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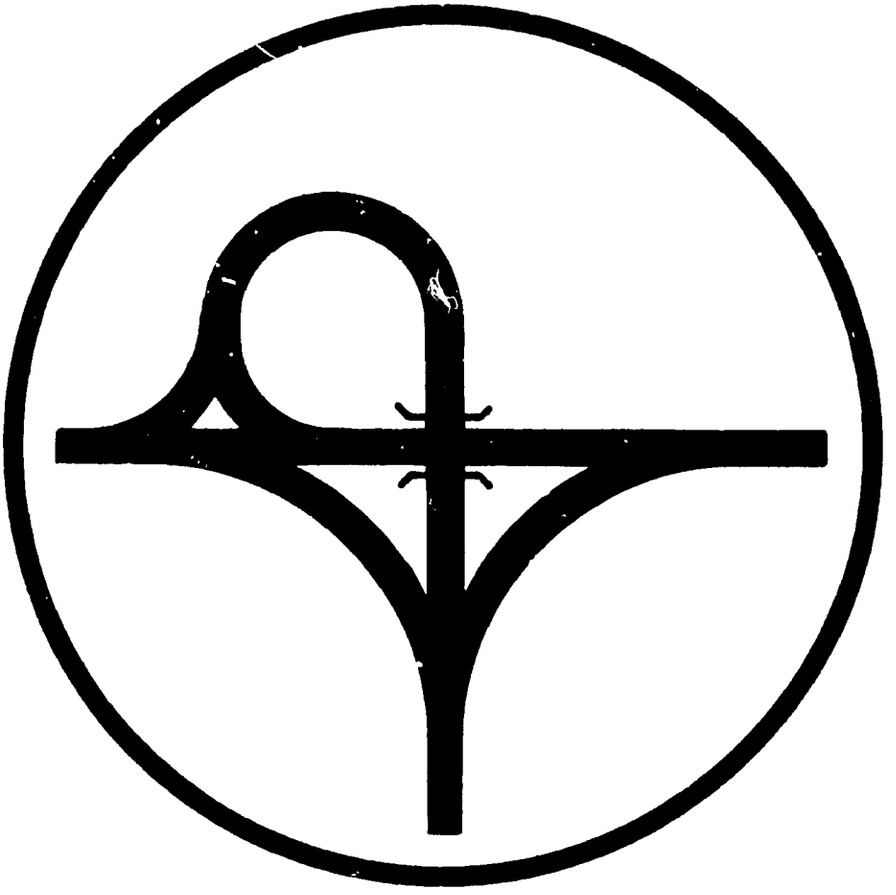

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for

UNITED STATES AGENCY for INTERNATIONAL DEVELOPMENT

Project Number - Highway Manual AID/OTr C-1420

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The Highway Research Board (HRB)

The Asphalt Institute

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The Nebraska and Montana Departments of Highways

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Lewis M. Chittim
Chief of Party
Roy Jorgensen Associates, Inc.

INTRODUCTION

This manual has been developed to provide guidance and assistance to highway design 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 Highway Administration policies with regard to standards of design and procedures for development of contract plans.
- To define criteria to guide judgments and decisions made by highway design personnel.
- To describe the most effective design techniques and procedures and to present charts, tables and other information found to be useful by designers.

The material in the manual has been reviewed and edited by a committee of HA personnel who are knowledgeable of current design requirements and procedures. 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 have been incorporated in the manual when it was evident that they would be more effective.

This initial publication should not be considered a completed comprehensive design manual — rather it is a first step toward orderly documentation of policies, procedures, instructions and guides.

Those persons who use the manual can contribute to its continuing improvement by submitting suggestions to the Director of Engineering, for ways in which the manual can be made more useful and practical. The Director will periodically assemble a committee of persons capable of acting on the suggestions for improving this manual. The committees will be chaired by the Director and will designate the improvements to be incorporated.

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CHAPTER ONE

DESIGN STANDARDS

PURPOSE

Standards have been developed to guide the design of highways and to ensure that motorist convenience, environmental, safety and esthetic considerations are implemented in the most economical manner consistent with the highway service considerations.

SOURCE OF STANDARDS

The basic design criteria in this section are taken from the AASHO Manual entitled *A Policy on Geometric Design of Rural Highway, 1965.* Reference should be made to this AASHO Manual for design criteria not covered in this section, and for more comprehensive background information regarding the development of criteria. Additional information on urban design and design related to safety can be found in the AASHO publication entitled. *A Policy on Design of Urban Highways and Arterial Streets, 1973.* The designer should refer to the Highway Administration's Standard Specifications for Highways and Bridges during design.

DEPARTURE FROM STANDARDS

Design policies and standards generally represent minimum values. Higher standards should be used within reasonable economic limits.

To ensure uniform practice on a nationwide basis, lower design standards may not be used without approval from the Director of Engineering (DOE).

DESIGN CONTROLS

Three basic factors control the selection of design standards:

1. The anticipated TRAFFIC VOLUME
2. The TERRAIN
3. An appropriate DESIGN SPEED

The various geometric design standards are selected on the basis of one or more of the control factors. These relationships are presented for each type of highway.

GEOMETRIC DESIGN STANDARDS

Geometric design standards for the various classes of highways are summarized on Standard Sheet No. 101.

Only desirable minimum standards are shown in the tables. Absolute minimum standards are contained in the notes. The geometric design standards are identified by the factors of design control. Their relationships are defined below.

Design Speed

The design speed is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern. Design speed governs the limits for curvature, sight distance and other geometric features.

Sudden changes in design speed along any highway should be avoided, particularly on roads with high design speeds. When geometrics have been selected for a project, the designer should check controlling design speeds at consecutive sections within the project. It is desirable that any change in design speed between sections be minimized and no greater than 25 kilometers per hour. Such changes should be effected over sufficient distance to permit drivers to change speed naturally and gradually before reaching the section of highway with the different design speed.

The designer should realize that in the design of multilane highways, intersections, and interchanges the capacity of the highway system may be a more heavily weighted design consideration than the design speed. In such cases, reference should be made to the Highway Capacity Manual. A copy of this manual is located in the Director of Engineering's files.

Degree of Curvature

The combination of design speed and maximum superelevation controls the maximum degree of curvature. Flatter curves must be provided where possible. Guidelines for desirable horizontal alignment are presented in Chapter Three. Transitions are also discussed in Chapter Three.

Superelevation

The rate of superelevation of a curve is controlled by the design speed and the degree of curvature. For a given degree of curve, specific superelevation rate is correct for only one driving speed.

The maximum superelevation rate has been established at 0.08 meter of vertical rise per 1.0 meter of horizontal distance. Guidelines for the application of superelevation is represented in Chapter Three.

Stopping Sight Distance

Stopping sight distance is controlled by design speed. The table below shows minimum and desirable stopping sight distance for various design speeds.

Design Speed, KPH		35	50	65	80	100
Stopping Sight Distance, m.	Minimum	47	63	83	106	152
	Desirable	47	63	90	137	212

All highway design should provide desirable stopping sight distance. Economic considerations, however, will necessitate the use of minimum standards under certain conditions.

Stopping sight distance is most important when designing vertical alignment. Guidelines for ensuring adequate stopping sight distance on vertical curves are presented in Chapter 4. Horizontal alignment should also be checked for stopping sight restrictions according to criteria in Chapter 3.

Passing Sight Distance

On 2-lane highways, consideration should always be given to providing passing sight distance. Guidelines on providing passing sight distance on vertical curves are presented in Chapter 4. Techniques for determining passing sight restrictions due to horizontal curvature are given in Chapter 3.

Gradients

Standard sheet No. 101 shows maximum gradients for each highway design type. Where economically feasible, grades should be less than the maximum. Under certain conditions, steeper grades are permitted. Minimum grades are sometimes stipulated to provide adequate longitudinal drainage. Guidelines for the design of vertical alignment are presented in Chapter 4.

Typical Sections

Typical sections for the highway types are shown on Standard Sheets No. 102 through 107. When selecting the typical section to be used in a design, the following guidelines should be followed:

Class A — Routes with ADT/VU count greater than 1000. If the DHV is greater than 750, however, a four-lane route should be studied.

Class B — Routes with ADT/VU count between 500 and 1000.

Class C — Routes with ADT/VU count between 200 and 500.

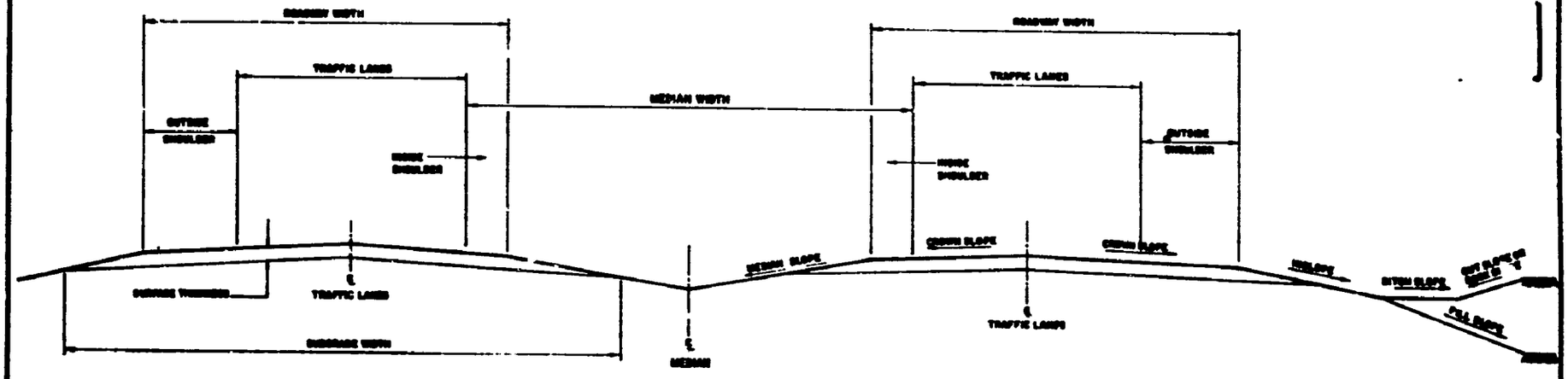
Class D — Routes with ADT/VU count less than 200.

Cross Slopes

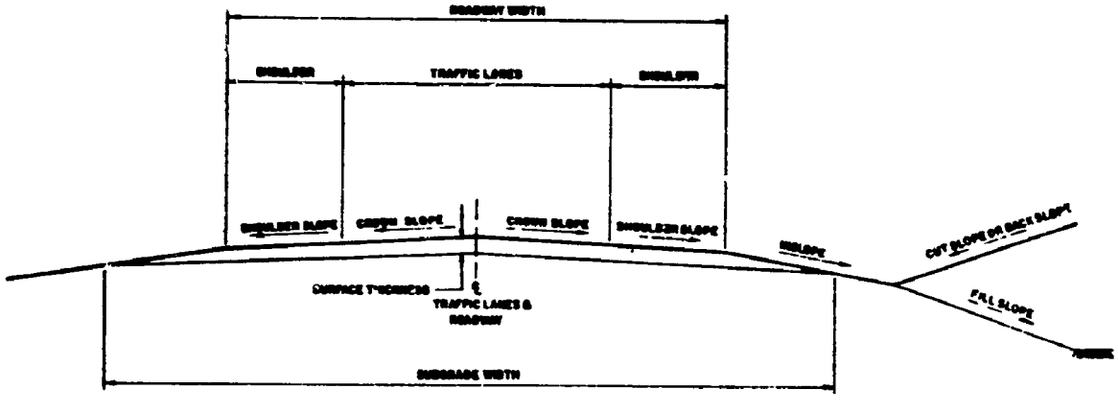
Rates and directions of cross slopes for driving lanes, shoulders and medians are shown on Standard Sheets No. 102 through 107.

ADT/VU — Average Daily Traffic/Vehicle Units
DHV — Design Hourly Volume (30th Highest hourly volume)

DIVIDED HIGHWAY NOMENCLATURE



2-LANE HIGHWAY NOMENCLATURE



DIVIDED HIGHWAY

		TERRAIN 1/			
		FLAT	ROLLING	MOUNTAINOUS	URBAN
MAXIMUM DESIGN SPEED MPH		100	80	65	65
MAX DEGREE OF CURVATURE 1/		3°00'	5°00	8°00	8°00
MIN RADIUS OF CURVE M		382	229	143	143
DESIRABLE MIN STOPPING SIGHT DISTANCE M 2/		212	137	90	90
MIN PASSING SIGHT DISTANCE M		670	550	455	455
MAX GRADIENT %		3	5	9	9
MINIMUM WIDTHS, M	TRAFFIC LANES	4@3.60	4@3.60	4@3.60	4@3.60
	INSIDE SHOULDER 3/	1.20	1.20	1.20	1.20
	OUTSIDE SHOULDER	3.20	3.20	3.20 4/	3.10
	MEDIAN	N	N	6 5/	6 5/

CUT SLOPES FOR VARIOUS CUT DEPTHS 6/	0 TO 2 M	4 1
	2 TO 4 M	3 1
	4 TO 6 M	2 1
	OVER 6 M	1½ 1
FILL SLOPES FOR VARIOUS FILL DEPTHS	0 TO 1 M	6 1
	1 TO 2 M	4 1
	OVER 2 M	2 1
CROSS SLOPES %	CROWN	3
	SHOULDER	3

4/ [illegible] MAY BE REDUCED TO A MIN OF 2.00 M IN MOUNTAINOUS TERRAIN INVOLVING HIGH COST OF ADDITIONAL WIDTH

5/ MEDIAN MAY BE REDUCED TO A MIN OF 3.00 M WHERE AREAS OF HIGH RIGHT-OF-WAY COST IN RUGGED MOUNTAINOUS TERRAIN AND ON LONG AND GENTLY SINUOUS

6/ FOR CUT SLOPES IN ROCK USE STANDARD SHEET NO 100

7/ COMBINATIONS OF MAXIMUM DESIGN STANDARDS WILL REQUIRE PRIOR APPROVAL OF THE DIRECTOR OF ENGINEERING

NOTES

1/ BASED ON THE MAXIMUM SUPERELEVATION RATE OF 6%

2/ THE ABSOLUTE MIN STOPPING SIGHT DISTANCES ARE 100M, 80M, 60 M, AND 55 M RESPECTIVELY

3/ WHERE SHOULDERS WILL BE 1.5 M WIDE EXCEPT, WHERE CONTINUOUS GUARDRAIL [illegible] WILL BE OFFSET AT LEAST 1.00 FROM THE EDGE OF THE TRAFFIC LANE

CLASS A

	TERRAIN 1/			
	FLAT	ROLLING	MOUNTAINOUS	URBAN
MAX DESIGN SPEED MPH	100	80	65	50
MAX DEGREE OF CURVATURE 1/	3°00	5°00	8°00	15°00
MIN RADIUS OF CURVE M	382	229	143	1 [illegible]
DESIRABLE STOPPING SIGHT DISTANCE M 2/	212	137	90	63
MIN PASSING SIGHT DISTANCE M	670	550	455	342
MAX GRADIENT %	3	5	8	8

CUT SLOPES FOR VARIOUS CUT DEPTHS 3/	0 TO 2 M	4
	2 TO 4 M	3 1
	4 TO 6 M	2 1
	OVER 6 M	1½ 1
FILL SLOPES FOR VARIOUS FILL DEPTHS	0 TO 1 M	6 1
	1 TO 2 M	4 1
	OVER 2 M	2 1
CROSS SLOPES %	CROWN	3
	SHOULDER	3

NOTES

1/ BASED ON THE MAXIMUM SUPERELEVATION RATE OF 6%

2/ THE ABSOLUTE MINIMUM STOPPING SIGHT DISTANCES ARE 152M 100M 0.5M AND 0.3M, RESPECTIVELY

3/ FOR CUT SLOPES IN ROCK USE STANDARD SHEET NO 100

4/ COMBINATIONS OF MAX DESIGN STANDARDS WILL REQUIRE PRIOR APPROVAL OF THE DIRECTOR OF ENGINEERING

CLASS B

	TERRAIN 1/			
	FLAT	ROLLING	MOUNTAINOUS	URBAN
MAX DESIGN SPEED MPH	100	80	65	50
MAX DEGREE OF CURVATURE 1/	3°00	5°00	8°00	15°00
MIN RADIUS OF CURVE M	382	229	143	76
DESIRABLE STOPPING SIGHT DISTANCE M 2/	212	137	90	63
MIN PASSING SIGHT DISTANCE M	670	550	455	342
MAX GRADIENT %	3	5	8	8

CUT SLOPES FOR VARIOUS CUT DEPTHS 3/	0 TO 2 M	4 1
	2 TO 4 M	3 1
	4 TO 6 M	2 1
	OVER 6 M	1½ 1
FILL SLOPES FOR VARIOUS FILL DEPTHS	0 TO 1 M	6 1
	1 TO 2 M	4 1
	OVER 2 M	2 1
CROSS SLOPE %	CROWN	3
	SHOULDER	3

NOTES

1/ BASED ON THE MAXIMUM SUPERELEVATION RATE OF 6%

2/ THE ABSOLUTE MIN STOPPING SIGHT DISTANCES ARE 152M 100M 0.5M AND 0.3M, RESPECTIVELY

3/ FOR CUT SLOPES IN ROCK USE STANDARD SHEET NO 100

4/ COMBINATIONS OF MAX DESIGN STANDARDS WILL REQUIRE PRIOR APPROVAL OF THE DIRECTOR OF ENGINEERING

CLASS C

	TERRAIN 1			
	FLAT	ROLLING	MOUNTAINOUS	URBAN
MAX DESIGN SPEED MPH	80	65	50	50
MAX DEGREE OF CURVATURE M 1/	5°00	8°00'	15°00'	8°00
MIN RADIUS OF CURVE	229	143	76	76
DESIRABLE STOPPING SIGHT DISTANCE M 2/	137	90	63	63
MIN PASSING SIGHT DISTANCE	550	455	342	342
MAX GRADIENT %	4	6	8	8

CUT SLOPES FOR VARIOUS CUT DEPTHS 3/	0 TO 2 M	4 1
	2 TO 4 M	3 1
	4 TO 6 M	2 1
	OVER 6 M	1½ 1
FILL SLOPES FOR VARIOUS FILL DEPTHS	0 TO 2 M	4 1
	OVER 2 M	2 1
CROSS SLOPES %	CROWN	3
	SHOULDER	3

NOTES

1/ BASED ON THE MAXIMUM SUPERELEVATION RATE OF 6%

2/ THE ABSOLUTE MIN STOPPING SIGHT DISTANCES ARE 100M 0.5M 0.4M AND 0.3M RESPECTIVELY

3/ FOR CUT SLOPES IN ROCK USE STANDARD SHEET NO 100

4/ COMBINATIONS OF MAX DESIGN STANDARDS WILL REQUIRE PRIOR APPROVAL OF THE DIRECTOR OF ENGINEERING

CLASS D

	TERRAIN 1/			
	FLAT	ROLLING	MOUNTAINOUS	URBAN
MAX DESIGN SPEED MP	65	50	38	36
MAX DEGREE OF CURVATURE 1/	8°00'	15°00	37°00'	37°00'
MIN RADIUS OF CURVE M	143	76	31	31
DESIRABLE STOPPING SIGHT DISTANCE M 2/	90	63	47	47
MIN PASSING SIGHT DISTANCE M	455	342	240	240
MAX GRADIENT %	5	7	8	8

CUT SLOPE FOR VARIOUS CUT DEPTHS 3/	0 TO 2 M	4 1
	2 TO 4 M	3 1
	4 TO 6 M	2 1
	OVER 6 M	1½ 1
FILL SLOPES FOR VARIOUS FILL DEPTHS	0 TO 2 M	4 1
	OVER 2 M	2 1
CROSS SLOPES %	CROWN	3
	SHOULDER	3

NOTES

1/ BASED ON THE MAXIMUM SUPERELEVATION RATE OF 6%

2/ THE ABSOLUTE MIN STOPPING SIGHT DISTANCES ARE 0.3M, 0.3M, 0.7M, AND 0.7M RESPECTIVELY

3/ FOR CUT SLOPES IN ROCK USE STANDARD SHEET NO 100

4/ COMBINATIONS OF MAX DESIGN STANDARD WILL REQUIRE PRIOR APPROVAL OF THE DIRECTOR OF ENGINEERING

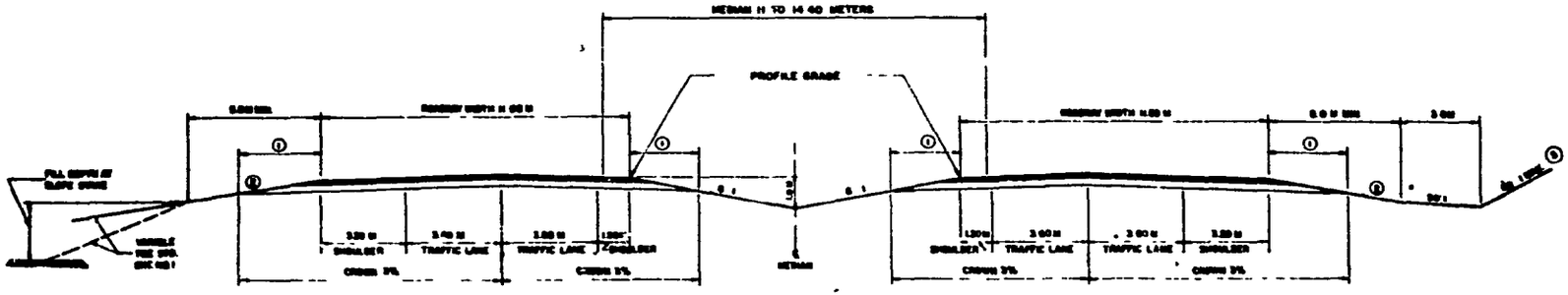
SYMBOL	REVISIONS DESCRIPTION	DATE	APPROVAL

DESIGNED
DRAWN
CHECKED
CHECKED BY DATE
APPROVED DATE

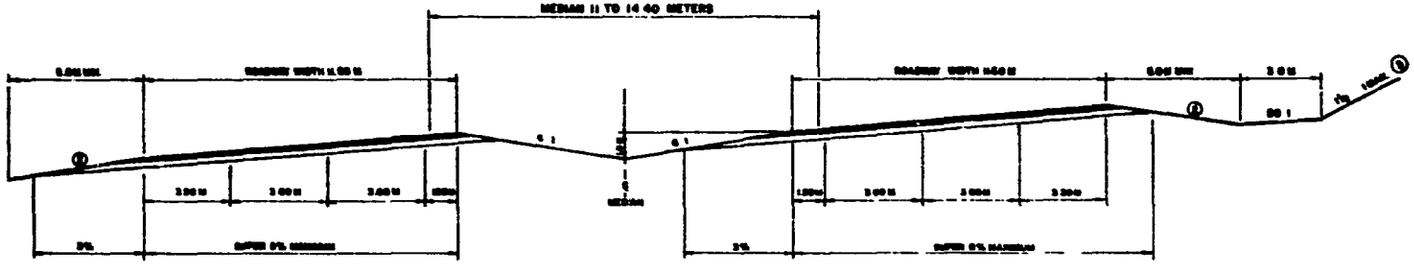
GEOMETRIC DESIGN STANDARDS

STANDARD SHEET NO 101

TANGENT SECTION



CURVED SECTION



NOTES:

1. COMPUTE DISTANCE TO NEAREST 0.1 METER
2. 6 : 1 DESIRABLE 4 : 1 SLOPE MAXIMUM
3. IN NORMAL CUT SLOPE SEE STANDARD SHEET NUMBER 101 FOR DITCH SLOPE IN SLOPE IN ROCK CUT SECTIONS SEE STANDARD SHEET NUMBER 100 FOR DITCH WIDTH AND BACK SLOPE

SYMBOL	REVISIONS DESCRIPTION	DATE	APPROVAL

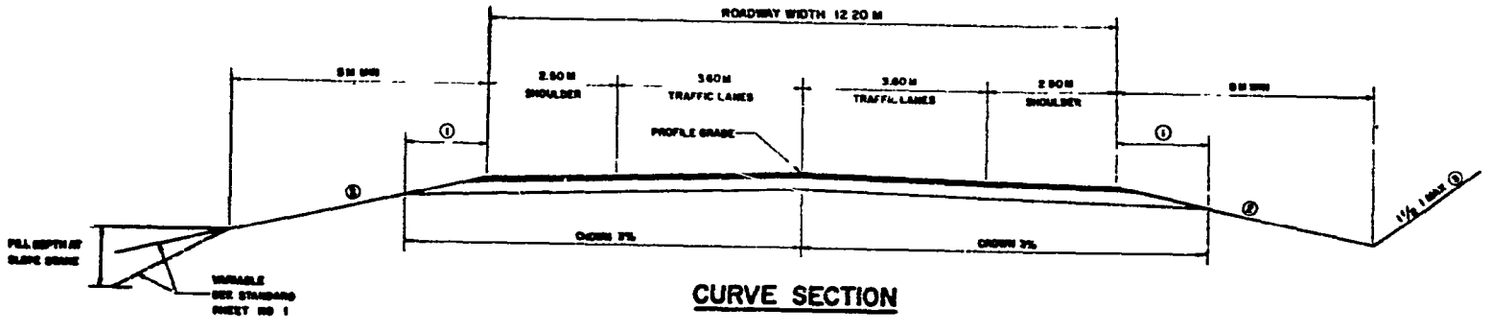
DESIGNED
DRAWN
CHECKED
SUBMITTED BY
APPROVED DATE

TYPICAL SECTION DIVIDED HIGHWAY

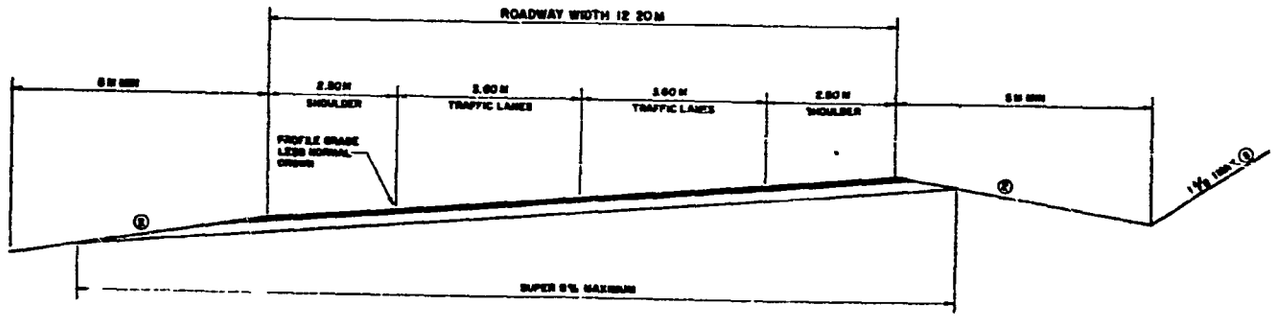
STANDARD SHEET NO 102

CLASS A

TANGENT SECTION



CURVE SECTION



NOTES

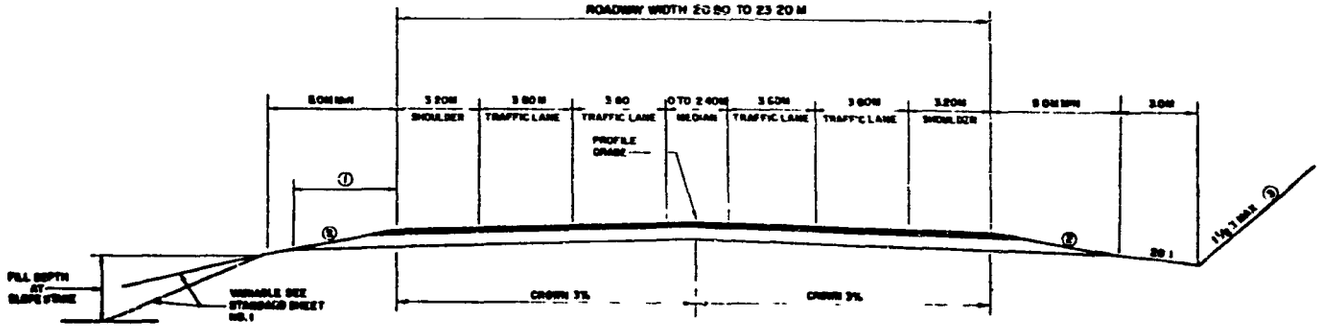
1. COMPLETE DISTANCE TO NEAREST 0.1 METER
2. 6 1 SLOPE DESIRABLE 4 1 SLOPE MAXIMUM
3. IN NORMAL CUT SLOPE SEE STANDARD SHEET NUMBER 101 FOR BACK SLOPE IN ROCK CUT SECTIONS SEE STANDARD SHEET NUMBER 108 FOR DITCH WIDTH AND BACK SLOPE

REVISIONS			
NUMBER	DESCRIPTION	DATE	APPROVAL

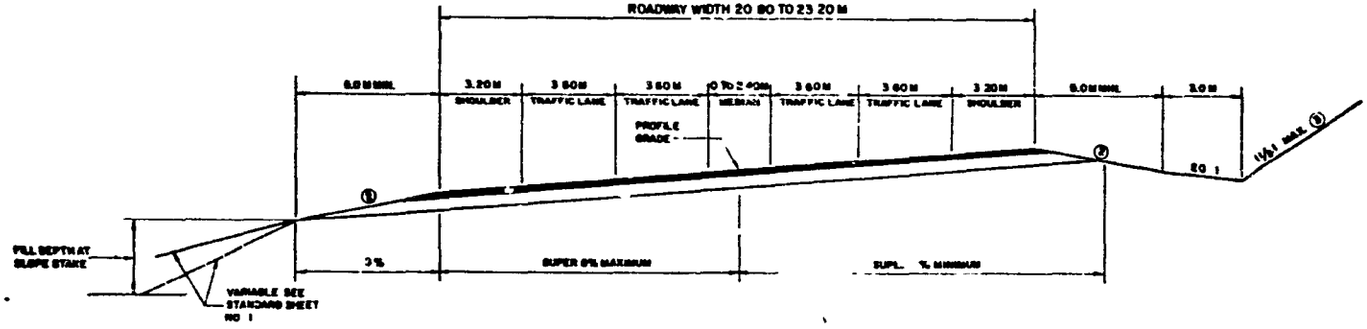
TYPICAL SECTION
CLASS A

STANDARD SHEET NO. 104

TANGENT SECTION



CURVED SECTION



NOTES

1. COMPUTE DISTANCE TO NEAREST 0.1 METER
2. 6:1 DESIRABLE 4:1 MAXIMUM
3. IN NORMAL CUT SLOPE SEE STANDARD SHEET NUMBER 101 FOR BACK SLOPE IN ROCK CUT SECTIONS SEE STANDARD SHEET NUMBER 108 FOR DITCH WIDTH AND BACK SLOPE

