for future resurfacing).

4/ 4:1 slopes may be used in Urban Areas. However, minimum lateral clearance should be in accordance with AASHTO "Guide for Selecting, Locating, and Designing Traffic Barriers".

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MINIMUM GEOMETRIC DESIGN STANDARDS FOR
RURAL ARTERIAL HIGHWAYS

DESIGN CRITERIA		Under 400	400 & Over		
	1/ Current ADT	Under 400	400 & Over		
	DHV		100 - 200	201 - 400	Over 400
NUMBER OF LANES		2		Check capacity warrants for auxiliary climbing lane or 4-lanes	
LANE WIDTH (Feet)		12			
SHOULDER WIDTH (Feet)	Total	6		8	10
	Surfaced	3/ To be determined during design.			
MINIMUM LATERAL CLEARANCE (Feet) 2/	Obstruction	30			
	Guardrail	Width of Shoulder			
VERTICAL CLEARANCE		16' - 3" (Minimum)			
BRIDGE WIDTH (Feet)		36		40	44
MINIMUM ROADWAY WIDTH AT BRIDGE ENDS		Bridge Width + 4'			
DESIRED MINIMUM RIGHT OF WAY BORDER WIDTH (Feet)		10	10 - 15	15 - 20	20
MINIMUM RIGHT OF WAY WIDTH (Feet)		120		130	150
SLOPE SCHEDULE – CUT SECTION – Foreslope (Within 30' of Pavement Edge)	Slope	4/ 6:1			
SLOPE SCHEDULE – CUT SECTION – Backslope	Slope	3:1			
SLOPE SCHEDULE – FILL SECTION – Within 30' of Pavement Edge	Slope	4/ 6:1			
SLOPE SCHEDULE – FILL SECTION – Outside 30' of Pavement Edge	Slope	3:1			

1/ The current ADT is the ADT expected after completion of the facility.
2/ Measured from the edge of the traveled lane.
3/ Generally, paved shoulders will not be utilized except as approved for special conditions.
4/ 4:1 slopes may be used in Urban Areas. However, minimum lateral clearance should be in accordance with AASHTO "Guide for Selecting, Locating, and Designing Traffic Barriers".

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MINIMUM GEOMETRIC DESIGN STANDARDS FOR 2-LANE RURAL COLLECTOR ROADS

DESIGN CRITERIA						
	Current ADT 1/	Under 400	400 & Over			
	DHV		100 - 200	201 - 400	Over 400	
MINIMUM DESIGN SPEEDS 2/	Level Terrain 3/	~~40~~ 55	~~50~~ 55	~~60~~ 55		
	Rolling Terrain 4/	~~30~~ 55	~~40~~ 55	~~50~~ 55		
SURFACED WIDTH (Feet)		24				
STRIPED LANE WIDTH (Feet)		11		12		
MINIMUM WIDTH OF SHOULDER (Feet) 5/		4	6	8		
MINIMUM BRIDGE WIDTH (Feet)		28	30	32	40	
MINIMUM ROADWAY WIDTH AT BRIDGE ENDS (Feet)		Bridge Width + 4'				
MINIMUM LATERAL CLEARANCE (Feet) 5/	Obstruction: 40 MPH & Under	10				
	Obstruction: Over 40 MPH 7/	~~10~~ 17	~~15~~ 20		~~18~~ 20	
	Guardrail	Width of Shoulder				
MINIMUM VERTICAL CLEARANCE		16' - 3"				
DESIRED MINIMUM R.O.W. BORDER WIDTH (Feet)		5 - 10	10 - 15	15 - 20		
MINIMUM R.O.W. WIDTH (Feet)		80	100	120		

SLOPE SCHEDULE

TRAFFIC VOLUME (DHV)		CUT SECTIONS: Foreslope – Depth of Ditch (Feet)	CUT SECTIONS: Foreslope – Slope	CUT SECTIONS: Backslope – Slope	FILL SECTIONS: Height of Fill 6/ (Feet)	FILL SECTIONS: Slope
Under 200	40 MPH & Under	2.5	4:1	3:1	Under 5	4:1
	Over 40 MPH.	3	4:1	3:1	Over 5	3:1
Over 200		3	4:1	3:1	Under 10 Over 10	4:1 3:1

1/ The current ADT is the ADT expected after completion of the facility.
2/ AASHTO minimum values are shown. Generally, provide at least a 40 MPH design speed.
3/ That condition where sight distances, as governed by both horizontal and vertical restrictions, are generally long or could be made to be so without construction difficulty or major expenses.
4/ That condition where the natural slopes consistently rise above and fall below the highway grade line and where occasional steep slopes offer some restriction to normal highway horizontal and vertical alinement.
5/ Measured from the edge of the striped lane.
6/ Measured from the finished shoulder.
7/ Distances indicated are based on use of 6:1 or flatter slope. Slopes steeper than 6:1 may be used beyond this distance. When 6:1 slopes are not utilized adjacent to the shoulder, the distance to obstruction should be as indicated in the AASHTO "Guide for Selecting, Locating, and Designing Traffic Barriers".

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GEOMETRIC DESIGN GUIDES FOR RURAL STATE AID COUNTY ROADS (FAS)

DESIGN CRITERIA						
DESIGN CRITERIA	1/ Current ADT		Under 400	400 & Over		
	DHV			100 - 200	201 - 400	Over 400
MINIMUM DESIGN SPEEDS 2/	3/ Level Terrain		40	50	60	
	4/ Rolling Terrain		30	40	50	
	Mountainous Terrain		30		40	
MINIMUM WIDTH OF SURFACING (Feet)			22		24	
MINIMUM WIDTH OF SHOULDER (Feet)			4	6	8	
MINIMUM BRIDGE WIDTH (Feet)	Under 50 MPH Design Speed		26	28	32	40
	50 MPH Design Speed & Over		28		40	
CRITERIA FOR EXISTING BRIDGES TO REMAIN IN-PLACE	Bridge Loading		H-15			
	Clear Width (Feet)	Desirable	28		32	
		Minimum	22		24	28
MINIMUM LATERAL CLEARANCE (Feet) 6/	Obstruction	40 MPH & Below	10			
		41 - 49 MPH 5/	10		15	
		50 MPH & Over 5/	10		15	18
	Guardrail		Width of Shoulder			
MINIMUM R.O.W. WIDTH (Feet)			See Section on R.O.W. in Chapter 11			
MINIMUM VERTICAL CLEARANCE			14'-6"			
SLOPES	Fill Slopes, Foreslopes, & Backslopes	Desirable	4:1 or Flatter			
		Minimum	3:1			
	Surfacing Cross Slopes	High Type Surf.	1.5 to 2 percent			
		Interm. Type Surf.	1.5 to 3 percent			
		Low Type Surf.	3 percent			

1/ The current ADT is the ADT expected after completion of the facility.
2/ AASHTO minimum values are shown. Generally, provide at least a 40 MPH design speed.
3/ That condition where sight distances, as governed by both horizontal and vertical restrictions, are generally long or could be made to be so without construction difficulty or major expenses.
4/ That condition where the natural slopes consistently rise above and fall below the highway grade line and where occasional steep slopes offer some restriction to normal highway horizontal and vertical alinement.
5/ Distances indicated are based on use of 6:1 or flatter slope. Slopes of 3:1 may be used beyond this distance. When 6:1 slopes are not utilized adjacent to the shoulder, the distance to obstruction should be as indicated in the AASHTO "Guide for Selecting, Locating, and Designing Traffic Barriers".
6/ Measured from the edge of pavement.

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Chapter 3

HORIZONTAL ALIGNMENT

Horizontal alignment establishes the general character of a rural highway, perhaps more than any other design consideration. The configuration of tangent highway sections and the curves that connect these tangents affects safe vehicle operating speed, sight distances, opportunity for passing and highway capacity.

Carefully considered, good design of highway alignment contributes to traffic safety and minimizes investment loss due to early obsolescence of the facility.

LOCATION SURVEYS

Most location surveys for state highways in Mississippi are the responsibility of the Districts--and are performed by District personnel. Completed surveys are submitted to the Roadway Design Division, along with pertinent design recommendations.

Designers normally will adhere to the alignment established by the Districts. If unusual circumstances are encountered during the design process, office projections may be computed for variations from the surveyed line--or additional field surveys may be requested if the departure from the surveyed line is significant.

The ultimate quality of the horizontal alignment is thus influenced by decisions of both District and Roadway Design personnel. Alignment decisions should be governed by the criteria set forth in this chapter.

GENERAL CRITERIA

Some criteria for horizontal alignment can be quite specific and measurable--design speed, maximum curvature and superelevation. But others are not as explicit, and require judgment and consideration of existing conditions.

These general criteria are outlined below:

- Alignment should be as directional as possible, but should be consistent with the topography. Winding alignment, composed of short curves, should be avoided since it usually is a cause of erratic operation.

- Generally, use flat curves throughout--avoid use of maximum permissible degree of curvature except where absolutely necessary.

- Keep the alignment consistent. Sharp curves should not be introduced at the ends of long tangents. Sudden changes from areas of easy curvature to sharp curvature should be avoided. Where sharp curvature must be introduced, it should be approached by successively sharper curves from the generally easy curvature.

- For a small deflection angle, the curve should be sufficiently long to avoid the appearance of a kink. Curves should be at least 500 feet long for a central angle of

5 degrees, and the minimum length should be increased 100 feet for each 1-degree decrease in the central angle.

- On long, high fills, keep the curvature as flat as possible. Under these conditions, it is difficult for drivers to perceive the extent of curvature.
- Avoid sharp compound curves. Where topography makes their use necessary, the radius of the flatter arc should not be more than 50 percent greater than the radius of the sharper arc.
- Avoid abrupt reversals in alignment (S curves). There must be sufficent tangent distance between the curves to assure proper superelevation runoff for both curves and sufficient distance for required signing.
- Avoid "broken back curves" (short tangent between two curves in the same direction). This arrangement is hazardous and is not pleasing in appearance.
- Horizontal alignment should be carefully coordinated with profile design. This is discussed in Chapter 4.

Horizontal and vertical alignment are probably the most important permanent elements of the highway. Thorough study is warranted to increase utility and safety--and to improve appearance. In many cases this may be accomplished without additional cost.

HORIZONTAL CURVES

Design of horizontal curvature is based principally on the established design speed and terrain conditions. Design standards and criteria for maximum permissible curvature are discussed in Chapter 2. The characteristics of horizontal curves and procedures for defining curvature are set forth in this chapter.

Horizontal curvature may consist of simple circular curves or a combination of circular curves with spiral transition curves at each end.

Simple Curves

Simple curves are a portion of the arc of a circle. The design elements of a simple horizontal curve, and their terminology, are shown in the diagram at the right.

Usually the P.I. station, the deflection angle (Δ) and the degree of curvature are established. The remaining curve data must be computed using the following formulas.

$$L = 100\frac{\Delta}{D}$$

$$R = \frac{5729.58}{D}$$

$$T = R\tan\frac{\Delta}{2}$$

$$E = R\left(\sec\frac{\Delta}{2} - 1\right)$$

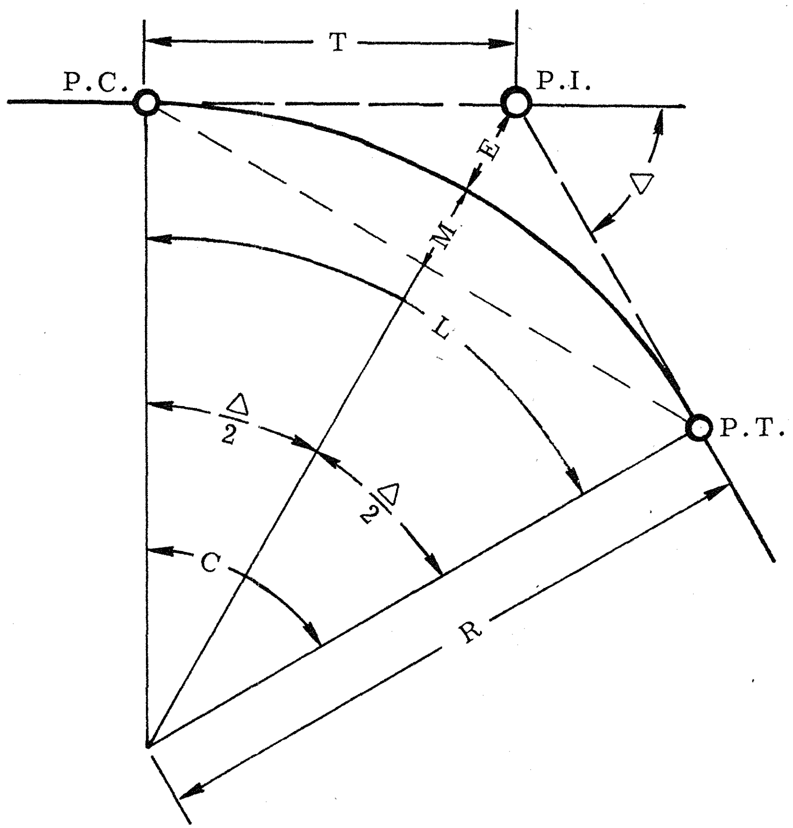
$$M = R\left(1 - \cos\frac{\Delta}{2}\right)$$

$$L.C = 2R\sin\frac{\Delta}{2}$$

P.C. Station = P.I. Station - T

P.T. Station = P.C. Station + L

SIMPLE HORIZONTAL CURVES



P.I. = Point of Intersection
P.C. = Point of Curvature
P.T. = Point of Tangency
△ = Deflection Angle
D = Degree of Curvature
L = Length of Curve (ft.)
R = Radius of Curve (ft.)
T = Tangent Length (ft.)
E = External Distance (ft.)
M = Middle Ordinate (ft.)
C = Central Angle (equal to △ angle)

Computation is considerably simplified with use of a standard table of functions for a 1-degree curve. Such tables give values of T and E for 1-degree curves and specific deflection angles. For any other degree of curvature (D), the values for T and E are then:

$$T = \frac{T\ (\text{for 1 degree})}{D} \qquad E = \frac{E\ (\text{for 1 degree})}{D}$$

Accuracy of calculating and recording curve data should be:

D	=	degrees to the nearest minute
△	=	degrees to the nearest second
All distances	=	nearest one-hundredth of a foot.

Spiral Transition Curves

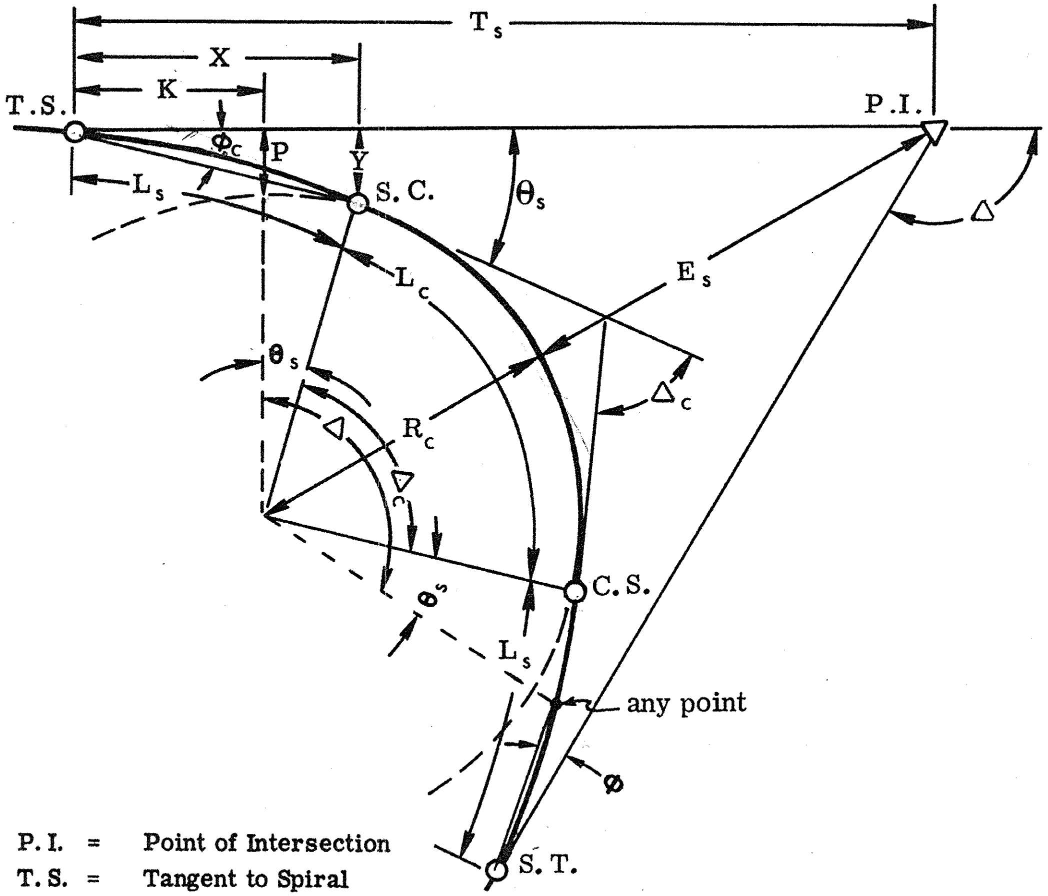
The purpose of spiral transition curves is to gradually ease the driver into and out of circular curves without a sharp break from the tangent sections.

Spiral transition curves are to be used with simple curves as indicated in the table on page 3-7. Their use is not required on state aid roads and spirals may be eliminated on specific curves within a project for sufficient cause.

Typical geometrics and terminology of spiral transitions are shown in the diagram on page 3-4.

Usually the P.I. station, the deflection angle (△) and the degree of curvature (D_c) are established.

SPIRAL TRANSITION CURVES



P.I.	=	Point of Intersection
T.S.	=	Tangent to Spiral
S.C.	=	Spiral to Curve
C.S.	=	Curve to Spiral
S.T.	=	Spiral to Tangent
T_s	=	Total Tangent Length
E_s	=	Total External Distance
Δ	=	Total Deflection Angle
Δ_c	=	Circular Deflection Angle
θ_s	=	Spiral Angle (angle between T and tangent at S.C. or C.S.)
Φ_c	=	Deflection angle from tangent at T.S. to S.C. or S.T. to C.S.
Φ	=	Deflection angle from tangent at T.S. or S.T. to any point on the spiral
D_c	=	Degree of Circular Curve
L_s	=	Length of Spiral (feet)
L_c	=	Length of Circular Curve
R_c	=	Radius of Circular Curve
X, Y	=	Coordinates of S.C. point related to T.S. point and offset from tangent
K, P.	=	Coordinates of offset of theoretical P.C. of circular curve (the distance of P is referred to as "throw")

Values for X, Y, K and P may be read directly from tables of spiral curve functions. The remaining curve data can be obtained from tables or computed from the following formulas.

$$\theta_s = \frac{L_s D_c}{200} \qquad \Delta_c = \Delta - 2\theta_s$$

$$L_c = \frac{100\Delta_c}{D_c} \qquad R_c = \frac{5729.58}{D_c}$$

$$T_s = \left(R_c + P\right)\left(\tan\frac{\Delta}{2}\right) + K \qquad E_s = \left(R_c + P\right)\left(\sec\frac{\Delta}{2}\right) - R_c$$

Curve stationing should be identified by the following procedures.

T.S. station	=	P.I. station - T_s
S.C. station	=	T.S. station + L_s
C.S. station	=	T.S. station + L_s + L_c
S.T. station	=	T.S. station + $2L_s$ + L_c

Accuracy of calculating and recording curve data should be:

D_c	=	degrees to the nearest minute
Δ, Δ_c and θ_s	=	degrees to the nearest second
All distances	=	nearest one-hundredth of a foot.

Pavement Widening on Curves

Under certain conditions pavements are widened on the inside edge of curves to allow for a greater width because rear wheels generally track inside front wheels when rounding a curve, and because drivers sometimes have difficulty in steering within the traffic lane on curves.

Curve widening shall be provided as shown in the table below for the various combinations of degree of curvature and pavement width.

Degree of Curvature	Widening in Feet for . . .	
	22-Ft. Pavement	20-Ft. Pavement
Below 2°	0.0	0.0
2° up to 4°	1.5	2.0
4° up to 6°	2.0	2.5
6° and over	2.0	3.0
State Aid	Standard SA-SE-1	

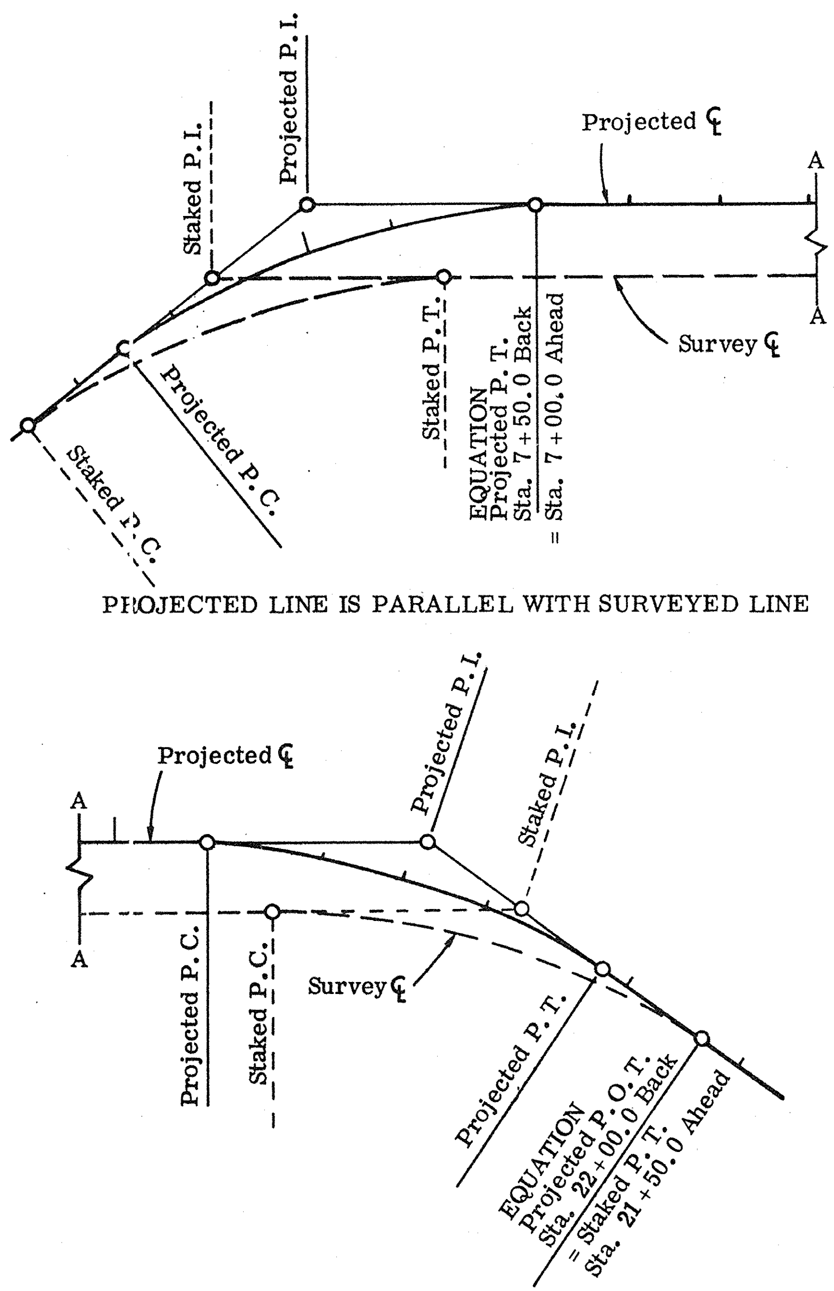
Widening shall be applied on the inside edge of pavement with transition distances at each end of the curve coincident with the superelevation runoff.

Equations

Frequently during design there is need to compute office projections of alignment--departures from the line surveyed in the field. These usually involve changes in length of alignment; and to avoid changing stationing throughout the project, equations in stationing are introduced. The equation identifies two station numbers, one that is correct when measuring on the line back of the equation, and one that is correct when measuring ahead.

Equations are discussed here because most commonly they are located at the P.T. of a horizontal curve. Proper procedures for documenting equations are shown in the two following examples.

TYPICAL EQUATIONS IN STATIONING



PROJECTED LINE IS PARALLEL WITH SURVEYED LINE

PROJECTED LINE RETURNS TO SURVEYED LINE

Parallel (Concentric) Curves on Divided Highways

When the median width of a divided highway is a constant distance of 64 feet or less, the stationing and all other alignment computations are based on a single survey base line--normally the center of the median. A common profile grade and one set of curve data serve for both roadways.

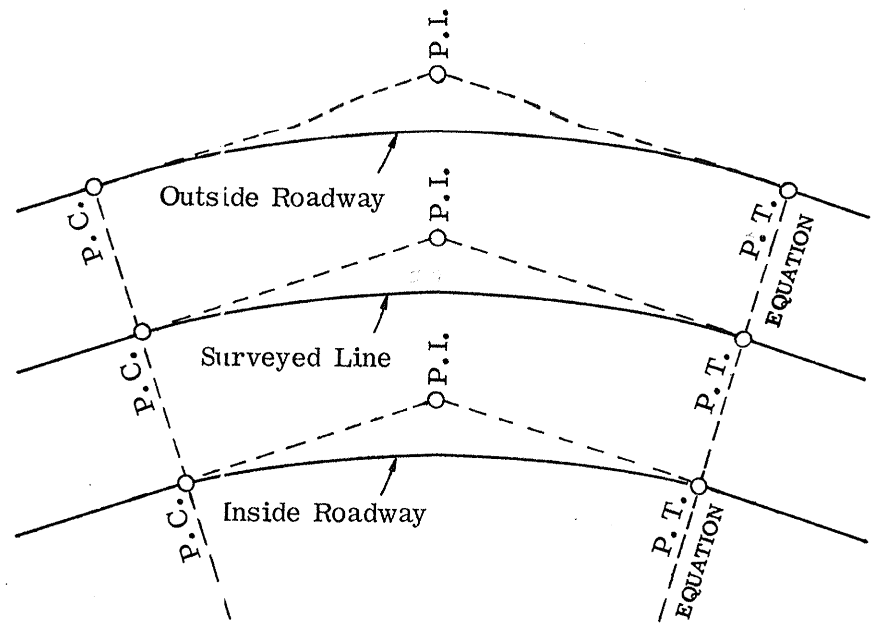
When the median width exceeds 64 feet, each roadway should have separate horizontal and vertical controls--even though there may have been a single survey base line. In other words, each roadway must have its own profile grade and horizontal curve data.

Two problems arise when dealing with independent horizontal curve controls:

1. The distance along the outside roadway is always longer than the survey stationing--and the distance along the inside roadway is always shorter. In order to use the survey stationing on the tangent following the P.T., it is necessary to introduce an equation in stationing at the P.T.

2. If the curves are to be truly parallel, they must be concentric (common center of radii)--and this means the degree of curvature of the outside roadway will be somewhat flatter than the surveyed curve, while the inside roadway curve will be sharper. Each must be identified separately.

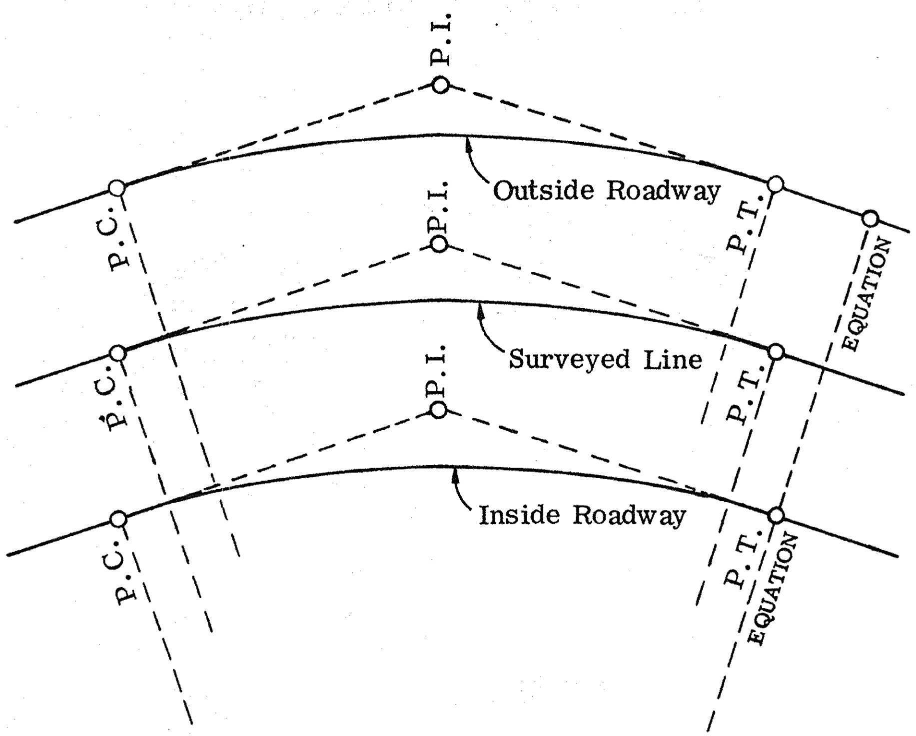
Parallel (concentric) curves are illustrated at the right. The deflection angle (Δ) and the P.C. stationing will be the same for all three lines. All other curve data will be different for each of the lines. The two equations will reestablish common stationing ahead from the P.T.



Non-Parallel Curves on Divided Highways

Another option is available for the situation described in the preceding section if it is not essential that the curves be precisely parallel. A reasonable approximation to parallel conditions can be attained if the degree of curvature for both roadways is the same as that used for the surveyed line. This situation is illustrated to the right on page 3-7.

For this alternative, the basic curve data for all three lines will be identical--except that the stationing of the P.C., P.I. and P.T. will be different in each case. The equation should be placed at the P.T. of the inside roadway to reestablish common stationing from that point ahead, and opposite the P.T. of the inside roadway to reestablish common stationing for the outside roadway.



SUPERELEVATION

The basic concepts and criteria for superelevation of curves were set forth in Chapter 2 under the discussion of design standards. Practical application of these criteria will be described in this chapter.

Design Tables

The next table, on the right, sets forth basic design criteria for rates of elevation (e) and superelevation runoff lengths (L) as related to an assumed design speed and degree of curvature. The maximum permissible degree of curvature (D) for each design speed also is identified.

DESIGN CRITERIA FOR SUPERELEVATION RATES AND RUNOFF LENGTHS *

D	V=40 mph		V=50 mph		V=60 mph		V=70 mph	
	e	L	e	L	e	L	e	L
0°15'	NC	0	NC	0	NC	0	NC	0
0°30'	NC	0	NC	0	RC	150	RC	150
0°45'	NC	0	RC	150	.024	200	.029	200
1°00'	RC	125	.023	150	.032	250	.039	250
1°17'	.018	125	.029	150	.040	250	.050	250
1°30'	.021	125	.033	200	.046	250	.058	300
1°40'	.023	125	.036	200	.050	250	.063	300
2°00'	.028	150	.042	200	.058	250	.074	350
2°27'	.033	150	.050	200	.068	300	.085	400
2°30'	.034	150	.051	200	.069	300	.086	400
3°00'	.040	150	.059	250	.079	350	.094	400
3°30'	.046	200	.067	250	.087	350	.099	400
3°54'	.050	200	.072	250	.092	350	.099	400
4°00'	.051	200	.073	250	.093	350	.100	400
5°00'	.061	200	.084	250	.099	350	D_{max}=4.0°	
6°00'	.070	200	.092	300	.100	350		
7°00'	.077	200	.098	300	D_{max}=5.5°			
8°00'	.084	200	.100	300				
9°00'	.089	250	D_{max}=8.5°					
10°00'	.093	250						
11°00'	.097	250						
12°00'	.099	250						
13°00'	.100	250						
	D_{max}=13.5°							

D = Degree of curve
V = Design speed
e = Rate of superelevation (ft./ft.)
L = Length of superelevation runoff (ft.) for 2-lane pavements
NC = Normal crown section
RC = Remove adverse crown, superelevate at normal crown slope

*State Aid Division--use Standard SA-SE-1

For 3-lane pavements ---------- L = (1.2) x (L for 2-lanes)
For 4-lane undivided pavements- L = (1.5) x (L for 2-lanes)

Spiral transition curves are required for the length of superelevation runoff for all curves listed in the table below the heavy line.

Normally the values for a particular design speed shall be used on all curves throughout a project. However, if it is anticipated that certain curves may experience actual operating speeds in excess of the overall design speed, all safety related design elements, including the maximum degree of curvature and superelevation design, should be based on the operating speed. An appropriate notation should be placed on the plans indicating that the curve has been designed for a specific operating speed.

Very flat curves will not require superelevation. In the table, these situations are identified with the symbol NC, meaning that the normal crown slope used on tangent sections can be carried through the curve.

The symbol RC means that it is necessary only to remove the adverse slope from the outside lane or lanes. All lanes will slope to the inside of the curve at the rate of the normal crown slope.

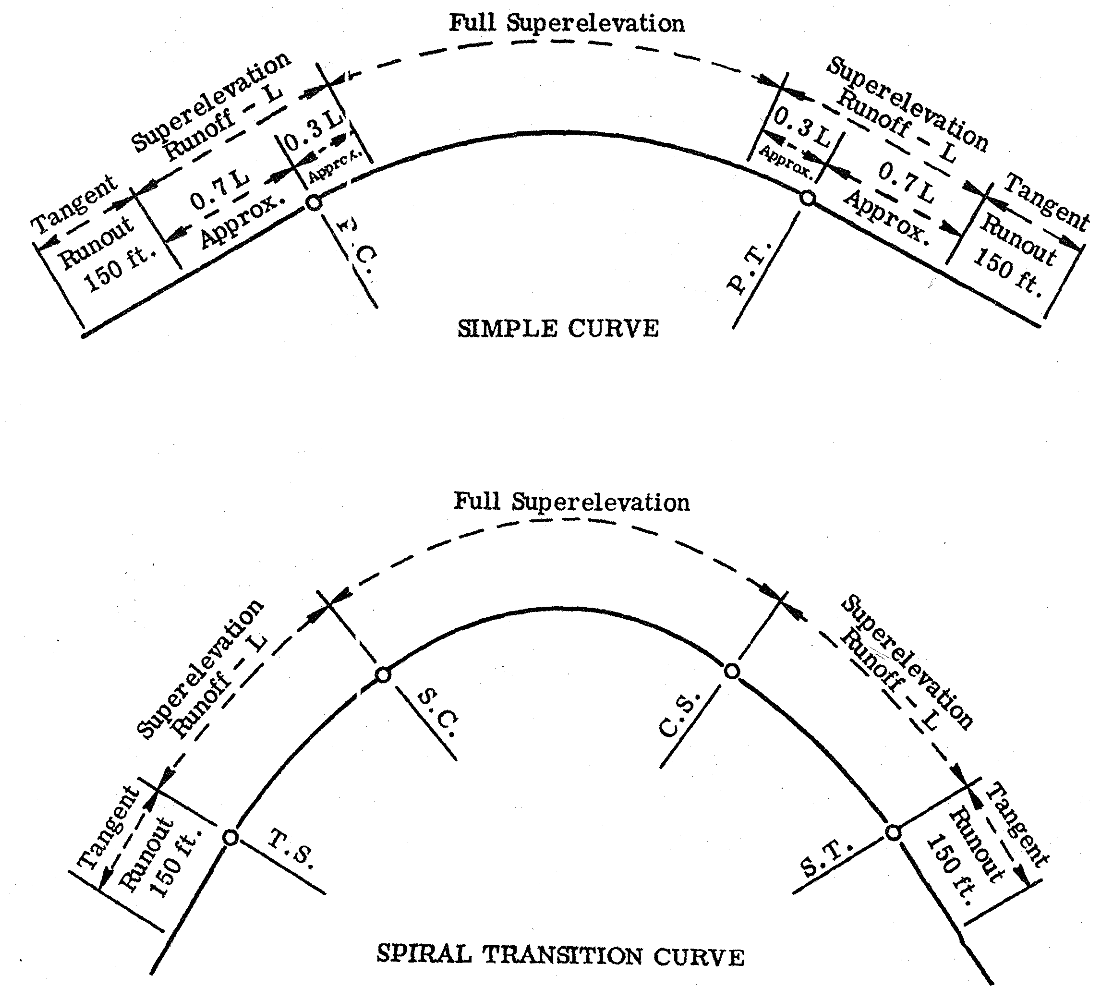
The indicated superelevation rates are applicable, regardless of the number of lanes. The runoff lengths shown are for 2-lane highways. For 3-lane and 4-lane pavements, the runoff lengths should be, respectively, 1.2 and 1.5 times the lengths shown for 2-lane pavements.

Superelevation Transition

To meet the requirements of comfort and safety, superelevation should be introduced and removed uniformly over a length adequate for the likely travel speeds. To be pleasing in appearance, the pavement edges should not be distorted as the driver sees them during the transition.

Practices for superelevation transition on simple curves and curves with spiral transitions are different--even though the rates of superelevation and runoff lengths are the same for a given degree of curvature and design speed. Criteria for applying superelevation transition are shown in the illustration at the right for both simple curves and spiral transition curves.

SUPERELEVATION TRANSITION



When spiral transition curves are used, the superelevation runoff is always coincident with the spiral length (T.S. to S.C. or C.S. to S.T.) and the designated full superelevation is provided between S.C. and C.S.

In the case of simple curves, approximately 0.7 of the superelevation runoff length should occur outside the limits of the curve (before the P.C. and after the P.T.), and about 0.3 of each runoff length should occur within the curve. These proportionate values are not precise--they may be adjusted slightly for the convenience of making the runoff coincide with 25-foot increments of stationing. The intent is a compromise between placing all of the transition on the tangent section (where superelevation is not needed) and placing all of the transition within the curve (where full superelevation is needed throughout the entire length.)

At the outer limits of the superelevation runoff sections (before and after the curve) the inside lane will be sloped at the normal crown rate and the outside lane will be a level section. An additional distance of 150 feet is provided for tangent runout to provide for transition of the outside lane from a level section to a normal crown slope.

Superelevation Rotation Point

Superelevation normally will be rotated about the roadway centerline--that is, the outside lane will rise and the inside lane will lower.

This creates a problem, however, in the case of divided highways with a relatively narrow median. A significant elevation differential may occur between the median shoulders. This makes it difficult to design median slopes adequate for drainage, safety and pleasant appearance. By rotating each roadway about its median edge of pavement, the elevation differential can be minimized.

The following criteria should be used to identify the proper type of superelevation:

CASE I. Superelevation Rotated Around the Centerline

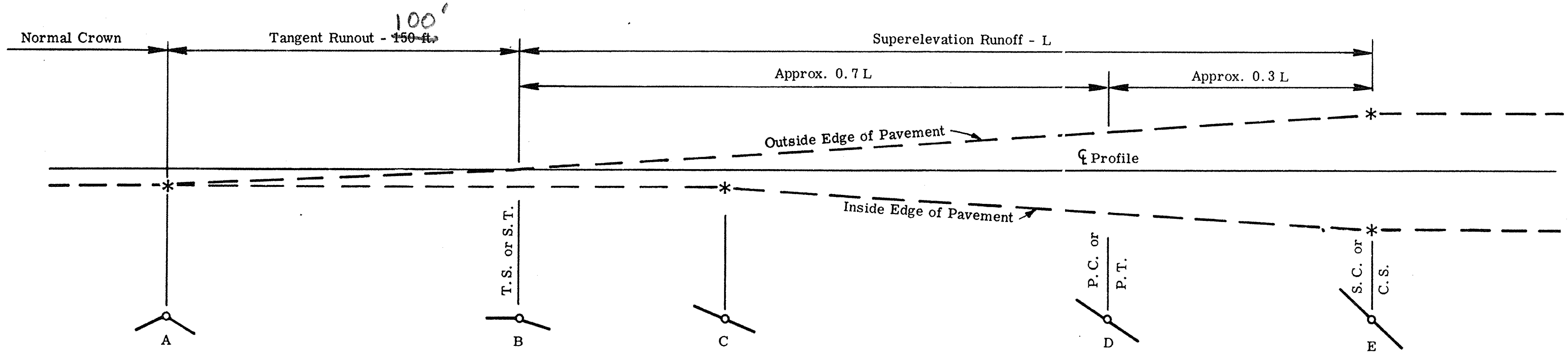
- All 2-lane roadways
- All 3-lane roadways--the third lane being an auxiliary lane such as a climbing lane
- All 4-lane or 6-lane roadways (2 or 3 lanes in each direction) separated by a median width greater than 64 feet.

CASE II. Superelevation Rotated Around Median Edges of Pavement

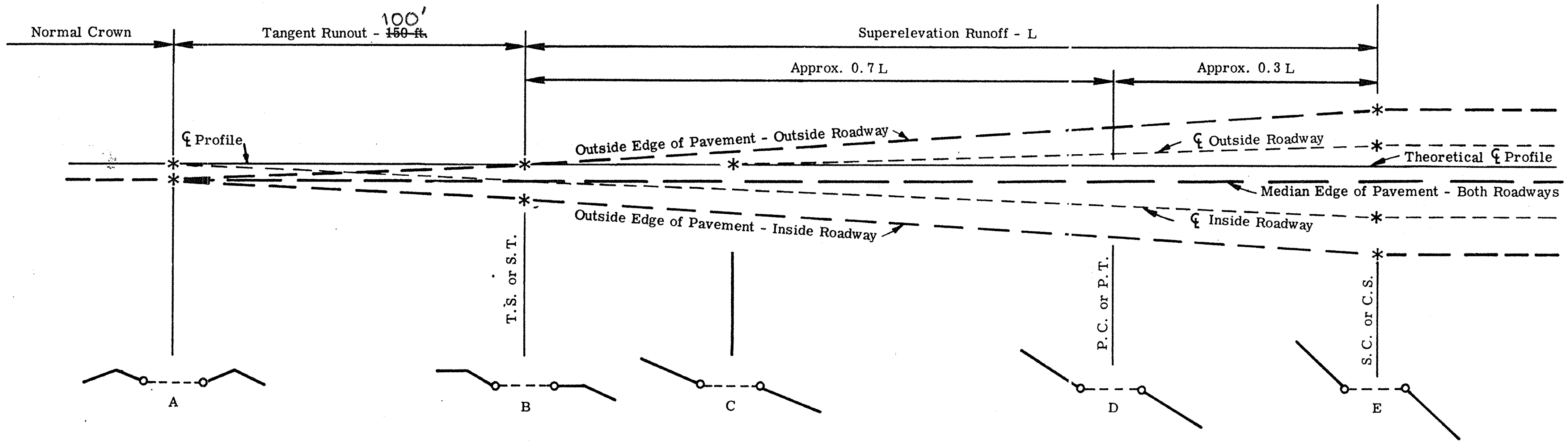
- All 4-lane or 6-lane roadways (2 or 3 lanes in each direction) separated by a median width of 64 feet or less.

Typical superelevation transitions for Cases I and II are illustrated in the diagrams on page 3-10.

CASE I SUPERELEVATION — ROTATION ABOUT CENTERLINE



CASE II SUPERELEVATION — ROTATION ABOUT MEDIAN EDGES



A	=	Normal Crown Section	C	=	Cross Slope at Normal Crown Rate	E	=	Full Superelevation
B	=	Adverse Crown Removed	D	=	Approximately 0.7 Full Superelevation	*	=	Short Vertical Curves at Angular Breaks

SAFETY CONSIDERATIONS

Many design considerations of horizontal alignment are directly related to traffic safety. These are summarized below.

Stopping Sight Distance

Obstructions along the inside of a curve may limit sight distance below that required for safe stopping. Such obstructions might include walls, cut slopes, wooded areas, buildings, high farm crops and sometimes guardrail. These situations should be checked out and adjustments made if necessary to assure stopping sight distance.

The design chart at the right shows the required middle ordinates for clear sight areas for each design speed. Under some conditions, it may be necessary to resort to field measurements or scaling of dimensions on plans.

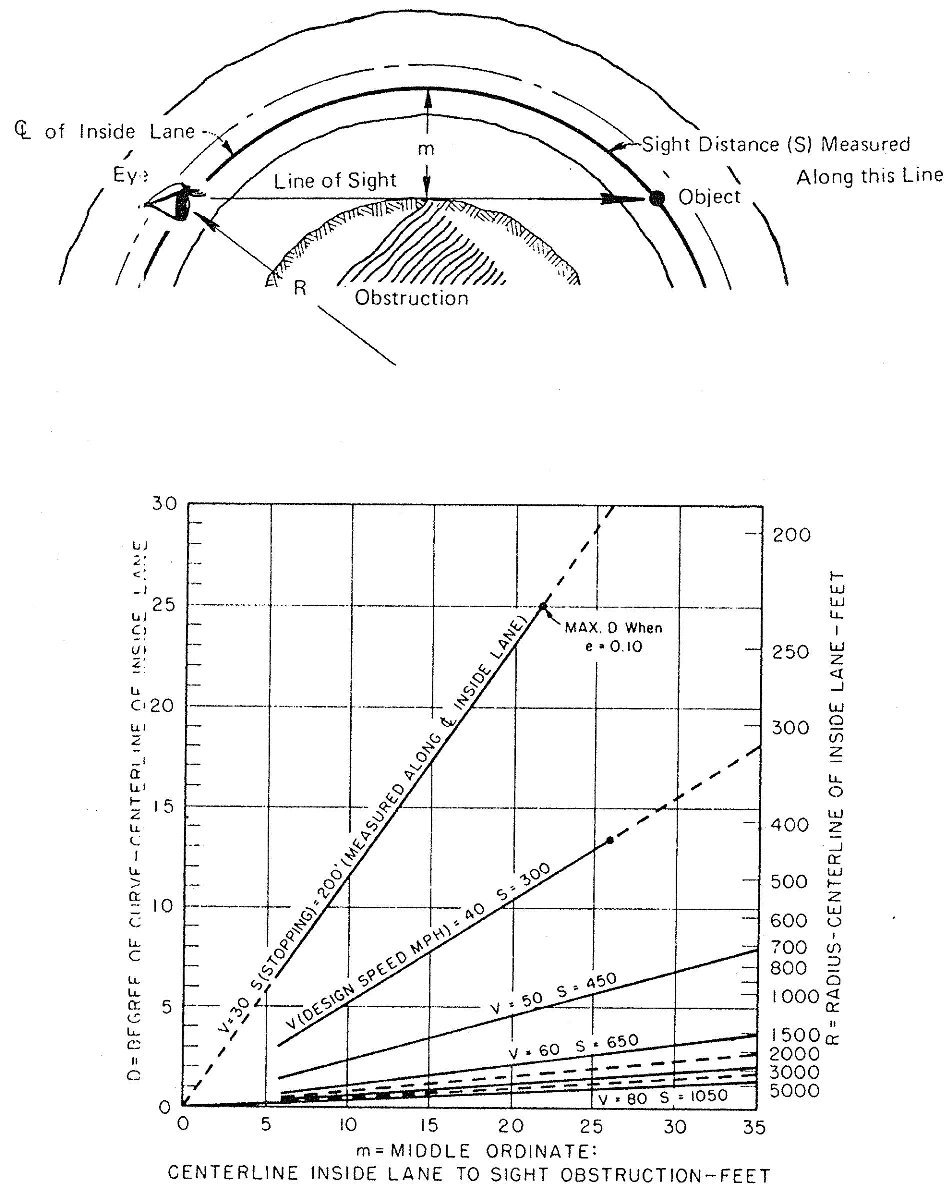
Passing Sight Distance

On high volume 2-lane roadways, consideration should be given to maximizing the opportunities for passing in order to maintain capacity.

Measurement of sight distance along horizontal curves for the purpose of identifying restricted passing areas can best be accomplished by direct scaling from the plans.

For marking of highways with restricted passing sight distance, see Chapter 10.

STOPPING SIGHT DISTANCE CRITERIA
FOR HORIZONTAL CURVES



Decision Sight Distances

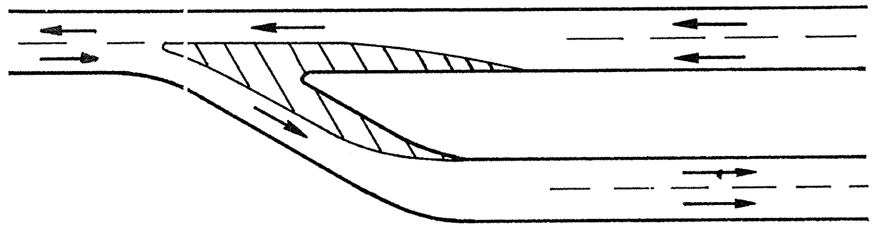
Drivers frequently are required to make decisions concerning vehicle operation. Occasionally the characteristics of the horizontal alignment can adversely affect the ability to make these decisions. Examples of these situations include:

- Proximity to Curves. Of prime importance is the view of the curve ahead, or at least a partial view to indicate direction of curvature.

- Curve Signing. Negotiating a curve requires a driver's full attention and thereby minimizes the effectiveness of signing within curves. The use of short tangents between curves usually results in inadequate lengths of tangent for proper signing. If the design speeds of the curves are equal to or greater than the legal speed, the length of tangent should be at least 300 feet plus the required distance for superelevation runoff. Distances up to 1,000 feet are needed for proper signing when the design speeds are less than the legal speeds.

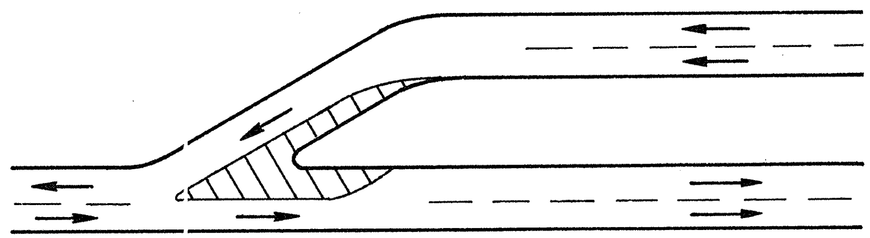
- Route Continuity. When a driver approaches a diverging roadway situation, such as Y-intersections, exit ramps on curves, or flat angle intersections, the main route should be distinctly emphasized with sufficient sight distance to eliminate any uncertainty on the part of the driver.

- Transition Areas. Areas of transition between two lanes and a greater number of lanes can be extremely hazardous. The transition layout which follows is undesirable and should be avoided.



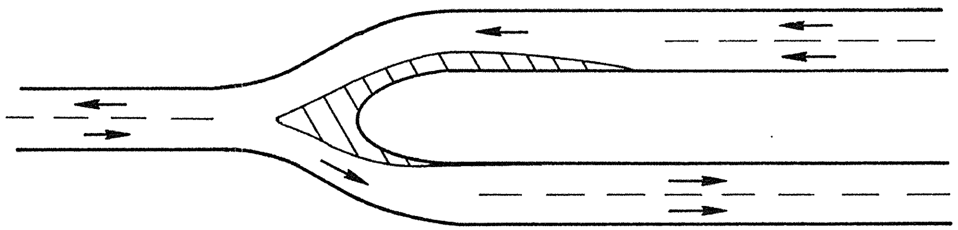
Drivers in both directions may inadvertently continue in a straight line at the junction point and find themselves traveling in the wrong lane of the 2-lane section--or against the flow of traffic in the multilane section. The drivers are dependent solely on signs and pavement markings, whereas poor visibility might negate both of these.

The most desirable transition layout is shown below.



With this layout, the driver entering the multilane section may continue on a straightline course, and the driver entering the 2-lane section is readily channeled into the proper lane. Either driver must make an unnatural turning movement to enter the wrong lane.

The transition layout on the next page is a compromise that is acceptable--but not the most desirable design.



The table which follows is a general guide for sight distances related to decision-making situations. This distance is the line of sight measured from the driver's eye to a point on the road surface at which a decision must have been made.

Predicted Speeds--MPH	Minimum Decision Sight Distance--Ft.
40	300
50	450
60	650
65	750
70	850
75	950

Predicted Speeds

Both design and predicted speeds should be considered. The next table provides a guide for predicting speeds under certain conditions. The values reflect the speeds which normally can be expected on tangent highway sections with open highway conditions and average roadside congestion--regardless of the design speed of the highway. Where considerable roadside congestion is present, the values may be reduced by 10 mph. For new locations, urban predicted speeds may be increased 5 mph.

Type of Road	Predicted Speeds--MPH		
	Level Terrain	Rolling Terrain	Hilly Terrain
INTERSTATE:			
Rural	70-75	70-75	70
Urban	60-65	60-65	60-65
PRIMARY:			
Rural	65-70	65-70	60-65
Urban	60-65	60-65	55-60
SECONDARY:			
Rural	65-70	60-65	60-65
Urban	60-65	55-60	55-60

Most important are the transition areas between tangent and curvilinear alignment. Abrupt changes should be avoided. The 85th percentile speeds on tangent sections of 50-mph design highways may range as high as 65 mph. And when a 50-mph curve is introduced abruptly at the end of a high speed section, there is usually a high incidence of run-off-the-road accidents.

Accident Data

When designing an improvement which basically follows the old alignment, accident data should be reviewed to determine if there is a history of accident experience which might pinpoint specific problems in alignment.

Superelevation

The rate of superelevation should be based on predicted speeds where there is a probability of actual operating speeds exceeding the overall design speed. Caution should be exercised to ensure that other safety-related design elements are not underdesigned.

Proper superelevation runoff should not be sacrificed because of other design considerations such as short tangents or proximity to bridge ends.

In questionable areas, surface contours should be plotted to assure proper coordination between horizontal and vertical alignment and superelevation, so as to avoid flat areas in the roadway surface that would permit ponding of water and encourage hydroplaning.

Chapter 4
VERTICAL ALIGNMENT

Most of the significant decisions regarding horizontal alignment are made during the processes of planning and performing location surveys. However, in the case of vertical alignment, the judgments and decisions of designers primarily establish the characteristics of the roadway.

GENERAL CRITERIA

Several general controls should be considered in the design of vertical alignment.

- Designers should strive for a smooth grade line with gradual changes, consistent with the type of highway and character of terrain, rather than a line with numerous breaks and short lengths of tangent grades.

- The "roller coaster" or "hidden dip" type of profile should be avoided. Such designs often are proposed in the interest of economy, to stretch the highway dollar--but they are aesthetically undesirable and extremely hazardous.

- A "broken back" grade (two crest or two sag vertical curves separated by a short tangent) generally should be avoided. One long vertical curve is more desirable.

- On a long grade it is preferable to place the steepest grade at the bottom and flatten the grade near the top.

- Moderate to steep grades should be reduced through intersections. This benefits vehicles making turns and serves to reduce potential hazards.

- Design decisions affecting sight distance should be based on predicted operating speeds at specific locations, rather than the overall design speed selected for the project. (See Chapter 3 for criteria on decision sight distances and predicted speeds.)

- Vertical sight distance restrictions will reduce passing opportunities. On higher volume 2-lane roads, consideration should be given to maximizing the passing opportunities so as to assure adequate capacity. In extreme cases it may be necessary to introduce passing lanes.

GRADES

The vertical alignment of a highway is referenced to a profile grade line consisting of a series of tangents, connected with vertical curves.

Grade Definition

The point where two grade tangents intersect is called a Vertical Point of Intersection (V.P.I.). Each V.P.I. is identified with a specific horizontal stationing and elevation.

The rate of slope between two adjacent V.P.I.'s is shown as a percent. The numerical value for percent of grade is the vertical rise or fall (feet) in a horizontal distance of 100 feet.

Grades are identified as plus (+) or minus (-) in the direction of the stationing. Rising grades are plus, falling grades are minus.

Maximum Grades

Maximum grades for particular design speeds and types of highways are outlined in Chapter 2. The maximum grades should be used only where absolutely necessary. Grades much flatter than maximum normally should be used.

Grades steeper than the designated maximum should be used only with prior approval of the Roadway Design Engineer.

Minimum Grades

Flat or level grades may be used for uncurbed pavements which are adequately crowned to drain laterally. With curbed pavements, a minimum grade of 0.4 percent should be used to facilitate longitudinal drainage.

Even on uncurbed pavements, it is desirable to provide a minimum of about 0.4 percent longitudinal grade because the original lateral crown slope may subsequently be reduced as a result of swell, consolidation, maintenance operations or resurfacing.

Roadside drain ditches and median swales require a steeper gradient for adequate drainage than is required for roadway surfaces. This is further discussed in the chapter on drainage.

Critical Lengths of Grade

The maximum grade in itself is not a complete design control. The term "critical length of grade" is used to indicate the maximum length of a designated upgrade which will not cause an unreasonable speed reduction of a loaded truck. AASHTO suggests a 15-MPH reduction as being reasonable--and on this basis, the critical length of an upgrade when approached by a level or nearly level section of roadway is as follows:

Upgrade, Percent	3	4	5	6	7	8
Critical Length of Upgrade (feet)	1700	1100	800	600	500	500

On moderate- to high-volume roads, where critical lengths of upgrade are substantially exceeded, consideration should be given to providing climbing lanes, particularly where truck volume is high. Climbing lanes are discussed later in this chapter.

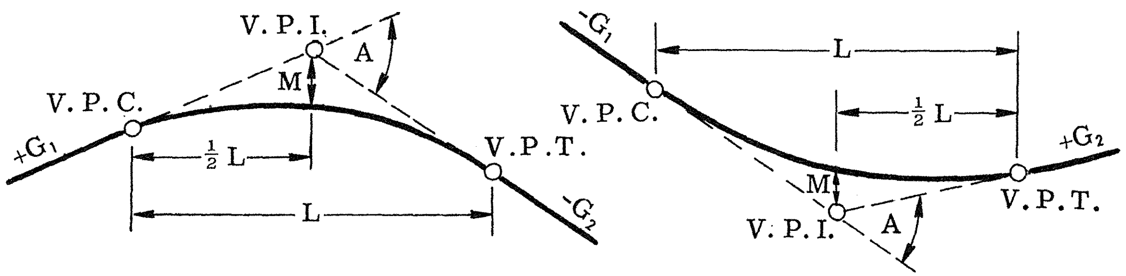
VERTICAL CURVES

Vertical curves are used to effect gradual change between tangent grades at their points of intersection. The major controls for design of vertical curves are related to sight distance and comfort.

Characteristics of Vertical Curves

Vertical curves have the properties of a simple parabolic curve--the vertical offset from the tangent at any point varies as the square of the horizontal distance from the end of the curve.

Curves which are offset below the tangents are called crest vertical curves--those which are offset above the tangents are sag vertical curves. Examples are shown below.



CREST VERTICAL CURVE

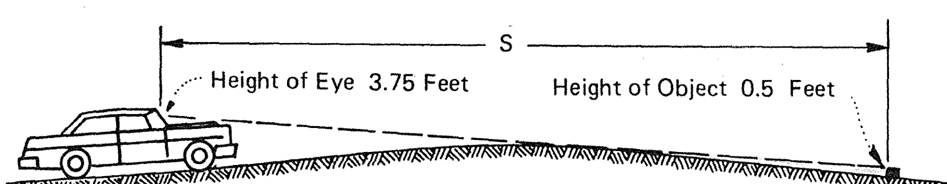
SAG VERTICAL CURVE

V.P.I.	=	Vertical Point of Intersection
V.P.C.	=	Vertical Point of Curvature
V.P.T.	=	Vertical Point of Tangency
G_1 and G_2	=	Tangent Grades in Percent
M	=	Middle Ordinate Offset Distance
A	=	Algebraic Difference of Grades
L	=	Length of Vertical Curve

Sight Distance Controls

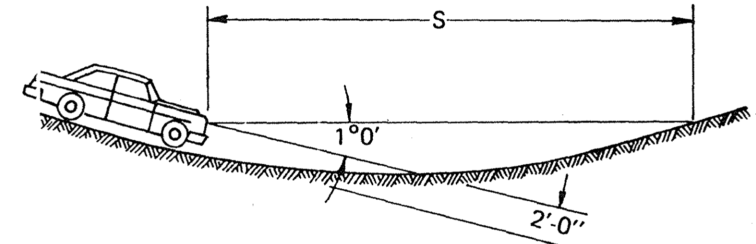
The principal concern in designing vertical curves is to assure that at least the minimum stopping sight distance is provided. The values set forth in the design standards for desirable and minimum sight distances apply to vertical curves.

Basic assumptions are illustrated in the next three drawings for conditions related to stopping sight distance on crest and sag vertical curves, and to passing sight distance on crest vertical curves.



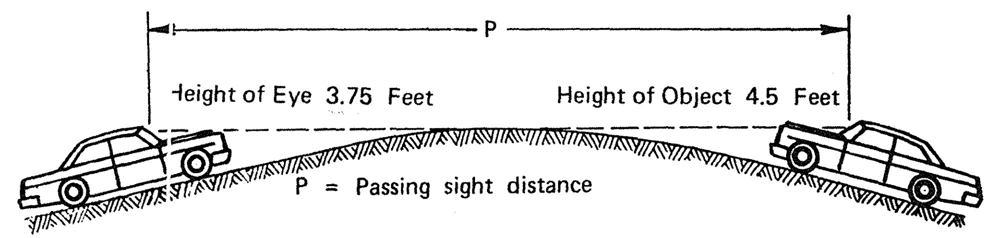
S = Stopping sight distance, feet

A driver must be able to see an object that may be on the road within the minimum stopping sight distance. The line of sight should not be obstructed by the crest of a vertical curve.



S = Headlight beam distance ≈ Stopping sight distance, feet

Nighttime driving conditions govern for sag vertical curves. The designated sight distance should be illuminated by the headlight beam with an assumed upward divergence of 1 degree.



The effect of vertical curve design on passing sight distance is of concern only with crest vertical curves on 2-lane highways.

Minimum Length of Vertical Curves

By analyzing the requirements relating to sight distance and the characteristics of the curve, determinations can be made as to the minimum permissible length of a vertical curve for particular situations.

The rate of change of grade along a vertical curve is constant--and is measured by dividing the algebraic difference between the grades by the length of the curve in feet (A/L). This value gives the percent change in grade per horizontal foot of curve.

The reciprocal of this value (L/A) represents the horizontal distance required to effect a 1-degree change in the gradient along the curve. The expression L/A is termed K, and is useful for determining minimum lengths of vertical curves.

Based on the geometrics of each sight distance condition and assumption, formulas are used to compute values of K for each design speed.

The minimum length of vertical curve is computed by the formula:

$$L = KA$$

where: L = minimum length of vertical curve in feet
A = algebraic difference in tangent grades in percent
K = a constant value for the design speed

Established values of K are shown at the right in the table of Required Sight Distances and Values of K for Vertical Curve Design.

It is emphasized that curves longer than minimum should be used to maximize sight distance where economically feasible. A vertical curve of at least 400-foot length should be used to avoid any appearance of an angular break in the vertical alignment, even though sight distance criteria may permit a shorter curve.

Generally, it is impractical to design crest vertical curves to provide for passing sight distance because of the high cost and the difficulty of fitting the required long vertical curves to the terrain. Ordinarily, passing sight distance will be provided only at those locations where combinations of horizontal alignment and vertical profile do not require the use of crest vertical curves.

For striping of highways with restricted passing sight distance, see Chapter 10.

REQUIRED SIGHT DISTANCES AND VALUES OF "K" FOR VERTICAL CURVE DESIGN

CRITERIA FOR STOPPING SIGHT DISTANCES

Design Speed - MPH	40	50	60	65	70
Minimum Stopping S.D. (feet)	275	350	475	550	600
K Value for:[1/]					
Crest Vertical Curves	55	85	160	215	255
Sag Vertical Curves	55	75	105	130	145
Desirable Stopping S.D. (feet)	300	450	650	750	850
K Value for:[1/]					
Crest Vertical Curves	65	145	300	400	515
Sag Vertical Curves	60	100	155	185	215

CRITERIA FOR PASSING SIGHT DISTANCES[2/]

Design Speed - MPH	40	50	60	65	70
Minimum Passing S.D. (feet)	1500	1800	2100	2300	2500
K Value for:[1/]					
Crest Vertical Curves	686	985	1340	1605	1895

[1/] K value is a coefficient by which the algebraic difference in grade may be multiplied to determine the length in feet of the vertical curve which will provide the designated sight distance.

[2/] Passing sight distance criteria are for design purposes only and should not be confused with criteria for marking no-passing zones as set forth in the Manual of Uniform Traffic Control Devices.

ESTABLISHING PROFILE GRADE

The profile grade normally will represent the finished surface elevation at the centerline of the roadway or the median edge of the pavement for divided highways with a raised median.

Profile grades may be computed manually, or by the computer. Manual computation procedures are described in the following paragraphs to assure understanding of the concepts.

Grade Computations

Initial efforts toward establishing the profile grade are recorded on a working profile. Using recommendations from the field, and adhering to standards and criteria in this manual, the designer plots a tentative grade line on the working profile with the stationing and approximate elevation of each V.P.I. clearly defined.

Starting at the beginning of the project, a grade should be computed which, when extended forward, would check in reasonably close to the plotted elevation of the first V.P.I. The rate of grade (percent) is computed by dividing the vertical difference by the horizontal distance, and multiplying by 100.

To the extent practical, the percent grade should be computed and recorded to two decimal places--and should be selected in the nearest multiple of 0.04 percent to facilitate field staking at 25-foot intervals.

It is desirable to locate V.P.I.'s at even stations or midway between stations for ease of computation. V.P.I. elevations should always be recorded to the nearest 0.01 foot.

After the first grade and V.P.I. elevation have been established, the process is repeated between subsequent V.P.I.'s. Each grade and V.P.I. elevation is recorded on the working profile.

Frequently it is necessary to adjust a grade line after the initial grade computations have been made. When making this adjustment, it may be necessary to compute the new grade to four or five decimal places to accurately check-in to a previously established V.P.I. elevation.

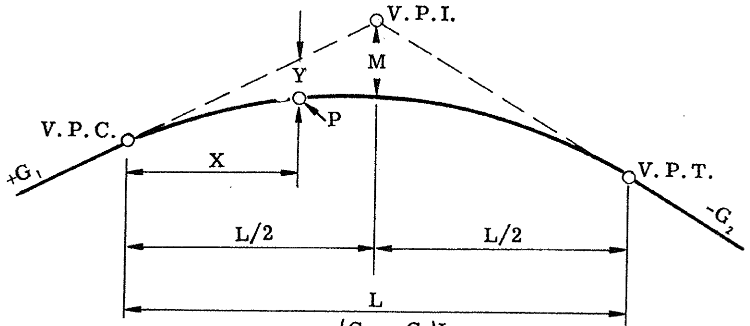
Vertical Curve Computations

After the tangent grades have been established, appropriate vertical curves must be designed for each V.P.I. Standards and criteria for sight distance and minimum curvature should be adhered to.

Vertical curve profile grade elevations are established by computing vertical offset distances between the tangent grade and the vertical curve at various points along the stationing. In the case of crest vertical curves, these offset distances are subtracted from the tangent grade elevations; for sag vertical curves, the computed offsets are added to the tangent elevation.

The diagram on page 4-6 illustrates a crest vertical curve--however, the formulas also are applicable to a sag vertical curve. The important things to recognize are the plus or minus characteristics of the grades when computing algebraic differences--and whether the offset distances are to be added to or subtracted from the tangent elevations.

VERTICAL CURVE COMPUTATIONS



$$M = \frac{(G_1 - G_2)L}{8}$$

$$Y = M\frac{X^2}{(L/2)^2}$$

Where:
- M = Middle Ordinate Distance at V.P.I. (feet)
- L = Length of Vertical Curve (stations)
- G_1 and G_2 = Tangent Grades (±percent)
- P = Any Point on the Vertical Curve
- X = Horizontal Distance from V.P.C. to P (stations)
- Y = Vertical Offset Distance (feet)

PROCEDURE:

1. Compute the minimum curve length which will satisfy the sight distance requirements for the design speed (the product of the albegraic difference in grades and the appropriate value for K selected from the table).

2. Select a vertical curve length, preferably in even multiples of 100 feet, which fits the terrain conditions and equals or exceeds the prescribed minimum length.

3. Compute the middle ordinate distance (M).

4. Compute the vertical offset distance (Y) at each station. For points between the V.P.C. and V.P.I., the distance X is measured ahead from the V.P.C. For points between the V.P.I. and V.P.T., the distance X is measured back from the V.P.T.

5. Establish curve elevations by subtracting Y distance from tangent elevations (crest vertical curves) or adding Y distance to tangent elevations (sag vertical curves).

When the grades have opposite signs (one is + and the other is -) the high point on crest vertical curves and the low point on sag vertical curves can be identified in terms of X distance from the V.P.C. by the formula:

$$X = L\frac{G_1}{G_1 - G_2}$$

Vertical offset distances (Y) at any horizontal distance (X) from the V.P.C. or V.P.T. can readily be computed using a calculator and the constant values (C) identified in the table on pages 4-7 and 4-8.

The formula is: $$Y = \left(\frac{G_1 - G_2}{L}\right)(C)$$

where:
- Y = Vertical Offset (feet)
- $G_1 - G_2$ = Algebraic difference in grades (%)
- L = Length of vertical curve (stations)
- C = Constant from table

The procedure is:

1. Compute the value of $\frac{G_1 - G_2}{L}$ for the vertical curve. This value can be locked in the calculator as a constant multiplier for all subsequent calculations for this curve.

2. Enter the table at the distance (X) which represents the horizontal distance from the V.P.C. to the first station. Select the corresponding value of the constant (C) and find the product of this value and the constant multiplier. This distance is the vertical offset to be added to or subtracted from the tangent grade elevation at the station.

3. Repeat the calculation at each station between the V.P.C. and the V.P.I.--based on the X distance from the V.P.C.

4. Continue the calculations for each station between the V.P.I. and the V.P.T. However, the value of C is based on the X distance between the station and the V.P.T.

VALUES OF "C" FOR VERTICAL CURVE COMPUTATIONS

X = HORIZONTAL DISTANCE   C = COEFFICIENT

X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C
1	0.000	51	0.130	101	0.510	151	1.140	201	2.020	251	3.150	301	4.530	351	6.160	401	8.040	451	10.170	501	12.550	551	15.180	601	18.060	651	21.190	701	24.570
2	0.000	52	0.135	102	0.520	152	1.155	202	2.040	252	3.175	302	4.560	352	6.195	402	8.080	452	10.215	502	12.600	552	15.235	602	18.120	652	21.255	702	24.640
3	0.000	53	0.140	103	0.530	153	1.170	203	2.060	253	3.200	303	4.590	353	6.230	403	8.120	453	10.260	503	12.650	553	15.290	603	18.180	653	21.320	703	24.710
4	0.001	54	0.146	104	0.541	154	1.186	204	2.081	254	3.226	304	4.621	354	6.266	404	8.161	454	10.306	504	12.701	554	15.346	604	18.241	654	21.386	704	24.781
5	0.001	55	0.151	105	0.551	155	1.201	205	2.101	255	3.251	305	4.651	355	6.301	405	8.201	455	10.351	505	12.751	555	15.401	605	18.301	655	21.451	705	24.851
6	0.002	56	0.157	106	0.562	156	1.217	206	2.122	256	3.277	306	4.682	356	6.337	406	8.242	456	10.397	506	12.802	556	15.457	606	18.362	656	21.517	706	24.922
7	0.002	57	0.162	107	0.572	157	1.232	207	2.142	257	3.302	307	4.712	357	6.372	407	8.282	457	10.442	507	12.852	557	15.512	607	18.422	657	21.582	707	24.992
8	0.003	58	0.168	108	0.583	158	1.248	208	2.163	258	3.328	308	4.743	358	6.408	408	8.323	458	10.488	508	12.903	558	15.568	608	18.483	658	21.648	708	25.063
9	0.004	59	0.174	109	0.594	159	1.264	209	2.184	259	3.354	309	4.774	359	6.444	409	8.364	459	10.534	509	12.954	559	15.624	609	18.544	659	21.714	709	25.134
10	0.005	60	0.180	110	0.605	160	1.280	210	2.205	260	3.380	310	4.805	360	6.480	410	8.405	460	10.580	510	13.005	560	15.680	610	18.605	660	21.780	710	25.205
11	0.006	61	0.186	111	0.616	161	1.296	211	2.226	261	3.406	311	4.836	361	6.516	411	8.446	461	10.626	511	13.056	561	15.736	611	18.666	661	21.846	711	25.276
12	0.007	62	0.192	112	0.627	162	1.312	212	2.247	262	3.432	312	4.867	362	6.552	412	8.487	462	10.672	512	13.107	562	15.792	612	18.727	662	21.912	712	25.347
13	0.008	63	0.198	113	0.638	163	1.328	213	2.268	263	3.458	313	4.898	363	6.588	413	8.528	463	10.718	513	13.158	563	15.848	613	18.788	663	21.978	713	25.418
14	0.010	64	0.205	114	0.650	164	1.345	214	2.290	264	3.485	314	4.930	364	6.625	414	8.570	464	10.765	514	13.210	564	15.905	614	18.850	664	22.045	714	25.490
15	0.011	65	0.211	115	0.661	165	1.361	215	2.311	265	3.511	315	4.961	365	6.661	415	8.611	465	10.811	515	13.261	565	15.961	615	18.911	665	22.111	715	25.561
16	0.013	66	0.218	116	0.673	166	1.378	216	2.333	266	3.538	316	4.993	366	6.698	416	8.653	466	10.858	516	13.313	566	16.018	616	18.973	666	22.178	716	25.633
17	0.014	67	0.224	117	0.684	167	1.394	217	2.354	267	3.564	317	5.024	367	6.734	417	8.694	467	10.904	517	13.364	567	16.074	617	19.034	667	22.244	717	25.704
18	0.016	68	0.231	118	0.696	168	1.411	218	2.376	268	3.591	318	5.056	368	6.771	418	8.736	468	10.951	518	13.416	568	16.131	618	19.096	668	22.311	718	25.776
19	0.018	69	0.238	119	0.708	169	1.428	219	2.398	269	3.618	319	5.088	369	6.808	419	8.778	469	10.998	519	13.468	569	16.188	619	19.158	669	22.378	719	25.848
20	0.020	70	0.245	120	0.720	170	1.445	220	2.420	270	3.645	320	5.120	370	6.845	420	8.820	470	11.045	520	13.520	570	16.245	620	19.220	670	22.445	720	25.920
21	0.022	71	0.252	121	0.732	171	1.462	221	2.442	271	3.672	321	5.152	371	6.882	421	8.862	471	11.092	521	13.572	571	16.302	621	19.282	671	22.512	721	25.992
22	0.024	72	0.259	122	0.744	172	1.479	222	2.464	272	3.699	322	5.184	372	6.919	422	8.904	472	11.139	522	13.624	572	16.359	622	19.344	672	22.579	722	26.064
23	0.026	73	0.266	123	0.756	173	1.496	223	2.486	273	3.726	323	5.216	373	6.956	423	8.946	473	11.186	523	13.676	573	16.416	623	19.406	673	22.646	723	26.136
24	0.029	74	0.274	124	0.769	174	1.514	224	2.509	274	3.754	324	5.249	374	6.994	424	8.989	474	11.234	524	13.729	574	16.474	624	19.469	674	22.714	724	26.209
25	0.031	75	0.281	125	0.781	175	1.531	225	2.531	275	3.781	325	5.281	375	7.031	425	9.031	475	11.281	525	13.781	575	16.531	625	19.531	675	22.781	725	26.281
26	0.034	76	0.289	126	0.794	176	1.549	226	2.554	276	3.809	326	5.314	376	7.069	426	9.074	476	11.329	526	13.834	576	16.589	626	19.594	676	22.849	726	26.354
27	0.036	77	0.296	127	0.806	177	1.566	227	2.576	277	3.836	327	5.346	377	7.106	427	9.116	477	11.376	527	13.886	577	16.646	627	19.656	677	22.916	727	26.426
28	0.039	78	0.304	128	0.819	178	1.584	228	2.599	278	3.864	328	5.379	378	7.144	428	9.159	478	11.424	528	13.939	578	16.704	628	19.719	678	22.984	728	26.499
29	0.042	79	0.312	129	0.832	179	1.602	229	2.622	279	3.892	329	5.412	379	7.182	429	9.202	479	11.472	529	13.992	579	16.762	629	19.782	679	23.052	729	26.572
30	0.045	80	0.320	130	0.845	180	1.620	230	2.645	280	3.920	330	5.445	380	7.220	430	9.245	480	11.520	530	14.045	580	16.820	630	19.845	680	23.120	730	26.645
31	0.048	81	0.328	131	0.858	181	1.638	231	2.668	281	3.948	331	5.478	381	7.258	431	9.288	481	11.568	531	14.098	581	16.878	631	19.908	681	23.188	731	26.718
32	0.051	82	0.336	132	0.871	182	1.656	232	2.691	282	3.976	332	5.511	382	7.296	432	9.331	482	11.616	532	14.151	582	16.936	632	19.971	682	23.256	732	26.791
33	0.054	83	0.344	133	0.884	183	1.674	233	2.714	283	4.004	333	5.544	383	7.334	433	9.374	483	11.664	533	14.204	583	16.994	633	20.034	683	23.324	733	26.864
34	0.058	84	0.353	134	0.898	184	1.693	234	2.738	284	4.033	334	5.578	384	7.373	434	9.418	484	11.713	534	14.258	584	17.053	634	20.098	684	23.393	734	26.938
35	0.061	85	0.361	135	0.911	185	1.711	235	2.761	285	4.061	335	5.611	385	7.411	435	9.461	485	11.761	535	14.311	585	17.111	635	20.161	685	23.461	735	27.011
36	0.065	86	0.370	136	0.925	186	1.730	236	2.785	286	4.090	336	5.645	386	7.450	436	9.505	486	11.810	536	14.365	586	17.170	636	20.225	686	23.530	736	27.085
37	0.068	87	0.378	137	0.938	187	1.748	237	2.808	287	4.118	337	5.678	387	7.488	437	9.548	487	11.858	537	14.418	587	17.228	637	20.288	687	23.598	737	27.158
38	0.072	88	0.387	138	0.952	188	1.767	238	2.832	288	4.147	338	5.712	388	7.527	438	9.592	488	11.907	538	14.472	588	17.287	638	20.352	688	23.667	738	27.232
39	0.076	89	0.396	139	0.966	189	1.786	239	2.856	289	4.176	339	5.746	389	7.566	439	9.636	489	11.956	539	14.526	589	17.346	639	20.416	689	23.736	739	27.306
40	0.080	90	0.405	140	0.980	190	1.805	240	2.880	290	4.205	340	5.780	390	7.605	440	9.680	490	12.005	540	14.580	590	17.405	640	20.480	690	23.805	740	27.380
41	0.084	91	0.414	141	0.994	191	1.824	241	2.904	291	4.234	341	5.814	391	7.644	441	9.724	491	12.054	541	14.634	591	17.464	641	20.544	691	23.874	741	27.454
42	0.088	92	0.423	142	1.008	192	1.843	242	2.928	292	4.263	342	5.848	392	7.683	442	9.768	492	12.103	542	14.688	592	17.523	642	20.608	692	23.943	742	27.528
43	0.092	93	0.432	143	1.022	193	1.862	243	2.952	293	4.292	343	5.882	393	7.722	443	9.812	493	12.152	543	14.742	593	17.582	643	20.672	693	24.012	743	27.602
44	0.097	94	0.442	144	1.037	194	1.882	244	2.977	294	4.322	344	5.917	394	7.762	444	9.857	494	12.202	544	14.797	594	17.642	644	20.737	694	24.082	744	27.677
45	0.101	95	0.451	145	1.051	195	1.901	245	3.001	295	4.351	345	5.951	395	7.801	445	9.901	495	12.251	545	14.851	595	17.701	645	20.801	695	24.151	745	27.751
46	0.106	96	0.461	146	1.066	196	1.921	246	3.026	296	4.381	346	5.986	396	7.841	446	9.946	496	12.301	546	14.906	596	17.761	646	20.866	696	24.221	746	27.826
47	0.110	97	0.470	147	1.080	197	1.940	247	3.050	297	4.410	347	6.020	397	7.880	447	9.990	497	12.350	547	14.960	597	17.820	647	20.930	697	24.290	747	27.900
48	0.115	98	0.480	148	1.095	198	1.960	248	3.075	298	4.440	348	6.055	398	7.920	448	10.035	498	12.400	548	15.015	598	17.880	648	20.995	698	24.360	748	27.975
49	0.120	99	0.490	149	1.110	199	1.980	249	3.100	299	4.400	349	6.090	399	7.960	449	10.080	499	12.450	549	15.070	599	17.940	649	21.060	699	24.430	749	28.050
50	0.125	100	0.500	150	1.125	200	2.000	250	3.125	300	4.500	350	6.125	400	8.000	450	10.125	500	12.500	550	15.125	600	18.000	650	21.125	700	24.500	750	28.125

VALUES OF "C" FOR VERTICAL CURVE COMPUTATIONS

X = HORIZONTAL DISTANCE C = COEFFICIENT

X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C	X	C
751	28.200	801	32.080	851	36.210	901	40.590	951	45.220	1001	50.100	1051	55.230	1101	60.610	1151	66.240	1201	72.120	1251	78.250	1301	84.630	1351	91.260	1401	98.140	1451	105.270
752	28.275	802	32.160	852	36.295	902	40.680	952	45.315	1002	50.200	1052	55.335	1102	60.720	1152	66.355	1202	72.240	1252	78.375	1302	84.760	1352	91.395	1402	98.280	1452	105.415
753	28.350	803	32.240	853	36.380	903	40.770	953	45.410	1003	50.300	1053	55.440	1103	60.830	1153	66.470	1203	72.360	1253	78.500	1303	84.890	1353	91.530	1403	98.420	1453	105.560
754	28.426	804	32.321	854	36.466	904	40.861	954	45.506	1004	50.401	1054	55.546	1104	60.941	1154	66.586	1204	72.481	1254	78.626	1304	85.021	1354	91.666	1404	98.561	1454	105.706
755	28.501	805	32.401	855	36.551	905	40.951	955	45.601	1005	50.501	1055	55.651	1105	61.051	1155	66.701	1205	72.601	1255	78.751	1305	85.151	1355	91.801	1405	98.701	1455	105.851
756	28.577	806	32.482	856	36.637	906	41.042	956	45.697	1006	50.602	1056	55.757	1106	61.162	1156	66.817	1206	72.722	1256	78.877	1306	85.282	1356	91.937	1406	98.842	1456	105.997
757	28.652	807	32.562	857	36.722	907	41.132	957	45.742	1007	50.702	1057	55.862	1107	61.272	1157	66.932	1207	72.842	1257	79.002	1307	85.412	1357	92.072	1407	98.982	1457	106.142
758	28.728	808	32.643	858	36.808	908	41.223	958	45.888	1008	50.803	1058	55.968	1108	61.383	1158	67.048	1208	72.963	1258	79.128	1308	85.543	1358	92.208	1408	99.123	1458	106.288
759	28.804	809	32.724	859	36.894	909	41.314	959	45.984	1009	50.904	1059	56.074	1109	61.494	1159	67.164	1209	73.084	1259	79.254	1309	85.674	1359	92.344	1409	99.264	1459	106.434
760	28.880	810	32.805	860	36.980	910	41.405	960	46.080	1010	51.005	1060	56.180	1110	61.605	1160	67.280	1210	73.205	1260	79.380	1310	85.805	1360	92.480	1410	99.405	1460	106.580
761	28.956	811	32.886	861	37.066	911	41.496	961	46.176	1011	51.106	1061	56.286	1111	61.716	1161	67.396	1211	73.326	1261	79.506	1311	85.936	1361	92.616	1411	99.546	1461	106.726
762	29.032	812	32.967	862	37.152	912	41.587	962	46.272	1012	51.207	1062	56.392	1112	61.827	1162	67.512	1212	73.447	1262	79.632	1312	86.067	1362	92.752	1412	99.687	1462	106.872
763	29.108	813	33.048	863	37.238	913	41.678	963	46.368	1013	51.308	1063	56.498	1113	61.938	1163	67.628	1213	73.568	1263	79.758	1313	86.198	1363	92.888	1413	99.828	1463	107.018
764	29.185	814	33.130	864	37.325	914	41.770	964	46.465	1014	51.409	1064	56.605	1114	62.050	1164	67.745	1214	73.690	1264	79.885	1314	86.330	1364	93.025	1414	99.970	1464	107.165
765	29.261	815	33.211	865	37.411	915	41.861	965	46.561	1015	51.511	1065	56.711	1115	62.161	1165	67.861	1215	73.811	1265	80.011	1315	86.461	1365	93.161	1415	100.111	1465	107.311
766	29.338	816	33.293	866	37.498	916	41.953	966	46.657	1016	51.613	1066	56.818	1116	62.273	1166	67.978	1216	73.933	1266	80.138	1316	86.593	1366	93.298	1416	100.253	1466	107.458
767	29.414	817	33.374	867	37.584	917	42.044	967	46.754	1017	51.714	1067	56.924	1117	62.384	1167	68.094	1217	74.054	1267	80.264	1317	86.724	1367	93.434	1417	100.394	1467	107.604
768	29.491	818	33.456	868	37.671	918	42.136	968	46.851	1018	51.816	1068	57.031	1118	62.496	1168	68.211	1218	74.176	1268	80.391	1318	86.856	1368	93.571	1418	100.536	1468	107.751
769	29.568	819	33.538	869	37.758	919	42.228	969	46.948	1019	51.918	1069	57.138	1119	62.608	1169	68.328	1219	74.298	1269	80.518	1319	86.988	1369	93.708	1419	100.678	1469	107.898
770	29.645	820	33.620	870	37.845	920	42.320	970	47.045	1020	52.020	1070	57.245	1120	62.720	1170	68.445	1220	74.420	1270	80.645	1320	87.120	1370	93.845	1420	100.820	1470	108.045
771	29.722	821	33.702	871	37.932	921	42.412	971	47.142	1021	52.122	1071	57.352	1121	62.832	1171	68.562	1221	74.542	1271	80.772	1321	87.252	1371	93.982	1421	100.962	1471	108.192
772	29.799	822	33.784	872	38.019	922	42.504	972	47.239	1022	52.224	1072	57.459	1122	62.944	1172	68.679	1222	74.664	1272	80.899	1322	87.384	1372	94.119	1422	101.104	1472	108.339
773	29.876	823	33.866	873	38.106	923	42.596	973	47.336	1023	52.326	1073	57.566	1123	63.056	1173	68.796	1223	74.786	1273	81.026	1323	87.516	1373	94.256	1423	101.246	1473	108.486
774	29.954	824	33.949	874	38.194	924	42.689	974	47.434	1024	52.428	1074	57.674	1124	63.169	1174	68.914	1224	74.909	1274	81.154	1324	87.649	1374	94.393	1424	101.389	1474	108.634
775	30.031	825	34.031	875	38.281	925	42.781	975	47.531	1025	52.531	1075	57.781	1125	63.281	1175	69.031	1225	75.031	1275	81.281	1325	87.781	1375	94.531	1425	101.531	1475	108.781
776	30.109	826	34.114	876	38.369	926	42.874	976	47.629	1026	52.634	1076	57.889	1126	63.394	1176	69.149	1226	75.154	1276	81.409	1326	87.914	1376	94.669	1426	101.674	1476	108.929
777	30.186	827	34.196	877	38.456	927	42.966	977	47.726	1027	52.736	1077	57.996	1127	63.506	1177	69.266	1227	75.276	1277	81.536	1327	88.046	1377	94.806	1427	101.816	1477	109.076
778	30.264	828	34.279	878	38.544	928	43.059	978	47.824	1028	52.839	1078	58.104	1128	63.619	1178	69.384	1228	75.399	1278	81.664	1328	88.179	1378	94.944	1428	101.959	1478	109.224
779	30.342	829	34.362	879	38.632	929	43.152	979	47.922	1029	52.942	1079	58.212	1129	63.732	1179	69.502	1229	75.522	1279	81.792	1329	88.312	1379	95.082	1429	102.102	1479	109.372
780	30.420	830	34.445	880	38.720	930	43.245	980	48.020	1030	53.045	1080	58.320	1130	63.845	1180	69.620	1230	75.645	1280	81.920	1330	88.445	1380	95.220	1430	102.245	1480	109.520
781	30.498	831	34.528	881	38.808	931	43.338	981	48.118	1031	53.148	1081	58.428	1131	63.958	1181	69.738	1231	75.768	1281	82.048	1331	88.578	1381	95.358	1431	102.388	1481	109.668
782	30.576	832	34.611	882	38.896	932	43.431	982	48.216	1032	53.251	1082	58.536	1132	64.071	1182	69.856	1232	75.891	1282	82.176	1332	88.711	1382	95.496	1432	102.531	1482	109.816
783	30.654	833	34.694	883	38.984	933	43.524	983	48.314	1033	53.354	1083	58.644	1133	64.184	1183	69.974	1233	76.014	1283	82.304	1333	88.844	1383	95.634	1433	102.674	1483	109.964
784	30.733	834	34.778	884	39.073	934	43.618	984	48.413	1034	53.458	1084	58.753	1134	64.298	1184	70.093	1234	76.138	1284	82.433	1334	88.978	1384	95.773	1434	102.818	1484	110.113
785	30.811	835	34.861	885	39.161	935	43.711	985	48.511	1035	53.561	1085	58.861	1135	64.411	1185	70.211	1235	76.261	1285	82.561	1335	89.111	1385	95.911	1435	102.961	1485	110.261
786	30.890	836	34.945	886	39.250	936	43.805	986	48.610	1036	53.665	1086	58.970	1136	64.525	1186	70.330	1236	76.385	1286	82.690	1336	89.245	1386	96.050	1436	103.105	1486	110.410
787	30.968	837	35.028	887	39.338	937	43.898	987	48.708	1037	53.768	1087	59.078	1137	64.638	1187	70.448	1237	76.508	1287	81.818	1337	89.378	1387	96.188	1437	103.248	1487	110.558
788	31.047	838	35.112	888	39.427	938	43.992	988	48.807	1038	53.872	1088	59.187	1138	64.752	1188	70.567	1238	76.632	1288	82.947	1338	89.512	1388	96.327	1438	103.392	1488	110.707
789	31.126	839	35.196	889	39.516	939	44.086	989	48.906	1039	53.976	1089	59.296	1139	64.866	1189	70.686	1239	76.756	1289	83.076	1339	89.646	1389	96.466	1439	103.536	1489	110.856
790	31.205	840	35.280	890	39.605	940	44.180	990	49.005	1040	54.080	1090	59.405	1140	64.980	1190	70.805	1240	76.880	1290	83.205	1340	89.780	1390	96.605	1440	103.680	1490	111.005
791	31.284	841	35.364	891	39.694	941	44.274	991	49.104	1041	54.184	1091	59.514	1141	65.094	1191	70.924	1241	77.004	1291	83.334	1341	89.914	1391	96.744	1441	103.824	1491	111.154
792	31.363	842	35.448	892	39.783	942	44.368	992	49.203	1042	54.288	1092	59.623	1142	65.208	1192	71.043	1242	77.128	1292	83.463	1342	90.048	1392	96.883	1442	103.968	1492	111.303
793	31.442	843	35.532	893	39.872	943	44.462	993	49.302	1043	54.392	1093	59.732	1143	65.322	1193	71.162	1243	77.252	1293	83.592	1343	90.182	1393	97.022	1443	104.112	1493	111.452
794	31.522	844	35.617	894	39.962	944	44.557	994	49.402	1044	54.497	1094	59.842	1144	65.437	1194	71.282	1244	77.377	1294	83.722	1344	90.317	1394	97.162	1444	104.257	1494	111.602
795	31.601	845	35.701	895	40.051	945	44.651	995	49.501	1045	54.601	1095	59.951	1145	65.551	1195	71.401	1245	77.501	1295	83.851	1345	90.451	1395	97.301	1445	104.401	1495	111.751
796	31.681	846	35.786	896	40.141	946	44.746	996	49.601	1046	54.706	1096	60.061	1146	65.666	1196	71.521	1246	77.626	1296	83.981	1346	90.586	1396	97.440	1446	104.546	1496	111.901
797	31.760	847	35.870	897	40.230	947	44.840	997	49.700	1047	54.810	1097	60.170	1147	65.780	1197	71.640	1247	77.750	1297	84.110	1347	90.720	1397	97.580	1447	104.690	1497	112.050
798	31.840	848	35.955	898	40.320	948	44.935	998	49.800	1048	54.915	1098	60.280	1148	65.895	1198	71.760	1248	77.875	1298	84.240	1348	90.855	1398	97.720	1448	104.835	1498	112.200
799	31.920	849	36.040	899	40.410	949	45.030	999	49.900	1049	55.020	1099	60.390	1149	66.010	1199	71.880	1249	78.000	1299	84.370	1349	90.990	1399	97.860	1449	104.980	1499	112.350
800	32.000	850	36.125	900	40.500	950	45.125	1000	50.000	1050	55.125	1100	60.500	1150	66.125	1200	72.000	1250	78.125	1300	84.500	1350	91.125	1400	98.000	1450	105.125	1500	112.500

Recording Profile Grades

The established profile grade elevations should be recorded to the nearest 0.01 foot on the cross-section sheets and along the bottom of the plan-profile sheets.

Also to be shown on the profile sheets are the stationing and elevation at each V.P.C., V.P.I. and V.P.T., the gradients between V.P.I.'s, and the length of each vertical curve.

SPECIAL CONSIDERATIONS

Field Recommendations

Recommendations with regard to design of profile grades may accompany the field survey data. Special considerations may be required for items such as high water levels, ditch flow lines, unusual soil conditions, road intersections, adjacent property development, or other unusual conditions which may control profile grade elevations.

Profile grades should be designed to assure adequate elevation above high water levels. Freeboard clearance above high water should be at least 5 feet for Interstate highways, 4 feet for Primary highways and 3 feet for other less important roads.

Ties with Adjoining Projects

A smooth transition is needed with adjoining projects. Existing grade lines should be considered for a sufficient distance beyond the beginning and end of a project to assure adequate sight distance. Connections should be made which are compatible with the design speed of the new project--and which can be utilized when the adjoining road section may be reconstructed.

Balancing Earthwork

Unless there are circumstances which preclude the possibility, it is desirable to design the profile grade to achieve a balance of earthwork. Excavation from the normal cut sections should be adequate to construct the fills--with no need for borrow material or for wasting excess material.

Wherever possible, earthwork should be balanced at bridge ends, railroad crossings and major highway intersections. Balance points normally should not exceed distances of about one-half mile to one mile.

Reasonable earthwork balance usually can be attained by minor adjustments in the grade line, such as:

- raising or lowering a tangent grade between two V.P.I.'s.
- raising or lowering a V.P.I. and adjusting the gradients to the adjacent V.P.I.'s.
- lengthening or shortening a vertical curve.

When the excess or deficiency of excavation is known, the required amount of grade adjustment can be estimated reasonably close on the basis of average cross-section widths (outside limits of cuts and fills) and the length of grade that will be affected.

Climbing Lanes

Climbing lanes offer a comparatively inexpensive means of overcoming losses in capacity and providing improved operation where congestion on grades is caused by slow trucks in combination with high traffic volumes. A 2-lane highway may be adequate with climbing lanes whereas a much more costly multilane highway would be necessary without them.

There are so many variables involved that hardly any given set of conditions can be described as "typical." A general criterion is: the DHV should not exceed the design capacity by more than approximately 20 percent. If there is reason to believe this value may be approached, a detailed capacity analysis should be made.

In this manual, two basic criteria are set forth to identify conditions where climbing lanes should not be considered. This will permit designers to make initial evaluations and determine whether or not a complete capacity analysis should be performed. The two criteria are:

- Critical Length of Grades. Earlier in this chapter there was discussion of critical lengths of grades which significantly reduce the speed of trucks. When the length of grade is less than the critical length, a climbing lane should not be considered. If the critical length is exceeded, the traffic volumes should be investigated.

- Traffic Volumes. The table on the right identifies minimum two-way DHV for consideration of climbing lanes, with gradient, length of grade and percentage of trucks as design factors. If the design DHV is less than the value in the table, a climbing lane should not be considered.

Climbing lanes, when warranted, should be 12-feet wide. The cross slope should be a continuation of the cross slope of the adjacent traffic lane. Desirably, the shoulder width should be the same as for the normal roadway section. A minimum shoulder width of 6 feet shall be provided.

Climbing lanes should begin no later than at a point where trucks will have slowed to about 30 MPH. The beginning of the lane should be preceded by a tapered section at least 250 feet long.

MINIMUM TRAFFIC VOLUMES FOR CONSIDERATION OF CLIMBING LANES ON 2-LANE ROADS

Gradient Percent	Length of Grade Miles	Minimum Two-Way DHV for Consideration of Climbing Lanes for Various Percentages of Dual-Tired Trucks			
		T = 3	T = 5	T = 10	T = 15
4	1/3	* 750	* 700	* 600	* 525
	1/2			550	450
	3/4		670	500	390
	1	750	640	470	370
	1 1/2	730	610	440	340
	2	710	590	420	340
5	1/3	* 690	* 640	* 550	* 480
	1/2		620	460	370
	3/4	650	540	380	300
	1	630	510	360	270
	1 1/2	600	490	340	260
	2	600	480	330	250
6	1/3	* 625	* 580	480	390
	1/2	570	470	330	250
	3/4	540	430	290	220
	1	530	420	280	210
	1 1/2	520	410	270	200
	2	510	410	270	200
7	1/3	470	410	310	240
	1/2	400	320	210	160
	3/4	380	300	200	150
	1	360	280	180	140
	1 1/2	350	270	170	130
	2	340	260	160	120

* DHV values over which 4-lanes are warranted

Climbing lanes should end no earlier than the point where a typical truck can regain a speed of about 30 MPH and can return to the normal lane without hazard insofar as sight distance is concerned. Normally a climbing lane should extend about 300 feet beyond the crest of a hill, plus an additional taper of at least 250 feet.

Drainage Structures

Where there are special controls affecting drainage flow lines, particular attention must be directed to profile grade design which will assure at least minimum cover over drainage structures. Criteria for minimum cover are set forth in the chapter on drainage.

Major Structures

Design of profile grades must be carefully coordinated with bridge design and with the controls related to vertical clearances and high water. Vertical clearances set forth in the design standards should be adhered to.

Following completion of bridge design, there should be verification that the required clearance actually will be provided--and that the grade controls shown on the bridge plans and on the road plans are identical.

Railroad Grade Crossings

The finished surface grade line must match the top of the rails at railroad grade crossings. In most instances, minor warping of the surface cross slopes will be required.

Adjacent Multilane Roadways

Normally, a common profile grade line is used for both roadways of divided highways when the median width is 64 feet or less.

For median widths in excess of 64 feet, independent profile grade lines may be desirable due to the natural terrain. However, an appreciable grade differential between the roadways should be avoided at crossovers for at-grade intersections. Traffic entering from the crossroad may make a wrong way movement if the pavement of the far roadway is obscured due to grade differential. Required safety slopes in the median will place further restrictions on the grade differential.

This problem is further complicated when a divided highway is to be provided by using the existing two lanes for one direction of travel and constructing two new lanes for the other direction.

For reasons of safety, it is desirable to have approximately the same elevation on both roadways at crossroads and crossovers. But in many instances, the existing two lanes may have poor vertical alignment--and attempts to match the elevations would sacrifice the desirable vertical alignment of the two new lanes. The location of crossovers may be adjusted slightly to improve the safety characteristics--but usually it is difficult to relocate a crossroad.

As a general rule in these situations, the grade of the crossover connection should not exceed 6 percent. Even without a crossover connection, large differences in elevation can cause problems in providing proper safety slopes. The table below suggests maximum elevation differential between adjacent roadways for various horizontal distances between centerlines.

Horizontal Distance ℄ to ℄ - Feet	Maximum Profile Grade Differential - Feet	
	With Crossover	Without Crossover
64	1.0	1.0
88	2.0	2.0
125	4.2	11.3
150	5.7	17.5
200	8.7	30.0
250	11.7	42.5

Profile grades at or near the maximum differential should be avoided wherever possible. Consideration should be given to reconstructing portions of the existing roadway at such locations.

Urban Grade Design

The design of vertical alignment on urban projects frequently involves special considerations. Vertical alignment often must be established on the basis of conditions such as existing streets and adjacent property development.

Where outside controlling factors are not severe, the normal practice of carrying the profile grade on the centerline, or on median edges of pavement, will work satisfactorily. When the controls are significant, it may be necessary to supplement the main profile with other elevation controls--such as gutter-line profiles or top-of-curb profiles. When this is necessary, these supplemental controls should be clearly shown on the typical section and on the plan-profile sheets.

Spline curves can be helpful in laying grades in urban areas where it is necessary to meet numerous elevations in relatively short distances. Elevations along spline curves should be shown at 25-foot intervals.

Special care must be taken to avoid flat spots where water will pond. Curb lines should have a gradient of at least 0.2 percent and preferably a minimum of 0.4 percent.

Vertical curves are not required when the algebraic difference in grades is 0.2 percent or less. Where vertical curves are required, they should be long enough to provide required sight distance, but should not be flattened to such an extent as to cause a drainage problem. Usually it is convenient to locate V.P.I.'s and crest vertical curves at or near the centerline of intersecting cross streets.

Elevation of tops of curbs should be level with or slightly below natural ground, so as to permit drainage flow into the gutter and avoid ponding of water behind the curb.

Where roadside development is extensive and the general elevation on one side is higher than on the other, an unsymmetrical section may be required. The crown point may be offset from centerline--and the total drop from crown line to gutter line will be more than normal on one side, and less than normal on the other. Unsymmetrical features must be clearly defined in the typical sections and also shown in the cross sections.

Chapter 5

CROSS SECTIONS AND EARTHWORK

Cross sectional views, right angle to the centerline, permit visualization of the relationship between the existing ground line and the typical section of the highway to be constructed. Cross sections also serve as a means for computing earthwork quantities and designing drainage.

This chapter sets forth guidelines for:

- using survey cross section notes.
- plotting original ground line and roadway templates.
- computing earthwork quantities.

PLOTTING OF GROUND LINE

The first step is to prepare the basic cross section sheets showing the shape and elevation of the existing ground lines. Cross section notes from the field survey are used for this purpose.

Cross sections may be plotted manually or by the computer with a data plotter.

Field Survey Notes

Typical field survey cross section notes are shown in the illustration on the right and are explained briefly thereafter.

TYPICAL

FIELD SURVEY NOTES FOR CROSS SECTIONS

1/	+ B.S.	H.I.	− F.S.	ELEV.	B.M. ELEV.	℄ (left)	℄ (right)
BM #1	4.18	315.35			311.171	R.R. Spike in	Base 10" Pine
T.P.	2.79	309.93	8.21	307.14		100' Rt. Sta.	174+25
181+72			9.3	300.6		7^{2} 7^{8} 8^{5} 150 100 50	9^{9} 10^{5} 11^{3} 50 100 150
182+00			8.9	301.0		$(+2^{2})$ $(+2^{1})$ $(+0^{8})$ 4^{9} 8^{7} 80 40 27 17 6	8^{9} 9^{5} 10^{5} 11^{3} 17 50 100 150
						0^{3} $(+1^{1})$ 150 120	
183+00			6.3	303.6		3^{0} 1^{6} 0^{4} 2^{4} 150 117 57 13	7^{7} 6^{8} 4^{2} 10^{7} 10^{1} 6 15 26 70 150
184+00			7.7	302.2		5^{2} 3^{8} 2^{1} 4^{3} 150 130 65 26	9^{1} 8^{1} 6^{8} 7^{3} 12 20 114 150
+79			9.5	300.4	F.L. Ditch	4^{0} 6^{7} 150 75 F.L. F.L.	11^{9} 14^{0} 75 150 F.L. F.L.
T.P.	6.22	312.38	3.77	306.16			
185+00			7.26 E.P.2/	305.12		7^{11} 7^{16} 7^{21} 150 100 50	7^{31} 7^{36} 7^{41} 50 100 150

1/ Headings on this line are for information only, and normally will not be shown on field survey notes.

2/ Edge of Pavement

In the example, the elevation control is from bench mark #1--a railroad spike in the base of a 10-inch pine tree, 100 feet right of station 174+25. The bench mark elevation is 311.171 feet.

The first column of the left page shows the stationing of the cross sections--and also identifies bench marks (B.M.) and intermediate survey turning points (T.P.).

The second column shows backsight rod readings from an instrument set up to a B.M. or a T.P.

The third column shows the computed height of instrument (H.I.)--found by adding the backsight rod reading to the established elevation for the B.M. or T.P.

The fourth column shows the foresight rod readings from the H.I. to points along the centerline or to a subsequent B.M. or T.P.

The fifth column shows the actual elevation of the centerline or T.P.--computed by subtracting the foresight from the H.I. elevation.

The sixth column shows the B.M. elevation, as well as notes to identify special features.

The cross section measurements are shown on the right page. The bottom figures of each row are the horizontal distances left and right of the centerline, and the top figures are the rod readings at those points.

Actual elevation at each point is found by subtracting the rod reading from the H.I. elevation. For example, the centerline elevation at station 181+72 is 300.6 feet (309.93 - 9.3)--and 150 feet left of centerline, the elevation is 302.7 feet (309.93 - 7.2).

Accuracy required for computed height of instrument (H.I.) shall be to one-hundredth (0.01) of a foot, and ground elevations shall be rounded to the nearest one-tenth (0.1) of a foot. Elevation of bridges, roadway pavement, flow line of drainage structures, etc., shall be to one-hundredth (0.01) of a foot.

Preparation for Machine Plotting

In most instances it is desirable to utilize machine plotting of cross sections. Manual plotting may be more convenient for special conditions such as intersections and interchange ramps.

Computer input will be punched directly from the cross section notes. Prior to submitting the notes to the computer section, the designer--in addition to checking the H.I. elevations--should perform the following:

- Repeat all H.I. elevations in red pencil in the third column at the top of each page.
- Encircle with red pencil and mark "omit" or "do not punch," any cross sections or extraneous data which are not to be plotted or included for earthwork calculations.
- Mark clearly, with red pencil, the beginning and ending limits.

With machine plotting, the computer converts the recorded rod readings to elevations which are then plotted.

Preparation for Manual Plotting

When cross sections are to be plotted manually, a similar conversion must be made to facilitate the plottings. Each rod reading in the notes must be subtracted from (or, when a plus rod reading, added to) the applicable H.I., and the actual elevation must be recorded in the notes immediately above the rod reading. Centerline elevations are recorded in column five adjacent to the rod reading. The designer should check the mathematics of all H.I. elevations and bench mark ties prior to computing the ground elevation at each point.

Scales

Cross sections normally will be plotted to a scale of 1 inch = 10 feet, both horizontally and vertically.

In urban areas involving greater detail of design, the horizontal and vertical scale should be 1 inch = 5 feet.

In special situations, other scales may be used. Any scale, other than 1 inch = 10 feet, shall be shown below the project number block in the upper right corner of each cross section sheet.

Sheet Layout

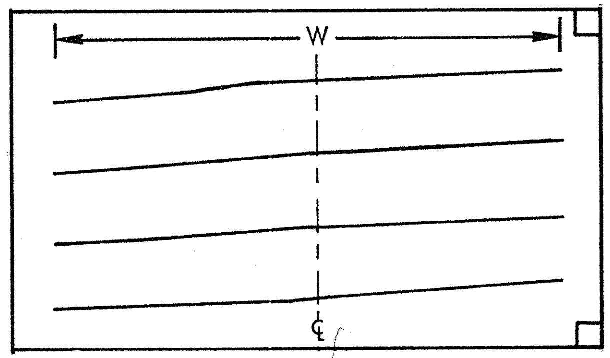
The layout of cross section sheets depends on the width of cross sections to be plotted and the horizontal scale selected. Three options are shown in the illustration at the right.

- Option 1 should be used when the total width of plotted cross-section exceeds 200 feet.[1]
- Option 2 may be used when the total width is less than about 150 feet.[1]
- Option 3 may be used for widths between 150 and 200 feet.[1]

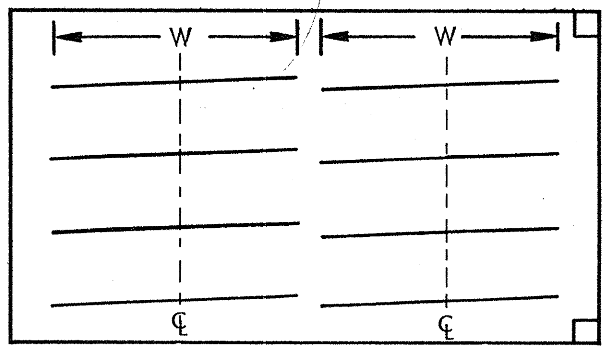
The options will provide the best utilization of space on each sheet, without undue crowding--thus keeping the total number of cross section sheets to a minimum.

[1] Horizontal scale: 1 inch = 10 feet.

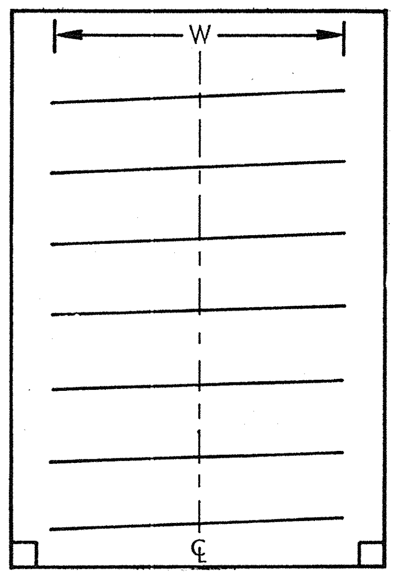
CROSS SECTION SHEET LAYOUT



OPTION 1



OPTION 2



OPTION 3

Plotting

Cross sections will always be plotted so that the survey stationing increases from the bottom to the top of each sheet.

Initial plotting should be with a sharp, hard pencil--all plotted information should then be inked.

A centerline symbol (℄) is placed on the bottom border of each sheet to identify the vertical line selected for centerline of the cross sections.

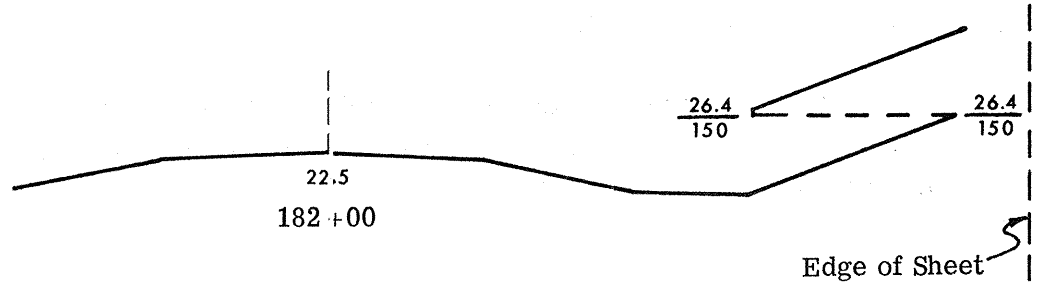
Horizontal distances each side of centerline are shown on the bottom border of the sheet at 10-foot intervals.

The elevation of the existing ground at the centerline is recorded to the nearest 0.1 foot (0.01 foot in the case of existing pavement) and shown immediately below the plotted cross section. The stationing of each cross section is recorded (in larger size numbers) below the centerline elevation.

The figure on page 5-5 is an example of cross sections plotted in accordance with the guidelines above and based on the cross section notes discussed earlier.

The vertical spacing between plotted cross sections should be sufficient to avoid overlapping. The spacing will depend on the scale used, and on the heights of fills or depths of cuts which must eventually be plotted on the cross section. Designers should refer to the working profile while plotting cross sections so that deep cuts or high fills can be anticipated and appropriate spacing provided between sections.

When an occasional cross section might extend beyond the edge of the sheet, the slope line may be extended by an offset match line, shown as follows.

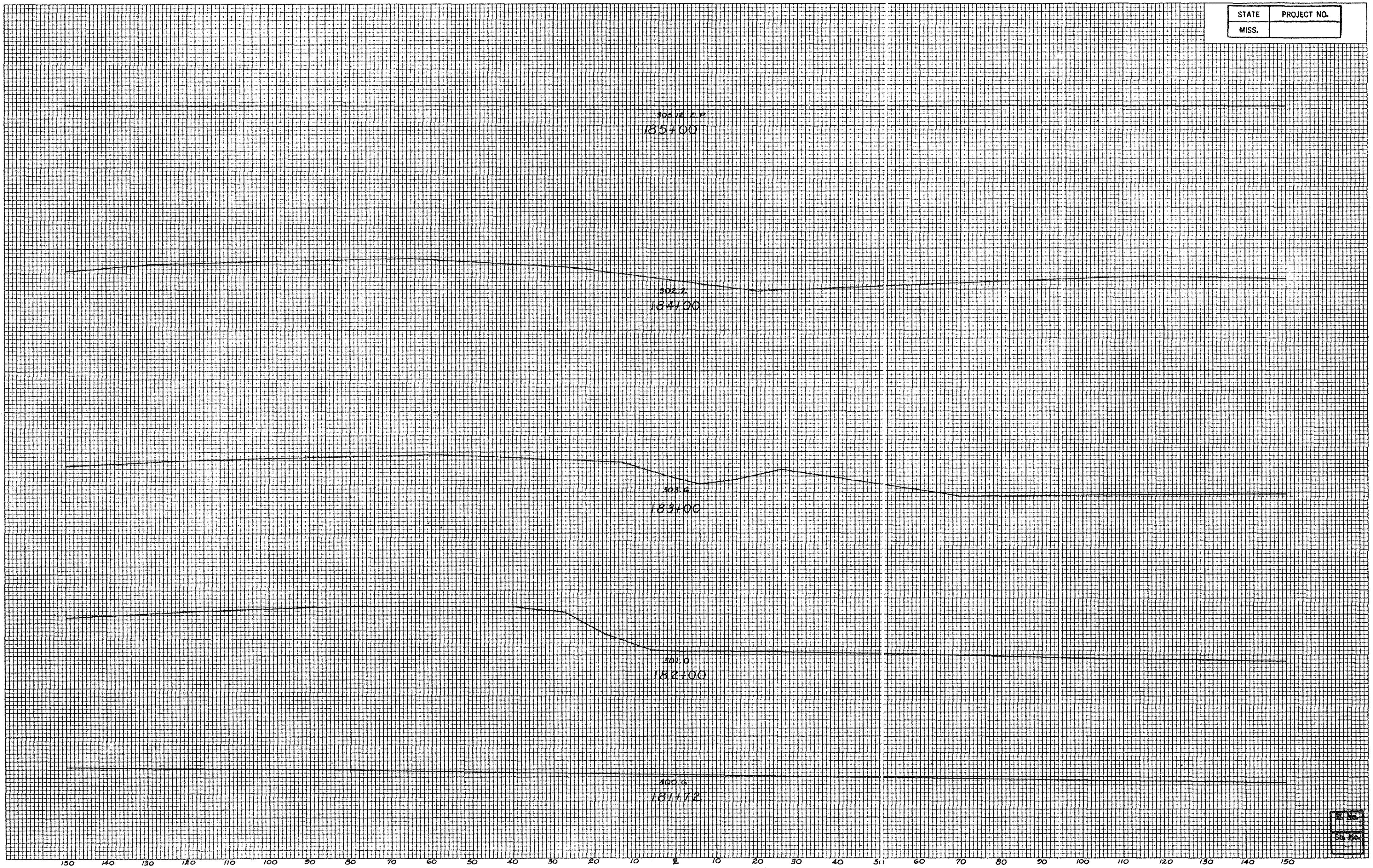


Sheet Identification

Each cross section sheet shall be identified with the project number in the space provided in the upper right corner--and with a sheet number in the lower right corner.

Sequential sheet numbers, beginning with 901, will be assigned as cross-section sheets are plotted. The entire mainline cross sections should be sequentially plotted from beginning to end without interruption. Any supplemental cross sections (ramps, channel changes, etc.) should be grouped at the end of the mainline cross sections--with each sheet clearly labeled in the lower right corner to identify the purpose and location of the supplemental cross sections.

TYPICAL PLOTTED CROSS SECTIONS OF EXISTING GROUND LINE



ROADWAY TEMPLATES

The roadway template is the graphical representation of the proposed roadway typical section superimposed on the plotted ground-line cross section.

When earthwork is computed manually, the plotted template is the basis for earthwork computations. Templates should be plotted in pencil soft enough to permit thorough erasure--because adjustments of profile grade may be necessary to attain desired balance of earthwork.

When the computer is used for earthwork calculations, the roadway templates should not be plotted until all adjustments have been made and the final grades have been established.

Typical Section Controls

The established typical section, or sections, for a project define the basic geometrics of the roadway template--including features such as:

- subgrade and crown slope
- safety slopes (as appropriate)
- cut and fill slopes
- location of ditch line
- vertical distance from profile grade to subgrade (structure thickness).

These basic criteria must be adhered to when plotting the roadway templates.

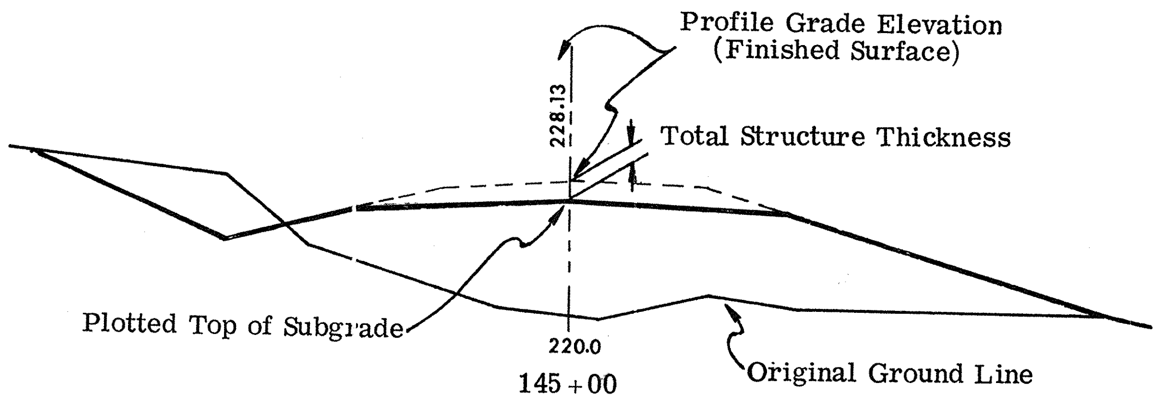
Elevation Controls

The elevation of each roadway template is controlled by the computed profile grade elevation for the particular stationing.

For 2-lane roadways, and for symmetrical multilane roadways having common profile grades, the elevation should be written vertically above the point representing the profile grade point of the template. In the case of multilane roadways, the profile grade elevation should be written above the profile grade point of each roadway. Grades should be recorded to two decimal places.

Plotting

Normally, the principal concern is to define the shape and limits of roadway excavation and embankment sections. It is not mandatory to plot the structure portion of the typical section. The top of subgrade may be plotted directly at an elevation of the profile grade minus the structure thickness, as shown below.



Generally, it is desirable to plot the surfacing elements for the sake of clarity to show conditions of pavement width transition, superelevation, intersections, ramps, etc. Surfacing must be plotted for urban sections to show relationships between curbs and the adjacent ground lines--and also to more clearly define drop inlets and other drainage structures.

Drainage Structures

All minor drainage structures will be plotted to scale on the appropriate cross sections as a basis for estimating lengths of culverts, flow lines, ends of structures, connecting side ditches, etc. These design procedures will be discussed in the chapter on drainage.

EARTHWORK COMPUTATIONS

Earthwork computations may be performed manually or with the computer. Generally, a combination of the two may be more adaptable. The computer should be utilized whenever possible to expedite computations and to more readily facilitate balance adjustments.

Typical rural projects are more adaptable to earthwork computations with the computer. Manual earthwork computations usually are more appropriate for urban highway and for unusual locations such as interchange areas.

The designer should determine the more appropriate approach as soon as possible upon receiving the survey data in order to:

- begin keypunching of cross section notes for computer computations, or
- begin plotting of existing ground-line cross sections for manual computations.

Computer Computations

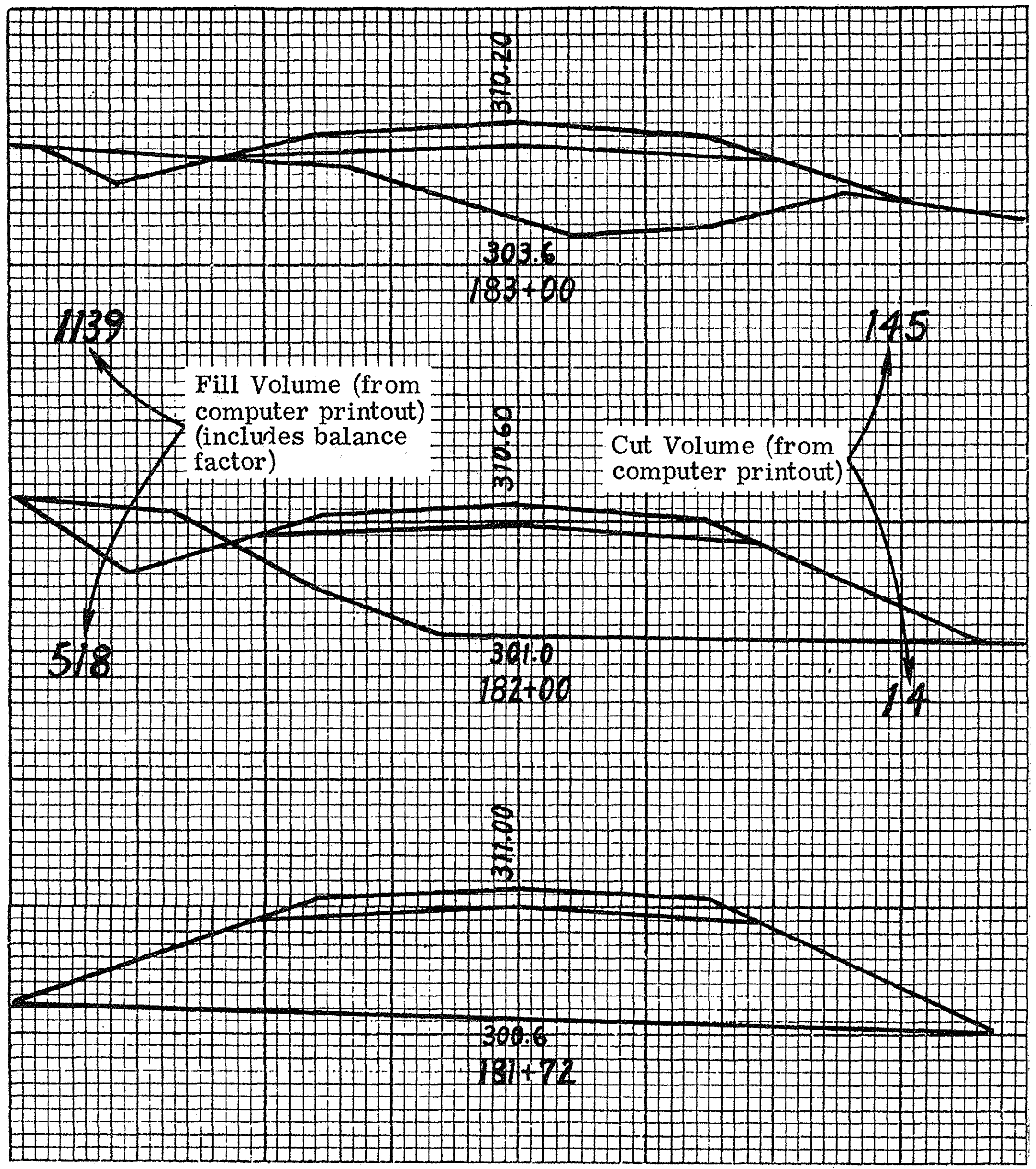
The Department's instruction manual showing the required input for computer earthwork programs is available to the designers. Computations are performed from information in the field survey cross section notes and from input data from the designer relative to profile grades and typical sections.

The printed output from the computer consists of (1) profile grade elevations, (2) profile gradients in percent, (3) superelevation rates, (4) description of each template including slope stakes, (5) cut and fill areas of each template, (6) earthwork volumes, (7) mass ordinates, (8) plot of mass ordinates, and (9) plot of slope stakes.

When the desired earthwork balance has been attained, and the final profile grades have been established, the roadway templates should be plotted on the cross sections and the earthwork volumes recorded on the cross sections as shown in the illustration on page 5-8. Embankment volumes should always be placed on the left--cut volumes on the right.

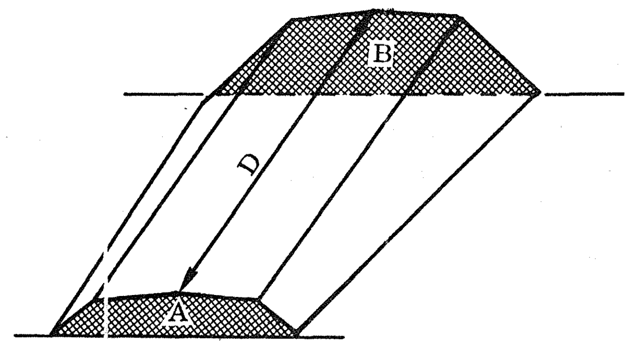
The effect of the balance factor will be discussed later in this chapter.

RECORDING OF COMPUTER EARTHWORK DATA ON CROSS SECTIONS



Manual Computations

Most techniques for manual computation of earthwork volumes are related to the concept of average end areas, as illustrated in the diagram and formulas below.



$$V = D\left(\frac{A + B}{2}\right) \div 27$$

$$\text{or } V = \frac{D(A + B)}{54}$$

where V = Volume between sections in cubic yards

A and B = End areas of adjacent sections in square feet

D = Distance between sections in feet

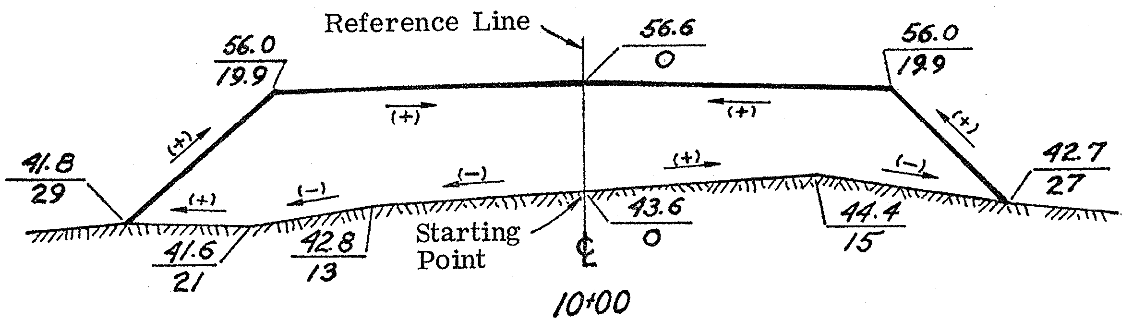
27 = Conversion factor from cubic feet to cubic yards

The end areas (A and B) can be measured with a planimeter or computed mathematically by the coordinate method or by breaking the area into several smaller geometric shapes.

Coordinate Method for End Areas

The coordinate method provides a convenient technique for calculating end areas for earthwork computation. This procedure also works well for end areas of other irregular shapes such as subbase and base course.

Vertical and horizontal coordinates are identified for each irregular breakpoint of the area, as shown in the figure below.



The upper figure at each point is the elevation--and the lower figure is the horizontal distance from the reference line (usually the centerline).

The principle is to multiply the difference in elevation of two adjacent points by the sum of the horizontal distances of the points from the reference line. The sign of the computation is plus (+) if the line slopes upward--and minus (-) if the line slopes downward. The end area of the section is one-half of the algebraic sum of the individual computations.

A convenient procedure is to start at the ground elevation at the centerline and perform the computations in a counterclockwise direction returning to the reference line--and then repeating the process in a clockwise direction for the left portion of the area. This computational sequence is illustrated by the arrows in the figure.

Computations for the end area of the example cross section are shown below.

$$
\begin{aligned}
A &= 1/2\,[(0.8 \times 15) - (1.7 \times 42) + (13.3 \times 46.9) + (0.6 \times 19.9)] + \\
&\quad 1/2\,[-(0.8 \times 13) - (1.2 \times 34) + (0.2 \times 50) + (14.2 \times 48.9) + \\
&\quad (0.6 \times 19.9)] \\
&= 1/2\,(12 - 71.4 + 623.77 + 11.94) + 1/2\,(-10.4 - 40.8 + 10.0 + \\
&\quad 694.38 + 11.94) \\
&= 288.16 + 332.56 \\
A &= 620.72
\end{aligned}
$$

End areas computed by this procedure can be used in the formula in the preceding section for computing volumes between sections.

Strip Stick Method for Volumes

The most common technique used by the Department is the "strip stick" method. This method retains the basic concept of the average-end-area approach--however, the design of the strip stick permits measurements of irregular sections in such a way that the accumulative readings on the sticks may readily be converted to volumes without the intermediate step of recording actual end areas.

Two strip sticks are available: one for scales of 1 inch = 10 feet, vertical and horizontal; and one for scales of 1 inch = 5 feet, vertical and horizontal. If scales other than these are used, conversion factors must be applied to the strip stick readings to reflect the proportionate difference in actual end areas.

The "strip stick" computation formula is:

$$V = (A \times D) + (B \times D)$$

or

$$V = D(A + B)$$

where V = Volume, in cubic yards
A = Stick reading at template section
B = Stick reading at adjacent template section
D = Distance between sections, in stations.

The figure on the right illustrates typical strip stick computations and procedures for recording earthwork data on the cross sections. The strip stick readings for embankment are recorded on the left shoulder of each section--and the readings for excavation on the right shoulder. The distance between stations 181+72 and 182+00 is 28 feet (0.28 station) and the embankment volume is computed as follows:

$$\begin{aligned} V &= (940 \times 0.28) + (670 \times 0.28) \\ &= 263 + 188 \\ &= 451 \text{ cubic yards} \end{aligned} \qquad \text{or} \qquad \begin{aligned} V &= 0.28(940 + 670) \\ &= 0.28(1610) \\ &= 451 \text{ cubic yards} \end{aligned}$$

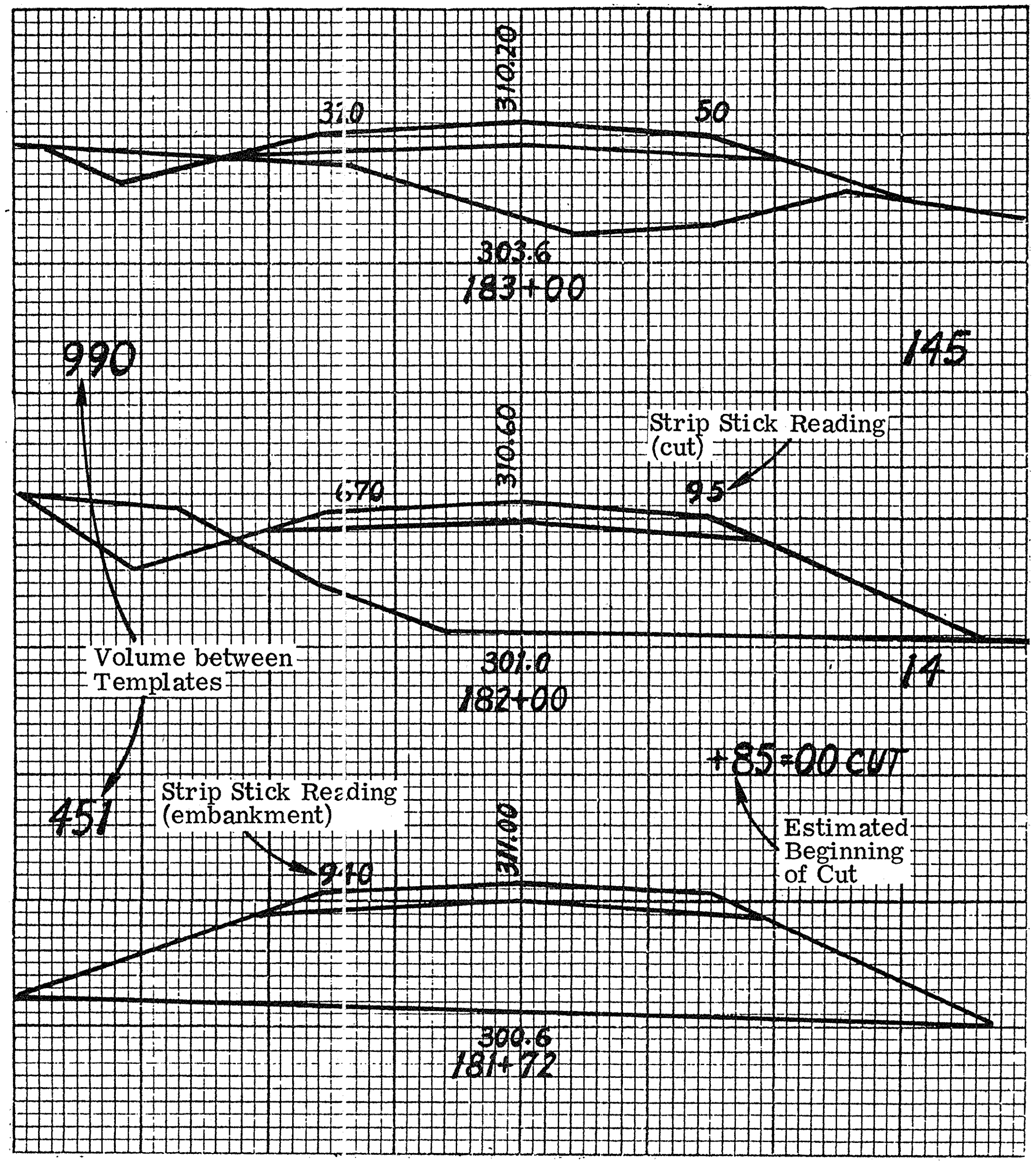
The figure "451" is recorded on the cross section to the left of and between the two cross sections.

There is no strip reading for cut at station 181+72, but it is estimated that the cut begins at 181+85. The distance between the beginning of the cut and station 182+00 is 15 feet. The volume of cut is:

$$\begin{aligned} V &= 95 \times 0.15 \\ &= 14 \text{ cubic yards.} \end{aligned}$$

The figure "14" is recorded to the right of and between the two sections.

METHOD OF SHOWING STRIP STICK EARTHWORK COMPUTATIONS ON CROSS SECTIONS



Since the distance (D) between stations 182+00 and 183+00 is exactly one station, it is evident that the actual volumes in cubic yards are the sums of the strip readings.

For embankment: V = 670 + 320 = 990 cubic yards
For cuts: V = 95 + 50 = 145 cubic yards

These figures are recorded on the cross sections.

Balance Factor

The volume of excavation required to construct an embankment may be considerably more than the measured volume of the embankment.

Normally a shrinkage will occur. That is, a certain volume of earth excavation will produce a lesser volume of embankment because of losses while hauling and, principally, because of the increased density due to compaction.

On the other hand, excavation from rock cuts tends to swell. Undisturbed rock occupies less volume than when broken and placed in an embankment.

If these conditions of shrinkage and swell are not considered, the theoretical volumes of cut and fill when balanced on paper will not balance during field construction.

For shrinkage, which is the most usual case, there are two methods of applying the balance factor.

- Increase the measured embankment quantity by the balance factor--to determine the amount of excavation actually needed to construct the embankments, or
- Decrease the excavation quantity by the balance factor to identify the quantity of embankment that will be produced.

The first method is used when a project is to be balanced with excavation from within the roadway prism. The second method is generally used when the roadway prism cannot be balanced and other borrow excavation is to be obtained.

The balance factor will vary with location and soil characteristics. A recommended balance factor usually will be shown on the design data sheet. In the absence of this recommendation, the designer should consult with the section head.

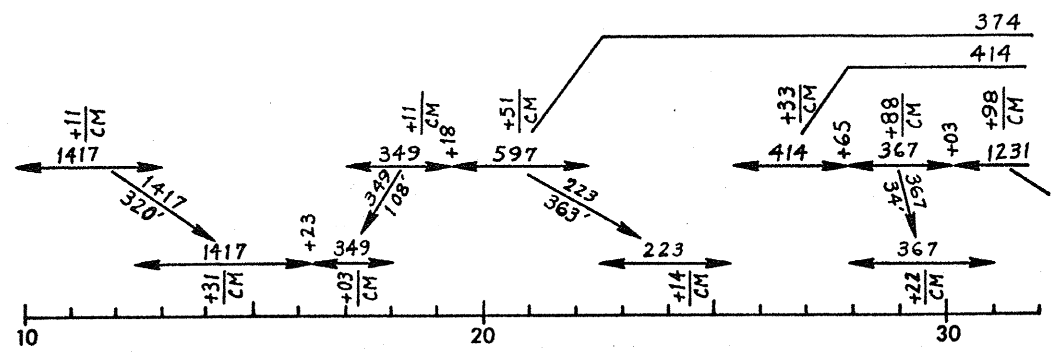
Earthwork Distribution

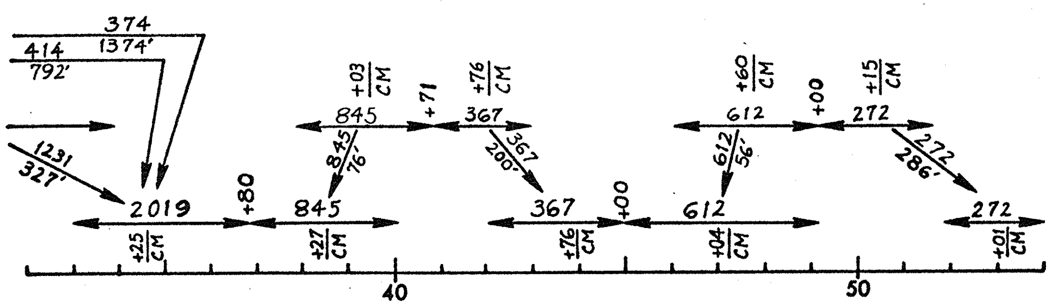
There is need to identify the earthwork distribution--where the excavation comes from and where it is to be deposited.

Two possible conditions arise: (1) the earthwork can be balanced from within the right-of-way, or (2) the earthwork cannot be balanced within the right-of-way. In the second case it becomes necessary to obtain borrow material or to waste excess material.

For projects which can be balanced from within the right-of-way, the distribution and the haul distances must be calculated and shown. Haul should be kept as short as possible with waste and cross-haul avoided unless it is an absolute necessity.

One method of showing the distribution is to prepare a chart as illustrated on the next page. After the earthwork is balanced, this data should be shown on the plan-profile sheets.



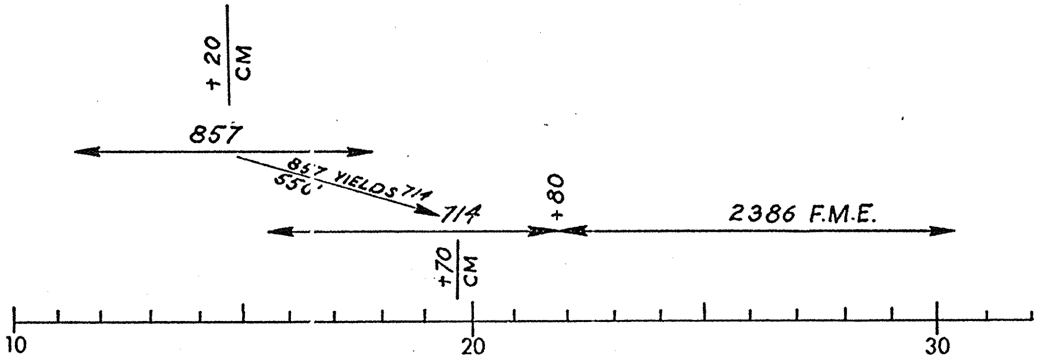


The center of mass (CM) is calculated for each area of excavation and embankment as the mid-point of the quantity of each. The haul distance is computed from the excavation center of mass to the embankment center of mass. A line indicating the distribution is drawn from the excavation center of mass to the embankment center of mass. The quantity of material is shown above the line and the distance below it. In the event the two centers of mass are on different plan-profile sheets, the haul distance is shown on the sheet with the embankment center of mass.

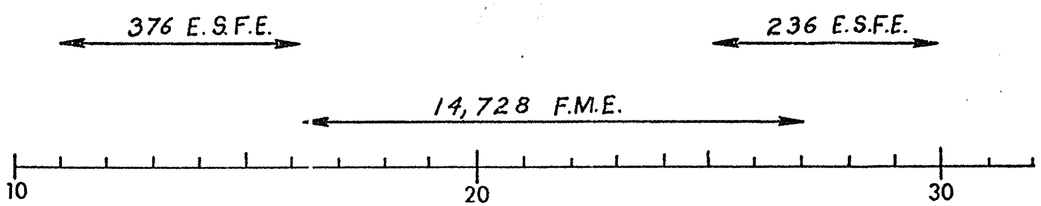
The haul is calculated by multiplying the volume (cubic yards) by the distance hauled (stations) to obtain the station yards of haul.

Projects which require borrow material are normally handled by one of the following methods.

Generally when 15 percent or more of the required embankment material is available from excavation within the right-of-way, the excavation is distributed and the remaining embankment is obtained from contractor-furnished material. In this case, the excavation is "yielded" (volume of excavation decreased by the balance factor). To simplify field measurements, the contractor-furnished portion should be recorded separately from the right-of-way excavation. An example of this type of earthwork distribution is shown below.



When the excavation within the right-of-way furnishes less than 15 percent of the required embankment, the excavation generally is identified as Estimated State Furnished Excavation (E.S.F.E.), and becomes the property of the contractor. It shall be excavated, used in the embankment if suitable, and paid for as borrow excavation (F.M.E.). The embankment is normally totaled each 1,000 feet and no balance factor is applied. An example of this type of earthwork distribution is shown below.



Chapter 6
DRAINAGE

For the purposes of this chapter, drainage design will include both hydraulic design and determination of physical standards. Designers will determine the runoff discharge, select the size and type of drainage structure, and satisfy the culvert strength requirements for the given location.

Drainage design should achieve the most effective and economical methods by which runoff waters can be passed through and removed from the roadway. The primary objectives shall be (1) to provide culvert openings for natural drainage channels, (2) to prevent undue accumulation and retention of water upon and adjacent to the roadway, and (3) to protect the roadway against storm and subsurface water damage.

Drainage installations must not create hazardous conditions for traffic nor should they in any way adversely affect conditions of adjoining properties.

DESIGN RESPONSIBILITIES

Responsibilities for drainage design are divided between the Bridge Division and the Roadway Design Division--based principally on the size of the drainage area involved. The districts have basic responsibility for furnishing the survey data and field information essential for drainage design.

Design of bank and channel protection shall be performed by the division responsible for design of the drainage structure. The Bridge Division is responsible for the structural adequacy of all box and bridge structures.

Bridge Division

Most major structures (bridges and box bridges) are designed by the Bridge Division. Responsibilities include:

- all locations requiring major bridges.
- all locations with structure requirements of the "box bridge" classification (exceeding 20 feet in width).
- all locations with drainage areas in excess of 1,000 acres.
- culvert locations for smaller drainage areas within the flood plain of a major crossdrain.
- all special design box culverts--such as nonstandard dimensions, skew angles, and improved entrance structures.

Information required by the Bridge Division for hydraulic design includes the following:

- Survey and field information
    + drainage area (square miles or acres)
    + a profile of the channel flowline for distances of 500 feet upstream and downstream from the centerline

+ typical section of the channel--both upstream and downstream of existing highways

+ waterway areas and descriptive information of existing hydraulic structures under nearby highways and railroads serving the same drainage area

+ highwater mark elevations (upstream and downstream of existing highways) and date of occurence.

- Roadway Design Division blue line work prints

  + layout sheet

  + roadway typical sections

  + plan-profile sheets of the location--to include the entire width of the flood plain.

Roadway Design Division

Most routine culvert installations will be designed by the individual roadway designers following the guides and criteria in this manual. The Hydraulic Section of the Division will provide technical assistance when required, and will conduct special investigations of all non-routine, unusual conditions (e.g., bridge replacements with culverts) and improved entrance structures.

Drainage design responsibilities of the Roadway Design Division include:

- design of most culverts accommodating drainage areas up to 1,000 acres.
- design of storm sewer systems.
- side ditch and channel erosion control treatments.

Design of culverts for drainage areas less than 200 acres will require the following minimum field information:

- drainage area (in acres)
- high-water mark elevations of the location
- descriptive information on existing culverts serving the same drainage area under nearby highways and railroads
- sufficient channel flowline profile to establish the natural channel slope, 200-300 feet up and down stream
- typical channel section.

Culvert design for drainage areas greater than 200 acres will require the same field information necessary for Bridge Division hydraulic design.

The roadway designer should review the submitted drainage data on receipt of a new project, and should immediately request of the district any omitted essential information.

State Aid Division

Policy and procedure require the County Engineer to have complete design responsibility for all drainage structures. On complex drainage areas, the County Engineer may request assistance from U.S. Geological Survey and the State Aid Division. Review of the County Engineer's design is made by the State Aid Division in all cases.

HYDROLOGY CRITERIA

The design of a drainage structure depends principally on the design discharge that must be accommodated. And the design discharge depends largely on the following:

- duration of rainfall
- intensity of rainfall
- drainage area size and characteristics.

Several basic hydrology criteria should be understood before discussing methods of determining design discharge.

Storm Design Frequency

It is important to realize what is meant by a 10-, 25-, 50- or 100-year frequency storm. A 100-year storm has a 1 to 100 chance, or a 1 percent chance, of occurring at any particular time. A 50-year storm has a 2 per cent chance of occurring at any particular time. Hence, a 25- or 10-year storm has a 4 percent or 10 percent chance, respectively, of occurring at any particular time.

The intensity of a storm is measured in inches per hour. The intensity of a 50-year storm will be much greater than the intensity of a 10-year storm in the same location. The intensity of a storm will vary with its duration, other factors being similar. The average rate of rainfall for a storm 10 minutes long will be much greater than the average rate of rainfall for a storm one hour long of comparable frequency, but the total amount of rain that falls will not vary in the same proportion.

A drainage structure designed for a 100-year storm will be much larger and more expensive than one designed for a 10-year storm. There is need to make economic comparisons between the increased costs of the larger structure and potential damages resulting from occasionally exceeding the capacity of a smaller structure.

The Department has established recommended storm design frequency criteria, as shown in Table 6-1,[1/] based on the system classification and the type of installation.

Table 6-1

RECOMMENDED STORM DESIGN FREQUENCY CRITERIA

Type of Installation	Road System		
	Interstate	Primary	Secondary/ State Aid
Cross Drains	100-year*	50-year	25-year**
Median Drains	50-year	50-year	25-year
Side Drains	50-year***	25-year***	25-year
Storm Sewers	10-year***	10-year***	10-year***

* Not less than 50-year storm through drainage structures; 100-year storm conveyance through structures, or both through structures and over the highway.

** Check function on the 50-year storm; use 50-year when warranted -- e.g., restrictive sags, principal service arteries, etc.

*** Side drains unusual on Interstate; use 50-year for cross drain channels, and depressed area inlets and drains.

NOTES:

1. Spacing of curb and gutter inlets on full-shoulder width highways should contain the 10-year storm runoff (50-year in depressed areas) on the shoulder; one-half of adjacent lane on other controlled-access highways; the width of adjacent lane on other multilane highways; one-third of adjacent lane on 2-lane, 2-way highways. (See page 6-32)
2. Median drain spacing should be designed so that water will not rise above the level of the subgrade for the 10-year storm.
3. Use 5-minute duration time for median and storm sewer design.

1/ An index to all illustrations in Chapter 6 is at the end of the chapter.

Storm or flood design for Interstate and Primary projects shall be the passage of the "design flood" (generally the 50-year flood for these two systems) through the culverts, and the conveyance of the "basic flood" (the 100-year flood) either through the culverts or both through the culverts and over the highway without causing significant damage. The design flood for Secondary and State Aid projects shall be the 25-year flood unless the culvert is in a restrictive sag vertical curve, or unless the roadway is a principal service artery -- in which case the 50-year flood shall be considered. Development within the flood plain may necessitate deviations from the foregoing criteria.

Flood Hazard Evaluation

For each culvert equivalent to 24" pipe and larger, the project plans shall show (1) estimated discharge, frequency, and estimated headwater elevation for the design flood, and also for the basic flood if it is different from the design flood, and (2) when available, the authentic discharge, high water elevation, and date of occurrence of the flood of record if it is greater than the basic flood. For example:

Q_{Design}	$Q_{100} = Q_D \times 1.17$	Q_{Record}	(Date of occurrence authentically gaged)
Hw_{Design}[2]	Hw_{100}	$H.W._{Record}$[2]	

Also, the following disclaimer is required in the plans: "Headwater elevation values shown on these plans are theoretical and may vary from actual conditions."

The design water surface profiles of streams with a flat angle approach which control the roadway grade shall be recorded on the plans.

Although each design discharge shall be computed on the basis of land use appropriate for the given location, no less than the probable 20-year projected land use shall be assumed for design.

[2] In this chapter, Hw is the designation for Headwater, and H.W. for High Water.

DESIGN DISCHARGE

Design discharge is the estimated amount of water, usually cubic feet per second, expected at a culvert location from a particular drainage area as a result of a design frequency storm.

Several methods are used for determining design discharge. The three methods most commonly used in Mississippi are shown below, along with criteria for their use. (With the design discharge determined--and considering culvert design practices described in the next section, page 6-15--proceed to Culvert Size Determination, page 6-17.)

1. Rational Method -- Used for drainage areas less than 10 acres, roadway slopes and storm sewer design in both urban and rural areas.

2. Method shown in U.S.G.S. 1967 Report on "Urbanization Effects on Floods in Jackson, Mississippi" -- Used for urban drainage areas greater than 10 acres, applicable to most of the state with adjustment.

3. FHWA Chart 1021 Method -- Used for rural drainage areas greater than 10 acres.

Three other methods are occasionally used:

4. Method shown in U.S.G.S. 1961 Report on "Floods in Missisippi--Magnitude and Frequency -- Primarily used with drainage areas in excess of one square mile.

5. U.S.G.S. Individual Stream Study Reports -- Generally used for areas larger than 1,000 acres.

6. Method shown in U.S.G.S. May 1970 Report on "Regression Analysis of All Small Drainage Area Flood Data in Mississippi."

Each of these methods is discussed in the following sections.

Rational Method

The formula for determining design discharge by the rational method is:

Q_{Design} = C x I x A

where:
- Q_{Design} = Discharge for desired frequency (cubic feet per second)
- C = Runoff Coefficient (type of soil, slope, and land use)
- I_{Design} = Rainfall intensity (inches per hour) for desired frequency (from Table 6-1)
- A = Drainage Area (acres)

Procedure:

1. Refer to Table 6-2, Runoff Coefficient Values, and select the value of "C", appropriate for the combination of terrain slope, land use, and soil classification.

2. Refer to Figure 6-1, Rainfall Duration--Intensity Regions map, and select the region number appropriate for the project location.

3. Select the Duration-Intensity chart appropriate for the region--Chart 6-1, 6-2, 6-3 or 6-4. Enter the chart at the duration time (bottom of chart) and go to the intersection with the design frequency curve, then horizontally left to the rainfall intensity value (I). The proper duration time will vary as follows:

$$T = \frac{10 \times L^{0.37}}{17^{C} \times S^{0.21}}$$

- T = Duration time (in minutes)
- L = Length of travel (in feet)
- C = Runoff Coefficient (Rational)
- S = Slope (in percent)

4. The drainage area in acres (A) may be given with field survey data or computed from mapped areas. The product of C x I x A will give the design discharge in cubic feet per second.

Example:

Primary project -- Warren County

A = 5.6 acres in interchange quadrants

Design frequency = 50-year

L = 350 feet
C = 0.70
S = 5.0%
T = 9 minutes

1. From Table 6-2, runoff coefficient (C) has a value of 0.7-- medians and side slopes.

2. From Figure 6-1, Warren County is in Region II.

3. From Chart 6-2 (Region II), the intensity (I) is 7.8 inches per hour. (Enter chart at duration of 9 minutes, intersect 50-year frequency and read horizontally to 7.8 inches per hour.)

4. Q_{Design} = C x I x A = 0.7 x 7.8 x 5.6
   = 30.6 cubic feet per second x 1.17 = Q_{100}

Table 6-2

RUNOFF COEFFICIENT VALUES (C)
for formula Q = C x I x A in
The Rational Method
(Drainage Areas 10 Acres or Less)

Slope	Land Use	Soil Classification: Rolling Plains Min.	Rolling Plains Max.	Sand or Sandy Loam Soils (Pervious) Min.	Sand or Sandy Loam Soils (Pervious) Max.	Black or Leossial Soils (Impervious) Min.	Black or Leossial Soils (Impervious) Max.
Flat (0% - 1%)	Cultivated			0.25	0.35	0.30	0.40
	Woodlands			0.15	0.20		
	Pasture			0.20	0.25		
	Paved	0.90		0.90		0.90	
	Residential	0.50	0.60	0.50	0.60	0.50	0.60
	Commercial	0.60	0.90	0.60	0.90	0.60	0.90
Rolling (1% - 3.5%)	Cultivated	0.40	0.45	0.45	0.65	0.50	0.70
	Woodlands			0.15	0.20	0.18	0.25
	Pasture	0.25	0.30	0.30	0.40	0.35	0.45
	Paved	0.90		0.90		0.90	
	Residential	0.55	0.60	0.50	0.60	0.50	0.60
	Commercial	0.60	0.90	0.60	0.90	0.60	0.90
Hilly (3.5% - 5.5%)	Cultivated			0.60	0.75	0.70	0.85
	Woodlands			0.20	0.25	0.25	0.30
	Pasture			0.35	0.45	0.45	0.55
	Paved	0.90		0.90		0.90	
	Residential	0.60		0.50	0.60	0.50	0.60
	Commercial	0.60	0.90	0.60	0.90	0.60	0.90
Mountainous (over 5.5%)	Woodlands					0.70	0.80
	Bare					0.80	0.90
Grassed ROW Slopes		0.70		0.70		0.70	

Within roadway right-of-way, use the following "C" values:

Pavement .... C = 0.9
Paved shoulder ..... C = 0.9
Non-paved shoulder . C = 0.7
Side slopes .... C = 0.7

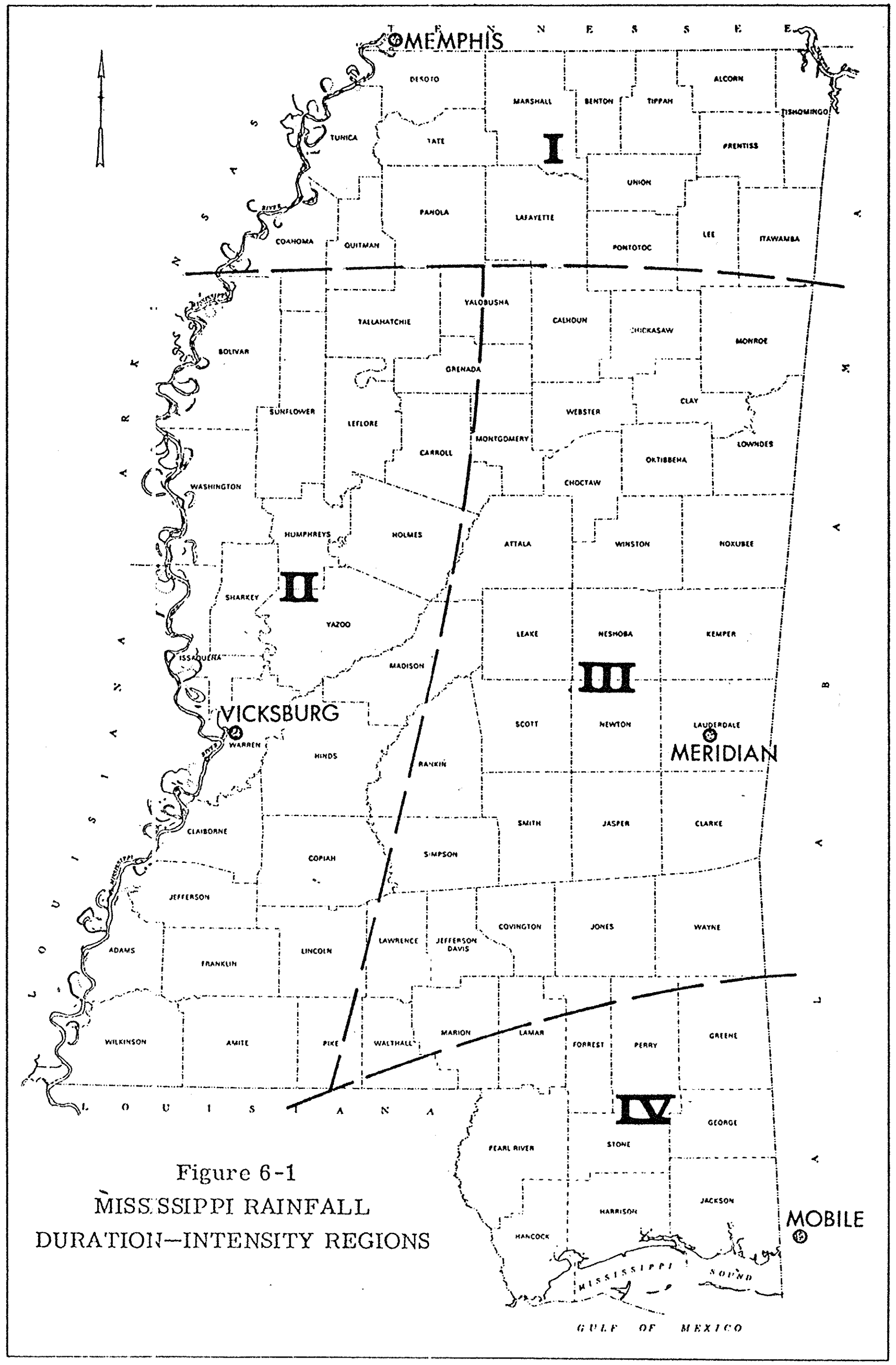


Figure 6-1
MISSISSIPPI RAINFALL
DURATION—INTENSITY REGIONS

Chart 6-1

RAINFALL DURATION-INTENSITY CURVES

REGION I

(Based on Data from Memphis, Tenn.)

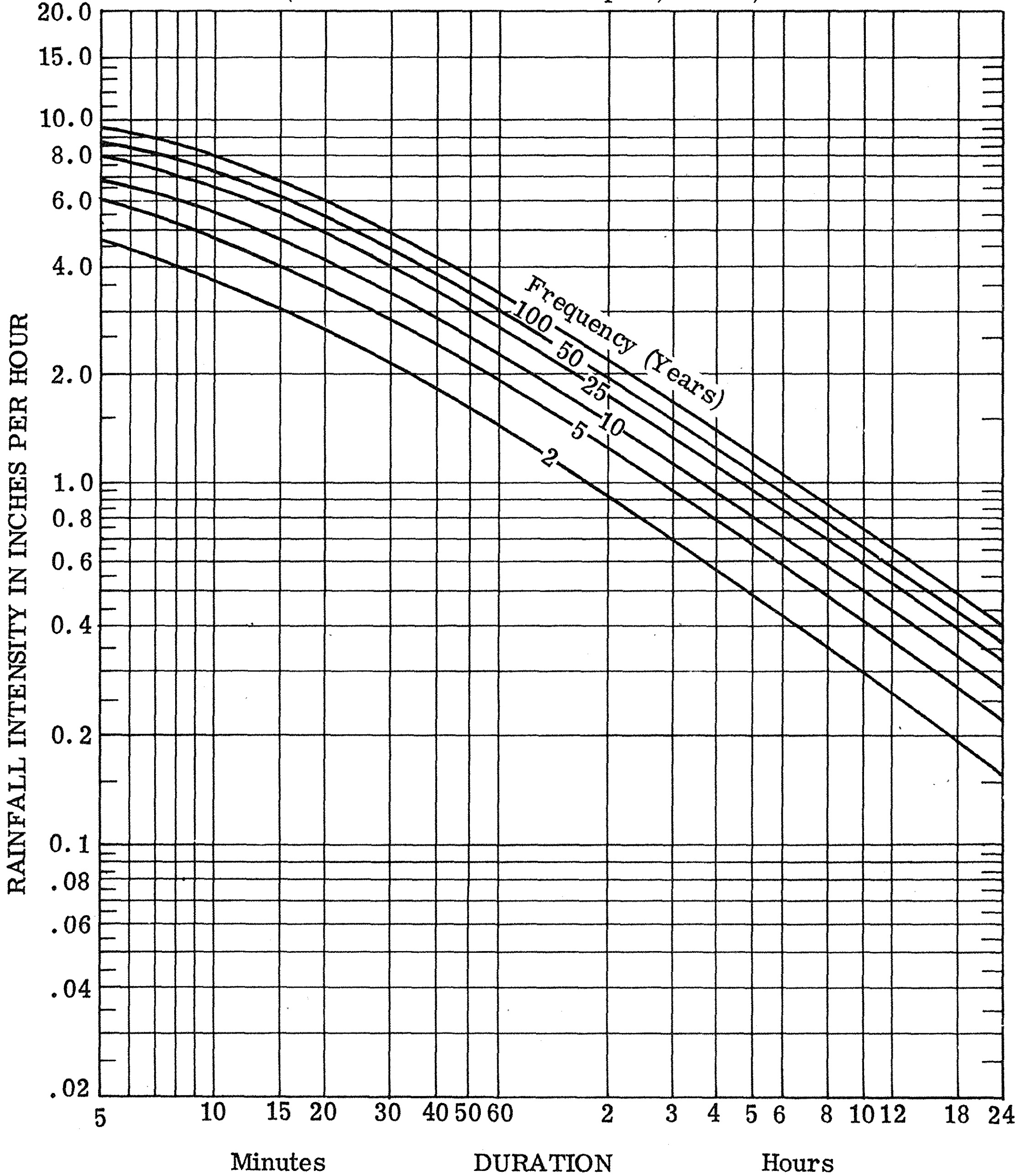


Chart 6-2

RAINFALL DURATION-INTENSITY CURVES

REGION II

(Based on Data from Vicksburg, Miss.)