REVISIONS			
NO.	DESCRIPTION	DATE	APPROVED

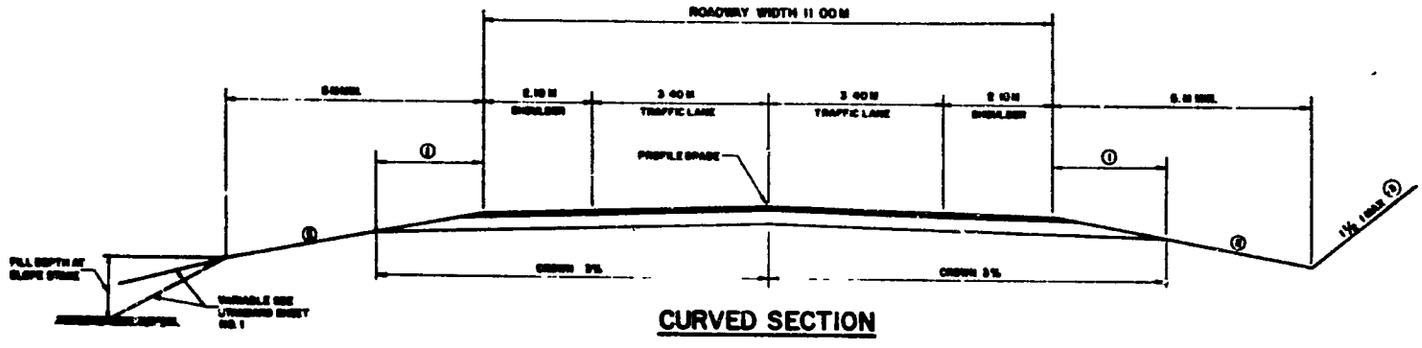
DESIGNED
DRAWN
CHECKED
SUBMITTED BY DATE
APPROVED DATE

DIVIDED HIGHWAY
FLUSH MEDIAN

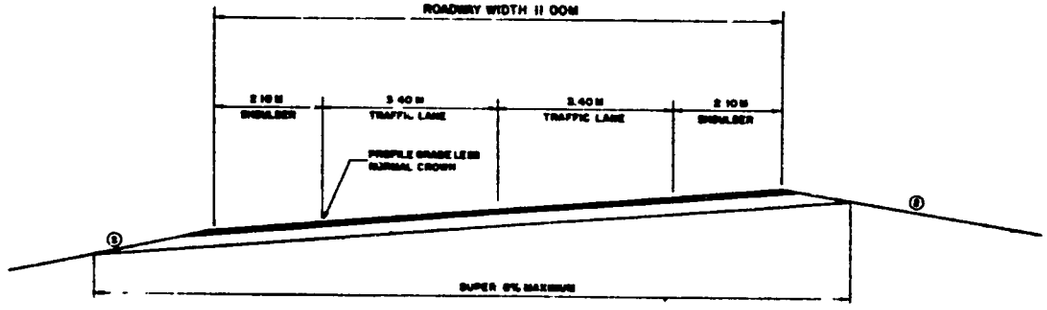
STANDARD SHEET NO. 103

CLASS B

TANGENT SECTION



CURVED SECTION



NOTES

1. GRADE TO NEAREST 0.1 METER
2. 0.1 SLOPE DESIRABLE, 0.1 SLOPE MAXIMUM
3. IN NORMAL CUT SLOPE SEE STANDARD SHEET NUMBER 101 FOR DITCH SLOPE IN ROCK CUT SECTIONS SEE STANDARD SHEET NUMBER 100 FOR DITCH WIDTH AND DITCH SLOPE

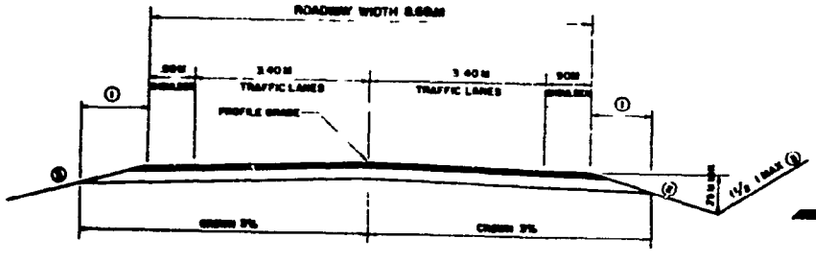
REVISIONS			
SYMBOL	DESCRIPTION	DATE	APPROVED

TYPICAL SECTION
CLASS B

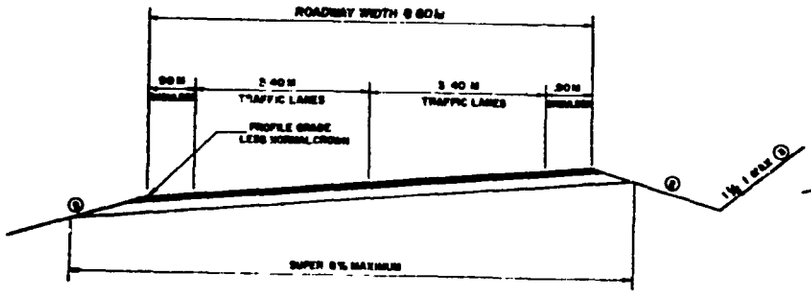
STANDARD SHEET NO. 100

CLASS C

TANGENT SECTION

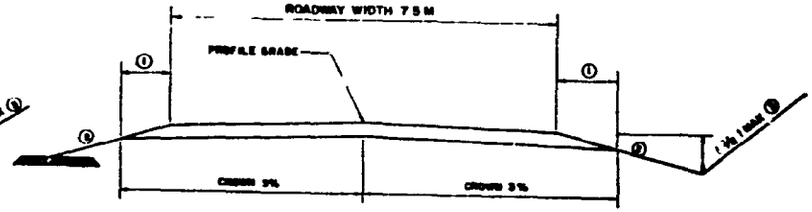


CURVED SECTION

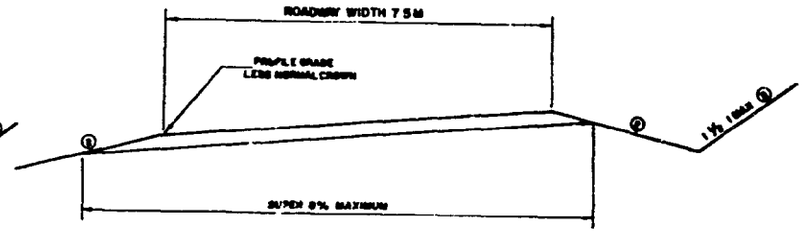


CLASS D

TANGENT SECTION



CURVED SECTION



NOTES

1. COMPUTE DISTANCE TO NEAREST 0.1 METER
2. 4 : 1 SPERABLE 2 : 1 MAXIMUM
3. IN NORMAL CUT SLOPE SEE STANDARD SHEET NUMBER 101 FOR BACK SLOPE IN ROCK CUT SECTIONS SEE STANDARD SHEET NUMBER 105 FOR DITCH WIDTH AND BACK SLOPE

REVISIONS			
ORIGINAL	DESCRIPTION	DATE	APPROVAL

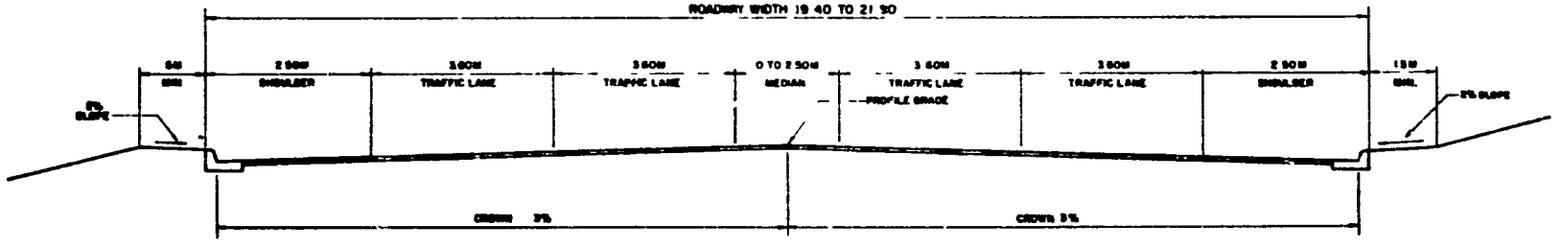
DESIGNED
DRAWN
CHECKED
SUBMITTED BY DATE
APPROVED DATE

TYPICAL SECTION
CLASS "C" AND "D"

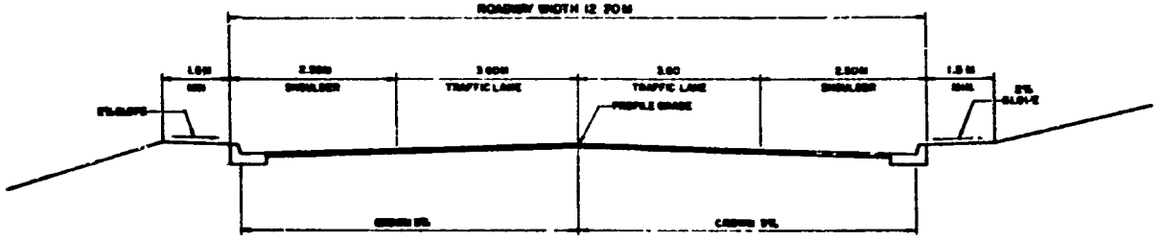
STANDARD SHEET NO 106

URBAN SECTION

FOUR LANE



TWO LANE

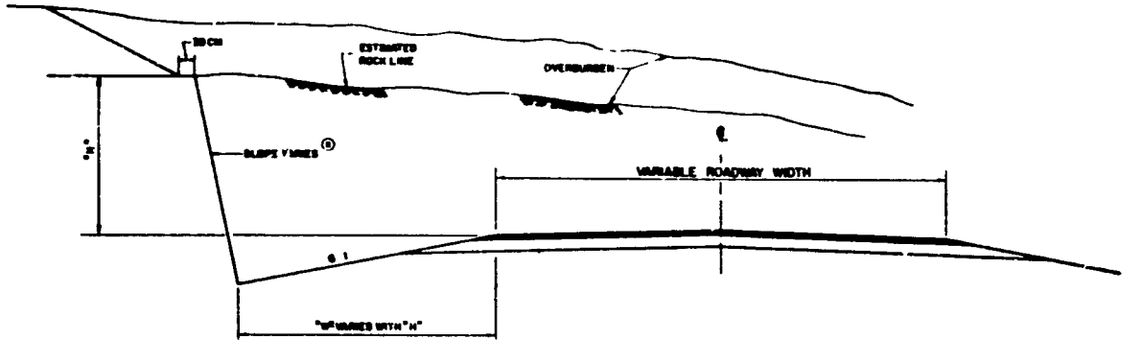


REVISIONS			
SYMBOL	DESCRIPTION	DATE	APPROVAL

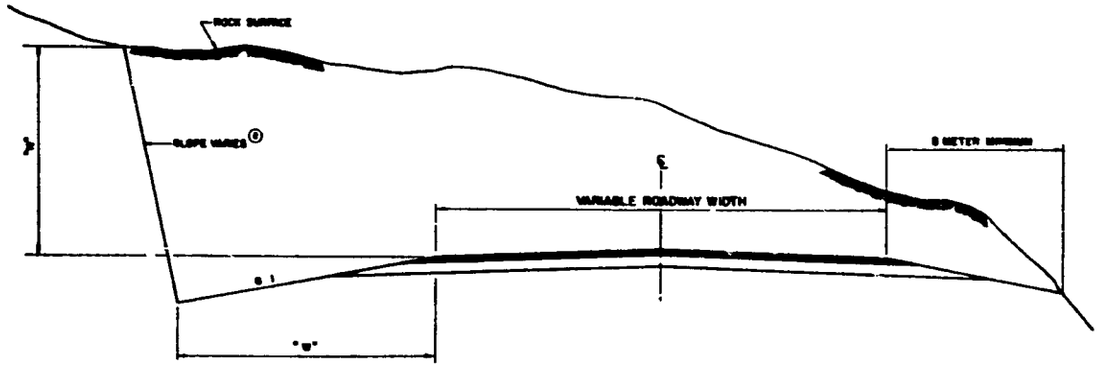
TYPICAL URBAN SECTIONS

STANDARD SHEET NO. 107

TYPICAL CUT SECTION IN ROCK ①
COVERED WITH COMMON OVERBURDEN



TYPICAL CUT SECTION IN ROCK ①



NOTES

1. TO BE USED IN ALL ROCK CUTS WHERE BACKSLOPES ARE STEEPER THAN 1½ : 1

2.

H	W	SLOPE②
0-6	3	VERTICAL
6-20	6	¼ : 1
20-30	8	¼ : 1
OVER 30	10	¼ : 1

② SLOPE WILL BE AS STEEP AS THE ROCK STRUCTURE WILL PERMIT BUT TO EXCEED THOSE SHOWN ABOVE

IF BENCHES ARE USED "W" DISTANCE FROM THE ABOVE TABLE MUST CORRESPOND WITH "H" DISTANCE MEASURED TO THE LOWEST BENCH. ALL BENCHING REQUIRES PRIOR APPROVAL.

PLANNED			
SYMBOL	DESCRIPTION	DATE	APPROVAL

DESIGNED
DRAWN
CHECKED
SUBMITTED BY DATE
APPROVED DATE

STANDARD CUT SECTION IN ROCK

STANDARD SHEET NO. 100

CHAPTER TWO

SOURCES OF INFORMATION

Many different kinds of information must be available to a highway designer. Some information is related to a specific project — other information is related to all projects.

This manual is a principal source of information providing general guidance on design policies and procedures.

Other sources of information to be used by designers are set forth below. They include field survey information, books, manuals, memorandums and related special engineering services.

FIELD SURVEY INFORMATION

Field survey information provides the basic data needed for the design of specific projects. The following field survey information normally is received for use throughout the design process:

- Plotted topographic maps
- Soils profiles showing the locations of drill logs and soils classifications
- Shrinkage factor recommendations
- Local water data and geologists' recommendations
- Existing drainage and drainage recommendations
- Irrigation and access recommendations
- Telephone and electric service information
- Recommended gradelines
- Narrow-band ownership maps
- Survey notes, including transit notes, level data, topography notes, property ties, cross-section data and drainage data.

BOOKS, MANUALS AND MEMORANDUMS

Several books, manuals and memorandums contain information needed by designers. These sources of information are cited below.

Administration Publications

The following items are published by the Highway Administration:

- Standard Specifications

  The book of "Standard Specifications for Highways and Bridges" describes work to be performed under various contract bid items.

- Supplemental Specifications

  A pamphlet of Supplemental Specifications sets forth the current amendments — additions, deletions and revisions — to the Standard Specifications

- **Standard Drawings**

  The book of Standard Drawings is a compilation of standardized details frequently used in highway design. As needed, the designer will select specific Standard Drawings to be included with each set of contract plans.

- Policy Memorandums

  New design policies often will be set forth in Administration policy memorandums. Designers will receive copies of these memorandums. Periodically those policies will be incorporated in revisions to the Design Manual.

AASHO Publications

The American Association of State Highway Officials has published several reference sources containing background information and derivations for design criteria. The AASHO publications used most often are *A Policy on the Geometric Design of Rural Highways*, commonly referred to as the "AASHO Blue Book", and *A Policy on the Geometric Design of Urban Highways*, commonly referred to as the "AASHO Red Book". More detailed guidance on specific areas of design are contained in the following AASHO publications.

- Guide Specifications for Highway Construction, 1972
- Standard Specification for Highway Bridges, Eleventh Edition, 1973.
- Construction Manual for Highway Bridges and Incidental Structures, 1973.
- Standard Specification for Highway Materials and Methods of Sampling and Testing, Part I, 1970.
- Standard Specification for Highway Materials and Methods of Sampling and Testing, Part II, 1970.

These publications are available in Director of Engineering files.

Supplier Publications

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

ENGINEERING SERVICES

The highway designer frequently will encounter design problems which require guidance and assistance of persons with specialized training and competence. The following organizations within the Administration are available to designers for special engineering services.

- Hydraulics Section
- Traffic Section
- Surfacing Section
- Bridge Design Division
- Right-of-Way Division

CHAPTER THREE

HORIZONTAL ALIGNMENT

GENERAL CONSIDERATIONS

Criteria for the horizontal alignment of highways are directed to providing vehicle operation at consistent speeds with safety and consideration for aesthetic and economic factors. This is accomplished primarily through use of design speed as an overall control.

Factors such as traffic volumes, terrain conditions and construction costs will influence decisions on appropriate design speed. After design speed is established, it is essential that the characteristics of the horizontal alignment assure continuous safe operation at that speed.

Alignment criteria involve two basic considerations :

1. The degree of curvature and superelevation
2. Sight distance

In the design of highway curves it is necessary to establish the proper relationship between design speed, degree of curvature and superelevation and sight distance.

Usually, horizontal alignment will be established in the field by location engineers in accordance with controlling design standards. It is the responsibility of the designer to check the alignment and verify compliance with standards.

STANDARDS FOR CURVATURE

Maximum Degree of Curvature

Degree of curvature is defined as the angular change a curve makes in a given distance along its length. In this manual the given distance is 20 meters. This means that a one-degree curve changes direction one degree in 20 meters ; a two-degree curve changes two degrees in 20 meters and so on. The maximum degree of curvature is limited by the design speed of the highway and the maximum superelevation permitted. Highway Administrations designate 8 percent as the maximum amount of superelevation. Using this maximum superelevation, the sharpest permissible curve for each design speed is as follows .

DESIGN SPEED	MAXIMUM DEGREE OF CURVE	RADUIS, M
35 KPH	37°00′	31
50 KPH	15°00′	76
65 KPH	8°00′	143
80 KPH	5°00′	229
100 KPH	3°00′	382

Never use curves sharper than those shown above.

Desirable Curvature

Avoid the use of maximum degree curves, unless they are economically necessary due to topographical conditions. For small deflection angles, curves should be long enough to avoid the appearances of kinks.

GENERAL ALIGNMENT CRITERIA

In addition to the alignment standards related to design speed, the designer should give consideration to the following general criteria:

- Avoid sharp curves at the ends of long tangents.
- Avoid sudden changes from easy curvature to sharp curvature.
- Avoid compound curvature — adjacent horizontal curvatures with no tangent length separating them.
- Avoid sharp reverse curvature. Provide adequate distance for superelevation runoff
- Avoid broken back curvature — two curves in the same direction separated by a short tangent length. Use a single longer curve for this situation.

SUPERELEVATION

Provide superelevations on horizontal curves to permit safe traverse of vehicles without excessive horizontal forces. The correct amount of superelevation depends on the sharpness of the curve and the speed of the vehicle.

Superelevations must be designed to fit particular conditions in urban areas.

Design superelevations according to Standard Sheet No. 301 for rural areas.

Amount of Superelevation

The maximum amount of superelevation for HA is 8 percent (A slope of 0.08m vertical to 1.0m horizontal).

Standard Sheet No. 301 shows the correct amount of superelevation for each combination of degree of curvature and design speed.

Transitions

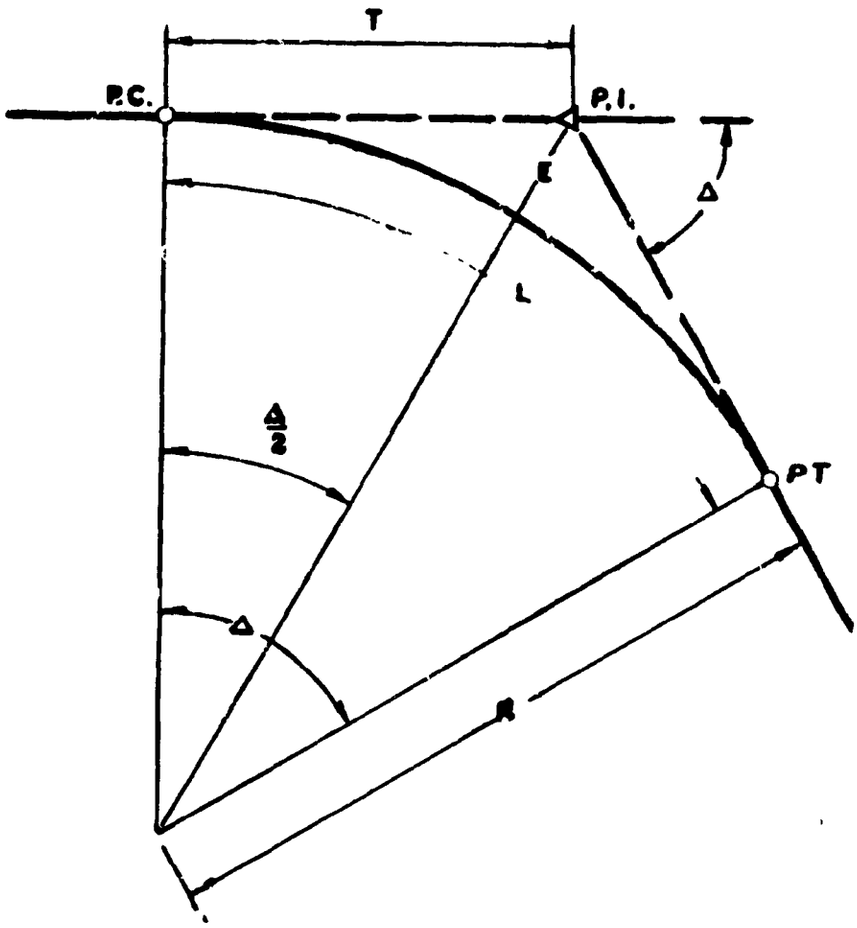
For simple curves, the transition from normal crown to full superelevation occurs entirely on the tangents preceding the P.C. and following the P.T. * This transition distance is labeled "runoff distance", and the required length depends on design speed, number of lanes and degree of curvature as indicated on Standard Sheet No. 301.

On 4-lane divided highways where both roadways have the same profile grade elevation, superelevation will be rotated about the profile grade. This profile grade is located on the inside edge of the pavement. On 2-lane highways and on 4-lane highways where the roadways have different profile grade elevations, superelevation on each roadway will be rotated about the inside edge of the traffic lane at an elevation of profile grade less normal crown.

* For explanation of abbreviations, see page 18.

SIMPLE CURVES

Computations of simple curves involve the relationships expressed in the formulas below. Arc definition is always used for curve computation. Usually the P.I. station, the deflection angle (Δ) and the degree of curvature (D) are established. The remaining curve data must be computed. *



* For explanation of abbreviations, see page 18.

P.I. = Point of Intersection

P.C. = Point of Curvature $\qquad L = \frac{20\,\Delta}{D} = \frac{\pi\, R\, \Delta}{180^\circ}$

P.T. = Point of Tangency $\qquad R = \frac{1145.92}{D} = \frac{20(360)}{2\,\pi\, D}$

Δ = Central Angle $\qquad T = R \tan \frac{\Delta}{2}$

D = Degree of Curvature

L = Length of Curve (m)

R = Radius of Curve (m) $\qquad E = R\left(\frac{1}{\cos\frac{\Delta}{2}} - 1\right)$

T = Tangent Length (m)

F = External (m) $\qquad E = R\left(\mathrm{Sec}\frac{\Delta}{2} - 1\right)$

π = 3.1416

Computation is simplified considerably by using a table of functions for a 1-degree curve. Where T and E are the tangent length and the external for a 1-degree curve with given Δ, then:

$$T = \frac{T_1}{D} \qquad E = \frac{E_1}{D}$$

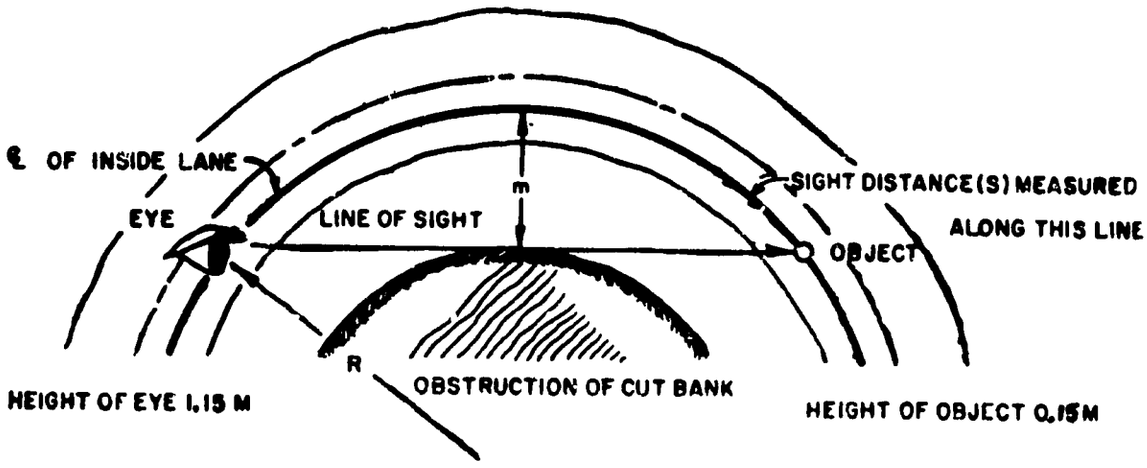
P.C. Sta. = P.I. Sta. − T

P.T. Sta. = P.C. Sta. + L

Specify the degree of curvature (D) to the nearest minute; calculate all other curve data and show to the nearest one-hundredth of a meter, or to the nearest second, whichever is applicable.

Sight Distances on Horizontal Curves

Alignment on horizontal curves takes into consideration that stopping sight distances may be affected by lateral obstacles such as houses, walls or high-cut slopes. The diagram below shows the geometric variables, together with the equations required for their solution.



LINE OF SIGHT IS 0.6M ABOVE INSIDE LANE AT POINT OF OBSTRUCTION

if S = Sight distance, in meters

R = Radius of centerline inside lane, in meters

D = Degree of curvature

m = Middle ordinate: (distance from centerline of inside lane to sight obstruction in meters)

Then

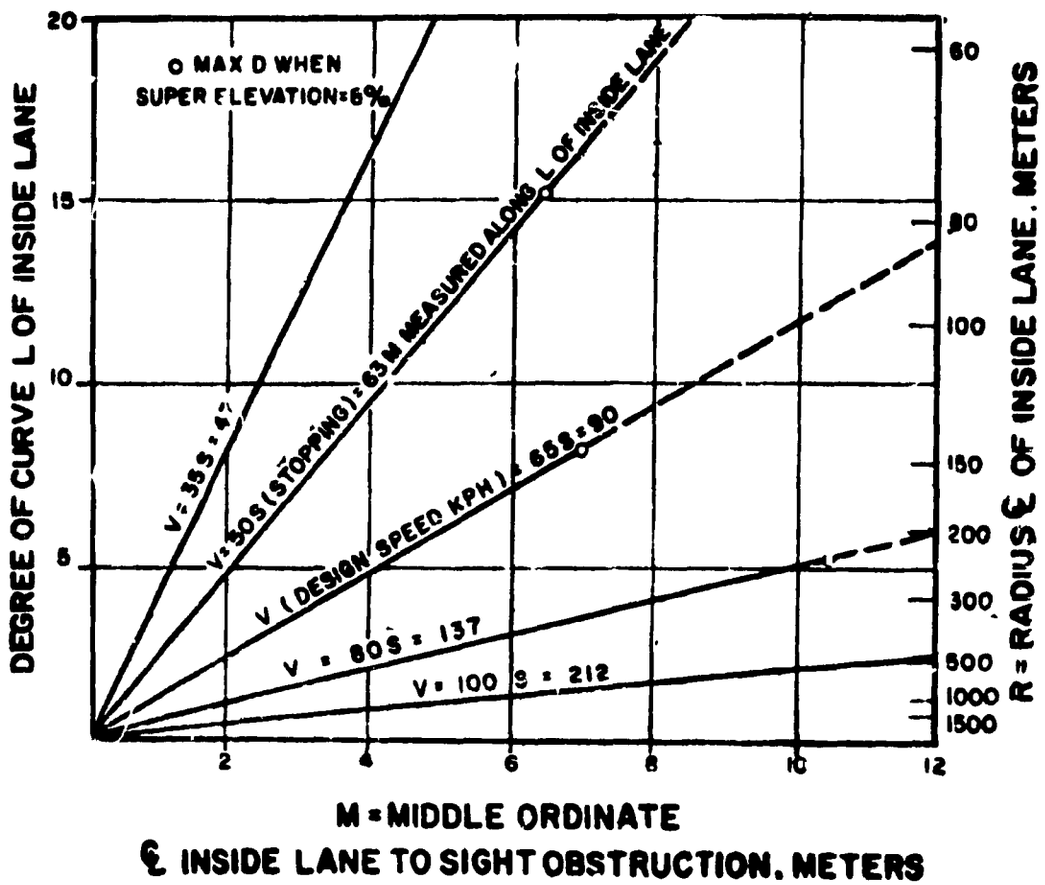
$$m = R\left[1-\cos\left(\frac{28.65S}{R}\right)\right]$$

and

$$S = \frac{R}{28.65}\cos^{-1}\left(\frac{R-m}{R}\right)$$

The graph below shows a linear plot of these equations for a variety of design speeds, from which the value of m can be found, given R (or D), and vice versa.

DESIGN SPEED KPH	35	50	65	80	100
STOPPING SIGHT DISTANCE METERS	47	63	90	137	212

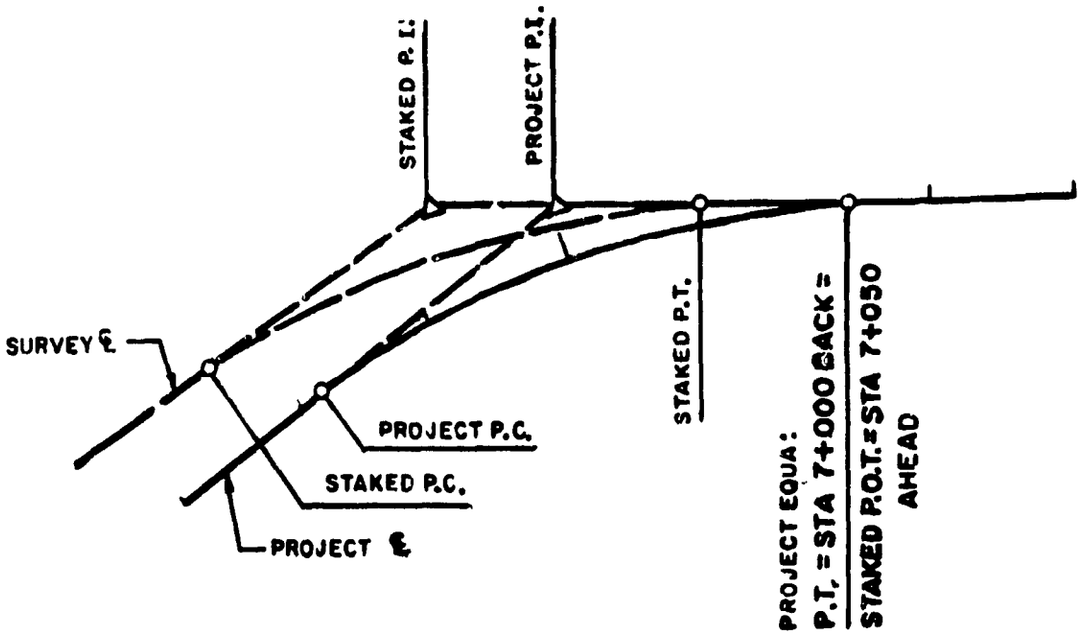


EQUATIONS

An equation is used to equate two station numbers, one that is correct when measuring on the line back of the equated station, and one that is correct when measuring on the line ahead of the equated station. Most equations result from office relocation, and are used where stationing is not continuous throughout a project — as discussed below.

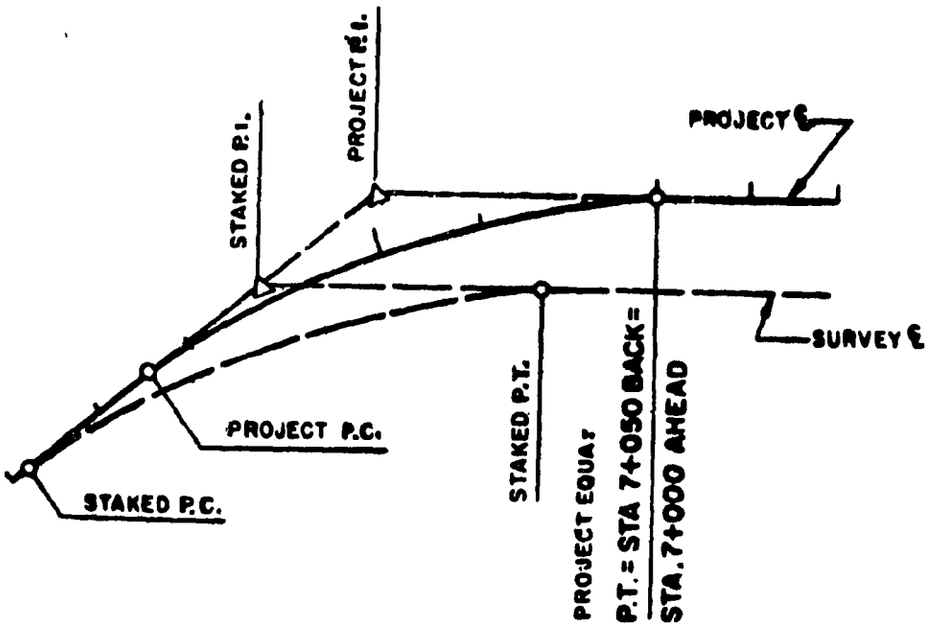
Locations of Equations

Equations are computed where the centerline to be used (project centerline) becomes coincident with the surveyed centerline (staked centerline) This situation is shown below.



EQUATED STATION WHERE PROJECTED LINE BECOMES COINCIDENT WITH SURVEYED LINE

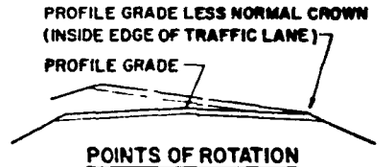
Equations are also computed in certain cases where projected lines become parallel with surveyed lines. If the project line remains parallel with the survey line for a considerable distance representing numerous cross sections, it is more convenient to compute an equation than to restation the cross sections. An example of such an equation is shown below.



EQUATED STATION WHERE PROJECTED LINE BECOMES PARALLEL WITH SURVEYED LINE

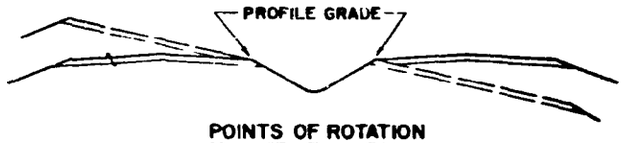
In general, show stationing to the nearest hundredth of a meter.

RADIUS OF CURVATURE IN METERS	DEGREE OF CURVATURE	35KPH			50KPH			65KPH			80KPH			100KPH		
		CROWN SLOPE	RUNOFF DISTANCE, M		CROWN SLOPE	RUNOFF DISTANCE, M		CROWN SLOPE	RUNOFF DISTANCE, M		CROWN SLOPE	RUNOFF DISTANCE, M		CROWN SLOPE	RUNOFF DISTANCE, M	
			2-LANE	4-LANE		2-LANE	4-LANE		2-LANE	4-LANE		2-LANE	4-LANE		2-LANE	4-LANE
4,583 66	0°15	NC			NC			NC			NC			RC	55	55
2,291 83	0°35	NC			NC			NC	40	40	RC	50	50	2		55
1,145 92	1°00	NC			RC	30	30	2			3			4		60
763 94	1°30	RC	30		2			3			4		50	6		70
572 96	2°00	RC			3			4		40	5		60	7	55	85
458 37	2°30	2			3			5		45	6		65	8	65	85
381 97	3°00	2			4			5		50	7	50	75	8	65	100
286 48	4°00	3			5		35	6	40	60	8	55	85	MAX	DEGREE	3°00'
229 18	5°00	3			5		40	7	45	65	8	60	85	8	65	100
190 99	6°00	4			6	30	45	8	50	70	MAX	DEGREE	5°00'			
163 70	7°00	4			6	35	50	8	50	75	8	60	85			
143 24	8°00	5			7	35	55	8	50	75						
127 32	9°00	5			7	40	60	MAX	DEGREE	8°00						
124 59	10°00	5			7	40	60	8	50	75						
104 7	11°00	5			8	40	60									
95 49	12°00	5			8	45	65									
88 15	13°00	6			8	45	05									
81 85	14°00	6			8	45	65									
76 39	15°00	8			9	45	70									
71 62	16°00	7			MAX	DEGREE	15°00									
63 66	18°00	7			8	45	70									
57 30	20°00	7														
52 09	22°00	8														
47 75	24°00	8														
44 07	26°00	8														
40 93	28°00	8	30													
38 20	30°00	8	35													
30 90	37°00	8	35													
		MAX	DEGREE	37°00												
		8	35													



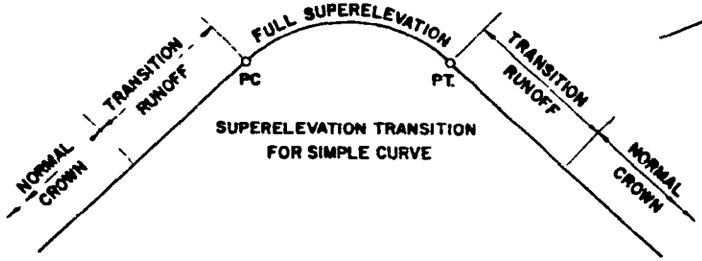
POINTS OF ROTATION

FOR 2-LANE HIGHWAYS AND 4-LANE DIVIDED HIGHWAYS WITH DIFFERENT PROFILE GRADE ELEVATIONS



POINTS OF ROTATION

FOR 4-LANE DIVIDED HIGHWAYS WITH SAME PROFILE GRADE ELEVATION



SUPERELEVATION TRANSITION FOR SIMPLE CURVE

NOTES

NC- NORMAL CROWN SECTION

RC- REMOVE ADVERSE CROWN, SUPERELEVATION AT NORMAL CROWN SLOPE

REVISIONS

STANDARD SUPERELEVATION

STANDARD SHEET NO 3C4

CHAPTER FOUR

VERTICAL ALIGNMENT

INITIAL CONSIDERATIONS

The vertical alignment of a highway is referenced to a gradeline which is shown as part of the highway profile. The elevations of the surfacing and other features of the highway are established from the gradeline.

Initially, working profiles are prepared in the predesign phase of highway development. These profiles are the basis for specifying the final gradeline and profile to be included in the contract plans by the designer.

VERTICAL ALIGNMENT STANDARDS

Grades

The slope or grade of each tangent is expressed in percent rise (+) or fall (—) to the second decimal place.

Maximum Grades

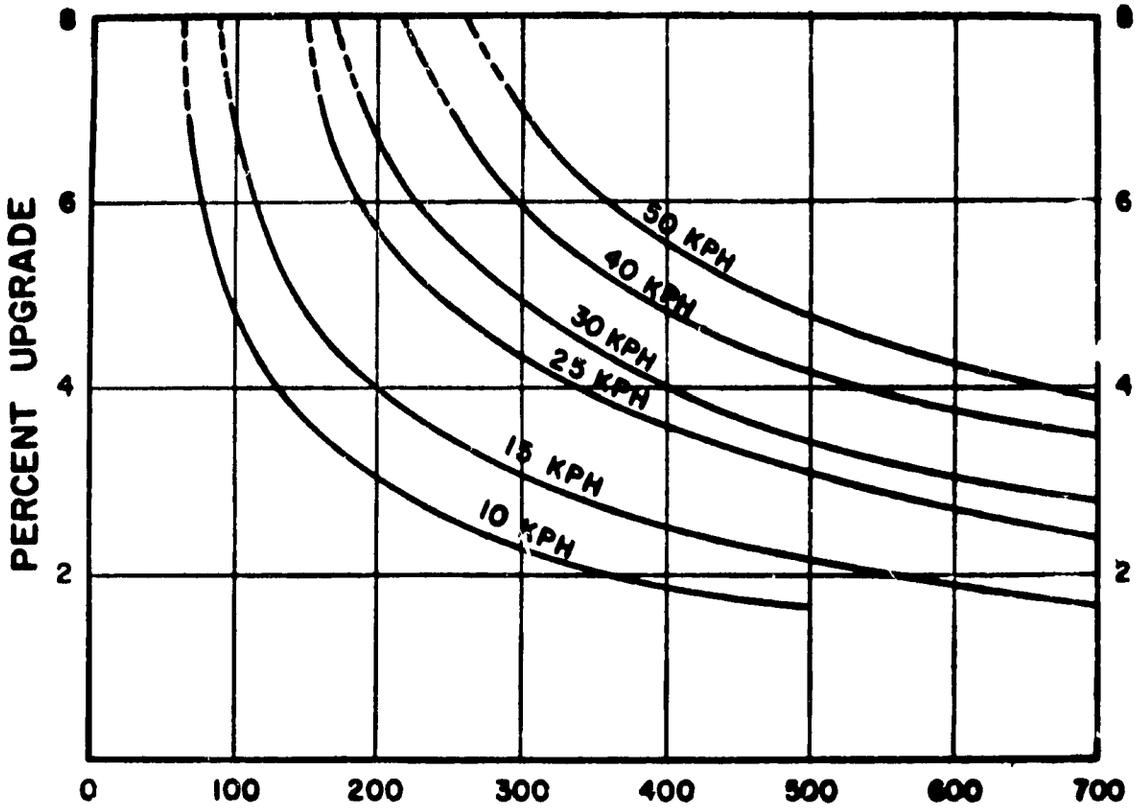
Maximum grades for each highway class are shown on Standard Sheet No. 101. Grades steeper than those shown can be used only with prior approval of the Director of Engineering.

Minimum Grades

In general, a flat or 0.00 percent grade is acceptable. For curbed or diked roadway sections and bridges, a grade of 0.50 percent is desirable. Flatter grades would cause the ponding of storm water across the traffic lanes.

Critical Lengths of Grade

The figure on the next page gives the critical lengths of grade tangent related to the percent of upgrade and the speed reduction in kilometers per hour for a typical heavy truck of 180 kilos per horsepower. (For normal design purposes a speed reduction of 25KPH is acceptable; however, depending on the preceding terrain, the permissible speed reduction on the upgrade may be increased following a downgrade or momentum grade.)



LENGTH OF GRADE-METERS

CRITICAL LENGTHS OF GRADE FOR DESIGN

ASSUMED TYPICAL HEAVY TRUCK OF 180 KILOS PER HORSEPOWER

For further details on the use of this figure, refer to the AASHO publications, *A Policy on Geometric Design of Rural Highways*, and the *Highway Capacity Manual*.

Vertical Curves

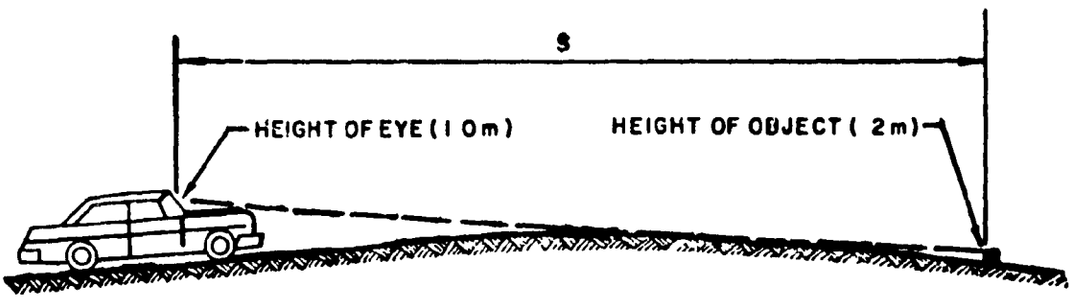
The stationing of each vertical P I. is identified to the nearest hundredth of a meter (0.01 m). Each vertical curve is identified by a curve length, L, usually defined to the nearest one-hundredth meter. The relationship between L and A, the algebraic difference in percent of grades, which is most useful in design is $\frac{L}{A}$. This factor, termed the K value, is the horizontal distance in meters required to effect a 1 percent change in grade; it is therefore a measure of curvature. Minimum K values with minimum and desirable stopping sight distances for both crest and sag vertical curves are shown in the table on the next page for a range of design speeds.

Design Speed KPH	35	50	65	80	100
Minimum K-value with minimum Stopping sight distance for · Crest vertical curves	5	9	16	27	55
Sag vertical curves	8	12	17	23	35
Minimum K-value with desirable Stopping sight distance for : Crest vertical curver	5	9	19	45	107
Sag vertical curves	8	12	19	31	52

Vertical curves on rural and non-curbed highways should be no less than 100 meters long, even when the desirable stopping sight distance is considerably less.

The following sections deal with the control of curve variables for crest and sag vertical curves to ensure that desirable stopping sight distances are achieved.

Crest Vertical Curves



S = STOPPING SIGHT DISTANCE, m
L = LENGTH OF VERTICAL CURVE, m
A = ALGEBRAIC DIFFERENCE IN GRADES, PERCENT

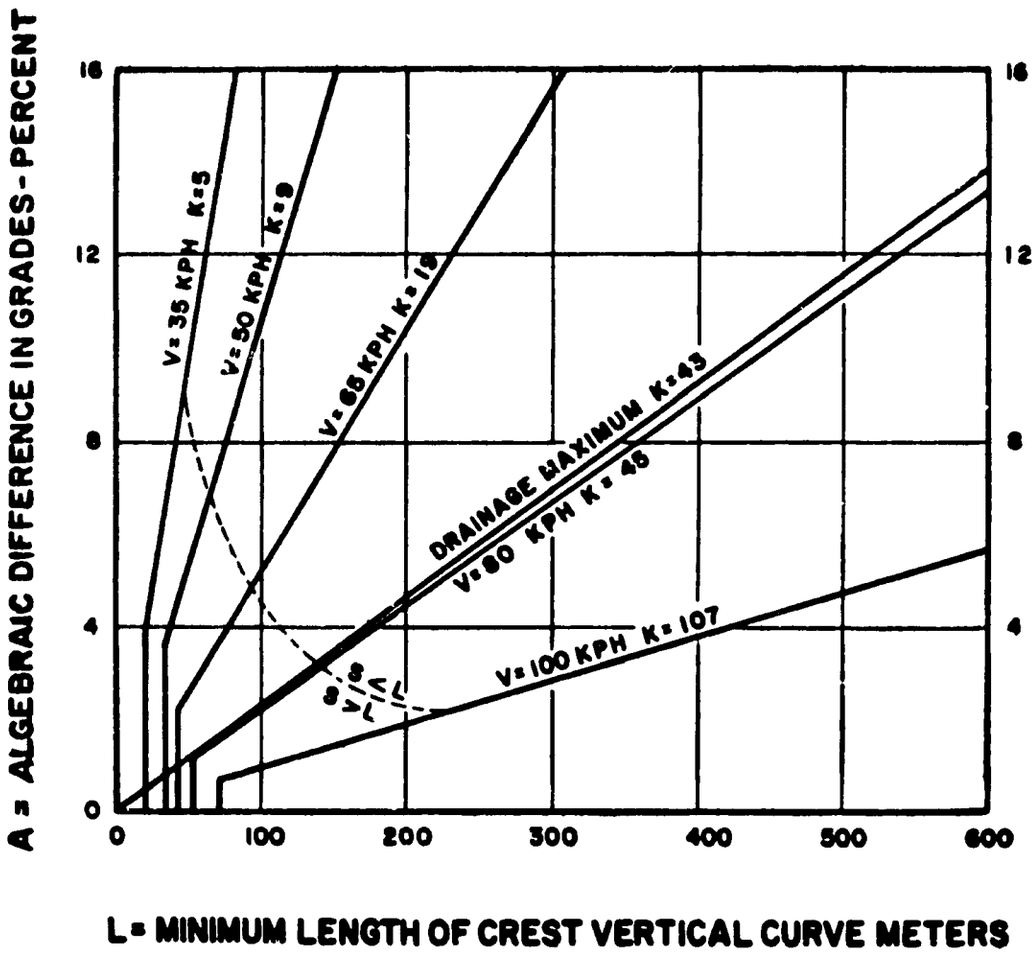
Minimum lengths of crest vertical curves as determined by sight distance requirements generally are satisfactory from the standpoint of safety, comfort and appearance. The equations and figure below may be used to determine the minimum length for different values of A to produce *desirable* stopping sight distance at each design speed.

When $S > L$

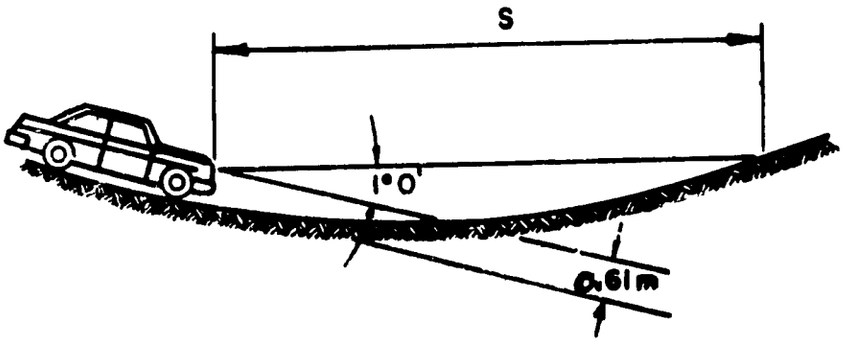
$$L = 2S - \frac{419}{A}$$

When $S < L$

$$L = \frac{AS^2}{419} \text{ and } L = KA$$



Sag Vertical Curves



S = Headlight beam distance

= Stopping sight distance, meters

L = Length of vertical curve, meters

A = Algebraic difference in grades, percent

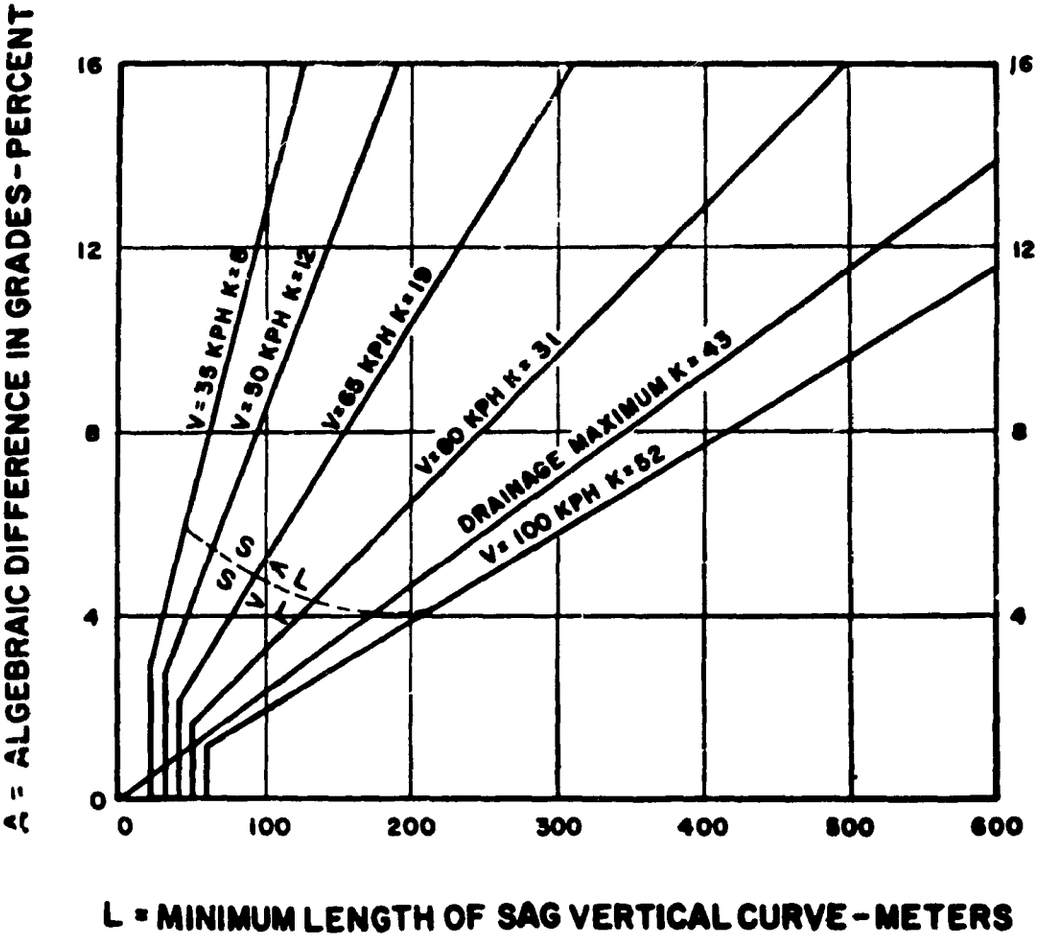
Minimum lengths of sag vertical curves depend mainly on headlight distance at night. For overall safety on highways, it is desirable that the light beam distance be nearly the same as the stopping sight distance; hence, the equations and figure which follow give minimum lengths for different values of A to produce *desirable* stopping sight distances at each design speed.

When S > L

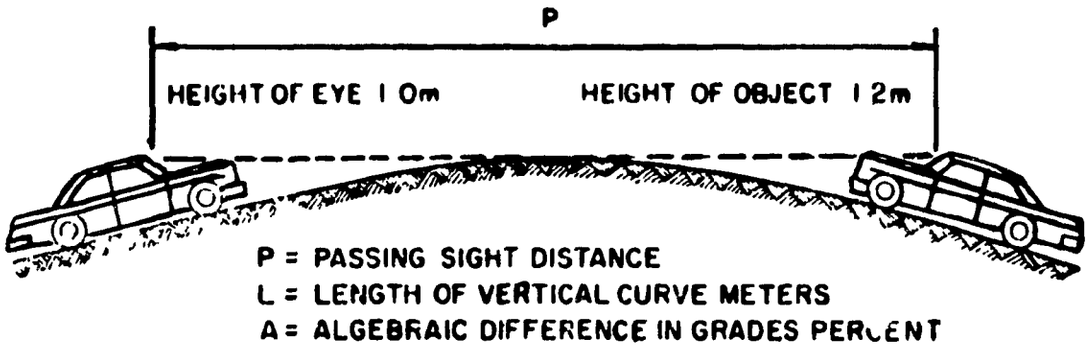
$$L = 2S - \frac{121.6 + 3.5S}{A}$$

When S < L

$$L = \frac{AS^2}{121.6 + 3.5S} \quad \text{And } L = KA$$


A = ALGEBRAIC DIFFERENCE IN GRADES-PERCENT
16
12
8
4
0
0
100
200
300
400
500
600
V=35 KPH K=6
V=50 KPH K=12
V=65 KPH K=19
V=80 KPH K=31
DRAINAGE MAXIMUM K=43
V=100 KPH K=52
S/S
V/A
F/L
L = MINIMUM LENGTH OF SAG VERTICAL CURVE-METERS

Passing Sight Distance



The geometrics concerning passing sight distances for crest vertical curves on a 2-lane highway are similar to those for stopping sight distance. The differences are (a) the height of object is considered as 1.2 meters, and (b) the minimum passing distances are six to ten times greater than the stopping sight distances for the same design speeds. The equations for minimum length of vertical curves are as follows :

When $P > L$

$$L = 2P - \frac{878}{A}$$

When $P < L$

$$L = \frac{AP^2}{878} \quad \text{and} \quad L = KA$$

The table below shows minimum passing sight distances and related K values for a range of design speeds.

Design Speed, KPH	35	50	65	80	100
Minimum passing sight distance for design, feet	240	342	455	550	670
Rounded K value for passing Sight distance, 2-lane highway	66	133	236	345	511

Do not be misled by these passing sight distance criteria. There are conditions that make it impractical to provide adequate passing sight distance at every vertical curve. In some instances it will be necessary to concede that certain areas be striped for "no passing". When this happens, the no-passing zone should be as short as practical to assure that passing can be permitted on a greater portion of the total project length.

Do not design vertical curves which nearly, but not quite, provide passing sight distance.

The designer should recognize the desirability of increasing the passing sight distance where appreciable grades are encountered.

BALANCING EARTHWORK

Projects will be designed to produce balanced earthwork unless particular features dictate otherwise. Material excavated from within the limits of the section should be the amount needed to construct embankments to the designed grade.

To attain balanced earthwork, grade adjustments generally are preferable to ditch widening. In some instances where grade controls are critical, it will not be possible to adjust grades to attain balanced earthwork. Provisions must be made to borrow or waste material as necessary.

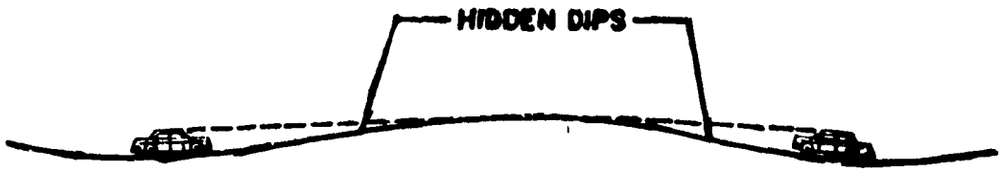
Adjustments to side slopes and areas within loops and ramps to either slightly reduce fill requirements or gain excavation should be weighed against possible aesthetic damage and maintenance problems in these areas.

Urban Areas

Due to the many vertical controls in urban areas, balancing earthwork is not usually a controlling factor in the design of urban highways. An excess of excavation is preferable to the need for borrow because of the high cost of borrow in urban areas.

Hidden Dips

Hidden dips in the profile are hazardous during passing maneuvers. Sight distance should not be sacrificed for earthwork balance. When practicable, use flatter grades and higher elevations through the low spots.



Balance Areas

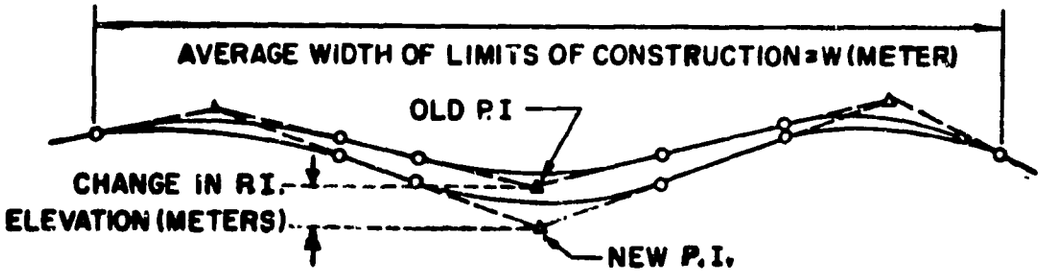
The desirable length of balance should be between one kilometer and one-and-a-half kilometers.

Short balances of 50 to 100 meters should generally not be shown on the plans; they should be shown as part of a combined larger balance.

Wherever possible, balance earthwork at bridge ends, railroad crossings and highway intersections.

Earthwork distribution plans should not require borrow to be hauled through one balance to another balance.

The change in elevation of a vertical P.I. required to produce a given volume of material can be computed using the formula below; for other information on earthwork distribution analysis, refer to Chapter 6 of this manual.



If the volume of additional excavation required is V (cubic meters),

$$\text{then } X = \frac{V}{500\,WL}$$

SPECIAL CONSIDERATIONS

Field-Recommendations

At the time of the preliminary survey, the District Engineer and possibly the Roadway Design Engineer should review the ground-line profile data and develop recommendations for certain grade-line controls. The working profile is then developed with notations indicating the recommended grade line to be established across low flats, lake beds, stream bottoms, important intersecting roads, in front of improved property, and at other places requiring special attention.

The designer should review and consider these recommendations and establish a tentative grade line on the working profile consistent with the design standards and the guidelines in this manual.

Ties with Adjoining Projects

A smooth transition is needed with adjoining projects. The designer should consider the grade line for a distance of at least 600 meters before and after the project. Connections with previously built projects should be compatible with the design speed of the new project.

A connecting grade should be established which satisfactorily adjoins the existing alignment and which can be utilized when the adjoining project is reconstructed.

Refer to as-built plans for alignment of adjoining highways and specify project numbers of adjoining projects at the beginning and the end of the project.

Smooth Grade Line

Changes in grade should be gradual and consistent with the type of highway and the character of terrain. Numerous breaks and short lengths of grade tangents should be avoided.

Broken-Back Grade Lines

A broken-back grade line — two vertical curves in the same direction separated by a short (150 meters or less) section of grade tangent - should be avoided. This is particularly important in sags where the full view of both vertical curves is not pleasing.

This type of grade line may be avoided by joining the vertical curves or replacing them with a single curve of greater length.

Relationship with Horizontal Curvature

Lengths of vertical curves and grades should be influenced by the lengths of the horizontal elements on which they are superimposed. The following guidelines should be considered:

- Horizontal curvature should lead vertical curvature and remain somewhat longer than the latter. Visually, they should be similar in length.
- The locations of vertical curve P.I.'s and horizontal curve P.I.'s should roughly coincide.
- Sharp horizontal curvature should not be introduced at the crest or at the low point of a vertical curve.
- Horizontal curvature and profile should be made as flat as feasible at highway intersections where sight distance along both highways is important.

Railroad Grade Crossings

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

In cases where a railroad has a maintenance road parallel to the tracks, it may be necessary to provide travel across the highway. Such cases, and those involving horizontal clearances, may require special consideration. The designer should contact and coordinate with the Railway System.

Drainage Structures

Chapter 7 discusses the cover thickness based on the strength of the culvert. For minimum thickness of cover for box culverts, refer to the standard plans.

Grade design in the vicinity of bridges should be coordinated with bridge design to ensure adequate high-water clearance at the bridge.

Soils Conditions

Areas of poor or wet soil conditions will be indicated in field recommendations, along with recommendations for minimum fill heights. Occasionally, areas of high water table are encountered. The water table elevation will be indicated in the Soil Survey Report. Final determination of fill height will be made by Road Design Engineer based on recommendations from the Soils Engineer. Upon receipt of the Soils Survey Report, the need for the selective placement of soils should be checked against the earthwork distribution to assure that cross-hauling is not necessary. If selective placement of soils is anticipated, earthwork distribution should not be finalized until selective placement is determined.

Structure Clearances

For design purposes the minimum vertical clearances at grade separations for through facilities is 4.5 meters. This value is intended for general guidance only ; final grade decisions should be coordinated with division responsible for the facility or structure design.

When setting a preliminary grade line, a rough estimate of superstructure depth is 1.5 meters for railroad structures and 1.2 meters for highway bridges.

It will frequently simplify bridge design if the low point in the grade line under a structure is set a sufficient distance from the intersection of the centerlines of the structure and the highway. This will allow drainage structures to clear bridge footings.

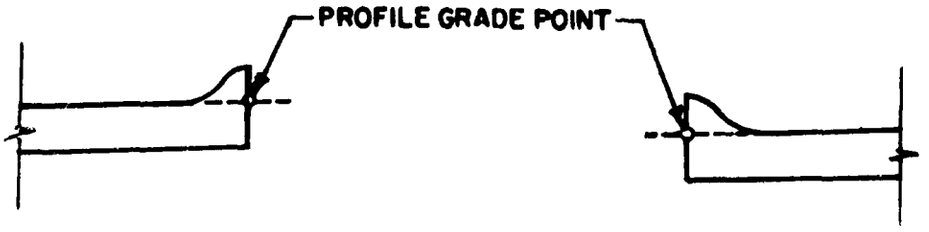
The grade line on bridge decks should preferably be a tangent. For long bridges where drainage is confined to the bridge deck, a 0.5 percent-grade is a desirable minimum.

URBAN GRADE DESIGN

The design of vertical alignment on urban projects frequently involves special considerations. Existing street elevations normally control vertical alignment. There may also be local laws which should be followed that establish minimum and maximum grades allowed on city streets.

Grades

The profile grade line is generally determined from the highest elevation point of the normal cross section. It is sometimes necessary to supplement the main profile with other profiles — gutter grade lines or other controlling grade lines. On curbed sections when the centerline is not the profile line, the profile should represent the elevation of the projection of pavement cross-slope onto back of curb, as in the figure below.



Spline curves or adjustable curves are helpful in establishing grades in urban areas where it is necessary to meet numerous elevations in relatively short distances. The gutter lines can be shown as spline curves, with the beginning and end of each spline curve tied into the grade lines. Elevations along spline curves should be shown at 10-meter intervals on vertical curves, and at 20-meter intervals on tangent profiles.

Vertical Curves

Vertical curves are not required on urban streets where the algebraic difference in grades is less than 0.2%. Curves must be long enough to ensure desirable stopping sight distance, but should not be flattened beyond this distance to such an extent as to make drainage a problem.