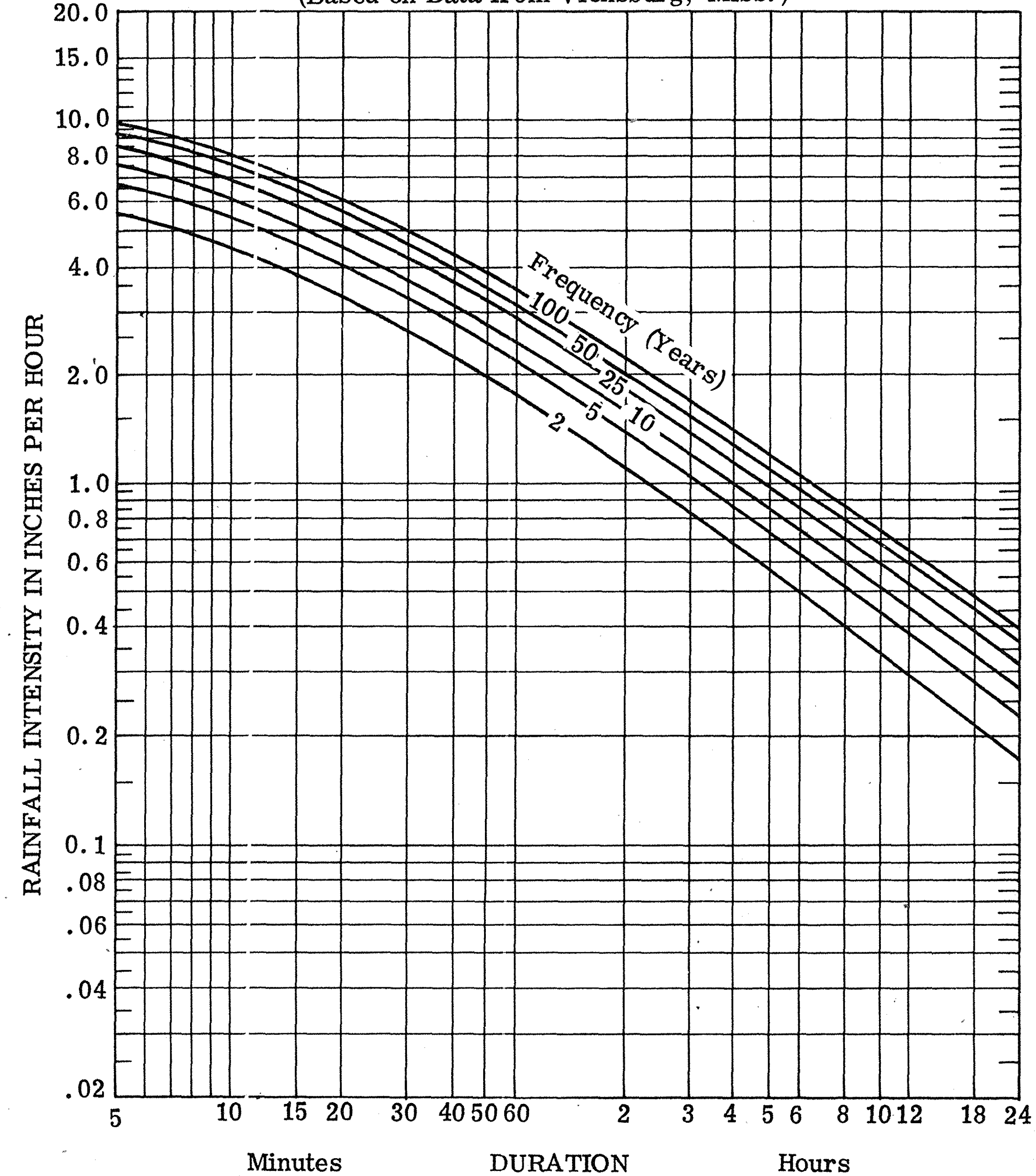


Chart 6-3

RAINFALL DURATION–INTENSITY CURVES

REGION III

(Based on Data from Meridian, Miss.)

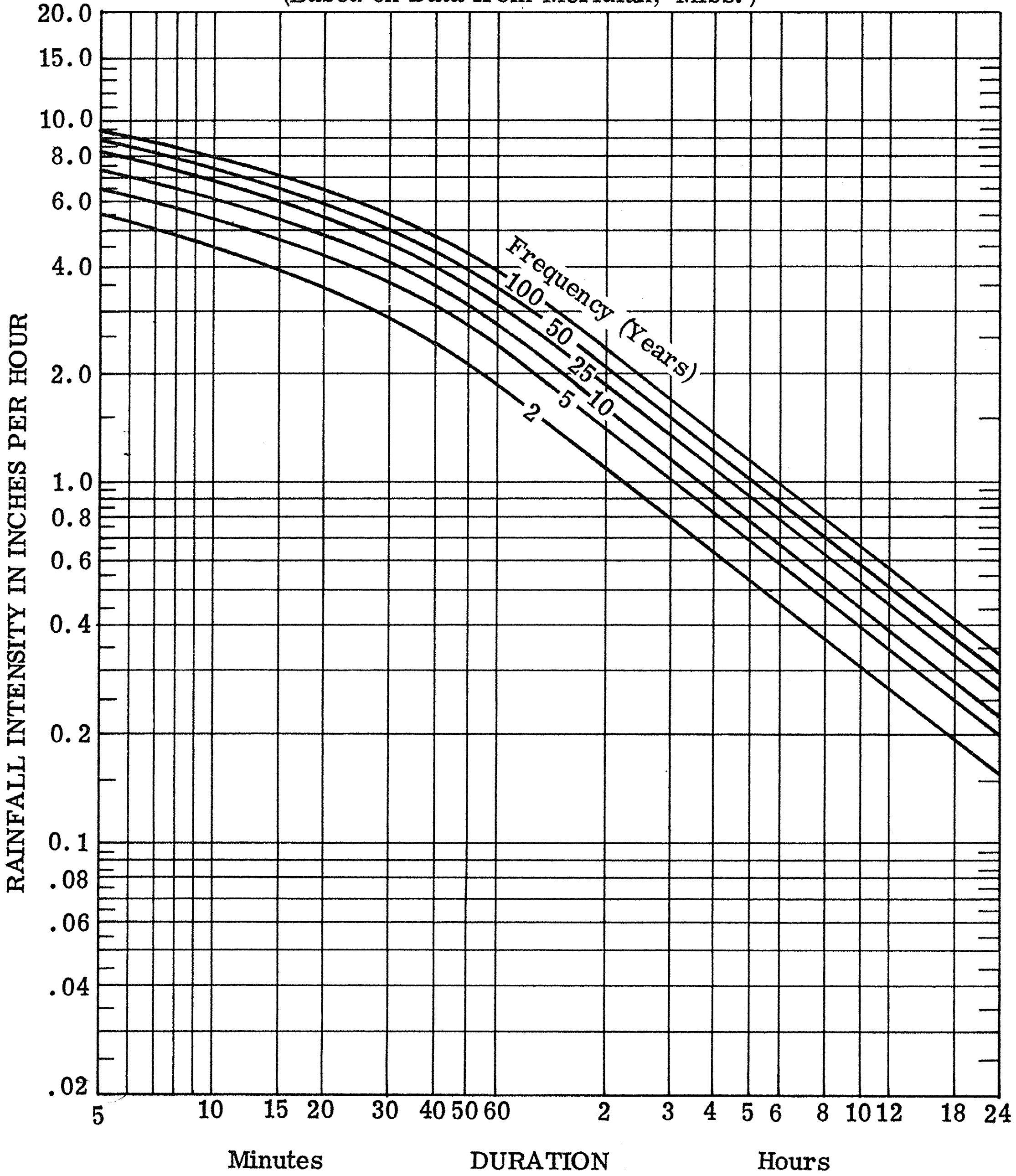
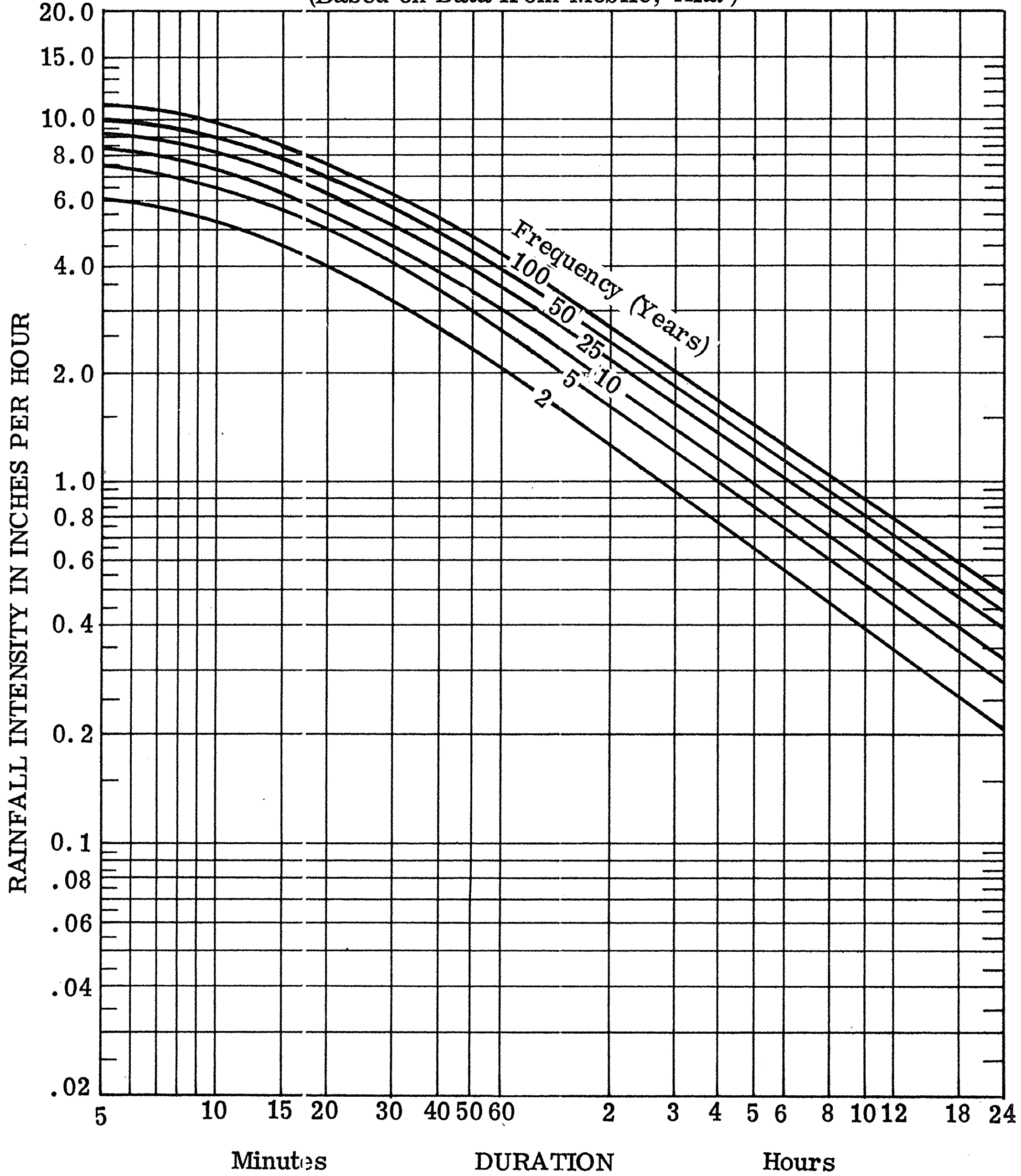


Chart 6-4

RAINFALL DURATION–INTENSITY CURVES

REGION IV

(Based on Data from Mobile, Ala.)



Method from U.S.G.S. 1967 Report

The U.S.G.S. 1967 Report on "Urbanization Effects on Floods in Jackson, Mississippi" sets forth a method for design discharge determination applicable to urban drainage areas over 10 acres.

Mean annual flood curves for streams in the Jackson area have been developed on the basis of certain percentages of the drainage basin having storm sewers and improved channels. The 50 percent to 60 percent curves represent average developed urbanized areas. Small paved areas, shopping centers, and other commercial and industrial areas can have as much as 100 percent of the basin improved. The designer must strive to accurately select the appropriate curve with consideration of probable future use.

Design discharges are determined in the following manner:

1. Consider the drainage area--its present development and potential future use. Select the most representative curve on Chart 6-5. Enter the horizontal (abscissa) scale with the the drainage area in square miles and vertically intersect the appropriate percentage curve. From this point, project horizontally to the vertical (ordinate) scale and read the mean annual discharge in cubic feet per second.

2. Adjust the discharge value for the desired storm frequency, using Chart 6-6. Enter the horizontal scale at the desired frequency interval (years), read vertically to the intersection with the curve, and project horizontally to read the ratio value.

3. The product of the mean annual flood (from Chart 6-5) and the ratio value (from Chart 6-6) gives the design discharge in cubic feet per second.

Example:

Primary project	=	urban Jackson, Mississippi
Drainage area	=	1.16 square miles
Development	=	50% storm sewers and improved channels
Design frequency	=	50-year

Q_{Design} = Mean Annual Flood x Ratio Value

1. Enter horizontal scale of Chart 6-5 at 1.16 square miles, read upward to 50 percent curve, project horizontally left to vertical scale and read discharge of 1,200 cubic feet per second.

2. On Chart 6-6, enter the horizontal scale at 50-year frequency, read vertically to the curve, project horizontally to the vertical scale and read the ratio value of 1.92.

3. Q_{Design} = 1,200 x 1.92 = 2,300 c.f.s.

Design discharges for urban areas computed by this method are directly applicable for the central one-third of the state. For other areas of the state, conversion factors are needed as follows:

Northern 1/3 of State:

Computed Q_{Design} x 0.9333 (reduction)

Southern 1/3 of State:

Computed Q_{Design} x 1.0667 (increase)

DESIGN DISCHARGE CHARTS

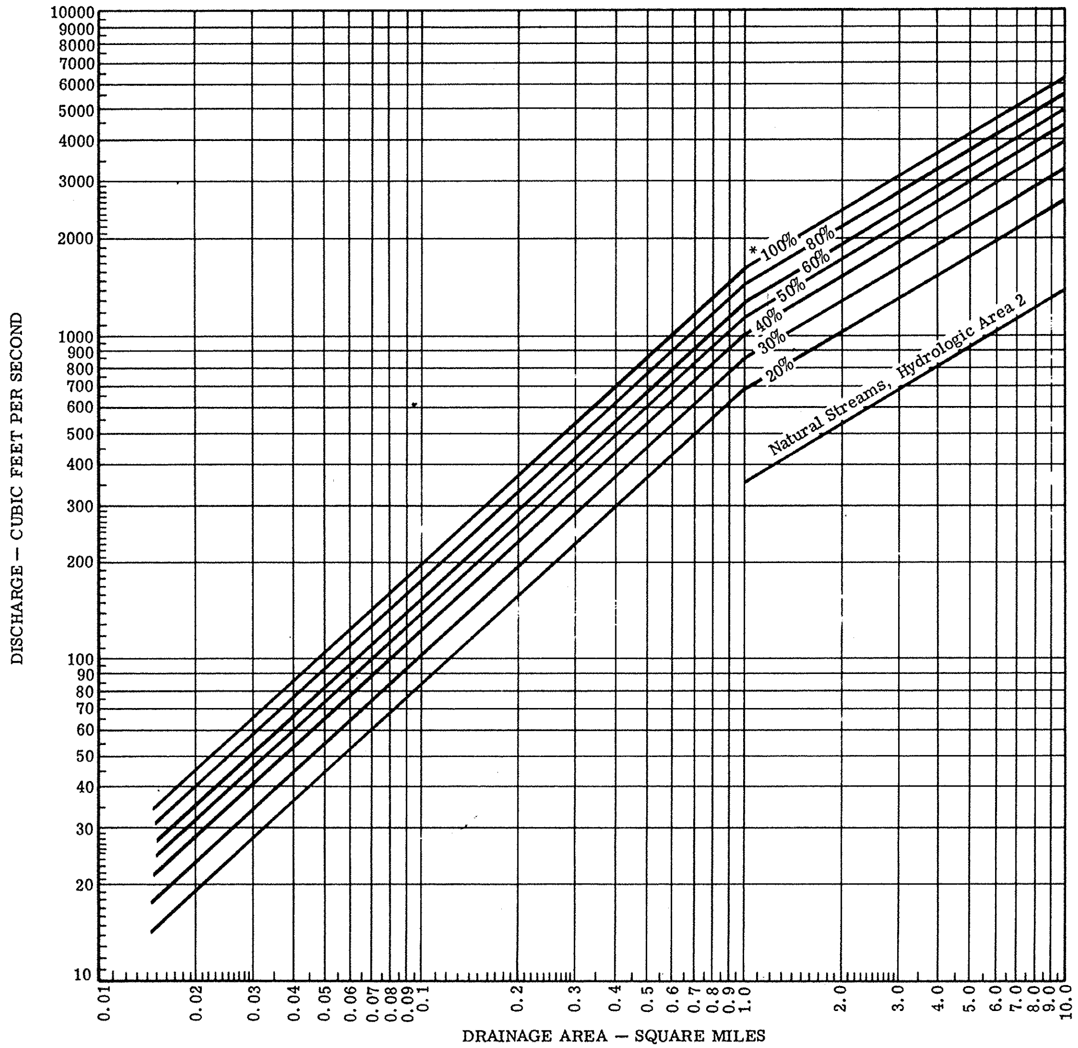
Urban Drainage Areas Greater Than 10 Acres

(BASED ON U.S.G.S. 1967 REPORT, "URBANIZATION EFFECTS ON FLOODS IN JACKSON, MISSISSIPPI")

CHART 6-5

MEAN ANNUAL FLOOD CURVES

City of Jackson Vicinity

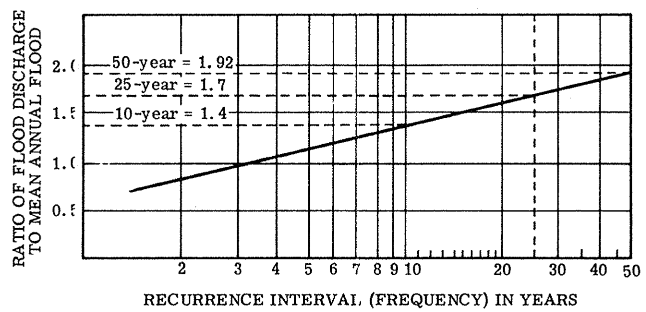


*Percent of basin with storm sewers and improved channels.

NOTE: Unless drainage area is extremely small and all-paved (like a shopping center) the curves for 50%-60% will give valid representation for urbanized areas.

CHART 6-6

DISCHARGE ADJUSTMENT VALUES FOR DESIGN-STORM FREQUENCIES



REGIONAL CONVERSION FACTORS

Northern 1/3 of State — Discharge x 0.933 (reduction)
Central 1/3 of State — Direct chart values
Southern 1/3 of State — Discharge x 1.0667 (increase)

FHWA "Chart 1021 Method-- Peak Rates of Runoff--Watersheds under 1,000 Acres"

This method of discharge determination normally should be used for rural drainage areas of over 10 acres and under 1,000 acres.

The basic formula is:

$$Q_{Design} = R.F. \times L.F. \times F.F. \times Q$$

where:

where:	Q_{Design}	=	Discharge for desired frequency (cubic feet per second)
	R.F.	=	Rainfall Factor
	L.F.	=	Land Factor
	F.F.	=	Frequency Factor
	Q	=	Unadjusted Discharge

The procedure is:

1. Refer to Figure 6-2 and select the rainfall factor for the specific location (these factors for Mississippi range from 1.35 in the north to 1.6 in the south).

2. Refer to Chart 6-7 and select the Land Factor (L.F.) appropriate for the slope and land use. Land use should reflect predicted future (20-year) use--and normally should be upgraded one level (e.g., pasture to mixed cover, etc.)

3. From the table at the bottom of Chart 6-7, select the Frequency Factor for the design frequency period (based on type of roadway system--Interstate, Primary, Secondary).

4. Enter the abscissa of Chart 6-7 at the given drainage area in acres, vertically to the intersection with the curve, then horizontally left to the value for the unadjusted discharge (Q).

5. The product of R.F. x L.F. x F.F. x Q, as determined above, gives the design discharge (Q_{Design}) in cubic feet per second.

The Land Factor is the most arbitrary factor in this equation and must be appropriately selected to obtain valid results.

Example:

Primary project	=	Scott County
Drainage area	=	200 acres
Land use	=	pasture land
Land slope	=	about 0.2%
Design frequency	=	50-year

1. From Figure 6-2, the Rainfall Factor for Scott County is 1.5.

2. From Chart 6-7, the Land Factor for pasture land on a 0.2% slope is 0.4. Upgrading this to the next higher type (mixed cover) gives a Land Factor of 0.6.

3. From the table at the bottom of Chart 6-7, the Frequency Factor for 50 years is 1.2.

4. Enter the abscissa of Chart 6-7 at 200 acres, ascend vertically to the intersection with the curve, then horizontally to the ordinate where the value for Unadjusted Discharge (Q) is approximately 290 cubic feet per second.

5. Substitute values in the equation:

$$Q_{50} = R.F. \times L.F. \times F.F. \times Q$$
$$= 1.5 \times 0.6 \times 1.2 \times 290$$
$$= 313 \text{ cubic feet per second.}$$

Table 6-3 shows a modification of the FHWA Chart 1021 Method that serves as a convenient shortcut for preliminary sizing of many of the culverts for smaller drainage areas. However, use of this table omits some information required for the project file record. The tables should be used only for preliminary sizing--standard design procedures must be followed.

Table 6-3 is developed to determine discharge for a Rainfall Factor of 1.50 and a Frequency Factor of 1.2 (50-year storm). Conversion factors are included in the tables to adapt to other conditions. The table also identifies alternative recommended culvert sizes for various ranges of design discharges.

Example:

Primary project	=	Calhoun County
Drainage area	=	200 acres
Land use	=	pasture land
Land slope	=	over 2%
Design frequency	=	50-year

1. From Table 6-3, the Land Factor is 0.6 for pasture land at over 2% slope. Upgrade the land use to mixed cover and the Land Factor becomes 1.0.

2. From Table 6-3, the combination of Land Factor of 1.0 with a drainage area of 200 acres gives an estimated discharge of 535 cubic feet per second.

3. Figure 6-2 shows that Calhoun County is in a region of 1.4 Rainfall Factor. Adjust the discharge as follows (refer to the Note on Table 6-3):

$$Q_{50} = Q_{Table} \times 0.9333$$
$$= 535 \times 0.9333$$
$$= 499 \text{ cubic feet per second.}$$

Since this is a Primary project with a 50-year Storm Design Frequency, no further adjustment of discharge is needed.

4. Enter the table of Recommended Alternative Culverts at 499 c.f.s. and read across to the listing of acceptable culverts--single 96", double 72" or triple 60" pipe culverts, and 10' x 6' box culvert. Selection of a specific culvert from among these alternatives usually will depend on factors such as allowable headwater, amount of cover, soil conditions and cost. The alternative identified with the asterisk (in this case, the 10' x 6' box culvert) normally will be the most economical installation.

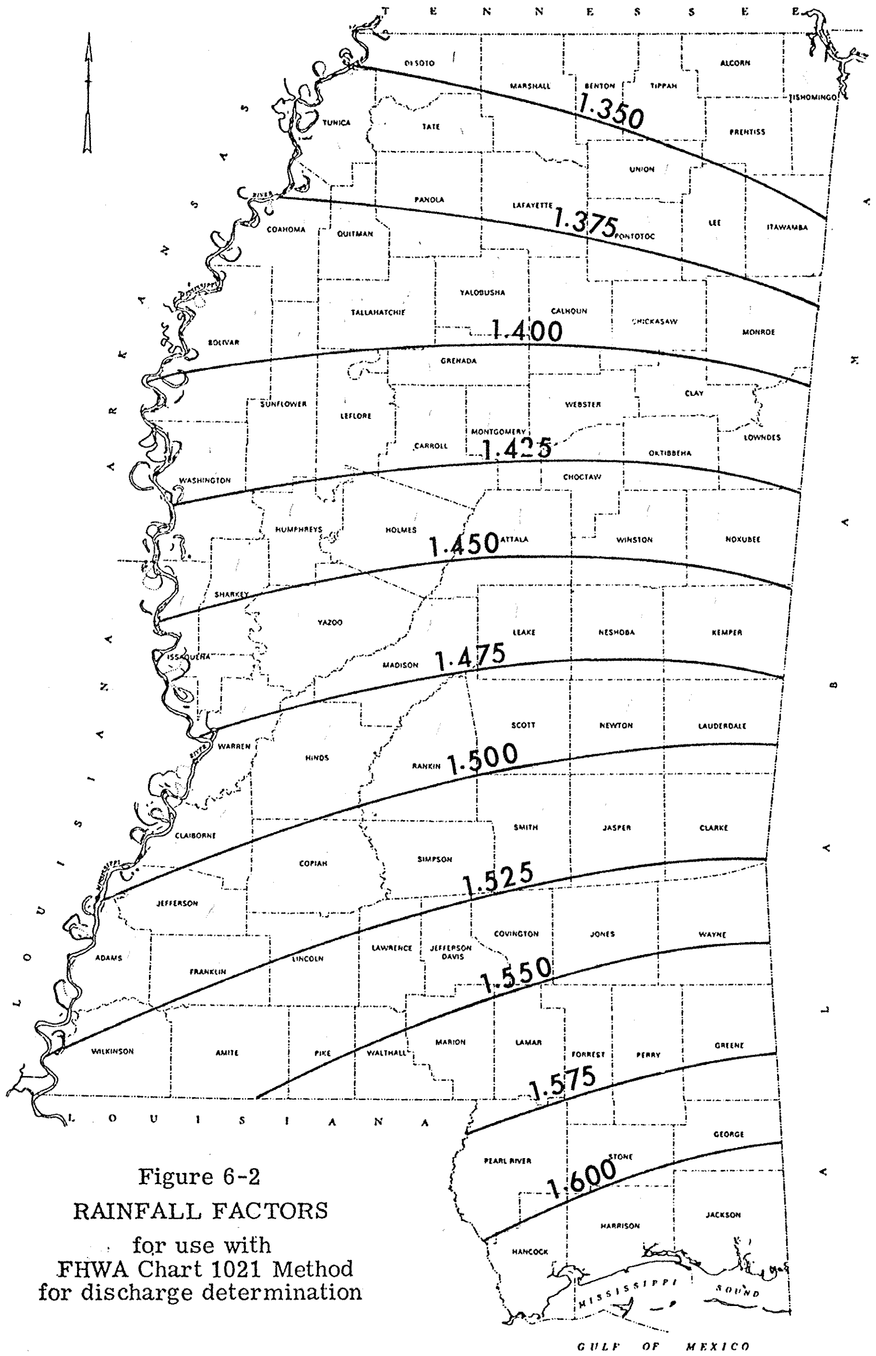
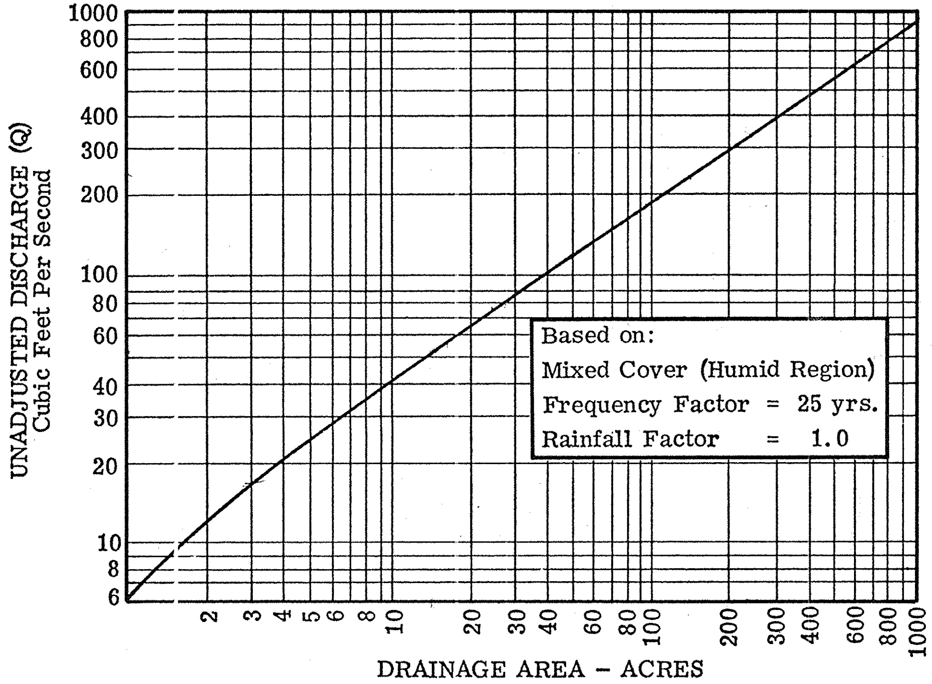


Figure 6-2
RAINFALL FACTORS
for use with
FHWA Chart 1021 Method
for discharge determination

Chart 6-7

DESIGN DISCHARGE DETERMINATION
RURAL DRAINAGE AREAS OF 10 ACRES TO 1000 ACRES
(Based on FHWA Chart 1021 Method)



LAND FACTOR (L. F.)			
Land Slope / Land Use	Steep Over 2%	Flat 0.2%	Very Flat No Ponds
100% Cultivated (Row Crops)	1.2	0.8	0.25
Mixed Cover	1.0	0.6	0.2
Pasture	0.6	0.4	0.1
Woods, Deep Forest Filter	0.3	0.2	0.05

FREQUENCY FACTOR (F. F.)				
Frequency Years	5	10	25	50
Factor	0.6	0.8	1.0	1.2

Q_{Design} = R. F.* x L. F. x F. F. x Q

*See Figure 6-2 for Rainfall Factor

Table 6-3

PRELIMINARY SIZING OF CULVERTS

Rural Drainage Areas 10 Acres to 1000 Acres

BASED ON FHWA CHART 1021 METHOD
Peak Rates of Runoff--Watersheds Under 1,000 Acres

LAND FACTOR					
Land Use*	Slope of Drainage Area				
	Over 2.0%	1.5%	1.0%	0.5%	Under 0.2%
Cultivated (row crops)	1.20	1.10	1.00	0.90	0.80
Mixed Cover	1.00	0.90	0.80	0.70	0.60
Pasture	0.60	0.55	0.50	0.45	0.40
Woods (deep forest filter)	0.30	0.28	0.25	0.23	0.20

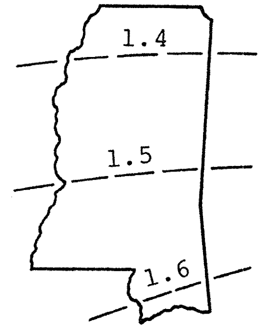
*In selecting land use, upgrade the existing use to next higher type for 20-year future use (e.g., pasture to mixed cover).

DISCHARGE IN CUBIC FEET PER SECOND									
Area (Acres)	Land Factor (L.F.)								
	0.05	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2
12	4	9	17	26	34	51	68	85	102
13	4	9	18	27	36	54	72	90	108
14	5	9	19	28	38	57	75	94	113
15	5	10	20	30	39	59	79	99	118
16	5	10	21	31	41	62	82	103	123
18	5	11	22	33	44	67	89	111	133
20	6	12	24	36	48	71	95	119	143
25	7	14	28	41	55	88	110	138	165
30	8	15	31	46	62	93	124	155	186
35	9	17	34	51	69	102	137	171	206
40	9	19	37	56	75	112	150	187	224
45	10	20	40	61	81	121	162	202	242
50	11	22	43	65	87	130	173	216	260
55	12	23	46	69	92	138	184	230	276
60	12	24	49	73	97	146	195	244	292
70	13	27	54	81	108	162	216	269	323
80	15	29	59	88	118	176	235	294	353
90	16	32	63	95	127	190	254	317	381
100	17	34	68	102	136	204	272	340	408
150	22	44	89	133	177	266	355	443	532*
200	27	53	107	160	214	321	428	535	642
250	31	62	124	186	247	371	495	619	742
300	35	70	139	209	279	418	558	697	836
350	39	77	154	231	308	462	617	771	925
400	42	84	168	252	336	505	673	841	1009
450	45	91	182	272	363	545	727	908	1091
500	49	97	195	292	389	584	778	973	1168
550	52	104	207	311	414	621	828	1035	1243
600	55	110	219	329	438	658	877	1096	1315
650	58	115	231	346	462	693	924	1155	1386
800	66	132	265	397	529	794	1058	1323	1587
1000	77	153	306	459	612	918	1224	1530	1836

*Nominal maximum discharge for double line of large pipe is about 500 c.f.s. (see Discharge Limits, page 6-16)

DISCHARGE Q — C.F.S.	RECOMMENDED ALTERNATIVE CULVERTS		
	PIPE	MULTIPLE PIPE	BOX CULVERTS
17 - 19	24"		
20 - 34	30"		
35 - 53	36"		
54 - 78	42"		
79 - 109	48"		
110 - 118	*54"		4' x 4'
119 - 147	*54"	2 - 42"	5' x 4'
148 - 156	60"	*2 - 42"	6' x 4'
157 - 177	*60"	2 - 48"	6' x 4'
178 - 190	*60"	2 - 48"	5' x 5', 7' x 4'
191 - 207	66"	*2 - 48"	5' x 5', 7' x 4'
208 - 220	66"	*2 - 48", 3 - 42"	6' x 5', 8' x 4'
221 - 236	*66"	2 - 54", 3 - 42"	6' x 5', 8' x 4'
237 - 246	*66"	2 - 54", 3 - 48"	6' x 5', 9' x 4'
247 - 266	72"	*2 - 54", 3 - 48"	7' x 5', 9' x 4'
267 - 287	72"	*2 - 54", 3 - 48"	7' x 5', 10' x 4'
288 - 295	72"	*2 - 54", 3 - 48"	10' x 4'
296 - 300	*72"	2 - 60", 3 - 48"	6' x 6', 8' x 5'
301 - 318	84"	2 - 60", *3 - 48"	6' x 6', 8' x 5'
319 - 328	84"	2 - 60", *3 - 48"	8' x 5', 12' x 4'
329 - 354	84"	2 - 60", *3 - 48"	9' x 5', 12' x 4'
355 - 369	84"	*2 - 60", 3 - 54"	9' x 5', 10' x 5'
370 - 380	84"	*2 - 60", 3 - 54"	8' x 6', 10' x 5'
381 - 410	84"	2 - 66", *3 - 54"	8' x 6', 10' x 5'
411 - 424	84"	2 - 66", *3 - 54"	8' x 6', 12' x 5'
424 - 440	84"	2 - 66", *3 - 54"	12' x 5'
441 - 484	96"	2 - 66", *3 - 54"	10' x 6', 12' x 5'
485 - 492	96"	2 - 72", 3 - 60"	10' x 6', *12' x 5'
493 - 530	96"	2 - 72", 3 - 60"	*10' x 6'
531 - 600	96"	2 - 72", *3 - 60"	8' x 8', 12' x 6', 16' x 5'
601 - 620	*96"	2 - 84", 3 - 66"	8' x 8', 12' x 6', 16' x 5'
621 - 636	108"	2 - 84", 3 - 66"	8' x 8', 12' x 6', *16' x 5'
637 - 656	108"	2 - 84", 3 - 66"	8' x 8', 14' x 6', *16' x 5'
657 - 742	108"	2 - 84", *3 - 66"	10' x 8', 14' x 6', 20' x 5'
743 - 820	108"	*2 - 84", 3 - 72"	10' x 8', 16' x 6', 20' x 5'
821 - 850	108"	*2 - 84", 3 - 72"	12' x 8', 18' x 6', 24' x 5'
851 - 880		*2 - 84", 3 - 72"	12' x 8', 18' x 6', 24' x 5'
881 - 954		2 - 96", *3 - 72"	12' x 8', 18' x 6', 24' x 5'
955 - 984		2 - 96", 3 - 84"	*12' x 8', 24' x 5'
985 - 1060		2 - 96", 3 - 84"	10' x 10', 14' x 8', *20' x 6'
1061 - 1150		2 - 96", 3 - 84"	*10' x 10', 14' x 8'
1151 - 1272		*2 - 96", 3 - 84"	16' x 8', 24' x 6'
1273 - 1320		2 - 108", *3 - 84"	12' x 10', 16' x 8'
1321 - 1341		2 - 108", 3 - 96"	*12' x 10', 18' x 8'
1342 - 1380		2 - 108", 3 - 96"	*12' x 10', 20' x 8'
1381 - 1490		2 - 108", 3 - 96"	*14' x 10', 20' x 8'
1491 - 1610		2 - 108", 3 - 96"	*14' x 10', 24' x 8'
1611 - 1788		*2 - 108", 3 - 96"	12' x 12', 16' x 10', 24' x 8'
1789 - 1860		3 - 96"	12' x 12', *16' x 10'
1861 - 2070		3 - 108"	*14' x 12', 18' x 10'

* Usually the most economical alternative.



RAINFALL FACTORS

INSTRUCTIONS:

1. **Determine Land Factor from table--based on identified land use and slope of drainage area.**

2. **Determine Discharge from table--based on Area and Land Factor.**

3. **Identify Recommended Alternative Culverts from table--based on discharge.**

Note:

Discharge values in table are based on Rainfall Factor of 1.5 and Design Storm Frequency of 50 years.

For conditions other than above, the discharge values in the table must be adjusted as shown below:

For R.F. of 1.4	--	$Q_{50} = Q_{Table} \times 0.9333$
For R.F. of 1.6	--	$Q_{50} = Q_{Table} \times 1.0667$
For 25-Year	--	$Q_{25} = Q_{Table} \times 0.8333$
For 10-Year	--	$Q_{10} = Q_{Table} \times 0.6667$
For 5-Year	--	$Q_{5} = Q_{Table} \times 0.5000$

See Figure 6-2 for appropriate Area Rainfall Factors.

U.S.G.S. 1961 Report

A method for discharge determination is shown in a U.S.G.S. 1961 Report, "Floods in Mississippi--Magnitude and Frequency." This method is used primarily with drainage areas in excess of one square mile and most likely several square miles, which is beyond the scope of this design manual. However, for those areas within the design limits, the Report outlines the design procedure on page 32 under the topic, Areal Frequency Curves. This method can be used as a comparison check for drainage areas approaching 1,000 acres --the approximate design limit of this manual.

U.S.G.S. Individual Stream Study Reports

U.S.G.S. Individual Stream Study Reports (generally of areas larger than 1,000 acres) may be used directly to identify discharge. Even if not used directly, they often indicate runoff discharge conditions for similar areas in the general vicinity of the study report. The Quiver River Report, for example, indicates runoff characteristics typical of the Mississippi Delta, and is used extensively for delta lands.

U.S.G.S. May 1970 Report

A May 1970 U.S.G.S. Report, "Regression Analysis of All Small Drainage Area Flood Data in Mississippi," describes another method for discharge determination.

The following equation was derived from this analysis:

$$Q_{\text{Mean Annual Flood}} = (2210A^{0.94})\,(S_0^{1.28})\,(S_2^{0.41})\,(F^{3.29})$$

where: A = drainage area in square miles
S_0 = soil index
S_2 = slope coefficient
F = forest cover coefficient

Values for these properties are available in table form. Frequently, the soil index and the forest cover coefficient are not known and must be furnished by the field personnel.

CULVERT DESIGN PRACTICES

Previous sections have been concerned principally with estimating the design discharge at culvert locations. The next step is to design culverts to fit the specific conditions--but several general criteria should be understood first.

Minimum Size Culverts

Department policy has established minimum sizes of culverts for particular installations--even though these sizes may have capacity exceeding the design discharge requirements. Minimum permissible sizes are shown in Table 6-4.

Table 6-4
MINIMUM SIZE CULVERTS

Roadway System	Box Culverts	Pipe Culverts				
		Cross Drains	Median Drains	Side Drains	Slope Drains	Stubouts
Interstate	4' x 4'	24"	18"	18"	15"	15"
Primary	*4' x 4'	18"	18"	15"	15"	15"
Secondary	*4' x 4'	18"	18"	15"	15"	15"

* In approved instances, extension of smaller existing box culverts is permissible.

Discharge Limits

In designing culvert installations, the following general limits of discharge should guide the selection of the type of culvert:

- Under 200 c.f.s. -- pipe culverts
- 200 -- 500 c.f.s. -- pipe is recommended--however, either multiple pipes or box culverts may be used.
- Above 500 c.f.s. -- either multiple pipes or box culverts are permitted.

Design documentation for 18" pipe culverts and arch pipe equivalents usually will require only verification of the allowable headwater (HW) and a record for the project file, to fulfill the design requirements. Analysis of outlet discharge velocity may be required for erosion control.

Pipe culverts and arch equivalents of 24" diameter and larger must have inlet and outlet control analysis, and other record information (see the section on Culvert Size Determination).

Generally, the nominal maximum discharge for a double line of large pipe culverts is about 500 c.f.s. (cubic feet per second). Additional lines of pipe should be investigated when conditions warrant.

Economic Comparisons

In some instances, single and multiple lines of pipe culverts can be substituted for box culverts, with considerable savings in cost of material and time of construction. There will be instances where a box culvert is the more practical structure--e.g., large size, excessive cover, inadequate cover, soil conditions, cattle and equipment passes, and others.

When there is an alternative between box culverts or pipe culverts, an economic comparison should be conducted and recorded. This comparison should consider the initial structure installation costs, the life expectancy, and the replacement costs of different types of culverts.

Pipe Culvert Alternates

For most pipe culvert installations, Department policy calls for Reinforced Concrete Pipe (R.C.P.). Under certain conditions, alternate types of pipe may be permitted. Table 6-5 shows the criteria for type of pipe.

Where alternates for cross drains exist, consider R.C.P. up to 36" diameter. When pipe is 36" diameter or larger, alternates of either R.C.P. or Bituminous Coated Paved Invert 3:1 Corrugated Metal Pipe are more comparable.

Type and Placement of Pipe

Lower headwater values can be achieved with arch pipe. Normally, arch pipe is used where the cover, outfall elevation or gradient is restrictive.

Generally, small drainage culverts are preferred in the vicinity of residential and farm lands--placed on a flow line similar to the culvert height below the adjacent lands. This will permit effective culvert performance and avoid detrimental ponding on the drainage area.

Table 6-5

CRITERIA FOR TYPES OF PIPE CULVERTS

Type of Roadway Surface	Cross Drains	Median Drains	Special Systems Storm Sewers, Siphons, Etc.	Side Drains
High Type Pavement*	(1)	(1)	(1)	(3)
Other than High Type Pavement	(2)	(2)	(1)	(3)

*High Type Pavement: Portland concrete cement or 1" minimum thickness bituminous concrete.

(1) Reinforced Concrete Pipe

(2) Three alternates are required:

- Reinforced Concrete Pipe
- Bituminous Coated Paved Invert Corrugated Metal Pipe
- Vitrified Clay Pipe--only 30" diameter or less
- Bituminous Coated Paved Invert Corrugated Aluminum Pipe--only 30" diameter or larger.

(3) Same as (2) above, with exception: for permissible conditions, Bituminous Coating and/or Paved Inverts may be omitted from the two metal corrugated pipes.

NOTE: For special installation site conditions--such as unstable support, steep gradients, high embankment, acidity or alkalinity of soil, other corrosive elements, or high potential for erosion--the elimination of one or more of the alternate pipes may be warranted.

CULVERT SIZE DETERMINATION

Procedures for determining culvert sizes and for documenting the design are discussed in this section. The basic steps are shown below.

1. For an approximate area of culvert opening with which to begin trial sizing, divide the calculated design discharge (c.f.s.) by 10 feet per second (maximum desired flow velocity).

2. Using the Headwater Depth Charts, as explained in this section, select acceptable trial culverts with an HW/D value of 1.2 to 1.5 for inlet-control conditions. Check HW for Q_{Design} and Q_{100}.

3. Use the Head for Culvert Charts and the Critical Depth Charts to determine outlet-control acceptance of trial culverts.

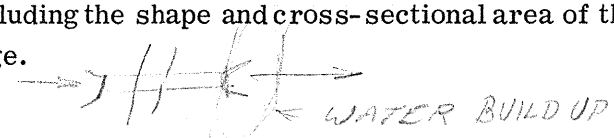
4. Refer to Hydraulic Engineering Circular No. 13 to verify the most satisfactory culvert size and/or entrance configuration.

Inlet and Outlet Control Culvert Flow

The characteristics of inlet and outlet controls must be considered in culvert size design. These controls influence the upstream water buildup or headwater (HW) necessary for a particular culvert to pass a specific discharge.

TAILWATER BUILD UP

Inlet control is the flow condition when the discharge capacity of a culvert is controlled at the culvert entrance by the depth of headwater (HW) and the entrance geometry, including the shape and cross-sectional area of the barrel, and the type of inlet edge.



WATER BUILD UP

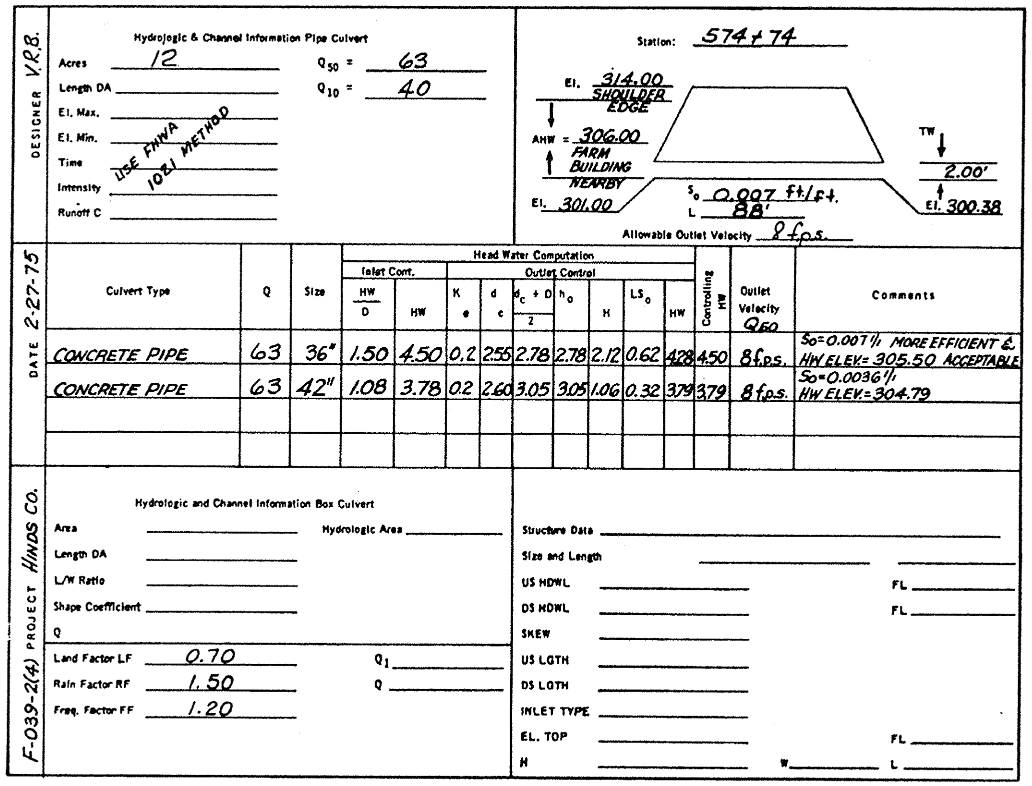
HEADWATER BUILD UP

Outlet control is the flow condition when the culvert entrance will allow the water to enter the culvert faster than the outlet conditions (tailwater and/or barrel friction) will allow flow through the culvert.

The design of culverts for all drainage areas of 3 acres or larger should consider these control characteristics, and computations should be recorded on a Culvert Design Form (see Figure 6-3) for documentation.

Figure 6-3

CULVERT DESIGN FORM


DESIGNER V.R.B.

Hydrologic & Channel Information Pipe Culvert

Acres 12
Length DA
El. Max.
El. Min.
Time
Intensity
Runoff C

USE FHWA 1021 METHOD

Q_{50} = 63
Q_{10} = 40

Station: 574+74

El. 314.00 SHOULDER EDGE
AHW = 306.00 FARM BUILDING NEARBY
El. 301.00
S_o 0.007 ft/ft.
L 88'
TW 2.00'
El. 300.38
Allowable Outlet Velocity 8 f.p.s.

DATE 2-27-75

Culvert Type	Q	Size	Inlet Cont. HW/D	Inlet Cont. HW	Outlet Control K_e	d_c	$\frac{d_c+D}{2}$	h_o	H	LS_o	HW	Controlling HW	Outlet Velocity Q_{50}	Comments
CONCRETE PIPE	63	36"	1.50	4.50	0.2	2.55	2.78	2.78	2.12	0.62	4.28	4.50	8 f.p.s.	So=0.007 '/' MORE EFFICIENT & HW ELEV.= 305.50 ACCEPTABLE
CONCRETE PIPE	63	42"	1.08	3.78	0.2	2.60	3.05	3.05	1.06	0.32	3.79	3.79	8 f.p.s.	So=0.0036 '/' HW ELEV.=304.79

PROJECT F-039-2(4) HINDS CO.

Hydrologic and Channel Information Box Culvert

Area
Hydrologic Area
Length DA
L/W Ratio
Shape Coefficient
Q
Land Factor LF 0.70
Rain Factor RF 1.50
Freq. Factor FF 1.20
Q_1
Q

Structure Data
Size and Length
US HDWL
DS HDWL
SKEW
US LGTH
DS LGTH
INLET TYPE
EL. TOP
H
W
FL
FL
FL
L

Improved Culvert Entrances

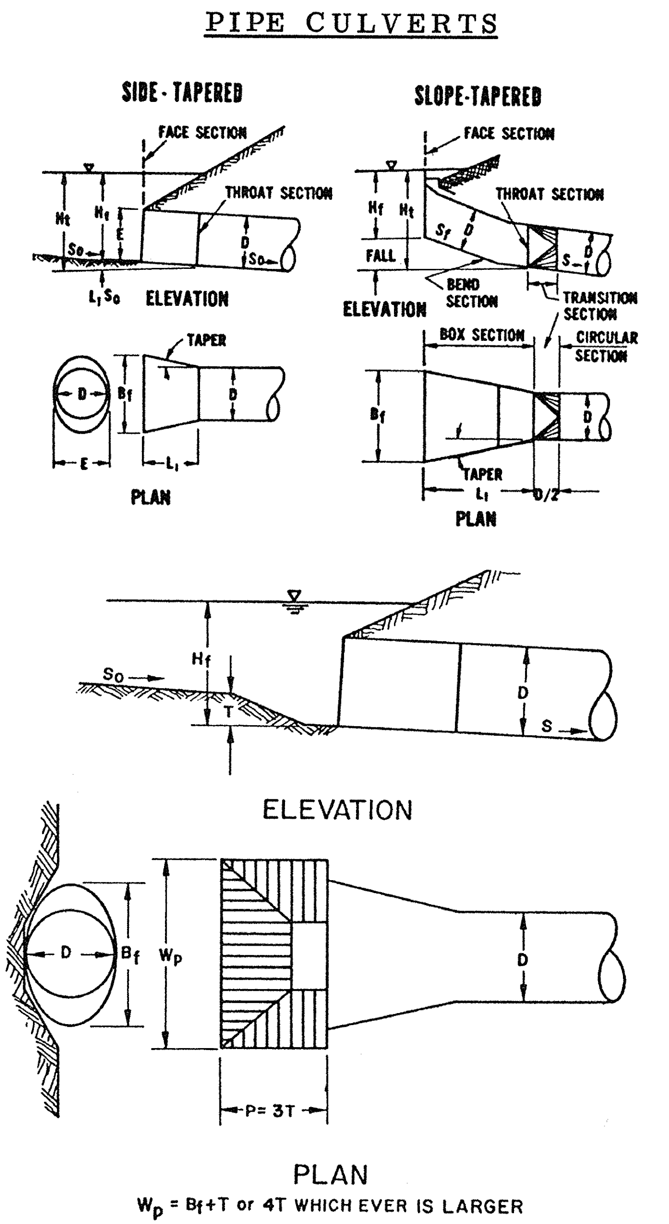
In inlet control, improved entrance structures for pipe and box culverts can increase efficiency and/or reduce the required culvert size. Examples of improved inlets are shown in Figure 6-4. Improved entrance structures on existing culverts may increase the culvert capacity sufficiently to accommodate increased discharges resulting from land-use developments.

Improvements at pipe and box culvert entrances include beveled entrance edges (without major change from the existing practice) and special-design entrance structures. Hydraulic Engineering Circular No. 13, "Hydraulic Design of Improved Inlets for Culverts," August 1972, presents details for design procedures. Ordinarily, this design will be handled by the Hydraulic Section.

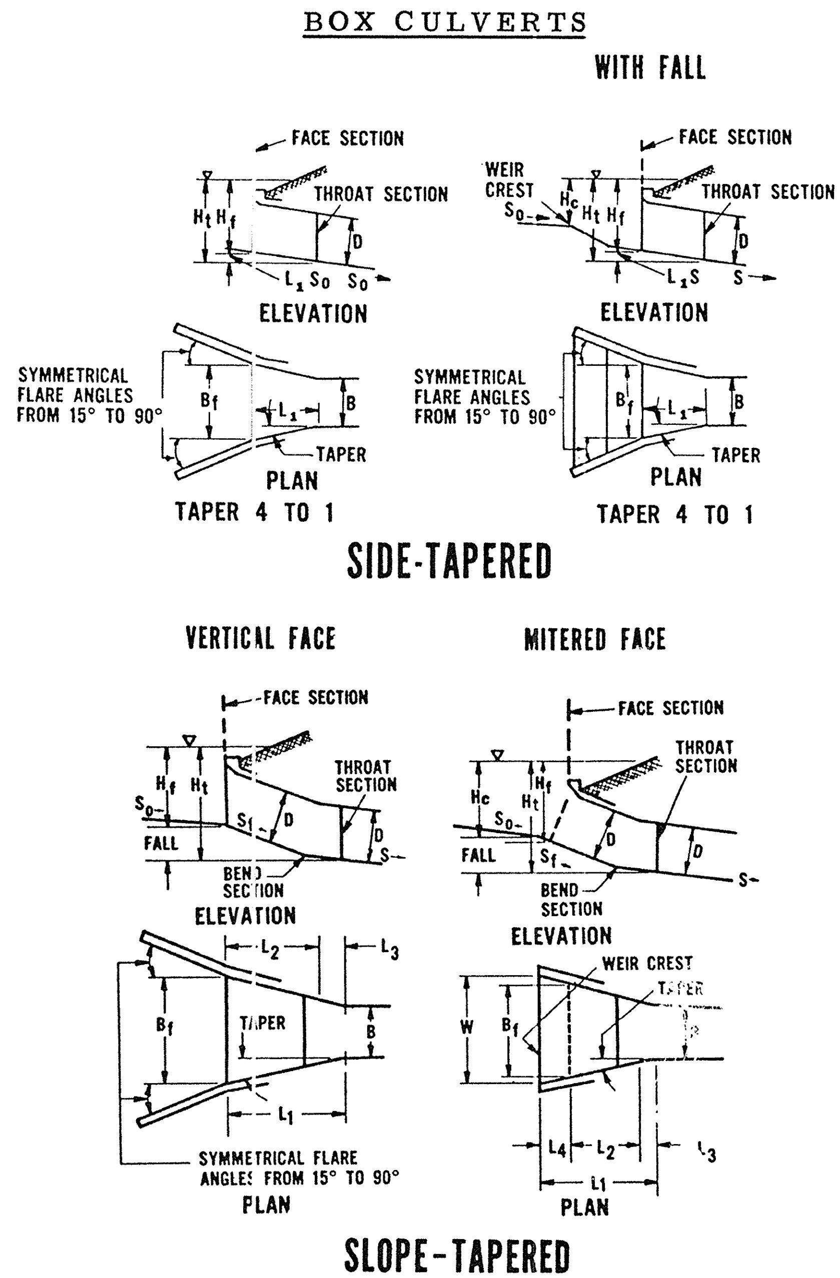
When the outlet control HW is acceptable and the inlet control HW is less, the culvert operates in outlet control at design discharge, and culvert entrance improvements would be of no advantage. However, when the outlet control HW is acceptable and the inlet control HW is greater, entrance improvements should be investigated in Hydraulic Engineering Circular No. 13, as indicated above. Computer analysis for improved entrance structures is available and should be used as a routine practice.

Figure 6-4

TYPES OF IMPROVED INLETS FOR PIPE AND BOX CULVERTS



SIDE-TAPERED INLET WITH CHANNEL DEPRESSION UPSTREAM OF ENTRANCE



Size Design of Concrete Pipe Culverts

The design discharge and the initial trial size pipe culvert (determined by the method for preliminary culvert sizing) provide the starting point for culvert design. The procedures for inlet control and for outlet control are as follows:

Inlet Control--Refer to Chart 6-8, "Headwater Depth for Concrete Pipe Culverts with Inlet Control: TAILWATER BUILD UP

1. Select appropriate HW/D scale, based on culvert entrance type. Usually this will be scale (2). Scale (1) is the turning point for HW/D scales--and all readings on scales (2) and (3) must be projected horizontally to scale (1) for the correct turning point.

2. Opposite the value of 1.2 on the appropriate HW/D scale, project horizontally to scale (1) for the turning point, align this 1.2 projected point with the design discharge on the "Discharge" scale, extend this straight line to intersect the "Diameter of Culvert" scale, and read diameter of pipe required.

3. When the intersecting point does not fall directly on a specific size pipe, the pipe closest to the intersection generally will suffice. Check this selection by aligning the chosen pipe diameter on the (D) scale with the design discharge on the (Q) scale, intersect the turning line of the HW/D scale, and project horizontally to the appropriate HW/D scale. If this HW/D value is 1.5 or less and is allowable, the selection is acceptable.

4. Enter the HW/D value on the design form, Figure 6-3. Get HW by multiplying HW/D by diameter of pipe. Enter HW on the form.

Example:

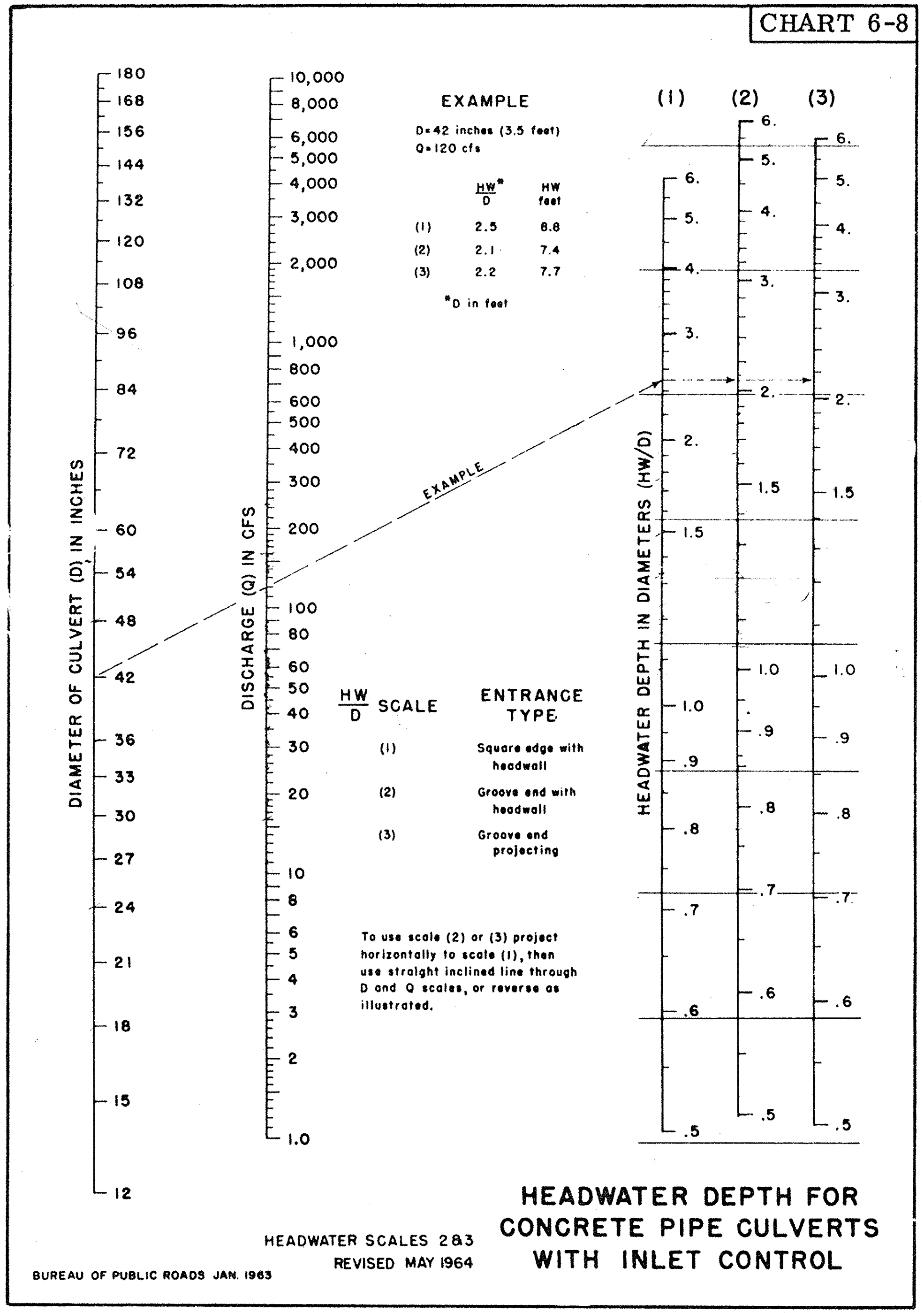
Select proper size concrete pipe culvert for design discharge of 63. c.f.s. and 10 feet of fill over pipe.

1. Refer to Chart 6-8. Entrance type is either groove end with headwall, or flared end section (not shown on chart). Use HW/D scale (2).

2. Project from 1.2 on the HW/D scale (2) horizontally to scale (1), align this point with discharge Q = 63 c.f.s., extend this straight line to the D scale, and read between a 36" and a 42" pipe.

3. Try a 36" pipe. Enter trial size on culvert design form. Align 36" pipe on D scale with 63 c.f.s. on Q scale, intersect HW/D scale (1), project horizontally to scale (2), and read 1.5. If the HW/D value had exceeded 1.5, the 42" pipe would have been the proper selection.

4. Enter HW/D value on the design form. Multiply the HW/D value (1.5) by the pipe diameter (D = 3.0 feet), giving an HW (Headwater) requirement of 4.50 feet for this pipe to pass the design discharge. Enter this on the design form. Adding headwater value (4.50 feet) to the flow line elevation of the pipe gives headwater elevation at pipe entrance. With 10 feet of fill over pipe, this headwater elevation is probably allowable and the pipe acceptable. However, outlet control conditions must be investigated, as explained in the following topic, to further verify the acceptance of this particular pipe.



Outlet Control--Concrete Pipe Culverts

1. Refer to Table 6-6, Entrance Loss Coefficients. Find applicable k_e value (for Concrete Pipe--Headwall and Groove Groove End, $k_e = 0.2$), and enter value on the design form.

2. Refer to Chart 6-9, Critical Depth--Circular Pipe, to determine critical depth (d_c). Enter the horizontal discharge (Q) scale with the design discharge and vertically intersect the pipe diameter curve. At this point project horizontally to the left to read the d_c value (d_c never greater than diameter of pipe). Enter value on the design form.

3. Calculate $\frac{d_c + D}{2}$. (D is diameter of pipe.) Enter value on the design form.

4. Tailwater (TW) is the water height at the downstream end of the culvert. Backwaters downstream from the culvert may cause detrimental TW. Refer to FHWA Hydraulic Design Series No. 3, Design Charts for Open-Channel Flow, Chapter 3, "Rectangular, Trapezoidal, and Triangular Channels (Trapezoidal Charts 15 - 28). With the existing channel bottom width, select the appropriate chart.

   Then, with the design discharge and Manning roughness coefficient (n) from Table 6-7 (Q x n value, if different from the chart) and the existing channel slope, determine the natural depth of flow, which can be the TW on the culvert. However, highwater from other downstream sources may cause a higher TW value. For the (h_o) value, use either the highest TW height or the $\frac{d_c + D}{2}$ value, whichever is greater. Enter the value on the design form.

5. Refer to Chart 6-10, Head for Concrete Pipe Culverts Flowing Full; $n = 0.012$. Align diameter of pipe and length of pipe on appropriate k_e scale to establish a turning point on the turning line. Through this turning point, align the discharge on the (Q) scale, and intersect the head (H) scale. This (H) value is the necessary differential head to pass the design discharge.

6. Refer to FHWA Hydraulic Design Series No. 3, Design Charts for Open-Channel Flow, Chapter 5, "Circular-Pipe Channels," to establish the pipe slope at the allowable velocity. Enter the discharge scale of the appropriate (n) value, ($n = 0.012$ for concrete pipe). Vertically intersect the horizontal projection for 8 feet per second of the appropriate velocity scale, read the permissible pipe slope (S_o), and record both velocity and slope on the design form.

7. Enter the product of the pipe length and pipe slope (LS_o) on the design form.

8. Evaluate the equation, $HW = H + h_o - LS_o$. The greater HW value will determine either inlet control or outlet control as governing. If the HW is higher than allowable, select a larger size pipe for another trial.

Example: (continued from Inlet Control example)
(See Figure 6-3)

1. Table 6-6 gives Entrance Loss Coefficient (k_e) of 0.2. Enter this value on the form.

2. Chart 6-9 gives Critical Depth, d_c, of 2.55. Enter this value on the form.

3. $\frac{d_c + D}{2} = \frac{2.55 + 3.0}{2} = 2.78$. Enter this value on the form.

4. Since this is a very shallow natural channel, the tailwater (TW) will be less than d_c; therefore, the h_o value will be $\frac{d_c + D}{2} = 2.78$. Enter this value on the form.

5. Refer to Chart 6-10. Assume a pipe length of 88 feet, and align the pipe diameter (36") and length (88') on the $k_e = 0.2$ scale to establish the turning point. At that point, align design discharge and intersect the (H) scale. Read 2.12, and enter the value on the form.

6. Refer to FHWA Hydraulic Design Series No. 3, Design Charts for Open-Channel Flow, Chapter 5, "Circular Pipe Channels." For 36" pipe, enter the discharge scale of $n = 0.012$ with 63 c.f.s., vertically intersect the horizontal projection of 8 feet per second on the $n = 0.012$ velocity scale, and read slope of pipe, approximately 0.007 feet per foot. Enter both velocity and slope on the form.

7. Enter the product of the pipe length and pipe slope ($L \times S_o = 88' \times 0.007'/' = 0.616'$) on the design form.

8. Evaluate the equation, $HW = H + h_o - LS_o$.
$HW = 2.12' + 2.78' - 0.62' = 4.28'$.
Enter this value on the design form.

In this example, inlet control governs with the greater HW value and the pipe appears to be acceptable.

Table 6-6

ENTRANCE LOSS COEFFICIENTS

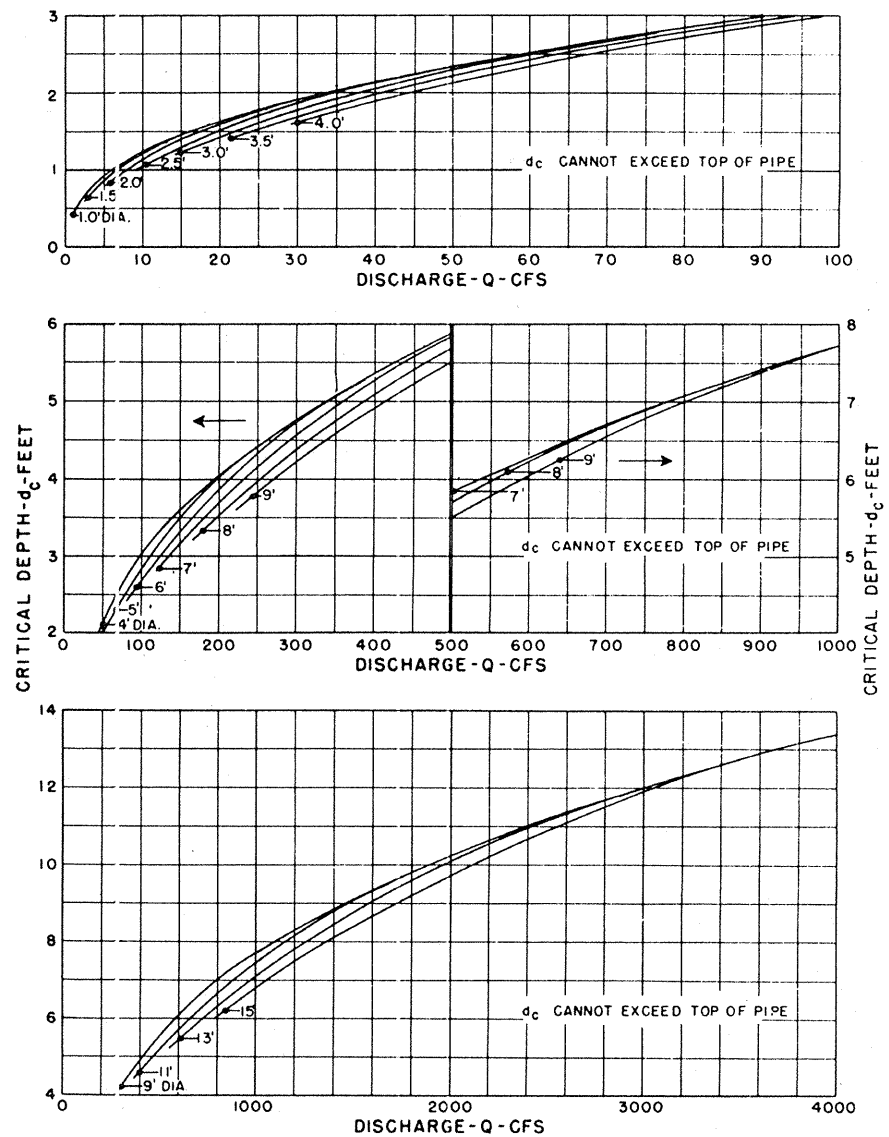
Coefficient k_e to apply to velocity head $\frac{V^2}{2g}$ for determination of head loss at entrance to a structure, such as a culvert or conduit, operating full or partly full with control at the outlet.

$$\text{Entrance head loss } H_e = k_e \frac{V^2}{2g}$$

Type of Structure and Design of Entrance	Coefficient k_e
Pipe, Concrete	
Projecting from fill, socket end (groove end)	0.2
Projecting from fill, square-cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls	
Square-edge	0.5
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension	0.2
Wingwalls at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7

*"End Section conforming to fill slope," made of either metal or concrete, is the section commonly available from manufacturers. Based on limited hydraulic tests, it is equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design, have a superior hydraulic performance. These latter sections can be designed using the information given for the beveled inlet.

CHART 6-9



BUREAU OF PUBLIC ROADS
JAN. 1964

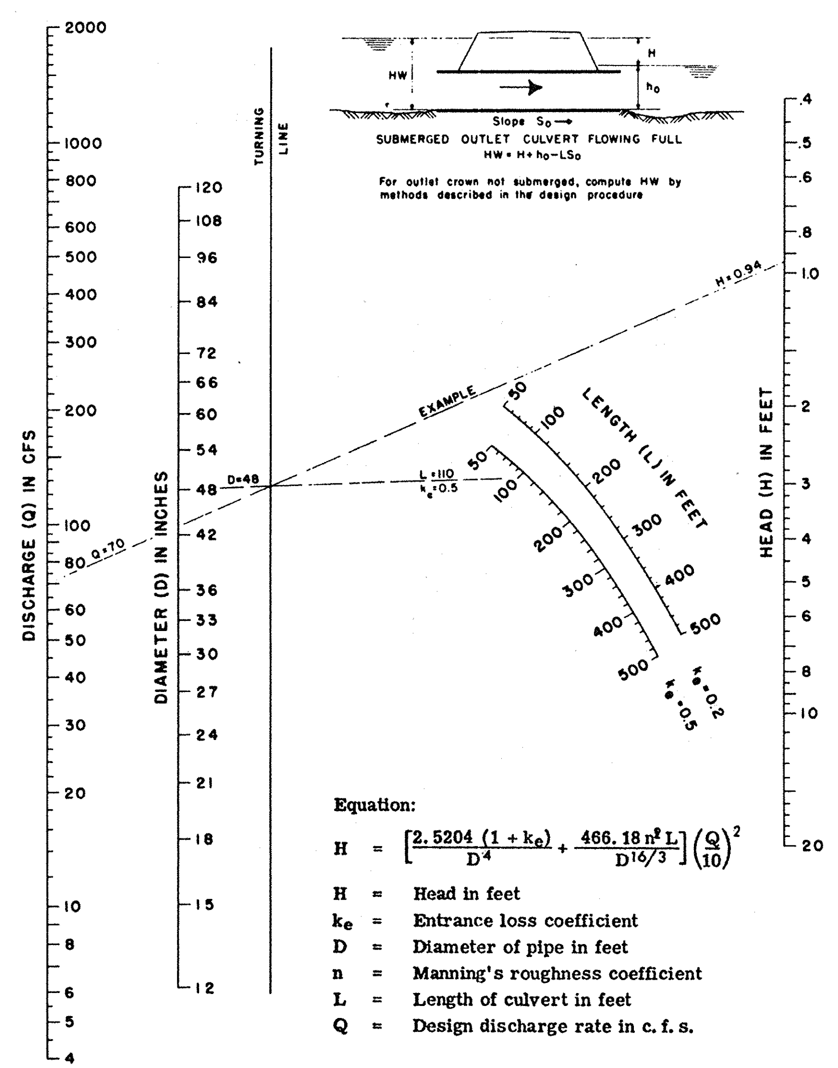
CRITICAL DEPTH
CIRCULAR PIPE

Table 6-7

MANNING ROUGHNESS COEFFICIENTS, *n*

	Manning's *n* range
I. Closed conduits:	
A. Concrete pipe	0.011–0.013
B. Corrugated-metal pipe or pipe-arch:	
1. 2⅔ by ½-in. corrugation (riveted pipe):	
a. Plain or fully coated	0.024
b. Paved invert (range values are for 25 and 50 percent of circumference paved):	
(1) Flow full depth	0.021–0.018
(2) Flow 0.8 depth	0.021–0.016
(3) Flow 0.6 depth	0.019–0.013
2. 6 by 2-in. corrugation (field bolted)	0.03
C. Vitrified clay pipe	0.012–0.014
D. Cast-iron pipe, uncoated	0.013
E. Steel pipe	0.009–0.011
F. Brick	0.014–0.017
G. Monolithic concrete:	
1. Wood forms, rough	0.015–0.017
2. Wood forms, smooth	0.012–0.014
3. Steel forms	0.012–0.013
H. Cemented rubble masonry walls:	
1. Concrete floor and top	0.017–0.022
2. Natural floor	0.019–0.025
I. Laminated treated wood	0.015–0.017
J. Vitrified clay liner plates	0.015
II. Open channels, lined (straight alinement):	
A. Concrete, with surfaces as indicated:	
1. Formed, no finish	0.013–0.017
2. Trowel finish	0.012–0.014
3. Float finish	0.013–0.015
4. Float finish, some gravel on bottom	0.015–0.017
5. Gunite, good section	0.016–0.019
6. Gunite, wavy section	0.018–0.022
B. Concrete, bottom float finished, sides as indicated:	
1. Dressed stone in mortar	0.015–0.017
2. Random stone in mortar	0.017–0.020
3. Cement rubble masonry	0.020–0.025
4. Cement rubble masonry, plastered	0.016–0.020
5. Dry rubble (riprap)	0.020–0.030
C. Gravel bottom, sides as indicated:	
1. Formed concrete	0.017–0.020
2. Random stone in mortar	0.020–0.023
3. Dry rubble (riprap)	0.023–0.033
D. Brick	0.014–0.017
E. Asphalt:	
1. Smooth	0.013
2. Rough	0.016
F. Wood, planed, clean	0.011–0.013
G. Concrete-lined excavated rock:	
1. Good section	0.017–0.020
2. Irregular section	0.022–0.027
III. Open channels, excavated (straight alinement, natural lining):	
A. Earth, uniform section:	
1. Clean, recently completed	0.016–0.018
2. Clean, after weathering	0.018–0.020
3. With short grass, few weeds	0.022–0.027
4. In gravelly soil, uniform section, clean	0.022–0.025
B. Earth, fairly uniform section:	
1. No vegetation	0.022–0.025
2. Grass, some weeds	0.025–0.030
3. Dense weeds or aquatic plants in deep channels	0.030–0.035
4. Sides clean, gravel bottom	0.025–0.030
5. Sides clean, cobble bottom	0.030–0.040
C. Dragline excavated or dredged:	
1. No vegetation	0.028–0.033
2. Light brush on banks	0.035–0.050
D. Rock:	
1. Based on design section	0.035
2. Based on actual mean section:	
a. Smooth and uniform	0.035–0.040
b. Jagged and irregular	0.040–0.045
E. Channels not maintained, weeds and brush uncut:	
1. Dense weeds, high as flow depth	0.08–0.12
2. Clean bottom, brush on sides	0.05–0.08
3. Clean bottom, brush on sides, highest stage of flow	0.07–0.11
4. Dense brush, high stage	0.10–0.14
IV. Highway channels and swales with maintained vegetation (values shown are for velocities of 2 and 6 f.p.s.):	
A. Depth of flow up to 0.7 foot:	
1. Bermudagrass, Kentucky bluegrass, buffalograss:	
a. Mowed to 2 inches	0.07–0.045
b. Length 4–6 inches	0.09–0.05
2. Good stand, any grass:	
a. Length about 12 inches	0.18–0.09
b. Length about 24 inches	0.30–0.15
3. Fair stand, any grass:	
a. Length about 12 inches	0.14–0.08
b. Length about 24 inches	0.25–0.13
B. Depth of flow 0.7–1.5 feet:	
1. Bermudagrass, Kentucky bluegrass, buffalograss:	
a. Mowed to 2 inches	0.05–0.035
b. Length 4 to 6 inches	0.06–0.04
2. Good stand, any grass:	
a. Length about 12 inches	0.12–0.07
b. Length about 24 inches	0.20–0.10
3. Fair stand, any grass:	
a. Length about 12 inches	0.10–0.06
b. Length about 24 inches	0.17–0.09
V. Street and expressway gutters:	
A. Concrete gutter, troweled finish	0.012
B. Asphalt pavement:	
1. Smooth texture	0.013
2. Rough texture	0.016
C. Concrete gutter with asphalt pavement:	
1. Smooth	0.013
2. Rough	0.015
D. Concrete pavement:	
1. Float finish	0.014
2. Broom finish	0.016
E. For gutters with small slope, where sediment may accumulate, increase above values of *n* by	*0.002*
VI. Natural stream channels:	
A. Minor streams (surface width at flood stage less than 100 ft.):	
1. Fairly regular section:	
a. Some grass and weeds, little or no brush	0.030–0.035
b. Dense growth of weeds, depth of flow materially greater than weed height	0.035–0.05
c. Some weeds, light brush on banks	0.035–0.05
d. Some weeds, heavy brush on banks	0.05–0.07
e. Some weeds, dense willows on banks	0.06–0.08
f. For trees within channel, with branches submerged at high stage, increase all above values by	*0.01–0.02*
2. Irregular sections, with pools, slight channel meander; increase values given in 1a–e about	*0.01–0.02*
3. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage:	
a. Bottom of gravel, cobbles, and few boulders	0.04–0.05
b. Bottom of cobbles, with large boulders	0.05–0.07
B. Flood plains (adjacent to natural streams):	
1. Pasture, no brush:	
a. Short grass	0.030–0.035
b. High grass	0.035–0.05
2. Cultivated areas:	
a. No crop	0.03–0.04
b. Mature row crops	0.035–0.045
c. Mature field crops	0.04–0.05
3. Heavy weeds, scattered brush	0.05–0.07
4. Light brush and trees:	
a. Winter	0.05–0.06
b. Summer	0.06–0.08
5. Medium to dense brush:	
a. Winter	0.07–0.11
b. Summer	0.10–0.16
6. Dense willows, summer, not bent over by current	0.15–0.20
7. Cleared land with tree stumps, 100–150 per acre:	
a. No sprouts	0.04–0.05
b. With heavy growth of sprouts	0.06–0.08
8. Heavy stand of timber, a few down trees, little undergrowth:	
a. Flood depth below branches	0.10–0.12
b. Flood depth reaches branches	0.12–0.16
C. Major streams (surface width at flood stage more than 100 ft.): Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Values of *n* may be somewhat reduced. Follow recommendation in publication cited if possible. The value of *n* for larger streams of most regular section, with no boulders or brush, may be in the range of	0.028–0.033

CHART 6-10



Equation:

$$H = \left[\frac{2.5204\,(1 + k_e)}{D^4} + \frac{466.18\,n^2 L}{D^{16/3}}\right]\left(\frac{Q}{10}\right)^2$$

- H = Head in feet
- k_e = Entrance loss coefficient
- D = Diameter of pipe in feet
- n = Manning's roughness coefficient
- L = Length of culvert in feet
- Q = Design discharge rate in c. f. s.