Where possible, P.I.'s of crest vertical curves should be located at or near the centerlines of cross streets.

Surface Drainage

Grade lines should be established to make the top of curb either coincident with or slightly below the natural ground. This permits adjacent surface drainage to flow into the gutter for controlled outlet at specified locations.

Try to avoid grades that impound water back of the curb.

Gutters should be placed on a grade of at least 0.5% to allow for adequate drainage. Avoid level sections of gutter or low spots in the gutter that do not have outlets.

At major intersections, a valley gutter is unacceptable. Valley gutters should generally be avoided as they may present a driving hazard, although they are allowable at minor intersections. As a general rule, take drainage runoff into the storm sewer system on the upstream side.

Existing Roadside Development

Occasionally, a situation will arise where extensive development exists on both sides of the street, and the ground or development on one side is higher than on the other. In this situation, a grade line may fit the development on one side but result in extensive property damage to the development on the other side. An unsymmetrical section may be used ; the total drop from crown point to gutter will be greater than normal on one side and less than normal on the other side.

The grade line should be placed so that the curb and gutter on the project will meet the curb and gutter existing on intersecting cross-streets.

SURFACE ELEVATION COMPUTATIONS

Normally, surface elevations will be computed and recorded to the nearest one-hundredth of a meter (0.01m). Grades should be computed and recorded as a percent to two decimal places (0.00%).

Profile grade points should be shown on typical sections as follows :

- For an undivided symmetrical section, at the centerline.
- For a divided section with median, at the intersection of the inside back of median curb and the pavement cross slope.

Grade elevations should be shown on profile views as follows :

- For a standard section and grade, at 20-meter intervals, using a scale of 1cm to 5 meters.
- For an irregular section or warped grade, at 10-meter intervals, using a scale of 1 centimeter to 2 meters.

A tolerance of +0.01m in elevation is permitted when a computed grade is projected to a previously established P.I. elevation.

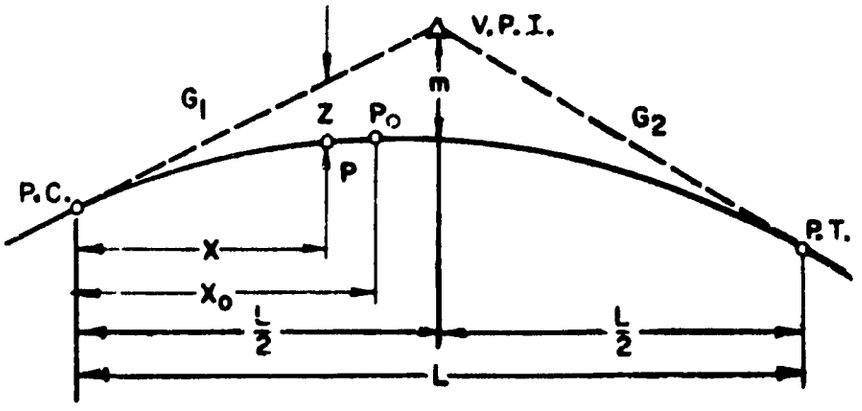
If necessary, additional decimal places will be used in grade computations to assure adherence to the P.I. elevation tolerance requirements.

Vertical Curve Elevations

The vertical curve is a parabolic arc. The offset distance from a parabola to its tangent varies as the square of the distance from its point of tangency. To determine profile grades on vertical curves, offsets from the tangent grades are computed and added to or subtracted from tangent grade elevations.

Computations

Dimensions and equations for use in vertical curve computations are shown below.



In any vertical curve :

Elev. of P.I. = Elev. of P.C. $+ G_1 \frac{L}{2}$

Elev. of P.T. = Elev. of P.C. $+ (G_1 + G_2) \cdot \frac{L}{2}$

$$m = \left(\frac{G_2 - G_1}{8}\right) L$$

$$Z = \frac{4m\,X^2}{L^2} = X^2 \frac{(G_2 - G_1)}{2L}$$

$$S = G_1 - \left[\frac{X.\,(G_1 - G_2)}{L}\right]$$

$$X_0 = \frac{LG_1}{G_1 - G_2}$$

Elev. of P_0 = Elev. of P.C. $- \dfrac{LG_1^2}{2\,(G_2 - G_1)}$

Where :

L = Horizontal length of curve, in stations

G_1 G_2 = Rates of grade, expressed algebraically in percent

m = middle ordinate, in meters

P = any point on the curve

Z = Tangent offset of point P, in meters

X = horizontal distance from the P.C. or P.T. to P, in stations

S = Slope of a line tangent to the curve at P, in percent

P_0 = is the high or low point of the curve

X_0 = horizontal distance from the P.C. to P_0 in stations.

When computing vertical curve elevations on a slide rule, using the middle ordinate method and the formula $Z = m\left(\frac{X}{L/2}\right)^2$, follow these steps :

1. Set the runner to m on the A scale;
2. Bring $\frac{L}{2}$ on the C scale to the runner;
3. Set the runner to any desired value of X on the C scale;
4. Read Z for that X value on the A scale.

Computation Procedures

Manual computation is facilitated by special columns for this purpose on standard sheets for earthwork computation.

Elevations are recorded for each cross-section station, P.I.'s are identified by asterisks, vertical curve lengths are identified, and the profile grade elevations along vertical curves are shown. The figure on the next page shows a portion of an earthwork computation sheet with grade computations properly recorded.

STATION	GRADES & V.C.	V.C. CORR.	ELEV.	CORR. ELEV.
650 + 000			16.08	
+ 850			15.91	
+ 900			15.73	
+ 950			15.56	
651 + 000			15.38	
+ 050			15.21	
+ 100		0.00	15.03	
+ 125	- 0.35%	+ 0.01	14.94	14.95
+ 150		0.04	14.85	14.89
+ 163		0.06	14.81	14.87
+ 175		0.08	14.76	14.84
+ 200		0.15	14.68	14.83
+ 216.7	V.C.	0.20	14.62	14.82
+ 225		0.24	14.59	14.83
+ 250	300 m	0.34	14.50	14.84
+ 275		0.24	14.64	14.88
+ 300		0.15	14.78	14.93
+ 316		0.11	14.86	14.97
+ 325		0.08	14.91	14.99
+ 335		0.04	15.05	15.09
+ 375	+ 0.55%	0.01	15.19	15.20
+ 400		0.00	15.33	15.33
+ 450			15.61	
+ 500			15.88	
+ 520			15.99	

High or Low Points on Curves

High points on crest vertical curves and low points on sag vertical curves can be calculated as follows:

$$= \frac{L\,G_1}{G_1 - G_2}$$ where P is the horizontal distance (in stations from the P.C. to the high or low point on the curve).

CLIMBING LANES

During the design of vertical alignment, consideration should be given to the possible need for climbing lanes.

A climbing lane is an additional lane provided for slow-moving vehicles on long, steep ascending grades. The design of climbing lanes is governed by several criteria such as design speed and length of grade. Refer to the *Highway Capacity Manual* for detailed design criteria. General criteria are presented below:

Lane Width

The widths of climbing lanes will be the standard lane-width for that class of roadway.

Shoulder Width

Shoulders adjacent to climbing lanes will be standard shoulder-width for that class of roadway.

Transition

The transition into a climbing lane will be on a 25 : 1 taper, and the transition out will be on a 50 : 1 taper.

Minimum Length

The minimum length for climbing lanes is 350 meters. If the design procedure indicates lengths below this limit, do not install a climbing lane.

Connecting Climbing Lanes

Two or more climbing lanes may occur on the same highway on the same long grade. If the distance from one climbing lane to the next is small, it is preferable to extend one climbing lane into the other to form one long climbing lane rather than leave a short stretch of 2-lane highway between them.

Climbing Lane Ends

The full climbing lane width is carried to a point beyond the crest of the hill where the truck has resumed a speed which is, at the most, only 25 KPH less than the average speed and can return to the through lane without hazard.

CHAPTER FIVE

CROSS SECTIONS

GENERAL CONSIDERATIONS

Cross sections provide graphical pictures of the relationships between proposed roadways and the existing ground surface. This chapter presents guidelines for the preparation of cross-section sheets, including:

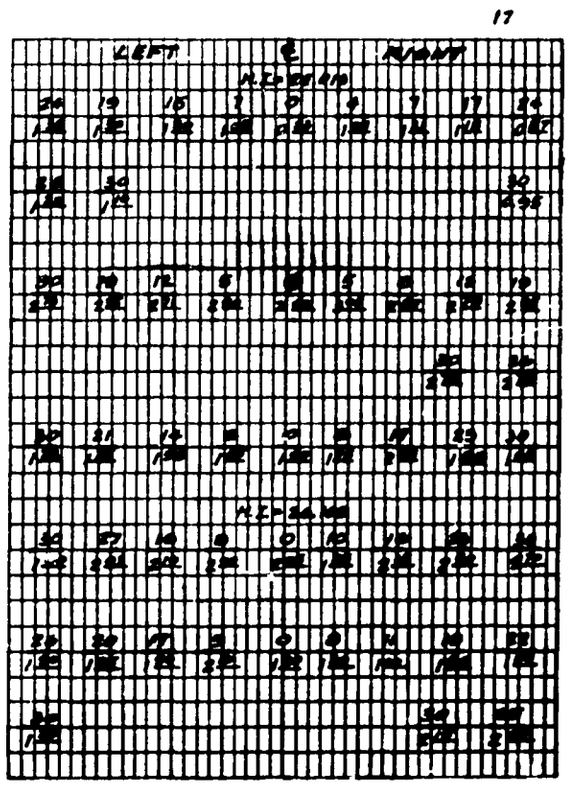
- preliminary cross sections
- roadway templates
- earthwork
- drainage
- miscellaneous.

CROSS SECTIONS

Survey Notes

The survey notes provide the data needed to prepare cross sections. A sample of these notes is shown below.

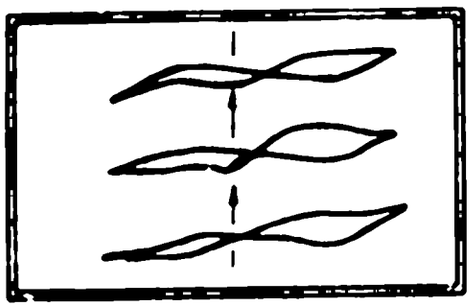
STA	BS +	HI	FS −	ELE		
		22.043				
11+960						
TP			1.107	20.936	NAIL IN	POST 20M RT
					STA. 11+965	
11+975	2.954	23.800				
12+000						
TP			0.955	22.845	STAKE	25M LT
					STA 12+040	
12+080	3.263	26.108				
12+100						



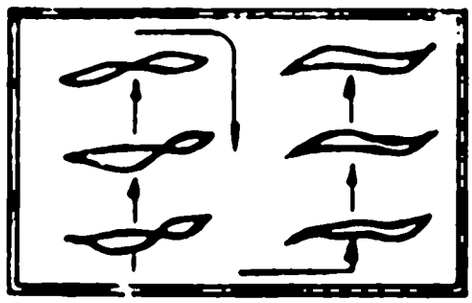
Generally, cross sections are required at a maximum interval of 25 meters in rural areas and 20 meters in urban areas. The following section gives guidelines for placing this information on cross-section sheets.

Sheet Layout

Place cross sections horizontally. When narrow sections would leave extra wide margins, a double column may be used as shown:



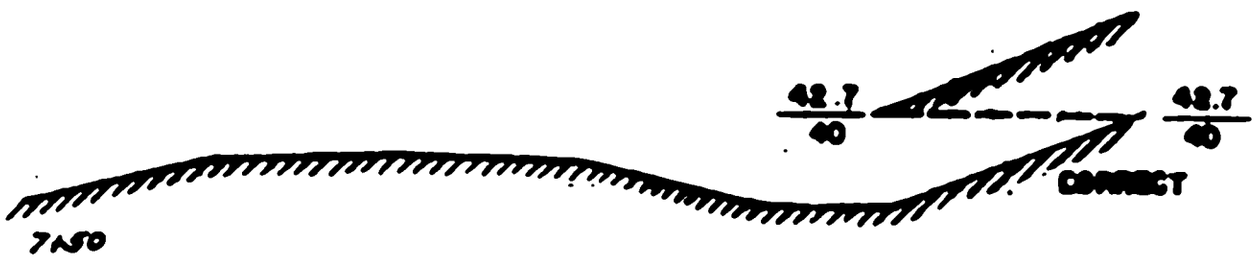
NORMAL OR WIDE SECTIONS

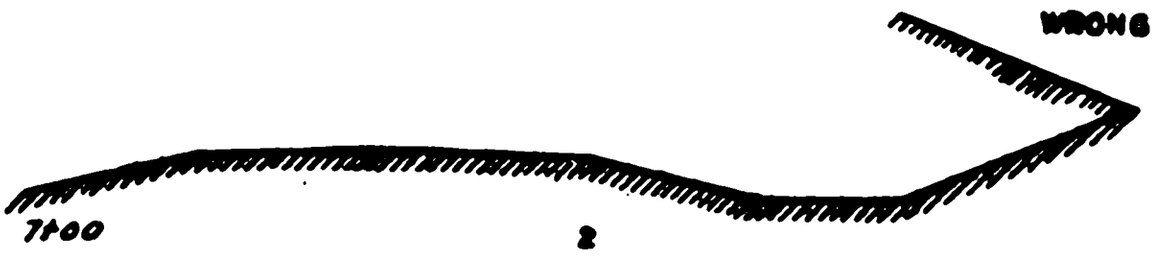


NARROW SECTIONS

The arrows in the diagram above show the order in which cross sections are read.

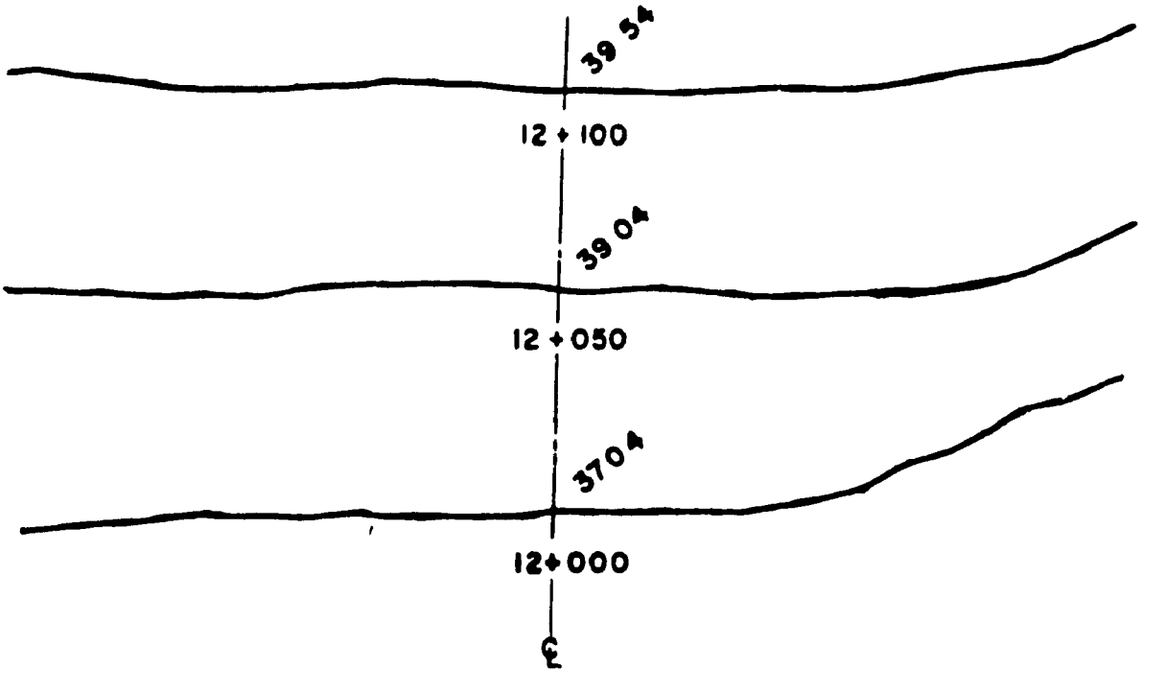
When cross-section slope lines would extend beyond sheet limits, the slope lines will be broken and indented — — not folded back onto the sheet. The break points will be identified by elevation and offset distance from centerline — as shown below:





Plotting

The initial plotting of present ground lines is made in pencil. Allow enough space vertically between ground lines to avoid overlapping of the completed cross sections after roadway templates are plotted. Space requirements can be determined by checking the profile and anticipating large cuts and fills. The plotted ground lines are identified by station numbers and elevations at centerline, as illustrated below:



PLOTTED GROUND LINES
Showing Station Numbers and Ground Elevations at Centerline

The centerline symbol ℄ is placed on centerline at the bottom of each cross-section sheet, as shown in the illustration above.

Scales

The following scales should be used for cross sections:

Rural Design	Horizontal	1cm = 1m
	Vertical	1cm = 0.5m
Urban Design	Horizontal	1cm = 0.5m
	Vertical	1cm = 0.2m
Special situations (for clarity)	Horizontal	1cm = 0.5m
	Vertical	or LESS

Scales are shown in the upper right-hand corner of all cross-section sheets.

Topography

Buildings, utilities and other major topography along the proposed route are shown on cross-section sheets. This helps to determine the effect of proposed construction on the existing facilities.

Topographic features are located using scaled distances for lateral location and plus station for longitudinal locations. These features are drawn on the nearest main-line cross section.

Sheet Numbers

As cross section sheets are drawn, sequential sheet numbers, beginning with 1, are written in pencil in the title blocks at the lower right corner of the sheets.

Inking

After the ground lines and topography have been pencil drawn and checked, the following items are inked :

- Ground lines
- Stationing
- Elevations of ground at centerline
- Major topography.

No other items on cross-section sheets will be inked.

ROADWAY TEMPLATES

After a typical roadway section has been determined and a tentative profile grade established, roadway templates are plotted on the cross sections.

Roadway templates are plotted in pencil. The plotted templates may require adjustment several times, so the pencil lead should be soft enough to permit complete erasures.

Typical Sections

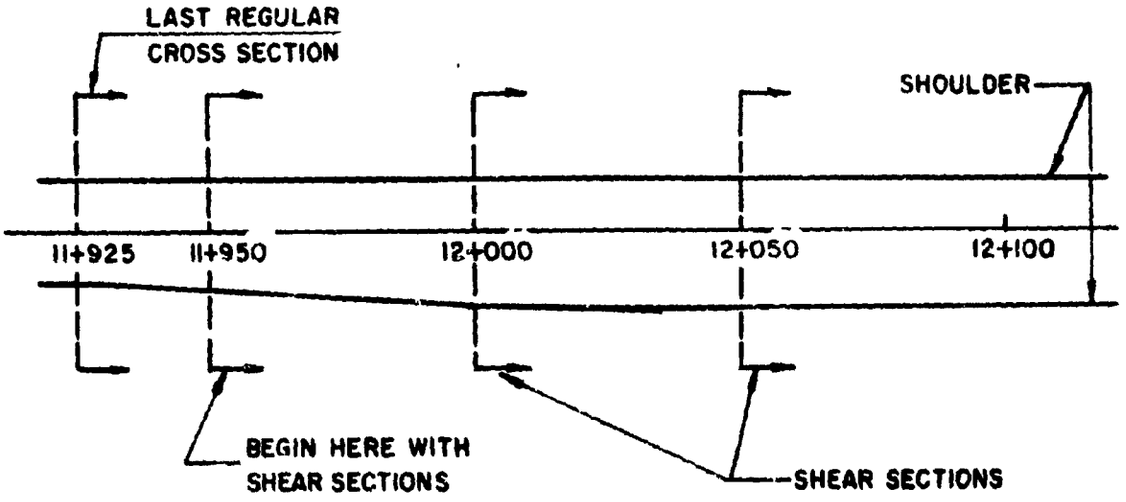
Standard typical sections are described with illustrations accompanying the geometric design standards in Chapter One.

Only the grading templates (subgrades and side slopes) need plotting to complete the cross sections. Surfacing is not shown. Unusual special excavation below the normal subgrade should be plotted.

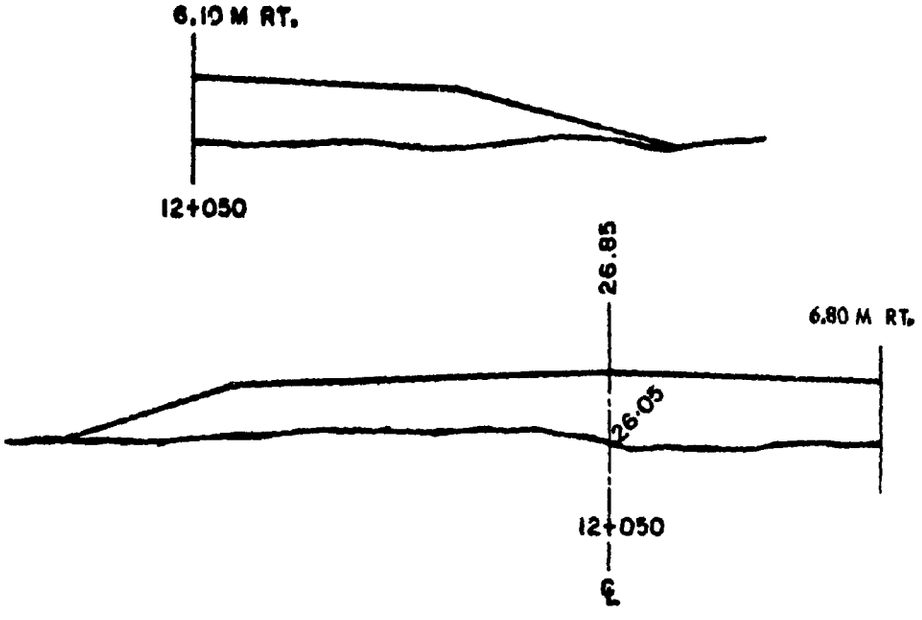
Shear Sections

Where applicable, shear sections will be inserted after the typical section. Examples for use of shear sections are roadside parking areas, climbing and acceleration lanes.

A vertical closing line is shown on each relevant cross section to indicate earthwork discontinuities, as between ramp and main-line sections. Shear sections are used when the roadway width changes from the typical section. The figure below illustrates where shear sections are drawn.



The figure below, taken from the above alignment, illustrates a typical shear section.



Grade Elevations

Profile grade elevations, representing finished grade, are read directly from the earthwork computation sheets and entered on the cross-section sheets.

Profile grade elevations are placed vertically above the profile grade points as shown in the previous example.

Slopes

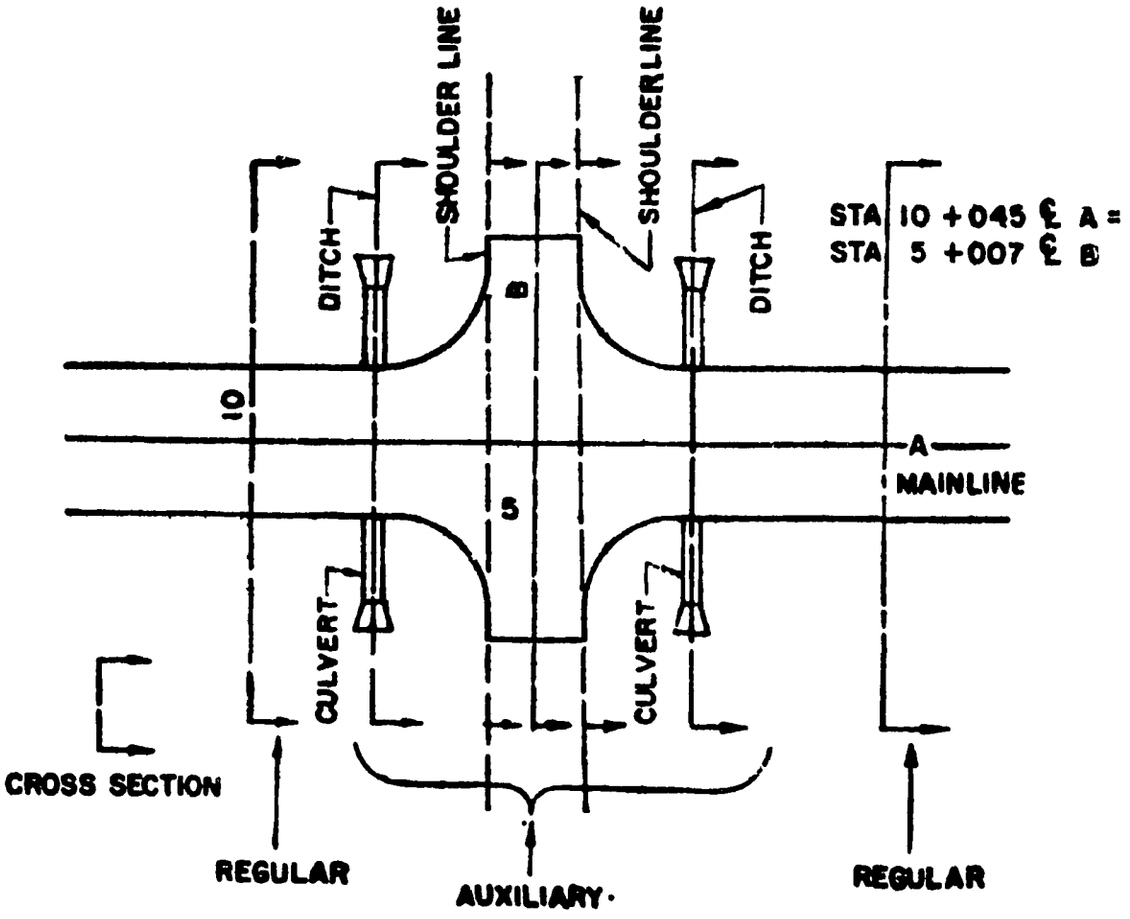
The basic policies and criteria for slopes are presented in Chapter Two. Back slopes, inslopes and median slopes are designed in accordance with these criteria for existing terrain conditions, cut depths and fill heights.

Intersections

Plot cross sections in the vicinity of intersections or entrance roads according to the following guidelines :

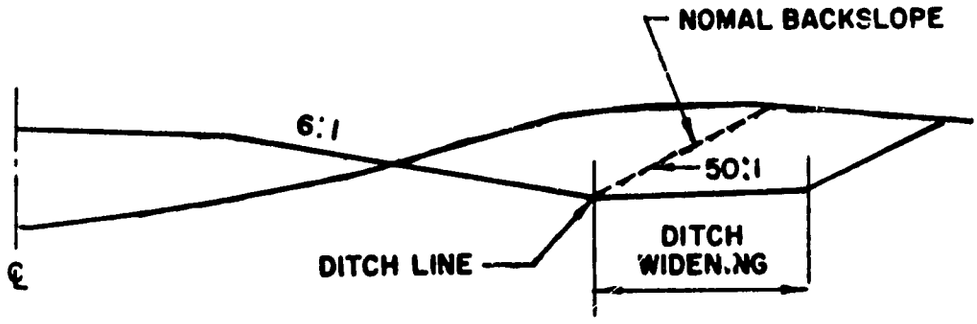
- Show intersecting roads on all main-line cross sections within the limits of the main-line cross section.
- Where high fills are encountered at an intersection, draw cross sections along the lines of the pipe culverts.
- Auxiliary cross sections of intersecting roads, where required, are drawn along the normal ditch line or through the ends of radii, whichever provides the widest section.

The following figure illustrates these guidelines.



Ditch Widening

Widening of ditches to balance quantities or secure additional excavation should be in accordance with the typical section being used. The figure below shows a commonly used ditch-widening section :



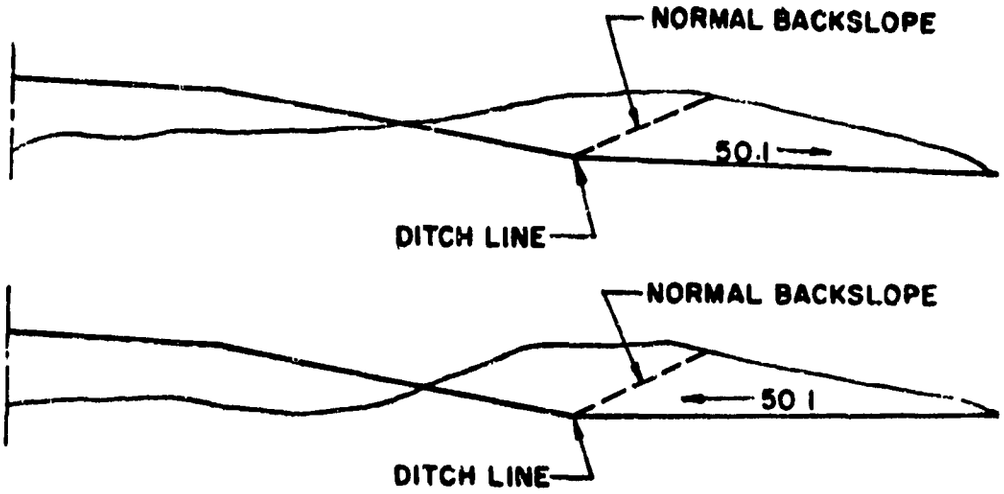
Daylighting

The term *daylighting* refers to the practice of removing small berms, hills and other surface irregularities which lie beyond the ditch line. Daylighting may be used to provide needed fill material and to increase sight distance on curves. Do not use daylighting if guardrail must be provided as a result — except for specifically designed turnout areas.

When daylighting is used to gain excavation or to improve sight distance, the following considerations should be taken into account :

- The need for a physical separation of runoff within the highway right-of-way and adjacent private property.
- The consequences of removal of the earth barrier regarding noise pollution, off-roadway glare, driver distraction, view from the road and from off the road, and other aesthetic considerations.

The figures below illustrate cross sections which may be used for daylighting.



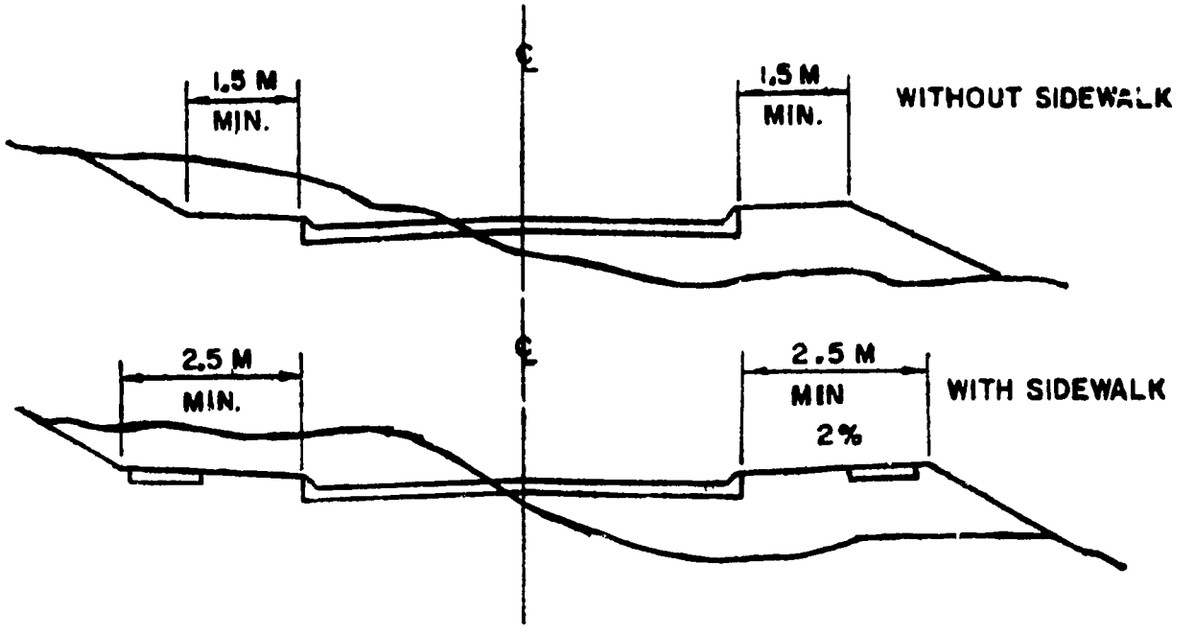
Slopes in Urban Areas

Gradelines in urban areas should be designed so that the top of the curb is either level with or preferably slightly below the existing ground. It is desirable to leave a natural appearance adjacent to the roadway.