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HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL
n = 0.012

Size Design of Box Culverts

As with pipe culverts, conditions of inlet and outlet control are significant in the design of box culverts. Procedures are described below.

Inlet Control--Box Culverts

References are Charts 6-11, 6-12 and 6-13. Chart 6-11 is used for regular box culverts. Charts 6-12 and 6-13 are used for box culverts with beveled inlet edges and provide a lower HW.

1. On Chart 6-11, select the proper HW/D scale based on the type of wingwall flare. Scale (1) is the turning line.

2. For the first trial size box culvert, divide the design discharge (c.f.s.) by 8 feet per second (the desirable velocity). This quotient is the approximate area of opening in square feet required for the box. The profile sheet will indicate the permissible height of box for the site. Divide the area of opening by the permissible standard height to get the box width. Assign only standard box heights and widths or spans.

3. Divide the design discharge (Q) by the standard box width (b) for the Q/b value for the scale of "Ratio of Discharge to Width (Q/b) in C.F.S. Per Foot" on Chart 6-11.

4. Align the height of the box on the (D) scale and the (Q/B) scale value; intersect the (HW/D) turning line and project horizontally to the appropriate scale. An HW/D of 1.2 for box culverts approaches the maximum allowable value. A larger box opening is required when the HW/D value exceeds 1.3.

Example: Selection of the proper size box culvert for a design discharge of 432 c.f.s. and 7 feet of fill at the culvert. Record data on the Culvert Design Form (Figure 6-5).

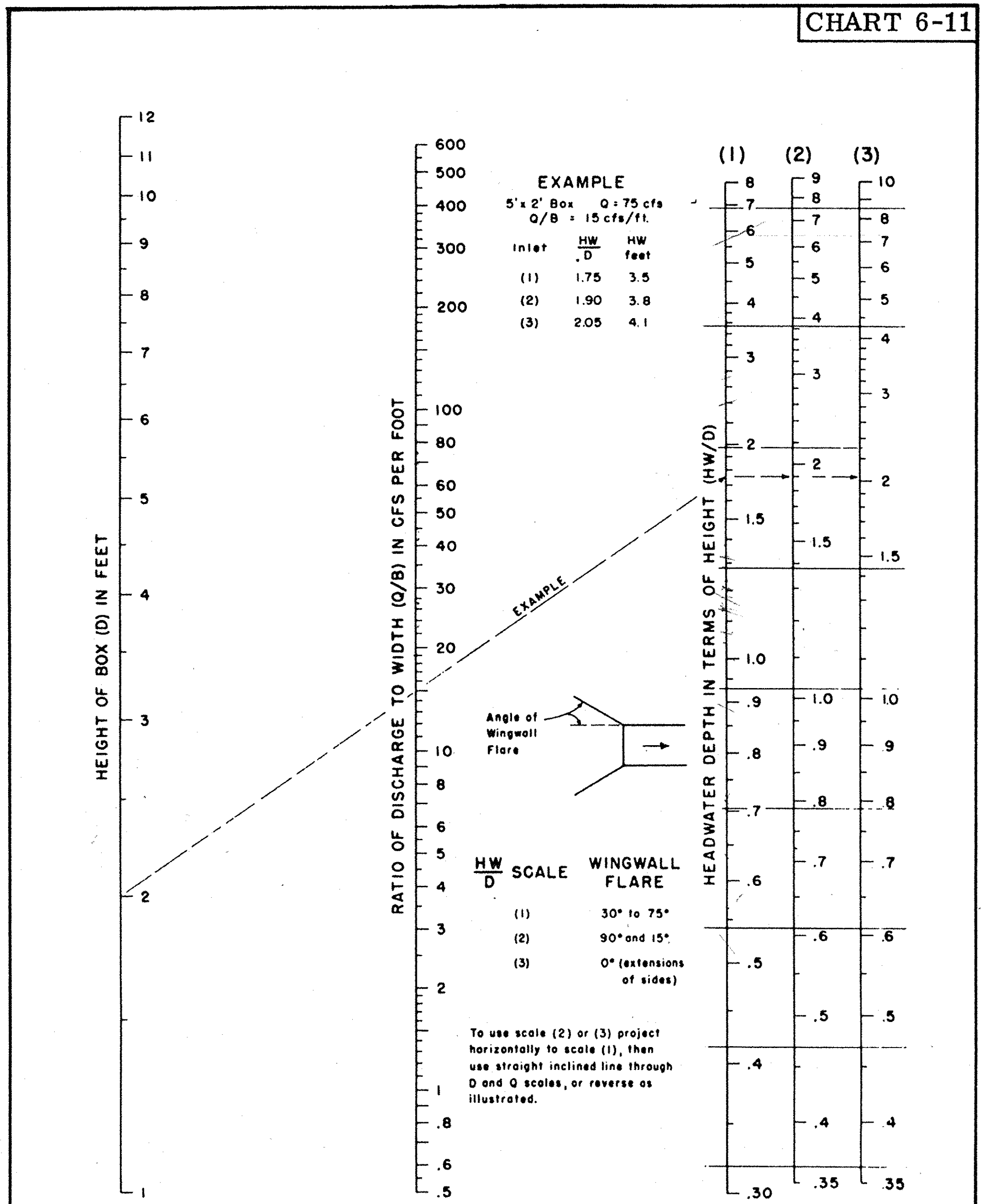
1. The wingwall flare will be either 90° or 15° ; therefore, you will select the (HW/D) scale (2) on Chart 6-11 (check Beveled Edge Charts 6-12 and 6-13).

2. Divide the design discharge (432 c.f.s.) by 8 f.p.s. to get 54.0 square feet, the approximate required area of box opening. The profile sheet shows only 7 feet of fill at the culvert, indicating that only a low-profile (height) box is permissible. Assume a box height of 4 feet. Divide the 54 square feet by 4-foot height, getting a 13.5-foot box width. A double cell 8' x 4' box is the first standard size which will meet the area requirement. Enter this trial size box culvert on the design form.

3. Divide the design discharge (Q) by the box width (b) to obtain the (Q/b) scale value. 432/16 = 27.0.

4. Align the height of box, 4 feet, on the (D) scale with 27.0 on the (Q/b) scale, and intersect the (HW/D) scale (1), the turning line, projecting horizontally to the (HW/D) scale (2) for the appropriate HW/D value of 1.22. This appears acceptable. Enter it on the design form.

   Multiply the HW/D value (1.22) by the height of box (4 feet) to obtain HW, or headwater on the culvert, of 4.88 feet. Enter the value on the design form. This headwater value added to the upstream flowline elevation of the box, gives the headwater elevation at the box entrance. In this example, the HW of 4.88 feet on the 7 feet of fill is near critical but probably allowable. The HW may be reduced with the beveled inlet edge charts.



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

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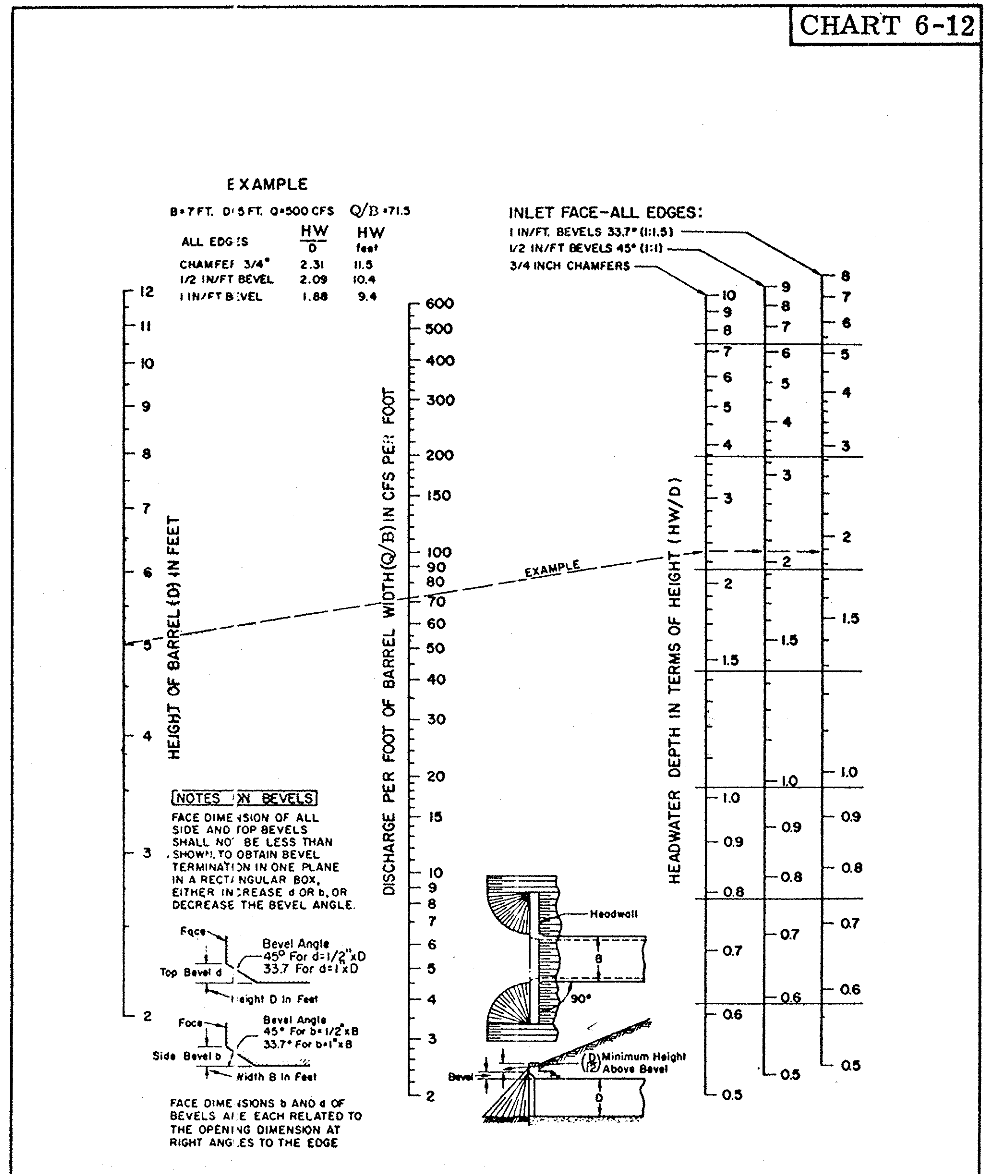


FEDERAL HIGHWAY ADMINISTRATION

HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
90° HEADWALL
CHAMFERED OR BEVELED INLET EDGES

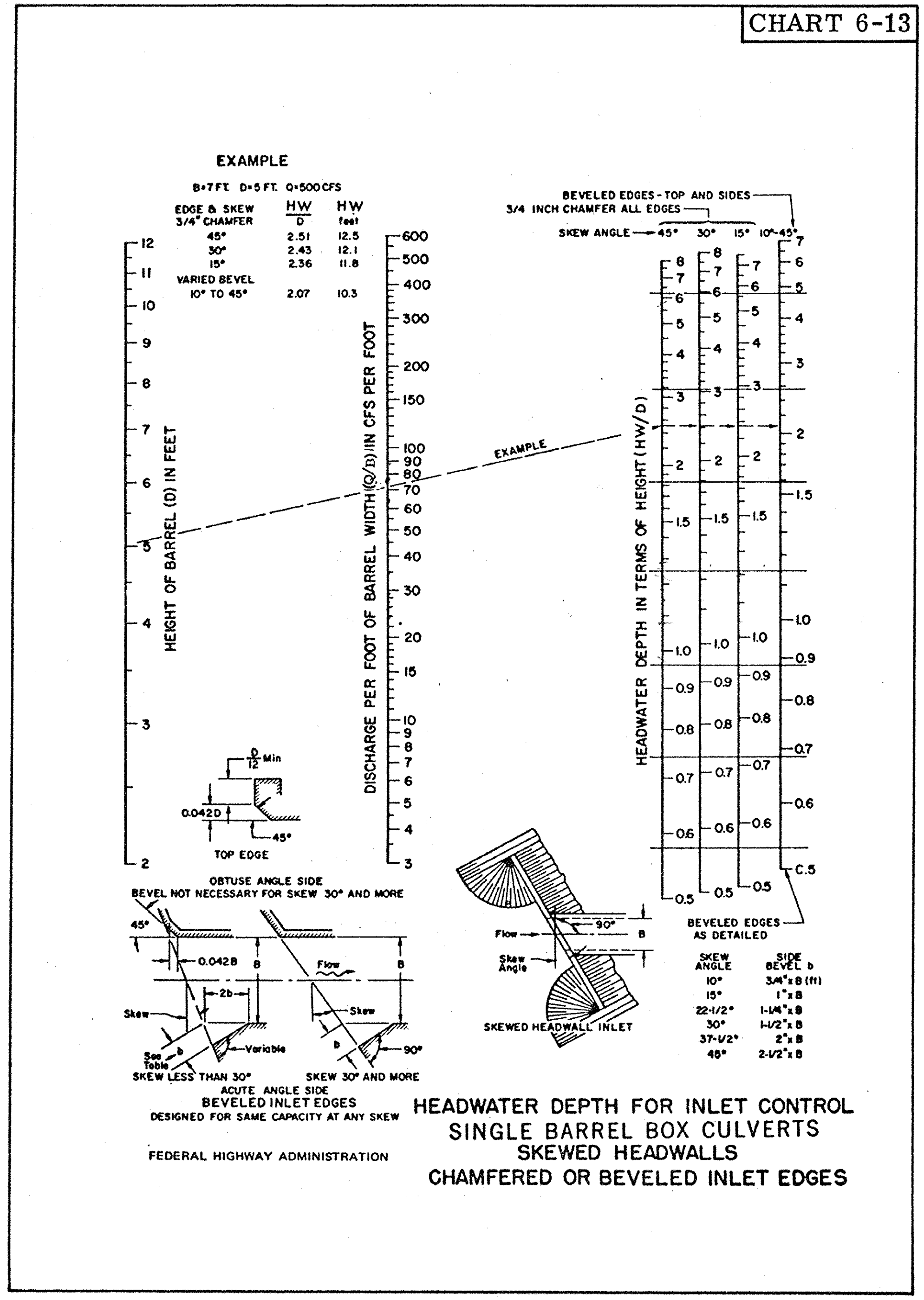


Figure 6-5

CULVERT DESIGN FORM
(Box Culvert Example)

DESIGNER V.R.B.

Hydrologic & Channel Information Box Culvert

Acres 211 — Q_{50} = 432
Length DA — Q_{10} =
El. Max.
El. Min.
Time
Intensity
Runoff C

USE FHWA 102' METHOD

Station: 511+45

El. 307.00
AHW = 304.50
El. 300.00
S_o 0.0012 ft/ft.
L 90'
TW 2.50'
El. 299.89
Allowable Outlet Velocity

DATE 2-27-75

Culvert Type	Q	Size	Inlet Cont. HW/D	Inlet Cont. HW	Outlet Control K_e	Outlet Control d_c	Outlet Control $\frac{d_c + D}{2}$	Outlet Control h_c	Outlet Control H	Outlet Control LS_o	Outlet Control HW	Controlling HW	Outlet Velocity Q50	Comments
Q/B = 432/16 = 27.0 CONCRETE BOX	432	DBL 8'x4'	1.22	4.88	0.5	2.80	3.40	3.40	1.22	0.11	4.51	4.88	8 fps.	LENGTH = 90' S_o = 0.0012% HW ELEV. = 304.88

PROJECT F-039-2(4) HINDS CO

Hydrologic and Channel Information Box Culvert

Area 211 Ac. — Hydrologic Area
Length DA
L/W Ratio
Shape Coefficient
Q
Land Factor LF 0.6 — Q_1
Rain Factor RF 1.5 — Q
Freq. Factor FF 1.2

Structure Data
Size and Length
US HDWL — FL
DS HDWL — FL
SKEW
US LGTH
DS LGTH
INLET TYPE
EL. TOP — FL
H — W — L

Outlet Control--Box Culverts

1. Refer to Table 6-6, Entrance Loss Coefficients (on page 6-23), to find applicable k_e value for Concrete Box Culvert. For wingwalls 10° to 20° to barrel, k_e = 0.5. Enter the value on the design form.

2. Refer to Chart 6-14, Critical Depth. Use the Q/B value to enter the horizontal scale; vertically intersect the heavy curve line, and at that point project horizontally to the d_c scale value. Record d_c on the design form.

3. Calculate $\frac{d_c + D}{2}$ (D is height of box), and enter the value on the design form.

4. Tailwater (TW) is the water height at the downstream end of the culvert. Backwaters downstream from the culvert may cause detrimental TW. Refer to FHWA Hydraulic Design Series No. 3, Design Charts for Open-Channel Flow, Chapter 3, "Rectangular, Trapezoidal, and Triangular Channels (Trapezoidal Charts 15 - 28)." With the existing channel bottom width, select the appropriate chart. Then, with the design discharge and Manning roughness coefficient (n) from Table 6-7 (Q x n value, if different from the chart) and the existing channel slope, determine the natural depth of flow, which can be the TW on the culvert. However, highwater from other downstream sources may cause a higher TW value. For the (h_o) value, use either the highest TW height or the $\frac{d_c + D}{2}$ value -- whichever is greater. Enter the value on the design form.

5. Refer to Chart 6-15, Head for Concrete Box Culverts Flowing Full, n = 0.012. Align area of box and length of box on the appropriate k_e scale to establish a turning point on the turning line. Through this turning point, align the design discharge on the (Q) scale and intersect the head (H) scale. This (H) value is the necessary differential Head to pass the design discharge. When this Head value exceeds 1.5 on box culverts less than 250 feet in length and on a flat slope, a larger box should be considered. Very long box culverts reasonably can have several feet of acceptable differential head.

6. Refer to FHWA Hydraulic Design Series No. 3, Design Charts for Open-Channel Flow, Chapter 3, "Rectangular Channels," to establish the box slope at the allowable velocity. Enter the discharge scale at the appropriate Q x n value, and vertically intersect the horizontal projection for 8 feet per second of the appropriate V x n value. Read the permissible minimum box slope (S_o). Record both velocity and slope on the design form.

7. Enter the product of the box length and box slope (LS_o) on the design form.

8. Evaluate the equation, HW = H_o + h - LS. The greater HW value will determine whether inlet control or outlet control governs. If the HW is higher than allowable, select a larger size box culvert for another trial.

Example: (continued from Inlet Control example)
(See Figure 6-5)

1. Table 6-6 shows the Entrance Loss Coefficient, k_e, of 0.5 Enter the value on the design form.

2. Enter Chart 6-14, Critical Depth, with Q/B = 432/16 = 27.0; vertically intersect the heavy curve line and horizontally project to the d_c scale value of 2.80'. Record it on the design form.

3. Calculate $\frac{d_c + D}{2} = \frac{2.80' + 4'}{2} = 3.40'$ and record it.

4. Let the (TW) value be insignificant and, therefore, use the $\frac{d_c + D}{2}$ value of 3.40' for the h_o value. Record it.

5. In Chart 6-15, assume a box length of 90 feet. Align area of box with length of box on the 0.5 k_e scale to establish the turning point on the turning line. Through this turning point align the design discharge (432 c.f.s.) on the (Q) scale and intersect the head (H) scale at 1.22. Record the differential head (H) necessary to pass the design discharge.

6. Refer to FHWA Hydraulic Design Series No. 3, Design Charts for Open-Channel Flow, Chapter 3, "Rectangular Channels," to establish box slope at allowable velocity. Enter the Q_n scale with Q x n = 432 x 0.012 = 5.18; vertically intersect the horizontal projection of the V_n value at 8 feet per second. V x n = 8 x 0.012 = 0.096. The intersection at 0.0012 feet per foot is the design slope (S_o). Record both the velocity and the slope.

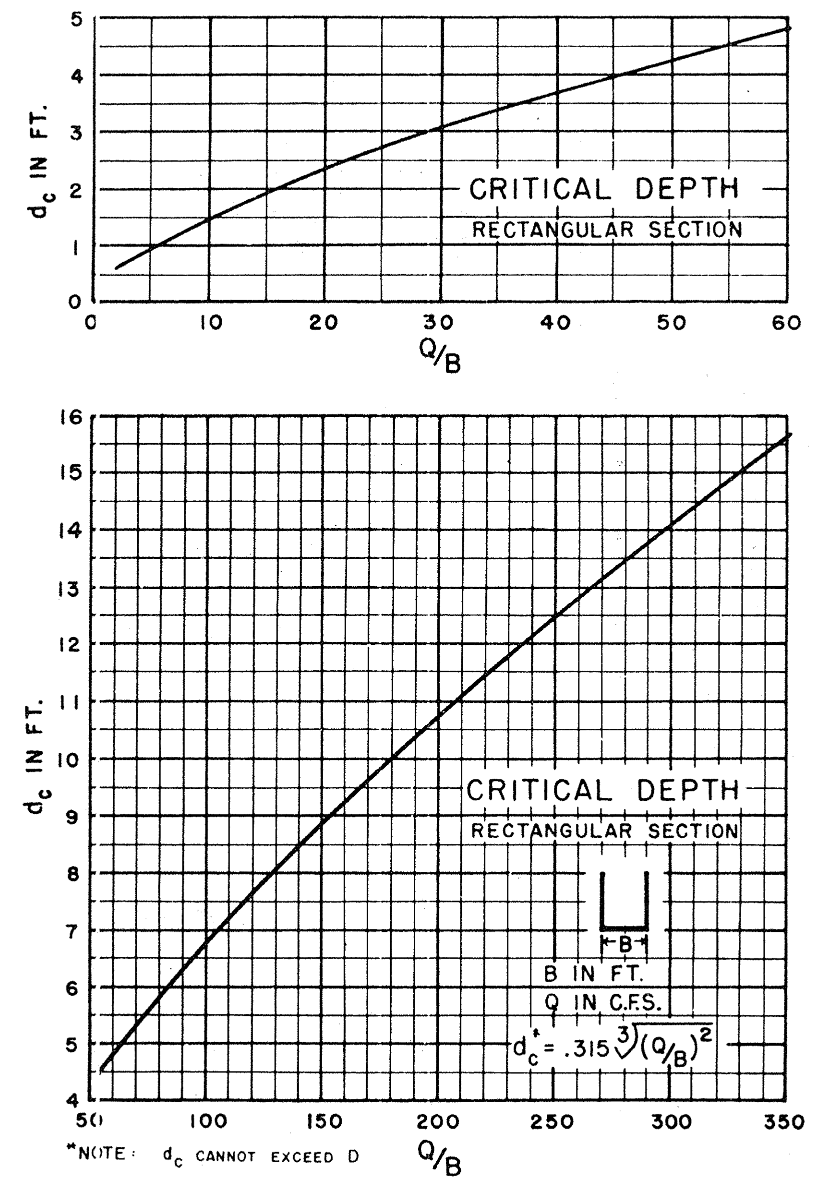
7. Record the product of the box length and box slope (LS_o), L x S_o = 90' x 0.0012 = 0.11, on the design form.

8. Evaluate the equation HW = H + h_o − LS_o. 1.22' + 3.40' - 0.11 = 4.51'. Record on design form.

Inlet control governs with the greater HW value. Although the HW is slightly above the allowable HW, this box will probably be acceptable.

Improved entrance structures should be considered -- especially when substantial reduction in cost may be realized -- by reducing the size of long culverts and by lowering a potentially detrimental headwater.

CHART 6-14



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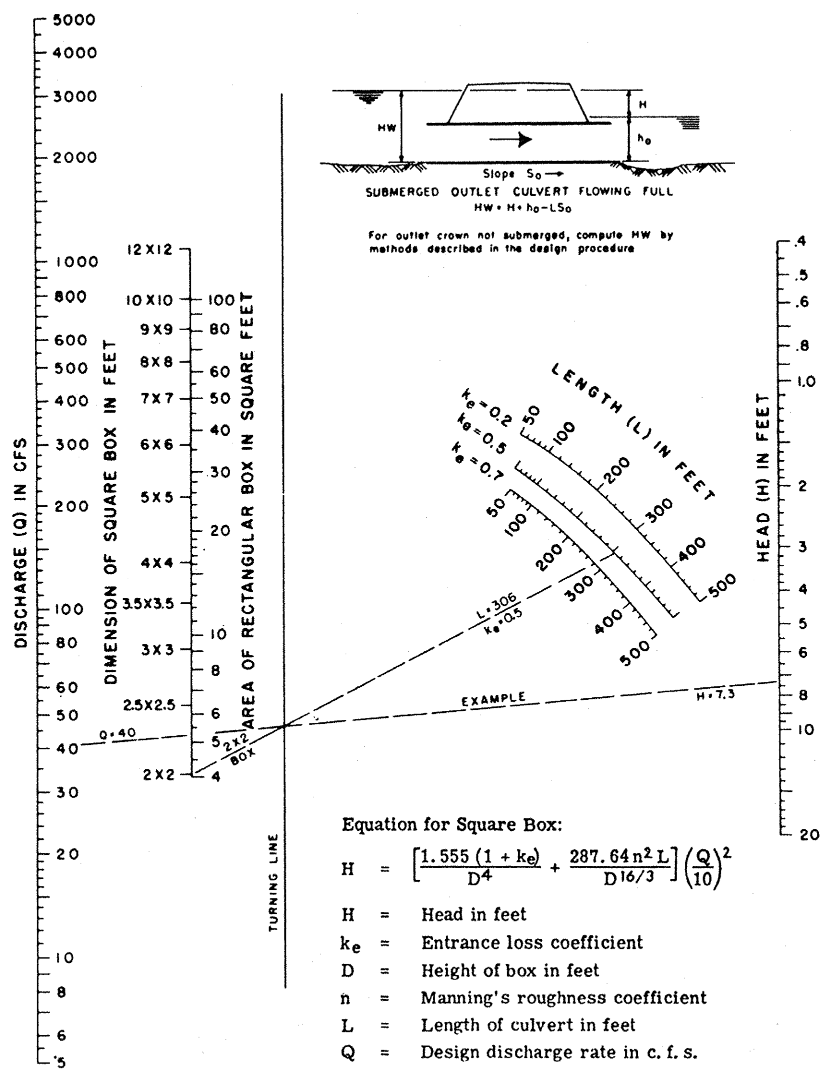
CRITICAL DEPTH
BOX CULVERT

CHART 6-15



Equation for Square Box:

$$H = \left[\frac{1.555\,(1 + k_e)}{D^4} + \frac{287.64\, n^2 L}{D^{16/3}}\right]\left(\frac{Q}{10}\right)^2$$

H = Head in feet
k_e = Entrance loss coefficient
D = Height of box in feet
n = Manning's roughness coefficient
L = Length of culvert in feet
Q = Design discharge rate in c. f. s.

HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN 1963

MEDIAN DRAINAGE

For medians between widely separated roadways, adequate drainage is provided by normal crossdrains under the roadway. With narrow medians, it is usually necessary to provide intermittent drop inlets, ideally located coincident with the crossdrains; however, separate median drain outlet culverts are installed as needed.

Design Criteria

Drainage design for depressed medians and interchange areas usually is based on the Rational Method because of the relatively small areas. Those portions of the roadway surface sloped toward the median should be included in the computed drainage area.

Median inlets must be placed at the low point of sag vertical curves -- the reach in either direction is critical for sag inlets and special care must be exercised. (See Table 6-8.)

Median Drain Inlet Spacing

For divided roadway sections separated 88 feet or less, centerline to centerline, median drains should be spaced to maintain no greater than 1 foot depth of flow for the 10-year rainfall. Although the median ditch may have a greater capacity on steeper grades, drain spacing distances should tend toward a more conservative distance of 500 to 600 feet nominal, and 1,000 to 1,200 feet maximum.

When zero percent grades are necessary, median ditch grades must be "warped" from back and ahead to the drain. The maximum recommended spacing is 300 feet in either direction. (See Table 6-8.)

Most facilities with widths in excess of 88 feet, centerline to centerline, will maintain individual inside ditch sections.

Table 6-8 shows inlet spacing criteria in sag vertical curves.

Table 6-8

MEDIAN DRAIN INLET SPACING
(Sag Vertical Curve -- 88 Feet, ℄ to ℄)

	Side Slopes			
	Both 6:1	6:1 and 4:1	Both 4:1	Both 3:1
Total Reach Back and Ahead	600'	500'	400'	300'
Pipe Size	18"	18"	18"	18"
Q c.f.s.	8.4	7.0	5.6	4.2

Note: The sag vertical median drains are more critically limited in reach. The 600 feet for the 6:1 side slopes are the total in two directions--300 feet back and 300 feet ahead--the reach capacity for the drain.

Standard Inlets

Several types of median inlets are available in the Roadway Design Drawings.

- Median Inlet for Pipe and Box Culverts
  (Design Drawing D-DI-1) -- Drop Inlet

  This design can be used when the crossdrain is at right angles to the highway centerline and the depth from the median flow line to the invert of crossdrain is less than 4 ft. 2 in. Within reason, smaller crossdrains can be skewed through this inlet.

- Median Inlet with Stack Pipe
  (Design Drawing D-DI-2) -- Drop Inlet

  This design should be used when the crossdrain is skewed and/or when the depth from the median flow line to the crossdrain invert is more than 4 ft. 2 in.

- Low Profile Median Inlet
  (Design Drawing D-LP-1) -- Drop Inlet with Grate on Foreslope

  This design should be used when outfall elevations are critical and abbreviated inlet heights are necessary.

  To minimize errant vehicles striking the inlet grate "head-on" (longer dimension of the grate) the grate should be placed on the foreslope adjacent to the paved roadway and not on the slope of median ditch plugs or crossovers.

- Modified Median Inlet -- Connecting Large Pipe Crossdrains
  (Design Drawing D-DI-3) -- Modified To Eliminate Unnecessarily Large Inlets and Junction Boxes

  This design is essentially the same as D-DI-1; however, an opening is cut into the large round or arch pipe crossdrain and the inlet sides are formed to connect the inlet to the pipe.

Design Drawing D-PA-1 details a paved apron for median inlets, and should be designated at all median inlet locations.

The most current safety measures must be incorporated in all median inlet design. Avoid protruding and/or sharp exposed edges. Strive for safe vehicle passage.

STORM SEWER DESIGN

Within the influence of urban areas, storm runoff waters collected in the roadway normally will be controlled with curb and gutter sections and will run off through storm sewer structures.

Municipal section drainage systems should limit the water ponding along the gutters and behind the curbs, to amounts that will not interfere with traffic or damage property. This is accomplished by placing either curb- or gutter-opening inlets or a combination of them, or drop inlets, at specific intervals and points.

Storm sewer discharges usually are determined by the Rational Method using a 10-year storm and 5-minute duration--except in sag verticals, where the 50-year storm is used. Curb opening inlets are more self-cleansing than grate inlets and should be preferred.

Determining Runoff Quantities

The following outline will serve as a guide for the development of a storm sewer system.

1. A set of working prints, 1" to 100' scale, is convenient to use in determining the initial overall drainage patterns of the storm sewer system.

2. With the aid of field information, quadrangle maps, and aerial photographs, outline on the working prints the drainage area limits that will be collected along the roadway, and determine the cumulative amounts of runoff discharge.

   Recommended runoff coefficients (C) for the Rational Method are:

   - 0.9 for paved roadway surfaces, paved shopping centers, etc.
   - 0.7 for roadway slopes and grassed commercial areas
   - 0.6 for grassed residential areas.

3. For long, uniform sections, it is helpful to compute a consistent specific discharge per unit of length. This may be done by measuring the drainage area for a typical section (say, 1,000 feet long), computing the total discharge for that section, and dividing by 10 to determine the average discharge per station.

   For example, to calculate discharge for one-half a roadway for a 1,000-foot distance, first add together the widths of half the median (1/2 x 20' = 10'), two lanes (2 x 12' = 24'), an auxiliary lane (12'), the curb and gutter section (2.75') and any typical behind-the-curb distance of over-the-curb flow (5'). Thus, 10' + 24' + 12' + 2.75' + 5' = 53.75 feet. Then multiply by the distance (53.75' x 1,000' = 53,750 square feet) and divide by square feet per acre (53,750 ÷ 43,560 = 1.23 acres).

   $Q_{Design} = C \times I \times A = 0.9 \times 7.6 \times 1.23$

   = 8.41 c.f.s. per 1,000 feet, or .841 c.f.s. per station (8.41 c.f.s. ÷ 10) of uniform roadway section.

4. Some sections of roadway will have significant runoff discharge flowing over the curb. On other sections the discharge will be intercepted behind the curb at specific locations near natural drains or low points. These discharges must be included in the tabulations for design purposes.

5. It is desirable to locate the more obvious inlet locations on the small-scale prints. Generally, regardless of the amount of discharge to be handled, curb inlets should be located upstream of street intersections, in sag vertical curves, and at the point on the outside curb of a curve prior to the beginning of superelevated sections. Intermediate curb inlets will be spaced according to the need.

Ponding Limits on Roadway

Water flow in the gutters should be confined to a width and depth that will neither obstruct nor cause hazard to traffic. The ponding width will have a corresponding depth, and the quantity of water carried will depend on the gutter gradient, gutter roughness coefficient, roadway cross slope, and inlet spacing.

The recommended limits of ponding are:

- Interstate and multilane highways with full shoulder width -- width of shoulder.
- Interstate and controlled access highways with less than full shoulder width -- one-half of adjacent lane.
- Other multilane highways -- width of adjacent lane.
- Two-lane, two-way highways -- one-third of adjacent lane.

Chart 6-16 is used for gutter capacity design. The chart is self-explanatory, with instructions and examples. The ponding width (Zy) is set from the criteria above--and the depth (y) is derived. With given restraints on ponding, determination can be made of the allowable accumulated runoff discharge that the gutter can accommodate; and this, in turn, will indicate the required spacing of inlets.

As an example, use the following values and procedures to determine curb and gutter capacity, "Discharge (Q) in CFS," from Chart 6-16.

1. Calculate Ratio Z/n:

   Z = reciprocal of roadway cross slope

   Given a roadway cross slope of 1.5625% or 0.015625 ft./ft.,

   $$Z = \frac{1}{0.015625} = 64$$

   n = coefficient of gutter roughness in Manning's formula = 0.013

   $$Z/n = \frac{64}{0.013} = 4923$$

2. Note the Grade of Channel (S) in ft./ft.

   S = 0.01 ft./ft.

3. Derive Depth at Curb (y) in feet

   Zy = ponding width = 14.75 ft.

   Z = 64 (from above)

   y = 14.75' ÷ 64 = 0.23 ft.

4. On Chart 6-16, align Ratio Z/n (4923) and Grade of Channel (S = 0.01 ft./ft.) to locate turning point on the Turning Line.

5. With that point, align Depth at Curb (y = 0.23 feet) to intersect Discharge (Q) in CFS. Read Q = 5.1 c.f.s., which is the capacity of this particular curb and gutter section.

Inlets

Generally, curb opening inlets are more reliable than gutter grate inlets; however, when gutter grate inlets are required, the grate bars should be parallel to the water flow to increase the capacity and minimize clogging. Safety measures must be considered with this grate bar arrangement to protect bicycles and other narrow wheel vehicles.

Procedures for determining inlet capacity and spacing of inlets are described below.

- Inlets on Grades

  The capacity per foot of inlet opening for curb inlets on grades can be determined in Chart 6-17, where the depth of flow (y) in the approach gutter is related to the gutter depression (a). If the y depth in the approach gutter is 0.23 feet and the gutter depression is 2 inches, the capacity per foot of inlet opening is 0.27 c.f.s. Thus, a 5-foot length of opening can intercept 1.35 c.f.s. (0.27 x 5), while a 10-foot opening can intercept 2.70 c.f.s. (0.27 x 10), and a 15-foot opening, 4.05 c.f.s. (0.27 x 15). It is not always more economical to intercept all the gutter flow at each curb inlet. Some portion (carryover) may be allowed to pass to succeeding inlets. But, care must be taken not to overload an eventual sag inlet, and to assure that the allowable ponding width is not exceeded.

- Inlets in Sags

  Refer to Chart 6-18 for the capacity of inlets at sag or low points. Generally, the water depth (D) is greater than that of inlets on grades. Intersect the heavy curve line with the D value and project horizontally left to get the capacity per foot of inlet in c.f.s. Suppose that D is 4.76 inches; then the capacity per foot of inlet is about 0.75 c.f.s. Inlets of 5 feet, 10 feet and 15 feet could intercept, respectively, 3.75 c.f.s, 7.50 c.f.s and 11.25 c.f.s. Sag inlets are designed for the 50-year storm--and not the 10-year storm, as in the general storm sewer system.

- Inlet Spacing

  Although the computed inlet spacing requirement may be of considerable distance--possibly 500 to 600 feet--actual spacing of inlets should be held to a maximum of 300 feet, and most often less. Inlets may be less than 100 feet apart --which is often the case at sag inlets and at locations with considerable over-the-curb flow. Inlets at sags may require supplemental inlets placed at short distances on either side. Liberal openings should be provided.

Storm Sewer Design Policies

In the design of storm sewers, certain policies should be maintained:

- Use a minimum size of 18-inch diameter concrete pipe for main lines and long laterals, and 15-inch diameter concrete pipe for short laterals.

- See Table 6-9 for minimum pipe slope required to maintain self-cleansing velocities. A progressive velocity should be achieved.
- See Chart 6-19 for pipe capacity on various gradients to determine the required size.
- At pipe or box size changes, strive to align the top inside surfaces (soffits) of the line, rather than the flow lines. This will ensure more effective performance.
- Use the 10-year storm design frequency for roadway sections on grade, and the 50-year for sags and zero grades.
- Use a 5-minute minimum duration time.

Runoff Discharge Tabulation

There is need for orderly tabulation of the runoff discharge computation to facilitate the storm sewer design. Worksheets with headings similar to those shown in Figure 6-6 provide convenient documentation.

Beginning in the uppermost reaches of the storm sewer system, tabulate by station the amount of discharge accumulating along the sewer run. Work from the upper reaches down the system gradient to the point of outfall release. Note that an outfall release may receive discharge from both back and ahead, and from both sides of the roadway.

Progressive time of concentration for the system will reduce the amount of discharge from that determined for each incremental contributing drainage area, and must be considered for proper storm sewer design.

Sizing Storm Sewer Lines

With the tabulated discharges, refer to Chart 6-19 to determine the pipe size necessary for the allowable gradients. Storm sewer line gradients should be generally similar to the roadway grade. The same size of pipe will run until the cumulative discharge attains the pipe capacity. When an abrupt reduction in gradient is encountered, an increase of more than one pipe size larger may be required. Never reduce the pipe size with an abrupt increase in gradient. Strive to align the inside top (soffit) of pipes when increasing the size. The resulting drop in the flow line will improve performance. Proceed in this manner down the system to, and including, the outfall pipe.

When, for various reasons, gradients must be minimized, the flow lines of concrete arch pipe consecutively increased in size may be aligned more effectively than round pipe. If possible, a slight drop is even preferred.

A hydraulic gradient is the line of elevations to which the water would rise in successive piezometer tubes along a storm sewer run. Differences in elevations for the water surfaces in the successive tubes represent the friction loss for that length of storm sewer. The friction slope is the slope of the line between the water surfaces.

The storm sewer run will not be under pressure if it is placed on a calculated friction slope corresponding to a certain quantity of water, cross-section, and roughness factor--and the surface of flow (hydraulic gradient) will be parallel to the top of the pipe. This is the desirable condition.

There may be reason to place the storm sewer run on a slope less than the friction slope. In that case, the hydraulic gradient would be steeper than the slope of the storm sewer run. Depending on the elevation of the hydraulic gradient at the downstream end of the run, it is possible to have the hydraulic gradient rise above the top of the pipe, creating pressure on the storm sewer system until the hydraulic gradient at some point upstream is once again at or below the top of the pipe.

Computation of the hydraulic grade line of a storm sewer run will not be necessary where (1) the slope and the pipe sizes are chosen so that the slope is equal to or greater than the friction slope, (2) the top surfaces of successive pipes are aligned at changes in size (rather than flow lines being aligned), and (3) the surface of the water at the point of discharge does not rise above the top of the outlet. The pipe will not operate under pressure in these cases, and the slope of the water surface under capacity discharge will approximately parallel the slope of the pipe invert. Small head losses at inlets, manholes, etc. may be disregarded if these structures are properly designed.

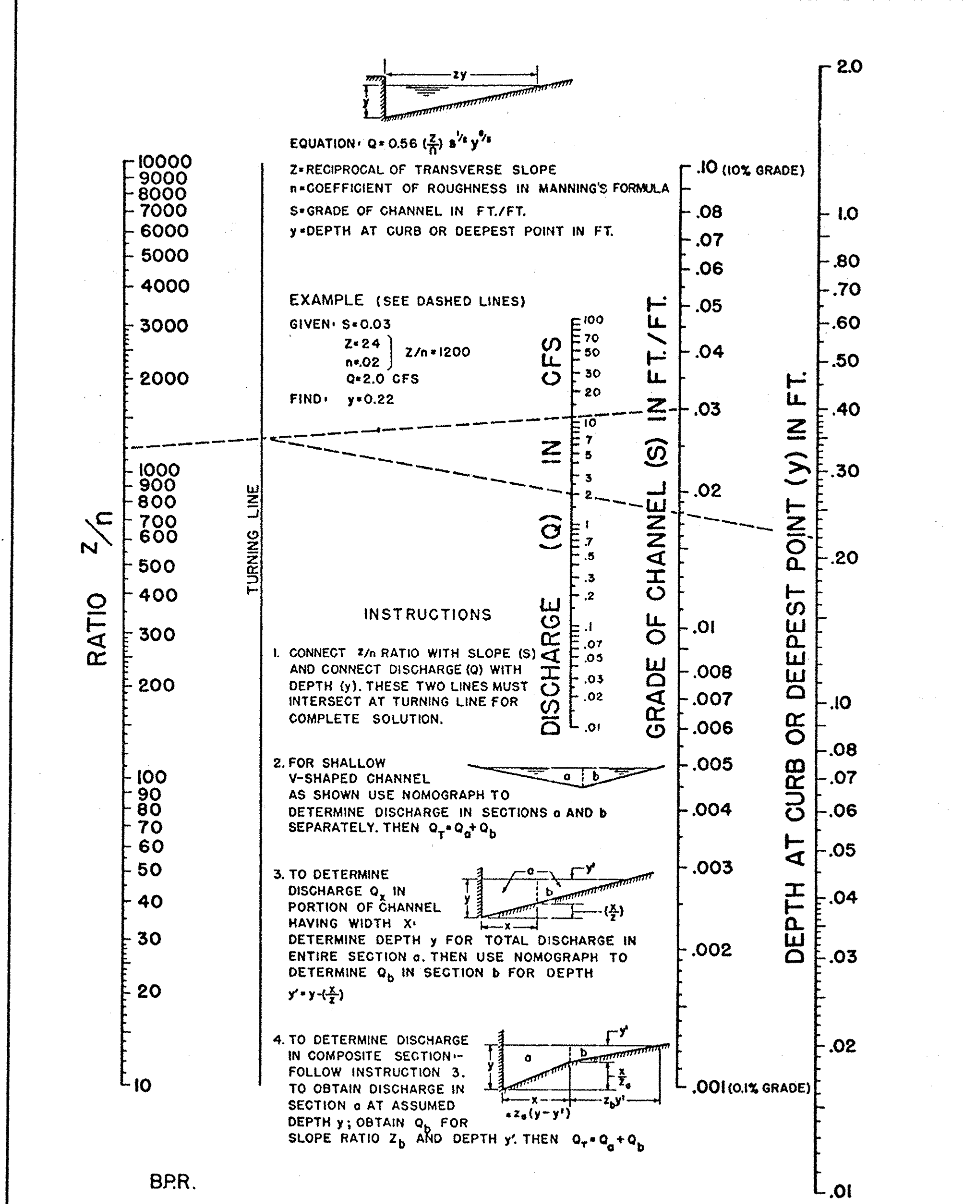
However, in cases where different sized pipe inverts are placed on the same grade, causing the smaller pipe to discharge against head, or when it is desired to check the storm sewer system against larger-than-design floods, it will be necessary to compute the hydraulic grade line of the entire storm system. Begin with the tailwater elevation at the storm sewer outfall and progress upward the length of the storm sewer. For every run, compute the friction loss and plot the elevation of the total head at each manhole and inlet.

If the hydraulic grade line does not rise above the top of any manhole or above an inlet entrance, the storm sewer system is satisfactory. If it rises above these points, blow-outs will occur through manholes and inlets. Pipe sizes or gradients can be increased as necessary to eliminate such blow-outs.

A hydraulic gradient must have an original base elevation above the outlet tailwater elevation. Any backwater effects of a significant tailwater elevation must be considered carefully.

Most pipe culvert design manuals describe hydraulic grade line computations.

CHART 6-16



NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

CHART 6-17

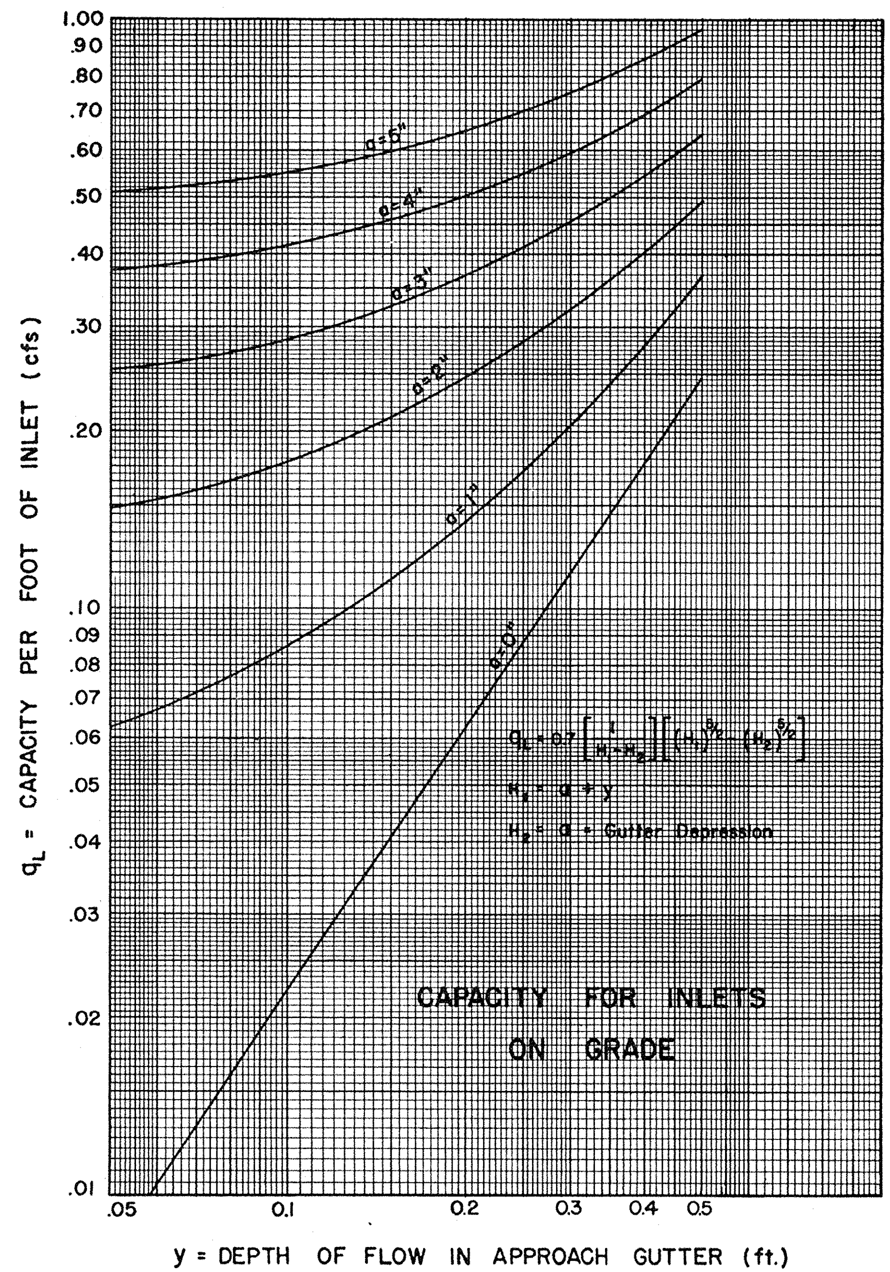
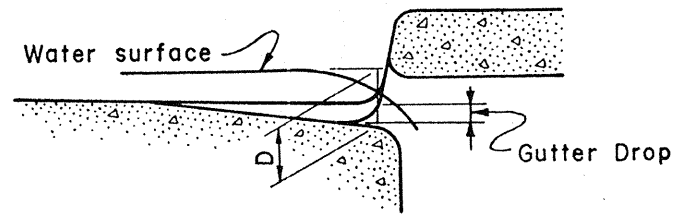
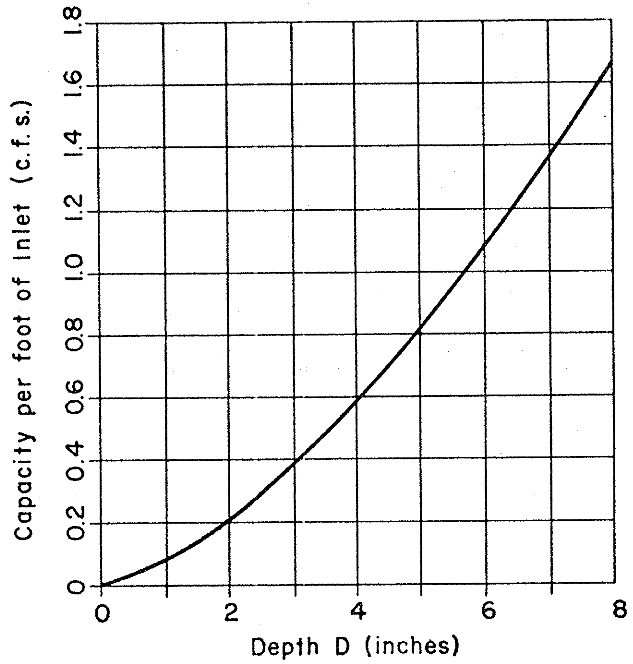


CHART 6-18



SECTION



CAPACITY
FOR
LOW POINT INLETS

Table 6-9

MINIMUM SLOPES REQUIRED FOR SEWERS TO MAINTAIN SELF-CLEANSING VELOCITY OF 2.0 FT. PER SEC. (SLOPE IN FT. PER FT.)

(n values for Manning's formula)

INSIDE PIPE	1/4 FULL			1/2 FULL			3/4 FULL			FULL		
	DISCH.	SLOPE		DISCH.	SLOPE		DISCH.	SLOPE		DISCH.	SLOPE	
DIA.	C.F.S.	n=0.013	n=0.024	C.F.S.	n=0.013	n=0.024	C.F.S.	n=0.013	n=0.024	C.F.S.	n=0.013	n=0.024
6"	.077	.010	.034	.20	.0049	.017	.32	.0039	.013	.40	.0049	.017
8"	.17	.0058	.020	.44	.0029	.0096	.71	.0023	.0076	.88	.0029	.0096
10"	.21	.0051	.018	.54	.0025	.0085	.88	.0020	.0066	1.08	.0025	.0085
12"	.31	.0040	.014	.79	.0020	.0067	1.26	.0016	.0052	1.58	.0020	.0067
15"	.48	.0030	.010	1.22	.0015	.0050	1.98	.0012	.0039	2.44	.0015	.0050
18"	.69	.0024	.0089	1.77	.0012	.0039	2.85	.0009	.0030	3.54	.0012	.0039
21"	.94	.0019	.0064	2.40	.0010	.0032	3.88	.0008	.0025	4.80	.0010	.0032
24"	1.23	.0016	.0054	3.15	.0008	.0027	5.04	.0006	.0021	6.30	.0008	.0027
30"	1.92	.0012	.0040	4.91	.0006	.0020	7.90	.0005	.0016	9.82	.0006	.0020
36"	2.76	.0010	.0032	7.08	.0005	.0016	11.4	.0004	.0012	14.2	.0005	.0016
42"	3.76	.0008	.0026	9.60	.0004	.0013	15.5	.0003	.0010	19.2	.0004	.0013
48"	4.91	.0007	.0022	12.6	.0004	.0011	20.3	.0003	.0008	25.2	.0004	.0011
54"	6.20	.0006	.0018	15.9	.0003	.0009	25.6	.0002	.0007	31.8	.0003	.0009
60"	7.68	.0005	.0016	19.6	.0003	.0008	31.6	.0002	.0006	39.2	.0003	.0008
72'	11.2	.0004	.0013	28.3	.0003	.0007	45.5	.0002	.0005	56.6	.0003	.0007
84"	15.2	.0003	.0010	38.5	.0002	.0006	62.0	.0002	.0004	77.0	.0002	.0006
96"	19.8	.0003	.0009	50.2	.0002	.0005	81.0	.0001	.0004	100	.0002	.0005
108"	25.1	.0003	.0008	63.5	.0002	.0004	102	.0001	.0003	127	.0002	.0004
120"	30.7	.0002	.0007	78.6	.0001	.0004	126	.0001	.0003	157	.0001	.0004

CONCRETE PIPE NEWS

CHART 6-19

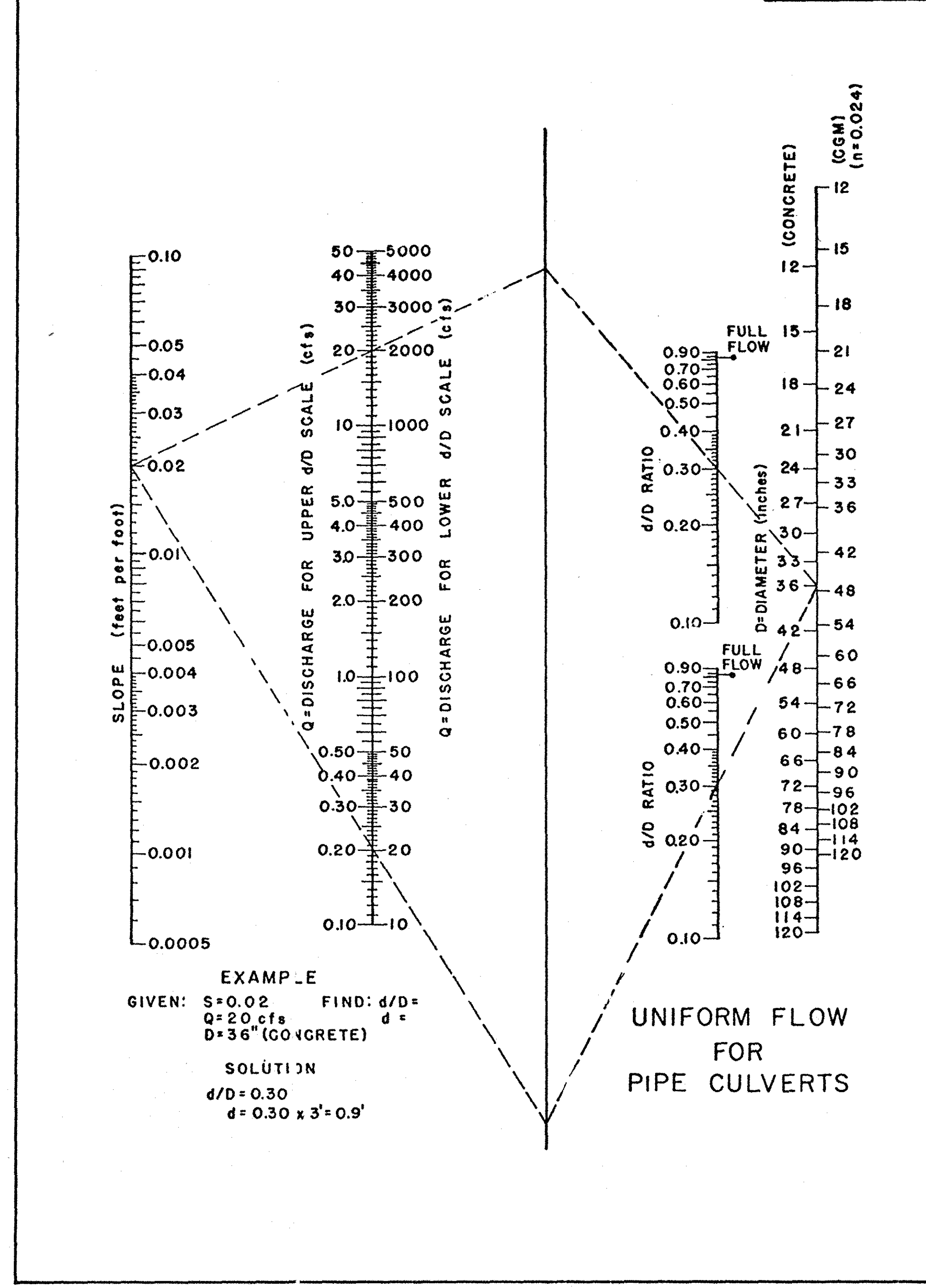


Figure 6-6

EXAMPLE STORM SEWER COMPUTATION FORMS

STORM SEWER INLET COMPUTATIONS

Inlet		D.A.	Q_a	Carry-over	Total Q_a	z	z/n	s	y	Ponded Width y x z	a	q_L	$L_a = \frac{Q_a}{q_L}$	L	L/L_a	a/y	Q/Q_a	$Q = Q_a \times Q/Q_a$	Carry-over	Remarks
No.	Station	No.	cfs	cfs	cfs			ft./ft.	ft.	ft.	ft.	cfs	ft.	ft.				cfs	cfs	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

STORM SEWER DISCHARGE COMPUTATIONS

From	To	Drainage Area No.	Total D.A. Ac.	Total C.A.	Length ft.	Time of Concentration — Minutes			I	Q	Design				Remarks
						Along Sewer Line	Inlet Time	Used in Design	In./Hr.	cfs	Dia. In.	Slope %	Cap. cfs	Vel. ft./sec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	

Subsurface Drainage--Storm Sewer

Generally the top one-third of the storm sewer pipe joints are not sealed in order to permit subsurface drainage to enter joints within the limits of the storm sewer system. A detail similar to Figure 6-8 should be included with the typical section sheets, indicating the trench and pipe arrangement, the porous material surrounding the pipe, and the portion of the pipe joints to remain unsealed.

Perforated pipe may extend to those reaches which are beyond the storm sewer lines, and the connection of the subdrain pipe to the junction should be well above the flowline of the junction box. Otherwise, when a head accumulates in the junction box, the subdrain pipe will empty underneath the junction box. Perforated pipe should not be subject to a pressure head.

Junction Boxes and Manholes

Junction boxes often will be necessary to connect behind-the-curb interception points with the main line at locations not coincident with curb inlets. These connections may require flow-line adjustments in the main line.

Manholes generally are not required--because of the common practice of using a curb inlet with a manhole cover for servicing purposes. However, if the need arises, as at an abrupt change of direction or when encountering utility lines, a manhole may be specified.

SUBSURFACE DRAINAGE

The purpose of subsurface drainage is to remove detrimental ground water in order to assure a stable roadbed and side slopes. Most often, those points or areas which require specific subsurface drainage will be determined during the process of field investigations. However, there are times when water-bearing formations are not revealed until construction has begun. "Bleeding" backslopes and apparent spring disruptions are two of the more obvious indications of this excessive groundwater.

Known spring and well points should be identified on the plans and a detail of a spring filter similar to Figure 6-7 should be included when necessary.

Perforated pipe underdrains, with perforations downward, will be installed to intercept most subsurface drainage waters. These pipes, available in sizes of 6-inch, 8-inch and larger diameters, may form a network of interceptors and be routed to a central point of collection and outfall. Ordinarily, a selected permeable backfill material will surround the underdrain pipe.

Subsurface drainage is of primary importance in curb and gutter sections of the roadway. Normally the top one-third of the storm sewer pipe joints will remain unsealed (but screened) to receive subsurface drainage. Along the limits of curb and gutter section where storm sewer pipe is not required, perforated underdrain pipe will be installed so as to empty into the junction box connecting the storm sewer pipe--at an elevation well above the flow line and as high as practicable above the storm sewer pipe. This will eliminate the possibility of perforated pipe emptying against a head developed in the junction box and forcing the water out the perforations and under the junction box.

Figure 6-8 shows two typical underdrain installations--one for a normal underdrain, and the other for a situation where a storm drain is used as underdrain.

Surface drainage should not be permitted to discharge into an underdrain. Underdrains should be permitted to empty into a roadway drainage system only when the outfall is not against a head.

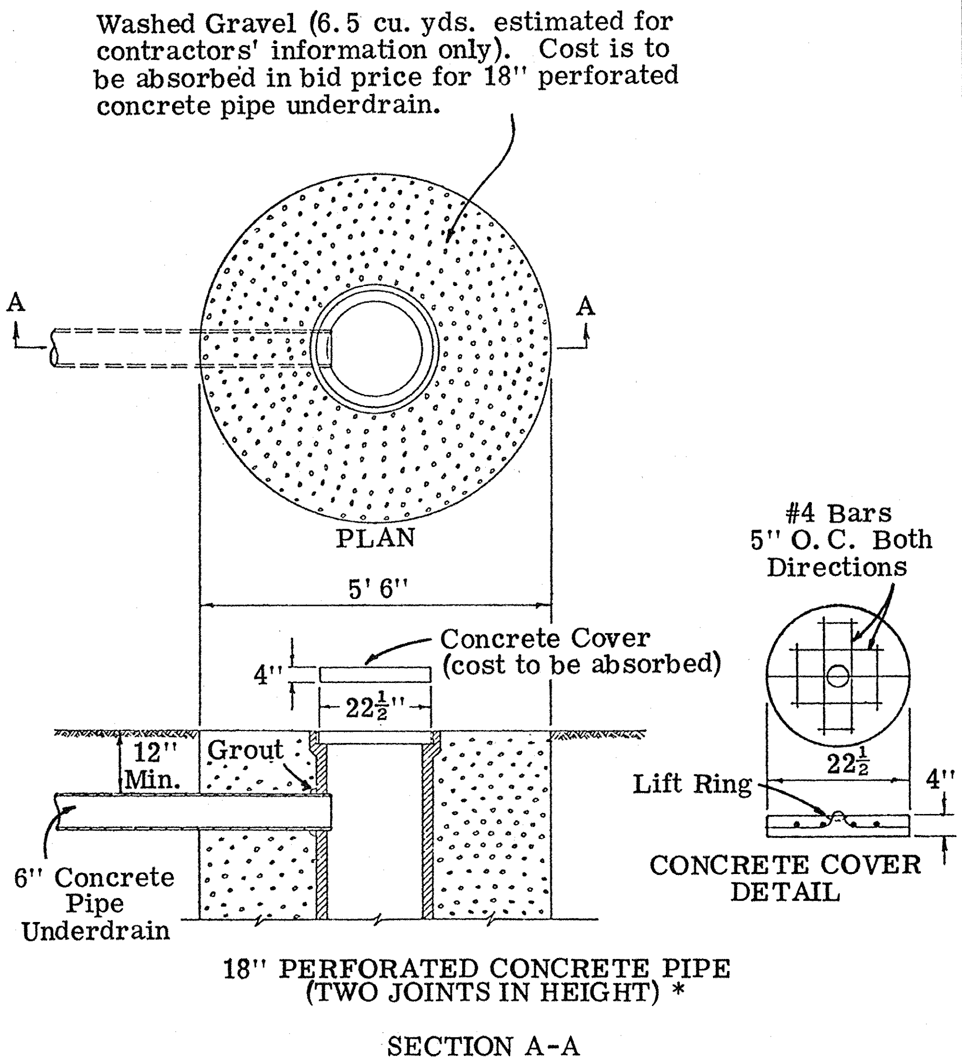
Underdrains of 6-inch diameter should be allowed to run no more than 500 feet. For distances over 500 feet, the minimum diameter should be 8 inches. A minimum of 0.20 percent pipe gradient is recommended.

Cleanouts should be installed on long runs of underdrain pipe. This may consist of a vertical small-diameter steel water pipe through which a pressure hose can be connected to flush out the system. The vertical pipe should be capped. Outlets for underdrains normally should be spaced no greater than 1,000 feet.

The soil test should be analyzed to determine the most appropriate alternative of using either metal or non-metal underdrain pipe for a specific location.

Figure 6-7

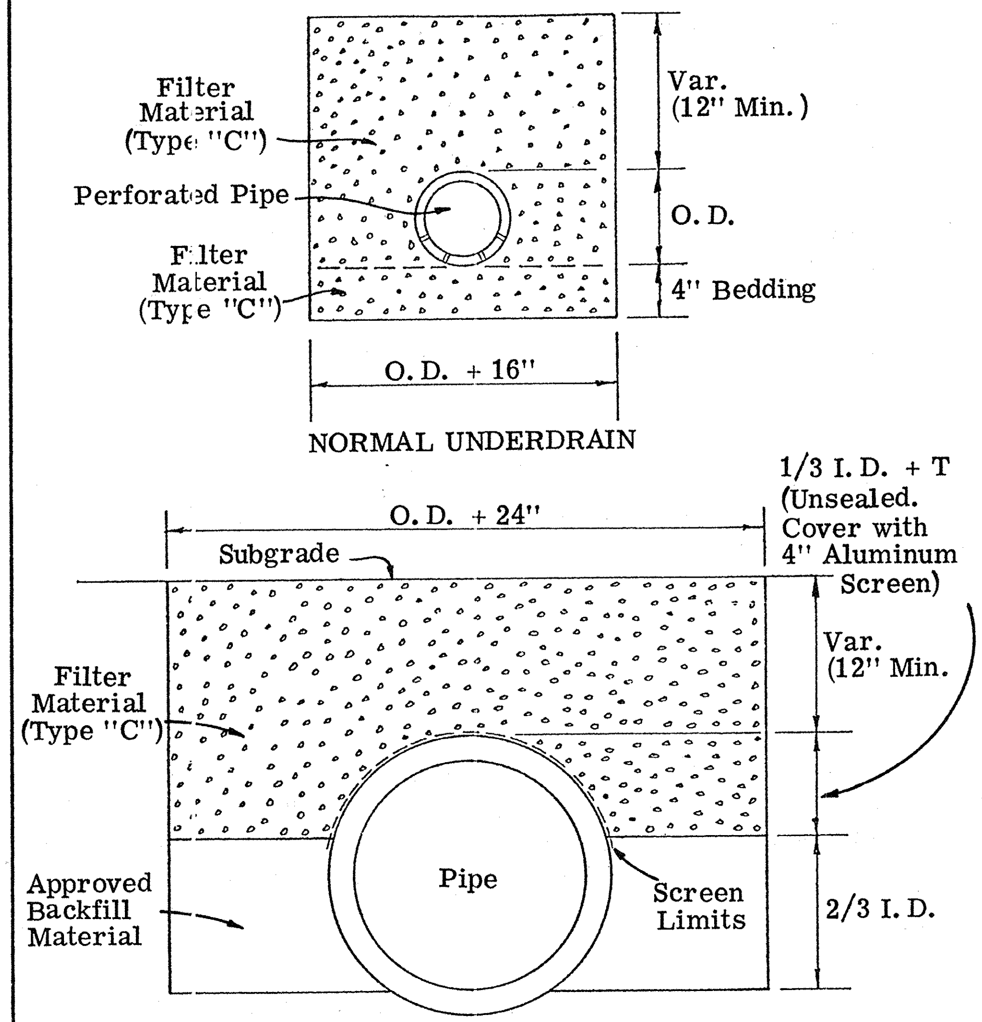
TYPICAL SPRING FILTER



* Perforations are to be nominal 1/4" diameter on 6" centers around pipe and along the length.

Figure 6-8

TYPICAL UNDERDRAIN INSTALLATIONS



STORM DRAIN USED AS UNDERDRAIN

OPEN CHANNELS

The main reasons for design and construction of open channels are:

- to permit better highway alignment;
- to economize by eliminating culverts or bridges where a stream recrosses the highway;
- to improve flow conditions in channels at bridges and culverts; and
- to protect the highway against flood damage.

Channel changes in the vicinity of bridges will be designed by the Bridge Division. Most other open channels will be designed by the Roadway Design Division.

Size and Shape

Trapezoidal channels are usually the most economical. For large flows, consideration should be given to channel bottom width of 12 feet and more. However, wide channels less than 1 foot deep are inefficient and are not recommended. When only moderate capacity is required, a V-shaped channel may be adequate.

Under average conditions, side slopes ranging from 2:1 to 3:1 are satisfactory. To facilitate maintenance, side slopes for ditches in interchange areas should be no steeper than 4:1.

Capacity Computations

For a particular location, the design discharge (Q) normally will be derived. The channel must be designed to safely accommodate this discharge--with due consideration of slopes and velocities.

The basic formula is:

$$Q = AV$$

where:
- Q = Discharge in cubic feet per second
- A = Cross-sectional area of water in square feet
- V = Mean velocity in feet per second.

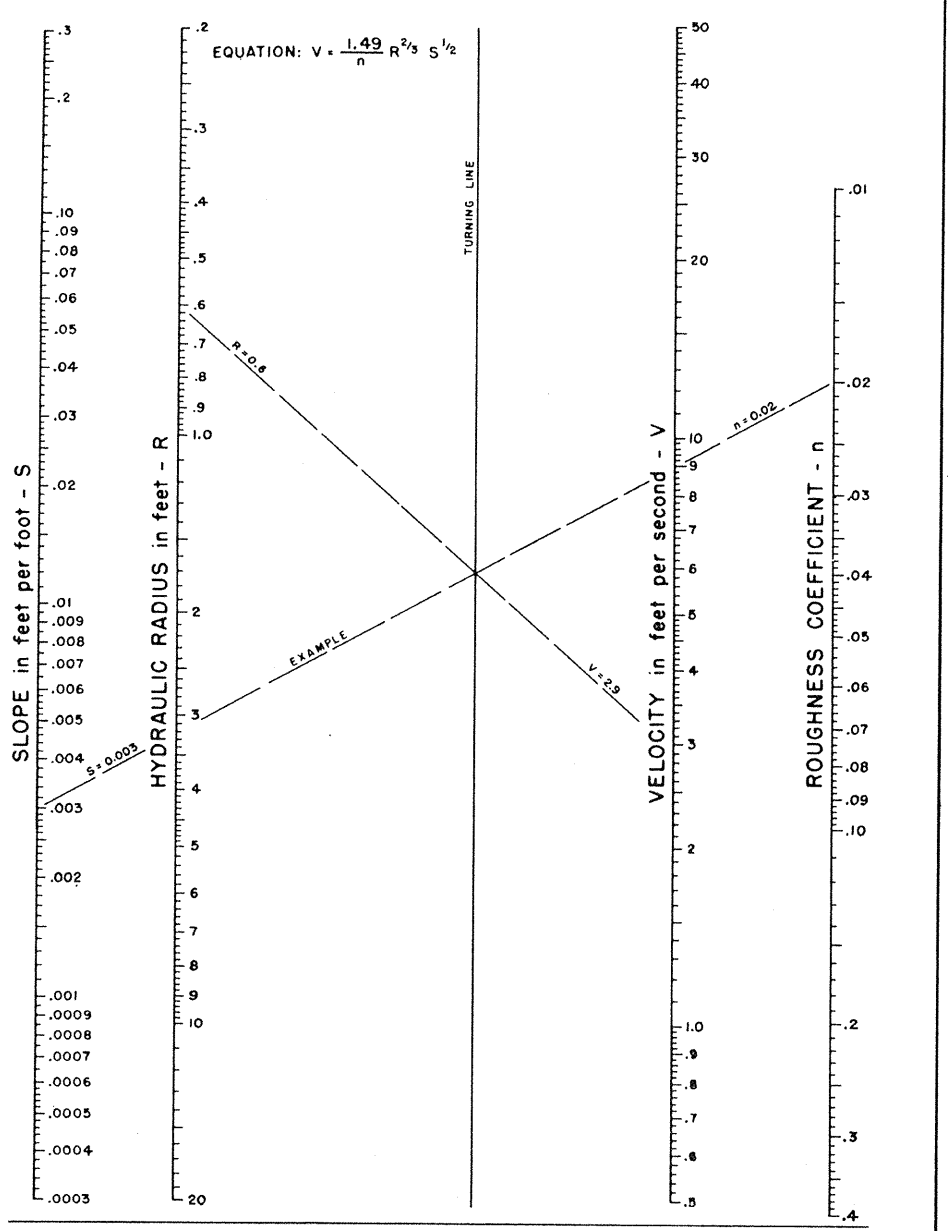
Assuming uniform flow, velocities can be computed by the Manning Equation, which is:

$$V = \frac{1.486}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

where:
- V = Mean velocity in feet per second
- n = Manning coefficient of channel roughness
- R = Hydraulic radius in feet
- R = A/WP, where A = cross-sectional area of water in square feet, and WP = wetted perimeter of channel in feet
- S = Channel slope in feet per foot.

By trial, various channel bottom widths and depths of flow are assigned and the respective A and WP are determined to derive the A x V value equal to the design discharge Q. Channel roughness coefficients (n) are shown on Table 6-7. Chart 6-20 is a nomograph for the solution of the Manning Equation.

CHART 6-20



NOMOGRAPH FOR SOLUTION OF MANNING EQUATION

Channel Alignment and Gradient

Changes in channel alignment should be as gradual as practicable. The radius of horizontal curvature of the centerline of a channel should be at least three times the bottom width of a trapezoidal channel or three times the width of a rectangular channel.

The gradient of a channel is often naturally established. Generally, channels width gradients less than 0.12 percent should be paved to prevent standing water. A minimum gradient of 0.25 percent is preferable for unlined channels.

Channel Lining

The need for channel lining will be determined by the velocity of flow. Table 6-10 indicates the maximum permissible velocities for unlined channels. Depending on the type of channel bed, linings may be necessary when permissible velocities are exceeded.

The types of lining to be considered are:

- excelsior blanket
- asphalt coated fiber glass roving
- solid sod
- riprap
- asphaltic concrete
- portland concrete.

The first two linings help protect the channel until vegetation can be established. The other linings are permanent protection.

Channel lining application is covered in Chapter 7.

Table 6-10
RECOMMENDED PERMISSIBLE VELOCITIES
FOR UNLINED CHANNELS

Type of Material in Excavation Section	Permissible Velocity (feet per second)	
	Intermittent Flow	Sustained Flow
Fine Sand (Noncolloidal)	2.5	2.5
Sandy Loam (Noncolloidal)	2.5	2.5
Silt Loam (Noncolloidal)	3.0	3.0
Fine Loam	3.5	3.5
Volcanic Ash	4.0	3.5
Fine Gravel	5.0	4.0
Stiff Clay (Colloidal)	6.0	4.5
Graded Material (Noncolloidal)		
Loam to Gravel	6.5	5.0
Silt to Gravel	7.0	5.5
Gravel	7.5	6.0
Coarse Gravel	8.0	6.5
Gravel to Cobbles (under 6 in.)	9.0	7.0
Gravel and Cobbles (over 8 in.)	10.0	8.0

PHYSICAL STANDARDS

This section describes the physical standards for pipe culverts and the criteria for their installation. The Bridge Division is responsible for the physical requirements of concrete box culverts.

Alternative Types of Pipe Culverts

Pipe culverts are manufactured in various sizes and shapes from several types of material. Types of pipe available for use in Mississippi include:

- Reinforced Concrete Pipe
- Reinforced Concrete Arch Pipe
- Corrugated Metal Pipe
- Corrugated Metal Arch Pipe
- Corrugated Aluminum Pipe
- Vitrified Clay Pipe.

Most installations will be reinforced concrete pipe. Under certain conditions (see Table 6-11), the other types will be permitted as alternatives.

Where alternates for cross drains exist, consider R.C.P. up to 36" diameter. When pipe is 36" diameter or larger, alternates of either R.C.P. or Bituminous Coated Paved Invert 3:1 Corrugated Metal Pipe are more comparable.

Lower headwater values can be achieved with arch pipe. Normally, arch pipe is used where the cover, outfall elevation or gradient is restrictive.

The corrugated metal and corrugated aluminum pipes should be specified in accordance with Table 6-11.

State Aid Division Policy on Type of Pipe Culvert

On state aid projects, the type of pipe culvert is selected based upon engineering judgment and is specified without alternates. The Division's and the Department's policies are identical whenever Federal funds are involved except that on some projects culverts are made a non-participating item and the choice of culvert type is made on the same basis as state aid projects.

Department Policy on Type of Pipe Culvert

The Department has adopted a policy defining conditions when pipe culverts must be of a specific material and when contractors may choose from alternative types of pipe. The criteria are set forth in Table 6-11.

Table 6-11

CRITERIA FOR TYPES OF PIPE CULVERTS

Type of Roadway Surface	Cross Drains	Median Drains	Special Systems Storm Sewers, Siphons, Etc.	Side Drains
High Type Pavement*	(1)	(1)	(1)	(3)
Other than High Type Pavement	(2)	(2)	(1)	(3)

*High Type Pavement: Portland concrete cement or 1" minimum thickness bituminous concrete.

(1) Reinforced Concrete Pipe

(2) Three alternates are required:

- Reinforced Concrete Pipe
- Bituminous Coated Paved Invert Corrugated Metal Pipe
- Vitrified Clay Pipe--only 30" diameter or less
- Bituminous Coated Paved Invert Corrugated Aluminum Pipe--only 30" diameter or larger.

(3) Same as (2) above, with exception: for permissible conditions, Bituminous Coating and/or Paved Inverts may be omitted from the two metal corrugated pipes.

NOTE: For special installation site conditions--such as unstable support, steep gradients, high embankment, acidity or alkalinity of soil, other corrosive elements, or high potential for erosion--the elimination of one or more of the alternate pipes may be warranted.

Strength Identification

The strength of reinforced concrete pipe is measured by class designations. Although other classes of concrete pipe are manufactured, the following three classes are most frequently designated:

Class III -- Standard Strength Reinforced Concrete Culvert Pipe
Class IV -- Extra Strength Reinforced Concrete Culvert Pipe
Class V -- Super Strength Reinforced Concrete Culvert Pipe.

Concrete arch pipe is identified as Class AII, Class AIII (Standard Strength) and Class AIV (Extra Strength). However, Class AIII is generally used and is understood, unless otherwise designated.

The strength of corrugated metal and corrugated aluminum pipe is measured in terms of the gage (thickness of metal). Corrugated metal pipe also comes with two different sizes of corrugation -- 2 2/3" x 1/2" and 3" x 1" --where the first number is the distance between crests and the second is the depth of corrugations. The larger corrugation produces greater strength than the smaller--with the same gage metal. At present, the 3" x 1" corrugation is used for 36-inch diameter pipe and larger.

Vitrified clay pipe comes in two classes--Standard and Extra Strength--but only Extra Strength is to be used for culvert installations.

Pipe Culvert Strength Requirements

Table 6-12 contains the information needed by designers to designate the strength requirements for individual culverts. The requirements are based principally on the size and shape of the culverts, the amount of cover over the pipe and, in some instances, the class of bedding and type of backfill.

Table 6-12

PIPE CULVERT HEIGHT-OF-COVER TABLES

CORRUGATED METAL PIPE -- 2 2/3" x 1/2" CORRUGATIONS					
Pipe Diameter (inches)	Maximum Cover -- Feet				
	*16 gage	14 gage	12 gage	10 gage	8 gage
15	56	60			
18	46	50			
24	30	33	40		
30		25	29		
36		22 (25,	23 (32)	26 (33)	
42			21 (42)	22 (44)	24 (48)
48			20 (40)	21 (42)	22 (43)
54			18 (36)	19 (38)	20 (40)
60				18 (36)	19 (38)
66				18 (35)	18 (36)
72					18 (34)
78					17 (27)
84					17 (21)

Minimum cover (top of pipe to subgrade) = 1 foot.

Values in parentheses represent maximum cover when pipe has been elongated 5 percent out-of-round vertically.

*Use 16 gage for side drains only where minimum cover above top of pipe is at least 2 feet.

CORRUGATED METAL PIPE -- 3" x 1" CORRUGATIONS					
Pipe Diameter (inches)	Maximum Cover -- Feet				
	16 gage	14 gage	12 gage	10 gage	8 gage
36	35 (40)	39 (50)	48 (73)	58 (88)	68 (98)
42	28 (34)	31 (42)	37 (63)	42 (76)	49 (84)
48	25 (30	26 (37)	30 (55)	34 (67)	38 (73)
54	22 (27)	23 (33)	26 (49)	29 (59)	32 (63)
60	21 (24)	22 (30)	23 (44)	26 (52)	27 (55)
66	20 (22)	20 (27)	22 (40)	23 (47)	25 (50)
72	19 (20)	20 (25)	21 (37)	22 (43)	23 (47)
78	18	19 (23)	20 (34)	21 (41)	22 (43)
84	17	19 (22)	19 (32)	20 (37)	21 (42)
90	16	18 (20)	18 (29)	19 (35)	20 (39)
96	15	18	18 (27)	19 (33)	19 (37)
102	14	17	18 (26)	18 (31)	19 (35)
108		17	17 (24)	18 (29)	18 (32)
114		16	17 (23)	18 (27)	18 (31)
120			17 (20)	17 (26)	18 (29)

Minimum cover: 36" - 96" pipe = 1 foot.
102" - 120" pipe = 2 feet.

Values in parentheses represent maximum cover when pipe has been elongated 5 percent out-of-round vertically.

CORRUGATED METAL PIPE ARCH 2 2/3" x 1/2" CORRUGATIONS			
Equivalent Round Pipe (inches)	Span - Rise (inches)	Gage	Maximum Cover (feet)
15	18 x 11	*14	13
18	22 x 13	*14	12
24	29 x 18	*14	10
30	36 x 22	14	10
36	43 x 27	14	8
42	50 x 31	12	8
48	58 x 36	12	8
54	65 x 40	12	8
60	72 x 44	10	8
66	79 x 49	8	8
72	85 x 54	8	8

Minimum cover (top of pipe to subgrade) = 1 foot.

*No. 16 gage may be used for side drains where minimum cover is at least 2 feet.

CORRUGATED METAL PIPE ARCH 3" x 1" CORRUGATIONS			
Equivalent Round Pipe (inches)	Span - Rise (inches)	Gage	Maximum Cover (feet)
36	43 x 27	16	12
42	50 x 31	16	12
48	58 x 36	16	12
54	65 x 40	16	12
60	72 x 44	16	12
66	73 x 55	16	17
72	81 x 59	16	15
78	87 x 63	16	14
84	95 x 67	16	12
90	103 x 71	16	12
96	112 x 75	14	11
102	117 x 79	14	10
108	128 x 83	12	9

Minimum cover:
43" x 27" -- 72" x 44" = 1 foot.
73" x 55" -- 95" x 67" = 1.5 feet.
103" x 71" -- 128" x 83" = 2 feet.

GAGE — THICKNESS	
Gage	Thickness (inches)
16	0.064
14	0.079
12	0.109
10	0.138
8	0.168

REINFORCED CONCRETE ROUND AND *ARCH PIPE				
Bedding	Backfill	Maximum Cover -- Feet		
		Class III Pipe	Class IV Pipe	Class V Pipe
Class C	Normal	17	24	30
Class B	Normal		29	36
Class B	**Imperfect Trench		90	115

Minimum cover (top of pipe to subgrade) = 1 foot.
Class of pipe and bedding are to be consistent throughout the pipe length.
Imperfect trench installation requires Class B bedding.
Class IV pipe is to be used in all imperfect trench installations where maximum cover permits.
Imperfect trench should be terminated when cover values permit normal backfill (see Figure 6-8).

*Concrete Arch Pipe, Class AIII, is used principally.
Class AIV is available, and has the same cover limits as round pipe.

**Round pipe only.

*VITRIFIED CLAY PIPE				
Bedding	Maximum Cover -- Feet			
	15" Pipe	18" Pipe	24" Pipe	30" Pipe
Class C	11	11	13	13
Class B	13	13	14	14

*Only Extra Strength clay pipe is permissible.
Class of bedding is to be consistent throughout pipe length.

CORRUGATED ALUMINUM PIPE -- 2 2/3" x 1/2" CORRUGATIONS					
Pipe Diameter (inches)	Maximum Cover -- Feet				
	*16 gage	14 gage	12 gage	10 gage	8 gage
12	**37 (22)	37 (27)	65	67	70
18	25 (15)	25 (18)	43	45	47
24	18 (12)	18 (13)	32	34	35
30		15 (11)	26	27	28
36		12 (9)	22	22	23
42		22	36	36	37
48			33	34	36
54			29	31	32
60				27	28
66				25	26
72					24

Minimum cover (top of pipe to subgrade) = 1 foot.
Maximum cover values are for riveted or helical fabricated pipe.

*Use 16 gage only for side drains where minimum cover is at least 2 feet.

**Values in parentheses are for spot-welded pipe.

See Design Drawing D-P1-I for additional information.

Maximum cover value is based on the distance from the top of the culvert to the elevation of the finished road surface. Minimum cover is measured from the top of the culvert to the top of the subgrade, since this will be the effective cover during construction operations.

In addition to culvert size and length, the following data should be shown on the plans to identify strength requirements:

Reinforced Concrete Pipe Culverts

- Class III is understood, unless otherwise indicated. Show class of pipe IV or V.

Concrete Arch Pipe Culverts

- Class AIII is understood--no special identification is required except for special conditions.

Corrugated Metal Pipe and Arch Pipe Culverts

- Show gage of metal (2 2/3" x 1/2" corrugations are assumed unless otherwise specified).

- Show gage of metal and size of corrugations if 3" x 1" corrugations are to be specified.

Corrugated Aluminum Pipe Culvert

- Show gage of metal.

Vitrified Clay Pipe

- Always show "Extra Strength."

Special Provision Against Deterioration

Under certain conditions there will be need for special treatment of corrugated metal and aluminum culverts to retard deterioration. The basic criteria for treatment are shown in the previous section on Department policy with regard to types of culverts. Other special considerations may be recommended with the field survey or as a result of soils testing. Designers will be advised of these conditions.

When special treatment is required, the description of the culvert shall be preceded by the phrase:

- Bituminous Coated, or
- Bituminous Coated Paved Invert.

Bedding and Backfill

The Standard Specifications provide for three types of culvert bedding--Class A, Class B and Class C.

Class C is the standard bedding and satisfies most installation conditions.

Class B is a special bedding which permits greater heights of cover. It is used only with high fills which exceed the limits for standard bedding.

Class A consists of a concrete cradle under the culvert and is used only for unique conditions.

Class C bedding is always assumed if there is no special note on the plans. If either Class A or Class B bedding is required, the type of bedding must be shown on the plans.

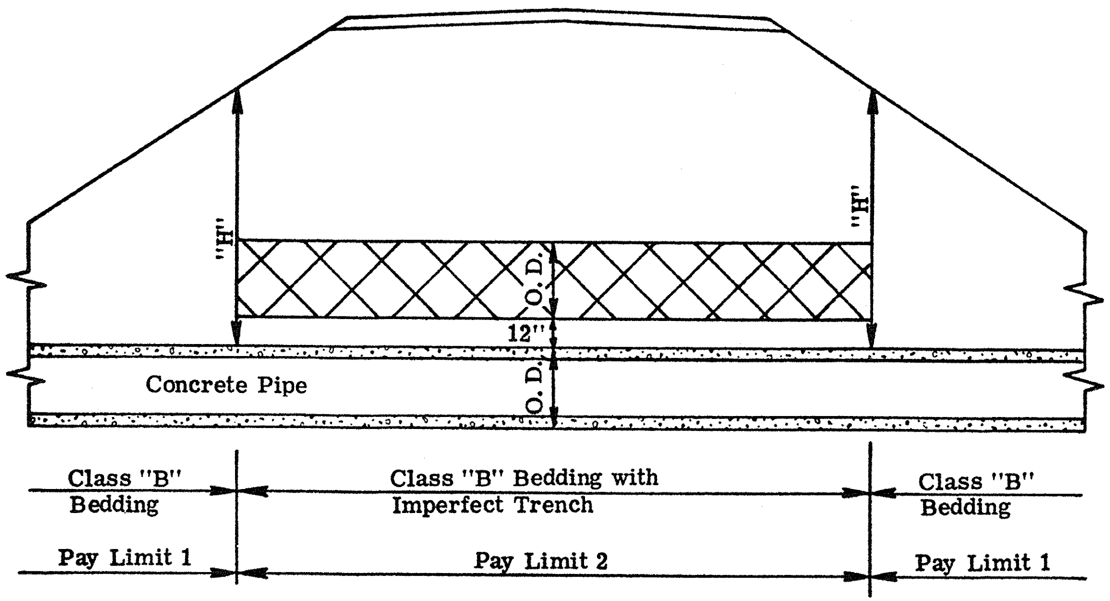
The standard backfilling procedure defined in the Specifications normally will be used--and no special notation is needed on the plans.

In the case of very high fills (as identified in the tables of maximum cover) it may be necessary to specify the Imperfect Trench Method of backfilling. This requirement must be shown on the plans. An imperfect trench installation detail is shown on Figure 6-9, including the different pay limits. The term "Imperfect Trench" will eventually be replaced by the term "Induced Trench."

Pay Limit 1 is normal installation as prescribed. Pay Limit 2 is imperfect trench installation.

Figure 6-9

TYPICAL IMPERFECT TRENCH INSTALLATION



<u>Pipe Culvert End Structures</u>

Four alternatives should be considered for the treatment of culvert ends at each installation. These are described below and criteria are shown to guide the selection of the appropriate end treatment.

1. <u>Concrete Headwalls</u>. Design details for standard cast-in-place concrete headwalls are shown in the Design drawings. Alternatives are included for various combinations of size of culvert, embankment slope, degree of skew, and number of pipes (single or multiple line installation).

   Concrete headwalls generally should be specified:

   - for multiple lines of pipe in deep channelized ditch sections.
   - for structures sufficiently removed from the travelway that headwalls are more economical than other types of end sections.
   - when right-of-way restrictions require special design abbreviated headwalls or straight headwalls parallel to the roadway. (Guardrails are generally required also.)

2. <u>Improved Entrance Pipe Sections</u>. Design details for standard prefabricated concrete improved entrance pipe sections are shown in the Design Drawings. These upstream (entrance) end pipe sections increase pipe efficiency and may permit decrease of the required pipe size. This pipe end section should be installed whenever practical, with due consideration to exceptions for headwall use. Recommendations are: align the culvert with the existing channel,

if practical, regardless of skew; and use the improved entrance section upstream and a flared end section downstream. Although special cases will arise, a maximum 45° skew angle should be maintained.

3. Flared End Sections. Design details for standard prefabricated concrete and metal flared end sections are shown in the Design Drawings. Flared end sections should be specified for most pipe installations, except in those instances listed under Headwall and Improved Entrance Section use. The 45@ maximum skew angle should be maintained.

For installations where the improved entrance section does not significantly enhance performance, a cost comparison between flared end sections and improved entrance sections will determine which should be used. In general, only small pipe for small flat drainage areas will be in this category.

4. No End Structure. In most cases, culverts under ramps and non-major turnout connections, no end structure is needed for culvert ends--except that the regular terminal section of culvert pipe should extend to the normal fill slope and natural ground intersection.

This detail is shown on Design Drawing M-R-1.

There can be instances where slope protection in the form of riprap or paving is necessary at the ends of culverts with no end structures. This condition must be considered in design.

Multiple Pipes

Where multiple pipes are to be installed and concrete headwalls are specified, the proper spacing between adjacent pipes is defined in the Design Drawing for headwalls.

When flared end sections are specified, the spacing between multiple pipes should be such that end sections will be in contact. Appropriate dimensions are shown in the Design Drawings for flared end sections.

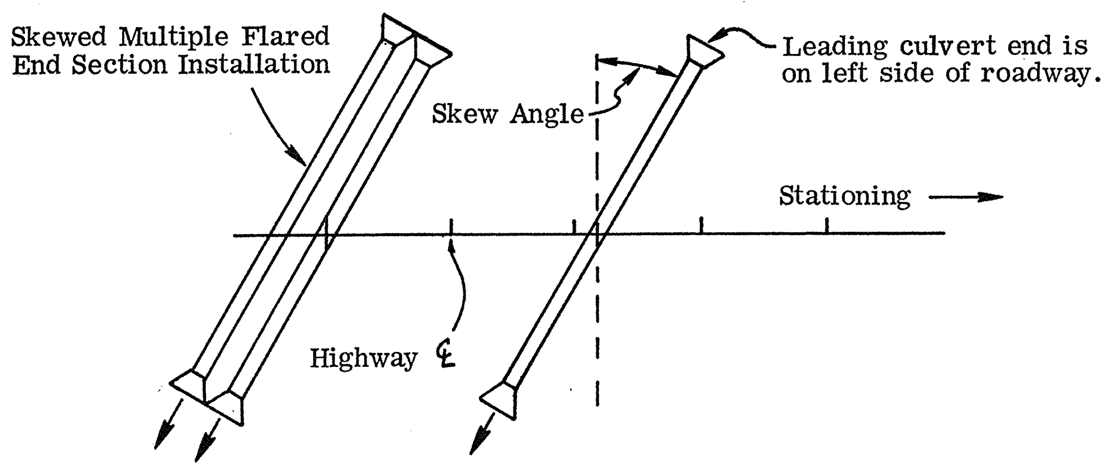
Multiple flared end sections on skewed pipes must be on a straight line alignment normal to the pipes, just as a non-skewed installation. (See the diagram on the next page.)

Skewed Installations

Wherever practical, pipe culvert installations should be designed to conform as closely as possible to natural drainage channels. A "standard skew" headwall usually can be installed satisfactorily, even though the degree of skew may be slightly different from the skew of the culvert. The amount of skew must be shown on the plans.

The degree of skew is measured as the angle between the pipe installation and a line perpendicular to the highway centerline--as shown in the diagram on the next page.

A culvert skew angle is described in terms of which end is forward--left forward, or right forward. If the skew angle in the illustration is 15°, the proper description of the skew (to be shown on the plans) is "15° skew left forward."



Box Culverts

The Bridge Division Standard Drawings include design details and guides for estimating quantities for box culvert installations. Designers normally can make direct reference on the plans to the drawing number, size of box, skew, headwalls and other pertinent information. Estimated quantities should be computed from the guides and recorded on the plans.

If there are any nonstandard conditions (in size, skew, headwalls, improved entrance structures, etc.) the Bridge Division should provide any needed supplementary drawings.

Culvert Lengths

The required length of pipe culverts normally should be determined by plotting the installation to scale on a cross section at the location, and measuring the plotted lengths. For skew installations, a plan view also should be drawn to scale.

When improved entrance and flared end sections are specified, they should be identified separately and considered in the reduction of overall culvert length.

The lengths of pipe culverts should be estimated and recorded to the nearest multiple of 4-foot increments. The length of box culverts should be calculated to the nearest 0.01 foot. Detailed information on dimensions and quantities for box culverts must be documented on standard computation sheets provided by the Department.

Structure Excavation

Detailed instructions and tables are found in the Department publication, "Structure Excavation Tables for Pipe Culverts, Headwalls, Box Culverts, and Minor Structures."

Tables may be used for state aid work provided pipe culvert constants are increased to include wall thickness. The Department's structure excavation width is 2 feet plus inside diameter and State Aid's width is 2 feet plus outside diameter.

INDEX TO ILLUSTRATIONS IN CHAPTER 6

Chapter 7
ROADSIDE DEVELOPMENT

This chapter provides design criteria and procedures for controlling soil erosion, landscaping and rest area development.

EROSION CONTROL

Vegetation

Most highway construction projects will require certain erosion control items to provide a vegetative cover on disturbed, barren soil areas to prevent soil erosion and improve the appearance of the roadside.

The "Vegetation Schedule" sheet prepared by the Roadside Development Section will specify the work items to be performed, pay item numbers, rates of application, seasonal requirements and any special notes related to the particular project.

The Vegetation Schedule may include items such as:

- topsoiling
- ground preparation
- fertilizing
- sprigging
- seeding
- mulching
- watering.

A typical Vegetation Schedule is shown on page 7-2.

Responsibilities

Responsibilities for erosion control design are shared by the Roadside Development Section and the squad leader assigned to each project.

The squad leader will furnish Roadside Development with the project number, location, station limits, original soil profile, type of project, typical section or slope schedule, and any field recommendations pertinent to the design.

Roadside Development will prepare a "Vegetation Schedule" sheet, which will become a part of the contract plans.

The squad leader will determine the square yards of the disturbed area to be vegetated; and will estimate quantities for each work item listed on the Vegetation Schedule.

Estimating Quantitites

Normally, the total disturbed area to be vegetated is determined from the construction limits. The transverse width is stripped on each station cross section for an accumulative total. This total is multiplied by 100 and divided by 9 to calculate the square yards of disturbed area. Experience shows that for estimating purposes a factor of 1.5 should be applied to the calculated value.

When the construction limits extend to or near the right-of-way line, the disturbed area may be determined by subtracting the area of the roadway from the area of the right-of-way. In this method the 1.5 factor is not applied.

VEGETATION SCHEDULE

EROSION CONTROL ITEMS		SEASONAL APPLICATIONS - DATES RATES				REQUIREMENTS
		SPRING & SUMMER		FALL & WINTER		THE APPLICATION OF THE SPECIFIED ITEMS SHALL CONFORM WITH THE REQUIREMENTS IN THE SPECIFICATIONS OR SPECIAL PROVISIONS
PAY ITEM NO.	ITEMS	RATES	DATES	RATES	DATES	THE PLANTING DATES AND RATES IN THIS SCHEDULE SUPERSEDES PLANTING DATES AND RATES IN THE SPECIFICATIONS
652-E	TOPSOIL (LVM-CONTR. FURN.)	4" THICK	MARCH 1 TO SEPTEMBER 1	4" THICK	SEPTEMBER 1 TO MARCH 1	PLACE ON CUT SLOPES AT APPROX. STATION LIMITS LISTED BELOW OR AS DIRECTED BY THE ENGINEER
655-H	STANDARD GROUND PREPARATION (TYPE II)	PER SQ. YD.	MARCH 1 TO SEPTEMBER 1	PER SQ. YD.	SEPTEMBER 1 TO MARCH 1	GROUND PREPARATION (TYPE II) REQUIRED ON AREAS TO RECEIVE SOLID SODDING OR SEEDING, AS APPLICABLE
656-A	AGRICULTURAL LIMESTONE	3 TONS/ACRE	MARCH 1 TO SEPTEMBER 1	3 TONS/ACRE	SEPTEMBER 1 TO MARCH 1	LIMESTONE SHALL BE MECHANICALLY SPREAD UNIFORMLY AND INCORPORATED INTO THE SOIL PRIOR TO PLANTING
656-B	COMBINATION FERTILIZER (13-13-13)	1000 LBS./ACRE	MARCH 1 TO SEPTEMBER 1	1000 LBS./ACRE	SEPTEMBER 1 TO MARCH 1	FERTILIZER " " " " " " " " " " " " "
(1) 656-C	SUPERPHOSPHATE	1 TON/ACRE (EST.)	MARCH 1 TO DECEMBER 1	———	———	SUPERPHOSPHATE (FOR BID ITEM PURPOSES)
(2)(3) 658-A	(W) SEEDING (BAHIA GRASS)	30 LBS./ACRE	MARCH 1 TO SEPTEMBER 1	30 LBS/ACRE	SEPTEMBER 1 TO MARCH 1	SEEDING REQUIRED ON DISTURBED AREAS
(2)(3) 658-A	(W) SEEDING (COMMON BERMUDA GRASS)	15 LBS./ACRE	MARCH 1 TO SEPTEMBER 1	15 LBS./ACRE	SEPTEMBER 1 TO MARCH 1	SEEDING REQUIRED ON DISTURBED AREAS. UNHULLED SEED MAY BE REQ'D. DURING DORMANT SEASON AS DIRECTED
(3) 658-A	(W) SEEDING (FESCUE-KY. 31)	———	———	25 LBS/ACRE	SEPTEMBER 1 TO MARCH 15	" " " " "
(3) 658-A	(W) SEEDING (CRIMSON CLOVER)	———	———	20 LBS/ACRE	SEPTEMBER 1 TO MARCH 15	" " " " "
907-659-A	VEGETATIVE MATERIAL FOR MULCH	2 TONS/ACRE (EST.)	MARCH 1 TO SEPTEMBER 1	2 TONS/ACRE (EST.)	SEPTEMBER 1 TO MARCH 1	THE ENGINEER WILL DESIGNATE THE RATES OF APPLICATION (SEE SUBSECTION 659.04)
659-B	BITUMINOUS MATERIAL FOR MULCH	125 GALS/TON (EST.)	MARCH 1 TO SEPTEMBER 1	125 GALS/TON (EST.)	SEPTEMBER 1 TO MARCH 1	" " " " " " " " " " "
664	(W) SOLID SODDING	PER SQ. YD.	MARCH 1 TO SEPTEMBER 1	PER SQ. YD.	SEPTEMBER 1 TO MARCH 1	SOLID SOD REQUIRED ON AREAS SPECIFIED IN THE CONTRACT OR BY THE ENGINEER
(4) 907-671	WATERING	20 GALS/SQ.YD. (EST.)		20 GALS/SQ.YD. (EST.)	SEPTEMBER 1 TO MARCH 1	TO BE USED AS DIRECTED IN THE PLANTING AND ESTABLISHING OF SEEDING AND SOLID SOD AS APPLICABLE

(1) ALL AREAS THAT HAVE BEEN VEGETATED, UNDER THIS CONTRACT, FOR AT LEAST (60) SIXTY DAYS, SHALL RECEIVE ADDITIONAL APPLICATION(S) OF FERTILIZER(S) OF THE TYPE(S) AND RATE(S) OF APPLICATIONS AS DETERMINED BY SOIL TEST OR AS DIRECTED DURING THE GROWING SEASONS THE CONTRACT IS IN FORCE. GROUND PREPARATION WILL NOT BE REQUIRED FOR THE ADDITIONAL APPLICATIONS. PAYMENT FOR ALL FERTILIZERS ACCEPTABLY APPLIED AS ADDITIONAL APPLICATION(S) WILL BE MADE IN ACCORDANCE WITH THE SUPERPHOSPHATE BID ITEM 656-C.

(2) PROPOSAL QUANTITIES ESTIMATED ON THE BASIS THAT 65% OF THE ACREAGE TO BE SEEDED WILL BE SEEDED DURING THE PERIOD MARCH 1 TO SEPTEMBER 1.

(3) PROPOSAL QUANTITIES ESTIMATED ON THE BASIS THAT 35% OF THE ACREAGE TO BE SEEDED WILL BE SEEDED DURING THE PERIOD SEPTEMBER 1 TO MARCH 1

(4) WATER WILL BE MEASURED FOR PAYMENT WHEN ORDERED AND APPLIED ON AN AREA UPON WHICH ITEMS OR COMBINATION OF ITEMS WHICH BY REFERENCE SYMBOL (W) ARE HERE LISTED.

TOPSOIL REQUIRED:

STATION	TO	STATION
50 + 00	———	57 + 00
80 + 00	———	85 + 00
112 + 00	———	120 + 00
157 + 00	———	163 + 00

The procedures for estimating work item quantities are as follows:

Topsoil: Normally, the station limits requiring topsoil will be specified on the Vegetation Schedule. The cubic yards of topsoil are determined by multiplying the areas (square feet) requiring topsoil by the thickness (feet), and dividing by 27 to convert to cubic yards; and then multiplying the calculated amount by 1.25 (25% shrinkage factor).

Topsoil furnished from within the right-of-way is paid for on a square-yard basis for placement.

Ground Preparation: The total square yards of disturbed area to be vegetated as shown on the typical section may include sprigging and topseeding, seeding, and solid sodding as specified on the Vegetation Schedule.

Fertilizers: The quantity of fertilizers (tons) is calculated from the square yards of ground preparation converted to acres multiplied by the rate per acre of each fertilizer (agricultural limestone, combination fertilizer and superphosphate).

Sprigging: The total area of sprigging is the ground-preparation area minus (-) the solid-sodding area. When sprigging is specified on the Vegetation Schedule to be planted during certain months only, the area is multiplied by the estimated percent to be sprigged. This percentage is shown on the Schedule.

Seeding: The quantities of seed are calculated from the ground-preparation area minus (-) the solid-sodding area converted to acres multiplied by the rate per acre of each type seed. The estimated percents of the area to be seeded in the spring and summer and the area to be seeded in the fall and winter are shown on the Schedule.

Mulching: The tons of vegetative material are calculated for ground preparation area minus (-) solid sod area converted to acres, multiplied by the rate per acre of mulch. The bituminous material is calculated by multiplying the tons of vegetative material by the rate of gallons per ton.

Watering: The quantity of water is calculated by multiplying the ground preparation area by the rate of gallons per square yard, dividing by 1000, and rounding to the nearest M/gals.

The erosion control items will be included sequentially in the Summary of Quantities for the project.

SPECIAL DITCH TREATMENT

Under certain conditions of ditch gradient and quantities of water, vegetation is difficult to establish before erosion occurs, and special treatment is necessary.

Sometimes, the characteristics of the ditch and the waterflow are such that vegetation alone will be inadequate--and it becomes necessary to install paved ditches.

Responsibilities

For most routine situations, the squad leader responsible for an individual project will conduct the analysis, and design appropriate ditch treatment in accordance with the criteria and procedures set forth in this manual. For unusual situations the Hydraulics Section will furnish guidance and assistance in design of ditches, channels, and other erosion control measures.

General Criteria

Some factors affecting ditch design are:

- type of soil
- ditch gradient
- volume of water (drainage area)
- steepness of ditch slopes.

More extensive ditch treatment is needed with steep ditch grades, large quantities of water and steep side slopes. The alternative treatments listed in order of increasing effectiveness for erosion control are:

- normal seeding and mulching
- excelsior blanket
- solid sod or asphalt coated fiberglass roving
- paved ditches.

Ditch Gradient

For analysis purposes, it is convenient to plot ditch grades on a working profile copy. Gradients should be plotted for all cut ditches and also for situations where the natural ground slopes toward the toe of fill slopes. A close approximation from the cross sections will be sufficiently accurate.

Notations should be made on the drainage profile working copy to indicate where the side ditch flow is released and carried away by a natural drainage channel--or is intercepted by a drop inlet or cross drain culvert.

Drainage Areas

The drainage area should be outlined on the working plan copy to show all of the area which contributes runoff to the ditch. This should include that portion of the pavement surface which is sloped toward the ditch, all construction slopes, and any area beyond the construction limits which drains toward the ditch. The area can readily be measured using the "strip stick."

The table of Criteria for Side Ditch Treatment, on page 7-5, is based on the following conditions:

- drainage area plotted at a scale of 1" = 100'
- use of a strip stick calibrated for cross sections plotted at a scale of 1" = 5' horizontally and vertically
- strip at 25' intervals (use of 0.25" x 0.25" grid overlay is very helpful).

Under these conditions, the numerical reading of the strip stick can be used directly with the table to determine proper ditch treatment.

Ditch Treatment Design

Design of ditch treatment normally will involve the following steps:

1. Select the proper columns in the table for the ditch slopes.

2. Select the appropriate ditch grade (%).

3. Identify the maximum strip stick reading permissible for each type of treatment.

CRITERIA FOR SIDE DITCH TREATMENT

Ditch Grade %	STRIP STICK VALUES 1/												Ditch Grade %
	6:1 Foreslope 6:1 Backslope			6:1 Foreslope 4:1 Backslope			4:1 Foreslope 4:1 Backslope			4:1 Foreslope 3:1 Backslope			
	No Treatment	Excelsior Blanket	Asphalt & Fiber Glass 2/	No Treatment	Excelsior Blanket	Asphalt & Fiber Glass 2/	No Treatment	Excelsior Blanket	Asphalt & Fiber Glass 2/	No Treatment	Excelsior Blanket	Asphalt & Fiber Glass 2/	
0.2	1250	2740	4900	1040	2270	4050	820	1810	3220	720	1570	2800	0.2
0.3	1250	3360	6000	1040	2780	4960	830	2210	3950	720	1920	3440	0.3
0.4	1300	3880	6920	1080	3210	5740	880	2560	4560	750	2220	3960	0.4
0.5	1260	3960	7070	1050	3280	5850	830	2610	4660	720	2270	4050	0.5
0.6	1090	3520	6270	900	2910	5200	720	2320	4140	630	2010	3600	0.6
0.7	950	3150	5620	790	2610	4660	630	2080	3710	550	1810	3220	0.7
0.8	890	2890	5160	740	2390	4220	590	1910	3400	510	1660	2960	0.8
0.9	820	2670	4720	680	2210	3950	540	1760	3140	470	1530	2720	0.9
1.0	740	2490	4450	610	2060	3670	490	1640	2940	420	1430	2550	1.0
1.5	540	1920	3440	450	1590	2840	360	1270	2260	310	1100	1960	1.5
2.0	440	1620	2900	370	1340	2400	290	1070	1910	250	930	1660	2.0
2.5	370	1420	2540	300	1180	2100	240	940	1670	210	810	1450	2.5
3.0	250	950	1725	200	800	1400	175	625	1125	150	550	975	3.0
3.5	200	825	1375	175	625	1125	125	500	900	100	425	775	3.5
4.0	150	625	1125	125	525	950	100	425	750	100	350	650	4.0
4.5	125	525	950	100	450	775	75	350	625	75	300	525	4.5
5.0	100	475	850	75	375	675	50	300	525	50	275	475	5.0
5.5		400	725		325	600		250	475		225	400	5.5
6.0		325	600		275	500		225	375		175	350	6.0
7.0		275	475		225	400		175	325		150	275	7.0
8.0		200	375		175	325		125	250		100	225	8.0
9.0		150	275		125	225		100	175		75	150	9.0
10.0		100	225		100	150		75	125		50	125	10.0

1/ For drainage areas plotted at a scale of 1" = 100', using a strip stick calibrated for cross sections plotted at a scale of 1" = 5' horizontally and vertically. A strip stick value of 824 equals 1 acre. The tabular values are the upper limits of strip stick readings for the particular type of side ditch treatment. A paved ditch is required for readings above the limits for asphalt and fiber glass.

2/ Asphalt coated fiber glass rovings. For solid sod, use only 75% of strip stick values shown.

NOTES:

This table was developed for average erosion resistant soils. For highly erosive soils, use only 60% of "strip values" shown.

Ditch grades exceeding 3.0% become more critical, requiring drastic "strip value" reductions when definite drainage areas are unknown. Ditch paving generally should begin where abrupt increases in ditch grades occur, i.e., 2.0%± to 6.0%±, even though other type "strip values" have not been exhausted.

4. Start the cumulative stripping process at the upstream end of the drainage area and continue until the reading shows the upper limit for normal seeding and mulching (no special treatment). The excelsior blanket will start at this location.

5. Continue cumulative stripping to the upper limit reading for excelsior blanket--and start the solid sod or asphalt coated fiber glass rovings at this point.

6. Continue cumulative stripping to the upper limit reading for solid sod or asphalt coated fiber glass rovings--and start the paved ditch at this point.

7. Whenever the ditch reaches an outlet, end the treatment and start stripping from zero reading at the upstream end of the next drainage area.

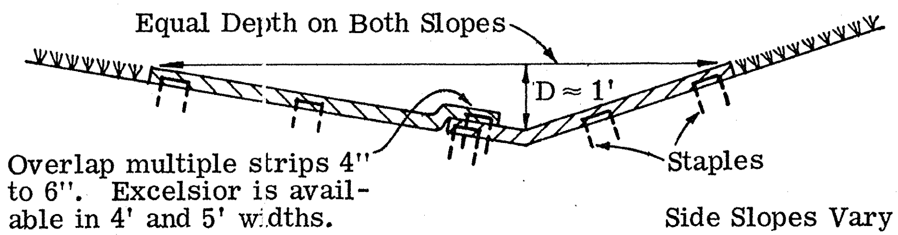
Typical sections of ditch treatment are shown in the figure at the right.

Normally the simple "V" shaped ditch will be used. For situations involving relatively large quantities of water, a flat bottom ditch with appropriate treatment will be designed by the Hydraulics Section.

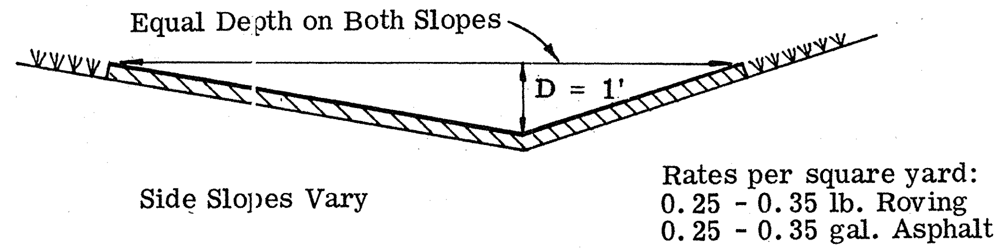
The units of measure for various types of ditch treatment are shown below:

Excelsior blanket	--	square yards
Solid sod	--	square yards
Asphalt coated fiber glass roving:		
Fiber glass	--	pounds per square yard
Asphalt	--	gallons per square yard
Paved ditch (P.C. concrete)	--	cubic yards
Paved ditch (bituminous)	--	tons

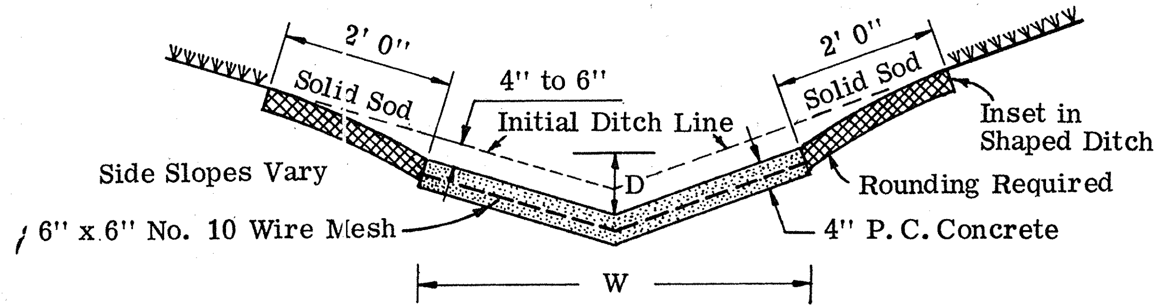
TYPICAL DITCH TREATMENTS



DITCH LINER
~~EXCELSIOR BLANKET~~



ASPHALT COATED FIBER GLASS ROVING



CONCRETE PAVED DITCH

D (minimum) = 6"
D (nominal) = 9"
D (maximum) ≈ 12"

Design flat bottom ditch when estimated depth of flow will exceed 12".

W (minimum) = 4'

Width is dependent on side slopes of ditch and depth to accommodate estimated flow. Equal depth on both slopes.

Normally concrete shall be specified when paved ditches are required. Bituminous paving will be specified only where unusual soil conditions may adversely affect concrete. Designers will be advised of these conditions.

The location and type of special ditch treatment should be shown on the plan sheets with these suggested symbols (press-on tapes are available):

DITCH LINER

Excelsior blanket	--	
Solid sod	--	
Asphalt coated fiber glass roving	--	
Paved ditch (P.C. Concrete)	--	
Paved ditch (Bituminous)	--	Designer's choice (seldom used)

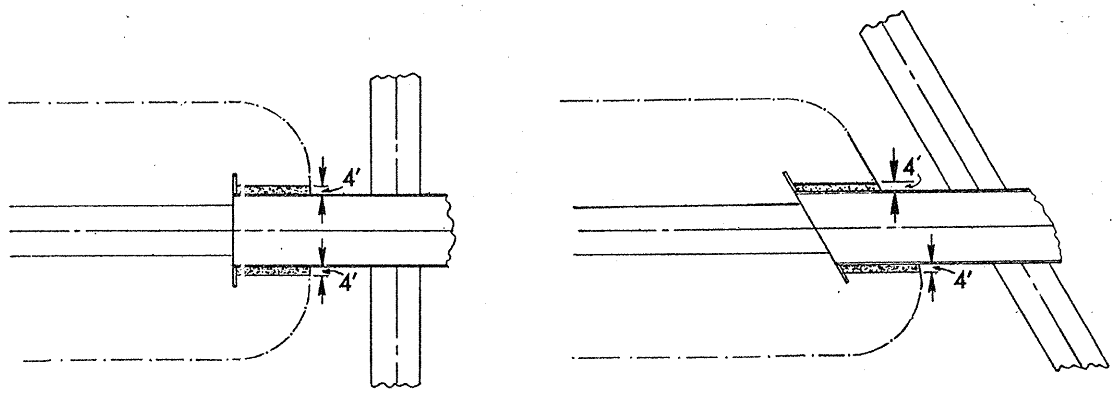
When the topography on the plan sheet is so congested that addition of the ditch treatment symbols would be confusing, the symbols should be omitted and an itemized list of quantities prepared which will identify the type of treatment by stationing.

OTHER EROSION CONTROL

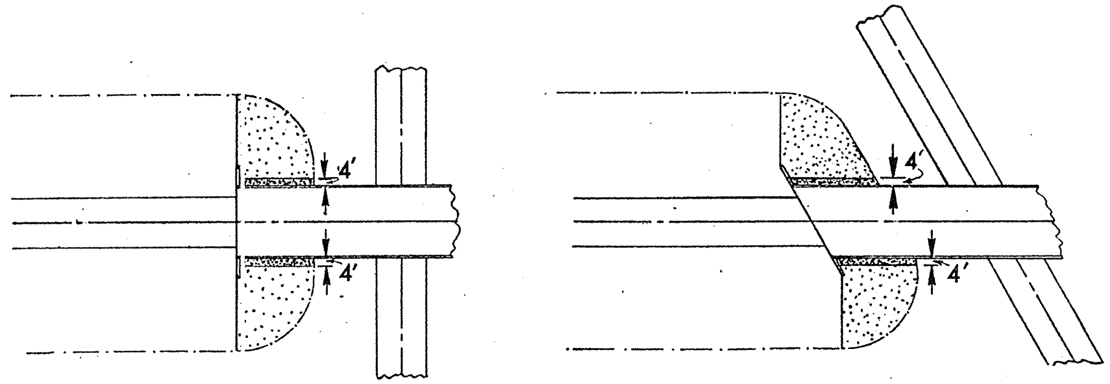
Slope Paving

Concrete slope paving should be provided underneath bridges at grade separation structures to prevent erosion. The details normally are shown on the bridge sheets and the quantities are included in the Bridge Summary of Quantities.

For typical rural projects, the slope paving is limited to the area beneath the bridge, as shown in the following examples.



For most urban projects, additional slope paving should be provided to wrap around the ends of the embankment, as shown below.



Bridge Item

Roadway Item

Details and quantities for the additional wrap-around slope paving must be shown on the roadway plans.

Riprap

To prevent excessive erosion, riprap may be required at various locations within the roadway right-of-way. Designers should direct particular attention to the following locations:

- outfall and intake ends of culverts
- bends in stream channels
- abrupt flowline changes
- excessive flowline grades
- confluence of two or more streams or channels
- existing erosion problems.

The designer should consult the Hydraulics Section when there is a question about the need for riprap.

LANDSCAPING AND REST AREA DEVELOPMENT

Special roadside development work may be specified during the planning process. This work may include landscaping of the roadside or development of roadside rest areas.

Responsibilities

The Roadside Development Section will design these projects and prepare contract plans.

For landscaping work, the contract plans normally will include:

- a title sheet and general layout
- summary of quantities
- vegetation schedule
- plan sheets showing individual plantings
- applicable standard drawings.

For roadside rest areas, the plans will include additional details on:

- site preparation
- buildings
- water and sewer installations
- other facilities.

Site preparation for rest areas may be included in contract plans for construction of the highway facility.

Safety Considerations

Special care should be taken to assure that growth of trees and shrubs will not obscure signs or sight distances for traffic movement--especially in the areas of intersections, interchanges or roadside parks.

Ultimate large-trunk-size trees planted or retained too close to the traveled way are potential hazards. Criteria for a recovery area of 30 feet from the traveled way is presently used. However, every consideration should be given to locating these trees at a further distance, especially in areas such as grade points, low fills, shallow cuts, diverging roadways, or other locations where it is likely that a vehicle may leave the roadway and strike a tree.

Chapter 8

HIGHWAY INTERSECTIONS

This chapter deals with highway intersections--ranging from simple intersections of rural roads to complex interchanges of major highways.

GENERAL

Intersections are a very important part of highway design. They affect capacity, speed and efficiency, and have a great effect on traffic safety.

Two general types of intersections will be discussed:

- Intersections at grade
- Interchanges.

Use of interchanges normally is limited to freeways or expressways with high traffic volumes where at-grade intersections would disrupt the flow of traffic and create hazardous conditions.

Because interchanges are quite expensive, careful analysis and planning must be performed to define their locations and justify their installation. Normally, these decisions are made during the planning process and no attempt will be made in this manual to discuss general warrants and criteria. Rather, emphasis will be placed on design criteria and procedures to be followed by designers.

Some considerations relating to turning movements are applicable to all types of intersections.

DESIGN VEHICLES

The shape and sharpness of curves, and the widths of turning roadways must be designed to accommodate the characteristics of vehicle operation.

Four basic classes of "design vehicles" have been established. The operating characteristics of these vehicles affect intersection design geometrics. The vehicle classes and their designations are:

P -- Passenger cars, and light panel and pickup trucks

SU -- Single unit trucks and busses

WB-40 -- Semi-trailer combinations with an overall wheelbase of 40 feet

WB-50 -- Semi-trailer combinations with an overall wheelbase of 50 feet.

General criteria for minimum intersection design are shown below by vehicle class:

P design -- Use at private driveways and local road intersections with highways; and at intersections of two minor highways carrying low volumes of traffic.

SU design -- In general, for conditions other than those described above, use the recommended minimum for rural highways.

WB-40 or WB-50 design -- Use where truck combinations which approximate the size of the design vehicles will be turning repeatedly.

AT-GRADE INTERSECTIONS

Most highways intersect at grade. At-grade intersections should provide adequately for anticipated turning and crossing movements. Typical geometric designs and design controls for at-grade intersections are discussed in this section.

General Types

Intersections at grade usually are the 3-leg (T or Y shape) or the 4-leg geometric form--and may be non-channelized, flared or channelized.

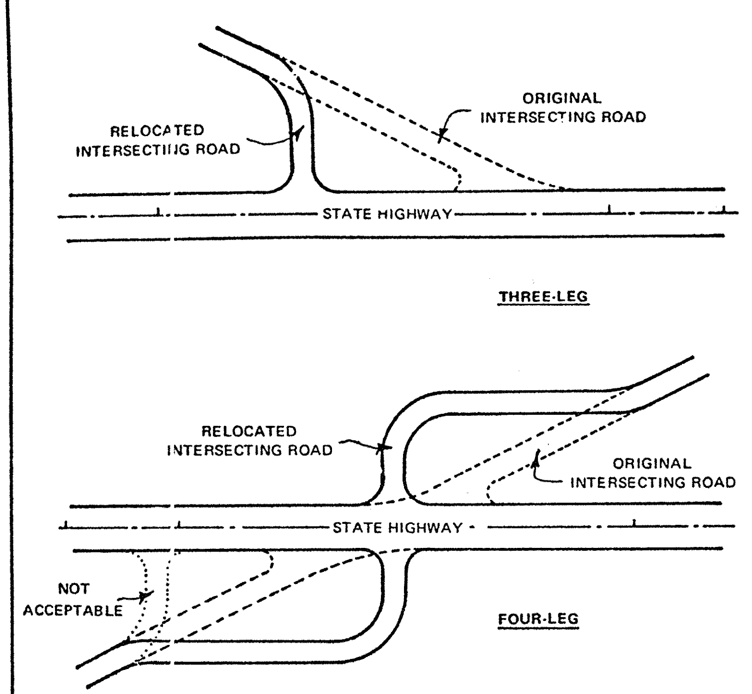
The principal factors which govern the choice of type of intersection and the design characteristics are the design hour-volume, the turning movements, the characteristics or composition of traffic, and the design speed.

Alignment

Regardless of the type of intersection, it is desirable for safety and economy that intersecting roads meet at or nearly at right angles. Roads intersecting at acute angles cause difficult turning movements and require extensive turning roadway areas--and they tend to limit visibility. Flat-angle intersections also increase the exposure time of vehicles crossing the main traffic flow and may increase the accident potential.

While a right-angle crossing normally is desired, some deviation is permissible. Angles above 60 degrees produce only a small reduction in visibility, and do not often warrant realignment.

Skewed intersections on major highways should be avoided where possible by means of relocations similar to those shown below:



RELOCATION OF SKEWED INTERSECTIONS

Intersection of highways on sharp curves should be avoided wherever possible since the superelevation complicates the intersection design and the curvature may contribute to sight distance problems.

Pavement Widths for Turning Roadways

Most of the simple intersections will require only the design of curved inner edges of pavement to accommodate right turns. Sometimes, however, there is need to design corner islands, or channelization--or even separate turning roadways. And when this happens, the designed width of the turning roadway becomes critical.

Criteria for widths of pavement are classified for the following types of operations:

Case I -- 1-lane, one-way operation--no provision for passing

Case II -- 1-lane, one-way operation--with provision for passing a stalled vehicle

Case III -- 2-lane operation--either one-way or two-way.

Widths for Case I usually are used for minor turning movements, and for moderate turning volumes where the connecting roadway is relatively short.

Case II widths are applicable to all turning movements of moderate to heavy traffic volumes that do not exceed the capacity of a single-lane connection.

Widths under Case III are applicable where operation is two-way, or where operation is one-way but two lanes are needed to handle the traffic volume.

The table of Design Widths of Pavement, at the right, shows appropriate widths for various combinations of traffic conditions.

DESIGN WIDTHS OF PAVEMENTS FOR TURNING ROADWAYS

R Radius on inner edge of pavement (feet)	Pavement Width in Feet for:								
	Case I 1-lane, one-way operation-- no provision for passing			Case II 1-lane, one-way operation--with provision for passing a stalled vehicle			Case III 2-lane operation-- either one-way or two-way		
	Design Traffic Condition								
	A	B	C	A	B	C	A	B	C
50	18	18	23	23	25	29	31	35	42
75	16	17	19	21	23	27	29	33	37
100	15	16	18	20	22	25	28	31	35
150	14	16	17	19	21	24	27	30	33
200	13	16	16	19	21	23	27	29	31
300	13	15	16	18	20	22	26	28	30
400	13	15	16	18	20	22	26	28	29
500	12	15	15	18	20	22	26	28	29
Tangent	12	15	15	17	19	21	25	27	27
Width modification regarding edge of pavement treatment:									
No Stabilized Shoulder	None			None			None		
Mountable Curb	None			None			None		
Barrier Curb: One Side	Add 1 foot			None			Add 1 foot		
Barrier Curb: Two Sides	Add 2 feet			Add 1 foot			Add 2 feet		
Stabilized Shoulder, One or Both Sides	None			Deduct shoulder width; minimum pavement width as under Case I.			Deduct 2 feet where shoulder is 4 feet or wider.		

Traffic Condition A -- Predominantly P vehicles, but some consideration for SU trucks.

Traffic Condition B -- Sufficient SU vehicles to govern design, but some consideration for semitrailer vehicles.

Traffic Condition C -- Sufficient semitrailer, WB-40 or WB-50 vehicles to govern design.

Speed-Change Lanes

Drivers who leave a highway at an intersection usually are required to reduce speed before turning. Drivers who enter a highway from a turning roadway accelerate until the desired open-road speed is reached. When deceleration or acceleration takes place directly on the highway, it disrupts the flow of through traffic--and is often hazardous. To minimize these conditions, the use of speed-change lanes is standard practice on highways which have expressway characteristics, and is frequent on other main highways.

Warrants for use of speed-change lanes cannot be stated definitely. Factors to be considered include speeds, traffic volumes, capacities, types of highways and services provided, arrangement and frequency of intersections, and accident experience.

The following conclusions generally are accepted:

- Speed-change lanes are warranted on high-speed and high-volume highways for vehicles entering or leaving the through traffic lanes.
- All drivers do not use speed-change lanes in the same manner--but they use them enough, on the whole, to improve the overall safety and operation of the highway.
- Utilization of speed-change lanes varies with volume--a majority of drivers use them at high volumes.
- The directional type of speed-change lane consisting of a long taper fits the behavior of most drivers and does not require maneuvering on a reverse-curve path.
- Deceleration lanes on approaches to intersections at-grade which also serve as storage lanes for turning traffic are particularly advantageous, and experience with them generally has been favorable.

Two types of speed-change lanes commonly are used. One provides an additional full lane width with a relatively short taper--the other uses a directional straight-line taper for the full distance between the edge of pavement and the PC or PT of the turning ramp roadway.

The straight-line taper is preferred for interchanges. For deceleration lanes, the straight taper is at an angle of about 2 or 4 degrees with the edge of through pavement. A uniform straight taper of 50:1 is used for acceleration lanes. Typical interchange exit and entrance ramps are included in the Standard Drawings.

The full width speed-change lanes are used at most other locations--and are essential at intersections where it is necessary to provide storage for vehicles making turning movements.

The next table, Design Lengths of Speed-Change Lanes, shows the appropriate lengths for various combinations of design speeds for the main highway and the turning roadway.

DESIGN LENGTHS OF SPEED-CHANGE LANES

Design Speed of Turning Roadway Curve (mph)		Stop Condition	15	20	25	30	35	40	45	50
Minimum Curve Radius (feet)			50	90	150	230	310	430	550	690
Design Speed of Highway (mph)	Length of Taper (feet)	Total Length of DECELERATION Lane, Including Taper (feet)								
40	190	325	300	275	250	200	-	-	-	-
50	230	425	400	375	350	325	275	-	-	-
60	270	500	500	475	450	425	400	325	300	-
65	290	550	550	525	500	475	450	375	325	-
70	300	600	575	550	550	525	500	425	400	350
Design Speed of Highway (mph)	Length of Taper (feet)	Total Length of ACCELERATION Lane, Including Taper (feet)								
40	190	-	325	250	225	--	-	-	-	-
50	230	-	700	625	600	500	400	-	-	-
60	270	-	1125	1075	1000	900	800	600	400	-
70	300	-	1550	1500	1400	1325	1225	1000	825	575

NOTE: Uniform 50:1 tapers are recommended where lengths of acceleration lanes exceed 1300 feet; or where design speeds exceed 70 mph; or elsewhere, if appropriate and space permits.

Sight Distances

For an intersection to function properly, adequate sight distance must be provided. The operator of a vehicle approaching an intersection should have an unobstructed view of the whole intersection in order to:

- make a safe directional decision,
- stop safely upon approaching the intersecting roadway, and
- avoid collisions.

The minimum sight distance considered safe is related to vehicle speeds and distances traversed during perception, reaction and braking times.

Wherever possible, Minimum Sight Triangles (Sight Flares) are provided at intersections so that the area within those sight triangles can be freed of any obstructions. Three-leg and four-leg intersections are to have the appropriate sight triangles, if possible.

Several conditions which affect sight distances are discussed under the following headings:

- directional decisions
- no-stop (or signalized) intersections
- stop control (immovable obstruction)
- stop control (minor crossroad)

Directional Decisions

The driver should have full view of any point of separation, either diverging or merging, far enough in advance of reaching that point to make the appropriate decision concerning desired direction.

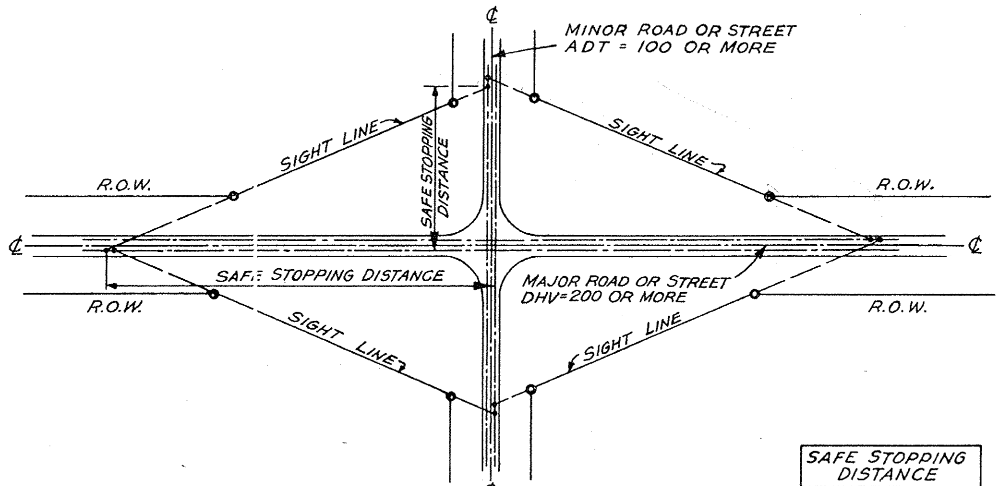
This criterion is discussed in detail in Chapter 3, "Horizontal Alignment"--and a table is presented which shows minimum "decision sight distances" for various predicted speeds.

No-Stop (or Signalized) Intersections

Right-of-way requirements at intersections at which the major road or street has a DHV of 200 or more and the minor road or street has a current ADT of 100 or more shall be determined on the basis of no-stop or signal control at the intersection, using the safe stopping distances which enable vehicles to stop at assumed design speed.

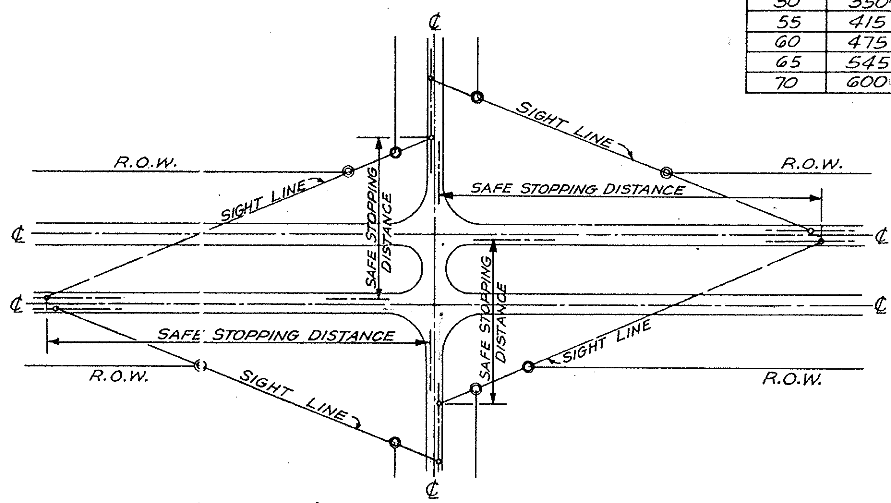
The drawings and table at the right illustrate no-stop (or signalized) right-of-way requirements for both 2-lane and 4-lane intersections and the safe stopping distance at assumed design speeds.

RIGHT-OF-WAY REQUIREMENTS AT NO-STOP (OR SIGNALIZED) INTERSECTIONS



NO STOP (OR SIGNALIZED) -- 2-LANE

SAFE STOPPING DISTANCE	
Assumed Design Speed	Safe Stopping Distance
15	80
20	120
25	160
30	200
35	235
40	275
45	310
50	350
55	415
60	475
65	545
70	600



NO STOP (OR SIGNALIZED) -- 4-LANE

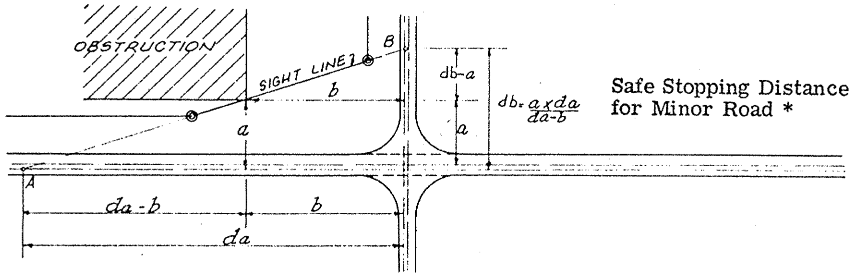
Stop Control (Immovable Obstruction)

Where an obstruction which cannot be removed except at prohibitive cost, fixes the vertices of the sight triangle at points that are less than safe stopping distances from the intersection, vehicles may be brought to a stop (after sighting other vehicles on the intersecting road) only if they are traveling at a speed appropriate to the available sight distance. If vehicles on one of the roads are permitted to travel at the design speed, the critical corresponding speed on the other road can be evaluated in terms of this design speed and the distances to the known obstruction.

In order to sign road B for the proper approach speed which will enable the vehicle to stop, calculate V_B by the formula,

$$db = \frac{a \times da}{da - b}$$

and determine the design speed from the table, "Safe Stopping Distance." See the drawing below.



* By interpolation, the design speed for minor road can be assigned.

Stop Control (Minor Crossroad)

Right-of-way requirements at intersections shall be determined with stop control on the minor road or street for each of the following conditions:

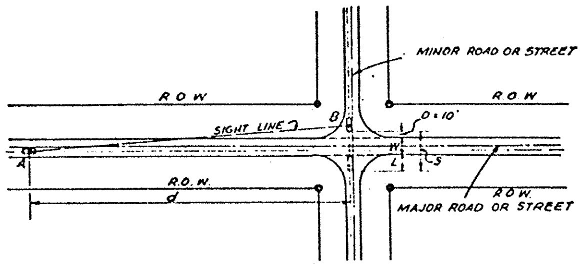
- Major road or street with DHV of less than 200--regardless of the traffic on minor road or street
- Minor road or street with current ADT of less than 100--regardless of traffic on major road or street
- All intersections of roads and streets with frontage roads.

In all cases, sufficient sight distance must be provided to enable stopped vehicles to safely cross the major road or street.

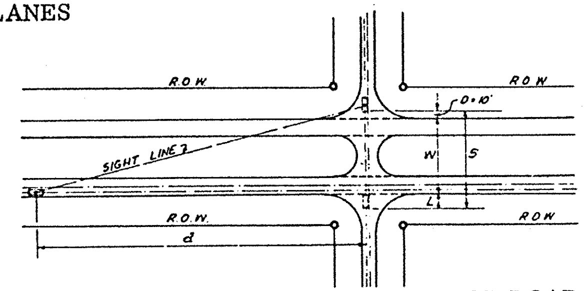
Generally, the right-of-way requirement at intersections for State Aid Roads shall be determined with stop control on the minor road or street.

Stop control on minor road is illustrated on the next page--for 2 lanes, 4 lanes, and 4 lanes with frontage roads.

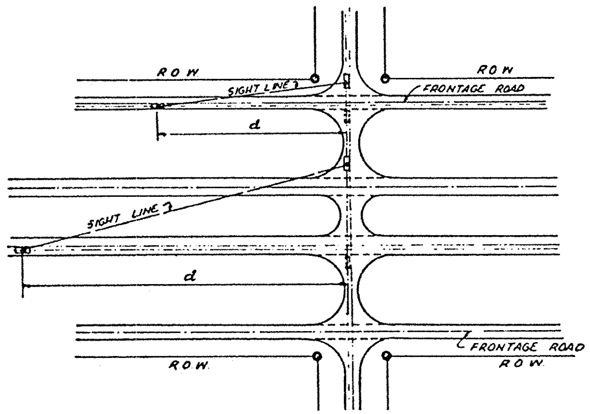
STOP CONTROL ON MINOR ROADS



STOP CONTROL ON MINOR ROAD
2 LANES



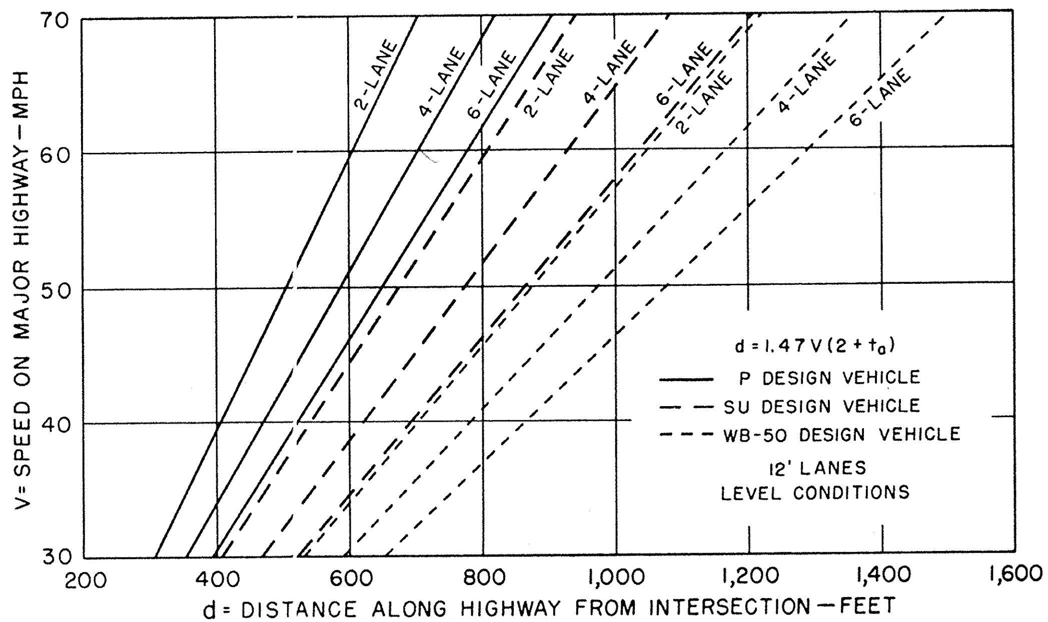
STOP CONTROL ON MINOR ROAD
4 LANES



STOP CONTROL ON MINOR ROAD
4 LANES WITH FRONTAGE ROADS

For safety, it is necessary that the driver of a stopped vehicle see enough of the major highway to be able to cross before a vehicle on the major highway reaches the intersection--even though this vehicle comes into view just as the stopped vehicle starts to cross.

The chart below shows the required sight distances along the major highway to allow a stopped vehicle to cross without requiring the approaching vehicle to slow down. Distances are shown for various combinations of number of lanes to be crossed, speed on the major highway, and the type of design vehicle.



SIGHT DISTANCES FOR INTERSECTIONS WITH STOP CONTROL

Distance Between Intersections

Hazardous conditions may be created when the distance between adjacent intersections is too small. The table below shows basic criteria for minimum spacing.

	Current ADT (Crossroad)	Minimum Spacing
Based on sight triangle for 65 MPH	0 - 100	250 feet
Based on distance for turn bays	100 - 750	400 feet
	750+	500 feet, or as required to separate traffic operations

These criteria apply to frontage road intersections with crossroads. And in cases where both frontage roads and ramp terminals intersect a crossroad, the spacing should be at least 300 feet--usually more.

Storage Lanes for Turns

Turn lanes, both left and right, provide storage space for turning vehicles, as well as space for deceleration and bypassing stopped vehicles. By moving these turning vehicles out of the through-traffic lanes, two objectives are accomplished: a safety factor is introduced by removing stopped or slow-moving vehicles from traffic lanes, and the design capacity of the highway can be maintained.

Storage lanes should be provided at all divided highway median openings, and at other locations when warranted by traffic volumes.

The length of a storage lane is determined by the number of vehicles to be stored, the types of vehicles and the type of traffic control governing the turning movement, the deceleration requirement where applicable, and the requirement for bypassing stopped vehicles.

If the intersection is controlled by traffic signals, the number of vehicles waiting to turn will be determined by the length of the signal cycle and signal phasing. The nomograph on the next page should be used for determining the length of storage lanes at signalized intersections.

For non-signalized intersections, the following relationships can be used as a guide for approximation of required storage length during peak hours.

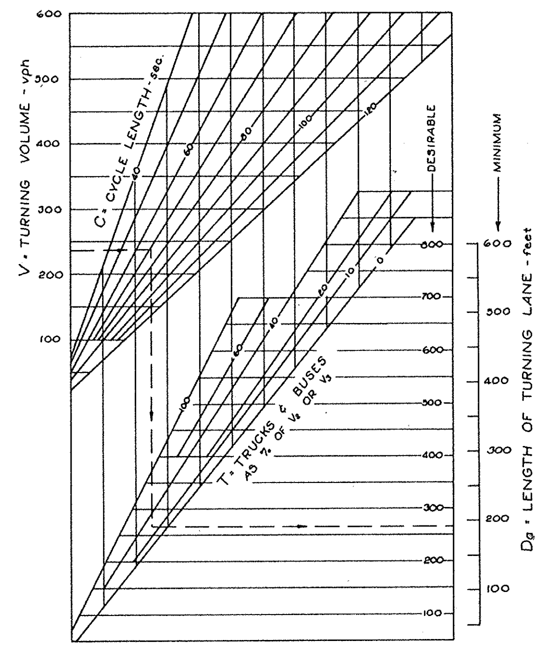
Turning vehicles per hour	30	60	100	200	300
Required storage length, feet	25	50	100	175	250

Where feasible, a minimum storage length of 100 feet should be used.

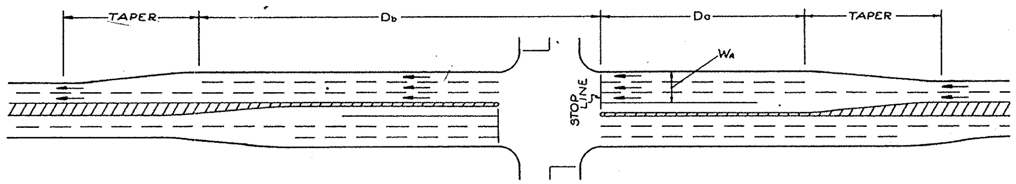
Storage lanes should be 12 feet wide (no less than 10 feet). A width of 12 feet should always be used when a restrictive curb is adjacent to the lane.

Taper lengths for storage lanes depend on the design speed of the approach roadway. Suggested lengths of taper are shown in the design tables on the next page. The tables also suggest dimensions for pavement widening beyond an intersection. In general, tapers should be as long and as smooth as practicable so that drivers will be encouraged to use the full length of the taper. This in turn will help to separate the turning vehicle from through traffic as quickly and effectively as possible and therefore reduce conflicts.

DESIGN OF TURNING LANES AT SIGNALIZED INTERSECTIONS



LENGTH OF RIGHT- OR LEFT-TURN LANE



LENGTH OF WIDENING BEYOND INTERSECTION

LENGTH REQUIRED FOR:*			TAPER feet
ACCELERATION		MERGING	
DESIGN SPEED mph	D_b-feet	D_b = 12 x G	
40	200	(G, Green interval in seconds)	200
50	525		250
60	900		300

* Use the larger of two values but not less than 300 feet.

LENGTH OF WIDENING IN ADVANCE OF INTERSECTION

LENGTH REQUIRED FOR: **			TAPER feet
DECELERATION		STORAGE	
DESIGN SPEED mph	D_a-feet	• Divide approach volume by number of lanes in W_A • Use volume per lane in above chart; find D_a on desirable scale (minimum scale for restricted conditions)	
40	150		175
50	200		225
60	250		275

** Use the larger of two values but not less than 200 feet.

Non-Channelized Intersections

Most at-grade intersections with local roads will be simple non-channelized intersections.

The figure on the next page shows two examples of non-channelized intersections--one at right angle to the main roadway and the other at a skew angle. Standard criteria for dimensions and radii are also shown in the figure.

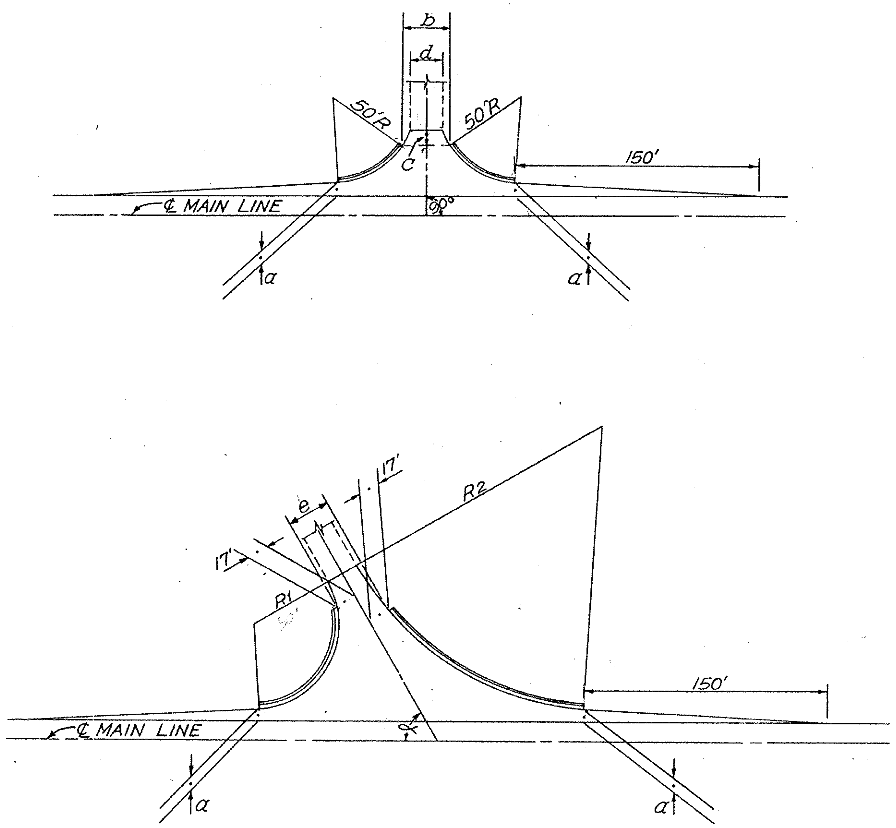
Special Treatment for At-Grade Intersections

At intersections with crossroads which have larger traffic volumes, various types of special treatment usually are required. General criteria for special treatment are set forth below.

Current ADT (Crossroad)	Special Treatment for At-Grade Intersections	
	Side Road	Main Highway
Under 100	No channelization	Turn bay on 4-lane only
100 - 1000	Simple channelization	Left-turn bays
*1000 - 2000	Channelize with left-turn bay	Left-turn bays and right-turn lanes
Over 2000	Design for signal intersection and conduct capacity analysis.	

* Turning movement count is required at all intersections where crossroad ADT is 1000 or more.

NON-CHANNELIZED INTERSECTIONS



a = Shoulder Width
b = 34' Minimum
c = 10' Minimum
d = Variable (20' Minimum)
e = 24' Minimum
∝ = Variable Angle (60° Minimum)
Note: When angle is less than 60°, try to relocate.
R_1 = 50' (40' when acute angle is less than 60°)
R_2 = Variable (radius point opposite smaller radius point)

Channelization

Potential conflicts between vehicles and between vehicles and pedestrians may be reduced through channelization of traffic movements. The traffic channels may be fixed to separate and direct traffic movements into specific and clearly defined vehicle paths.

The edges of traffic channels are formed and delineated by traffic islands. Islands may be formed by curbs or other raised devices or may be marked out simply in paint on the pavement surface. One of the most desirable treatments is a raised island with mountable curbs. However, installation of curbs should generally be avoided in areas where high speeds may be expected. In some cases barrier curbs are required to protect pedestrians. Within an intersection area, medians and outer separations are also considered as islands.

Islands can be grouped into three functional classes and most islands serve two or all of these functions:

- Directional islands control and direct traffic movement and guide the motorist into the proper channel.
- Divisional islands separate opposing traffic flows, alert the driver to the crossroad ahead, and regulate traffic through the intersection. These islands are often introduced on undivided highways at intersections and are particularly advantageous in controlling left turns at skewed intersections and in preventing wrong-way turns into right-turning traffic lanes.
- Refuge islands at or near crosswalks aid or protect pedestrians crossing the roadway. Such an island may be required for pedestrians at intersections where complex signal phasings are used. Refuge islands may also serve as areas for installation of traffic control devices.

Functions of Channelization

Channelization may be used for one or more of the following purposes:

- To prevent vehicle conflicts caused by the overlapping of maneuver areas. This separation makes it possible to present the driver with only one important decision at a time.

- To control the angle of conflict and reduce relative speeds in merging, diverging, weaving and crossing maneuvers. The potential severity of conflict may be decreased substantially by reducing the angle between the vehicle paths.

- To reduce excessive pavement areas caused by skewed and flared intersection arrangements. Large areas of open pavement may confuse drivers and cause erratic and improper maneuvers.

- To control speed by bending or funneling movements to support stop sign controls or reduce speed differentials prior to merging, weaving or crossing maneuvers.

- To protect pedestrians by providing a safe refuge between traffic streams.

- To protect and store turning and crossing vehicles by enabling them to slow or stop out of the path of other traffic flows. This is sometimes referred to as "shadowing."

- To block prohibited movements by making it impossible or inconvenient to perform illegal, improper or unsafe maneuvers.

- To segregate traffic movements with different requirements in terms of speed, direction, and stop or right-of-way control.

- To locate and protect traffic control devices such as signs and signals where the most desirable location for these devices is within the intersection area.

Principles of Channelization Design

Channelization design does not lend itself to standardization. Traffic volumes, pedestrian patterns and physical conditions vary, requiring individual treatment of each intersection. AASHTO's "Geometric Design Policy," 1965, presents guides for various elements of the design, but the combination of elements within a specific design is an engineering art.

Good design should adhere to the following principles:

- The proper traffic channels should seem natural and convenient to drivers and pedestrians.

- There should be no choice of vehicle paths leading to the same destination.

- The number of islands should be held to a practical minimum to avoid confusion.

- Islands should be large enough to be effective. Islands that are too small are ineffective as a method of guidance and often present problems in maintenance. The minimum distance across the midsection of an island should be 25 feet in order to have enough room to place any necessary signing.

- Channelization should be visible. It should not be introduced where sight distance is limited. When an island must be located near a high point in the roadway profile or near the beginning of a horizontal curve, the approach end of the island should be extended so that it will be clearly visible to approaching drivers.

- The major traffic flows should be favored. In "bending" the roadways, those which have the heaviest traffic volumes or the fastest speeds should be "bent" the least.

- Conflicts should be separated so that drivers and pedestrians may deal with only one conflict and make only one decision at a time.

- Islands should be designed for the assumed design speed of the road. The approach end treatment and delineation should be carefully designed to be consistent with the speed characteristics of the roadway design.

Delineation of Islands

Delineation is critical in good channelization design. Island delineation can be divided into three types:

- Raised islands outlined by curbs

  This type can be applied universally and is the most positive. Mountable curbs should be used in all but special cases.

- Islands delineated by pavement markings, buttons or raised (jiggle) bars placed on all paved areas

  This delineation is used in urban areas where speeds are low and space is limited, or in rural areas to overcome maintenance problems.

- Non-paved areas formed by pavement edges, possibly supplemented by delineators on posts or other guide posts, or a mounded earth treatment or appropriate landscaping.

  This type necessarily applies to larger islands and is logical mostly at rural intersections where there is sufficient space.

Island Offset

Islands should be offset from the edges of the traveled way. Failure to offset can make an island appear more restrictive than it actually is and can have a psychological effect on drivers, causing them to make erratic movements as they approach the intersection.

The island offset should be increased in direct relation to the design speed and the width of the open area preceding the end of the island. A maximum offset of 12 feet is generally accepted for high speed roads.

Channelized Intersections--Low Traffic Volumes

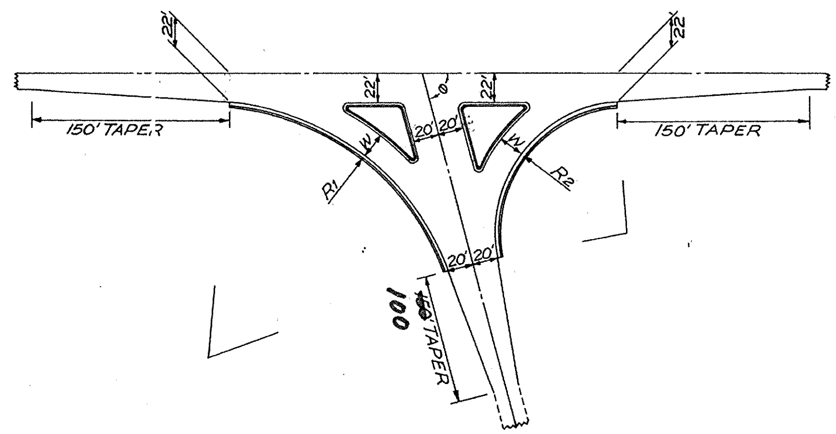
The figure at the right illustrates a typical T-intersection and shows appropriate channelization for low traffic volume conditions.

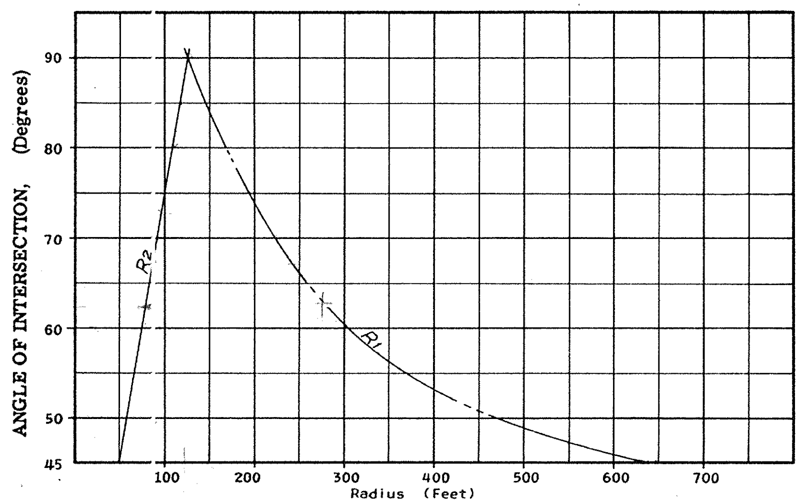
The principal design variables are the lengths of the radii and the widths of the ramps. The radii vary with the angle of intersection. Proper design radii can be determined by entering the chart at the intersecting angle on the ordinate and finding the intersection with each of the curves labeled R_1 and R_2. The design radii lengths will be found along the bottom of the chart.

Ramp widths, "W", can be found in the table of Design Widths of Pavements for Turning Roadways, shown earlier in this chapter.

A typical layout for a low-volume 4-leg channelized intersection is shown on page 15.