When the natural ground is above or below the top of the curb, and a cut or a fill is required, follow these criteria :

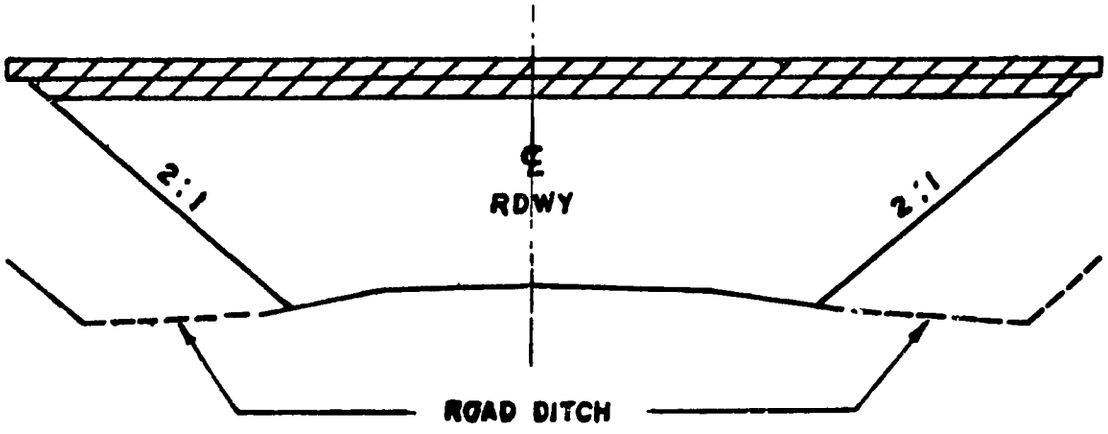
- Provide a minimum 1.5 meter bench or berm behind the curb, level with the top of the curb and sloped 2% toward the roadway.
- When a sidewalk is installed, widen the bench or berm behind the curb to 2.5 meters before beginning the cut slope or the fill slope.
- Use a 6: 1 cut slope or fill slope to natural ground, except where a steeper slope is necessary to stay within the right-of-way limits.

The figures below illustrate these criteria:



Bridge End Slopes

At grade separations, the backslopes of the road must be the same as the bridge end slopes. Backslope transitions, if necessary, must be made to avoid cutting into bridge end slopes. The standard bridge end slope is 2:1.

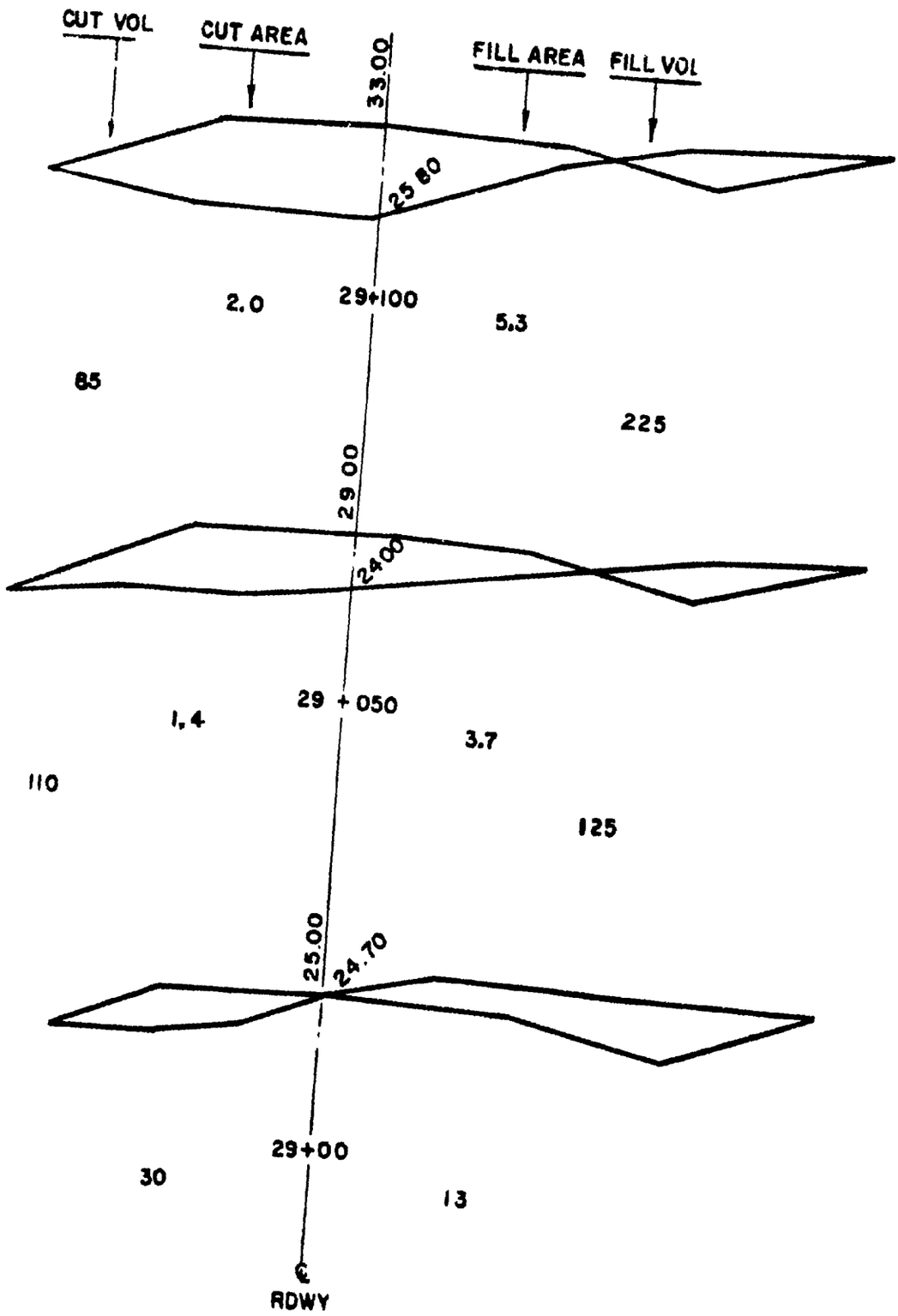


Before plotting roadway templates at grade separations, check the roadway typical sections with the bridge plans to see that they are the same.

EARTHWORK

Procedures for computing earthwork are presented in Chapter Six. Guidelines for recording earthwork data on cross-section sheets are presented below.

Earthwork data recorded on cross section sheets are (1) the areas of cut and fill, in square meters, at each cross section and (2) the volumes of cut and unadjusted fill, in cubic meters, between adjacent cross sections. This data is recorded in pencil, with cut quantities on the left and fill quantities on the right, as shown on the next page. The column headings are identified at the top of each sheet, using an imprint of a standard rubber stamp provided for this purpose. The following illustration demonstrates the use of the rubber stamp and the placement of the areas and volumes.


CUT VOL
CUT AREA
FILL AREA
FILL VOL
33.00
25.80
2.0
29+100
5.3
85
225
29.00
24.00
29 + 050
1.4
3.7
110
125
25.00
24.70
29+00
30
13
℄
RDWY

DRAINAGE

The basic policies and criteria for drainage are presented in Chapter Seven. Guidelines for showing drainage items on cross sections are presented below.

Drainage items are shown in pencil. Drainage details may be modified several times, so the pencil lead should be soft enough to permit erasures.

Culverts

Culverts must be fully described on cross-section sheets. Each description includes a drawing and a note. The details of the drawings and the contents of the notes are discussed and illustrated below.

Mainline Culverts Without Skews

Main-line culverts without skews are drawn on the closest adjacent cross section of the main line. Each culvert drawing shows lines representing the top of the pipe, the flowline of the pipe and, where applicable, flared end-terminal sections

Mainline Culverts With Skews

Skewed main-line culverts are drawn on the closest adjacent cross sections of the main line. Each culvert drawing shows lines representing the top of the pipe, the flowline of the pipe and, where applicable, flared end-terminal sections.

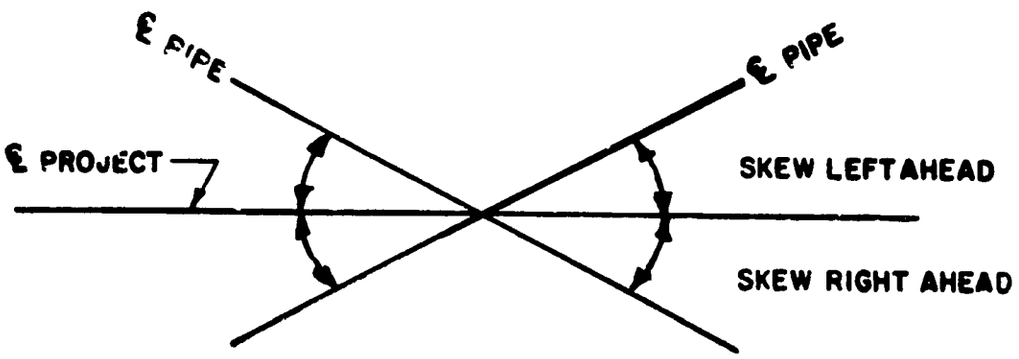
Approach Pipes and Median Drains

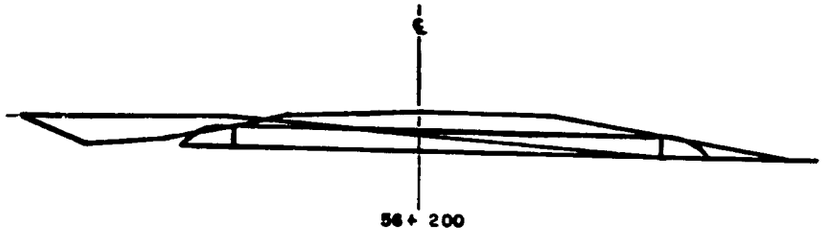
Approach pipes and median drains are shown as circles on the closest adjacent main-line cross sections.

Notes

Culvert drawings are supplemented with notes containing the following data, as appropriate:

- Location of culvert at main-line centerline section.
- Description of pipe, including inside diameter.
- Amount of skew in degrees, measured right or left as shown below:

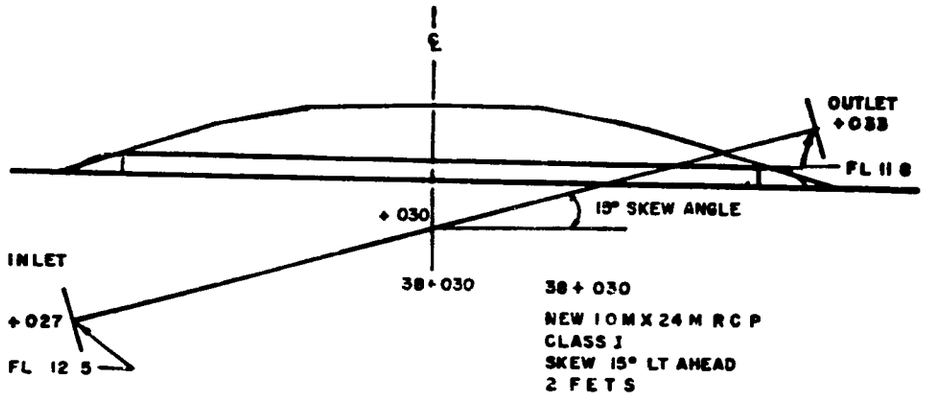




56+200

NEW 0 6M X 20M R C P
CLASS I
2 F E T S
1 2M COVER
25 C M CULV EXC

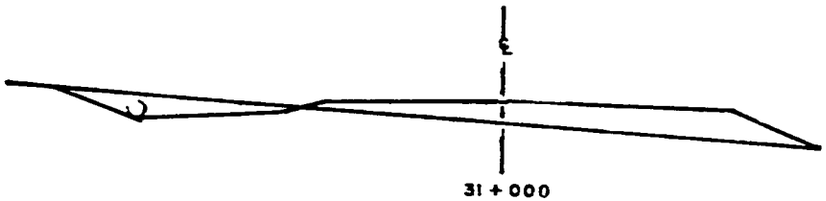
MAINLINE CULVERT WITHOUT SKEW



38+030

NEW 1 0M X 24 M R C P
CLASS I
SKEW 15° LT AHEAD
2 F E T S
1 5 M COVER
1 8 0 CM CULV EXC

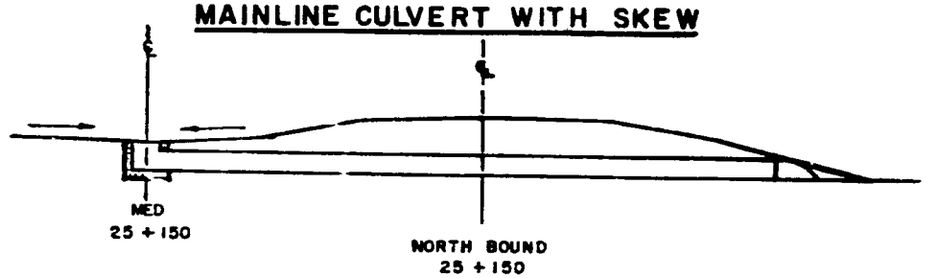
MAINLINE CULVERT WITH SKEW



31+000

NEW 0 6M X 14 M R C P DRAIN
CLASS 2
2-F E T S
0 6M COVER
5 0 CM CULV EXC

APPROACH PIPE



25+150 (NORTH BOUND)

NEW 0 6M X 20M R C P DRAIN
CLASS I
1-F E T S RT
1-NEW MEDIAN INLET COVER
TYPE I
1 0 M COVER
20 0 CM CULV EXC

MEDIAN DRAIN

- Description of end treatment
- Height of cover, measured from the top of the pipe to the top of the finished surface
- Cubic meters of culvert excavation
- Quantity of bedding material.

Drop Inlets and Storm Sewers

Drop inlets and storm sewers are shown on the nearest main-line cross sections. Draw drop inlets to the top-of-wall elevations and show the flowlines and the tops of pipes. Where storm sewers run parallel to the main line, their locations and flowlines are shown on each main-line cross section.

Drop inlets and storm sewers also are described by a note. Each note indicates the station location, full descriptions of the items required and the cubic meters of culvert excavation. A typical note is shown below:

17 + 051
NEW 0.3m × 10m R.C.P. (CL.2)
1 NEW DROP INLET LT.
15 C.M. CULV. EXC.
CONN. TO NEW M. H.

Drain Ditches

Inlet and outlet drain ditches are drawn on cross sections, and described by notes wherever they are used. Each note indicates the station location, the cubic meters of additional excavation, whether it is an inlet ditch or an outlet ditch and whether it is left or right of the main line. A typical note is shown below:

25 + 025
25 C.M. ADD. EXC.
OUTLET DT. LT.

Large Pipe Installations

A typical note for large culverts should be in the format shown below:

1250 + 000
NEW 5m × 50m (description of pipe here)
COVER = 3.0m
SKEW = 30° LT. AHEAD
ENDS SKEWED 20° WARP SLOPES TO FIT
145 C.M. BEDDING MATERIAL
175 C.M. CULVERT EXC.
6.0 C.M. CLASS D CONC. (cutoff walls)
61.4 C.M. TYPE B RANDOM RIPRAP (inlet and outlet)

Curb and Gutter Sections

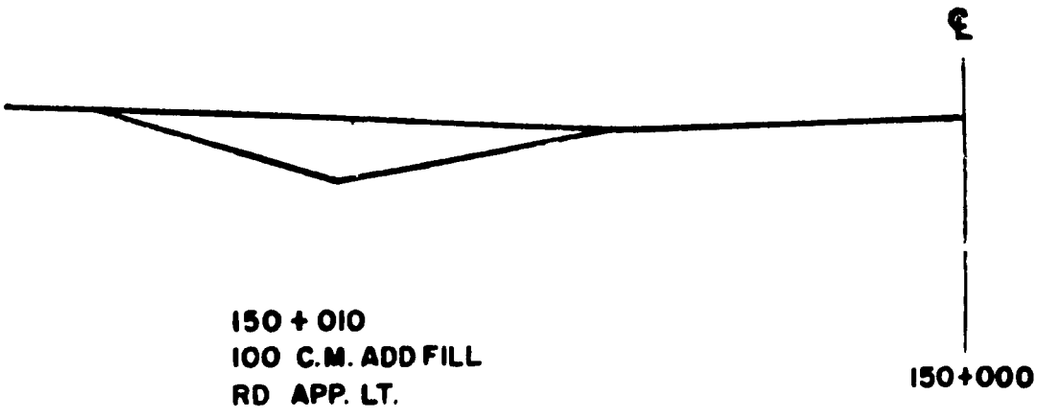
Curbs and gutters are drawn on cross sections only where they adjoint drop inlets.

MISCELLANEOUS

Several types of miscellaneous items are also shown on cross-section sheets. Guidelines for showing some of the most common items are presented below.

Road Approaches

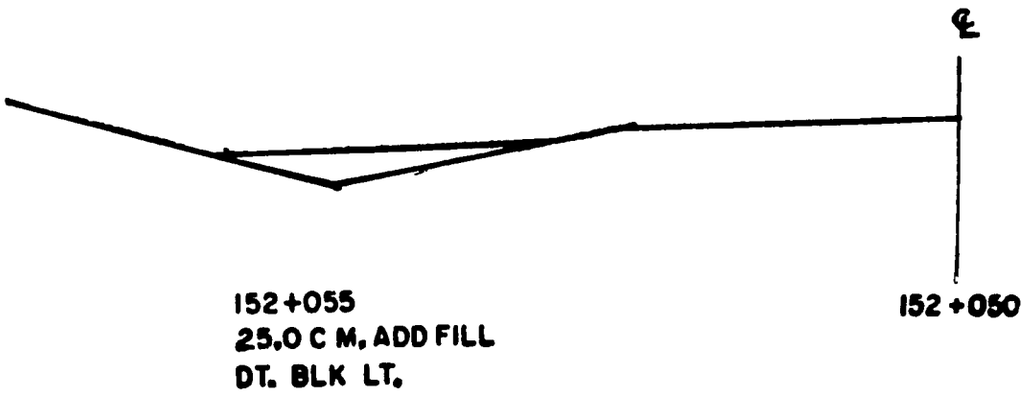
Road approaches are drawn on the closest adjacent cross sections of the main line and noted in the manner shown below :



Individual cross sections of road approaches are not shown except in cases of unusual special design.

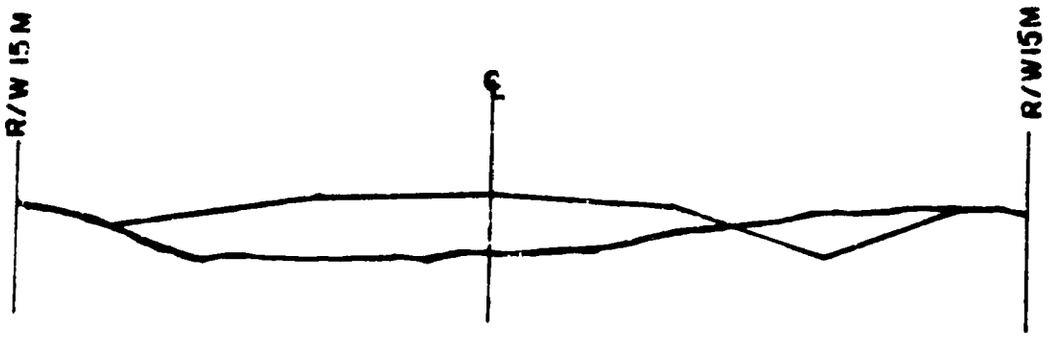
Ditch Blocks

Ditch blocks are drawn on the nearest cross section of the main line and noted in the manner shown below :



Right-of-Way Limits

Right-of-way limits are shown on the first cross section of each sheet where these limits are constant. In transition areas the limits are shown on each cross section.



CHAPTER SIX

EARTHWORK COMPUTATIONS

GENERAL CONSIDERATIONS

Earthwork computations are to be done using the methods and guidelines presented in this chapter.

Earthwork computations involve these basic steps :

- Computing cross-section areas of cut and fill
- Computing volumes of excavation and embankment
- Plotting mass diagrams and computing haul.

COMPUTATION SHEETS

Record earthwork computations on computation sheets provided by the Director of Engineering. A sample computation sheet, properly completed, is shown on the next page.

The first five columns of the sheet (grades, vertical-curve data, grade elevations, stations and distance between stations) are completed during the process of computing grades. The remaining columns will be used for documenting cross-section areas, with volumes between cross sections and mass curve data used for plotting mass diagrams.

Prepare computation sheets for each 1000 meter-section of roadway. This will speed the preparation of mass diagrams as explained later.

EARTHWORK COMPUTATION SHEET

SHEET ___ OF ___ SHEET

LOCATION _____ DATE _____ PROJ NO _____

STATIONS _____ CH _____ DISTANCE _____ CH _____ GRADES _____ CH _____

VERT _____ CH _____ AREAS _____ CH _____ VOL _____ CH _____ MASS _____

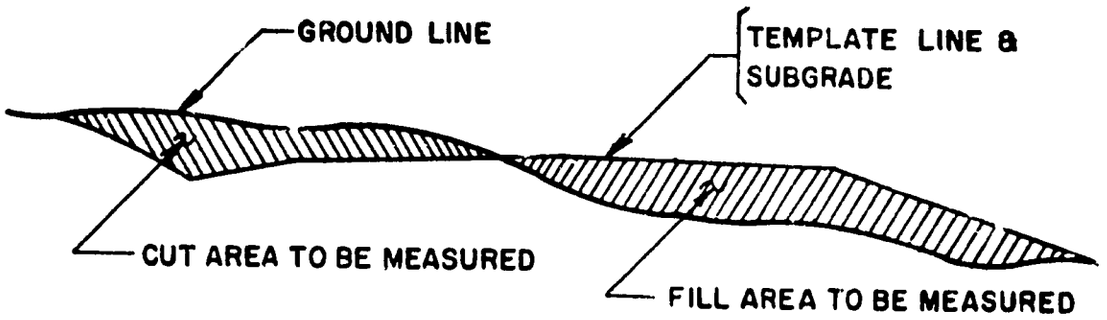
GRADES %	V C CORR	CORR ELEV / ELEV	STATIONS	DISTANCE	AREAS IN SQUARE METERS: CUT AREA	CUT AVERAGE AREA	FILL AREA	FILL AVERAGE AREA	VOLUMES IN CUBIC METERS: EXCAVATION CLASSIFICATION	EXCAVATION ROCK	EXCAVATION TOTAL	EMB ACTUAL	EMB +	MASS CURVE DATE: CUT +	FILL −	Σ
		16.00	650+800		0		54									
				50		0		53			0	2650	3180	0	3180	
		15.91	+850		0		52									3180
				50		0		51.5			0	2575	3090	0	3090	
		15.73	+900		0		51									6270
				50		0		48			0	2400	2880	0	2880	
		15.5[illegible]	1950		0		45									9150
				50		0		40			0	2000	2400	0	2400	
		15.33	651+00		0		35									11550
				50		0		33			250	650	1980	0	1730	
		15.21	+050		10		31									13280
				50		15		18			750	900	1080	0	330	
	0.00	15.03 / 15.03	+100		20		5									13610
				25		17.5		12.5			438	313	376	62	0	
	+ 0.01	14.95 / 14.94	+125		15		10									13548
				25		13.5		10			338	250	300	38	0	
	+ 0.04	14.83 / 14.83	+150		12		10									13510
				13		17.5		7.5			228	98	118	110	0	
	+ 0.06	14.67 / 14.81	+163		25		5									13493
				12		27.5		2.5			330	30	36	294	0	
	+ 0.08	14.54 / 14.76	+175		30		0									13106
				25		32		0			800	0	0	800	0	
	+ 0.15	14.83 / 14.68	+200		34		0									12306
				16.7		31		0			518	0	0	518	0	
	+ 0.20	14.82 / 14.62	+216.7		28		0									11788
				8.3		29		0			241	0	0	241	0	
	+ 0.24	14.83 / 14.49	+225		30		0									11547
				25		30		0			750	0	0	750	0	
	+ 0.34	14.84 / 14.50	+250		30		0									10797
				25		30.5		0			763	0	0	763	0	
	+ 0.24	14.88 / 14.64	+275		31		0									10034
				25		30.5		0			763	0	0	763	0	
	+ 0.15	14.93 / 14.78	+300		30		0									9271
				16		30		0			480	0	0	480	0	
	+ 0.11	14.97 / 14.86	+316		30		0									8794
				9		31		0			270	0	0	270	0	
	+ 0.08	14.99 / 14.91	+325		32		0									8521
				25		28		0			700	0	0	700	0	
	+ 0.04	15.09 / 15.05	+350		24		0									7821
				25		35		0			875	0	0	875	0	
	+ 0.01	15.20 / 15.19	+375		46		0									6946
				25		43		0			1075	0	0	1075	0	
	+ 0.00	15.33 / 15.33	+400		40		0									5871
				50		43		0			2150	0	0	2150	0	
		15.61	+450		46		0									3721
				50		44		0			2200	0	0	2200	0	
		15.88	+500		42		0									1521
				50		45		0			2250	0	0	2250	0	
		16.16	+550		48		0									+ 729
				50		46		0			2300	0	0	2300	0	
		16.43	+600		44		0									+ 3079
				50		45		0			2250	0	0	2250	0	
		16.71	+650		46		0									+ 5279
				50		43		45			2150	225	270	1880	0	
		16.98	+700		40		9									+ 7159
				50		39		15			1950	750	900	1050	0	
		17.26	+750		38		30									8200
				50		34		27			1700	1350	1620	80	0	
		17.53	651+800		30		33									8289

-0.35% 300 ft +0.55%

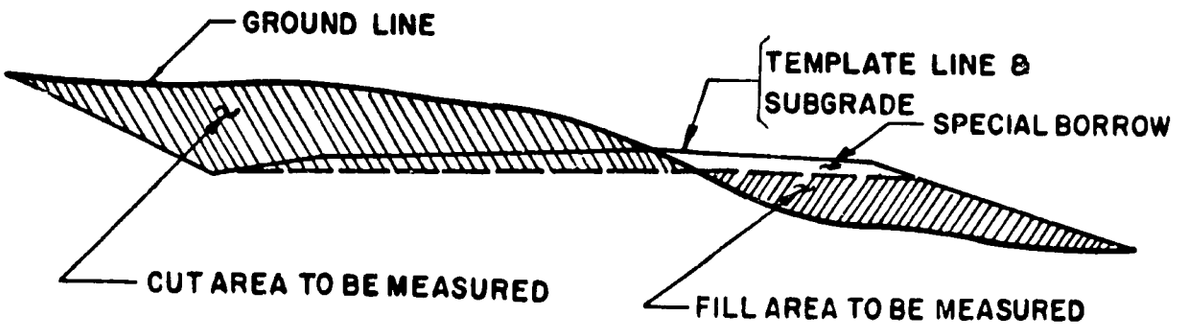
COMPUTING CROSS-SECTION AREAS

Definition of Areas

The end areas to be computed are defined by the ground lines and the template lines, except in fill areas where select borrow is used. Where special borrow is used, fill areas will be computed to the bottom of the select borrow. See the example below.



SECTION WITHOUT SELECT BORROW



SECTION WITH SELECT BORROW

Computation Method

Measure the end areas in square meters, using either a planimeter or a mathematical method. If a planimeter is used, instructions accompanying the instrument should be followed in determining the proper scales to use.

The end areas for cuts and fills will be recorded below each cross section, as described in Chapter Five.

COMPUTING VOLUMES

Computation Formula

Compute volumes of excavation and embankment using the average end-area formula as shown below:

$$V = \frac{A_1 + A_2}{2} \times D$$

Where:

V	=	Volume, in cubic meters.
$A_1 + A_2$	=	Sum of cut- or fill-end areas of adjacent sections, in square meters.
D	=	Distance between sections, in meters.

Transfer the cut- and fill-area figures for each cross section from the cross-section sheet to the computation sheet and record them in the *Area* column. The *Average Area* column shows the average of the adjacent cross-section areas. Record the volumes in the *Total* column for excavation and in the *Actual* column for embankment. If instructions have been given to classify certain areas as rock excavation, record the cut volume in the *Rock* column.

Transfer the volumes of excavation and embankment from the *Total* and *Actual* columns and record between cross sections, as discussed in Chapter Five.

Shrinkage and Swell Factors

Adjust the volumes of embankment recorded in the *Actual* column for shrinkage and swell. Record the adjusted volumes in the *Emb.* + column.

Adjust volumes for shrinkage and swell as recommended by the District Engineer. In the absence of recommendations from the District Engineer, use the standard tables as presented below.

STANDARD SHRINKAGE TABLE

AVERAGE END AREA M^2	SHRINKAGE FACTOR
0-5	1.45
5-15	1.35
15-35	1.25
35-50	1.15
Over 50	1.10

The Standard Swell Table is used when rock quantities are involved. To obtain the *Emb.* + volume, multiply the *Actual* embankment by the swell factor appropriate for estimated percentage of rock.

STANDARD SWELL TABLE

ESTIMATED PERCENT ROCK	SWELL FACTOR
0 10	1.00
11-25	0.95
26-50	0.90
51-75	0.80
76-90	0.75
91-100	0.70

Mass Curve Data

Mass Curve data are computed and recorded in the last three columns of the computation sheet.

Where the excavation quantity exceeds the embankment quantity between two cross sections, the difference is recorded in the *Cut* + column. When the embankment exceeds the excavation, the difference is recorded in the *Fill* — column.

In the last column, record the accumulated difference between cut and fill at each cross section. An accumulated surplus of excavation is identified with the plus symbol: +. Where there is insufficient accumulated excavation for the required fill, the mass curve value is identified with the minus symbol: —.

Computation sheets are prepared for each 1000-meter section of roadway. At the beginning of each section, record the mass in the last column as 0 (zero) and compute the mass accordingly. This makes it easier to prepare mass diagrams as discussed in the next section.

COMPUTING HAUL

Haul will be computed for all projects. The steps involved in computing haul are:

- Plotting the mass
- Computing the balance points
- Computing haul under curve.