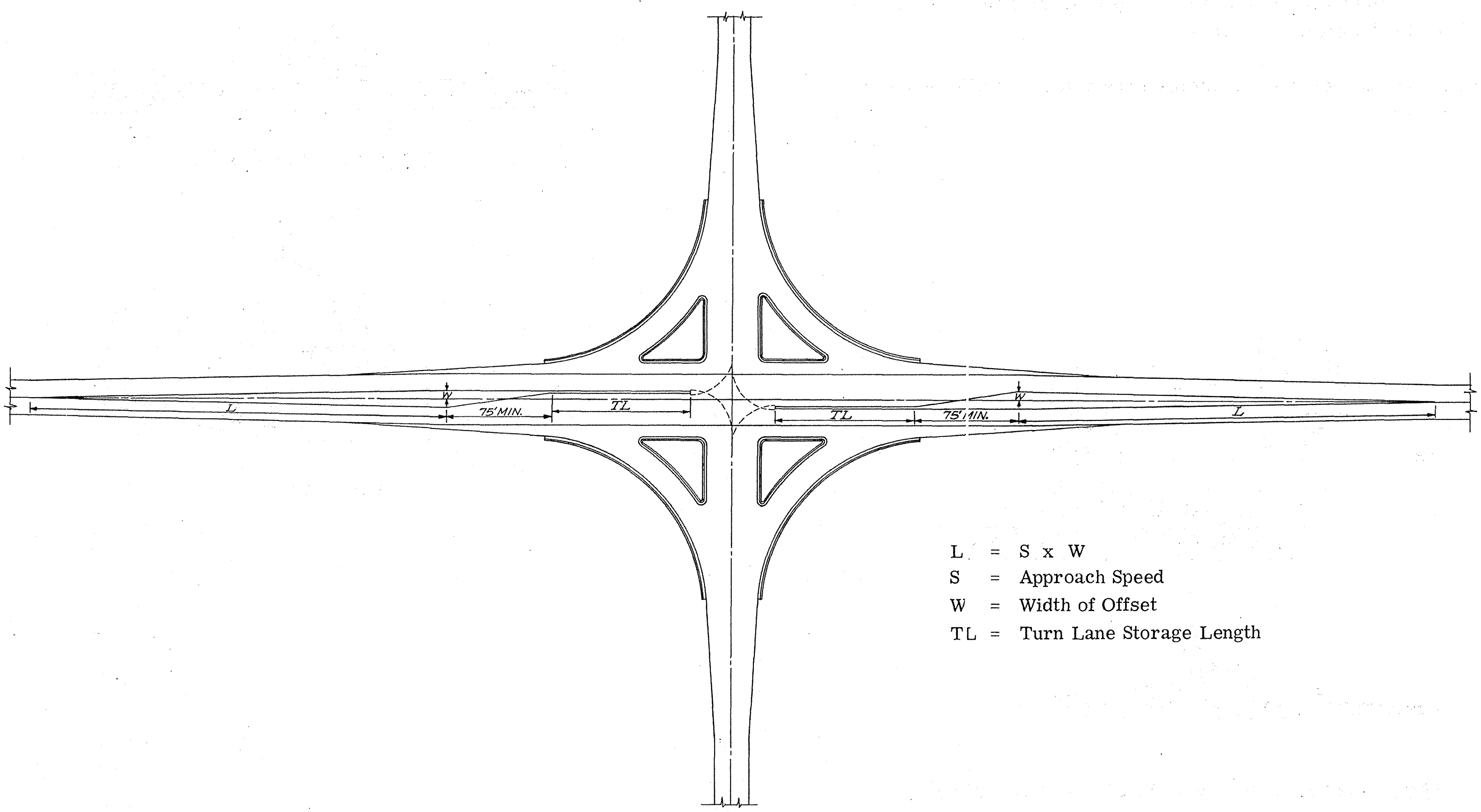
DESIGN CRITERIA
LOW-VOLUME CHANNELIZED INTERSECTION





RELATION BETWEEN INTERSECTING ANGLE AND RADII
(Based on 100-foot taper on local road, 150-foot taper on main line, and maintaining a 25-foot minimum width island.)

TYPICAL LAYOUT
LOW - VOLUME CHANNELIZED INTERSECTION
(4 legs, left turn lane on main line)

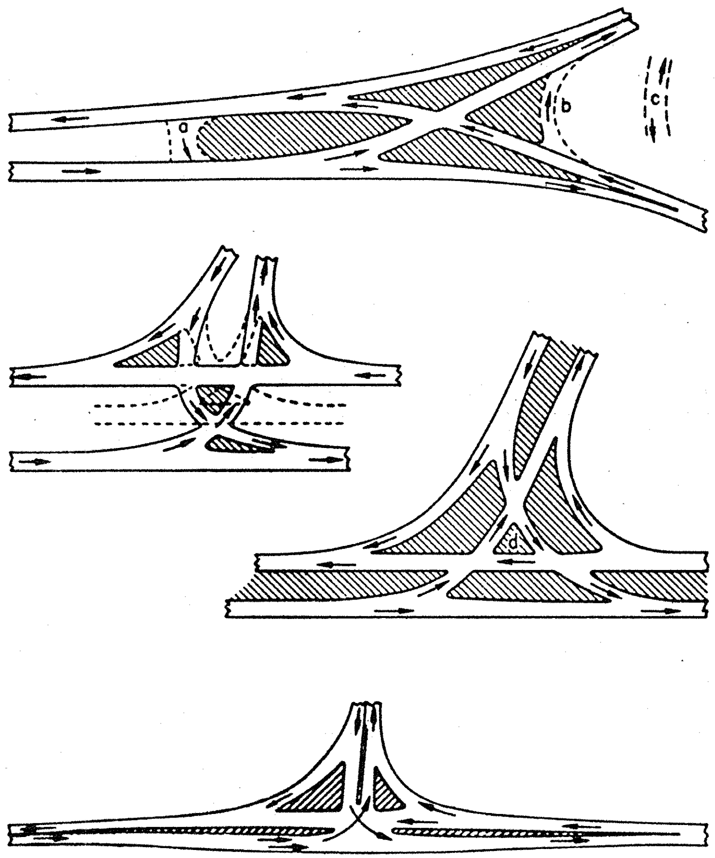


L = S x W
S = Approach Speed
W = Width of Offset
TL = Turn Lane Storage Length

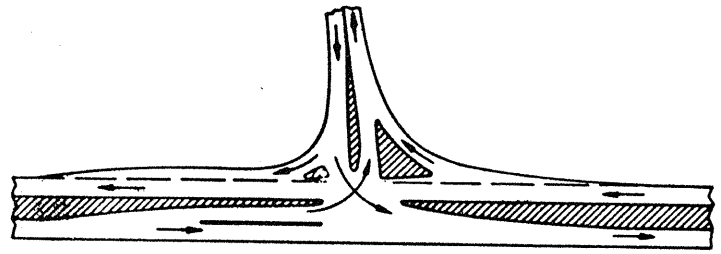
Channelized Intersections--High Traffic Volumes

With higher traffic volumes, channelization of intersections usually becomes more complex. Each situation must be studied individually with regard to volumes of turning movements, traffic lane configurations, potential conflicts and practical signing arrangements.

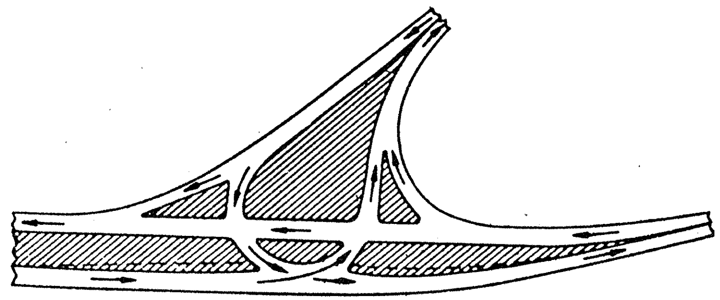
Typical layouts for T or Y intersections with high traffic volumes are shown as follows.



WITH DIVISIONAL ISLAND AND TURNING ROADWAYS



WITH MEDIAN LANES



BULB TYPE

MEDIAN OPENINGS

Median openings shall be provided on all divided highways--except those divided highways with Type 1 Access Control.

Median openings shall be spaced as follows:

- In urban areas, median openings shall be spaced no closer than 880 feet.
- In rural areas, median openings shall be spaced no closer than 1760 feet.

Generally, median openings are provided for all existing roads, streets and highways--provided such median openings are not spaced closer than 880 feet in urban areas or 1,760 feet in rural areas. Waiver of these minimum distances can be made only where existing roads, streets or highways with existing traffic patterns of prominent degree must cross the medial divider. Median openings provided for roads, streets and highways then become control points for determining spacing and location of intermediate median openings. The maximum number of equally spaced intermediate openings should be provided between control points.

Any deviation from the equal or minimum spacing-distance requirement must be approved by the Roadway Design Engineer.

Control Radii

Control radii reflect the path of design vehicles making a left turn at low speeds.

The following control radii can be used for minimum practical design:

R = 40' -- Accommodates P vehicles and occasional SU vehicles with some swinging wide

R = 50' -- Accommodates SU vehicles and occasional WB-40 vehicles with some swinging wide

R = 75' -- Accommodates WB-40 and WB-50 vehicles with only a few swinging wide.

Shape of Median Ends

The shape of the ends of medians at openings normally depends on the effective median width. In this case the effective median width is not the normal width between edges of traffic lanes--rather, it is the remaining width of the divider adjacent to the median left-turn lane.

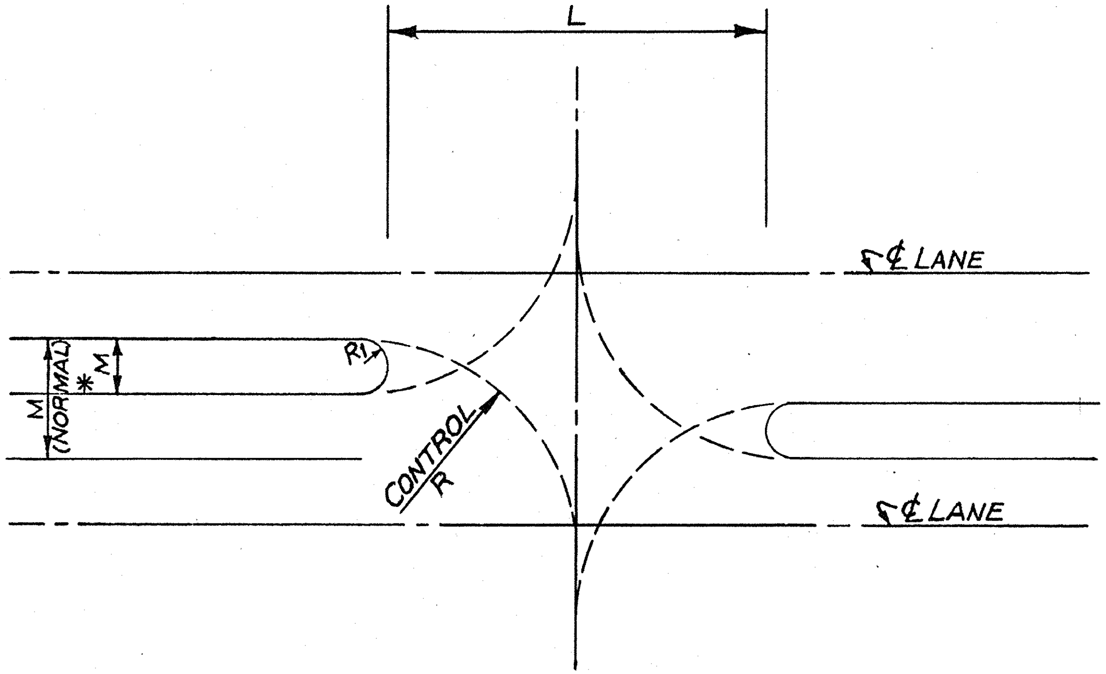
The table below shows criteria for shapes of median ends for various conditions of effective median width.

Effective Median Width	Median End Shape
Less than 10 feet	Semicircular
10 feet - 64 feet	Bullet
Over 64 feet	Treated as separate intersections

Examples of median opening design for each of the conditions above are shown in the figures on the next three pages.

MEDIAN OPENING DESIGN CRITERIA

(For effective median width of 64 feet or less)

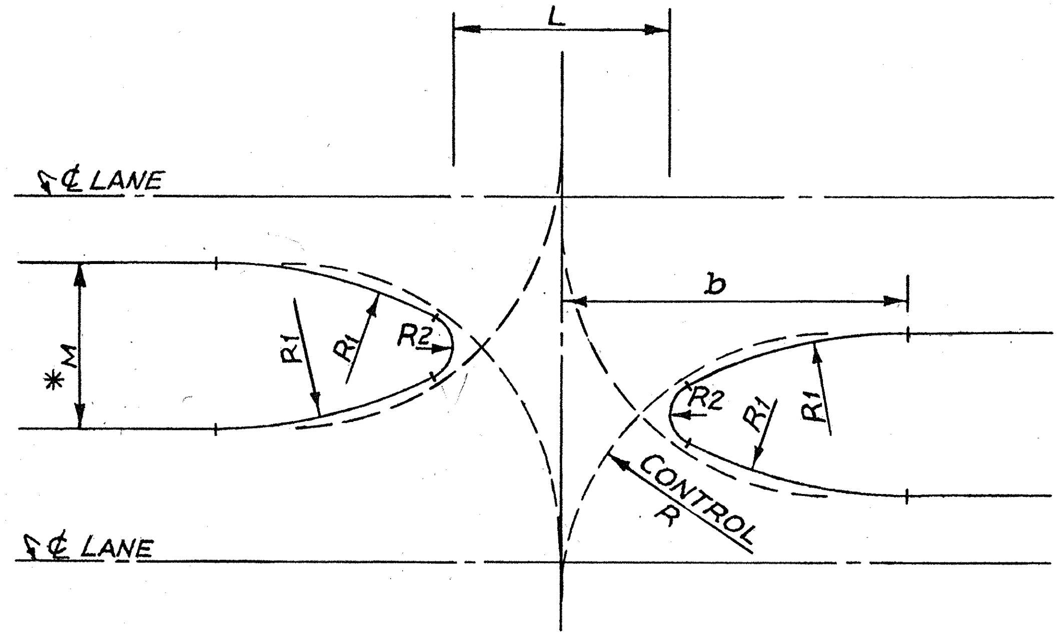


SEMICIRCULAR ENDS

*M = Less than 10 feet

L = 2 x Control R

$R_1 = \frac{M}{2}$



BULLET-NOSE ENDS

*M = 10 feet – 64 feet

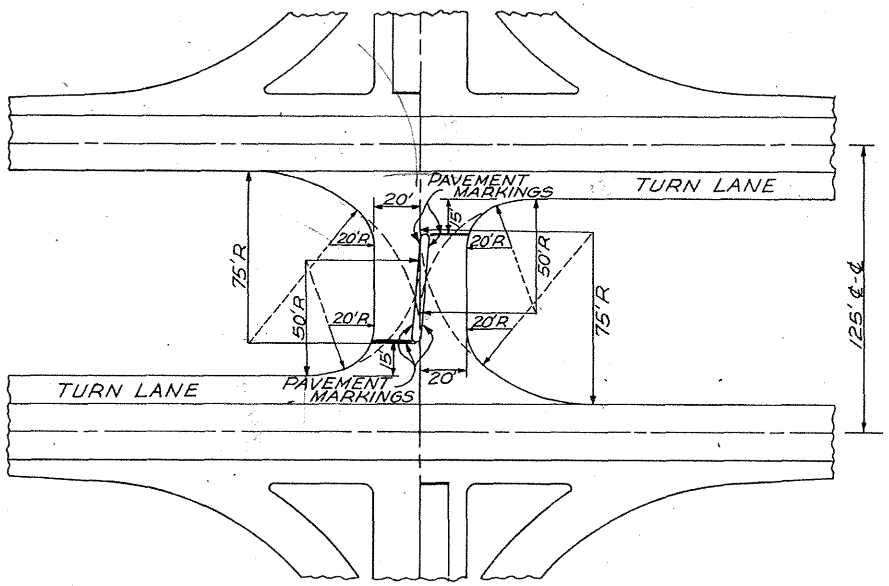
M* Width of Median (Feet)	Dimensions in Feet, when					
	R = 90'		R = 150'		R = 230'	
	L	b	L	b	L	b
20	58	65	66	78	71	90
30	48	68	57	85	63	101
40	40	71	50	90	57	109
50	—	—	44	95	51	115
60	—	—	—	—	46	122
70	—	—	—	—	41	128

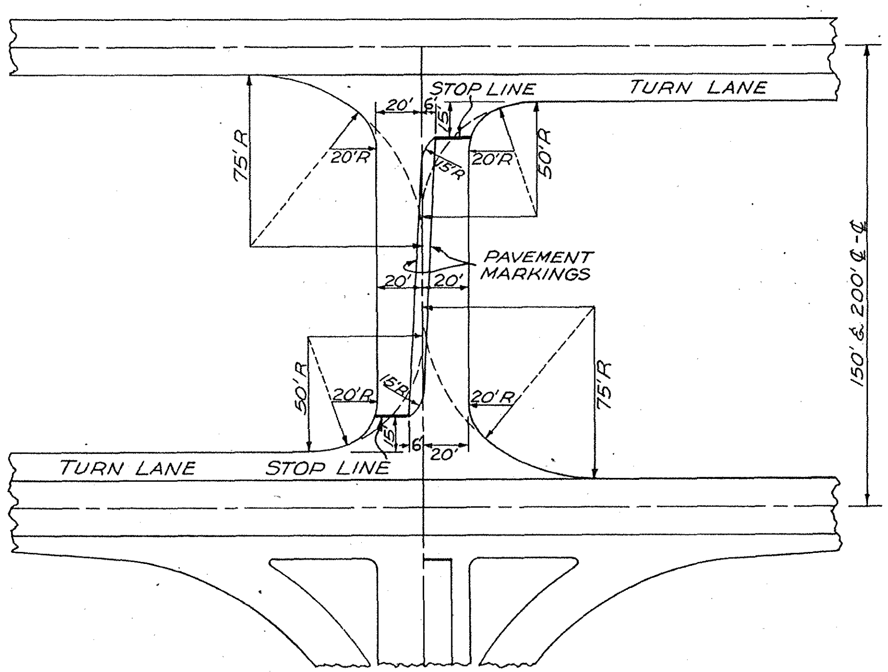
$R_2 = \frac{M}{5}$

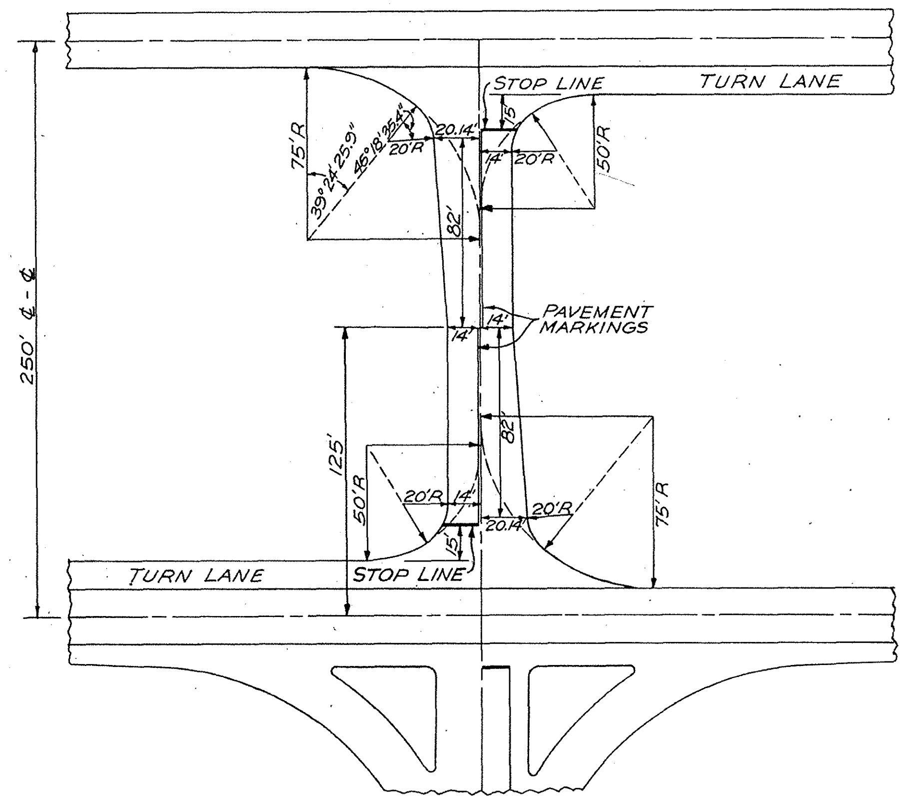
*The controlling median width (M), for the purpose of determining the length of opening, is the remaining width of divider adjacent to the median left-turn lane.

TYPICAL MEDIAN OPENINGS

Wide Medians - Crossovers At Intersections

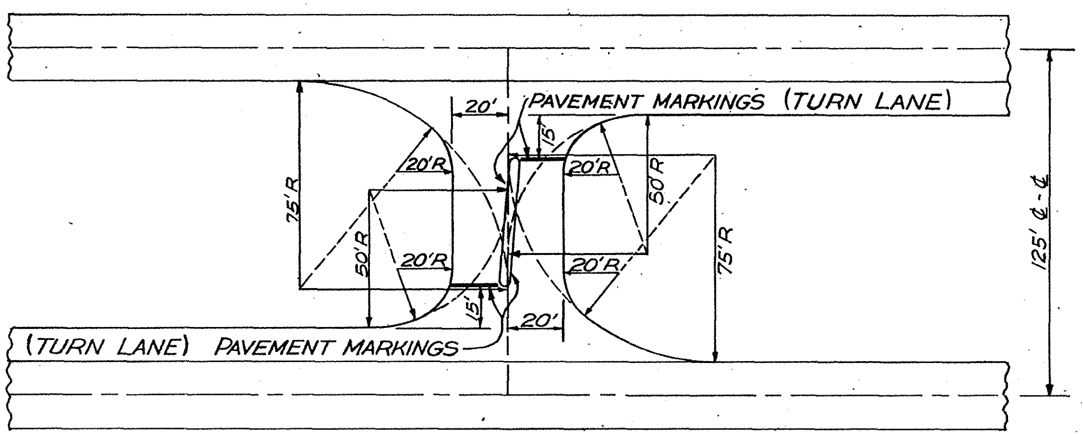


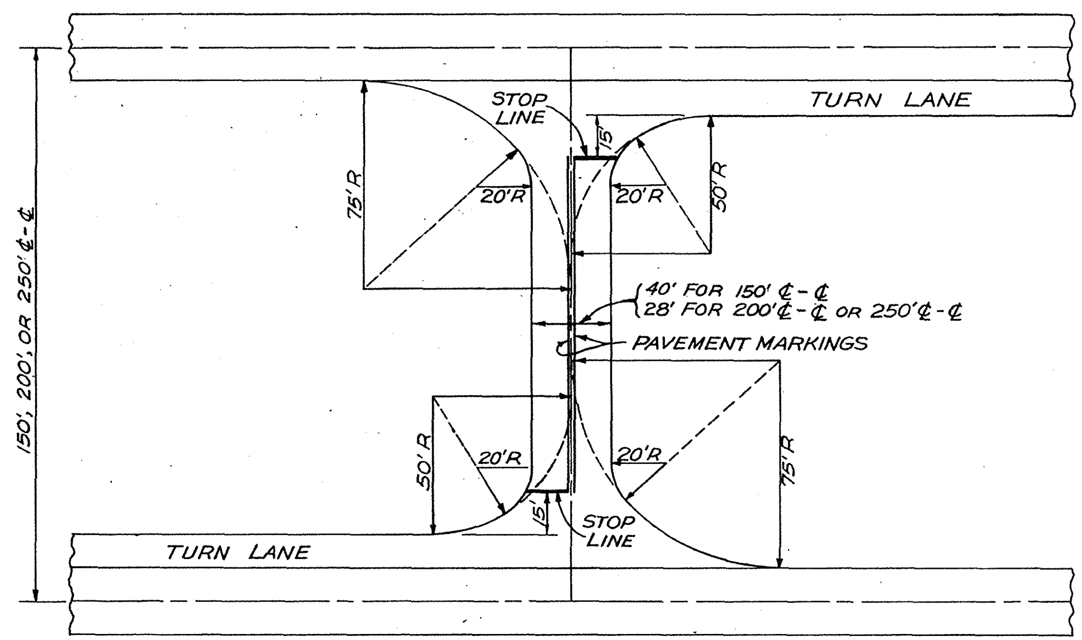




TYPICAL MEDIAN OPENINGS

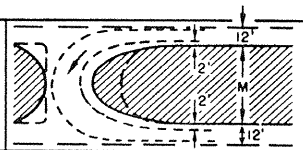
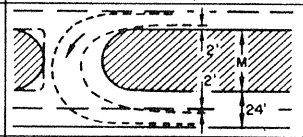
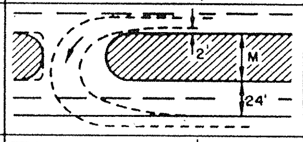
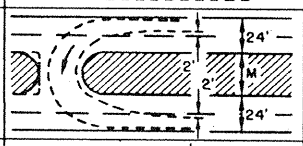
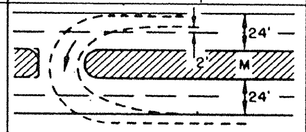
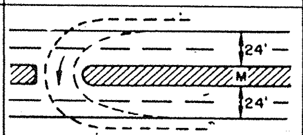
Wide Medians - Crossovers Without Road Intersections





Median Openings for U-Turns

Median openings designed to accommodate vehicles making U-turns only, are needed on some divided highways. Preferably, a vehicle should be able to begin and end the U-turn on the inner lanes next to the median--but the required median widths are larger than practicable on some highways. The following chart shows the median widths required for U-turn maneuvers by various design vehicles.

TYPE OF MANEUVER		M–Min. width of median–feet for design vehicle			
		P	WB-40	SU	WB-50
		Length of design vehicle			
		19'	50'	30'	55
Inner Lane to Inner Lane		32	60	64	70
Inner Lane to Outer Lane		20	48	52	58
Inner Lane to Shoulder		10	38	42	48
Outer Lane to Outer Lane		8	36	40	46
Outer Lane to Shoulder		0	26	30	36
Shoulder to Shoulder		0	16	20	26

INTERCHANGE DESIGN

The definition of an interchange is a grade-separated intersection with interconnecting roadways (ramps) for turning traffic between highway approaches.

Interchanges--Types and Adaptability

Interchanges are classified in a general way according to the number of approach roadways or intersection legs, as 3-leg, 4-leg, and multileg interchanges. These are further separated into more specific types, as the T and Y interchanges for the 3-leg; diamond, cloverleaf and directional interchanges for the 4-leg; and rotary, combination, and directional interchanges for the multileg. General types are illustrated in the figure on the next page.

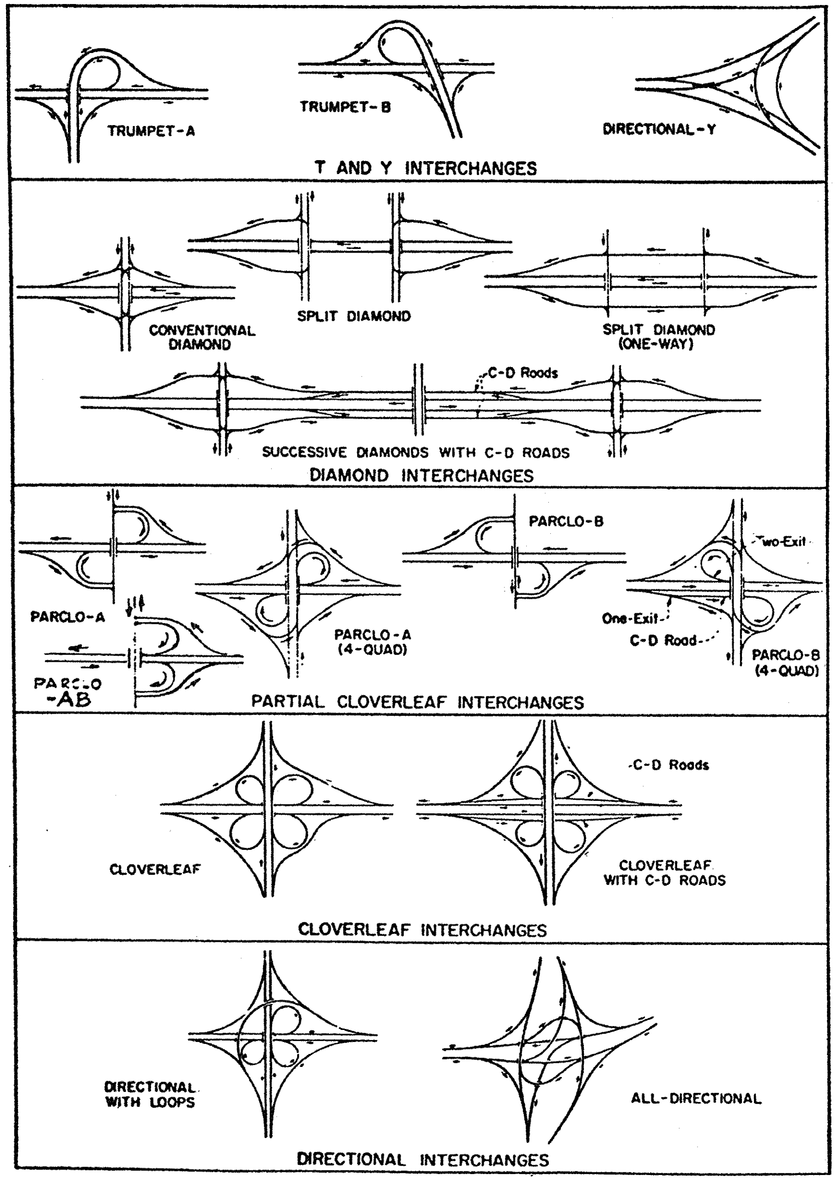
The specific form varies with physical controls (topography and culture), pattern and volume of traffic, and types of intersecting highways.

- T and Y Interchanges. The most common forms are the "trumpet" and the "directional Y." These involve a single structure. Where one freeway is intercepted by another, multistructure arrangements are apt to be used, providing directional forms of interchanges.

- Diamond Interchange. The simplest and perhaps most common type of interchange in urban areas is the "diamond." It consists of 4 one-way diagonal or parallel ramps, and can be designed within a relatively narrow right-of-way, entailing little, if any, extra width beyond that provided for the basic highway. The diamond interchange is adaptable exclusively to major-minor crossings, particularly in urban areas. Efficiency and capacity can be increased substantially by the use of a "split diamond."

INTERCHANGES

GENERAL TYPES AND TERMINOLOGY



- Partial Cloverleaf. This form usually involves two loop ramps and two or four outer ramps. Parclo (partial cloverleaf) interchanges are suitable along freeways at intersections with some primary highways in rural areas and with some major streets in urban areas.

- Cloverleaf (or Full Cloverleaf). The full cloverleaf has outer connections and loops in all quadrants. Cloverleaves are adaptable to intersections of freeways with major highways where speeds are high on both facilities.

- Directional Interchange. This form uses direct or semi-direct connections for one or more left-turning movements. Interchanges which involve two freeways nearly always call for directional layouts.

Specific forms of interchanges normally fit along a freeway in accordance with the type of intersecting facility, as follows:

In rural areas,

at minor road	--	diamond (channelized) or parclo-B (2-quadrant).
at primary highway	--	parclo-A (4-quadrant), cloverleaf (with C-D roads), or directional interchange.
at intersection of freeway	--	directional or all-directional interchange.

In urban areas,

at minor street	--	diamond.
at major street	--	diamond, split diamond, parclo-A (4-quadrant) or parclo-B (4-quadrant).
at intersection of freeway	--	directional or all-directional interchange.

Trends in Interchange Design

Interchanges have changed in form, shape and adaptability over the years. The trend today is toward:

- simplicity
- uniformity
- regularity (fewer forms, uniform numbers and shapes of ramps)
- single exits, and avoiding left-hand ramps.

Operational Uniformity

A consistent arrangement by which drivers exit in a uniform manner along a freeway is an essential feature of present-day design. Thus, regardless of the interchange at which the driver departs the freeway, he would always be confronted with the same type of exiting procedure--a single exit in advance of the structure. Considering the need for high capacity, appropriate level of service, and maximum safety in conjunction with freeway operations, it is necessary and justifiable to provide this uniformity.

Interchange Spacing

Spacing of interchanges has a pronounced effect on the operation of freeways. Proper spacing usually is difficult to attain in areas of concentrated urban development because of traffic demand for frequent access.

In urban areas the spacing of interchanges on freeways should rarely be less than 2/3 mile or 3600 feet (900-foot ramp plus 1800-foot weaving section plus 900-foot ramp). Preferably, the minimum should be upwards--4000 to 5000 feet. As an average, a minimum spacing of one mile is considered appropriate in urban districts. For conditions of heavy weaving or in conjunction with major interchanges, longer distances may be required. In outlying and rural areas, interchange spacing is more appropriately set at 1 1/2 and 2 miles.

Collector-Distributor Roads

A collector-distributor (C-D) road is an auxiliary roadway, separated laterally from and generally parallel to the freeway traveled way. It collects and distributes traffic from several access connections between a selected point of ingress to, and a selected point of egress from, the freeway traveled way. It provides greater capacity and permits higher speeds to be maintained on the through traveled way. C-D roads may be appropriate within an interchange, through two adjacent interchanges, or continuously for some distance along freeways through several interchanges.

Speed-Change Lanes

A speed-change lane is an auxiliary lane, including tapered areas, provided primarily for the acceleration or deceleration of vehicles entering or leaving the through traffic lanes. Speed-change lanes are required on expressways, and usually are warranted on high-speed and on high-volume highways at important intersections, and to some degree at minor intersections. The length of a speed-change lane depends on the relative design speed of highway and ramp, and on gradient. On freeways, deceleration-lane requirements are generally in the range of 400 to 600 feet, and acceleration-lane requirements in the range of 600 to 1200 feet.

The gradual taper arrangement--straight or slightly curved--normally is the most favorable design for both deceleration and acceleration. A parallel-lane or full-auxiliary-lane arrangement may be called for in case of adverse grade or to comply with capacity requirements. Width of auxiliary lanes should be equal to the width of through traffic lanes--12 feet on freeways.

Exit and Entrance Terminals

Ramp terminals may be similar to at-grade intersections, as at diamond or partial cloverleaf interchanges. They involve the same elements of design as any at-grade intersection.

Or, ramp terminals may be gradual or directional, where ramp traffic merges with or diverges from through traffic at flat angles. Design features for these terminals are illustrated in the figure at the the right. Of particular concern are speed-change lanes, nose offsets, nose tapers and recovery areas, and nose and merging-end radii.

Merging and Diverging Maneuver Areas

The merging maneuver area is the portion of acceleration lane contiguous with the through traveled way. Likewise, the diverging maneuver area is the portion of deceleration lane contiguous with the through traveled way. Minimum maneuver length requirements are in the range of 400 to 600 feet for merging, and 300 to 500 for diverging. Actually, the direct influence of merging and diverging maneuvers is considered to be double the above values; and these longer maneuver influence lengths, 600 to 1200 feet, are used as controls in design of successive exits and entrances, as discussed below.

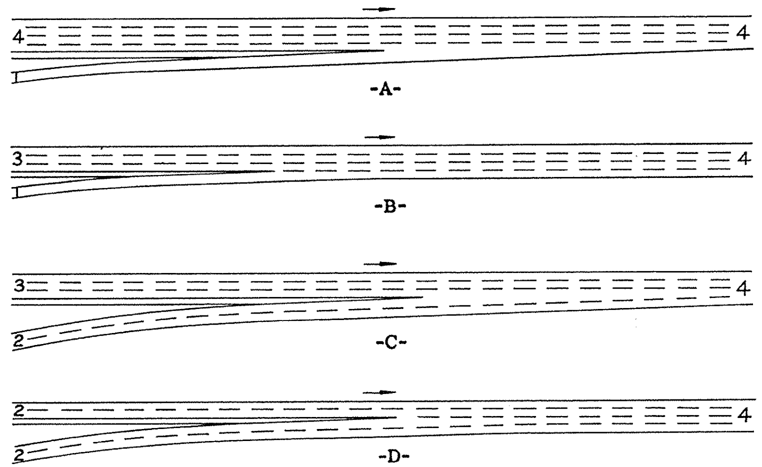
Lane Balance

The number of lanes on a freeway beyond the point of mergence should be equal to or greater than the number of lanes on the freeway in advance of the point of mergence, plus the number of lanes on the entrance ramp, minus 1. The number of lanes on a freeway in advance of the point of divergence should be equal to or greater than the number of lanes on the freeway beyond the point of divergence, plus the number of lanes on the exit ramp, minus 1.

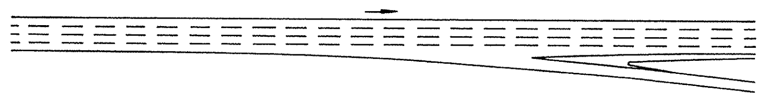
At ramp exits, the highway traveled way normally should not be reduced by more than one traffic lane at a time.

At ramp exits, the number of lanes going away (freeway plus ramp) normally should be equal to one more than the number on the freeway approaching the exit. This always provides an "optional lane" on which a driver has the choice of proceeding either on the freeway or on the ramp.

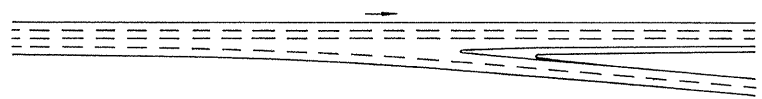
ENTRANCE AND EXIT TERMINALS



LANE ARRANGEMENTS FOR MERGING TRAFFIC



LANE ARRANGEMENT FOR DIVERGING TRAFFIC:
NORMAL SINGLE-LANE EXIT



LANE ARRANGEMENT FOR DIVERGING TRAFFIC:
NORMAL TWO-LANE EXIT

Distance Between Successive Ramp Terminals

Proper distance should be maintained between ramp terminals in succession. Minimum distances are predicated on the principle of not allowing the maneuver influence length of one ramp to overlap the maneuver influence length of the succeeding ramp. These distances are in the range of 600 to 1200 feet, as noted above. Minimum distances for signing also correspond to this range.

Between two successive exits or entrances on a freeway, spacing should be not less than 1200 feet. Minimum distances of 800 to 1200 feet are appropriate in conjunction with collector-distributor or major-interchange roadways. Within other interchange areas, distances of 600 to 800 feet may be appropriate.

Weaving Sections

Weaving sections permit the crossing of traffic streams moving in the same general direction by merging and diverging maneuvers, and they occur frequently along expressways and freeways in urban areas. Weaving sections are inherent in some interchanges, such as the cloverleaf and those with semidirect connections, and are also found between the ramps of successive interchanges.

Weaving sections are designed, checked and adjusted so that the service volume or capacity is greater than the design hourly volume. The operational features and capacity of a weaving section are dependent upon its length, number of lanes, speed of operation, and relative volumes of individual movements. The established relations of these factors are shown in Figure 7.4 and Table 7.3 in the Highway Capacity Manual, and are recommended as a basis for design.

Lengths of weaving sections should also be checked for required minimum distance between successive ramps. In the case of a weaving section--an entrance ramp followed by an exit ramp--the minimum distance should be predicated on two non-overlapping maneuver influence lengths; this calls for twice the indicated lengths of 600 to 1200 feet, or weaving section lengths in the range of 1200 to 2400 feet. Thus, minimum weaving lengths would be 1800 to 2400 feet on freeways, and 1200 to 1500 feet on high-type C-D roads.

Weaving may be removed from the freeway by the use of C-D roads, or it may be completely eliminated by introducing a grade-separation structure.

Ramp Types

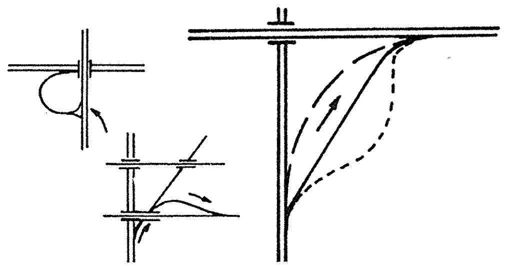
A right-turning ramp is normally a direct-connection type--that is, a ramp on which traffic turns right to go right. Such ramps are either curvilinear, straight-line or diagonal, or reverse-curve; and in all cases, they produce a right exit/right entrance situation (see examples A in the figure on the next page). Other operational patterns such as right exit/left entrance, or left exit/right entrance (examples D and E in the figure) are special adaptations rarely used in modern design for right-turning ramps.

Left-turning ramps, on the other hand, are separated into distinctive configurarions geometrically and operationally. The three basic geometric forms are the loop (example B), the semidirect (examples C, D and E), and the direct connection (example F).

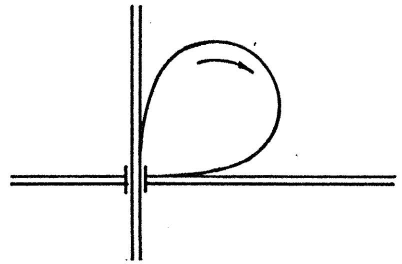
The loop--the most indirect of the three--always assumes a right exit/right entrance situation. The direct connection--the most direct of the three --always assumes a left exit/left entrance pattern. The semidirect connection (sometimes referred to as the jughandle ramp) can be arranged to produce three different operational configurations--right exit/right entrance, right exit/left entrance, and left exit/right entrance.

The various types of ramps can be thought of as individual elements or building blocks which, along with other units such as approach roadways and grade separation structures, can be assembled to produce many forms of interchanges.

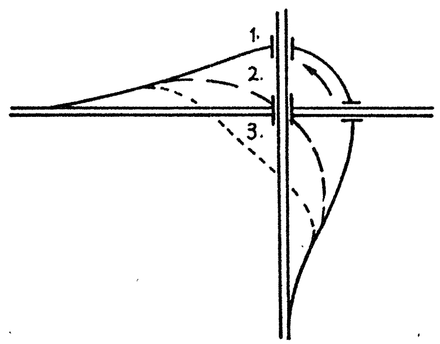
TYPES OF RAMPS



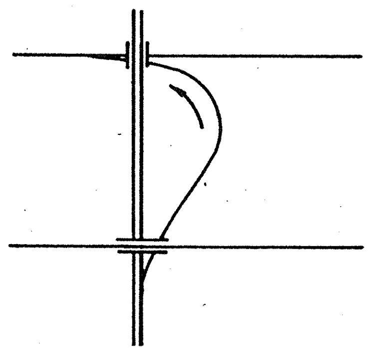
A RIGHT-TURN RAMP
Right Exit/Right Entrance



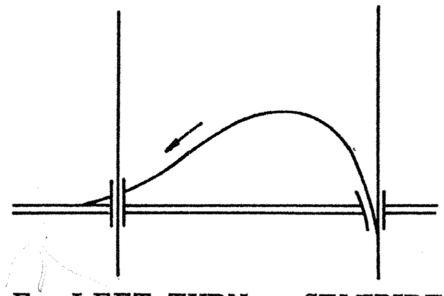
B. LEFT-TURN – LOOP
Right Exit/Right Entrance



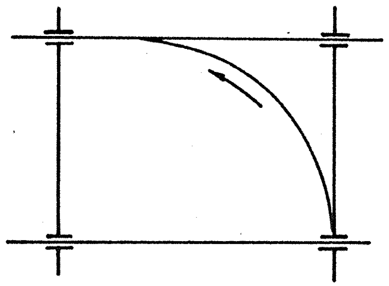
C. LEFT-TURN – SEMIDIRECT
Right Exit/Right Entrance



D. LEFT-TURN – SEMIDIRECT
Right Exit/Left Entrance



E. LEFT-TURN – SEMIDIRECT
Left Exit/Right Entrance



F. LEFT-TURN – DIRECT CONN.
Left Exit/Left Entrance

Ramp Design Speed

Except for directional-type interchanges of major highways, it is rarely feasible to provide ramps on which turning traffic can travel in the same range of speeds as on the through roads. But it is desirable that drivers be able to use ramps at as high a speed as practicable so that they will require little conscious effort to decrease from or increase to the speed of through traffic. The design speed of the ramps, therefore, should be related to the design speeds of the intersecting roadways.

Guide values for ramp speeds in terms of highway design speeds are shown in the following table. Desirable design speeds should be used where feasible.

Highway design speed, mph	30	40	50	60	65	70
Ramp design speed, mph						
Desirable	25	35	45	50	55	60
Minimum	15	20	25	30	30	30
Minimum radius, feet						
Desirable	150	300	550	690	840	1040
Minimum	50	90	150	230	230	230

Ramp Profiles

Ramp grades should be as flat as feasible to minimize the driving effort required in maneuvering from one road to the other.

The profile of a typical ramp usually consists of a central portion with an appreciable grade, coupled with terminal vertical curves and connections to the profiles of the intersection legs. The steeper central portion of the ramp usually is relatively short and has only moderate operational effect. Even so, ramp gradients should generally be limited to a range of values as shown below.

Ramp design speed, mph	15-20	25-30	35-40	45-50
Ramp gradient, percent	6-8	5-7	4-6	3-5

The values above apply to both up-ramps and down-ramps--but in special cases, one-way down-ramps may be steeper by up to 2 percent.

The customary practice of designing only centerline profiles and tying them into the through road centerline at both ends will not always result in a smooth connection. Profile grades should be established for the ramp edge of pavement and coordinated with the extension of the cross slope of the main roadway. Desirable terminal profiles are more readily produced through use of spline curves and edge of pavement base lines.

Ramp Cross Section

The pavement for ramps should be generally consistent with the criteria previously set forth in this chapter for turning roadways.

For single-lane one-way ramps at interchanges, the Department has established the following consistent criteria for cross-section geometrics:

- Pavement width -- 16 feet
- Shoulder width -- 6 feet left and 10 feet right
- Paved shoulder -- 3 feet left and 6 feet right.

For loops, the standard cross section should be as follows:

- Pavement width -- 20 feet with a curb on right
- Shoulder width -- 6 feet left and 10 feet right
- Paved shoulder -- 3 feet left.

Intersections at Diamond Ramp Terminals

The intersection of ramp terminals with minor crossroads at diamond interchanges requires special design considerations. Although it would appear that this situation would be treated as any other normal intersection, there are two unique features not usually found in other intersections in rural areas.

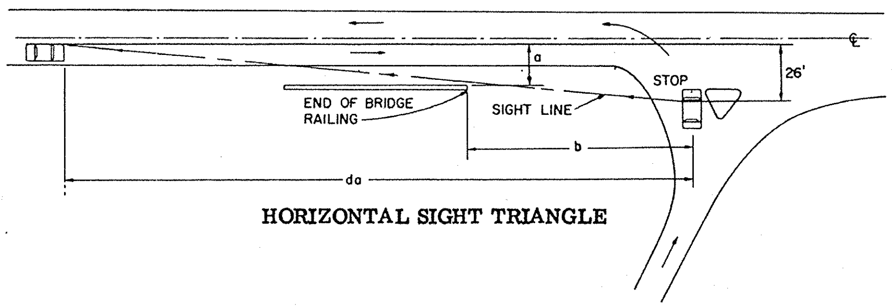
First, the ramps at diamond interchanges are always one-way so that no crossing of the crossroad is involved; and second, there is invariably a structure in the vicinity which may restrict sight distance. This restriction may control the location of the ramp terminal where signals are not used.

The length of highway open to view from the ramp terminal must be greater than the product of the design speed (or predicted speed) of a vehicle on the crossroad and the time necessary for the vehicle entering the crossroad from a stopped position on the ramp to start and complete a left turn into the crossroad. The required sight distance along the crossroad is shown below for various design speeds on the crossroad and various design vehicles at the ramp terminal.

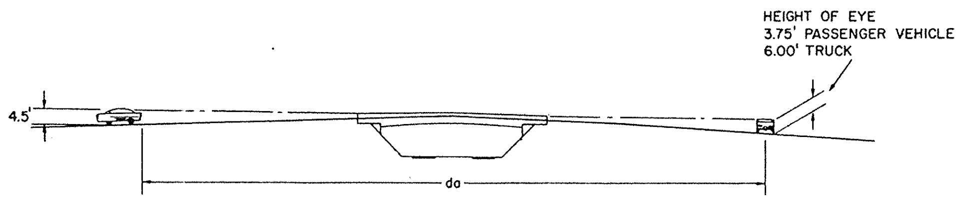
Design Speed on Crossroad	Sight Distance Required To Permit Design Vehicle To Turn Left from Ramp to Crossroad--feet		
	Design Vehicle at Ramp Terminal		
	P	SU	WB-50
70	740	1060	1430
60	630	910	1230
50	530	760	1030
40	420	610	820
30	320	460	620

The horizontal sight triangle should be checked with regard to piers, abutments, railings or other obstructions. And the vertical sight distance should be checked in terms of length of vertical curve and algebraic difference of grades. The check is best done graphically. Typical conditions at a diamond interchange ramp terminal are shown in the following illustration--where "da" is the measured available sight distance.

MEASUREMENT OF SIGHT DISTANCE
AT DIAMOND RAMP TERMINALS



HORIZONTAL SIGHT TRIANGLE



VERTICAL SIGHT DISTANCE

If the available sight distance is less than the requirements shown in the table, one or more of the following adjustments should be made.

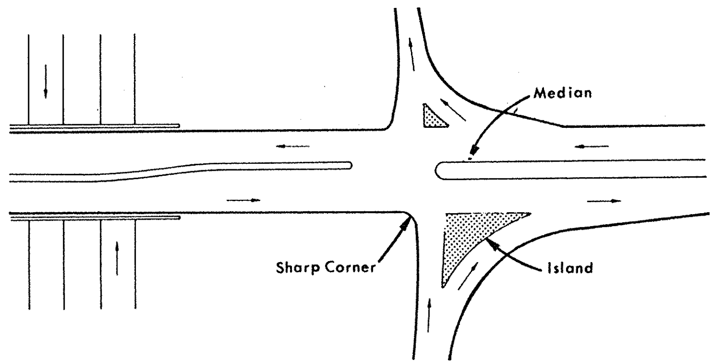
- Lengthen the vertical curve.
- Relocate the ramp terminal farther from the structure.
- Install traffic signals at the ramp terminal intersection.

One additional factor should be considered. An inherent problem of diamond interchanges is the possibility that--in spite of signing--a driver will enter one of the exit terminals from the crossroad and proceed along the freeway in the wrong direction. Attention to several details of design at the intersection can discourage this hazardous maneuver.

In the figure below, a "sharp" or angular intersection is provided at the junction of the left edge of the ramp pavement and the right edge of the through pavement. The control radius is tangent to the centerline, not the edge. This tends to discourage improper right turns into the one-way ramp.

Islands can be used to channelize traffic into proper paths. And where economical, a median provides an effective deterrent to left-turn movements into the exit ramp.

DETERENTS TO WRONG-WAY TURNS
AT DIAMOND INTERCHANGE RAMP TERMINALS



DESIGN CONSIDERATIONS

Chapter 9

PAVEMENT STRUCTURE

This chapter deals with criteria and procedures for designing a pavement structure and for estimating quantities of contract pay items. Pavement design policies specifically applicable to State Aid projects are set forth in a separate State Aid Base Design Manual.

GENERAL RESPONSIBILITIES

Responsibilities for analyses of materials and design of pavement structures are shared jointly by the District, the Roadway Design Division and the Central Laboratory.

The District conducts the initial soil investigation and prepares an original soil profile which identifies the characteristics of the roadbed material. Based on this data, initial design recommendations are developed and submitted to the Roadway Design Division along with other survey information.

Material samples are submitted to the Central Laboratory for analyses, and recommendations are prepared for the design of any special treatments.

The Roadway Design Division reviews all data and recommendations, makes any appropriate revision, prepares a pavement type determination, and finalizes the design to be shown on the contract plans.

After the embankments have been constructed, the District makes a soil investigation and prepares a final soil profile to verify the accuracy of the original soil profile, and makes recommendations, if needed, for any adjustment in the structure design.

The squad leader is advised of the pavement structure details, and he is responsible for design of the roadway typical sections and elevations to accommodate the pavement structure. Also, he is responsible for estimating the pay item quantities.

STRUCTURE COMPONENTS

The Department recognizes four basic components of a pavement structure:

- Pavement
- Base Course
- Subbase Course
- Design Soil Treatment.

The various alternatives for each of the basic components are described below.

Pavement

The pavement is the top component of a pavement structure on which vehicles travel. There are three standard types of pavement:

- Bituminous Surface Treatment
- Hot Bituminous Pavement
- Portland Cement Concrete Pavement.

The use of bituminous surface treatment is limited to the lower traffic volume roads with a projected ADT of 3,000 or less. The hot bituminous pavement and portland cement concrete pavement are both high type pavements, and either may be specified for major highways. The choice usually is based on economics, soil conditions and other governing factors.

Base Course

The component immediately below the pavement is the base course. The three most common and frequently used bases are:

- Granular Base Course
- Cement Treated Granular Base Course
- Plant Mix Bituminous Base Course.

The granular base course ordinarily is limited to the lower traffic volume roads with bituminous surface treatment. Plant mix bituminous base usually is used under hot bituminous pavement and portland cement concrete pavement. The cement treated granular base course may be specified under all three of the pavement types.

Subbase Course

The subbase course is beneath the base. It is usually constructed of a more economical material of lesser quality than the base course. The two standard types are:

- Granular Subbase Course
- Cement Treated Granular Subbase Course.

Design Soil Treatment

"Design soil" is defined as that portion of the roadbed consisting of the three feet of soil immediately below the subbase. This may be undisturbed natural earth strata in areas of excavation or embankment constructed with unclassified excavation.

Under certain conditions, it may be necessary to specify special treatment of the design soil. Three types of treatment are:

- Lime Treated Design Soil Course
- Cement Treated Design Soil Course
- Lime-Cement Treated Design Soil Course.

Design soil treatment must be considered in the design of pavement structures. Although the treatment is not considered a part of the total pavement structure, its allowable credit may eliminate or reduce the thickness of the subbase course.

STRUCTURE THICKNESS

The total pavement structure may be made of various components described in the preceding section. The principal criteria for the thickness of the pavement structure courses are related to the traffic volume, proportionate number of trucks, California Bearing Ratio (CBR), and soil characteristics of the roadbed.

The analysis of traffic and the roadbed soil conditions results in a Structural Number (SN) which may be converted to thickness of pavement layers through the use of suitable layer coefficients.

Pavement and Base Course Combinations

To facilitate the structure design process, several standard combinations of pavement and base courses have been established for alternative consideration. These combinations are shown in the table below. They are related principally to traffic volume and structural number.

PAVEMENT AND BASE DESIGN CRITERIA 1/

Projected Traffic ADT	Pavement Type and Thickness	Base Course Thickness		
		Granular Base	Cement Tr. Base	Bitum. Base
Under 1000	Dbl. Bitum. Surface Tr.	8	-	-
	Dbl. Bitum. Surface Tr.	-	6"	-
1000 - 2000	Dbl. Bitum. Surface Tr.	11"	-	-
	Dbl. Bitum. Surface Tr.	-	8"	-
2000 - 3000	Dbl. Bitum. Surface Tr.	-	8"	-
	3" Hot Bitum. Pavement 2/	-	8"	-
	$2\frac{1}{2}$" Hot Bitum. Pavement 2/	-	-	$5\frac{1}{2}$"
3000 - 4000	4" Hot Bitum. Pavement	-	8"	-
	3" Hot Bitum. Pavement	-	-	6"
Over 4000	5" Hot Bitum. Pavement	-	8"	-
	4" Hot Bitum. Pavement	-	-	6"
	8" P.C. Concrete Pavement, conventional or continuously reinforced	-	6" OR 4"	
Interstate	4" Hot Bitum. Pavement	-	-	$8\frac{1}{2}$"
	9" Conventional Reinforced Concrete Pavement	-	6" OR 4"	
	8" Continuously Reinforced Concrete Pavement	-	6" OR 4"	

1/ This chart IS NOT a complete design process. The subbase and/or design soil treatment must be determined to complete the pavement structure.

2/ Minimum design for the legal load limit of 73,280 pounds.

Subbase and Design Soil Treatment

After a particular combination of pavement and base course has been selected, the subbase course and design soil treatment are designed to provide the remainder of the structural number required for the specific soil conditions.

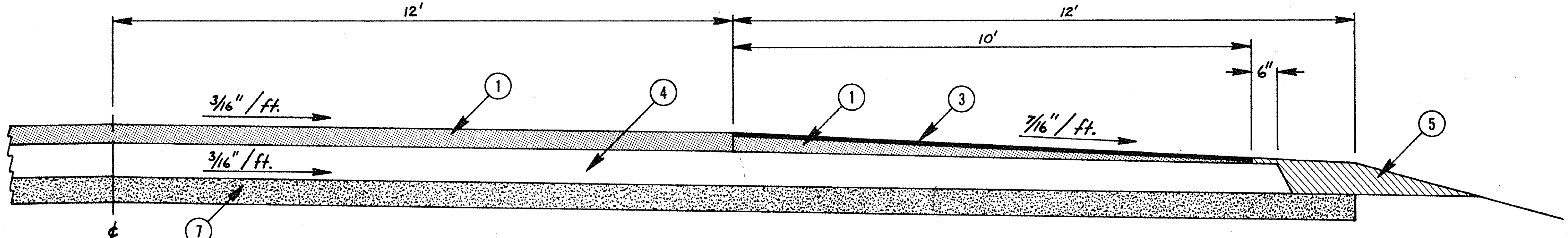
Various combinations of these two components may be specified. With sufficient thickness of subbase course, the design soil treatment may not be necessary. Additional thickness of design soil treatment will eliminate or reduce the required thickness of subbase course. Criteria for required structural numbers and coefficients of relative strength are shown in the Department publication, "Thickness Design of Pavement Structures for Highways and and Streets."

PAVEMENT DETAILS

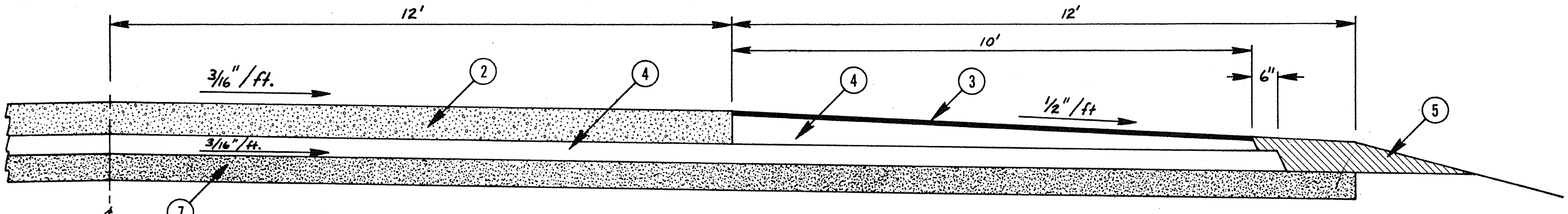
Examples of three types of pavement are shown on page 9-4, the sheet of Typical Pavement Details.

The design details of the pavement structure courses must be clearly identified in the contract plans. Typical sections should be prepared showing the thickness, geometric shapes and dimensions to be constructed. Example typical sections are shown in model contract plans in Chapter 12.

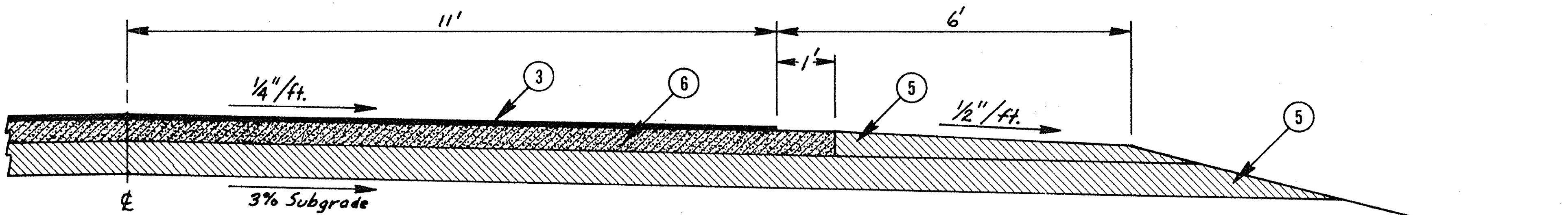
TYPICAL PAVEMENT DETAILS



HOT MIX BITUMINOUS PAVEMENT



PORTLAND CEMENT CONCRETE PAVEMENT



DOUBLE BITUMINOUS SURFACE TREATMENT

(1) Hot mix bituminous pavement

(2) Portland cement concrete pavement

(3) Double bituminous surface treatment

(4) Plant mix bituminous base course

(5) Granular material

(6) Cement treated granular base course

(7) Cement treated or lime treated design soil course

Layers of Hot Bituminous Pavement

Hot bituminous pavement normally is designed and constructed in several layers. Each layer is identified separately on the typical section because the specifications are different and each type of layer is measured and paid for separately.

The three types of layers are:

- Leveling Course
- Binder Course
- Surface Course.

The leveling course is used only to correct irregularities in an existing pavement that is to be overlaid with hot bituminous pavement.

Depending on the total thickness of pavement, various combinations of binder and surface courses may be used. Typical designs are shown below.

Total Thickness of Pavement	Layers	
	Binder Course	Surface Course
$1\frac{1}{2}$"	-	$1\frac{1}{2}$"
$2\frac{1}{2}$"	$1\frac{1}{2}$"	1"
3"	$1\frac{1}{2}$"	$1\frac{1}{2}$"
4"	2 @ $1\frac{1}{2}$"	1"
$4\frac{1}{2}$"	2 @ $1\frac{1}{2}$"	$1\frac{1}{2}$"
5"	1 @ 2" and 1 @ $1\frac{1}{2}$"	$1\frac{1}{2}$"

Stage Construction

Under certain conditions, some form of stage construction may be specified for paving of a project. This might include:

- a grading and drainage project--with all paving planned as a future project.

- a project which includes only a portion of the total pavement--with additional courses planned at a future date.

In these cases, the typical section should clearly show details of the work to be included in the current contract. Any future pavement should be shown with a dotted line to identify the thickness of the ultimate pavement structure--but detailed descriptions of the future course need not be shown.

Special Designs

In addition to showing typical sections of the main highway, separate typical sections may be needed for paving of supplemental roadways such as:

- interchange ramps
- frontage roads
- intersecting roads
- driveways.

Because soil conditions may vary, the details of the pavement structure may not be consistent throughout the project length. Thickness may vary--and special treatment of unstable material may be specified for some sections. Each different situation must be represented by a typical section--clearly indicating the design details and applicable limits by stationing.

INTERSECTION AND DRIVEWAY PAVEMENTS

The paving of intersections must be identified on the plans and quantities included in the estimate. Details of pavement should be shown on typical sections and identified with particular locations as needed.

The following general criteria are applicable.

Public Road Intersections

Intersections with public roads normally will be paved to the right-of-way line. If the existing road is paved, the new pavement may extend beyond the right-of-way line as needed.

Driveways and Ramps

Driveway and ramp are terms used to designate a private connection between the roadway and the adjoining property. Driveways are curbed and ramps are without curbs.

Existing paved driveways and ramps are reconstructed and paved as required to provide a smooth connection. Driveways not currently paved should be paved to the curb returns, and ramps to the highway shoulder line. The remainder of the driveway or ramp will be surfaced with granular material.

BRIDGE END PAVEMENT AND LUG ANCHORS

The use of high type pavement requires the consideration of special design criteria at bridge ends. Other locations also require special treatment when concrete pavement is specified.

Bridge End Pavement

Because of potential differential settlement between a bridge deck and adjacent roadway pavement, a specially designed reinforced concrete slab shall be provided to assure a continuing smooth transition. Whenever high type pavement is used, bridge end pavement is to be the same width as the bridge--other design details are included in the Standard Drawings.

Lug Anchors

Concrete pavement can be expected to expand and contract with changes of temperature. This can become critical at the ends of pavement where there is more freedom of movement. To minimize this longitudinal movement, concrete lug anchors must be specified. They are cast monolithically on the underside of the pavement in a transverse pattern, and act as a type of anchor with the roadbed.

Design details for concrete pavement lug anchors and their installation are shown in the Standard Drawings.

Lug anchors should be specified at locations such as bridge ends, railroad crossings, and terminal connections with existing or future hot bituminous pavements.

ESTIMATING QUANTITIES

The designer must compute estimated quantities of required materials in terms established for contract pay items. Computation worksheets should be documented carefully and placed in the project file folder. Estimated quantities, along with pay item numbers, are recorded in the Summary of Quantities in the contract plans.

Generally, quantity estimates should be made in accordance with the following criteria.

Rigid Pavement

Rigid pavement is measured in terms of square yards of surface area.

Estimates must be made separately for each type of pavement (reinforced cement concrete, plain cement concrete, or continuously reinforced concrete) and each thickness.

The following items are estimated in terms of linear feet:

- expansion joints (with dowels)
- expansion joints (without dowels)
- concrete lug anchors.

Bridge end pavement is estimated on a square yard basis.

Hot Bituminous Pavement

Hot bituminous pavement is estimated in terms of tons of material. A unit weight of 110 pounds per square yard per inch of thickness should be used for estimating purposes.

Separate estimates are made for each of the identified layers of hot bituminous pavement--surface course, binder course and leveling course.

Bituminous Surface Treatment

A bituminous surface treatment may consist of one or more layers of aggregate cover material.

A double bituminous surface treatment (D.B.S.T.) normally consists of the following sequence of operations:

1. Application of asphalt cement
2. Application of coarse aggregate
3. Second application of asphalt cement
4. Application of seal aggregate.

The type and kind of aggregate cover material are specified as a portion of the pay item nomenclature.

Seal aggregate cover material may be crushed slag, gravel or stone, all of which are type VI. As an alternate bid item, state projects with a low volume of traffic may include expanded clay aggregate, type VIII.

Coarse aggregate cover material may be types I, II, II modified, and III, all of which are crushed slag or stone; or types IV, V, and V modified, all of which are crushed or uncrushed gravel.

Normally, alternate coarse aggregate cover materials will be specified. Type I, crushed slag or stone, and type IV, uncrushed gravel, will be specified for a granular base course. Type II, crushed slag or stone, and type V, uncrushed gravel, will be specified for a cement treated granular base course.

The asphalt cement is estimated in gallons at a combined rate of application of 0.75 gallons per square yard.

Both applications of aggregate are measured in cubic yards--but have separate pay items.

For estimating purposes, the rates of application are:

- Coarse Aggregate -- 0.52 cubic foot per square yard
- Seal Aggregate -- 0.28 cubic foot per square yard.

Prime Coat

A bituminous prime coat should be specified for treatment of the compacted granular base course which is to precede construction of a bituminous base, hot bituminous pavement or bituminous surface treatment.

The prime coat is expressed in gallons at a rate of application of 0.35 gallons per square yard.

Plant Mix Bituminous Base Course

The unit of measurement for plant mix bituminous base course is tons of material complete-in-place. A unit weight of 110 pounds per square yard per inch of thickness should be used for estimating purposes.

Cement Treated Subbase or Base Course

Three contract pay items must be estimated for cement treated courses:

- cubic yards of granular material
- barrels of portland cement
- square yards of soil-cement-water mixing-- for each depth course.

The rate of application for the cement is shown as a percent (by volume) of the granular material to be stabilized. The appropriate percentage for individual projects will be determined by analysis of the materials--and will be specified for the designer.

The barrels of portland cement are estimated by the following formula:

$$P.C. = A \times D \times R \times 0.01 \times 6.75$$

where P.C. = Portland cement in barrels
A = Area in square yards
D = Depth in yards (inches converted to yards)
R = Percent cement by volume
0.01 = factor to convert % to decimal
6.75 = $27 \div 4$ (27 cu. ft./cu. yd.; 4 cu. ft./bbl.)

then

$$P.C. = 0.0675 \times A \times D \times R$$

Granular Subbase or Base Course

Granular material for subbase or base is measured and estimated by the cubic yard or ton. Each different class or group designation must be identified and estimated separately.

When measured by the ton, the weight shall be determined by dry-weight at 100% proctor density with an estimated unit dry-weight for each class as follows:

Class	Lbs./Cu. Ft.
1 and 2	131
3 and 4	129
5 and 6	127
Other classes	114

Lime Treated Design Soil Course

Two contract pay items must be estimated for lime treated design soil:

- tons of hydrated lime
- square yards of soil-lime-water mixing-- for each depth and class.

The rate of application for the lime will vary depending on the soils analysis of individual projects--or even sections of highway within a project. The designer will be advised of station limits for treatment and the appropriate class and rate of lime application in terms of pounds per square yard.

Soil-lime-water-mixing is measured by the square yard, complete in place, for each required course. Therefore, only one mixing operation is estimated regardless of the number of applications of materials and the number of mixing operations.

The estimated tons of hydrated lime are:

$$H.L. = A \times D \times R \div 2000$$

where

H. L. = Hydrated lime in tons
A = Area in square yards
D = Depth in inches
R = Rate -- lbs./sq.yd./inch depth
2000 = pounds/ton

Cement Treated Design Soil Course

Two contract pay items must be estimated for cement treated design soil:

- barrels of cement
- square yards of soil-cement-water mixing-- for each depth course.

For the method of estimating barrels of portland cement, see the section titled "Cement Treated Subbase or Base Course."

Lime-Cement Treated Design Soil Course

Three contract pay items must be estimated for lime-cement treated design soil:

- tons of hydrated lime
- barrels of cement
- square yards of soil-lime-cement-water mixing-- for each depth course.

For methods of estimating barrels of portland cement and tons of hydrated lime, see sections titled "Cement Treated Subbase or Base Course" and "Lime Treated Design Soil Course."

Soil-lime-cement-water mixing is measured by the square yard, complete in place, for each required course. Therefore, only one mixing operation is estimated regardless of the number of applications of materials and the number of mixing operations.

Pavement Skid Reduction

Reduction of skidding accidents to a minimum requires the provision of as high a level of skid resistance throughout the life of the pavement as is economically feasible. Two designs currently under consideration by the Department are plastic grooving of concrete pavement, and open-graded plant mix pavement. Both designs offer good potentials for skid reduction.

Chapter 10

MISCELLANEOUS DESIGN

PROTECTIVE BARRIERS

The purpose of protective barriers is to reduce accident fatalities and injuries by decreasing severity of crashes. Three types of barriers are discussed in this section:

- Longitudinal guardrail
- Median barriers
- Impact attenuators.

Designers should recognize that a protective barrier is in itself a roadside obstacle and thus its installation may not contribute to safety. Generally, a barrier is warranted only at locations where the severity of a collision with the roadside feature would be greater than that with the traffic barrier. Where traffic barrier requirements are indicated by warrants, the roadway should be examined to determine the feasibility of adjusting site features so that the barrier will not be required.

The criteria and procedures herein for protective barriers are based principally on the findings and recommendations of two reports--(1) the AASHTO Report on "Highway Design and Operational Practices Related to Highway Safety" (yellow book) and (2) NCHRP Report 118, "Location, Selection, and Maintenance of Highway Traffic Barriers." Designers should refer to these publications for additional background on the subject.

Guardrail

All new guardrail installations shall be blocked-out steel W-beam with wood or steel posts. Details of the beam, posts, spacing, terminal ends and typical installations are shown in the standard drawings.

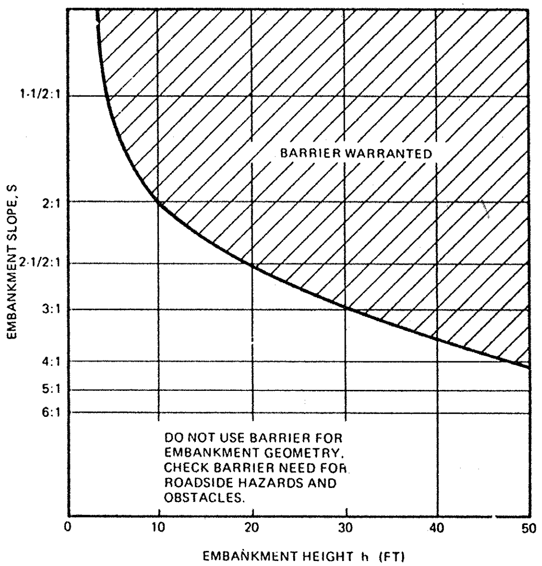
The following general criteria shall govern decisions concerning new guardrail installations:

Bridge Ends. Flared guardrail installations shall be provided at all bridge ends. For State Aid System construction, this requirement applies only to Federal-aid projects.

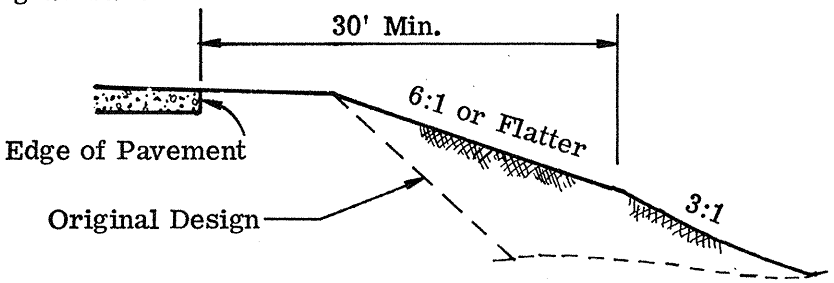
Abrupt Embankment. Dropoffs having a slope greater than 2:1, depth greater than 2 feet, and located within 30 feet of traveled way, warrant a longitudinal barrier installation. Because an abrupt embankment may extend a considerable length along the roadway, the probability of an errant vehicle contacting the dropoff is greater than that of a vehicle hitting a roadside fixed object. For this reason, barrier installations may be needed at dropoffs located more than 30 feet from the traveled way to provide roadsides with a consistent degree of safety.

Ditches near roadways can be a severe hazard if their cross sections are such that they cannot be traversed successfully by errant vehicles. Although a barrier may be warranted on a relative severity basis, it is presumed that the cross section of a ditch can be altered to be less hazardous at less cost than installing a barrier. For this reason, ditches near a roadway will not alone justify the use of a traffic barrier.

Sloped Embankments. Height and slope of roadway embankments are basic factors in determining guardrail needs. The figure below (from NCHRP Report 118) shows an "equal severity curve" for various combinations of embankment height and slope. A longitudinal guardrail installation is warranted when the point of intersection falls above the curve.



However, designers should consider the alternative of modifying the embankment slopes as shown below and avoiding the use of guardrail.



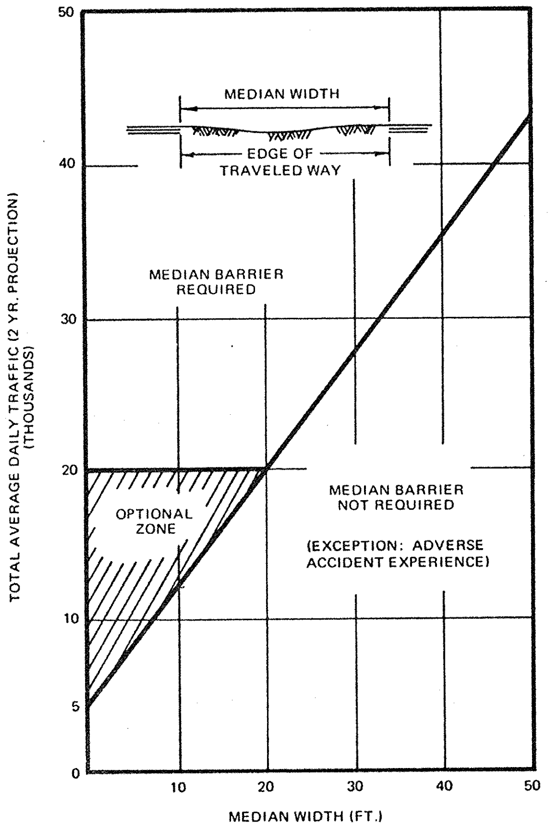
Roadside Obstacles. Examples of roadside obstacles include non-traversable hazards such as permanent bodies of water with depths greater than 2 feet or fixed objects such as trees, bridge piers and abutments, culvert headwalls, unyielding sign supports, light poles and posts. Guardrail protection normally is warranted if obstacles or fixed objects are within 30 feet of the edge of the traveled way on a road with a current ADT volume of 400 or more and with a design speed of 50 mph or greater. Where the design speed is less than 50 mph or the current ADT is less than 400, a clear roadside recovery area should be provided 15 to 20 feet or more from the edge of the traffic lane, in accordance with Chapter 2.

The length of guardrail installations normally should be designed as multiples of 12.5-foot increments, measured by the linear foot along the face of the rail from center to center of end posts for each section. The pay item (linear feet of guardrail) includes both rail and posts required to complete the installation. Terminal sections, bridge end sections and reflectors are paid for per unit. (On State-aid projects, terminal and bridge-end sections are included in payment for linear feet of guardrail).

Median Barriers

The basic function of median barriers is to prevent vehicles out of control from crossing the median and entering opposing lanes to collide with vehicles moving in the opposite direction. Effective median barriers should be installed on all high-volume, high-speed divided highways with narrow medians where engineering studies establish the need.

Warrants for median barriers are determined principally by median width and traffic volume. NCHRP Report 118 provides the chart shown on the next page as a basis for warrants.



From a practical standpoint, a median must be at least 9 feet wide to provide adequate horizontal clearance between a median barrier and the edges of the pavement. Median barriers are not warranted if median width exceeds 30 feet, except on the basis of adverse accident experience.

The most common types of median barrier are the blocked-out W-beam guardrail and the concrete barrier with a sloping face. The concrete barrier is preferred in narrow medians where regular maintenance is difficult or impractical. Details for both types of median barriers are included in the Department's standard drawings.

Impact Attenuators

There are some instances where a fixed obstruction in a particularly hazardous location must remain in place and driver protection cannot be afforded by conventional barriers. Impact attenuators (crash cushions) have been developed to absorb the kinetic energy of out-of-control vehicles in a very short distance and at a rate which will limit or avoid serious injury to restrained passengers.

There are presently four types of impact-attenuating devices in general use today which have been found to have a satisfactory performance record. These are steel barrels, plastic sand-filled drums, water-filled cells and light-weight aggregate cartridges. Reference for further information on these devices should be made to NCHRP Report 118.

The principal use of impact attenuators is to alleviate existing dangerous conditions. New highway design normally should avoid the need for these devices. But under some conditions, such as an exit gore or an elevated roadway, an impact attentuator is the only logical answer.

Currently, the Department has no standard drawings or specifications for impact attenuators. A special design is required to fit the particular conditions, utilizing the best techniques and practices from other sources.

FENCING

Design responsibilities for fencing are limited to providing fences as required for fully controlled access highways. Arrangements for any needed fencing on other highways will be made with landowners during right-of-way negotiations.

Fencing should be designed as outlined in the AASHTO publication, "An Informational Guide on Fencing Controlled Access Highways."

Types of Fence

The Department uses two basic types of fence on freeways--woven wire and chain link--with options as to type of posts and height of chain link fence. General design criteria are shown below:

Woven Wire (rural areas)

- Normally, use with timber posts.
- Use concrete posts within limits of interchange areas (between extremities of exit or entrance ramps).
- Always use timber posts adjacent to rest areas to preserve natural appearance.
- On multilane highways with wide medians, where structures are installed for passage of animals, use comparable fence across the median on each side of the path to allow passage of animals without permitting access to the roadway.

Chain Link (urban or built-up areas)

- Normally, use 5-foot high chain link.
- Use 6-foot high chain link where pedestrian traffic is likely to be heavy.
- At junkyard locations, use chain link with lattice of a height to sufficiently screen the junkyard from the highway.

Details of the different types of fences, posts and gates are shown in the standard drawings--along with examples of typical installations.

Estimating Quantities

Estimates of fencing quantities shall be made in accordance with the standard specifications to include the following pay items:

- Linear feet of fence of the type and size to be installed, exclusive of openings
- The number of posts by type of material, by type of post--line posts, brace posts and gate posts--and by length
- The number of gates of specified type and size
- Linear feet of single-strand barbed wire.

Estimated quantities should be shown on each plan sheet and the total of all fencing summarized on the Summary of Quantities sheet.

Fencing Plans

Fencing work may be included with the roadway construction project, or may be performed under a separate fencing contract. Normally, a fencing contract will be let to include the limits of several roadway construction projects.

When fencing is included with other construction work, the fencing requirements are shown on the plan portion of the plan-profile sheets. For separate fencing, contract plan sheets are drawn to a scale of 1" = 200', and interchange layouts to a scale of 1" = 100', showing only a plan view with items pertinent to the fencing, such as right-of-way width, "no access" limits, drainage structures, bridges, drainage easements, ditch crossings, etc. Since a profile view is not needed, two conventional plan views may be shown on each sheet, thereby conserving space.

PAVEMENT MARKINGS

Contract plans for roadway paving shall include provision for all required pavement markings--including items such as painted stripes, thermoplastic pavement markings, two-way reflective markers, and pavement messages.

The purpose of pavement marking is to provide traffic control communication to the driver. The communication may include designation of the roadway centerline, areas of no passing, edge of pavement, lane delineation and warning or instructional messages. Pavement marking is directly related to the design of the highway and is a feature of traffic control and operation which the designer must consider in the geometric layout of the highway. The Department has adopted the standard pavement markings set forth in the Manual on Uniform Traffic Control Devices for Streets and Highways. Designers should be familiar with the manual and adhere to the criteria for pavement markings.

Estimating Quantities

Quantities of pavement marking shall be estimated in terms of the pay item unit of measure called for by the specifications. General guidelines are are as follows:

Centerlines, Lane Lines and Pavement Edge Lines

- Measured by miles (three decimal places)
- Separate estimates by type of line (skip or continuous) and by color.

No-Passing Lines and Detail Traffic Stripes

- Measured by linear feet.

Messages and Arrows

- Measured by the square foot.