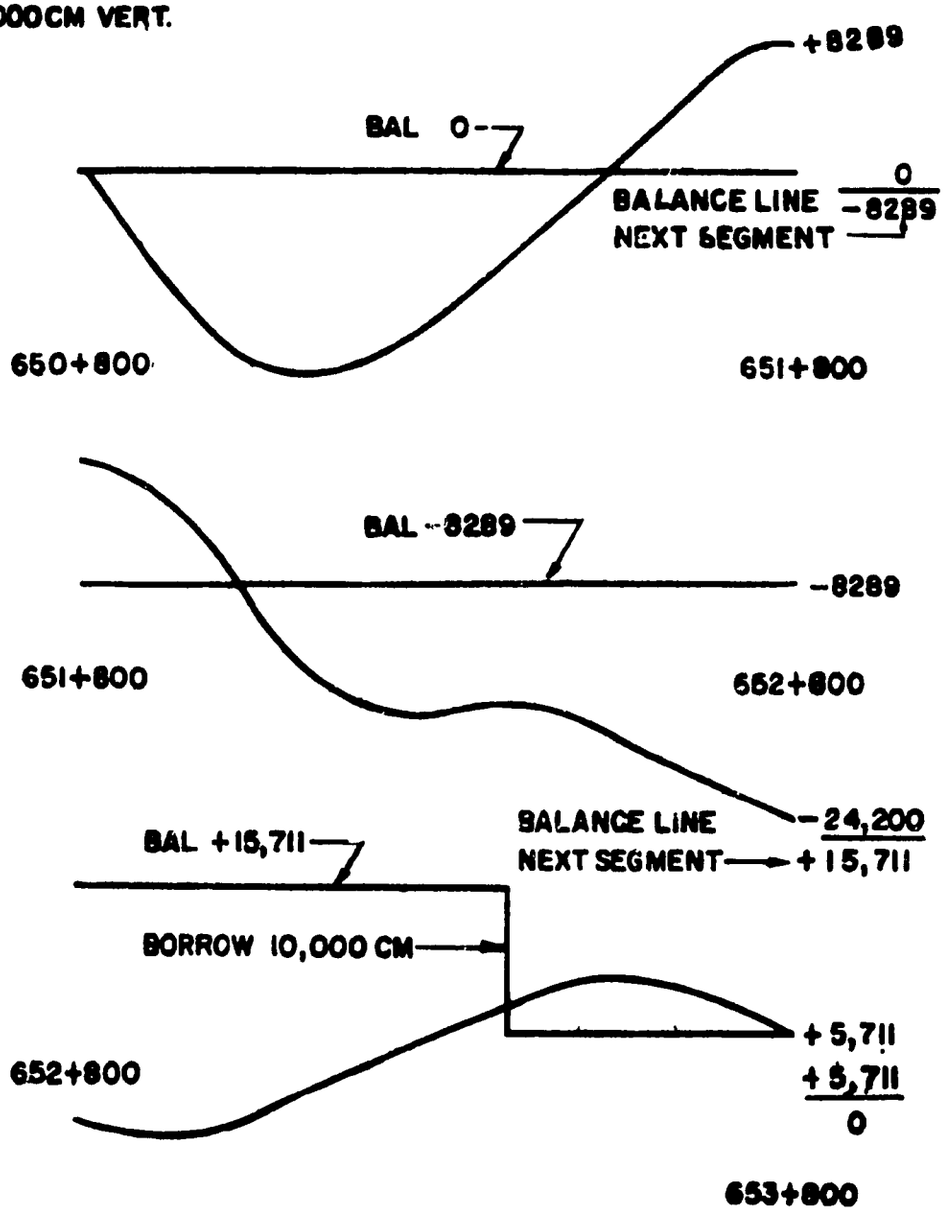
Plotting the Working Mass Diagram

Using cross-section paper, plot the accumulative mass at each station as shown in the last column of the computation sheet. The horizontal scale should be 100 meters per centimeter. A vertical scale should be selected which adequately illustrates the changes in accumulative mass — normally a scale between about 5,000 to 50,000 cubic meters per centimeter. If space permits, 1000-meter segments of mass may be plotted on one sheet. If a review of the mass diagram indicates that more balanced earthwork is necessary, grade adjustments may be made at this time. Any grade adjustments will affect the mass diagram already plotted. To avoid replotting the entire mass diagram, the original mass diagram should be plotted in 1000-meter segments per line, beginning each line with mass at 0 (zero) and the balance line in its *relative* position with the mass. An example mass diagram is shown on the next page. The first 1000-meter segment is plotted using the mass data from the earthwork computation sheet shown at the beginning of this chapter.

By plotting mass diagrams in this manner, grade changes will require replotting of the mass curve only on the sheet where the grade changes are made. Subsequent sheets can be revised by simply adjusting the balance lines.

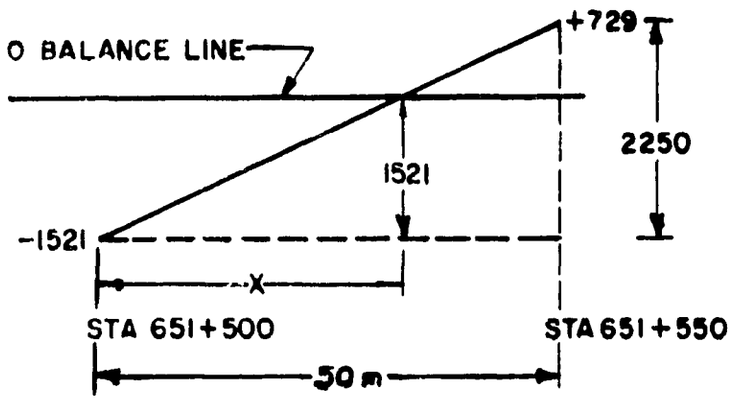
Mass diagrams used to compute haul usually require several sheets. These will not be included in the contract plans. Instead, the contract plans will include an abbreviated one-sheet mass diagram condensed from the original. Guidelines for preparing mass diagrams for the contract plans are presented in Chapter Fifteen.

SCALE:
1 CM = 100 CM HORIZ.
1 CM = 5000CM VERT.



Computing Balance Points

Once the grades have been finalized and the earthwork has been balanced, compute balance points and earthwork quantities for summarization. It is not necessary to compute earthwork quantities for each balance point. Several small balance points may be combined within distances of approximately 300 meters. Where a balance point falls between the stations listed on the computation sheet, compute the stationing using a straight line relationship. For example, the stationing of the balance point between stations 651 + 500 and 651 + 550 (see the example computation sheet) is computed as follows:



Stationing of Balance Point = 651 + 500 Plus X meters

$$X = \frac{1521}{2250} \times 50$$

$$X = 33.1\text{m}$$

Stationing of Balance Point = 651 + 500 + 33m = 651 + 533

Compute the stationing of each balance point to the nearest tenth of a meter on the computation sheet and record to the nearest meter on the mass diagram.

When the balance points have been documented, calculate the excavation quantities and the adjusted embankment quantities between balance points. Check these calculations to see that:

- Excavation equals adjusted embankment between each pair of adjacent balance points.
- The sum of the total excavation and embankment quantities between balance points equals the sum of the sheet totals for the entire project.

Record the excavation and adjusted embankment quantities between balance points on the computation sheet and the mass diagram.

Computing Haul

Haul — to be computed in *kilometer cubic meters* — is represented by the areas between the mass curve and the balance line. To compute haul, measure the areas between balance points with a planimeter and convert the areas to kilometer cubic meters by using a formula based on the plotting scales.

The following formula may be used :

Kilometer cubic meters per square centimeter= Stations per cm × Cubic meters per cm.

Record the haul between balance points on the computation sheet and the mass diagram.

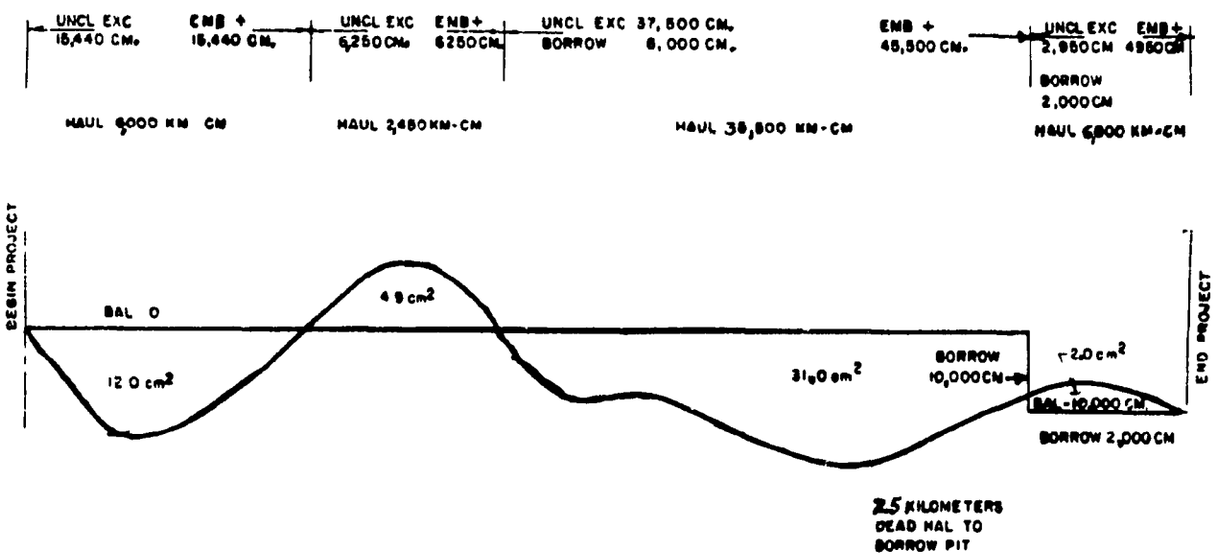
Borrow

When borrow is to be used from sources other than the roadway prism, the excavation and the haul are both charged to the section where the material is deposited.

Deadhaul must be computed separately from the borrow source to the highway centerline and combined with the haul for distributing the material.

When borrow is used, the balance line on the mass diagram should be adjusted downward at the stationing where the haul road intersects the centerline. The amount of downward adjustment should reflect the total amount of borrow.

TYPICAL HAUL COMPUTATIONS FOR BORROW



CHAPTER SEVEN

DRAINAGE

GENERAL CONSIDERATIONS

The ultimate objective of good highway drainage design is to prevent the accumulation and retention of water on and adjacent to the highway. This can be accomplished by means of the following :

1. Anticipation of the amount and frequency of storm and other surface water runoff.
2. Identification of natural areas of concentration of surface, ground and stream waters.
3. Evaluation of hydrological controls, such as design discharge rates.
4. Provision for the most efficient disposal structures and facilities considering the initial cost, type and importance of the highway, and maintenance costs.

Economic Considerations

During the design of adequate highway drainage and systems of erosion control, the following economic factors should be considered :

- The cost of construction and right-of-way.
- Useful life and cost of replacement or extension.
- Delays, interruptions and inconvenience to traffic due to flooding or roadway failures.
- Injuries and hazards to persons and vehicles caused by flooding or roadway failures.
- Damage to highway drainage facilities with resultant repair and maintenance costs.
- Damage to private and public property and utilities.
- Pavement or subgrade failure with resultant costs of repair.
- The cost of repairing or replacing other public facilities or utilities due to contamination or flooding of public water supplies or sewerage systems and the resultant dangers to public health.

RUNOFF ESTIMATES

lasic Policy and Considerations

he runoff estimate or design discharge depends upon many variables. Some of the more nportant are (1) duration and intensity of rainfall, (2) frequency of storms, (3) shape, size, lope and imperviousness of the drainage area, and (4) changes in runoff characteristics of the rainage area due to changes in land use.

xperience and judgment are essential in making runoff estimates. Estimates may vary onsiderably because present methods of estimating are not exact and drainage areas often ack reliable hydrological data.

The Rational Method is used to calculate the design discharge. The nomograph on page 7-7 which is based on the Rational Method is used for this purpose. The nomograph simplifies the calculation by combining the factors of rainfall intensity, K factor, time of concentration and drainage area.

An explanation of this method is given on this and the following pages.

Rational Method

The Rational Method for computation of design discharge is based on the formula, $Q = KiA$, where

- Q = runoff or design discharge, in cubic meters or cubic feet per second
- K = coefficient of runoff
- i = intensity of rainfall, in centimeters or inches per hour
- A = drainage area, in square kilometers or acres.

Coefficient of Runoff (K)

The coefficient of runoff, K, is expressed as a percentage to which the peak runoff is reduced due to *transitory storage*.

This value depends primarily on the watershed *vegetation* and *soil porosity*. The K factor will drop in value as the density of the vegetation cover or the soil porosity or both increase. This is because more water is held back on the surface by the vegetation cover or soaks into the ground due to the porosity of the soil.

Determination of K is arbitrary and should be selected with care. In these values will generally range from 20 to 70 percent.

The following table will serve as a guide in determining K factors. K values for the same type surface may vary at different times of the year under different conditions. For example, during the rainy season K factors will approach 100% since the ground will eventually become saturated and rain, that in drier seasons would be absorbed, would now become runoff water.

Pavements (concrete or asphalt)	0.70 to 0.95
Gravel or Macadam pavements	0.35 to 0.70
Impervious soils[1]	0.40 to 0.65
Impervious soils, with turf[1]	0.30 to 0.55
Slightly pervious soils[1]	0.15 to 0.40
Pervious soils[1]	0.01 to 0.10
Wooded areas depending on surface slope and water	0.01 to 0.20

[1] Coefficients are for slopes from 1 to 2 percent. For greater slopes increase the coefficient by 0.2 for every 2 percent of slope. The coefficient, however, cannot exceed 1.0.

TABLE 7-1

In urban areas when several surface types are included within the drainage area, a weighted average for K based on surface area will be used ; for example,

Given : Total drainage area = 0.12 square kilometers

Made up of Pavement and rood surface .01 square kilometers

Dense residential area .05 square kilometers

Cultivated land clay .06 square kilometers

Find : Coefficient of Runoff for drainage area.

Solution :

$$\frac{.01}{.12} \times 0.80 = 0.07$$

$$\frac{.05}{.12} \times 0.60 = 0.25$$

$$\frac{.06}{.12} \times 0.35 = 0.18$$

Coefficient of Runoff (K) = 0.50

In rural areas where generally the drainage areas are much larger and the surface types are more varied the above method may not prove satisfactory. The designer's own decision on K factor based on a through field investigation of the drainage area and his own judgement will give better values than the weighted average method.

DESIGN STORM FREQUENCIES

Design storm frequencies by drainage facility type and design location are given in the following table :

Design Location	Culverts and Approach pipes	Storm Sewers Systems	Roadway Gutters	Bridges (A Structure over 6 meters)
National	50 yr.	50 yr.	50 yr.	50 yr.
Intraprovincial	50 yr.	50 yr.	50 yr.	50 yr.
Secondary	50 yr.	10 yr.	10 yr.	50 yr.
Local	25 yr.	10 yr.	10 yr.	50 yr.

TABLE 7-2

Occasionally a design storm frequency higher or lower than those in the table may be used in unusual circumstances. If a lower frequency than those tabulated is used, caution should be exercised to see that increased back water will not cause damage upstream. Also the increased chances of losing the structure or roadway or both should be carefully considered.

RATIONAL METHOD NOMOGRAPH

CHART I

DEFINITION OF SYMBOLS AND INSTRUCTION FOR USE

The symbols on the nomograph are defined as follows:

H = The difference in elevation between the upper most point of the drainage area and the culvert invert or stream bottom measured in meters or feet.

L = Length of stream or water course between the uppermost point of the drainage area and the culvert or bridge site measured in kilometers or miles.

T = Time of concentration which is the time necessary for precipitation to reach the structure site from the furthermost point in the drainage area.

G = Rainfall measured in centimeters or inches per hour that can be expected at least once in every 10 years for various areas.

I = Intensity of rainfall in centimeters or inches per hour for the time of concentration.

A = Drainage area measured in square kilometers or acres.

P = Discharge in cubic meters or cubic feet per second if all rainfall in the drainage area reached the structure site disregarding the K factor.

K = Coefficient of runoff, expressed as a percentage.

Q_{10} = 10 year design discharge in cubic meters or cubic feet per second.

To determine the design discharge, Q, values for H, L, G, A and K must first be found. Values for H*, L and A are found using the surveyed topographic data obtained in the field and topographic maps of the area.

Values for G are obtained from the map of 10-year storm design rainfall shown earlier in this chapter. Values for K are obtained as discussed earlier in this chapter.

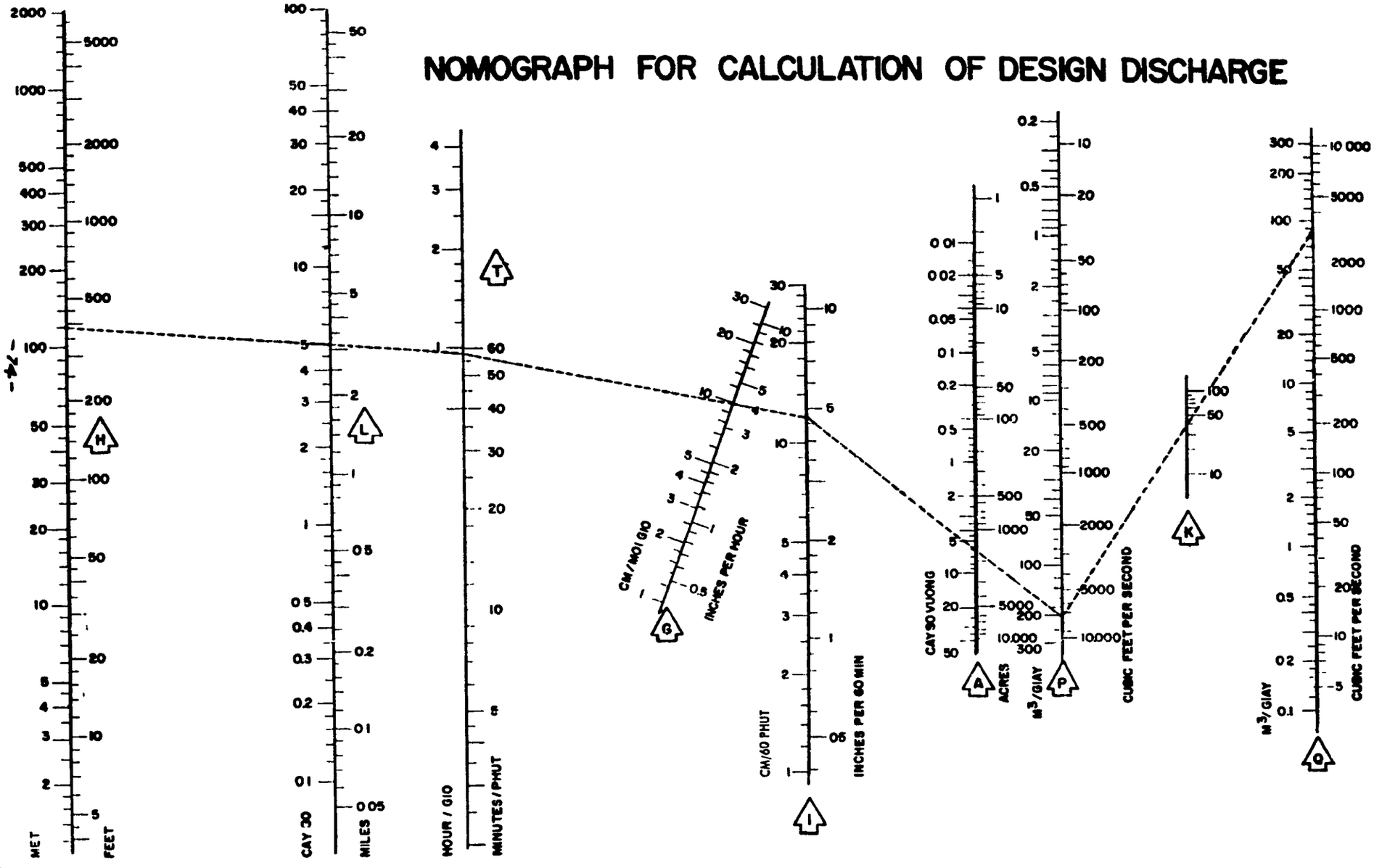
When these values are found, proceed as outlined below:

1. Connect with a straightedge, the elevation differential, H, and the length of water course, L, and extend this line to intersect scale T.
2. Connect with a straightedge this time of concentration, T, and the 10-year storm design rainfall, G, and extend this line to intersect scale I.
3. Connect with a straightedge this rainfall intensity, I, and the area, A, and extend this line to intersect scale P.
4. Finally, connect with a straightedge this unmodified discharge, P, and the coefficient of runoff, K, and extend the line to intersect scale Q.
5. The value obtained on the scale Q is the design discharge for a 10-year storm.

To modify this value to obtain other storm frequencies follow the procedure outlined earlier in the section entitled *Rainfall Intensity*.

* NOTE If the uppermost 15% length of the stream shows a marked increase in slope, such as 3 or more times greater than the overall slope, the H should be reduced by approximately 1/2 of the elevation difference between the uppermost point, and the point 15% of the stream length from the uppermost point.

NOMOGRAPH FOR CALCULATION OF DESIGN DISCHARGE



The following example illustrates the above procedure.

Problem :

A bridge site is 5 kilometers (3.1 miles) downstream and 120 meters (390 feet) lower than the remotest point in the drainage area. Determine the 50-year design discharge at the bridge site.

Solution :

1. The following information is first determined :

H = 120 meters (390 feet)

L = 5.0 kilometers (3.1 miles)

G = 10cm per hr. (4 inches per hour)

A = 6.0 square kilometers (1480 acres)

K = 40%

2. On the nomograph, begin by drawing a line from H = 120 meters through L = 5.0 kilometers, intersecting T at 58 minutes.
3. Begin a second line at T = 58 minutes, extending it through G = 10cm per hour, intersecting I at 12.0cm per 60 minutes.
4. Begin a third line at I = 12.0cm per 60 minutes, extending it through A = 6.0 square kilometers, intersecting P at 210 cubic meters per second.
5. Finally, begin a fourth line at P = 210 cubic meters per second, extending it through K = 40 percent, intersecting Q_{50} at 90 cubic meters per second.
6. Using the factor of 1.50 obtained from table 7-3, Q_{50} equals 90 × 1.50 or 135 cubic meters per second (4760 cubic feet per second).

The nomograph can be expanded to deal with watersheds larger than the limits shown. For example, in the above problem if the area had been 15 square kilometers instead of 6 square kilometers, the value for P would have fallen off of the scale. This situation is corrected by multiplying the A, P and Q scales by 10.

With the scales modified, a new line is drawn from the original turning point on the I scale through 1.5 square kilometers (now 15 square kilometers), intersecting the P scale at 48 cubic meters per second (now 480).

A second line is drawn from P = 48 cubic meters per second (now 480) through K = 40%, intersecting Q_{10} at 20 cubic meters per second (now 200).

CULVERT DESIGN

Nearly all drainage involves the use of some kind of pipe or box culvert. Culvert design involves consideration of the following factors :

- Culvert material and structural requirements
- Culvert location
- Culvert size
- Multiple installation
- End sections
- Inlet structures
- Outlet velocity
- Culvert length and extension
- Slope and alignment
- Bedding and fill requirements.

Culvert Material and Structural Requirements

The material used for culverts falls into several categories, listed in the table below. Reference should be made to the Standard Specifications for information on the structural requirements for type of pipe.

	Material Code	Material Type
Drain Pipe	ACP	Asbestos Cement Pipe
	PVC	Polyvinyl Chloride
	CP	Vitrified Clay Pipe
Culvert Pipe	RCP	Reinforced Concrete Pipe
	NRCP	Nonreinforced Concrete Pipe
	CMP/ACCMP	Corrugated Metal Pipe and Asphalt-Coated CMP
	CIP	Cast-Iron Pipe
	SPP/PA	Structural Plate Pipe and Pipe Arches
	RCAP	Reinforced Concrete Arch Pipe

Sewer Pipe

Culvert Location

Culvert locations will be noted on the premilinary survey; a design discharge may also be specified. All location and culvert data will be reviewed at the plan in-hand inspection.

Culvert Sizes

Culverts will be selected according to both hydraulic and economic considerations, using the charts and methods outlined on the following pages.

The following table shows the minimum sizes of culverts to be used.

Type of Structure	Minimum Size
Cross Drain Pipe	.60 m
Approach Road Drain Pipe	.40 m
Box Culvert (Width × Height)	1.5 m X 1.25 m

Selection of culvert size can easily be made by use of the culvert charts and the following procedure.

Step 1 : List design data.

a. Design discharge, Q, in cubic meters per second (cubic feet per second).

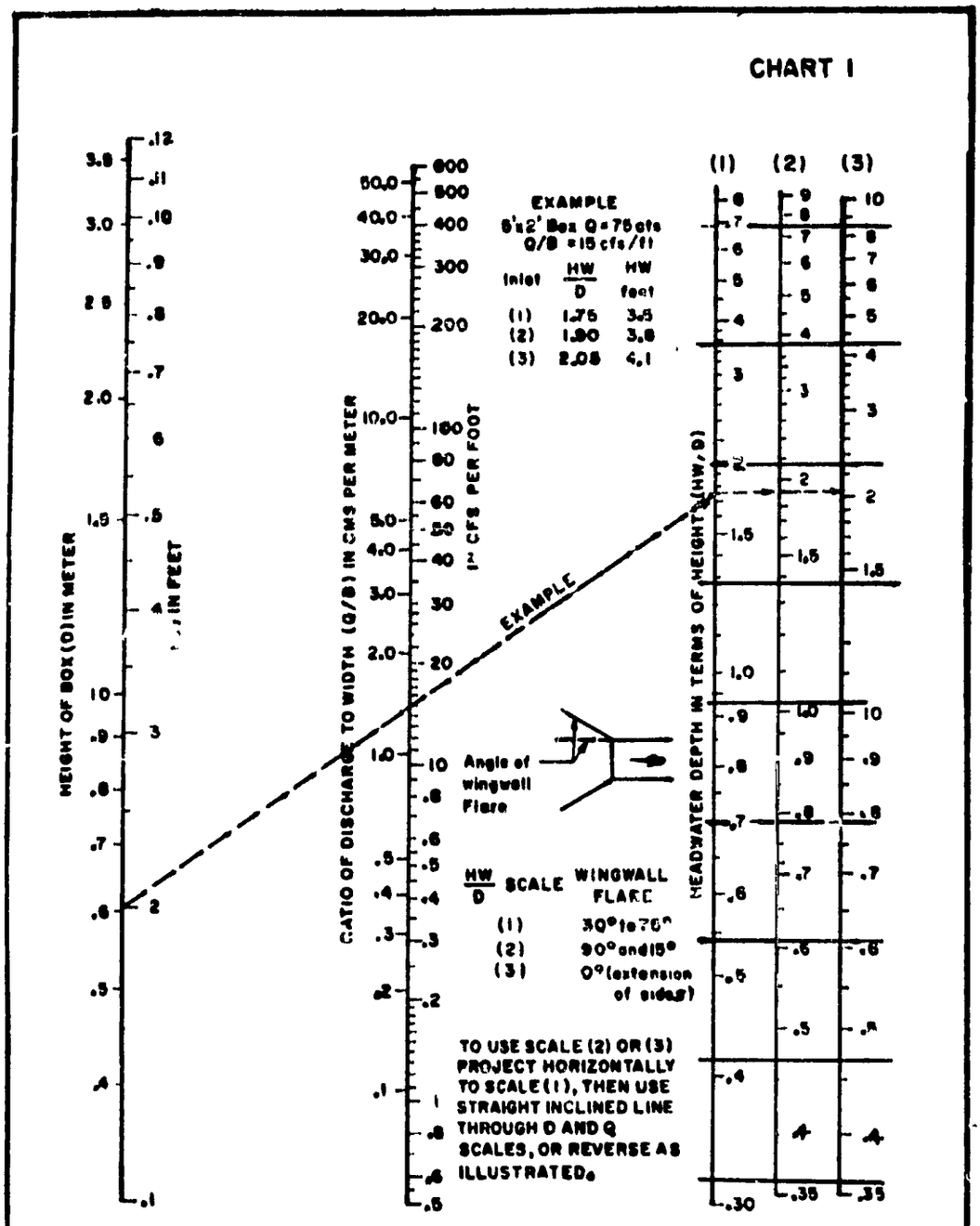
b. Allowable $\frac{HW}{D}$ radio, where HW is the vertical distance from the culvert invert (flow-line) at the entrance to the water-surfaces elevation permissible in the headwater pool or approach channel, and D is the diameter of round pipes, the rise of pipe arches, or height of opening of box culverts.

$\frac{HW}{D}$ should not exceed 0.9 for large structures (a structure having a span of 6 meters (20 feet) or greater). Small culverts, in certain instances, may have an allowable $\frac{HW}{D}$ of greater than one, even up to 2, 3 or possibly 4. It should be realized that culverts having a $\frac{HW}{D}$ greater than one will cause increased backwater and temporary flooding conditions upstream. The allowable headwater depth should be 0.5 meter (1.6 feet) or more lower than the subgrade at the shoulder.

c. Type of culvert and entrance type.

Step 2 : Using the appropriate chart and starting at the right side of the chart, intercept the discharge, Q, and determine the size of culvert needed.

NOTE : The above material and the nomographs consider only those culverts which operate under inlet control. (See note accompanying the nomographs) As most culvert installations will generally operate under inlet control, outlet control will not be discussed here, but there are many books on hydraulics of culverts that go into detail in the complicated outlet control area if the designer wishes to pursue it. A manual on outlet control is available in the DOE files.