Raised Pavement Markers

- Measured by number of markers.

The measurement of traffic stripes shall be from end to end of each individual stripe. In the case of skip lines, the measurement shall include nominal skip intervals as well as painted sections.

Detailed traffic stripes are measured from end to end of individual stripes, excluding nominal skip intervals, without regard to color of individual paint stripes; however, thermoplastic detailed stripe is separated by color.

Pay items are based on a striping width of 4 inches. When a striping width of other than 4 inches is specified, the measured length shall be adjusted in the ratio of the specified width to 4 inches.

Warrants for Pavement Edge Lines

Pavement edge lines shall be provided on all Interstate highways and on other classes of roads with a present ADT of 1,500 or more. In order to make the edge striping continuous between two major points, if the majority of the length has counts that exceed 1,500 ADT, the entire distance between the two points shall be marked with edge lines. Edge lines shall be solid white, except on the left edge of each roadway of divided streets and highways, which shall be solid yellow. All edge lines shall be paint.

Use of Thermoplastic Markings

On all sections of Interstate highways and on other highways with a present ADT of 1,500 or more, the centerline, lane lines and no passing barrier lines shall be 125-mil-thickness hot extruded thermoplastic instead of paint. Where thermoplastic markings are used, raised reflection markers shall be placed in the skips on 40-foot centers.

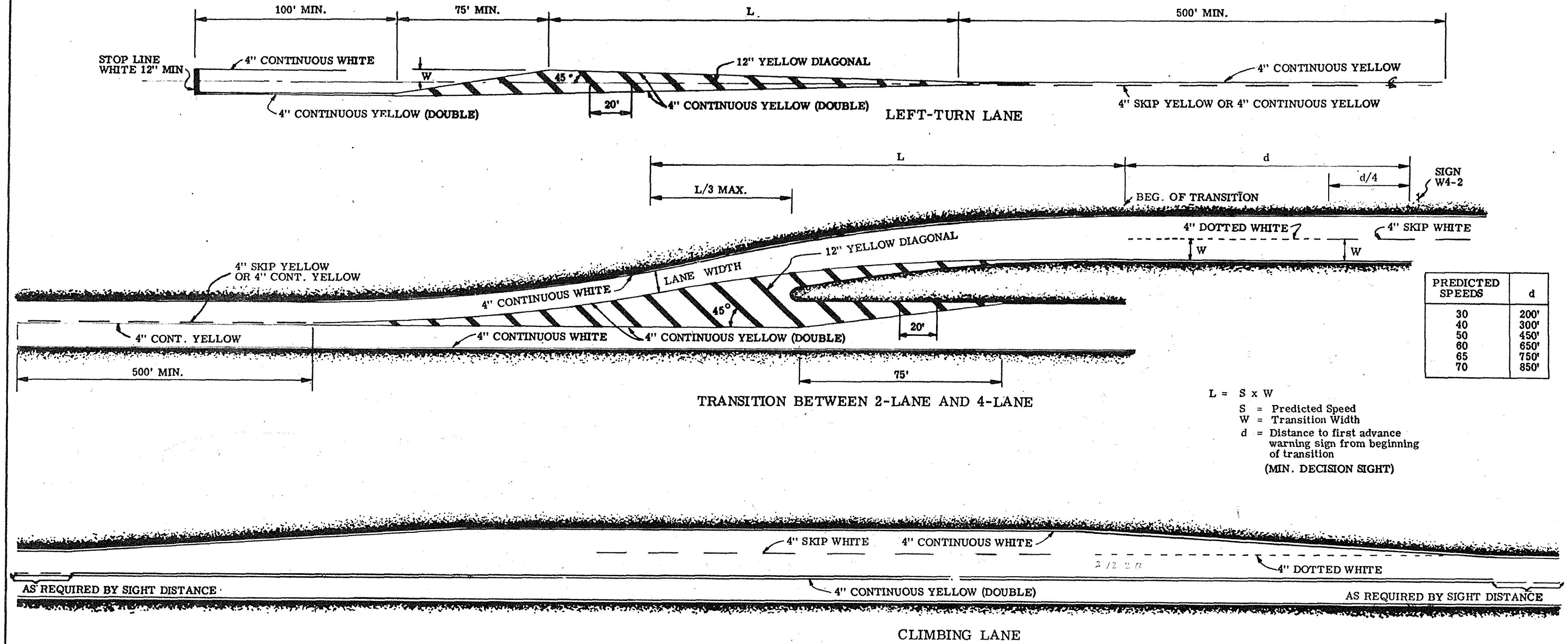
Where thermoplastic is used as described above, it should also be used for any special or detail markings--such as cross walks, stop lines, arrows, ramp gore markings and left-turn slots.

Railroad advance markings shall always be of thermoplastic--except on State-aid projects, where paint may be used.

Plan Sheets

Sufficient details of pavement markings should be shown in the plans, either by Department standard drawings or by special detailed sheets. Typical striping details required for channelized intersections, climbing lanes and transitions for turn lanes are indicated in the drawings on pages 10-7, 10-8 and 10-9.

TYPICAL PAVEMENT MARKINGS



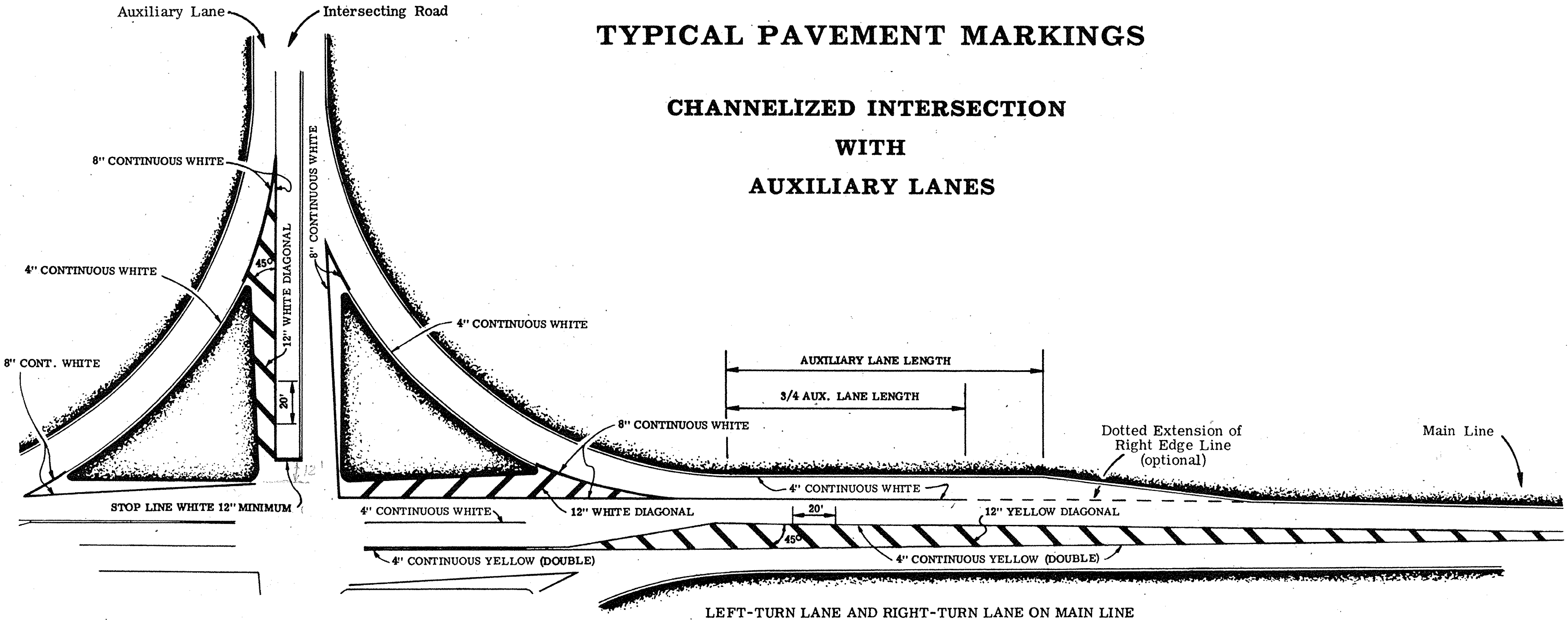
PREDICTED SPEEDS	d
30	200'
40	300'
50	450'
60	650'
65	750'
70	850'

L = S x W

S = Predicted Speed
W = Transition Width
d = Distance to first advance warning sign from beginning of transition
(MIN. DECISION SIGHT)

TYPICAL PAVEMENT MARKINGS

CHANNELIZED INTERSECTION WITH AUXILIARY LANES

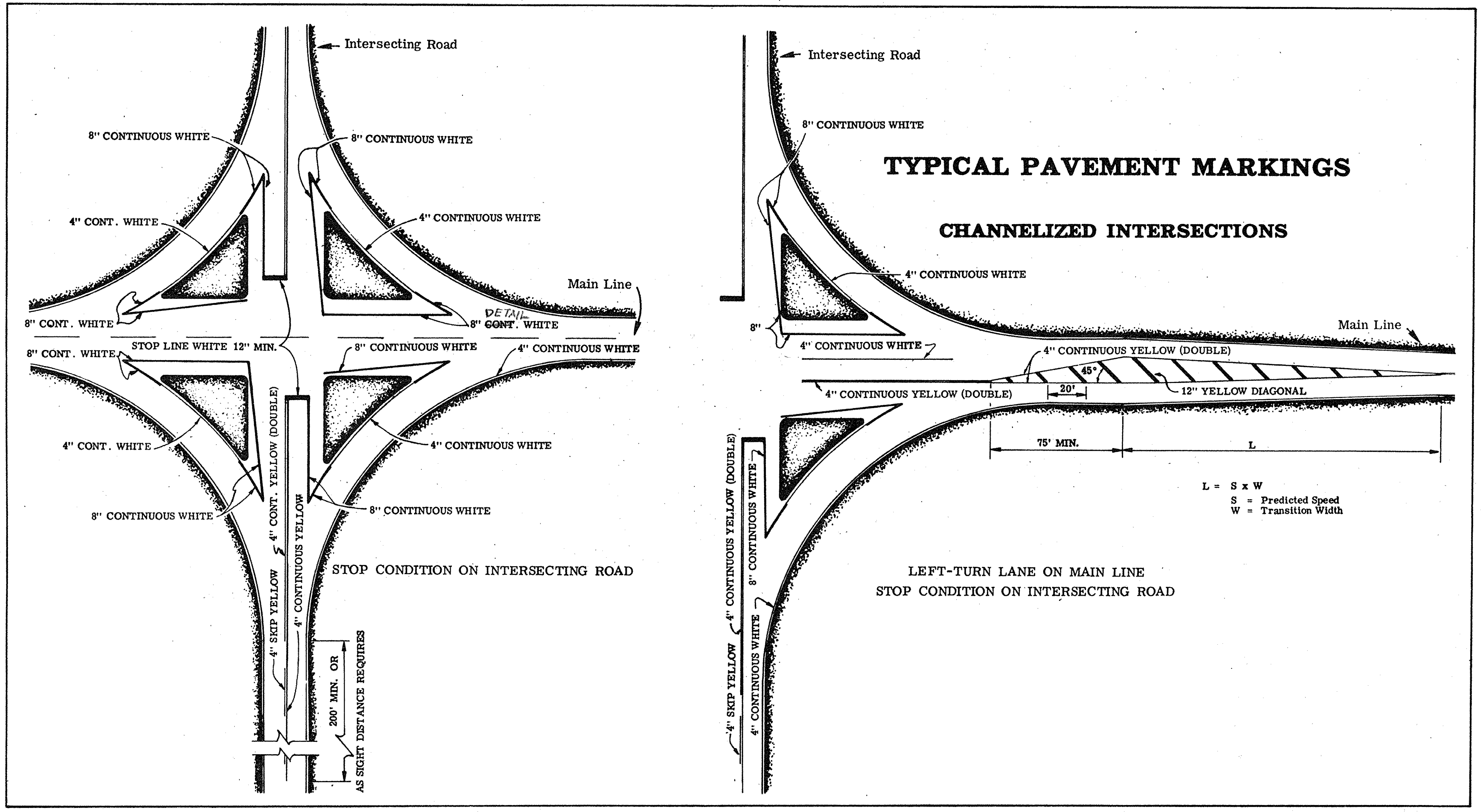


LEFT-TURN LANE AND RIGHT-TURN LANE ON MAIN LINE

STOP CONDITION ON INTERSECTING ROAD

TYPICAL PAVEMENT MARKINGS

CHANNELIZED INTERSECTIONS



SIGNING

Three types of signing must be considered for highway projects:

- Construction signing
- Temporary signing
- Permanent signing.

The Manual on Uniform Traffic Control Devices provides the basic criteria for signing practices. Department standard drawings show specific applications for Mississippi.

Construction Signing

Construction signing is required on all projects where construction work will interfere with the normal movement of traffic on or across the roadway. The purpose is to give advance warning of the construction and to guide and control traffic in or around the construction area.

The standard drawings for construction projects show the most needed signs, the sizes to be used, typical sign and barricade installations, and details of drums and various types of barricades.

Designers should prepare a line drawing of the project (not necessarily to scale) and show the desired construction signing on the drawing. It may be necessary to specify special phase signing for various phases of construction work--these should be clearly identified and described. Completed line drawings should be reviewed and approved by the Signing Specialist.

Line drawings should be included with the contract plans on sheets entitled "Details of Construction Signing," or "Details of Construction Phase Signing" where several phases are appropriate.

It is not necessary to prepare a detailed estimate of construction signing requirements. Such signing will be included in the lump sum pay items for Maintenance of Traffic.

Temporary Signing

Temporary signing is applicable to Interstate projects only. It is required whenever permanent signing is not included in the final construction project--or when permanent signing under a separate signing project cannot be completed before the roadway is to be opened to traffic.

Temporary signing may be installed by the roadway contractor or by the Traffic Control and Safety Division to expedite the opening of a newly constructed section of roadway to traffic.

If temporary signing is to be installed by the contractor as a part of the construction project, the required signing will be designed by the Signing Specialist prior to the final field inspection. The temporary signing will be included in the contract plans as a lump sum pay item.

When temporary signing is to be performed by the Traffic Control and Safety Division, there is no need for formal signing plans.

Permanent Signing--Interstate Projects

Permanent signing is required on all newly constructed roadway sections before, or as soon as possible after, the roadway is opened to traffic.

Permanent signing is normally accomplished under a separate signing contract. However, signing of short sections of roadway may be included with the roadway contracts.

The Signing Specialist is responsible for design of signing and preparation of signing plan sheets. Regular plan sheets usually will be at a scale of 1" = 200'. For interchanges and rest areas, a scale of 1" = 100' is preferred.

The design procedures will include:

- placing desired standard signs and guide signs at appropriate locations on the plan sheets
- determining actual sizes of all guide signs
- conducting field inspections and making necessary changes
- determining the length and size of all sign supports
- making detailed drawings of individual directional signs
- identifying requirements for delineators, hazard markers and guardrail
- computing quantities of all applicable pay items and preparing a summary of quantities.

State Aid Division

Construction and temporary signs are absorbed items, but permanent signs are contract items and are paid for by appropriate pay item.

TRAFFIC SIGNALS

Traffic signals are considered for installation at intersections when warranted as outlined in the Manual on Uniform Traffic Control Devices for Streets and Highways. The 20-year projection used for geometric design of the roadway can be used for anticipating signal installation; however, normally only a 5-year projection is used to determine if signals should be installed at non-signalized intersections.

Design Considerations

If investigation reveals the possibility of need for a signal installation, the Traffic Control and Safety Division should be requested to make a detailed analysis of the location to determine if a signal should be installed.

If there are existing signals, the designer should notify the Traffic Control and Safety Division in order that a determination can be made whether the existing signals should be reworked under the proposed construction contract, left in place and adjusted by state forces to match the new construction, or removed.

The geometric design of intersections should be based on the existence of a traffic signal, unless the traffic volume warrants clearly indicate otherwise.

Design Procedures

Assistance can be obtained from Traffic Control and Safety Division in developing the geometric requirements for a signalized intersection.

When a signal is to be installed under the construction contract, plans will be developed by the Traffic Control and Safety Division for the signal installation and these plans will be inserted in the construction plans. The designer should coordinate his plan development with the Traffic Control and Safety Division's signal plan development to allow for proper sheet numbering, pay item listing, plan completion dates, field inspection, geometric design, etc.

LIGHTING

Increased attention is given to providing fixed highway lighting in the interest of traffic safety.

General Warrants

The AASHTO publication "An Informational Guide for Roadway Lighting" presents generally accepted warranting conditions for installing fixed highway lighting. These criteria are applicable in Mississippi. Additional information is available in NCHRP Report No. 152, "Warrants for Highway Lighting."

Department policy specifically calls for highway lighting of the following locations:

- Interchanges between Interstate routes.
- All interchanges having a total estimated traffic interchange volume of 7000 or more vehicles per day. The traffic interchange volume is defined as the estimated total average daily traffic for the year 1975 entering or leaving the Interstate highway within an interchange area.
- Sections of through roadway with median widths of less than 16 feet.
- All sections of through roadway with six or more through travel lanes.
- Sections of roadways approaching illuminated interchange areas for sufficient distances before interchange area to safely transition drivers from unlighted to lighted areas.
- all rest stops and hospitality stations--including entrance and exit ramps as well as the site area.

Additionally, attention should be directed to those locations experiencing a large number of night accidents. If the ratio of night to day accidents is considerably higher than the statewide average for similar locations, it is probable that lighting may be expected to reduce the night accident rate.

Design Responsibilities

The Lighting Specialist has basic responsibility for design of lighting, preparing the contract plans and recommending specifications. Normally, the lighting contract will be separate from the roadway construction contract. There is need, however, for a considerable amount of coordination with the road and bridge design units and with the Construction Division.

Where future lighting is to be installed and there is need for cable crossings beneath the roadway or other paved areas, the conduit should be installed as a part of the paving contract.

A lighting layout should be transmitted to the Bridge Division for bridges on which future lighting will be installed, so that brackets for messenger cable, lighting assembly mounts and anchor bolts will be provided as parts of the bridge structure.

The Testing Division should be provided with a lighting layout of all High Mast Projects so that soil tests can be obtained and recommendations prepared for foundation requirements. The Bridge Division will recommend foundation design requirements based on the soil test information.

The Lighting Specialist and the Signing Specialist shall coordinate the location of lighting assemblies and sign structures.

All projects in urban areas should be reviewed by the Lighting Specialist to investigate the need for future lighting.

The Lighting Specialist shall recommend specifications to the Specification Section of the Construction Division.

RIGHT-OF-WAY

Discussion in this section is limited to the responsibilities and procedures of the Roadway Design Division in defining right-of-way requirements.

General Procedures

When a survey is received in Roadway Design, the property map is forwarded to the Right of Way Division. Pertinent information from this map is also recorded on the plan-profile sheets.

Following the field inspection(s), and after the designer has made all changes that will affect property owners, final right-of-way plans are submitted to the Right of Way Division. The Right of Way Division then furnishes the District with a set of plans to be used for field staking of right-of-way.

Any subsequent changes by the Design Division should be noted, and revised prints should be furnished to the Right of Way Division.

Right-of-Way Widths

The principal guide for design of right-of-way is the identification of actual construction limits established by the roadway designer. Construction limits represent the toe of fill or top of cut backslope, and should be shown in the plan view with short (0.2") broken lines with dots and skips.

The right-of-way must be wide enough to accommodate the construction limits plus a border width. Desired minimum border widths for various classes of highways are shown in the design standards in Chapter 2.

Right-of-Way Configurations

Right-of-way should be shown with as few breaks and changes in width as possible, with consideration given to ease of writing right-of-way descriptions.

The following general criteria should apply:

- Where there is need for a width change close to the P.C. or P.T. of a horizontal curve, the breaks should be made coincident with the curve points.
- Where width changes are required both right and left, the break points should coincide with the same stationing if possible.
- Breaks in width should not occur in drainage channels, roads and drives where installation of right-of-way markers would be impractical.

Beginning or Ending of Project

When right-of-way is designed at the beginning or ending of a project and those points are within the limits of an individual property ownership, consideration should be given to acquiring right-of-way through the ownership for future connecting projects so the owner will not have to be contacted again.

Easements

Under certain conditions it is preferable to obtain an easement to property rather than to purchase the right-of-way.

There are two types of easements. The type of easement and its purposes should be identified on the plans. The two types are described below:

Temporary Easements

A temporary easement should be obtained when it is not necessary to obtain permanent possession of the land or permanent right of access on which construction work is to be performed. The acquisition of a temporary easement will usually be required:

- to obtain proper grade on private ramps.
- for inlet and outlet ditches at drainage structures.
- for channel changes where future maintenance is not anticipated.
- for, in some cases, fill or cut slopes (normally in urban areas where commercial development of adjacent property is likely).
- on urban projects to provide construction area for installation of storm drains and driveways.

Permanent Easements

A permanent easement shall be obtained when it is not necessary to obtain permanent possession of the land, but where a permanent right of access is needed. The acquisition of a permanent easement will usually be required:

- for channel changes where it is anticipated that future maintenance of the channel will be required.
- for railroad right-of-way agreements where (1) the required highway right-of-way coincides with the railroad right-of-way at a grade crossing or separation, or (2) where the railroad parallels the highway and the highway improvement will encroach on the railroad right-of-way.

Access Control

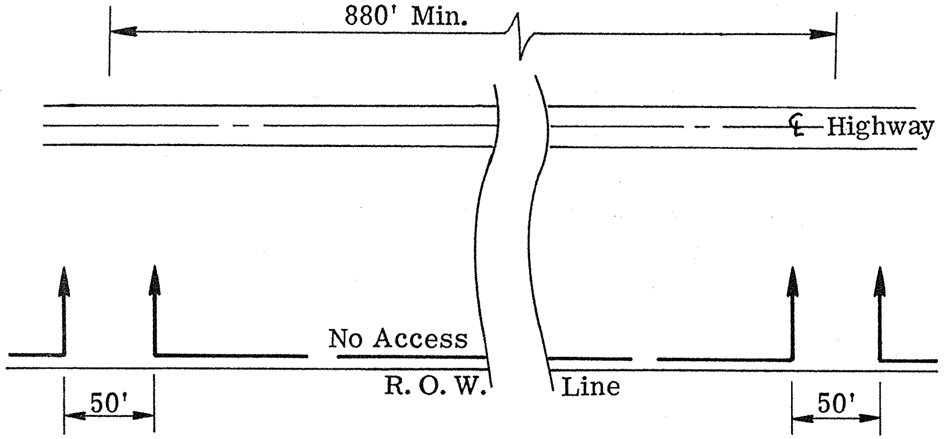
When access control is specified, it is essential that the access control lines be shown clearly on the plans. This is indicated on the plans with thick broken lines just inside the right-of-way line. A written commission order will be required on all projects (except Interstate highways) that are to have control of access. A note for future reference pertaining to this commission order is to be shown on the title sheet of the plans.

Following are the various types of access control which are used:

Type 1. Highways with full control of access and on which vehicular access is permitted to or from the highway only at interchanges.

Type 2-A. Highways on which right-of-way has been provided for future frontage roads. Until the frontage roads are constructed, vehicular access from abutting property may be permitted directly to and from the highway.

Type 2-B. Highways on which vehicular access is permitted at established entrances and enits. Access rights between such entrances and exits are purchased at the time of right-of-way acquisition. A typical situation is shown below:



The model plans in Chapter 12 show typical examples of proper identification of right-of-way lines and access control lines on the plan sheets.

AT-GRADE RAILROAD CROSSINGS

Projects with at-grade railroad crossings require special consideration by designers. The railroad company will perform all work necessary for the adjustment of their tracks to meet altered or established highway grades and will construct the roadway grade crossing as indicated on approved state highway plans. The railroad company will also install flashing light signals, gates, guardrail, or other required protective devices in accordance with State Highway Department plans.

All work by the railroad company will be accomplished by agreement between the railroad company and the State Highway Commission for work on a force account basis to provide for reimbursement by the Department of all construction costs to the railroad company.

Plans for field inspection should be submitted to the Construction Division as soon as they are available--three sets for Primary projects and two sets for Secondary projects. It is desirable that a railroad representative participate in the field inspection.

The Construction Division will be responsible for negotiations with the railroads and will prepare the required railroad agreements. Following the field inspection, the Roadway Design Division will prepare final plans and submit copies to the Construction Division for further processing with the railroad company (eight sets for Primary projects, seven sets for Secondary projects).

In the case of highway improvement or highway relocation necessitating a use permit or easement on or across railroad right-of-way for proposed construction, the Right of Way Division of the Department will prepare and acquire the required easement from the railroad.

WEIGH STATIONS

Whenever a proposed project involves a crossing of the state line or relocation of a section of highway where there is an existing weigh station, determination should be made as to the need for new weigh station facilities. The State Maintenance Engineer will contact the Motor Vehicle Comptroller for recommendations as to appropriate new or replacement facilities.

If a weigh station is to be provided, the State Maintenance Engineer will initiate and coordinate planning actions with the Motor Vehicle Comptoller, the District Office, the Roadway Design Division and others as necessary.

After a site has been selected and surveys completed, the Roadway Design Division will design the weigh station facilities to be compatible with the roadway improvements, and will prepare contract plans and a cost estimate. The State Maintenance Engineer will obtain the approval of the Motor Vehicle Comptroller and will prepare a letter of agreement defining the execution of the construction by the Department and the terms of cost reimbursement by the Motor Vehicle Comptroller.

Preparation of the weigh station site normally will be included with the roadway contract. Construction of the buildings and other facilities should be a separate contract.

AIRWAY-HIGHWAY CLEARANCES

Highways in the vicinity of airports must be designed to provide minimum clearance between the highways and the navigable airspace.

Navigable airspace is defined as the space above the approach surfaces adjacent to the runway. The bottom of the approach surface is established by a specified guide path ascending upward from the end of the runway. Highway appurtenances such as overhead signs or light standards must not penetrate the navigable airspace.

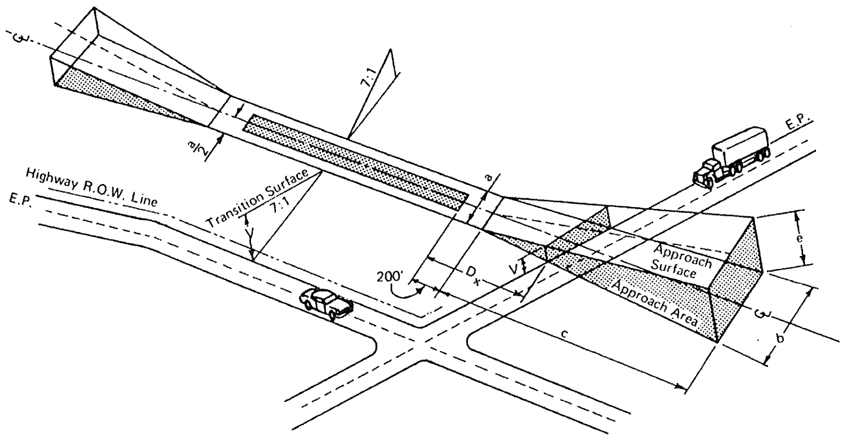
Criteria for clearances are set forth in the table and drawing at the right.

Minimum vertical clearances between the roadway surface and the zone of navigable airspace shall be 25 feet for Interstate highways and 15 feet for other highways. A comparable minimum vertical clearance above railroads shall be 25 feet.

If there is an airport within two miles of a proposed highway project, the Mississippi Aeronautics Commission should be contacted to identify the class of airport and verify the current status of airway-highway clearance regulations.

Airport Type	Average Runway Length	Width of Approach Area (and Approach Surface)		Horizontal Length of Approach Area Beyond Clear Zone (c)	Elevation of Approach Surface Above Runway at Distance "C" (e)	C. E. Slope of Approach Surface (Guide Path)	Minimum Horizontal Distance from End of Roadway or Landing Strip to Nearest E. P. (D)	Minimum Vertical Clearance at E. P. (V)
		At Clear Zone End (a)	At Approach End (b)					
Minor	Less than 4200'	250'	2250'	10,000'	500'	20 : 1	200'	Absolute Minimum 15'
Local	5000'	400'	2400'	10,000'	250'	40 : 1	300'	•
Trunk	6750'	500'	2500'	10,000'	250'	40 : 1	300'	Interstate 17'
Continental	9000'	500'	2500'	10,000'	250'	40 : 1	300'	•
Inter-Continental	Over 10,000'	500'	2500'	10,000'	250'	40 : 1	300'	Railroads 25'
Instrument Landing System	–	1000'	16,000'	50,000'	1000'	50 : 1	300'	

Approach data conform to FAA Technical Standards TSO N18 and TSO N6b.



AIRWAY-HIGHWAY CLEARANCES

CURB RAMPS FOR THE HANDICAPPED

In compliance with Section 228 of the Highway Safety Act of 1973, curb ramps for the handicapped shall be provided across curbs constructed or replaced across pedestrian crosswalks. These shall provide adequate and reasonable access for the safe and convenient movement of physically handicapped persons, including those in wheelchairs.

Detailed drawings of special curb ramps shall be included in the contract plans.

Chapter 11
STATE AID DIVISION

The Division of State Aid Road Construction was established by the Mississippi Legislature in 1949 for the purpose of administering state aid road programs. This legislation also provided for a State Aid System, composed of the principal collector and distributor roads exclusive of interstate, U.S. and state highways, to form a net work of secondary roads.

Although this manual is directed principally to the design of state highways, most of the basic policies and criteria for road design are equally applicable to the State Aid System. There are some differences, however, and the purpose of this chapter is to identify specific criteria and procedures followed by the State Aid Division.

State Aid Division Responsibilities

The Division of State Aid Road Construction is directed by the State Aid Engineer. It is the responsibility of the State Aid Engineer and his staff to:

- prepare and adopt uniform design standards and specifications for construction and maintenance of state aid projects.
- approve additions to the System.
- approve all construction programs.
- approve plans and specifications for construction projects.
- authorize advertisement for bids.
- concur in the awards of contracts.
- approve and disburse all payments made from the project fund.
- approve final acceptance of completed projects.
- make annual and other periodic inspections of completed projects to ensure they are properly maintained by the respective County Board of Supervisors.

County Responsibilities

Each County Board of Supervisors, as the governing agency, is required by statute to appoint a County Engineer, who shall be a registered professional engineer, to act for and on behalf of the Board to administer the engineering functions at the county level, subject to the rules and regulations promulgated by the State Aid Engineer.

It is the responsibility of the Board of Supervisors to:

- designate the county roads to be included in the State Aid System.
- prepare and adopt annual construction programs.
- acquire rights-of-way for state aid projects.
- advertise for bids.
- award contracts.
- assure adequate maintenance of completed projects.

The County Engineers normally are responsible for making surveys, preparing plans, specifications and contract proposal documents, attending lettings, supervising and inspecting construction, and submitting Progress and Final Estimates. Counties may obtain the services of consulting engineers for some or all of these responsibilities, but as County Engineers and not Consulting Engineers.

Design Guides

State aid roads usually are constructed to geometric design standards somewhat lower than for comparable highways on the State Secondary System. The AASHTO publications "Geometric Design Guide for Local Roads and Streets" and "Bridge Specifications" (latest edition), supplemented with policy and criteria set forth by the State Aid Division, serve as the basis for design of state aid projects--except that the width of bridges to remain in place must equal or exceed the approach pavement width, and design speed must be 30 mph or more. These design guides are summarized in Chapter 2; see the tables entitled:

- Geometric Design Guides for Rural State Aid County Roads
- Geometric Design Standards Based on Design Speed.

The standards generally permit steeper foreslopes and backslopes on state aid roads than are permitted on state highways. And the requirements are less for lateral clearance from the pavement edge. But in the interest of safety and ease of maintenance, the slopes on state aid projects should be designed no steeper than 3:1 (preferably flatter)--and the lateral clearance, free of obstructions, should be as wide as economically feasible.

Striping and marking of completed projects will be in accordance with the "Manual on Uniform Control Devices."

Standard Specifications and Drawings

The State Aid Division has published a book of "Standard Specifications for State Aid Road and Bridge Construction." This publication, along with appropriate supplemental specifications and special provisions, is furnished to County Engineers.

Standard drawings have been developed by the State Aid Division covering specific details of bridges, guardrail, superelevation and signing. These drawings are available to the County Engineers and should be incorporated in the contract plans when appropriate.

It should be noted that criteria and procedures for superelevation and curve widening for the State Aid System are different from those for the State Highway System.

Base Design

The criteria and procedures for design of base course thickness on state aid roads are set forth in a manual entitled "CBR Method of Base Design and Charts," published by the State Aid Division. These procedures should be adhered to, rather than the criteria in this manual for state highways.

Special charts are available from the State Aid Division to assist in estimating quantities of base materials for various combinations of crown width, surface width, side slopes and base course thickness.

Right-of-Way

State law requires that rights-of-way for state aid projects must be provided by the Board of Supervisors without any cost to the project fund.

The established policy of the State Aid Division is that uniform right-of-way width may be obtained as permanent right-of-way, and construction easements may be obtained for those areas outside the normal right-of-way. These easements revert to the property owners when the project is accepted for maintenance. The Board must obtain permission to re-enter these areas to alleviate any special maintenance problems that may arise, such as slides or impaired drainage, particularly at structures. The Board need not maintain these areas on a regular basis.

It is desirable that a right-of-way width sufficient to accommodate all elements of the design cross section plus appropriate border areas be furnished without easements. Utilities on state aid projects must be accommodated within the right-of-way in accordance with State Aid Policy adopted January 17, 1972.

Technical Assistance

Engineers of the State Aid Division will review all designs and plans submitted by the counties to check for adequacy and compliance with applicable geometric standards.

Additionally, the County Engineers may obtain technical guidance and assistance from the various divisions of the State Highway Department as may be needed in specialized cases.

Chapter 12

CONTRACT PLANS ASSEMBLY

Previous chapters have set forth criteria and procedures for the design of individual elements of highway construction. These designs must be incorporated in plans so they can clearly be understood by contractors and materials suppliers--as well as by the Department's personnel assigned to supervision and inspection of the project.

Several terms and phrases are frequently used throughout plan development. To ensure a clear understanding, they are defined as follows:

- Survey

  The term "survey" refers to all field information necessary for plan development, including all field notes, property maps and plan-profile sheets.

- Field Inspections

  Field inspections are divided into two categories:

  + Preliminary Field Inspection

    The preliminary field inspection is required on all projects after preliminary plans have been developed, including title sheet, typical sections, plan-profile sheets with tentative grades, construction and right-of-way limits, size of drainage structures, and bridge lengths and widths. After completion of all revisions agreed upon during preliminary field inspection, plans are printed for final right-of-way and utilities.

    4 R.O.W.
    1 Ea. Utility
    1 Utility Sec.
    1 District
    1 Soil Mechanics
    1 Environmental

  + Final Field Inspection

    The final field inspection is made after the Roadway Design Division has completed the plans. This inspection is the final review of the plans prior to printing such plans to be included in the P. S. & E. assembly.

- P. S. & E. Assembly

  The abbreviation "P. S. & E." means Plans, Specifications and Estimates. The P. S. & E. Assembly includes a complete set of plans, specifications, all special provisions and supplemental specifications not approved as standard, the cost estimates, all approved agreements with railroads, utilities and municipalities, the proposal assembly, and the utility and right-of-way certificates.

  The numbers of plans and documents required in State Aid P. S. & E. Assembly are listed on page 12-12.

To ensure consistent interpretation of the plans, individual plan sheets should have standard format and content, and the sequence of assembling the various types of plan sheets should always be the same. The purpose of this chapter is to present guidelines for uniform preparation of plans.

General Content and Sequence

Most sets of plans will contain the following types of sheets assembled in the sequence shown:

1. Title Sheet
2. Detailed Index and General Notes
3. Typical Sections
4. Summary of Quantities (Roadway and Bridge)
5. Estimated Quantities (Roadway and Bridge)
6. Plan-Profile Sheets
7. Special Design Sheets - Roadway (Detail Sheets and Standard Drawings)
8. Bridge Drawings
9. Special Design Sheets - Bridges
10. Cross Section Sheets.

Several other types of drawings may be required for use by the project engineer--sheets of form grades, property maps and other details--but these are not included with the contract plans.

Project Identification

Each plan sheet must be clearly identified with its project number. On the title sheet, this number is shown in the center heading and in a preprinted block in the upper right corner. On all other sheets, the project number is recorded in the upper right corner in a preprinted--or stamped--block.

Designers will obtain the project number from the approved project program. Each element of the number has a special meaning as described in Standard Operating Procedure No. ADM-02-08-02-000.

Sheet Numbers

Two numbering systems are used--working numbers and sheet numbers.

Working numbers are assigned to groups of particular sheets for identification during the design process as follows:

- Title Sheet

  The title sheet is always No. 1.

- Typical Section Sheet

  The first sheet is always No. 2 and any additional sheets are 2-A, 2-B, 2-C, etc.

- Plan-Profile Sheet

  The first mainline plan-profile sheet is always No. 3 and subsequent mainline plan-profile sheets are numbered in sequence. Additional plan-profile or special design sheets which supplement a particular sheet will have the same number as the mainline sheet plus an alphabetical designation in sequence.

Working numbers are temporary and have no value after the plans are printed for P. S. & E. Assembly, except that working numbers shown on the title sheet along the mainline are retained for reference purposes.

When plans have been completed and are ready for final assembly (P. S. & E. Assembly), each sheet is given a number in proper sequence. Blocks of numbers have been reserved for the various categories of drawings, as shown on the next page.

Sheet Numbers	Type of Drawing
1 - 100	Title sheet through plan-profile sheets and other special-design roadway sheets
101 - 365	Standard roadway design drawings
366 - 465	Reserved numbers to be used when first group exceeds 100 sheets
466 - 765	Bridge drawing sheets
766 - 900	Special design sheets for bridges
901 and above	Cross section sheets.

The title sheet will always be sheet No. 1. This number should appear in the preprinted block in the upper right corner. On all other sheets, the numbers should be recorded in a block in the lower right corner.

Revisions

It is important that design revisions be carefully recorded after each of two milestone events.

Any design changes which are made after the final right-of-way and utility plans have been submitted to the Right-of-Way Division and the Utility Section, must be recorded on the plan-profile sheet in the revision block in the upper right corner. The revision block should contain the date and the designer's initials. The revision number should be shown in a triangular block /1\ opposite the revision block and also at the point on the sheet where the revision was made. Revised sheets should be submitted immediately to the Right of Way Division and Utility Section. They must have up-to-date information as this may affect right-of-way negotiations and utility adjustments.

The second milestone event is completion of the plans for the P.S. &E. Assembly. Prior to the printing of plans for the assembly (half-scale), all revision dates and revision symbols should be erased and the Detailed Index Sheet stamped with a revision block showing P.S.& E. PLANS - DATE __________ and REVISIONS in the upper right corner of the sheet. The date the plans are printed should be recorded in the revision block and any subsequent revisions should be recorded by date and sheet number in the revision block. The revision date should also be recorded in the revision block of each individual sheet which is revised.

Standard Symbols

Standard symbols and abbreviations are shown on Standard Drawing No. 101 and the last sheets in this manual. These standards should consistently be adhered to on all plans.

Model Plans

The types of plan sheets are discussed on the following pages, with special instructions and comments related to each. Refer to the model plan sheets assembled at the end of the chapter. These sheets do not represent a single complete set of plans--rather, they are selected individual sheets to serve as examples for particular conditions.

The County Engineer designing State Aid projects should refer to model plans furnished by the State Aid Division for correct state-aid plan assembly.

TITLE SHEET

The title sheet is always sheet No. 1 and serves as the cover sheet for the plans. It provides a considerable amount of information and serves as a general index and reference sheet for the project. This sheet is always prepared on linen and all information is required to be shown in ink.

Title Information

The project number, route number, county, and a general description of the location of the project should be shown in the center of the sheet immediately below the words "State Highway". Project numbers are obtained from the approved project program. Project numbers should be shown in two forms: first, a combination of alphabetical designations and numerals to comply with FHWA regulations, and second, all numerals to comply with Department regulations. This system of numbering is explained in S. O. P. ADM-02-08-02-000.

General Location

The general location of the project in relation to the entire state should be identified with a small circle on the small scale state map shown in the upper right corner of the sheet.

Project Layout

A small scale layout of the entire project alignment is shown in the center of the sheet. The scale is variable but generally is either 1" = 1000' or 1" = 2000', depending on the length of the project. The minimum information required on the layout includes township, range, section lines and number, urban and municipal limits, county roads, all highways, rivers, all streams requiring bridges, railroads, airfields, cities or towns, approximate distance from either end to the next city or town, the project alignment, the last station of each plan-profile sheet, and sheet number, omitted sections, bridges, the beginning and ending stations, and the project number of adjoining projects. The project alignment is always the predominate line on the layout.

The area covered by each mainline plan-profile sheet should be sketched over the alignment and each sheet identified by the working number and last station. Station numbers should be multiples of 30 whenever the plan-profile sheets are drawn to a scale of 1" = 100'.

General Index

The number of sheets of each category and the total number of sheets in the plans should be recorded in the General Index block in the upper left corner.

Bridge Locations

All bridges and box bridges should be listed immediately to the left of the project layout. Each structure is identified by an alphabetical designation, total length, number of spans, and length. Even though several bridge lengths may be shown, only those bridges with lengths along the centerline of the project are included in the length data.

Equations

All equations along the centerline of the project must be listed, including the length of each equation with the appropriate sign. An algebraic summation is then made to obtain a total length of all equations.

Exceptions

Exceptions are omitted sections within the project limits. Bridges in place (excluding box bridges) are always shown on the layout as omitted sections and included in the length of exceptions.

Length Data

The project length data are listed in five increments--length of roadway, length of bridges, net length of project, length of exceptions, and gross length of project.

The length of the roadway is the difference between the beginning and ending stations plus (or minus) the total length of the equations minus the length of bridges and exceptions. The length of bridges includes only those bridges along the centerline which will be constructed on the project. A box bridge is defined as a box culvert which has a clear distance between the inside faces of the end supports exceeding 20 feet, measured along the centerline of the project. It is included in the length of bridges on grading projects only.

The net length of the project is the sum of the roadway length and bridge length, and the gross length is the sum of the net length and the exceptions.

As a general rule, the length data on 4-lane facilities are computed along the centerline of median whenever the median width is constant, or along the centerline of the right lane whenever the median width is variable.

All computations pertaining to project length are made to the nearest 0.01 foot and the nearest 0.001 mile, always dropping the ten-thousandth of a mile instead of rounding up to the next thousandth.

Design Controls

Design control data which are obtained from the project design data sheet (RWD-600) should be recorded in the space provided.

Access Control

All controlled access facilities except interstate require a statement on the title sheet declaring the project to be a controlled access facility and stating the type of control (reference S.O.P. ADM-23-01-00-000).

DETAILED INDEX AND GENERAL NOTES

The second sheet of the plans normally will be a combination sheet titled "Detailed Index and General Notes". The detailed index will contain a description of each sheet in the plans grouped under the same titles and sequence as in the General Index.

The title of each group of sheets should be underlined and the total number of sheets within the group should be shown in parentheses immediately to the right.

Sheet Sequence Within Groups

Typical section sheets should be arranged in sequence with the most important typical section first, and ending with the least important. This sequence generally is:

1. Main facility
2. Interchange ramps and loops
3. Interchange local road
4. Other highways
5. Streets
6. Frontage roads
7. County roads
8. Access roads
9. Detour roads.

Quantity sheets should be arranged in the following sequence:

1. Summary of quantities (roadway)
2. Summary of quantities (bridges)
3. Estimated quantities (roadway)
4. Estimated quantities (bridges).

Plan-profile sheets should be arranged in the sequence as depicted on the model sheet, "Detailed Index and General Notes". The first sheet should be the first mainline sheet and the working number will be 3. The limits of this model sheet contain an interchange; five supplemental sheets (3-A through 3-E) are required to show all features of the interchange and are placed immediately after the mainline sheet. Immediately following the supplemental sheets are the remaining mainline sheets--assigned working numbers 4 and 5.

The General Index on the title sheet has the heading "Special Design - Roadway Items." This is separated into two categories on the Detailed Index Sheet, the first being Detail Sheets and the second, Standard Drawings. The Detail Sheets generally pertain to several locations or to the entire project and are not arranged in any particular sequence. However, Standard Drawings are arranged in numerical sequence.

Bridge drawings (standards) are arranged in numerical order, and Special Design Sheets - Bridges are arranged in alphabetical and numerical order.

Revision Dates

The latest revision date for a Standard Drawing, Bridge or Roadway, should be adjacent to the sheet number.

General Notes

General Notes will be limited to information specifically applicable to a particular project. Information contained in the standard specification or special provision should not be shown as a general note.

TYPICAL SECTIONS

Depending on the complexity of the project, one or more sheets of typical sections may be required in each set of plans.

The mainline typical section should be shown first, with other typical sections following in the sequence described on page 12-5.

Each typical section should be clearly identified by name and station limits.

Two model sheets of typical sections are shown, one for a grading project and the other, a paving project.

Grading Typical Section

Details of the pavement structure are not required on typical sections when pavement is not included in the project. However, the total pavement structure thickness (above subgrade) and the proposed slope of the pavement and shoulders should be shown as a hidden line. Typical section scales are seldom specified; however, a scale of 1" = 5' usually is sufficient for grading projects, including 4-lane facilities up to 64-foot constant median width. Variable median widths and widths over 64 feet generally require a scale of 1/8" = 1' to depict the full facility and independent details for one or both lanes.

Criteria for slopes as related to heights of cuts and fill should be shown. This information can be obtained from the project design data sheet (RWD-600) which should conform to the information shown in the design standard tables in Chapter 2.

Notes which apply specifically to the typical section should be listed.

The typical section should be drawn and labeled as 1/2 cut section and 1/2 fill section. Special details such as slope benching are also shown on the typical section sheets.

Paving Typical Sections

Large scale drawings are required to clearly depict the various courses in the pavement structure for paving projects or combination grading and paving projects. Generally, a scale of 1" = 2' is adequate to show all details.

The various courses should be indexed by number and described on the right side of the sheet as shown on the model. All terminology should be identical to the terminology in the Standard Specifications. All courses must be accurately described as to width, thickness and type of material.

When the pavement structure of a 4-lane facility is symmetrical, only one roadway (2-lanes) need be shown.

Pavement structure recommendations are submitted by the districts and, when approved by the Roadway Design Engineer, become a part of the Designer's project file.

QUANTITIES

Model sheets are shown for four different types of quantity sheets:

- Summary of Quantities -- Model Sheet No. 5
- Summary of Quantities (Bridge) -- Model Sheet No. 6
- Estimated Quantities (Roadway) -- Model Sheet No. 7
- Estimated Quantities (Bridge) -- Model Sheet No. 8

If the project is for roadway only, the sheets for bridge quantities are not included.

Summary of Quantities -- Model Sheet No. 5
Summary of Quantities (Bridge) -- Model Sheet No. 6

The purpose of these sheets is to summarize all estimated quantities by pay item. Pay items are arranged by groups and are referenced to sections of the Standard Specifications to clarify pay items in each category:

- Roadway Items

  Roadway items include all pay items in Sections 200 and 300, and pay item Nos. 601 through 629 except 619 of Section 600.

- Erosion Control Items

  Erosion control items include all pay items in Section 650.

- Paving Items

  Paving items include all pay items in Sections 400 and 500, and pay item No. 619.

- **Bridge Items**

  Bridge items include all pay items in Section 800 except box bridges.

- **Box Bridge Items**

  Box bridge items include pay item 804-BB and pay items 805 and 206--quantities required for the box bridge only.

- **Traffic Control Items**

  Traffic control items include all items not included in the roadway and paving items--pay items 630 through 634.

Two pay items may appear in more than one of the categories. Pay item 815-F, concrete slope paving, is both a roadway and bridge item. The portion of the slope paving 4 feet outside the vertical limits of the bridge is a roadway item, and that portion beneath and within this 4-foot limit of the bridge is abridge item. Pay items 815-A through 815-E may be either bridge items or erosion control items, depending on the use.

Within each category, the items are arranged in numerical order by pay item. All pay item numbers, correct terminology and unit of measure are contained in the Standard Specifications or Special Provisions.

The summary of quantities shall always indicate the unit of measure and the preliminary quantities, and have a blank column for final quantities. Quantities are further divided by counties, and by urban and rural areas.

Any notes required to explain how quantities were obtained or to define rates of application not contained in the Standard Specifications should be shown as indicated on the model sheet.

Bridge quantitites are summarized separately from other items, to allow the Bridge and Roadway Design Divisions to complete their plan work independently. Generally, the same rules apply to both roadway and bridge summary sheets.

Estimated Quantities (Roadway) -- Model Sheet No. 7
Estimated Quantities (Bridge) -- Model Sheet No. 8

In addition to the Summary of Quantities sheet, roadway plans generally contain a second sheet entitled, "Estimated Quantities (Roadway)". If the project includes bridges, a similar sheet, "Estimated Quantities (Bridge)," is included. The purposes of these sheets are (1) to separate quantities by location or structure, (2) to consolidate information shown throughout the plans, and (3) to provide information not shown elsewhere.

Depending on the items required, the roadway sheet(s) generally will contain columns for pipe culverts, box culverts, box bridges, ditch treatment, guardrail, curb and gutter, riprap or other items which appear at several locations.

The bridge sheet consolidates all information by individual structure and by components for various pay items.

The format of each sheet is standardized as much as possible--and the model sheets are considered typical for most projects. Quantities are further subdivided by counties, and by urban and rural areas.

PLAN-PROFILE SHEETS

Plan-profile sheets show the vertical and horizontal alignments, topography, right-of-way, construction items, and other details necessary for construction.

Several examples of model plan-profile sheets are shown in this chapter for different conditions:

Sheet No. 9 - Rural 2-Lane

Sheet No. 10 - Rural 4-Lane

Sheet No. 11 - Rural 2-Lane, Paving Only

Sheet No. 12 - Rural 4-Lane, Paving Only

Sheet No. 13 - Urban

Sheet No. 14 - Interchange Ramp

The model sheets cover most of the situations that will be encountered in preparing plan-profile sheets--and are generally self-explanatory.

The basic survey information is recorded first on the sheets--items such as horizontal alignment, curve data, topography, bench marks, groundline profile, and groundline elevations. This information should be inked. All other design information may be recorded in pencil.

Scales

Scales normally will be 1" = 100' horizontally and 1" = 10' vertically. Larger scales should be used in urban areas and other situations where there is need to show considerable detail. The example sheet No. 13 uses a horizontal scale of 1" = 20' and a vertical scale of 1" = 5'.

Elevations

The two rows of figures along the bottom of the sheet represent profile elevations -- the bottom row is the original groundline and the upper row is the plan grade.

In the case of paving plans, the groundline elevations are not shown--only the plan grade elevations. And the groundline profile is shown as a hidden line.

Earthwork Distribution

Earthwork distribution diagrams should appear above the plan grade elevations and below the original ground profile. Instructions for earthwork distribution diagrams are given in Chapter 5.

Notes

Notes on plan-profile sheets should be brief, clear, and consistent. The format and location of the various types of notes should follow the examples shown in the model sheets.

LAYOUT SHEETS

A layout sheet is required for all interchanges. The purpose of this sheet is to provide a plan view with the following information:

- horizontal alignment and curve data,
- pavement width throughout the interchange,
- right-of-way required,
- access controls,
- bridges, and
- design year ADT and distribution.

Topography, drainage structures, and other information are not shown, as indicated by Model Sheet No. 15.

The layout sheet should be inserted in the plans immediately after the mainline plan-profile sheet which includes the intersection station of the mainline and local road.

DETAIL SHEETS

The purpose of detail sheets is to show design details that cannot be described adequately on the plan-profile sheets.

Detail sheets may be required for median barriers or special guardrail installations, slope paving, lighting or signal installations, pavement marking or intersections. Vegetation schedules are included with detail sheets.

Model Sheet No. 16 shows an example of Pavement Marking Details.

Model Sheet No. 17 shows an example of Intersection Details.

The Department's Standard Drawings which are applicable to the project should be identified in the Detailed Index and inserted in the plans immediately following the Detail Sheets.

CROSS SECTION SHEETS

Cross section sheets are always the last group of sheets listed in the Detailed Index and the first sheet is always sheet No. 901.

Cross sections are a part of the plans but are always printed separately and are furnished to the contractor and the project engineer.

The entire mainline cross sections should be sequentially numbered from beginning to end without interruption. Any supplemental cross sections (ramps, frontage roads, local roads, channel changes, etc.) should be grouped after the mainline cross sections -- with each sheet clearly labeled in the lower right corner as to purpose and location.

Two model cross section sheets are shown in this chapter:

- sheet No. 901 -- two-lane
- sheet No. 968 -- multilane with divided median

Detailed instructions for preparing cross section sheets are presented in Chapter 5.

FORM GRADES

The purpose of preparing form grades is to graphically determine the profiles of ramps at intersections of roadways. This is usually done by coordinating the plan with the profile. In most cases, the plan-profiles are prepared on separate drawings due to the large scale of each drawing. The scale normally used for the plan view is 1" = 20' or 1" = 30'. The scale normally used for the profile view is 1" = 25' horizontally and 1" = 2' vertically.

The objective is to establish a smooth profile for both edges of the ramp pavement at 25-foot intervals, and to provide means for graphically determining the grade at any location. Form grades are normally not included in the plan assembly, but are furnished to the project engineer.

Plan View

The purpose of the plan view is to:

- determine location of construction joints or crossover crown line,
- determine pavement slopes and slope transitions,
- accurately scale pavement width at any location,
- check rate of cross slope and maximum algebraic difference, and
- check for proper pavement drainage.

The plan view should be drawn similar to the example, and should clearly show:

- elevations at 25-foot intervals along the control line of the ramp,
- pavement slope line, perpendicular (radially) to the ramp control line,
- pavement slope (percent), recorded above the pavement slope line (with an arrow, if there is doubt as to direction of slope), and
- pavement width, recorded below the pavement slope line.

Profile View

The purpose of the profile view is to:

- graphically define the profiles of the ramp edges and intersected roadways to a scale large enough to read to the nearest hundredth foot, and
- establish the best grades possible, by coordination with the plan view.

The profile view should be prepared by:

- plotting the control elevations from the plan view (from tie points to nose points),
- fitting splined curves to calculated profiles,
- smoothing out any abrupt changes with splined curves, and
- clearly labeling each pavement edge or joint line.

Reference Data

AASHTO, A Policy on Geometric Design of Rural Highways (Blue Book), 1965: Tables VII-12, VII-13, and VII-14 (pp. 360, 363); and Jack Leisch & Associates, Notes on Techniques of Geometric Highway Design, Chapter 5.

P. S. & E. ASSEMBLY REQUIREMENTS
STATE AID DIVISION

FEDERAL AID SECONDARY PROJECTS

PLANS

3 Sets of half-scale plans with standards
2 Sets of half-scale plans without standards
2 Sets of half-scale plans with layout, quantity, typical section sheets, and bridge layout sheets (where bridges are included).

DOCUMENTS

5 Sets of contract documents.

The P. S. & E. Assembly also includes the following:

1. Right-of-Way Certificate
2. Satisfactory agreement concerning all utilities involved within the limits of this project
3. A copy of the option on County designated material pits
4. Copy of the County Engineer's preliminary estimate.

STATE AID PROJECTS

PLANS

3 Sets of half-scale plans with standards
2 Sets of half-scale plans without standards.

DOCUMENTS

5 Sets of contract documents.

The P. S. & E. Assembly also includes the following:

1. Right-of-Way Certificate
2 Satisfactory agreement concerning all utilities involved within the limits of this project
3. A copy of the option on County designated pits
4. Copy of the County Engineer's preliminary estimate.

FED. ROAD REG. NO.	STATE	STATE PROJECT NO.	SHEET NO.
3	MISS.	BP-0006-1(44)	1

GENERAL INDEX

FOR DETAILED INDEX OF PLANS SEE SHEET NO. 2

DESCRIPTION	NUMBER OF SHEETS
TITLE SHEET	1
DETAILED INDEX, GENERAL NOTES	1
TYPICAL SECTIONS	2
QUANTITIES	7
PLAN AND PROFILES	15
SPECIAL DESIGN - ROADWAY ITEMS	40
BRIDGE DRAWINGS	
SPECIAL DESIGN - BRIDGES	59
CROSS-SECTIONS	123
TOTAL SHEETS	248

STATE OF MISSISSIPPI
STATE HIGHWAY DEPARTMENT

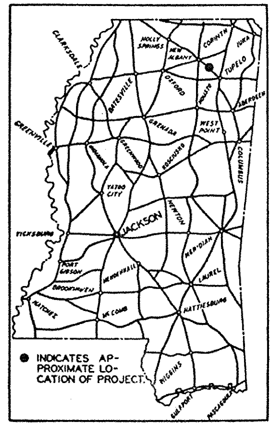
PLAN AND PROFILE OF PROPOSED
STATE HIGHWAY
STATE PROJECT NO. BP-0006-1(44)

98-0006-01-044-10

U.S. HIGHWAY NO. 78 BETWEEN
NEW ALBANY AND SHERMAN
UNION COUNTY

SCALES

PLAN 1 IN.=100 FT.
PROFILE (HOR. 1 IN.=100 FT.; VERT. 1 IN.= 10 FT.)
LAYOUT 1 IN.= 3,000 FT.



● INDICATES APPROXIMATE LOCATION OF PROJECT.

DESIGN CONTROL

70 MPH = V (SPEED DESIGN)
917 FT. = MIN. SIGHT DISTANCE
ADT (1970) = 6860: ADT (1990) = 17,150
DHV = 2,144 : D = 52 % T = 15 %

STA. 429+50 BEGINNING OF PROJECT
= STA. 429+50 OF FED. AID PROJ. NO. F-006-1 (17)

STA. 755+00 END OF PROJECT
= STA. 755+50 BEG. OF PROJ. NO. SP.-0006-1(45)

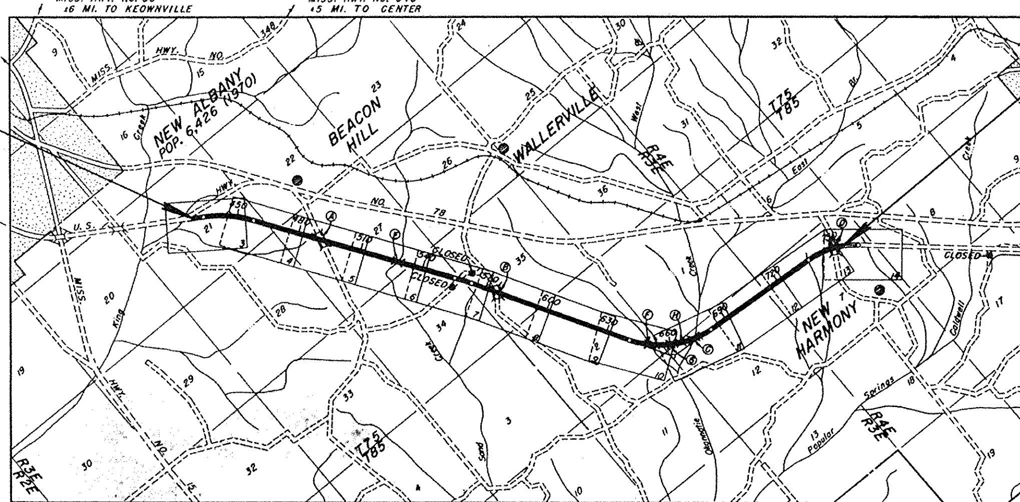
MISS. HWY. NO. 30 ±6 MI. TO KEOWNVILLE

MISS. HWY. NO. 348 ±5 MI. TO CENTER

MISS. HWY. NO. 15 ±12 MI. TO BLUE MOUNTAIN

U.S. HWY NO. 78 ±9 MI. TO MYRTLE

U.S. HIGHWAY NO. 78 ±2 MI. TO SHERMAN



MISS. HWY. NO. 15 ±15 MI. TO PONTOTOC

AMPLE UNLOADING FACILITIES ON S.L. & S.F. RR. AND G.M. & O. RR. IN NEW ALBANY.

LIST OF BRIDGES REQD.

(A) UNDERPASS: STA. 17+88.32 TO STA. 22+11.57
1@90', 2@120', 1@90 SPANS (BOX GIRDER)
LENGTH 423.14'

(B) UNDERPASS: STA. 18+04.68 TO STA. 22+25.38
1@104', 1@110', 2@102' SPANS
LENGTH 420.70'

(C) OVERPASS: STA. 668+05.85 RT. LANE,
STA. 669+14.00 LT. LANE 3@70' SPANS
REQD. LENGTH ON RT. LANE 210.96'

(D) UNDERPASS: STA. 23+30.83 TO STA. 26+55.17
1@80', 2@88', 1@66' SPANS
LENGTH 324.34'

(E) BOX BRIDGE: STA. 529+50 (20'X8')
LENGTH ALONG ℄ = 22.13'

(F) BOX BRIDGE: STA. 650+50 (20'X6')
LENGTH ALONG ℄ = 31.80' (SK. 45°)

(G) BOX BRIDGE: STA. 661+50 (28'X8')
LENGTH ALONG ℄ = 34.89' (SK. 30°)

(H) BOX BRIDGE: STA. 664+70 (24'X10')
LENGTH ALONG ℄ = 27.27'

(1) NOTE: THIS PROJECT IS DECLARED BY THE STATE HIGHWAY COMMISSION TO BE A "CONTROLLED ACCESS FACILITY" WITHIN THE MEANING OF CHAPTER 313, MISSISSIPPI LAWS OF 1956, AND IS SUBJECT TO ALL RESTRICTIONS AS SHOWN BY ORDER OF SAID COMMISSION DATE 27 JUNE 1972, IN MINUTE BOOK 97, PAGE 151.

(2) NOTE: ACCESS TO AND EXIT FROM THIS HIGHWAY WILL BE PERMITTED ONLY THROUGH INTERCHANGE, OR, SUCH OTHER POINTS AS MAY BE ESTABLISHED BY PUBLIC AUTHORITY AND AS SHOWN ON THE PLANS.

CONVENTIONAL SYMBOLS

COUNTY LINE
TOWN CORPORATION LINE
SECTION LINE
ROAD OR TRAVELED WAY
RAILROAD
SURVEY LINE
BRIDGES

EQUATIONS

681+78.11 BK. = 682+57.53 AH. -79.42 FT.

EXCEPTIONS

NONE

LENGTH DATA_COMPUTED ALONG RT. LN.

LENGTH OF ROADWAY	32,143.53 FT.	6.087 MI.
LENGTH OF BRIDGES	327.05 FT.	0.061 MI.
LENGTH OF PROJECT (NET)		6.148 MI.
LENGTH OF EXCEPTIONS	NONE FT.	0.000 MI.
LENGTH OF PROJECT (GROSS)		6.148 MI.

REVISIONS | DATE | BY

APPROVED:

DIRECTOR DATE

MISSISSIPPI STATE HIGHWAY DEPARTMENT

APPROVED:

DIVISION ENGINEER DATE

FEDERAL HIGHWAY ADMINISTRATION
DEPARTMENT OF TRANSPORTATION

DESCRIPTION OF SHEET	WORKING NUMBER	SHEET NUMBER
TITLE SHEET	1	1
DETAILED INDEX AND GENERAL NOTES SHEET		2
TYPICAL SECTION SHEET (3)		
MAIN FACILITY - B.O.P. TO STA. 328+38$^{.655}$ (CEDAR LAKE ROAD)	2	3
MAIN FACILITY - STA. 331+25$^{.245}$ (CEDAR LAKE ROAD) TO E.O.P.	2-A	4
INTERCHANGE RAMPS	2-B	5
QUANTITY SHEETS (4)		
SUMMARY OF QUANTITIES		6
SUMMARY OF QUANTITIES (BRIDGE ITEMS)		7
DRAINAGE STRUCTURES, FENCING, GUARD RAIL, CURBING & PAVED DITCHES		8
BRIDGE QUANTITIES		9
ESTIMATED QUANTITIES FOR TRAFFIC CONTROL		
PLAN AND PROFILE SHEETS (8)		
MAIN FACILITY - B.O.P. TO STA. 340+00	3	10
INTERCHANGE LAYOUT - CEDAR LAKE ROAD INTERCHANGE	3-A	11
S.E. RAMP	3-B	12
S.W. RAMP	3-C	13
N.E. RAMP AND N.E. FRONTAGE ROAD	3-D	14
N.W. RAMP	3-E	15
MAIN FACILITY - STA. 340+00 TO STA. 370+00	4	16
MAIN FACILITY - STA. 370+00 TO E.O.P.	5	17
SPECIAL DESIGN - ROADWAY ITEMS (14)		
DETAIL SHEETS		
PLAN OF MEDIAN BARRIER AND GUARD RAIL INSTALLATION FROM B.O.P. TO CEDAR LAKE ROAD BRIDGE		18
BRIDGE END PAVEMENT		19
SLOPE PAVING AT BRIDGE		20
VEGETATION SCHEDULE		21
TYPICAL SCHEDULE FOR LOCATION OF LIGHTING ASSEMBLIES, U.G. ELECTRIC CABLE AND U.G. LIGHTING CONDUIT.		22
DETAILS OF CONSTRUCTION SIGNING		23
STANDARD DRAWINGS		
CONTINUOUSLY REINFORCED CONCRETE PAVEMENT : 24' WIDE	P-CRP-1	102
CONTINUOUSLY REINFORCED CONCRETE PAVEMENT : 16' WIDE	P-CRP-1B	104
DOWEL AND JOINT DETAILS	P-DJ-1A	109 (1-25-72)
EROSION CONTROL	R-EC-1	125
FENCE : TYPICAL INSTALLATIONS	F-TI-1	141 (8-20-71)
GUARD RAIL : BEAM TYPE	G-GR-1	160 (11-22-71)
GUARD RAIL INSTALLATION	G-GR-3C	168 (7-15-71)
JUNCTION BOX FOR PIPE CULVERT	O-JB-1	231
HEADWALLS FOR CONCRETE PIPE, 3:1 SLOPES, 0°-15° SKEW	HW-3100	251

DESCRIPTION OF SHEET	WORKING NUMBER	SHEET NUMBER
SPECIAL DESIGN SHEETS - BRIDGE DRAWINGS (5)		
BRIDGE A, RT. LN. STA. 328+30$^{.23}$, LT. LN. STA. 328+47$^{.29}$ (CEDAR LAKE ROAD)		
ELEVATION LAYOUT	A1 OF 5	466
END BENT NO. 1 DETAILS	A2 OF 5	467
END BENT NO. 2 DETAILS	A3 OF 5	468
BOX GIRDER PIER BENT DETAILS	A4 OF 5	469
DECK PLAN	A5 OF 5	470
CROSS SECTIONS (42)		
MAIN FACILITY		901-927
CEDAR LAKE ROAD INTERCHANGE RAMPS		928-935
RELOCATION CEDAR LAKE ROAD		936-942
TOTAL SHEETS		78

STATE	PROJECT NO.
MISS.	F-0000-0(0)

PS&E PLANS - DATE 16 DEC 75

REVISIONS		
DATE	SHEET NO.	BY
31 DEC 75	5 & 9	AWK

GENERAL NOTES:

(1) PUBLIC UTILITIES
A. UNITED GAS CORPORATION, D'IBERVILLE, MISS.
B. MISS. POWER COMPANY

(2) 35% SHRINKAGE FACTOR AND THE BALANCE POINTS USED IN THE EARTHWORK DIAGRAM ARE FOR DESIGN ESTIMATING PURPOSES ONLY.

(3) A SOIL PROFILE, PREPARED FOR THIS PROJECT, ON SAMPLES TAKEN FROM HOLES AT LOCATIONS INDICATED IN THE TEST REPORTS ARE ON FILE IN THE DISTRICT AND CENTRAL CONSTRUCTION OFFICES AND ARE AVAILABLE FOR EXAMINATION. THE DEPARTMENT DOES NOT GUARANTEE THAT THE MATERIALS AS SHOWN IN THE REPORTS ARE NECESSARILY TO BE FOUND OUTSIDE THE LIMITS OF THE TEST HOLES.

EROSION CONTROL SYMBOLS

INDICATES EXCELSIOR BLANKET (REQ'D)
INDICATES ASPHALT COATED FIBERGLASS ROVING (REQ'D)
INDICATES PAVED DITCH (REQ'D)

MISSISSIPPI STATE HIGHWAY DEPARTMENT
DETAILED INDEX AND GENERAL NOTES
F-0000-0(0)
RANKIN CO.

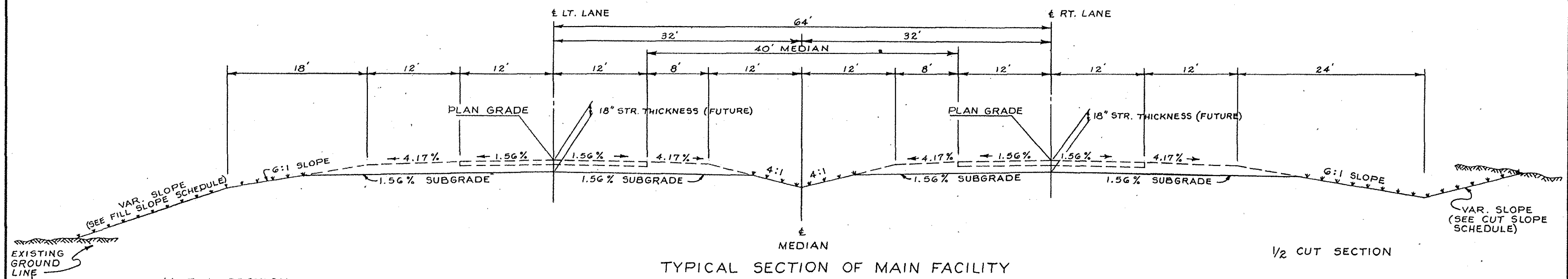
REVISIONS | DATE | BY

DESIGNED ___ DETAILED ___ TRACED ___
CHECKED ___ ISSUED ___ DATE ___

WORKING NUMBER

SHEET NUMBER 2

STATE	PROJECT NO.
MISS.	SP-0000-00(00)



TYPICAL SECTION OF MAIN FACILITY
(STA. 425+14.23 TO 593+00)

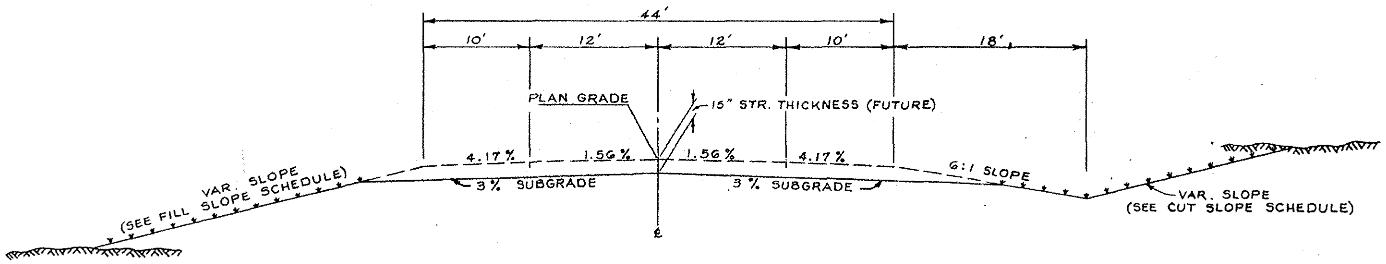
FILL SLOPE SCHEDULE	
*FILL HEIGHT	SLOPE
0 - 10'	6:1
10' - 20'	4:1
OVER 20'	3:1

* FROM SHOULDER EDGE TO GROUND LINE

CUT BACKSLOPE SCHEDULE	
HEIGHT	SLOPE
0 - 10'	6:1
10 - 20'	4:1
OVER 20'	3:1

NOTES:

1. NO CONSTRUCTION REQUIRED ABOVE SUBGRADE THIS CONTRACT.
2. (***) INDICATES AREA TO BE TREATED AS PER VEGETATION SCHEDULE.



RELOCATED CO. RD.
AT STA. 502+25

REVISIONS | BY | DATE

MISSISSIPPI STATE HIGHWAY DEPARTMENT

TYPICAL SECTIONS
(GRADING)

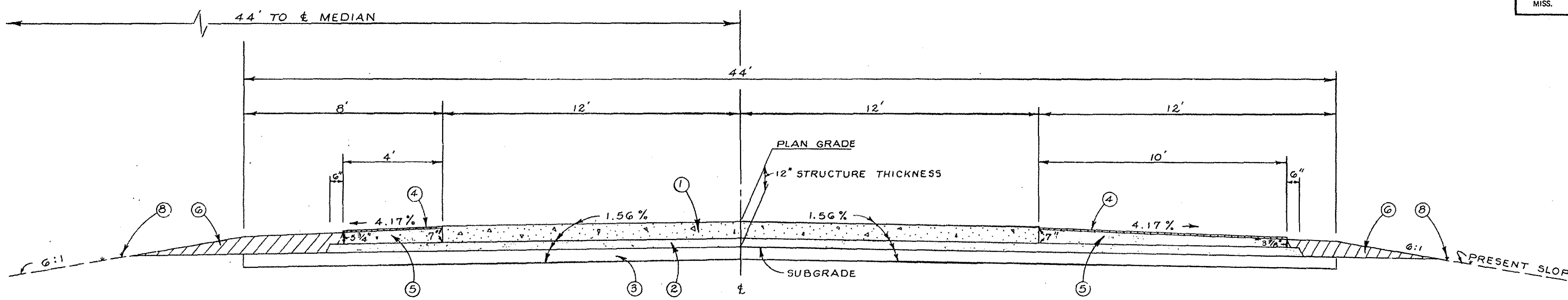
SP-0000-00(00)
HINDS COUNTY

DESIGNED ____ DETAILED ____ TRACED ____
CHECKED ____ ISSUED ____ DATE ____

WORKING NUMBER 2

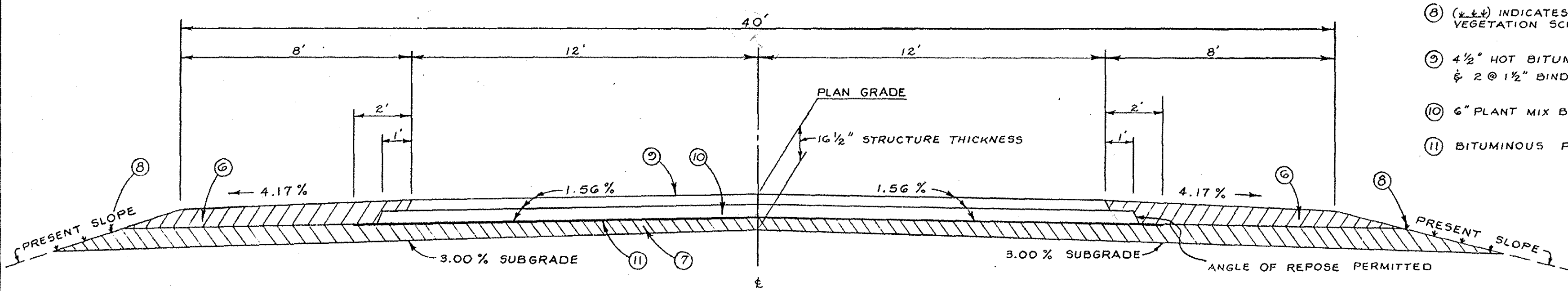
SHEET NUMBER 3

STATE	PROJECT NO.
MISS.	SP-0000-0(00)



TYPICAL SECTION OF MAIN FACILITY (4-LANE)
(RT. OR LT. LANE IN DIRECTION OF TRAFFIC)
STA. 1249+32 TO 1442+50
STA. 1500+00 TO 1560+90

1. 8" CONTINUOUSLY REINFORCED CEMENT CONCRETE PAVEMENT.
2. 4" PLANT MIX BITUMINOUS BASE COURSE
3. 6" LIME TREATED DESIGN SOIL (CLASS A, 28.4 + 15.8 LBS. PER SQ. YD. EST.)
4. DOUBLE BITUMINOUS SURFACE TREATMENT
5. 7" & VAR. DEPTH PLANT MIX BITUMINOUS BASE COURSE
6. VAR. DEPTH GRANULAR MATERIAL (CLASS 3, GROUP C)
7. 6" & VAR. DEPTH GRANULAR MATERIAL (CLASS 9, GROUP C) (SUBBASE COURSE)
8. (⁎⁎⁎) INDICATES EROSION CONTROL TREATMENT (SEE VEGETATION SCHEDULE)
9. 4½" HOT BITUMINOUS PAVEMENT (1 @ 1½" SURFACE COURSE & 2 @ 1½" BINDER COURSES)
10. 6" PLANT MIX BITUMINOUS BASE COURSE
11. BITUMINOUS PRIME COAT



TYPICAL SECTION OF 2-LANE ROADWAY
STA. 10+00 TO 133+50

MISSISSIPPI STATE HIGHWAY DEPARTMENT

TYPICAL SECTIONS
(PAVING)

SP-0000-0(00)
HINDS CO.

REVISIONS | BY | DATE

DESIGNED____ DETAILED____ TRACED____
CHECKED____ ISSUED____ DATE____

WORKING NUMBER 2-A
SHEET NUMBER 4

STATE	PROJECT NO.
MISS.	RF-0000-0(00)

SUMMARY OF QUANTITIES

PAY ITEM NO.	PAY ITEM	UNITS	PRELIMINARY	FINAL	PRELIMINARY	FINAL	PRELIMINARY	FINAL
	ROADWAY ITEMS		HINDS CO.		RANKIN CO.		TOTAL	
201-A	CLEARING AND GRUBBING	LUMP SUM	L.S.		L.S.		L.S.	
203-A	UNCLASSIFIED EXCAVATION (F.M.)	C.Y.	37,962		48,321		86,283	
204-A	HAUL OF EXCAVATION	STA. YD.	327,992		302,006		629,998	
206	STRUCTURE EXCAVATION	C.Y.	45		94		139	
323	CLASS B IN-GRADE PREPARATION	MILE	0.481		2.612		3.093	
601	CLASS B STRUCTURAL CONCRETE	C.Y.	2		11		13	
602	REINFORCEMENT	LB.	21		131		152	
603-1 OR 603-8	18" REINF. CONCRETE (CLASS III) OR VITRIFIED CLAY (EXTRA STRENGTH) PIPE	L.F.	120		480		600	
603-1	18" REINFORCED CONCRETE PIPE, CLASS III	L.F.	88		320		408	
603-1	30" REINFORCED CONCRETE PIPE, CLASS III	L.F.	112		0		112	
603-1	54" REINFORCED CONCRETE PIPE, CLASS IV	L.F.	0		108		108	
603-2	18" REINFORCED CONCRETE END SECTION	EACH	2		6		8	
603-2	30" REINFORCED CONCRETE END SECTION	EACH	2		0		2	
603-5	22" x 13" CONCRETE ARCH PIPE, CLASS A III	L.F.	0		120		120	
603-6	22" x 13" CONCRETE ARCH END SECTIONS, CLASS A II	EACH	0		2		2	
907-618	MAINTENANCE OF TRAFFIC	LUMP SUM	L.S.		L.S.		L.S.	
620	MOBILIZATION	LUMP SUM	L.S.		L.S.		L.S.	
621-A	FIELD LABORATORY	EACH	0		1		1	
	EROSION CONTROL ITEMS							
212	STANDARD GROUND PREPARATION (TYPE II)	S.Y.	28,220		153,237		181,457	
213-A	AGRICULTURAL LIMESTONE	TON	12		64		76	
213-B	COMBINATION FERTILIZER (10-20-10)	TON	3		16		19	
213-C	SUPERPHOSPHATE	TON	6		32		38	
214-A	SEEDING (BERMUDAGRASS)	LB.	90		480		570	
215-A	VEGETATIVE MATERIALS FOR MULCH	TON	12		64		76	
215-B	BITUMINOUS MATERIAL FOR MULCH	GAL.	1,500		8,000		9,500	
(1) 219	WATERING @ TWO DOLLARS & FIFTY CENTS ($ 2.50)	M/GAL.	564		3,065		3,629	
(2) 226-A	SOLID SODDING	S.Y.	131		576		707	
	PAVING ITEMS							
403-2	HOT BITUMINOUS PAVEMENT BINDER COURSE	TON	1,117		6,068		7,185	
403-3	HOT BITUMINOUS PAVEMENT SURFACE COURSE	TON	372		2,022		2,394	
	BOX BRIDGE ITEMS							
206	STRUCTURE EXCAVATION	C.Y.	235		0		235	
804-BB	CLASS BB STRUCTURAL CONCRETE	C.Y.	245		0		245	
805	REINFORCEMENT	LB.	26,218		0		26,218	

(1) SEE NOTE (4) ON VEGETATION SCHEDULE.