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

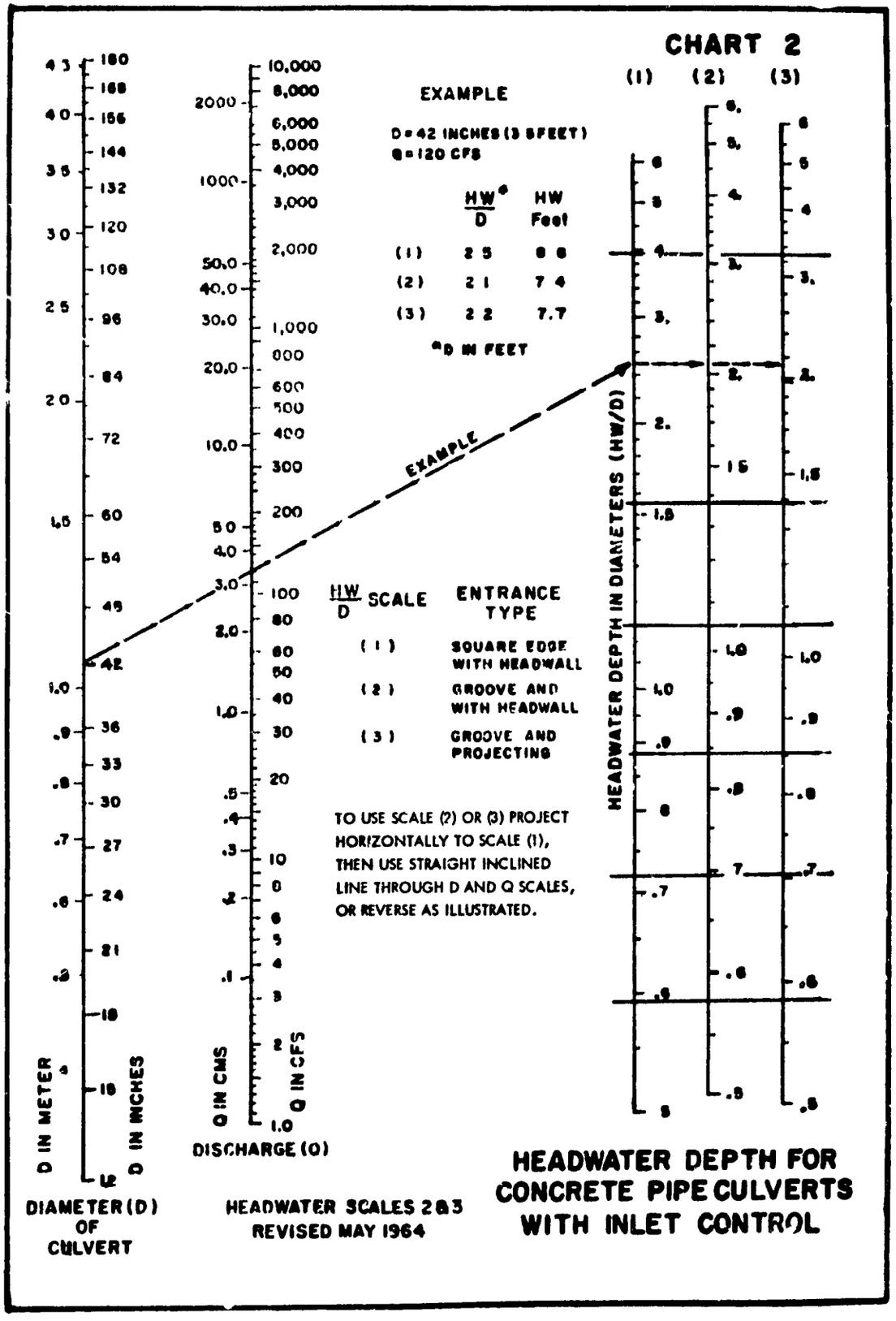
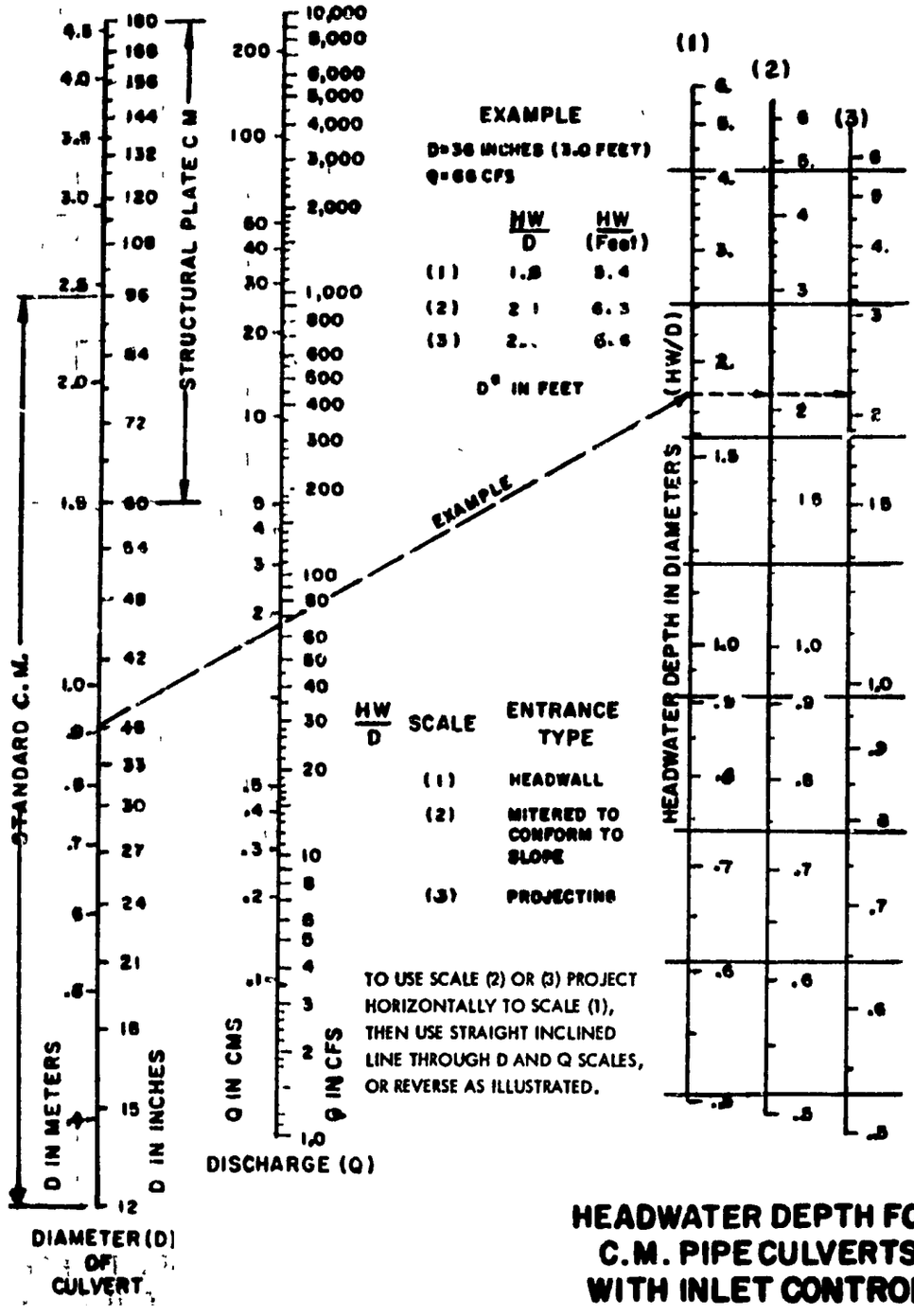


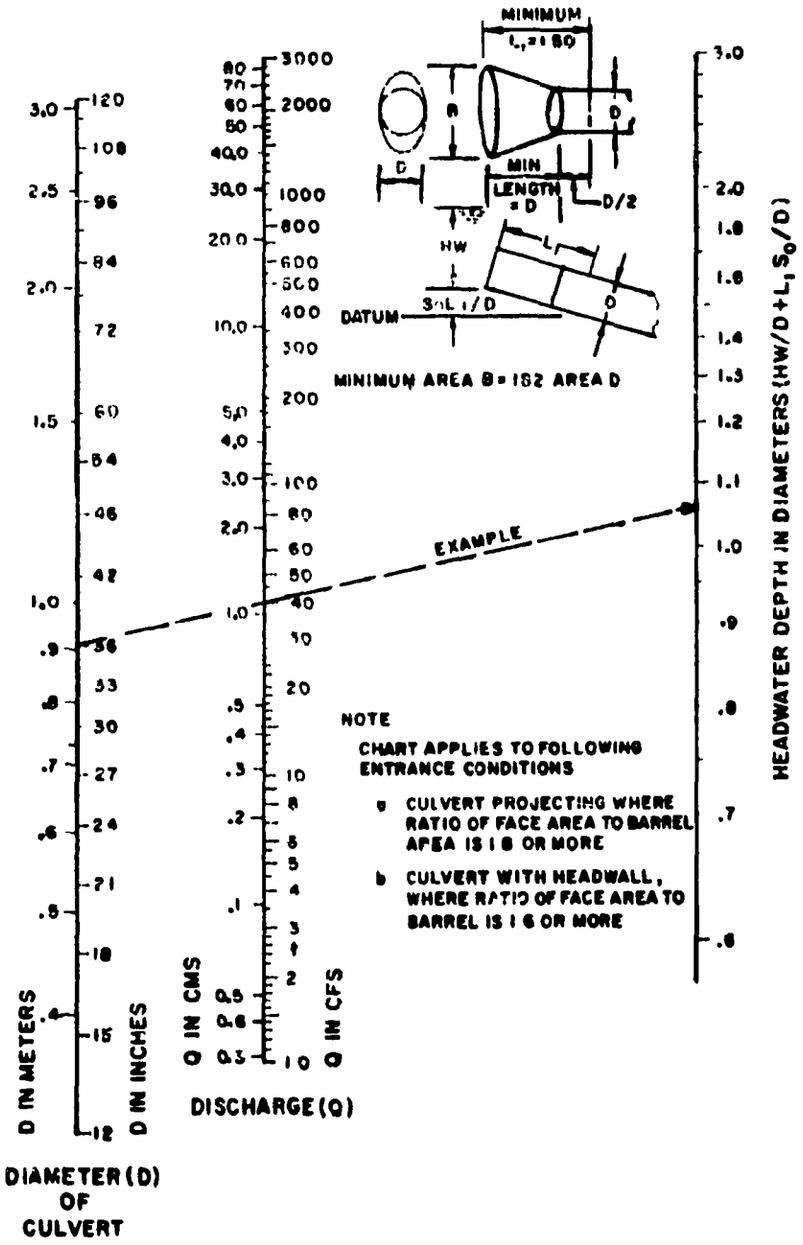
CHART 2
EXAMPLE
D = 42 INCHES (3.5 FEET)
Q = 120 CFS
HW/D* HW Feet
(1) 2.5 8.8
(2) 2.1 7.4
(3) 2.2 7.7
*D IN FEET
EXAMPLE
HW/D SCALE ENTRANCE TYPE
(1) SQUARE EDGE WITH HEADWALL
(2) GROOVE AND WITH HEADWALL
(3) GROOVE AND PROJECTING
TO USE SCALE (2) OR (3) PROJECT HORIZONTALLY TO SCALE (1), THEN USE STRAIGHT INCLINED LINE THROUGH D AND Q SCALES, OR REVERSE AS ILLUSTRATED.
(1) (2) (3)
HEADWATER DEPTH IN DIAMETERS (HW/D)
D IN METER
D IN INCHES
Q IN CMS
Q IN CFS
DISCHARGE (Q)
DIAMETER (D) OF CULVERT
HEADWATER SCALES 2 & 3 REVISED MAY 1964
HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

CHART 3

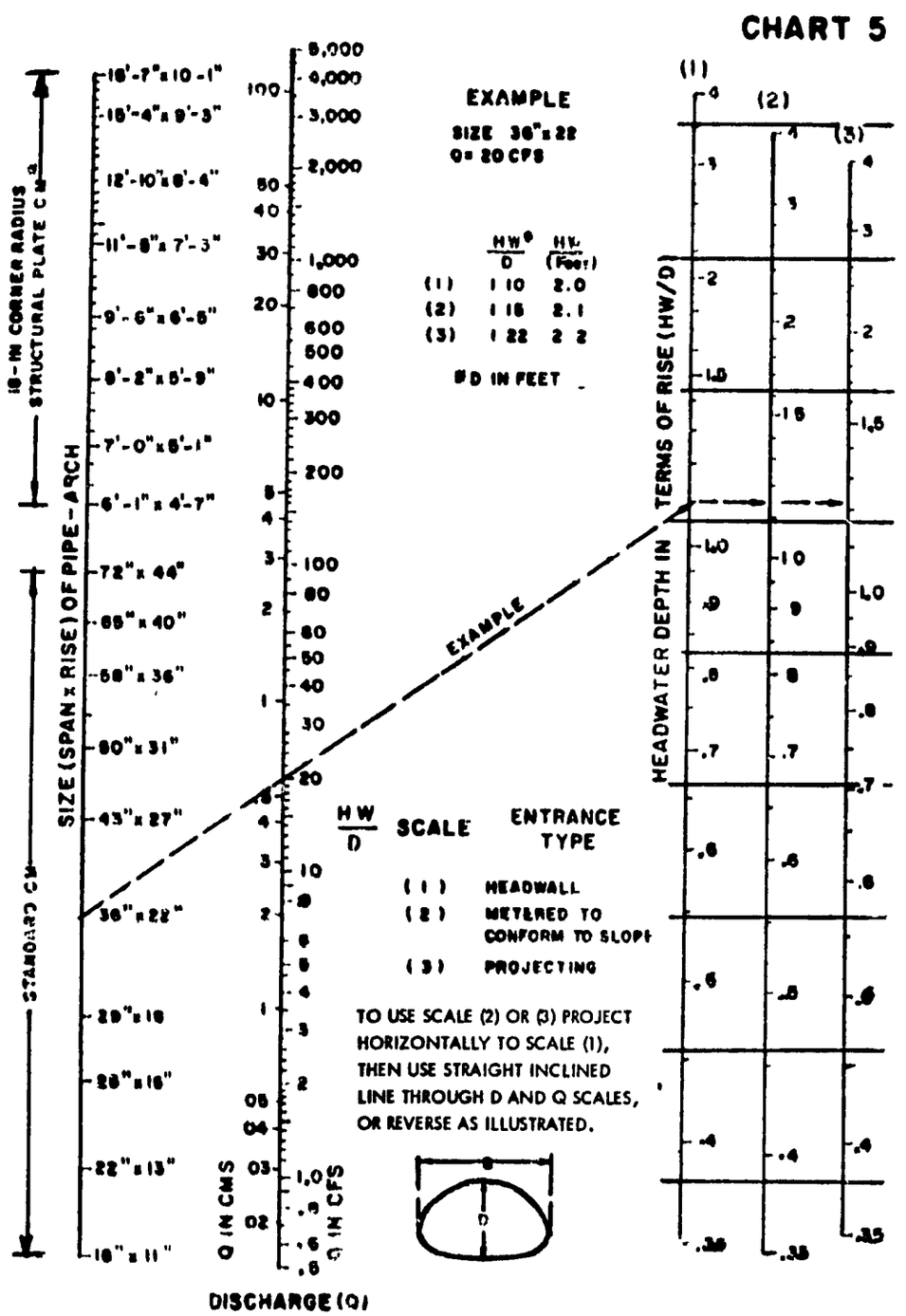


HEADWATER DEPTH FOR C.M. PIPE CULVERTS WITH INLET CONTROL

CHART 4



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH TAPERED INLET INLET CONTROL

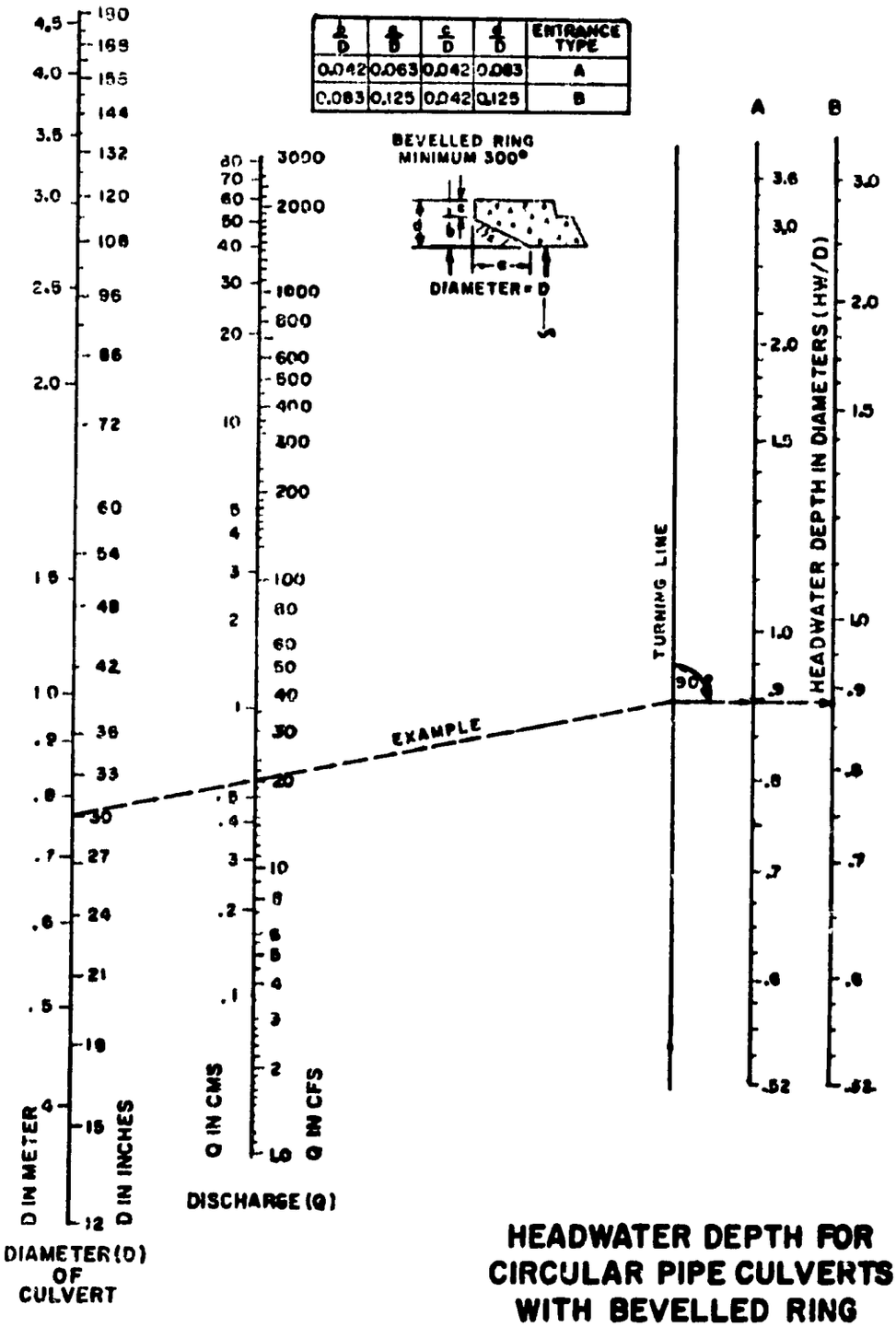


HEADWATER DEPTH FOR C. M. PIPE-ARCH CULVERTS WITH INLET CONTROL

ADDITIONAL SIZES NOT DIMENSIONED ARE LISTED IN FABRICATOR'S CATALOG

CHART 6

$\frac{a}{D}$	$\frac{b}{D}$	$\frac{c}{D}$	$\frac{d}{D}$	ENTRANCE TYPE
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B



HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELLED RING INLET CONTROL

Talbot Method

An alternate method of determining the cross-sectional area of a waterway opening is the use of the widely known Talbot formula. The formula is : $A = C\sqrt[4]{D^3}$, where A = area of waterway opening in square feet, D = drainage area in acres, and C = a coefficient that depends upon the slopes, shape and character of the area to be drained. This is presented in the form of a nomograph for ease of use.

It will serve as a check of other methods of determining water openings.

This formula is recommended primarily for structures requiring a waterway opening of up to 400 square feet. In addition, the formula is intended for a rainfall intensity of 10cm/hr (4 inches per hour) for one hour or less. For locations having greater intensities than this, the required opening may be computed by multiplying the area of the drainage structure obtained from the formula by the ratio :

$$\frac{\text{rainfall intensity at the location}}{\text{10cm (4")}}$$

The key to the use of the formula is the judgment exercised by the Engineer in the choice of a value for the coefficient C.

Example use of monograph:

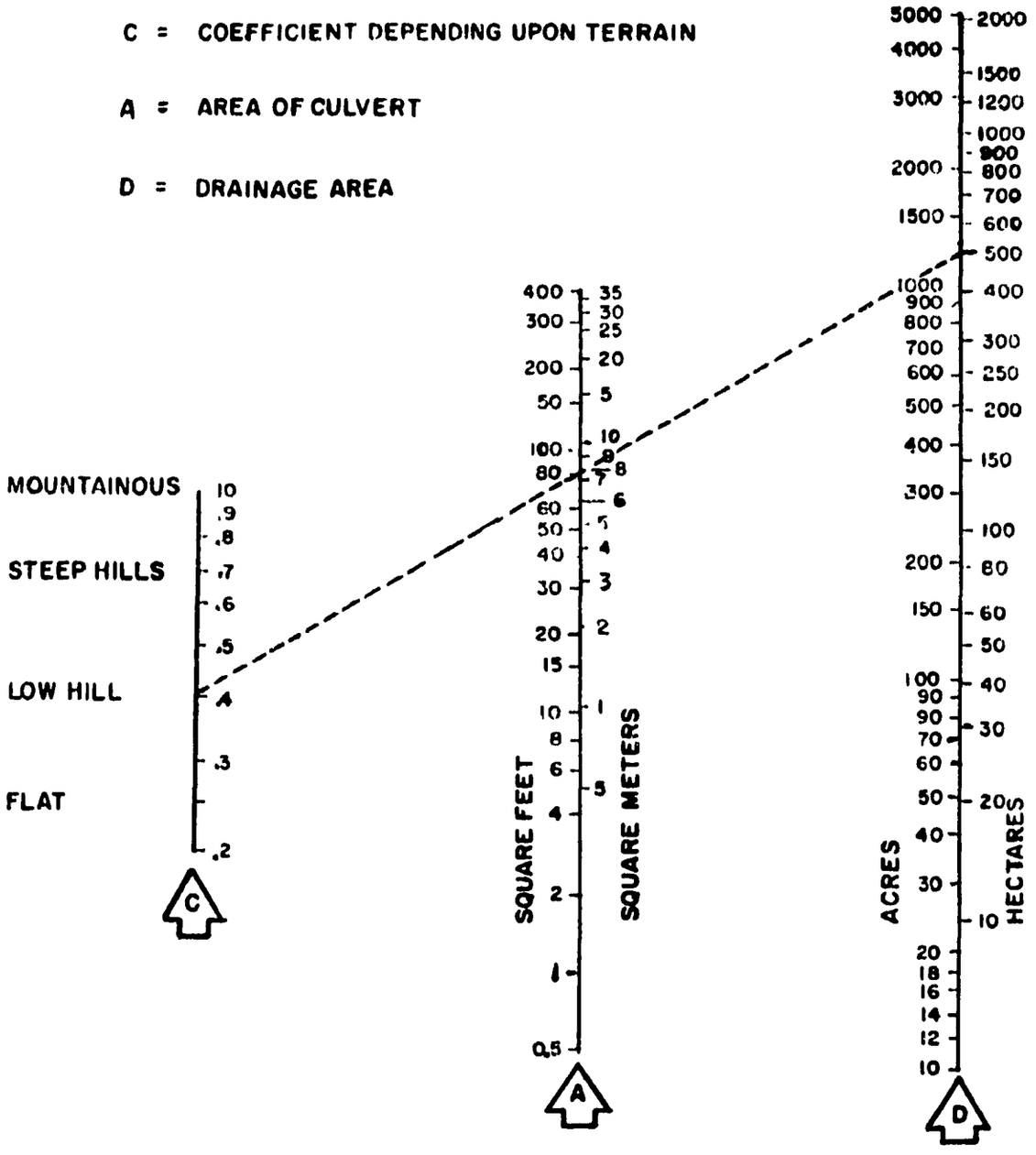
Determine the size culvert required for a drainage area of 500 hectares.

On nomograph, line from *C.* of .4 (Low Hills) to the *D* line (drainage area) of 500 hectares passes through the *A* line (opening size) at 80 square feet. These values can then be converted into hectares and square meters and placed on the computation sheet.

C = COEFFICIENT DEPENDING UPON TERRAIN

A = AREA OF CULVERT

D = DRAINAGE AREA



MONOGRAPH FOR TALBOT FORMULA

$$A = C\sqrt[4]{D^3}$$

Calculation Sheet

Computation sheet entitled *Culvert/Bridge Openings* should be used when designing all culvert sizes and bridge openings. The following illustration shows a completed computation sheet.

PROJECT _____

HYDROLOGIC INFORMATION
CULVERT/BRIDGE OPENINGS

DESIGNER N. V. T.
DATE 15-5-74
CHECKED BY T. V. G

CULVERT/ BRIDGE DESCRIPTION	DISCHARGE CALCULATIONS							OPENING CALCULATIONS							REMARKS
	HYDROLOGIC FACTORS					DISCHARGE		TALBOT			NOMOGRAPH				
	H m	L km	G cm/mm	A km²	K %	Q10 m²/sec	Q— m²/sec	C %	D HECTARES	A m²	CHART USED	HW/D	ENTRANCE TYPE	OPENING SIZE	
PIPE STA 280+153	3	.55	75	0.1	90	3.3	4.95	25	10	3	6	.9	A	1.82	USE PIPE Ø = 2M CONC
PIPE ST 282+120	4	.40	7.5	0.25	80	8.7	13.05				6	2	A	1.9	EMBANKMENT NOT HIGH ENOUGH
											6	9	A	2.7	" "
											1	9	1	30x2.15	HW = 1.9 OK

1 M = 3.28 ft 1 M³ = 35.31 ft³

Multiple Installations

The use of multiple barrel installations should be avoided whenever possible. While multiple barrel installations in theory will double or triple the installations' capacity, they also present a flow restriction to debris, which results in a partial or complete blockage of the installation. When such an installation is necessary to provide an adequate waterway, it will be identified by the station representing the center of the installation.

End Sections

The need for culvert headwalls and other end sections should be based on the physical, hydraulic, safety and aesthetic conditions prevailing at the site. Flared end-terminal sections (F.E.T.S) should be used on the upstream end of rural culverts whenever feasible. The material of the flared end-terminal section should match the pipe material. When using F.E.T.S., considerations should be given to using them on both ends of the culvert, especially if the water crossing is subject to reverse flow at times. Headwalls should only be specified as a last resort as they are a very serious traffic hazzard.

When headwalls are needed, they should be designed with wingwalls which are flared away from the flowline of the pipe at an angle of between 30^0 and 75^0 degrees.

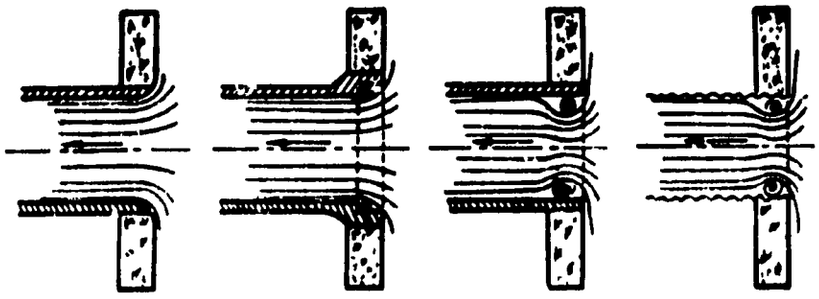
The use of headwalls or other protection such as rip rap should be considered for the following situations:

- twin and triple installations;
- culverts with slopes too steep for F.E.T.S. attachment;
- broken-back culverts where the possibility of slippage exists, for example drop structures in backslopes.

Inlet Improvements

The basic reason for considering inlet improvement structures for culverts is increased flow capacity. An inlet that provides a smooth transition from open channel flow to culvert flow increases the flow capacity in two ways: (1) there is less head loss due to turbulence at the entrance; (2) the contraction of the stream at the leading edge of the culvert is decreased or even eliminated.

This improvement in made in basically two ways. When using concrete pipe, a well-rounded inlet or its equivalent as shown below should be used. When metal pipe is used, a flared end section is preferred. This end section will have the same effect as the well-rounded inlet used for concrete pipes. The diagrams on the next page show where the turbulence and contraction are located and how a rounded inlet eliminated them.



ROUNDED STEPPED OR BELL SQUARE EDGED

There is another important reason for improving inlets. The height of water on the upstream side of a culvert required to produce a given discharge in a culvert flowing full is much less than the height required to produce the same discharge in the same culvert flowing partly full due to a poorly designed inlet. This difference in height may be the difference between flooding the adjacent property and a good design.

Outlet Velocity

The outlet velocities of all culverts and stream velocities when designing bridge abutments should be checked for possible erosion problems. Each site must receive individual consideration by the designer since there is no one velocity above which slope protection will always be needed. Tolerable outlet and stream velocities can vary considerably. A bridge or culvert site in a rocky defile may be able to withstand almost unlimited velocities, while at another site velocities of 3 meters per second could endanger an embankment consisting of fine sand.

In cases where erosion would result, the following alternatives should be considered:

- Increase the culvert size
- Design a broken-back structure
- Provide rip rap at the inlet or outlet
- Design an improved inlet and/or outlet for the structure.

Culvert Lengths

Culvert lengths are computed directly from the drainage cross section, which is drawn along the flowline. (See Chapter 5).

For method of measurement the designer should refer to the Standard Specification, Section 601: *Culverts and Storm Drains.*

Culvert Extension

Culverts to be extended should be in good condition, and shall be extended with like material, if possible.

Concrete pipe culverts shall be extended using a concrete collar or elbow to join old and new sections. Corrugated metal pipe culverts shall be extended using a connecting band. Vitrified clay or cast iron pipe may be extended by use of a concrete collar. Structural plate pipe extensions will be considered on an individual basis. The Bridge Division will be contacted for a recommendation before extending a box culvert.

Slopes and Alignment

Abrupt changes in slope or direction are undesirable with regard to maintenance and pipe durability under abrasive flow.

It is preferable that drainage pipes follow the natural slope of the ground to minimize pipe excavation and allow for gravity drainage. The velocity of flow in a pipe, a minimum of 0.6 m/sec., shall be sufficient to prevent sedimentation of sludge and light mineral matter.

CONDUIT LOADING AND STRENGTH REQUIREMENTS

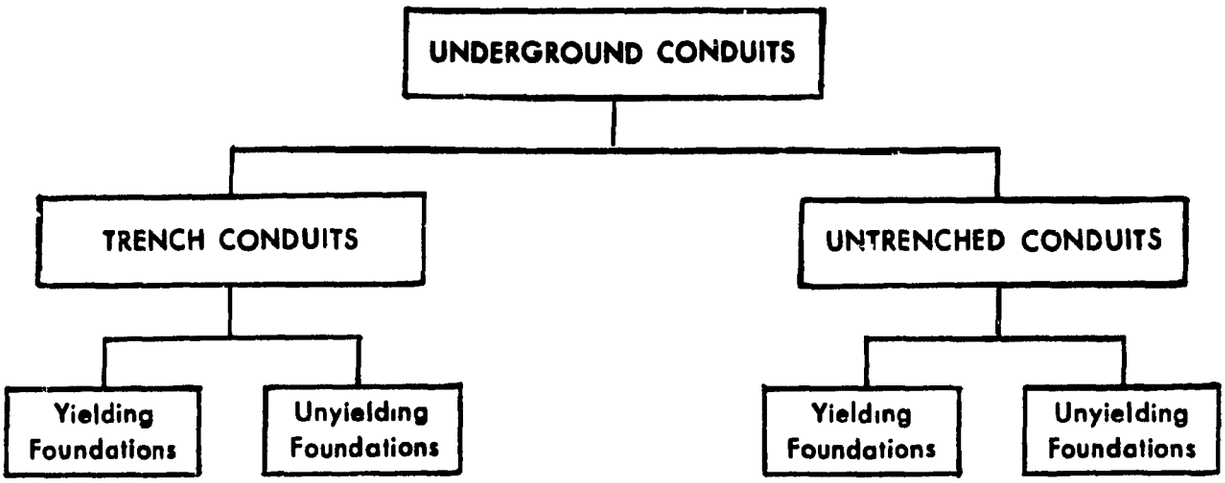
Loads

After the culvert size has been determined using methods discussed earlier in this Chapter, the class or strength must be specified. To do this, the backfill load which acts upon the conduit must first be determined.

This section presents equations for calculating the backfill loads, as presented in the AASHO publication, *Standard Specifications for Highway Bridges, 1973.*

For a more detailed discussion on determining backfill loads the designer should consult the above mentioned publication, a text on culvert design, or a concrete pipe handbook. When specifying metal pipes, the manufacturer's technical manuals should be consulted.

Underground conduits are classified as follows:



Earth pressures or loads on culverts may be computed ordinarily as the weight of earth directly above the structure. For box culverts and culverts with cast-in-place inverts or footings, the weight of the earth may be taken at 70 percent of its actual weight. For flexible and rigid pipes, not cast-in-place, the weight of the earth may be taken at 83 percent of its actual weight.

The following are recommended formulas for the above conditions.

(1) Culverts in trench on yielding and unyielding subgrade, or culverts untrenched on yielding subgrade:

$$P = WH$$

(2) Culverts untrenched on unyielding foundation (such as rock or piles):

$$P = W\,(9.37H - 4.25B) \text{ for } H > 1.7B.$$

$$P = 12.64\,BW\,(e^{k} - 1) \text{ for } H < 1.7B.$$

Where $k = \dfrac{0.385H}{B}$

P = the unit pressure in kilograms per square meter due to earth backfill.

B = width in meters of trench, or in case there is no trench, the overall width of the culvert.

H = depth in meters of fill over culvert.

W = effective weight per cubic meter of fill material, which may be taken as 70 percent, or 83 percent, of actual weight in accordance with above stated provisions.

e = 2.7182818 = base of natural logarithms, abstract number.

For design purposes, a culvert will be considered to be in an untrenched condition if the width of the trench is greater than 3 times the outside diameter of the conduit.

Live Loads

When the depth of fill is 0 6 meters (2 feet) or more, concentrated loads shall be considered as uniformly distributed over a square, the sides of which are equal to 1 3/4 times the depth of fill.

The shear produced by such loads shall be calculated as provided for dead loads.

When such areas from several concentrations overlap, the total load shall be considered as uniformly distributed over the area defined by the outside limits of the individual areas, but the total width of distribution shall not exceed the total width of the supporting slab. For single spans, the effect of live load may be neglected when the depth of fill is more than 2.5 meters (8 feet) and exceeds the span length ; for multiple spans it may be neglected when the depth of fill exceeds the distance between faces of end supports or abutments. When the depth of fill is less than 0.6 meter (2 feet), the wheel load shall be distributed as in slabs with concentrated loads.

Structural Requirements

The minimum structural requirements which must be met by all types of drainage pipes are found in the Standard Specifications. Tables and other information regarding allowable fill heights over each class of a particular type of conduit can be found in the pipe manufacturer's literature.

Structural and fill requirements for conduits crossing a railroad may differ from the normal situation. Coordination with the railroad authorities in such cases will be handled by the Railroad Liaison Engineer who shall be supplied with prints and other data on the proposed design for presentation to the railroad.