(2) INCLUDES 250 S.Y. ESTIMATED TO BE USED AS DIRECTED.

REVISIONS | BY | DATE

MISSISSIPPI STATE HIGHWAY DEPARTMENT

SUMMARY OF QUANTITIES
(ROADWAY)

RF-0000-0(00)
YAZOO CO.

DESIGNED ____ DETAILED ____ TRACED ____
CHECKED ____ ISSUED ____ DATE ____

WORKING NUMBER

SHEET NUMBER 5

STATE	PROJECT NO.
MISS.	F-FG-0013-2(16)

PAY ITEM NO.	PAY ITEM	UNIT	QUANTITIES	
	BRIDGE SUMMARY		PRELIMINARY	FINAL
801	Foundation Exc. For Bridges	C.Y.	188	
804 B	Class "B" Bridge Concrete	C.Y.	366.53	
804-T	50' Prest. Conc. Beams	L.F.	497.50	
804-T	68' Prest. Conc. Beams	L.F.	338.75	
805	Reinforcement	Lb.	73,496	
813-A	Concrete Railing	L.F.	336	
907-803-A	Test Piles (14" x 14" Conc.)	Each	2	
907-803-B	Loading Tests	Each	1	
907-803-B	Ultimate Loading Tests	Each	1	
907-803-E Or 907-803-F	14" x 14" Prec. Conc. Piling 14" x 14" Prest. Conc. Piling	L.F.	2,100	
815-F	Concrete Slope Paving	C.Y.	79	

MISSISSIPPI STATE HIGHWAY DEPARTMENT

SUMMARY OF QUANTITIES
(BRIDGE ITEMS)

PROJECT F-FG-0013-2(16)
13-0013-02-016-10

COPIAH COUNTY

REVISIONS | BY | DATE

DESIGNED HSH DETAILED HSH TRACED JWB
CHECKED HSH ISSUED JB DATE 6-27-73

WORKING NUMBER

SHEET NUMBER 6

STATE	PROJECT NO.
MISS.	SP-0000-0(00)

PIPE CULVERT DRAINAGE STRUCTURES

WORK. SH. NO.	STATION	CONC., B.C.C.M., OR V.C. PIPE * 15"	18"	24"	CONCRETE PIPE CLASS III 18"	30"	36"	54"	CLASS IV	42"	CL. IV, CL. "B" BED 18"			CONCRETE ARCH PIPE 22"x13"	65"x40"	CONC. FLARED END SECTIONS 18"	30"	36"	42"	54"	22"x13"	65"x40"	INLETS, JCT. BOXES, HDWLS, COLLARS, & PAVED INLET APRONS INLET NO.	STANDARD	WIDTH	LENGTH	HEIGHT	OPENINGS	CL. "B" CONC.	REINF.	CASTING	GRATING	PAVED APRON	COVER MAT'L.	STR. EXCAV.	REMARKS
5	83+25	40																																	—	UNDER RAMP LT.
3	86+70				164											2																			27.4	
4	103+14				20											1							C.I.#1	D-SS-2	2'-6"	5'	3.66	1 - 18"	2.16	202	59				4.4	FROM CI #1 TO DITCH
5	124+75													224							4														51.9	DBL. LINE
8	211+50													80							1			** LPI-1			MIN.(6:1)		0.66	52		197	1.3		15.0	UNDER LT. LANE
	UNITS	L.F.	L.F.	L.F.	L.F.	L.F.	L.F.	L.F.		L.F.	L.F.			L.F.	L.F.	EACH	EACH	EACH	EACH	EACH	EACH	EACH							C.Y.	LB.	LB.	LB.	C.Y.	C.Y.	C.Y.	
	TOTALS	160	84	40	548	132	88	120		148	224			304	92	14	6	4	4	2	5	2							13.19	1412	708	1182	18.2	83	267.8	

* PIPE ALTERNATES - CLASS III CONCRETE, BITUMINOUS COATED CORRUGATED METAL, OR EXTRA STRENGTH VITRIFIED CLAY

** SPECIAL DESIGN LOW PROFILE INLET (SEE DETAILS ON SH. NO. ___)

*** CONCRETE ARCH PIPE - CLASS A III AASHTO M206-73

BOX BRIDGE QUANTITIES

WORKING SH. NO.	STATION	LENGTH ALONG ℄	SIZE	STATE STANDARDS	LENGTH	CL. "BB" CONC.	REINF.	STR. EXCAV.	REMARKS
4	91+25	22.375	DBL. 10 X 10	IBD-10-2W; IBJL-1; IWD-5	70.3	244.74	26,218	234.7	
6	166+05	25.596	20 x 8	IBS-8-2W; IBJL-1; IWS-4; ISK-30-4W	87.2	320.63	46,960	331.7	SK. 30° LT. FWD.
						C.Y.	LB.	C.Y.	
	TOTALS								

BOX CULVERT QUANTITIES

WORKING SH. NO.	STATION	SIZE	STATE STANDARDS	LENGTH	CL. "B" CONC.	REINF.	STR. EXCAV.	REMARKS
6	180+00	8 x 6	IBS-6-2W; IBJL-1; IWS-3; IBSM-3W	131.1	120.93	24,441	134.0	MOD. FOR 12' HIGH FILL
8	219+17	12 x 8	IBS-8-2W; IBJL-1; IWS-4; ISK-15-4W	73.2	128.72	17,715	177.6	SK. 15° RT. FWD.
					C.Y.	LB.	C.Y.	
	TOTALS				249.65	42,156	311.6	

BRIDGE END PAVEMENT

BR. ABUTMENT AT STATION	W	W1	W2	A	B	ANGLE "Z"	PAV'T	JOINT
157 + 59.21	39.50	19.75	19.75	20.00	20.00	0°	88.14	39.50
160 + 00.79	39.50	19.75	19.75	20.00	20.00	0°	88.14	39.50
179 + 44.21	39.50	19.75	19.75	20.00	20.00	0°	88.14	39.50
180 + 85.79	39.50	19.75	19.75	20.00	20.00	0°	88.14	39.50
UNITS							SQ. YDS.	LIN. FT.
TOTALS							352.56	158.00

DITCH TREATMENT QUANTITIES

WORK. SH. NO.	ASPHALT COATED FIBERGLASS ROVING	RIP RAP	PAVED DITCH	SOLID SOD	~~EXCELSIOR BLANKET~~	REMARKS
3			7	44	98	
4	751	14	81	487	1173	
5	574	11	10	60	490	
	275	15	15	50	100	EST. TO BE USED AS
						DIRECTED
	S.Y.	TONS	C.Y.	S.Y.	S.Y.	
TOTALS	* 1600	40	113	641	1861	

* ESTIMATED RATES OF APPLICATION : 0.35 GAL./S.Y. ASPHALT
0.35 LBS./S.Y. FIBERGLASS ROVING

GUARD RAIL QUANTITIES

WORK. SH. NO.	STATION	GUARD RAIL TYPE I		CABLE ANCHORAGE TYPE 2		BR. END SECTION TYPE "A"	TYPE "E"	REMARKS
3	81+19	75		1		1		LT. OF ℄
3	81+19	175		1			1	RT. OF ℄
3	83+19	175		1			1	LT. OF ℄
3	83+19	75		1		1		RT. OF ℄
		L.F.		EACH		EACH	EACH	
	TOTALS	500		4		2	2	

ESTIMATED EARTHWORK QUANTITIES

WORK. SH. NO.	UNCL. EXCAV. (F.M.)	HAUL OF EXCAV.	BORROW EXCAV. (FME)	MUCK EXCAV.	CHANNEL EXCAV.
3	16,212	236,187			3,800
4	3,583	937,770	161,469	11,194	
5	11,121	68,950			
5-8	771	3,277			
6	26,895	215,160	6,383		
	C.Y.	STA. YDS.	C.Y.	C.Y.	C.Y.
TOTALS	58,582	1,461,344	167,852	11,194	3,800

SUMMARY OF HYDRAULIC DESIGN DATA

W. SH. NO.	STATION	CULV. SIZE	* DESIGN FLOOD (50-YEAR FLOOD) DISCHARGE (C.F.S.)	HEADWATER (ELEV.)	* BASIC FLOOD (100 YEAR FLOOD) DISCHARGE (C.F.S.)	HEADWATER (ELEV.)	FLOOD OF RECORD (DATE OF OCCURENCE) DISCHARGE (C.F.S.)	HIGHWATER (ELEV.)	CONTROLLING HEADWATER UPSTREAM FLOW LINE	H_W DEPTH (FT.)
4	91+25	DBL. 10 x 10	1840	305.2	2153	306.4	(FEB. 2, 1955) 2380	307.4	294.2	11.0/12.2
6	166+05	20x8	1300	311.4	1521	312.4	—	—	302.6	8.8/9.8
6	180+00	8x6	376	310.8	440	311.6	—	—	303.7	7.1/7.9
8	219+17	12x8	864	310.7	1011	311.9	—	—	301.3	9.4/10.6

* HEADWATER ELEVATION VALUES SHOWN ON THESE PLANS ARE THEORETICAL AND MAY VARY FROM ACTUAL CONDITIONS.

MISSISSIPPI STATE HIGHWAY DEPARTMENT

ESTIMATED QUANTITIES
(ROADWAY)

SP-0000-0(00)
HINDS CO.

REVISIONS | BY | DATE

DESIGNED ___ DETAILED ___ TRACED ___
CHECKED ___ ISSUED ___ DATE ___

WORKING NUMBER

SHEET NUMBER 7

BRIDGE	BEGIN STATION	SPANS - SIZE	OVERALL LENGTH	ITEM	CLASS "B" BRIDGE CONCRETE C.Y.	CLASS "S" BRIDGE CONCRETE C.Y.	REINFORCEMENT LBS	CONCRETE RAILING L.F	40' PREST. CONCRETE BEAMS L.F.	50' PREST. CONCRETE BEAMS L.F.	90' PREST. CONCRETE BEAMS L.F.	110' PREST. CONCRETE BEAMS L.F.	10BP42 STEEL PILING L.F.	12BP53 STEEL PILING L.F.	12BP53 STEEL TEST PILES EACH	LOADING TESTS EACH	FOUNDATION EXCAVATION FOR BRIDGES C.Y.
A	73+10	3 @ 40'	1,050'	SPANS	1,092.12		240,472	2,100	4,531.50		1,256.50	768.25					
		1 @ 90'-8 3/8"		END BENTS	28.10		3,728						480				
		1 @ 110'		INT. BENTS	596.99	93.35	70,812							6,230	6		394
		1 @ 89'-3 5/8" 16 @ 40'	BRIDGE A	TOTALS	1717.21	93.35	315,012	2100	4531.50		1256.50	768.25	480	6,230	6	1	394
B	447+18.875	5 @ 50	250'	SPANS	261.98		62,300	500		1,492.50							
				END BENTS	56.57		8,082						800				
				INT. BENTS	64.78		5,353							550	2		
			BRIDGE B	TOTALS.	383.33		75,735	500		1,492.50			800	550	2	1	

MISSISSIPPI STATE HIGHWAY DEPARTMENT

ESTIMATED BRIDGE QUANTITIES

PROJECT SP-0002-3(14)
79-0002-03-014-10

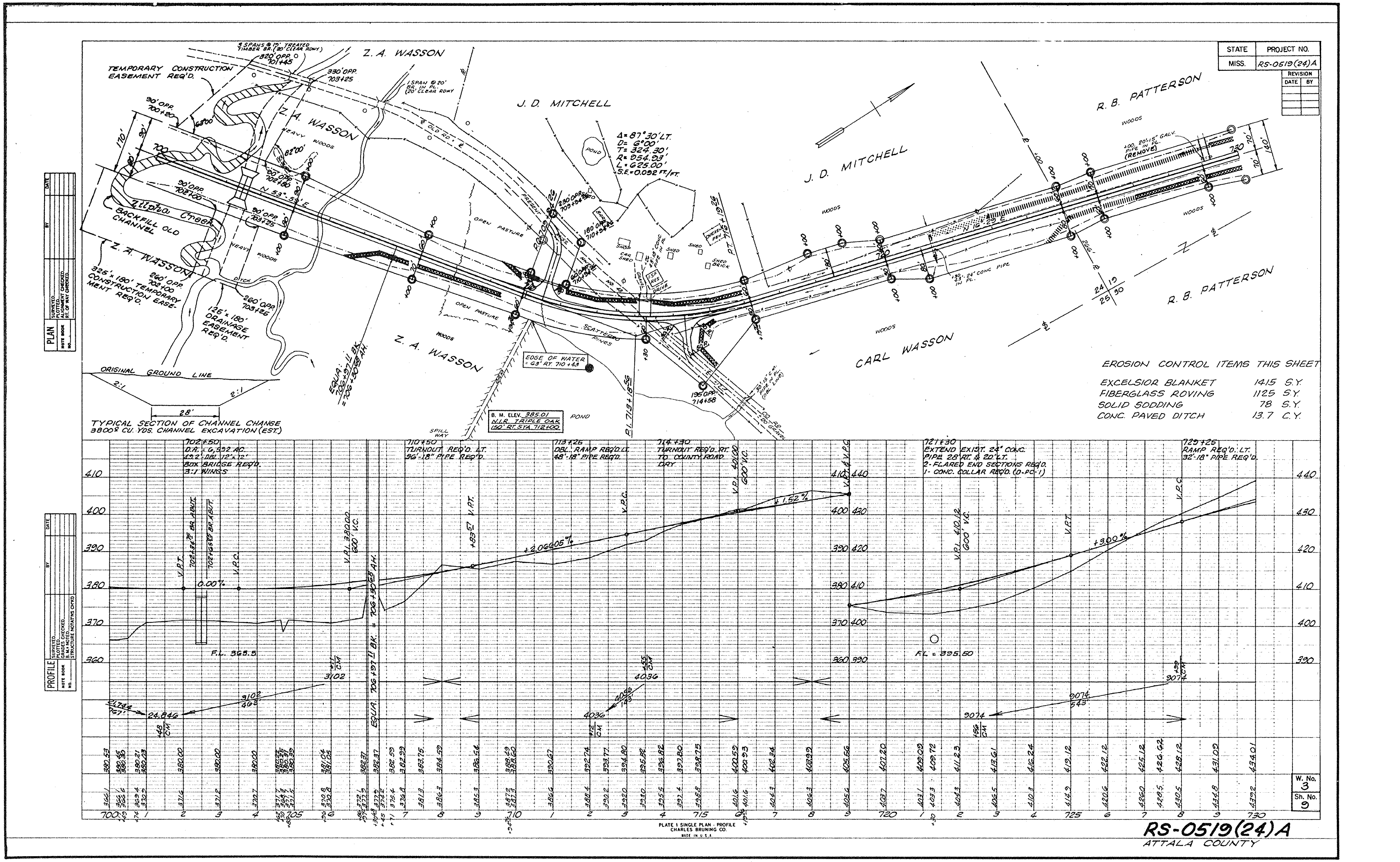
NOXUBEE COUNTY

REVISIONS | DATE | BY

DESIGNED ____ DETAILED ____ TRACED ____
CHECKED ____ ISSUED ____ DATE ____

WORKING NUMBER

SHEET NUMBER 8


STATE | PROJECT NO.
MISS. | RS-0519(24)A
REVISION
DATE | BY
Z. A. WASSON
J. D. MITCHELL
R. B. PATTERSON
CARL WASSON
TEMPORARY CONSTRUCTION EASEMENT REQ'D.
BACKFILL OLD CHANNEL
325'x180' TEMPORARY CONSTRUCTION EASEMENT REQ'D.
126'x180' DRAINAGE EASEMENT REQ'D.
Δ= 87°30' LT.
D= 6°00'
T= 324.30'
R= 954.93'
L= 625.00'
S.E.= 0.092 FT/FT.
EDGE OF WATER 63' RT. 710+43
B. M. ELEV. 385.01 N.I.R. TRIPLE OAK 150' RT. STA. 712+00
EQUA: 11 BK. 706+97 = 706+30 AH.
ORIGINAL GROUND LINE
TYPICAL SECTION OF CHANNEL CHANGE
3800± CU. YDS. CHANNEL EXCAVATION (EST.)
EROSION CONTROL ITEMS THIS SHEET
EXCELSIOR BLANKET 1415 S.Y.
FIBERGLASS ROVING 1125 S.Y.
SOLID SODDING 78 S.Y.
CONC. PAVED DITCH 13.7 C.Y.
702+50 D.A. = 6,592 AC. 13'2" DBL 12'x12' BOX BRIDGE REQ'D. 3:1 WINGS
710+50 TURNOUT REQ'D. LT. 36'-18" PIPE REQ'D.
713+26 DBL. RAMP REQ'D. LT. 48'-18" PIPE REQ'D.
714+30 TURNOUT REQ'D. RT. TO COUNTY ROAD DRY
721+30 EXTEND EXIST. 24" CONC. PIPE 28' RT. & 20' LT. 2-FLARED END SECTIONS REQ'D. 1- CONC. COLLAR REQ'D. (D-PC-1)
725+25 RAMP REQ'D. LT. 32'-18" PIPE REQ'D.
0.00%
+2.06605%
+1.52%
+3.00%
V.P.I. 380.00 600' V.C.
V.P.I. 401.00 600' V.C.
V.P.I. 410.12 600' V.C.
F.L. 365.5
F.L. = 395.50
PLAN
PROFILE
W. No. 3
Sh. No. 9
PLATE 1 SINGLE PLAN - PROFILE CHARLES BRUNING CO. MADE IN U.S.A.
RS-0519(24)A
ATTALA COUNTY

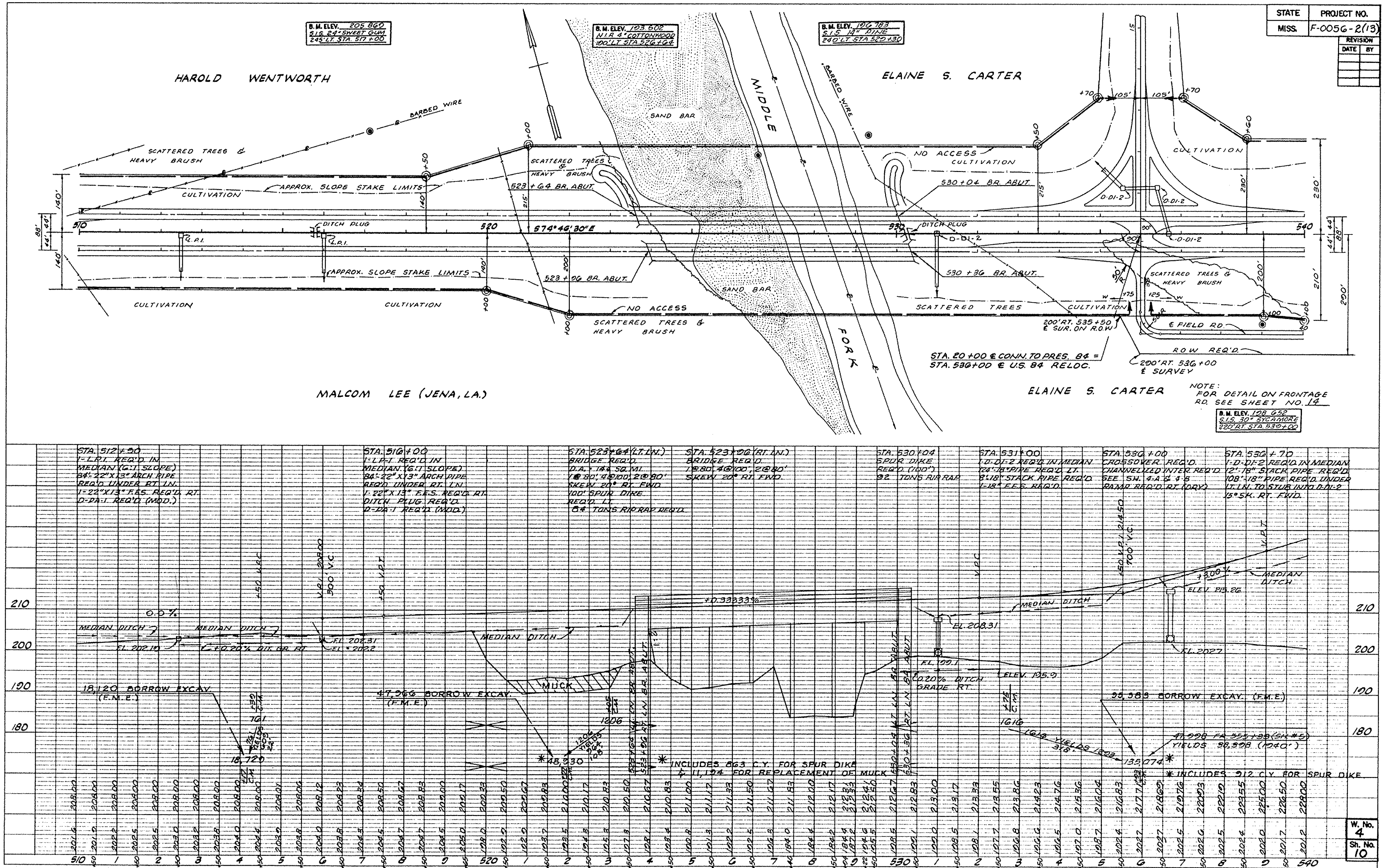
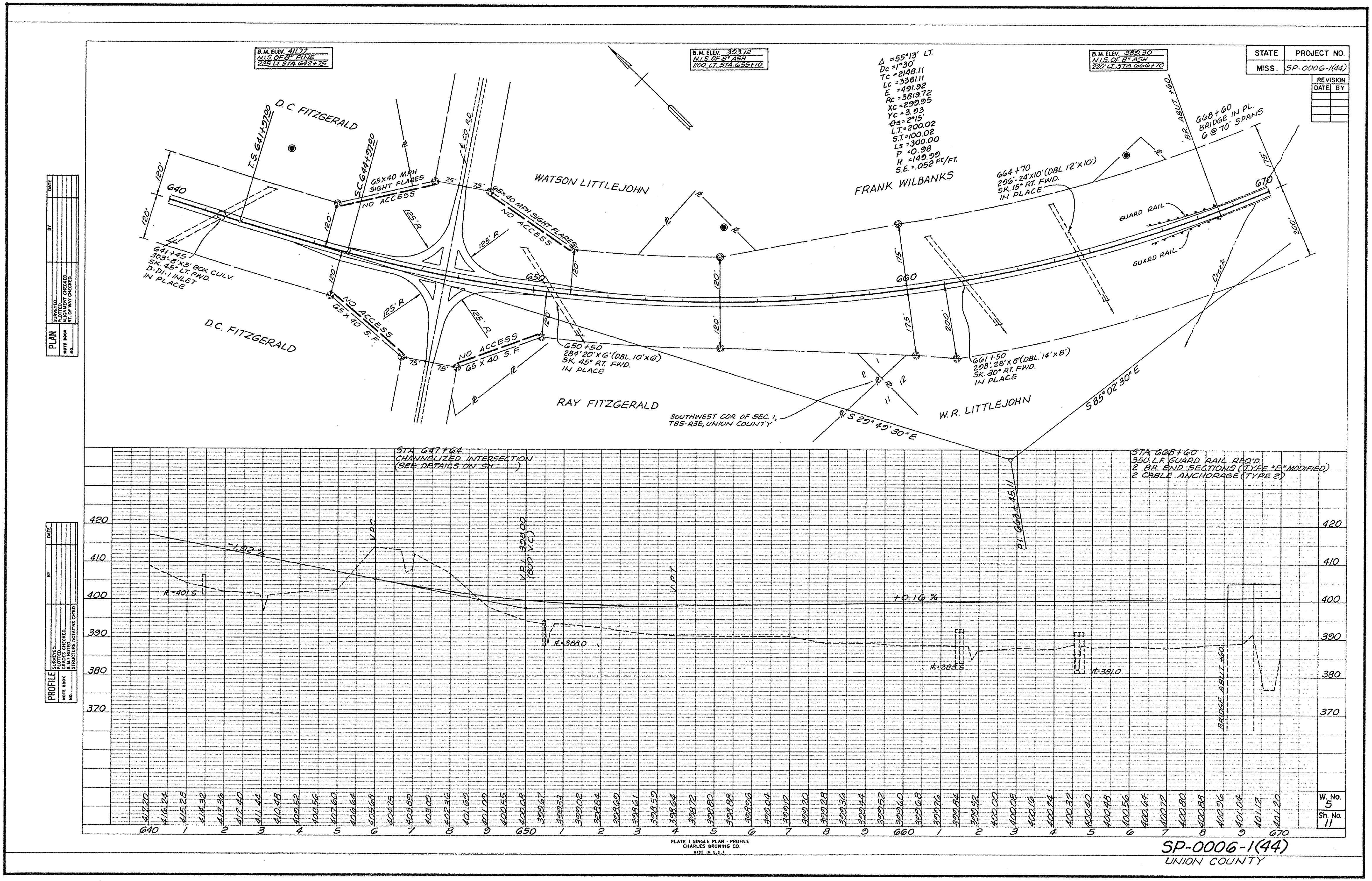
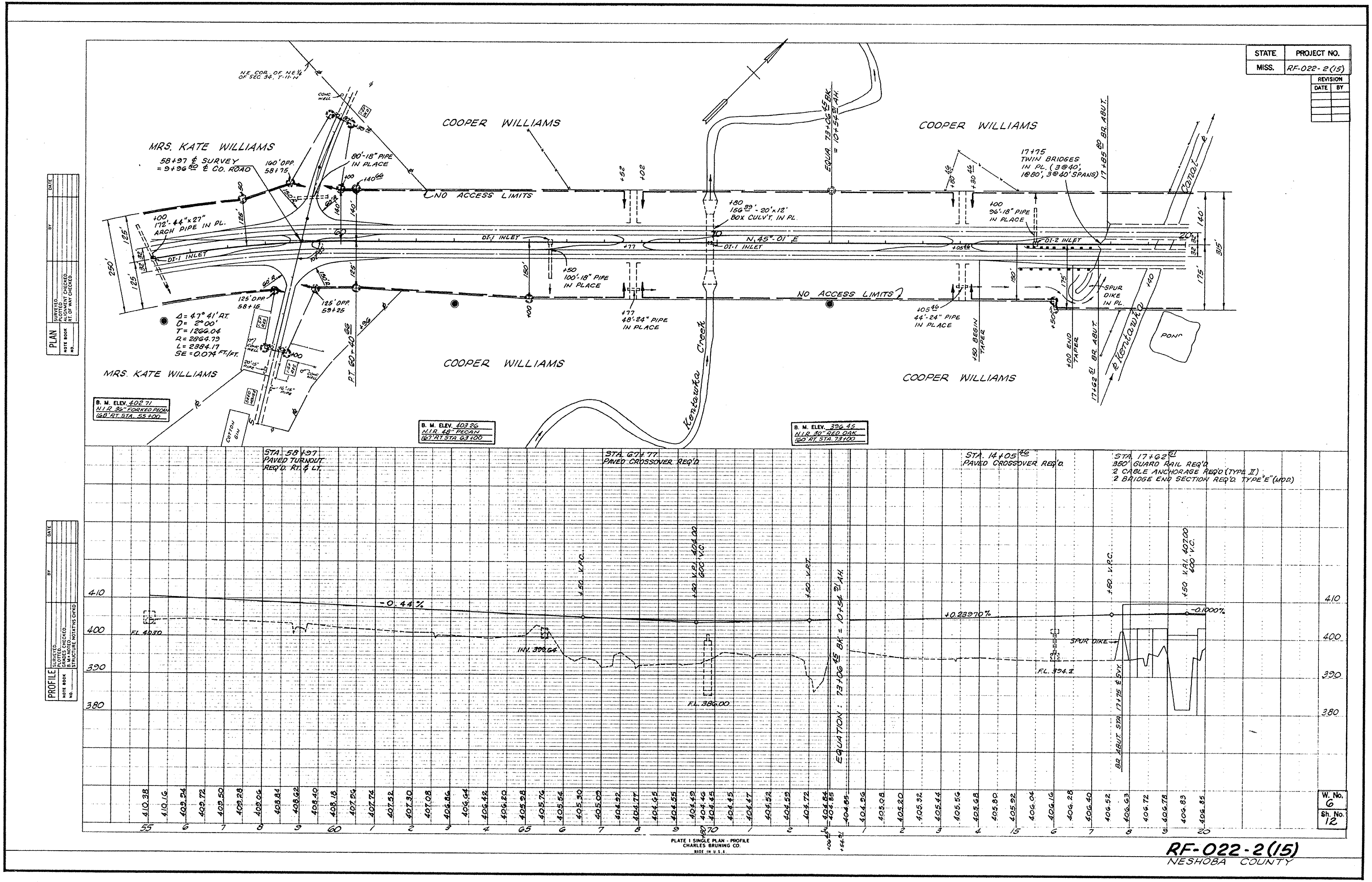


PLATE 1 SINGLE PLAN - PROFILE
CHARLES BRUNING CO.
MADE IN U.S.A.

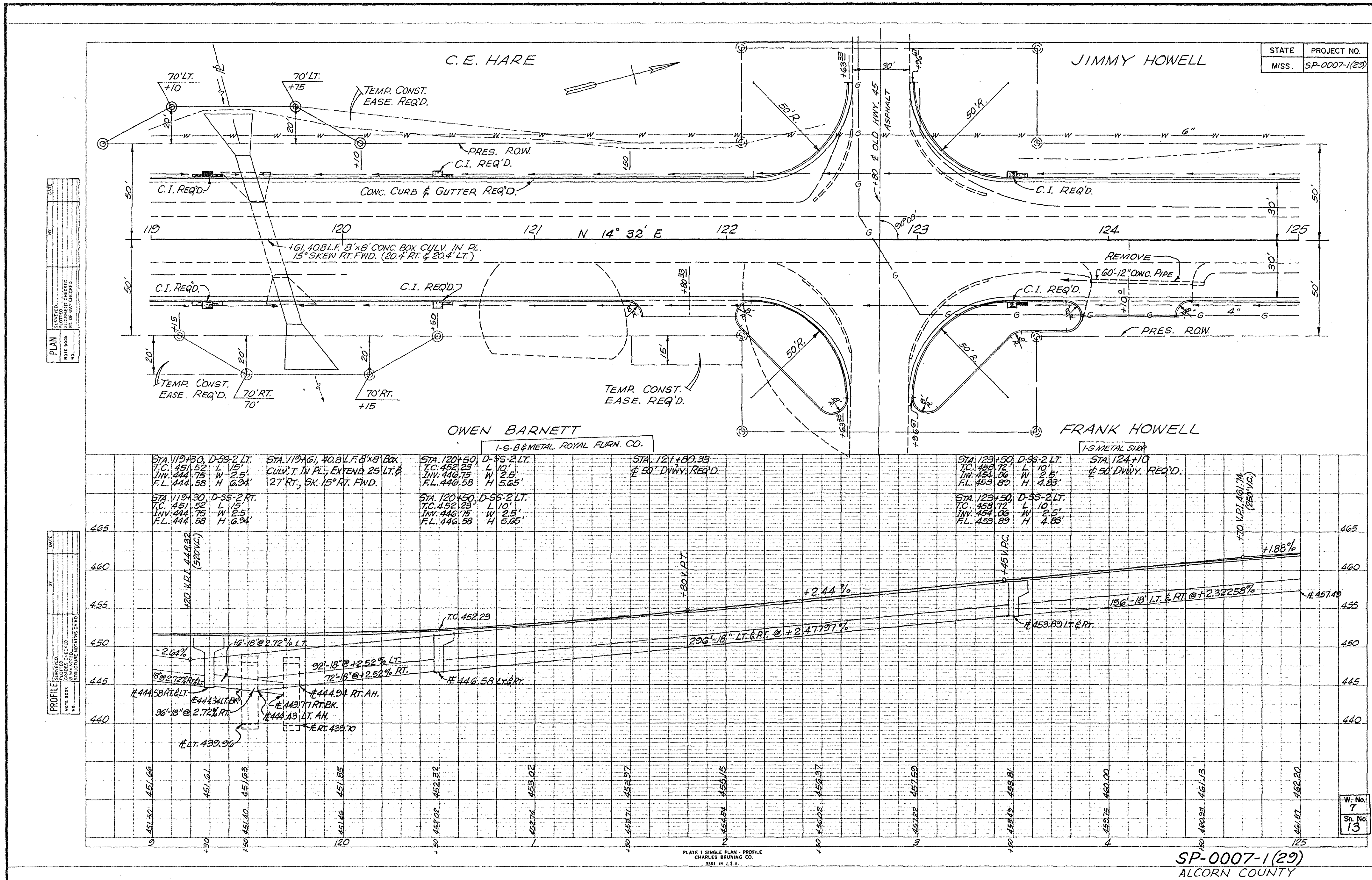
F-0056-2(13)
UNION CO.


STATE | PROJECT NO.
MISS. | SP-0006-1(44)
REVISION
DATE BY
B.M. ELEV. 411.77
N.I.S. OF 8" PINE
225 LT. STA. 642+75
B.M. ELEV. 393.12
N.I.S. OF 8" ASH
200' LT. STA. 655+10
B.M. ELEV. 389.30
N.I.S. OF 8" ASH
220' LT. STA. 666+70
Δ =55°13' LT.
Dc =1°30'
Tc =2148.11
Lc =3381.11
E =491.92
Rc =3819.72
Xc =299.95
Yc =3.93
θs =2°15'
L.T.=200.02
S.T.=100.02
Ls =300.00
P =0.98
K =149.99
S.E.=.052 FT./FT.
D.C. FITZGERALD
WATSON LITTLEJOHN
FRANK WILBANKS
RAY FITZGERALD
W.R. LITTLEJOHN
T.S. 641+97.00
S.C. 644+97.00
65x40 MPH SIGHT FLARES
NO ACCESS
65 x 40 S.F.
641+45
303'-8'x5' BOX CULV.
SK. 45° LT. FWD.
D-DI-1 INLET
IN PLACE
650+50
284'-20'x6'(DBL. 10'x6')
SK. 45° RT. FWD.
IN PLACE
661+50
298'-28'x8'(DBL. 14'x8')
SK. 30° RT. FWD.
IN PLACE
664+70
296'-24'x10'(DBL 12'x10')
SK. 15° RT. FWD.
IN PLACE
668+60
BRIDGE IN PL.
6 @ 70' SPANS
BR. ABUT. + 60
GUARD RAIL
Creek
SOUTHWEST COR. OF SEC. 1,
T8S-R3E, UNION COUNTY
S 29°49'30" E
S 85°02'30" E
STA. 647+64
CHANNELIZED INTERSECTION
(SEE DETAILS ON SH.)
STA. 668+60
350 L.F. GUARD RAIL REQ'D.
2 BR. END SECTIONS (TYPE "E" MODIFIED)
2 CABLE ANCHORAGE (TYPE 2)
P.I. 663+45.11
V.P.C.
V.P.I. 398.00
(800' V.C.)
V.P.T.
-1.92%
+0.16%
BRIDGE ABUT. +60
FL.=401.5
FL.=388.0
FL.=383.5
FL.=381.0
420
410
400
390
380
370
417.20 416.24 415.28 414.32 413.36 412.40 411.44 410.48 409.52 408.56 407.60 406.64 405.68 404.75 403.89 403.09 402.36 401.69 401.09 400.55 400.08 399.67 399.33 399.05 398.84 398.69 398.61 398.59 398.64 398.72 398.80 398.88 398.96 399.04 399.12 399.20 399.28 399.36 399.44 399.52 399.60 399.68 399.76 399.84 399.92 400.00 400.08 400.16 400.24 400.32 400.40 400.48 400.56 400.64 400.72 400.80 400.88 400.96 401.04 401.12 401.20
640 1 2 3 4 5 6 7 8 9 650 1 2 3 4 5 6 7 8 9 660 1 2 3 4 5 6 7 8 9 670
PLAN
PROFILE
W. No. 5
Sh. No. 11
PLATE 1 SINGLE PLAN - PROFILE
CHARLES BRUNING CO.
MADE IN U.S.A.
SP-0006-1(44)
UNION COUNTY

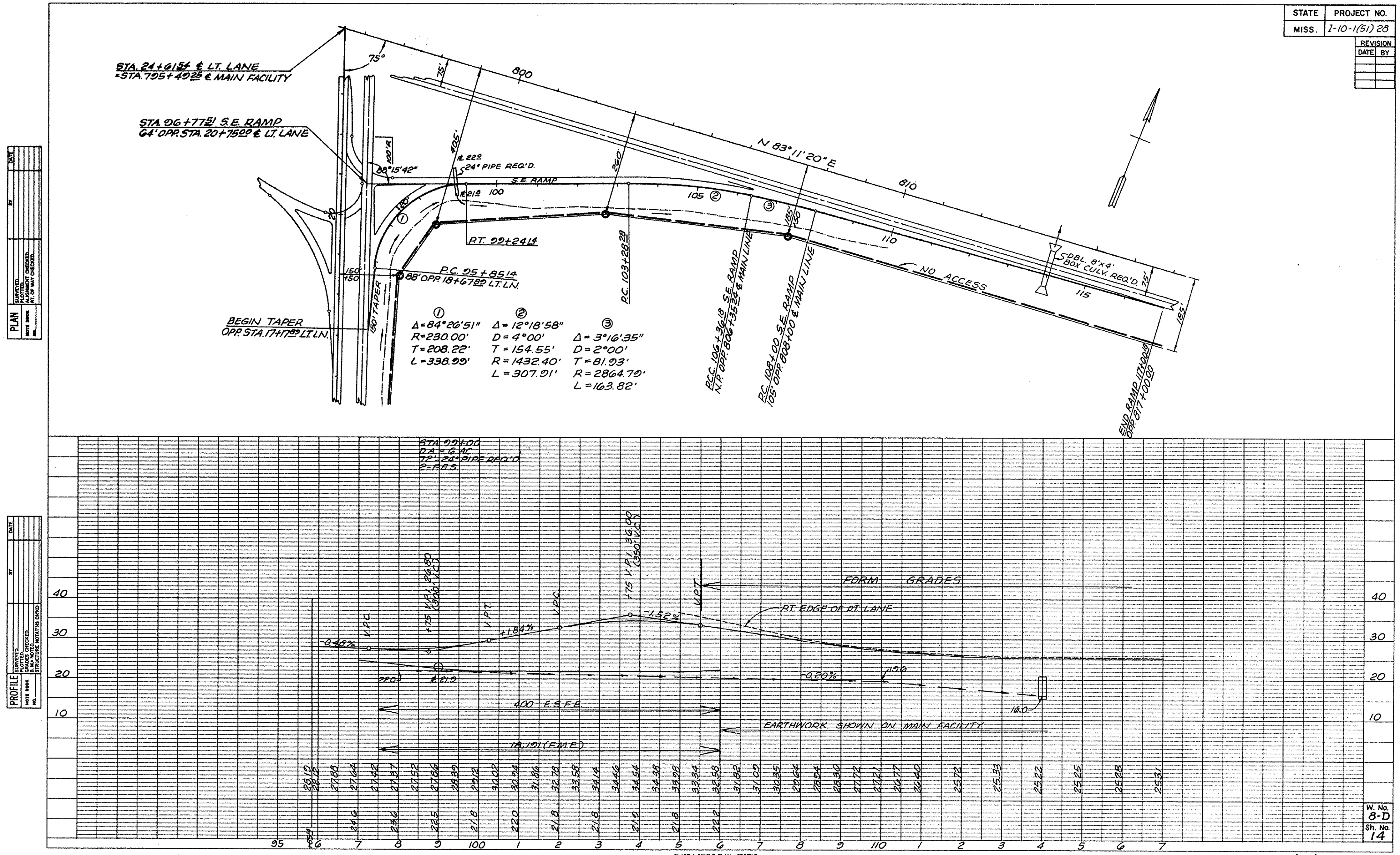


RF-022-2(15)

NESHOBA COUNTY


STATE
PROJECT NO.
MISS.
SP-0007-1(29)
C.E. HARE
JIMMY HOWELL
OWEN BARNETT
FRANK HOWELL
70' LT. +10
70' LT. +75
TEMP. CONST. EASE. REQ'D.
PRES. ROW
C.I. REQ'D.
CONC. CURB & GUTTER REQ'D.
50'R.
30'
+63.33
+80 ℄ OLD HWY. 45 ASPHALT
N 14° 32' E
119
120
121
122
123
124
125
+61, 408 L.F. 8'x8' CONC. BOX CULV. IN PL. 15° SKEW RT. FWD. (20.4' RT. & 20.4' LT.)
REMOVE
60-12" CONC. PIPE
PRES. ROW.
70' RT.
70'
+15
+50
1-S-B & METAL ROYAL FURN. CO.
1-S METAL SHOP
STA. 119+30, D-SS-2 LT. T.C. 451.52 L 15' INV. 444.75 W 2.5' F.L. 444.58 H 6.94'
STA. 119+30, D-SS-2 RT. T.C. 451.52 L 15' INV. 444.75 W 2.5' F.L. 444.58 H 6.94'
STA. 119+61, 40.8 L.F. 8'x8' BOX CULV. T. IN PL., EXTEND 25' LT. & 27' RT., SK. 15° RT. FWD.
STA. 120+50, D-SS-2 LT. T.C. 452.23 L 10' INV. 446.75 W 2.5' F.L. 446.58 H 5.65'
STA. 120+50, D-SS-2 LT. T.C. 452.23 L 10' INV. 446.75 W 2.5' F.L. 446.58 H 5.65'
STA. 121+80.33 ℄ 50' DVWY. REQ'D.
STA. 123+50, D-SS-2 LT. T.C. 458.72 L 10' INV. 454.06 W 2.5' F.L. 453.89 H 4.83'
STA. 123+50, D-SS-2 LT. T.C. 458.72 L 10' INV. 454.06 W 2.5' F.L. 453.89 H 4.83'
STA. 124+10 ℄ 50' DVWY. REQ'D.
+20 V.P.I. 448.32 (520' V.C.)
+80 V.P.T.
+45 V.P.C.
+70 V.P.I. 461.74 (250' V.C.)
-2.64%
+2.44%
+1.88%
T.C. 452.23
16'-18" @ 2.72% LT.
92'-18" @ +2.52% LT.
72'-18" @ +2.52% RT.
296'-18" LT. & RT. @ +2.47797%
156'-18" LT. & RT. @ +2.32258%
℄ 457.45
℄ 453.89 LT. & RT.
℄ 446.58 LT. & RT.
18" @ 2.72% RT. & LT.
℄ 444.58 RT. & LT.
℄ 444.34 LT. BK.
36'-18" @ 2.72% RT.
℄ 444.94 RT. AH.
℄ 443.77 RT. BK.
℄ 444.43 LT. AH.
℄ RT. 439.70
℄ LT. 439.96
465
460
455
450
445
440
451.66
451.61
451.63
451.85
452.32
453.02
453.97
455.15
456.37
457.59
458.81
460.00
461.13
462.20
451.50
451.40
451.46
452.02
452.74
453.71
454.84
456.02
457.22
458.43
459.75
460.93
461.87
9
+30
+50
120
+50
1
+50
2
+50
3
+50
4
+50
125
W. No. 7
Sh. No. 13
PLATE 1 SINGLE PLAN - PROFILE CHARLES BRUNING CO.
MADE IN U.S.A.
PLAN
PROFILE
SP-0007-1(29)
ALCORN COUNTY

STATE	PROJECT NO.
MISS.	I-10-1(51) 28

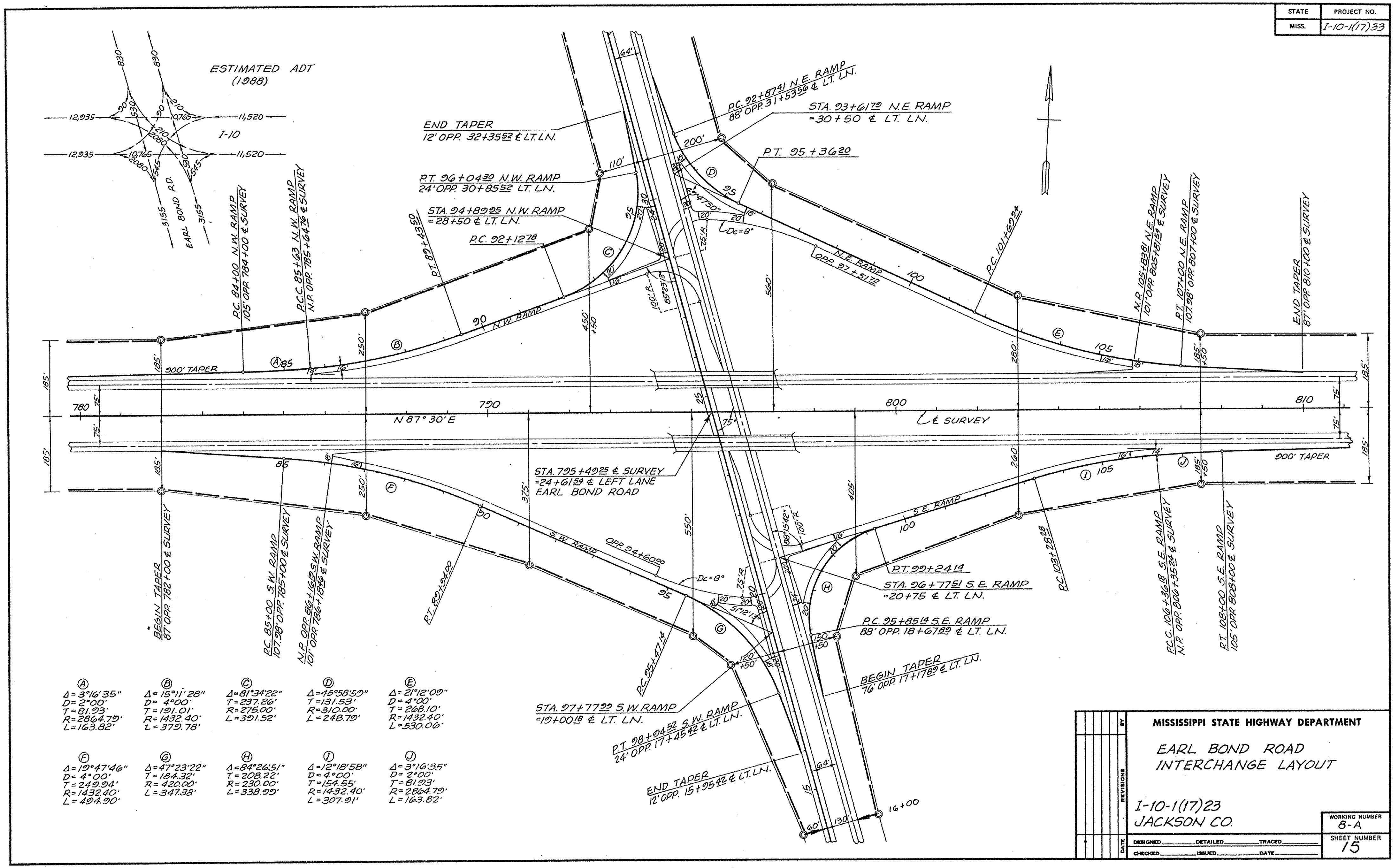


W. No. 8-D
Sh. No. 14

PLATE 1 SINGLE PLAN - PROFILE
CHARLES BRUNING CO.
MADE IN U.S.A.

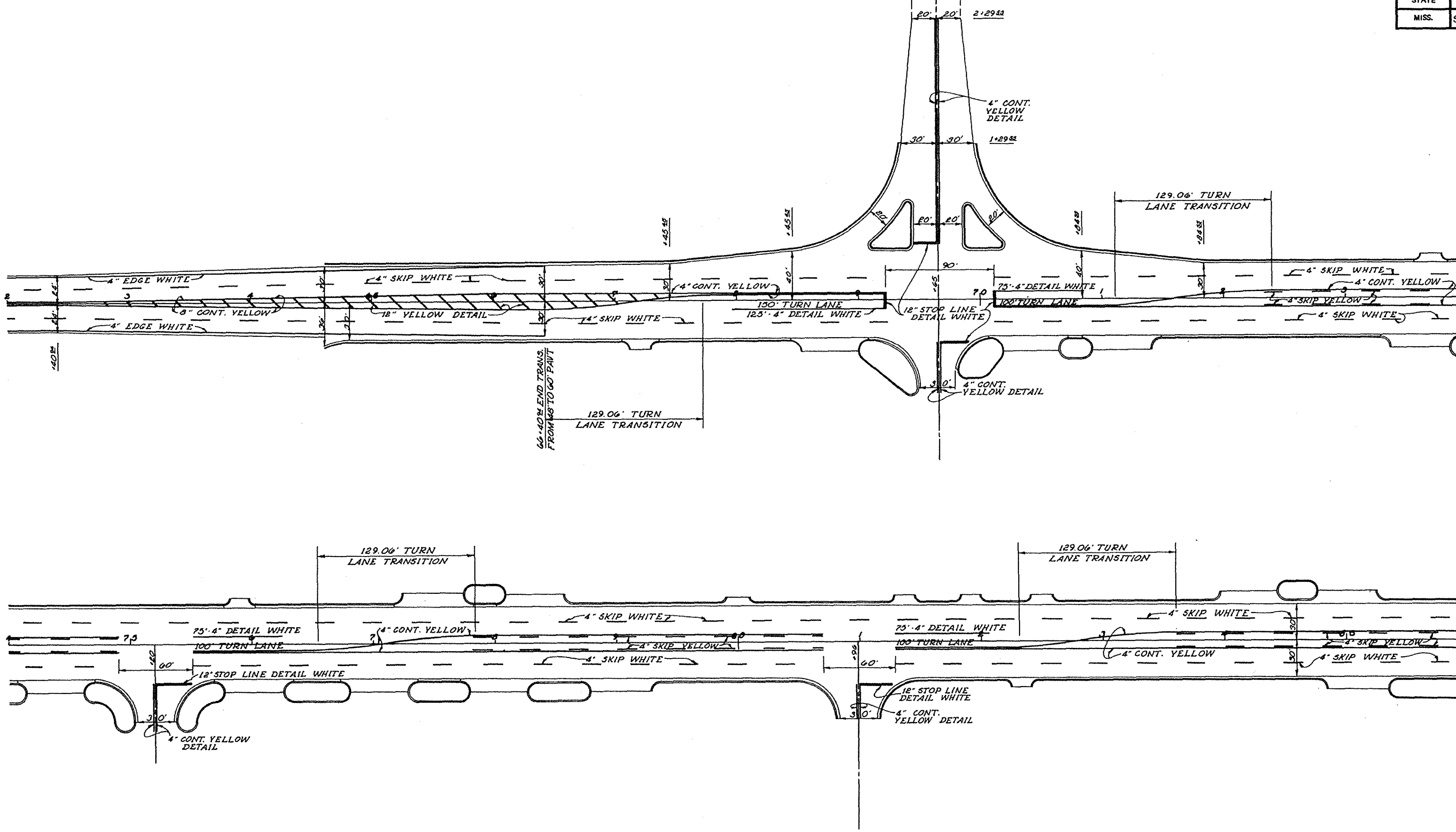
S.E. RAMP DEDEAUX RD. INTERCHANGE I-10-1(51) 28

JACKSON CO.



STATE MISS.
PROJECT NO. I-10-1(17)33
ESTIMATED ADT (1988)
I-10
EARL BOND RD.
12,935
11,520
10,765
830
3155
END TAPER 12' OPP. 32+35.52 ¢ LT. LN.
P.T. 96+04.30 N.W. RAMP 24' OPP. 30+85.52 LT. LN.
STA. 94+89.25 N.W. RAMP =28+50 ¢ LT. LN.
P.C. 92+12.78
P.T. 89+43.50
P.C. 84+00 N.W. RAMP 105' OPP. 784+00 ¢ SURVEY
P.C.C. 85+63 N.W. RAMP N.P. OPP. 785+64.76 ¢ SURVEY
P.C. 92+87.41 N.E. RAMP 88' OPP. 31+53.56 ¢ LT. LN.
STA. 93+61.79 N.E. RAMP =30+50 ¢ LT. LN.
P.T. 95+36.20
N.E. RAMP OPP. 97+51.72
P.C. 101+62.94
N.P. 105+83.81 N.E. RAMP 101' OPP. 805+81.4 ¢ SURVEY
P.T. 107+00 N.E. RAMP 107.98' OPP. 807+00 ¢ SURVEY
END TAPER 87' OPP. 810+00 ¢ SURVEY
900' TAPER
N.W. RAMP
N 87° 30' E
¢ SURVEY
STA. 795+49.25 ¢ SURVEY =24+61.54 ¢ LEFT LANE EARL BOND ROAD
S.W. RAMP
OPP. 94+60.90
Dc=8°
BEGIN TAPER 87' OPP. 782+00 ¢ SURVEY
P.C. 85+00 S.W. RAMP 107.98' OPP. 785+00 ¢ SURVEY
N.P. OPP. 86+16.19 S.W. RAMP 101' OPP. 786+18.6 ¢ SURVEY
P.T. 89+94.00
P.C. 95+47.14
STA. 97+77.29 S.W. RAMP =19+00.18 ¢ LT. LN.
P.T. 98+04.52 S.W. RAMP 24' OPP. 17+45.42 ¢ LT. LN.
END TAPER 12' OPP. 15+95.42 ¢ LT. LN.
S.E. RAMP
P.T. 99+24.14
STA. 96+77.51 S.E. RAMP =20+75 ¢ LT. LN.
P.C. 95+85.14 S.E. RAMP 88' OPP. 18+67.89 ¢ LT. LN.
BEGIN TAPER 76' OPP. 17+17.89 ¢ LT. LN.
P.C. 103+28.38
P.C.C. 106+36.18 S.E. RAMP N.P. OPP. 806+35.24 ¢ SURVEY
P.T. 108+00 S.E. RAMP 105' OPP. 808+00 ¢ SURVEY
16+00
(A) Δ=3°16'35" D=2°00' T=81.93' R=2864.79' L=163.82'
(B) Δ=15°11'28" D=4°00' T=191.01' R=1432.40' L=379.78'
(C) Δ=81°34'22" T=237.26' R=275.00' L=391.52'
(D) Δ=45°58'59" T=131.53' R=310.00' L=248.79'
(E) Δ=21°12'09" D=4°00' T=268.10' R=1432.40' L=530.06'
(F) Δ=19°47'46" D=4°00' T=249.94' R=1432.40' L=494.90'
(G) Δ=47°23'22" T=184.32' R=420.00' L=347.38'
(H) Δ=84°26'51" T=208.22' R=230.00' L=338.99'
(I) Δ=12°18'58" D=4°00' T=154.55' R=1432.40' L=307.91'
(J) Δ=3°16'35" D=2°00' T=81.93' R=2864.79' L=163.82'
MISSISSIPPI STATE HIGHWAY DEPARTMENT
EARL BOND ROAD INTERCHANGE LAYOUT
I-10-1(17)23
JACKSON CO.
WORKING NUMBER 8-A
SHEET NUMBER 15
REVISIONS
DESIGNED DETAILED TRACED
CHECKED ISSUED DATE

STATE	PROJECT NO.
MISS.	SP-0007-1(29)



MISSISSIPPI STATE HIGHWAY DEPARTMENT

PAVEMENT MARKING DETAILS

STA. 62+00 TO STA. 86+00

SP-0007-1(29)
ALCORN CO.

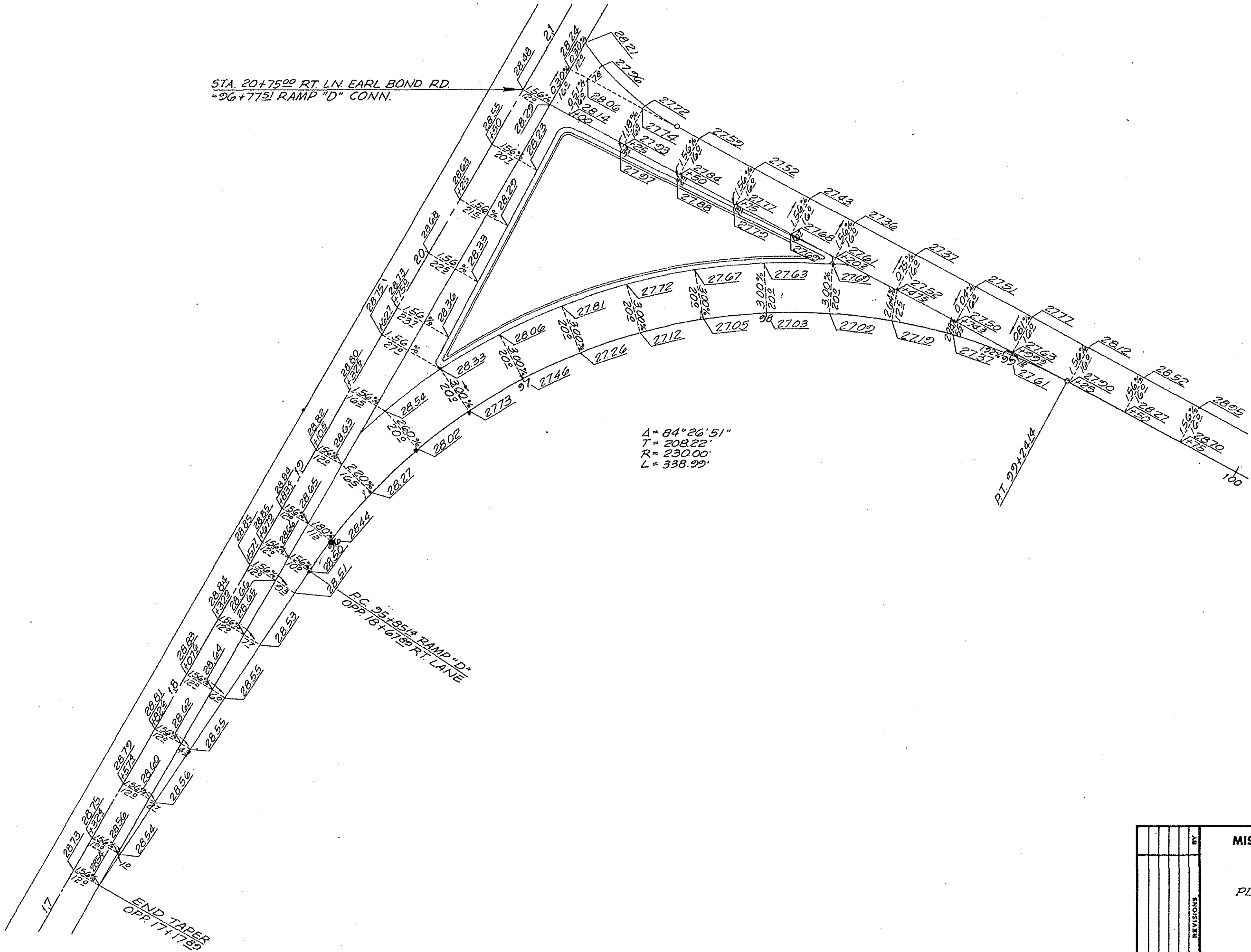
REVISIONS | BY | DATE

DESIGNED ______ DETAILED ______ TRACED ______
CHECKED ______ ISSUED ______ DATE ______

WORKING NUMBER 23

SHEET NUMBER 16

STATE	PROJECT NO.
MISS.	I-10-1(17) 34



MISSISSIPPI STATE HIGHWAY DEPARTMENT

FORM GRADES

PLAN OF S.W. RAMP CONN.
TO EARL BOND RD.

I-10-1(17) 34
JACKSON CO.

REVISIONS	DATE	BY

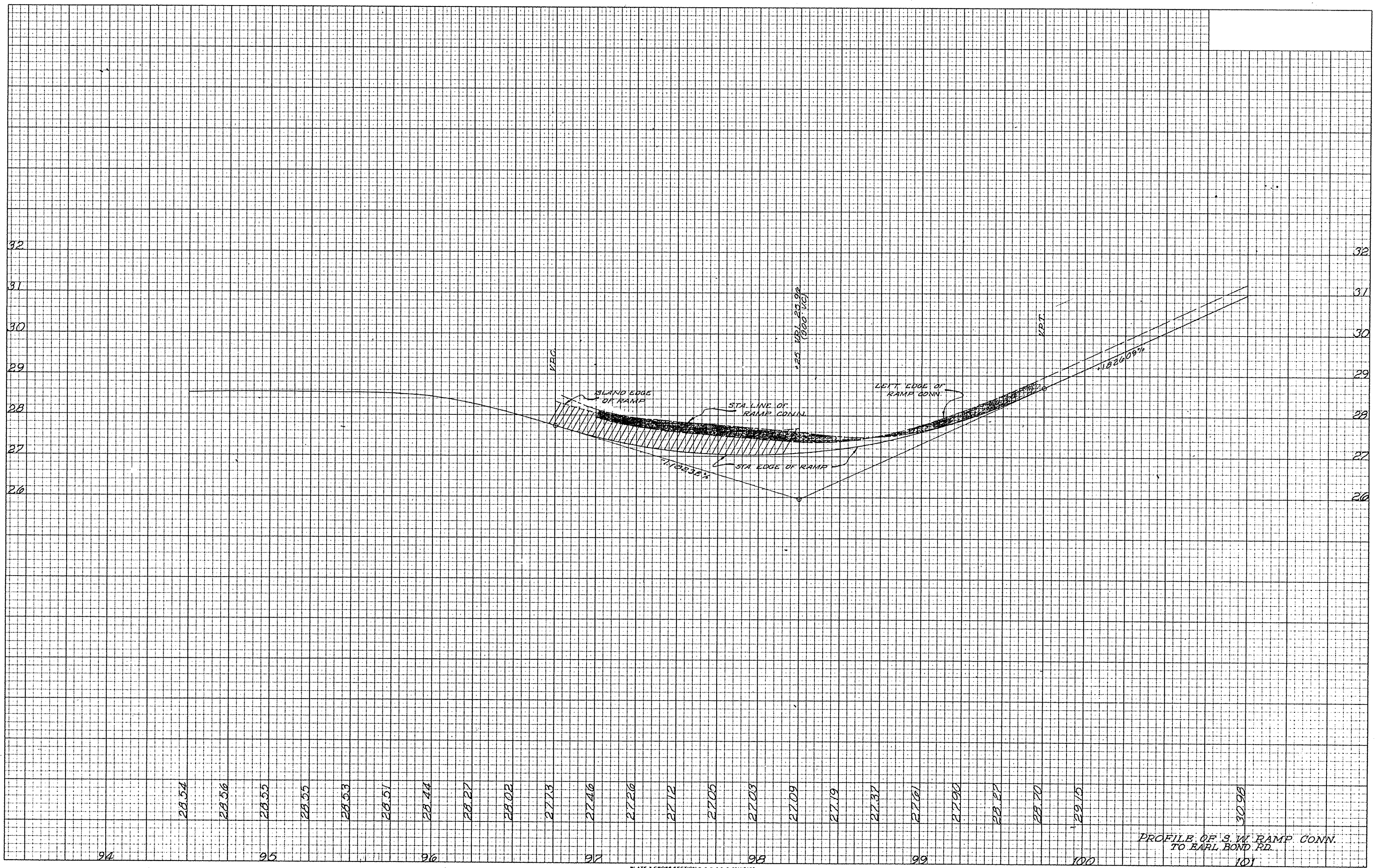
DESIGNED ______ DETAILED ______ TRACED ______
CHECKED ______ ISSUED ______ DATE ______

WORKING NUMBER

SHEET NUMBER

FINAL SURVEY		BY	DATE
NOTE BOOK	SURVEYED		
	PLOTTED		
NO.	TEMPLATE		
	AREAS		
	AREAS CHECKED		

ORIGINAL SURVEY		BY	DATE
NOTE BOOK	SURVEYED		
	PLOTTED		
NO.	TEMPLATE		
	AREAS		
	AREAS CHECKED		

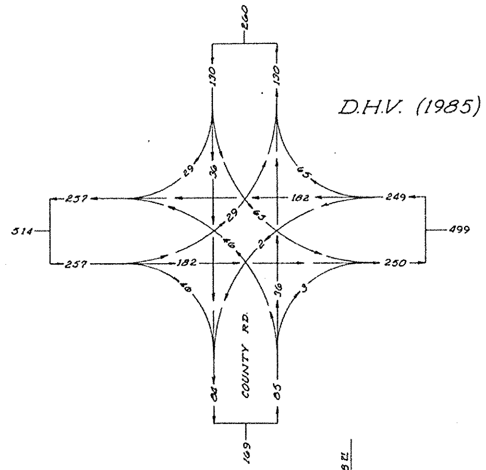


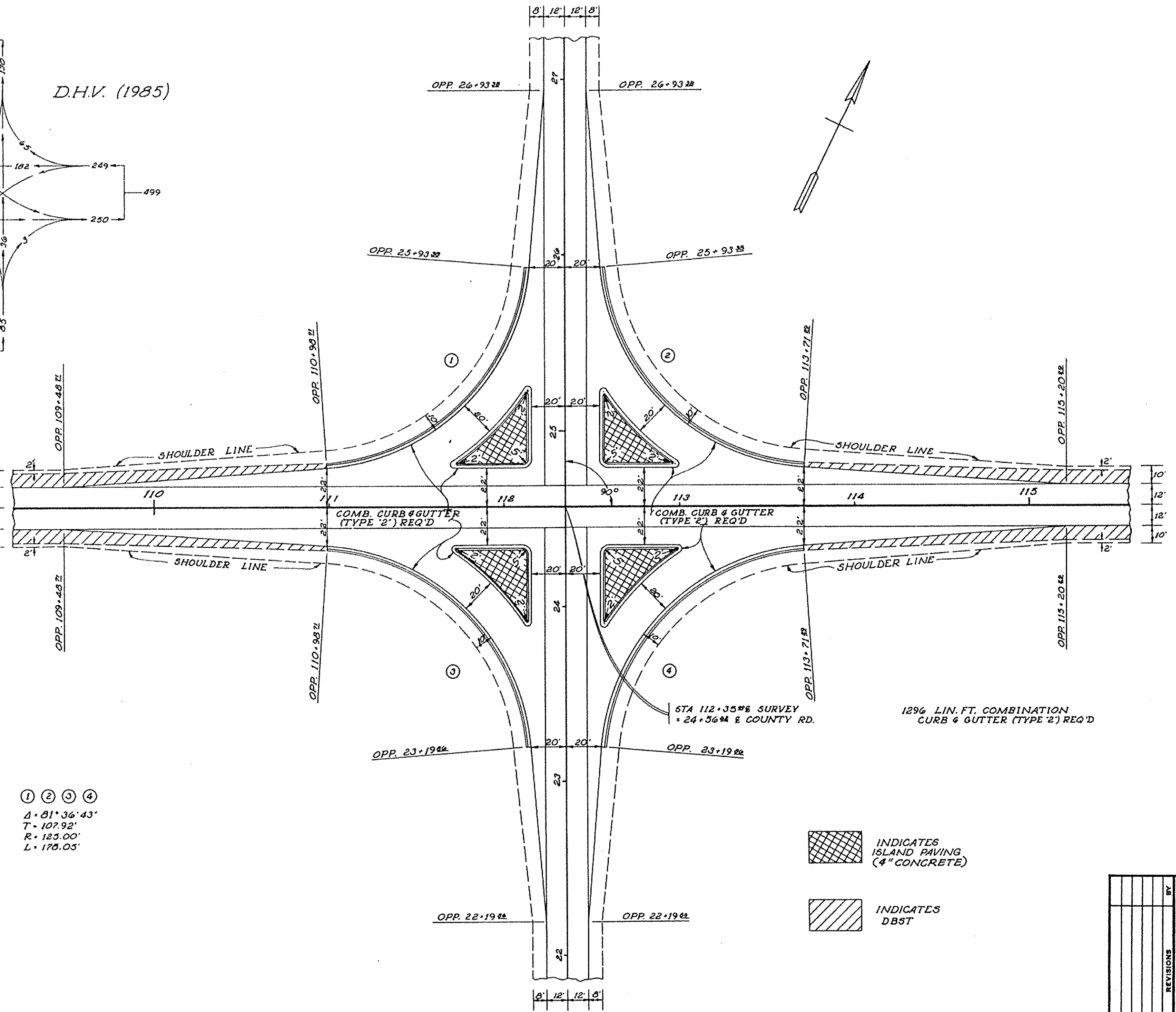
PROFILE OF S.W. RAMP CONN.
TO EARL BOND RD.

FORM GRADES

I-10-1(17)34
JACKSON CO.

STATE	PROJECT NO.
MISS.	BP-0015-3(18)





① ② ③ ④
Δ = 81° 36' 43"
T = 107.92'
R = 125.00'
L = 178.05'

INDICATES ISLAND PAVING (4" CONCRETE)

INDICATES DBST

MISSISSIPPI STATE HIGHWAY DEPARTMENT

INTERSECTION DETAIL
COUNTY ROAD AT STA. 112+35

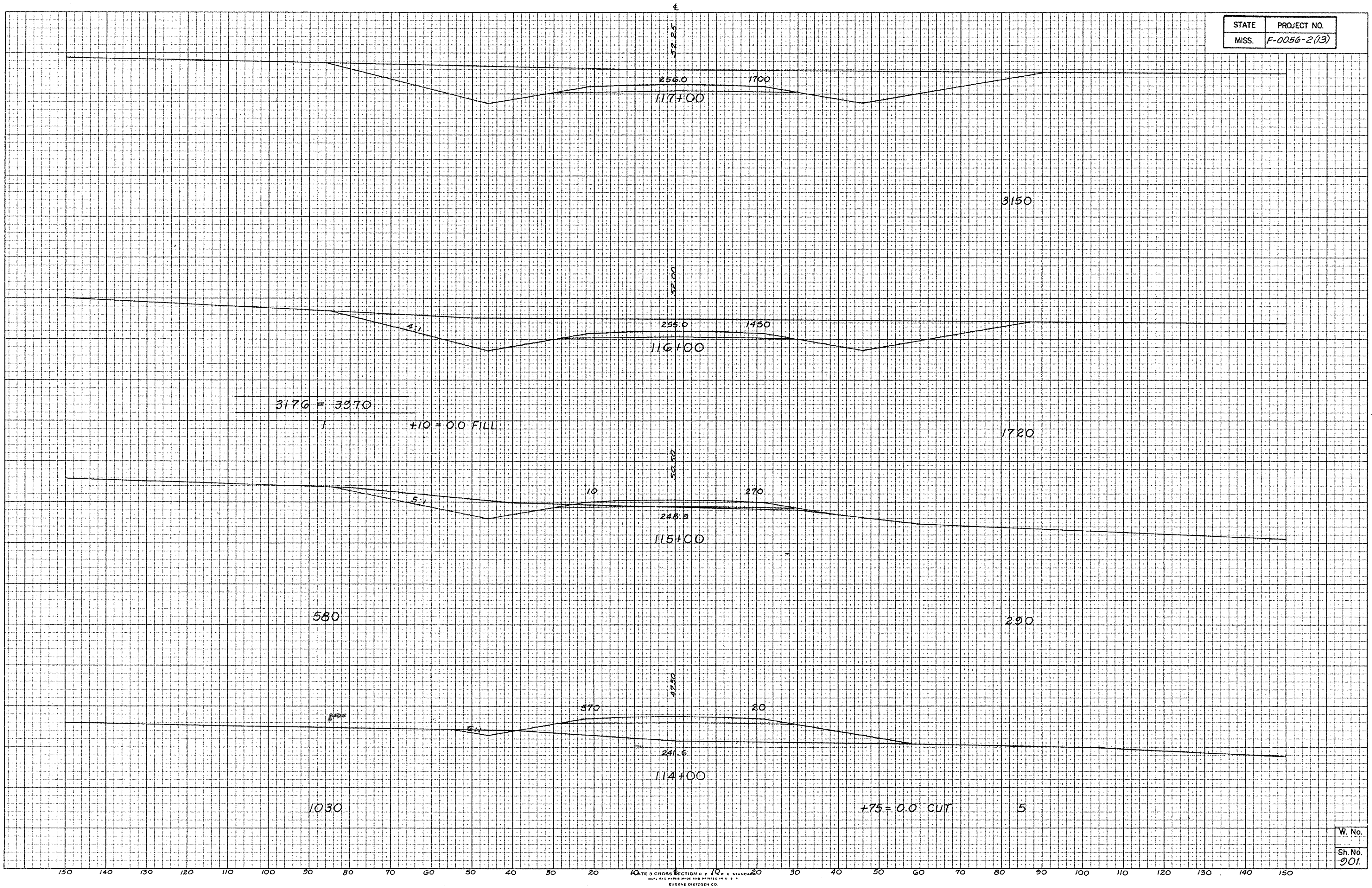
BP-0015-3(18)
ALCORN CO.

REVISIONS | BY | DATE

DESIGNED ______ DETAILED ______ TRACED ______
CHECKED ______ ISSUED ______ DATE ______

WORKING NUMBER 24
SHEET NUMBER 17

STATE	PROJECT NO.
MISS.	F-0056-2(13)

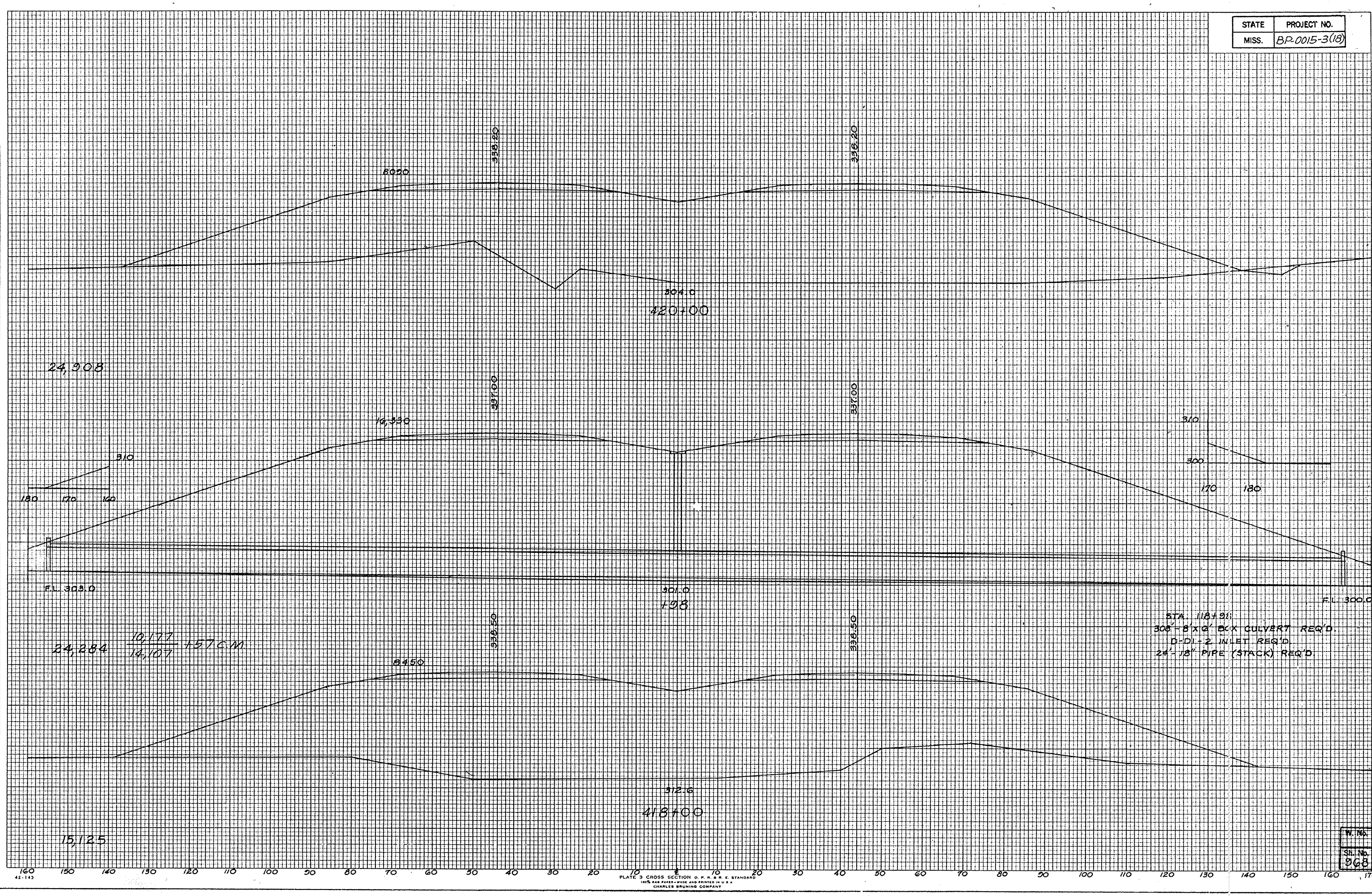


FINAL SURVEY — SURVEYED, PLOTTED, TEMPLATE, AREAS, AREAS CHECKED — NOTE BOOK, NO — BY — DATE

ORIGINAL SURVEY — SURVEYED, PLOTTED, TEMPLATE, AREAS, AREAS CHECKED — NOTE BOOK, NO — BY — DATE

W. No.

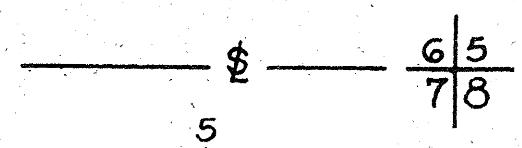
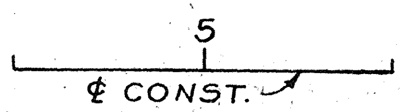
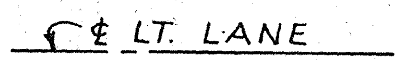
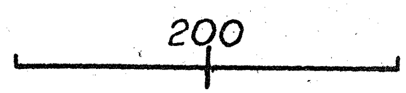
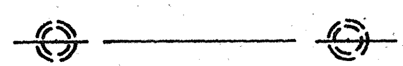
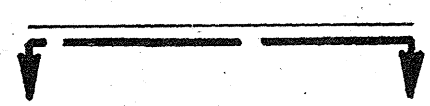
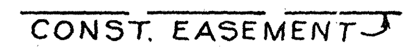
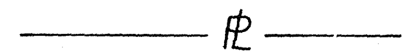
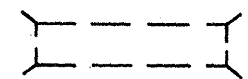
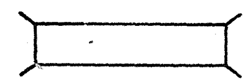
Sh. No. 901.



STATE
PROJECT NO.
MISS.
BP-0015-3(18)
8050
338.80
338.20
304.0
420+00
24,908
16,330
337.00
337.00
310
180
170
160
310
300
170
180
F.L. 308.0
301.0
+98
F.L. 300.0
STA. 118+91:
308'- 8'x 9' BOX CULVERT REQ'D.
D-DI-2 INLET REQ'D.
24'-18" PIPE (STACK) REQ'D.
24,284
10,177
14,107
+57 C.M.
8450
338.50
338.50
312.6
418+00
15,125
W. No.
Sh. No.
968
PLATE 3 CROSS SECTION
CHARLES BRUNING COMPANY

STANDARD SYMBOLS

Some of the standard symbols will be shown here in order to assist in uniformity of size, line weight, and symbol. Other symbols and abbreviations are shown on sheet number 101 of the Department State Standards.

ITEM	SYMBOL	RAPIDOGRAPH NO.
County line		3
Township & Range line		3
Section line & corner		2
Centerline of construction		1
Centerline of (label) (unstationed)		1
Centerline of survey		2
Construction slope limit		0
Right of way & markers (existing)		1
Right of way & markers (proposed)		1
No access limit		3
Easement line		1
Property line		0
Grade line profile		2
Original ground line (grading)		1
Original ground line (paving)		1
Angle		1
Benchmark		1
Bridge (existing)		1
Bridge (proposed)		1
Building		1
Culvert (existing)		1
Culvert (proposed)		1

ITEM	SYMBOL	RAPIDO-GRAPH NO.
Ditch plug		1
Fence	BARBED WIRE	0
Fire plug		0
Guardrail		1
Inlet		1
Manhole		1
Railroad		1
Road (existing)	18 FT. D.B.S.T.	0
Stream or creek	MUDDY CR.	1
Power line above ground		0
Telegraph line above ground		0
Telephone line above ground		0
Gas service line	— G — G —	0

ITEM	SYMBOL	RAPIDO-GRAPH NO.
High pressure gas line	— HG — HG	0
Power line underground	— P — P —	0
Sanitary sewer	— SS — SS —	0
Telephone line underground	— T — T —	0
Water line	— W — W —	0
Well	(W)	0
Tank underground	GAS	0
North Arrow		1

Line weight:		RAPIDO-GRAPH NO.
0.010"		00
0.014"		0
0.018"		1
0.022"		2
0.035"		3
0.047"		4