Bedding Requirements

The load that a pipe will support depends in part on the width of the bedding contact area and the quality of the contact between the pipe and bedding. To develop the full load-bearing capacity of a pipe, a segment of the bottom of the pipe equal to or greater than one-fourth of the outside diameter (B) must be firmly supported. Bell holes must be carefully excavated at proper intervals to ensure that no part of the load is supported solely by the bells.

To ensure positive contact between the bedding and the pipe surface, careful selection of bedding materials must be made.

Bedding materials larger than 30 millimeters may cause stress concentrations. A blend of materials consisting of sand or sandy soil, all of which passes the 9.5mm sieve and not more than 10 percent passing a No. 0.075mm sieve, is preferred.

The depth of the bedding should be one-fourth the outside diameter of the pipe but not less than 15 centimeters. For rock or other incompressible materials, the trench should be undercut a minimum of 15 centimeters.

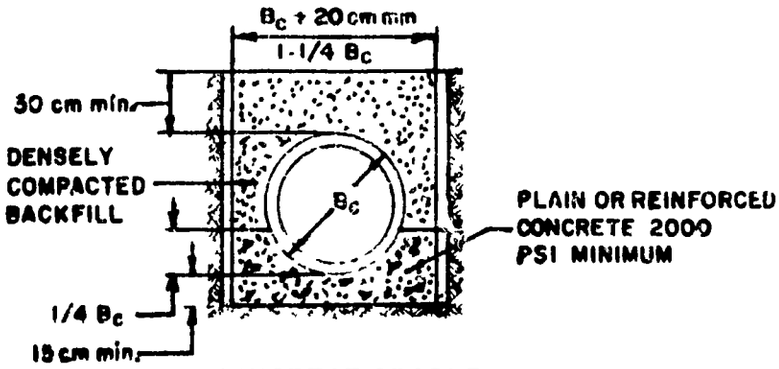
Pipe bedding should normally be continuous between manholes or in the case of a roadway cross section, continuous throughout the fill. In addition, the same class of conduit should be maintained throughout the installation. The three classes of bedding for both circular and arch culverts are shown on the next page for trench and embankment bedding. Normally, the installation will be Class B, shaped subgrade ; however, in cases where heavy loading is anticipated, such as at railroad crossings or in high fills, two solutions are open :

- Increase the supporting strength of the conduit by specifying a higher class for the conduit.
- Increase the support capacity by using Class A.

In situations where the bearing capacity of the soil is very low and heavy loading is anticipated, the use of tram piles should be considered. These tram piles would be used with Class A bedding.

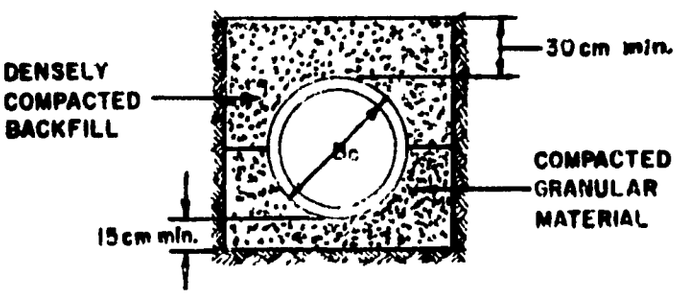
TRENCH BEDDINGS

CLASS A



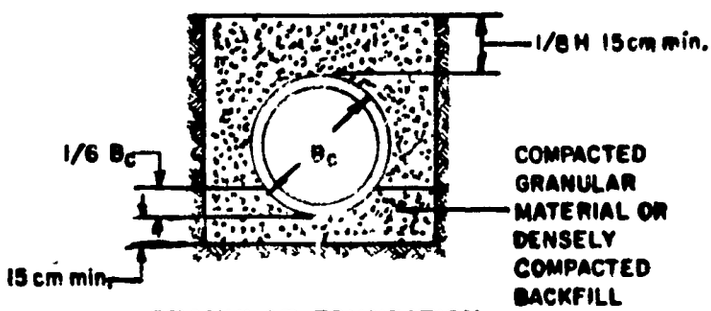
CONCRETE CRADLE

CLASS B



GRANULAR FOUNDATION

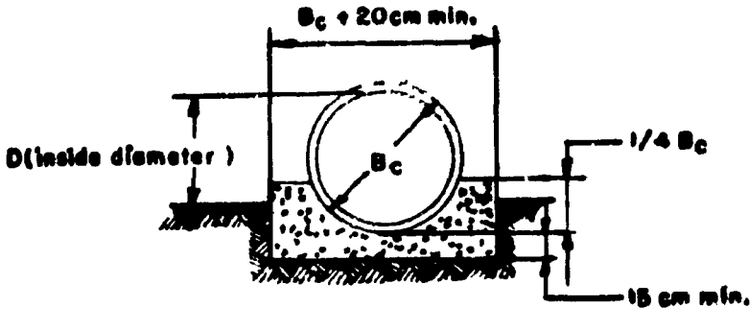
CLASS C



GRANULAR FOUNDATION

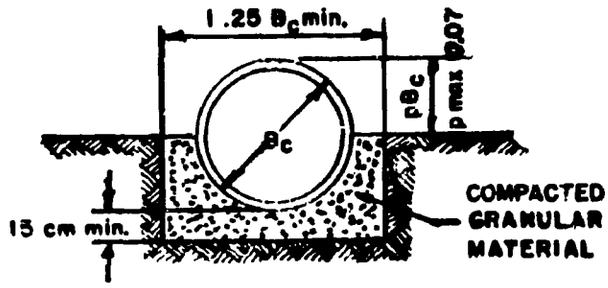
UNTRENCHED BEDDINGS

CLASS A



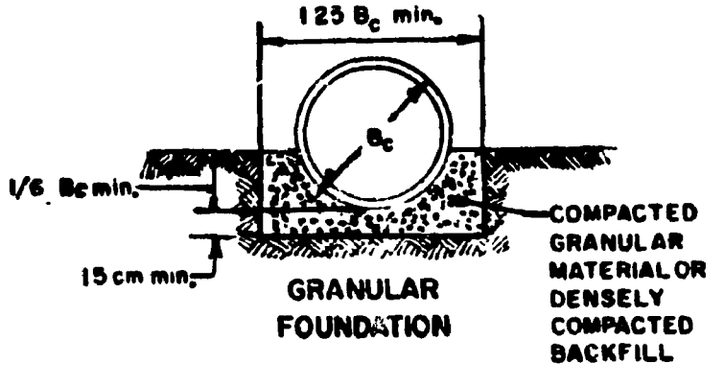
CONCRETE CRADLE

CLASS B



GRANULAR FOUNDATION

CLASS C



STRUCTURE EXCAVATION MEASUREMENT

Quantities of required structural excavation shall be computed for conduit and major and minor structures in accordance with Section 205, *Subsurface Structure Excavation*, and Section 501, *Structure Excavation* of the Standard Specifications.

OPEN-CHANNEL FLOW

At times it may be judged more economical to reroute a small stream or river channel rather than build a structure to allow the water to pass under the road. This rerouting is called a *channel change*. Channel changes should be considered as a last-resort method of drainage control. Channel changes will normally require maintenance for a number of years after construction in order to keep its cross section constant. There is also a constant problem of channel erosion, particularly where the channel and streambed join. To design an extensive channel change requires a knowledge of the hydraulics of open-channel flow and sound engineering judgment. The discussion of hydraulics in this manual does not provide the knowledge of open-channel flow needed for the more difficult design problems; nevertheless, a brief review of some of the hydraulic principles governing open-channel flow should be helpful to the designer.

Flow in open channels is classified as steady or unsteady. Unsteady flow results from variations in the supply and will not be covered in this manual. Although the flow in most channels during the storm period is an excellent example of unsteady flow, we are usually interested in designing a channel to carry a peak flow that recurs with a selected frequency. Considering the peak flow as steady flow greatly simplifies the design of drainage channels.

Steady flow occurs when the quantity of water passing any section of the stream is constant. Steady flow is further classified as uniform if velocity and depth of flow are constant, and nonuniform or varied if velocity and depth of flow change from section to section.

To have uniform flow, the grade must be constant and all cross sections of flow must be identical in form, roughness and area, necessitating a constant mean velocity. Under uniform flow conditions, the depth and the mean velocity for a particular discharge are said to be normal. Under these conditions, the water surfar is parallel to the streambed. Normal depth is also defined as the depth at which uniform flow will occur when a given quantity of water flows through a long channel of uniform dimensions, roughness (n) and slope.

Uniform flow conditions are rarely attained in drainage channels, but the error in assuming uniform flow in a channel of fairly constant slope and cross section is small in comparison to the error in determining the design discharge if the channel cross section, roughness and slope are fairly constant over a sufficient distance to establish essentially uniform flow; equations such as that of Manning give reliable results.

The Manning Equation

Water flows in a sloping drainage channel because of the force of gravity. The flow is resisted by the friction between the water and the wetted surface of the channel. The quantity of water flowing (Q), the depth of flow (d), and the velocity of flow (V) depend upon the channel shape, roughness and slope (S_0).

$$V = \frac{1.49}{n} R^{2/3} S^{1/2} \quad (1)$$

Where

V = mean velocity in feet per second (f.p.s.).

n = Manning coefficient of channel roughness.

R = hydraulic radius, in feet.

S = slope, in feet per foot. When the Manning equation applies, $S = S_0$.

Some n values for various types of channels are given on page 99.

R, the hydraulic radius, is a shape factor that depends only upon the channel dimensions and the depth of the flow. It is computed by the equation.

$$R = \frac{A}{WP} \quad (2)$$

Where

A = cross-sectional area of the flowing water in square feet taken at right angles to the direction of flow.

WP = wetted perimeter or the length, in feet, of the wetted contact between a stream of water and its containing channel, measured in a plane at right angles to the direction of flow.

Another basic equation in hydraulics is:

$$Q = AV \quad (3)$$

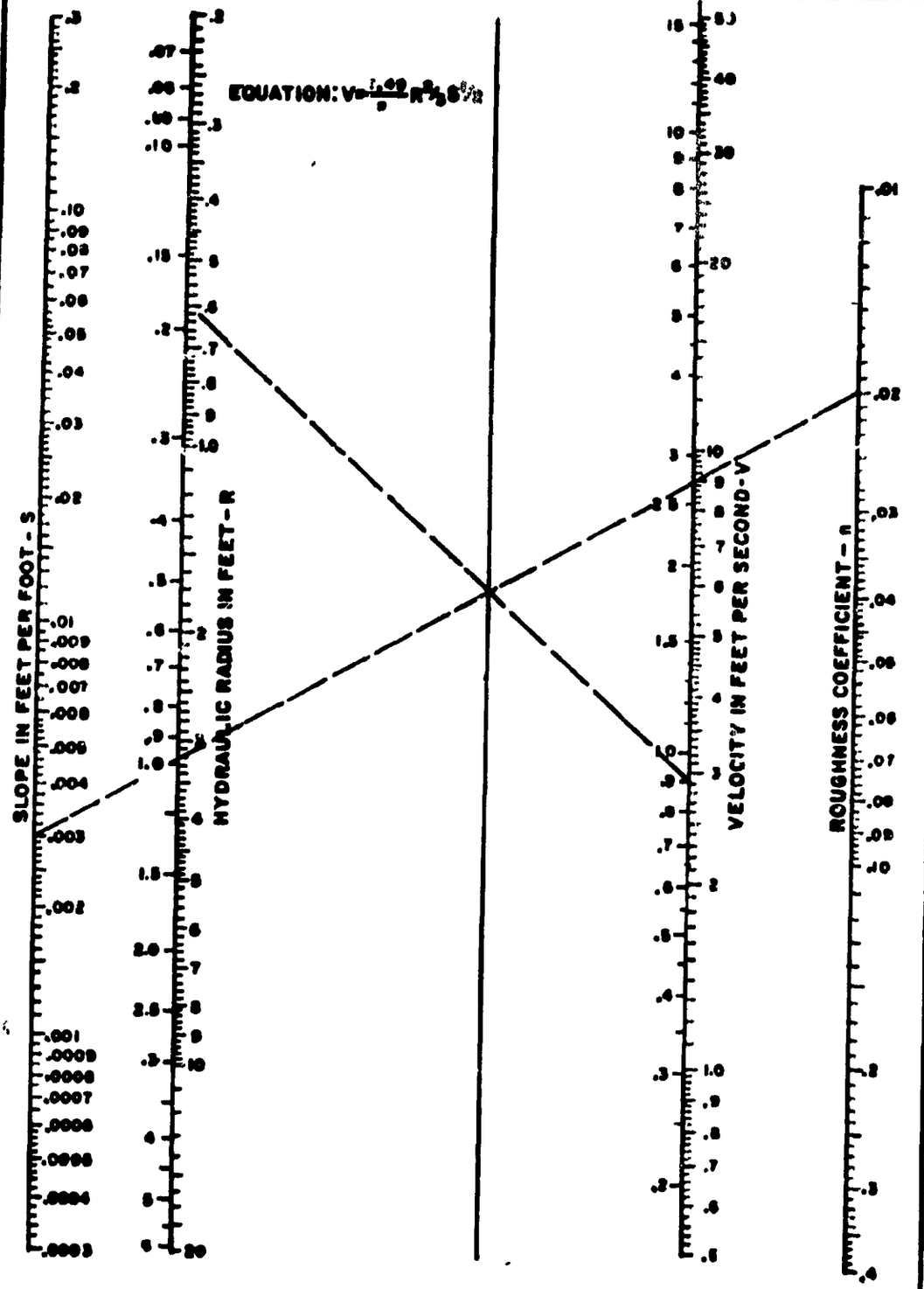
or discharge (Q) is the product of the cross-sectional area (A) and the mean velocity (V).

By combining equations (1) and (3), the Manning equation can be used to compute discharge directly or

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2} \quad (4)$$

When a channel cross section is irregular in shape, such as one with a relatively narrow, deep main channel and a wide shallow overbank channel, the cross section must be subdivided and the flow computed separately for the main channel and for the overbank channel. The same procedure is used when different parts of the cross section have different roughness coefficients. In computing the hydraulic radius of the subsections, the water depth common to two adjacent subsections is not counted as wetted perimeter.

The slopes of the proposed channel change and streambed must match, to prevent degradation of the streambed. Where the new channel is much shorter than the old channel, matching both the existing slope and streambed elevations at both ends at the same time may prove to be impossible. In cases such as this consideration should be given to incorporating a drop structure into the design. An alternate to the drop structure is to steepen a middle segment of the new channel and line it with rip rap.



MANNING CHART 1

ROUGHNESS COEFFICIENTS FOR USE IN MANNING EQUATION

Closed conduits :	MANNING n RANGE
A. Concrete pipe	0.011-0.013
B. Corrugated metal pipe or pipe arch :	
1. $2^2/_3$ by $^1/_2$-in. corrugation (riveted pipe)	
a Plain or fully coated	0.024
b. Paved invert (range values are for 25 and 50 percent of circum ference 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. 3 by 1-in. corrugation	0.027
3. 6 by 2-in. corrugation (field bolted)	0.032
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

Lined open channels :	MANNING n RANGE
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 (rip rap)	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 (rip rap)	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

Unlined open channels :	MANNING n RANGE
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 gravely, 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. Rocks	
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

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 all above values of n by 0.002

V. **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. Bermuda grass, Kentucky bluegrass, buffalo grass:
      a. Mowed to 2 inches 0.07-0.045
      b. Length 4 to 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. Bermuda grass, Kentucky bluegrass, buffalo grass:
      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. Lengthabout 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

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 0.04-0.05
      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 0.01-0.10
   2. Irregular sections, with pools, slight channel meander; increase values in 1 a-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. The value of n for larger streams of most regular sections, with no boulders or brush, may be in the range of from 0.028-0.033

Open Channel Flow Calculation Sheet

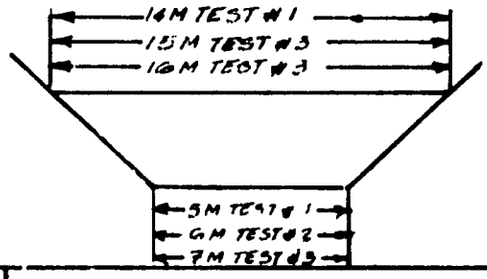
A computation sheet covering open-channel flow has been prepared for the convenience of the designer. The following illustration shows a properly completed computation sheet

HYDROLOGIC INFORMATION
OPEN CHANNEL FLOW

PROJECT 2.(03)260+560 EA
CHANNEL LOCATION [illegible]
DESIGNER N V T
DATE 19-5-74
CHECKED BY T. V. R.

SKETCH

Q = 30 M³/SECOND = 1059 FT³ SECOND



A ft²	R ft	S ft/ft	n	Q ft³/sec	V ft/sec	REMARKS
153.33	3.23	0.003	0.03	920	6.0	BOTTOM 5 M TOO SMALL
169.47	3.34	0.003	0.03	1033	6.1	BOTTOM 6 M TOO SMALL
185.61	3.43	0.003	0.03	1155	6.2	BOTTOM 7 M OK

CALCULATIONS

TEST # 1

WP = 5M + 2√(1.5² + 4.5²) = 14.49 M = 47.53 FT

A = 5 + 14 × 1.5 = 14.25 M² = 153.33 FT²

R = A/WP = 153.33 / 47.53 = 3.23

Q = AV = 153.33 × 6 = 920 FT³/SECOND

TEST # 2

WP = (14.49 + 1) 3.28 = 50.91 FT

A = (14.25 + 16) 10.76 = 169.47 FT²

R = 169.47 / 50.91 = 3.34

Q = 169.47 × 6.1 = 1033 FT³/SECOND

TEST # 3

W = (14.49 + 2) 3.28 = 54 FT

A = (14.25 + 3) 10.76 = 185.61 FT²

R = 185.61 / 54.09 = 3.43

Q = 185.61 × 6.2 = 1150 FT³/SECOND

1M = 3.28 ft 1M³ = 35.31 ft³

CHAPTER EIGHT

HIGHWAY INTERSECTIONS

General Consideration

All highway intersections fall into one of the following three classes:

- At-grade intersections
- Grade separations
- Interchanges

The design criteria for at-grade intersections are presented in this Chapter. For more information on all three classes, the AASHO Manuals entitled *A Policy on Geometric Design of Rural Highways, 1965*, and *A Policy on Design of Urban Highways and Arterial Streets, 1973*, should be consulted. These books are located in the Director of Engineering's files.

Design Factors

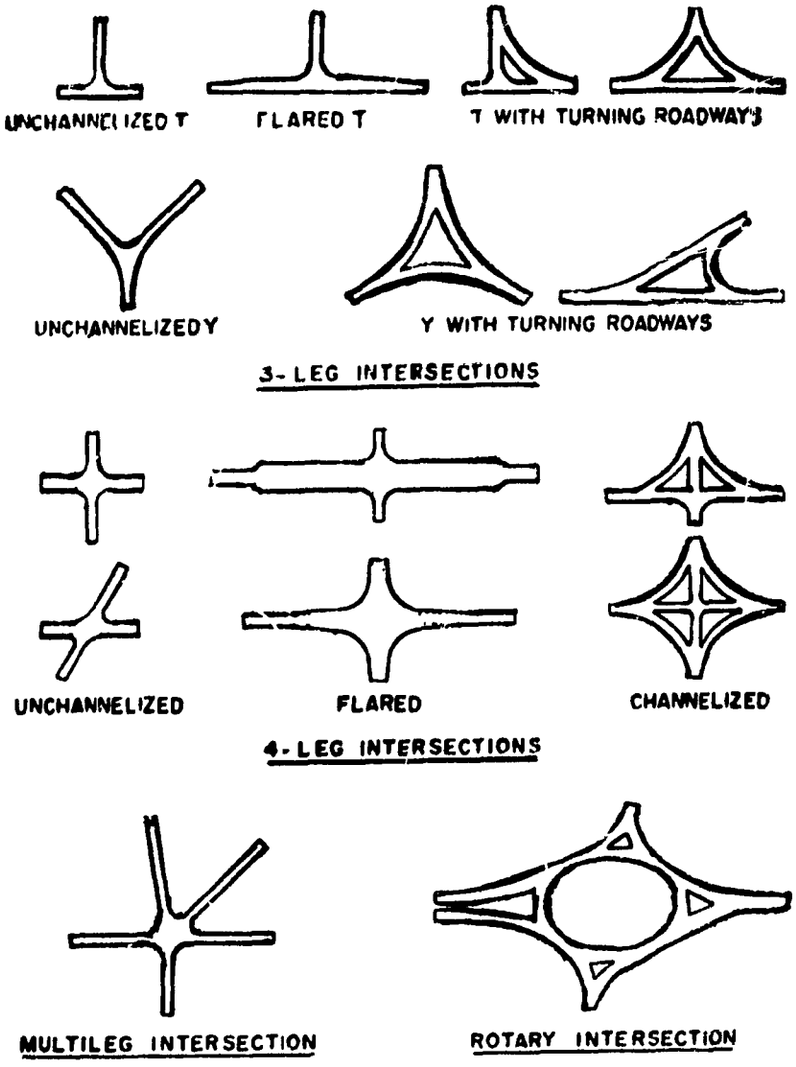
Although several intersections, especially those which are close together in urban projects, may have factors in common, the design of each intersection in general is treated as an individual problem. Some of the factors which determine the design of an intersection are shown below, grouped into four main categories:

- Human
  - + driving habits
  - + decision and reaction times
  - + effects of surprise
- Traffic
  - + intersection capacities
  - + turning movements
  - + size and operating characteristics of vehicles
  - + control of vehicle movements within the intersection
  - + vehicle speeds
  - + pedestrian movements
  - + accident history and experience
  - + unusual traffic volumes due to seasonal, social or recreational facilities

- Physical
  - + topography
  - + geometric design criteria
  - + highway improvements and associated requirements
  - + physical requirements of channelization, if any
- Economic
  - + cost of improvement
  - + right-of-way costs and availability
  - + effect on adjacent businesses or properties.

General Types of At-Grade Intersections

Illustrated on the next page are the most commonly used three, four and multileg intersections. Most intersection designs will be based on one of these general types. For more illustrations of at-grade intersections the designer should refer to one of the AASHO manuals in the Director of Engineering's files.



GENERAL TYPES OF AT-GRADE INTERSECTIONS

Stopping Sight Distance

Minimum stopping sight distances as stated in Chapter One are provided on each leg of an intersection consistent with its design speed. An extension to the table of stopping sight distances, for low speeds, is shown in table 8-1. Desirable stopping sight distances should be provided wherever possible.

STOPPING SIGHT DISTANCE FOR TURNING ROADWAYS

Design Speed, KPH		20	30	40	50
Stopping Sight Distance, m.	Minimum	15	30	45	60
	Desirable	15	30	45	60

Table 8-1

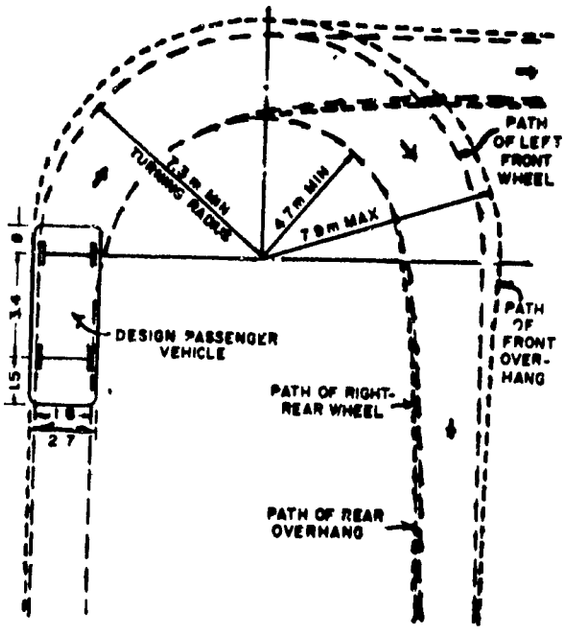
In addition to observing the requirements for minimum stopping sight distance, the designer should be sure that signing and other structures at or near the intersection will not obstruct the driver's view of approaching vehicles.

The location of each intersection and approach should be reviewed to be sure that sight restrictions do not create a hazardous situation. Where possible, the location should be adjusted to avoid sharp blind curves and deep-cut or fill sections.

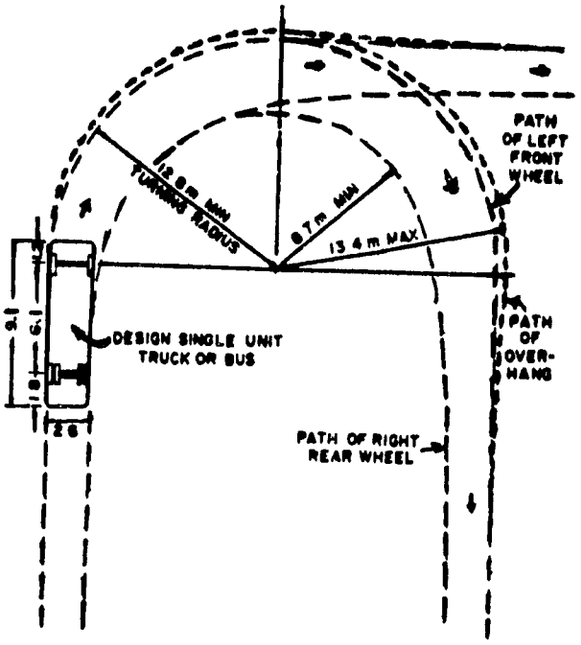
Approaches should not be hidden behind crest vertical curves, nor located off high fills, especially where the existing ground falls away from the through highway. If an approach to a high fill is unavoidable, a 5-meter minimum platform on the same slope as the shoulder will be provided. Intersections occurring on horizontal or crest vertical curves are undesirable with respect to operation as well as sight distance. When selecting an intersection location, avoid horizontal and vertical curvatures wherever possible; for major intersections, a grade change or even a grade separation may be warranted.

Curve Geometrics

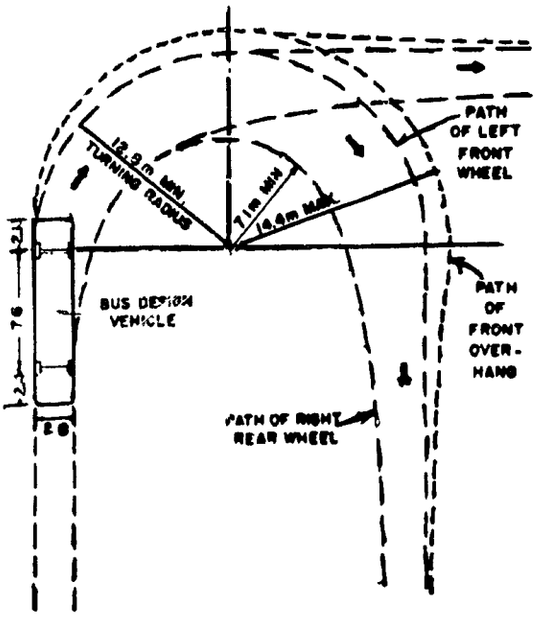
The determination of turning radii should be based on the figures on the following pages, which show the turning circle templates of four standard design vehicles · passenger car (P), single-unit truck (SU), bus and semitrailer combination (WB-50).



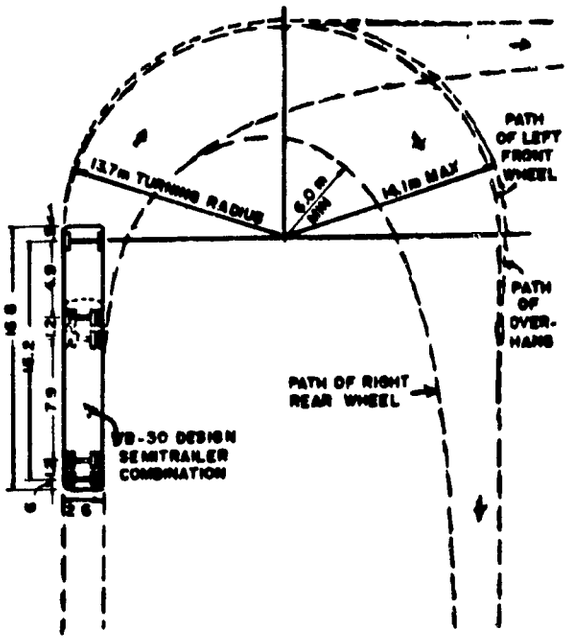
MINIMUM TURNING PATH FOR P DESIGN VEHICLE



MINIMUM TURNING PATH FOR SU DESIGN VEHICLE



MINIMUM TURNING PATH FOR BUS DESIGN VEHICLE



MINIMUM TURNING PATH FOR WB-50 DESIGN VEHICLE

Compound Curves

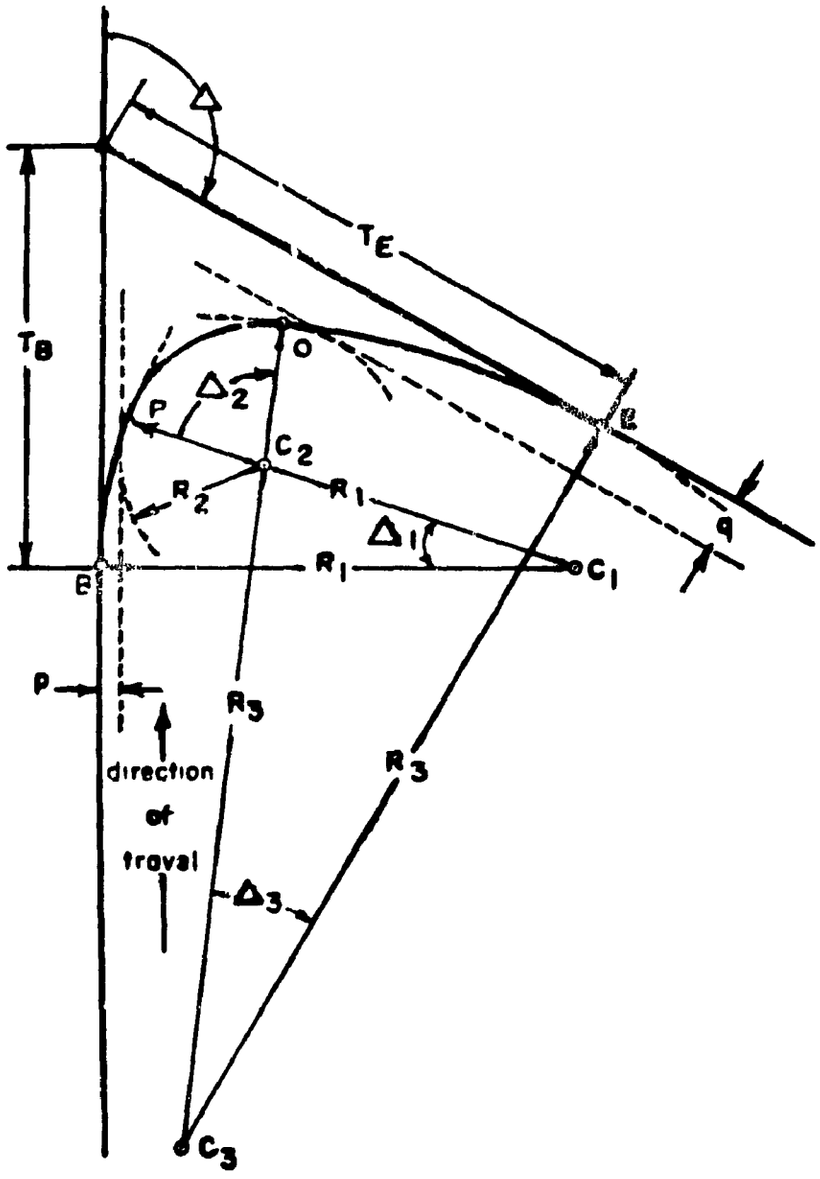
For most right-angled intersections, a single circular arc joining the tangent edges of pavement is adequate design. However, the use of such an arc as the inside pavement edge in oblique-angled turns may lead to an unduly large paved area and can create difficulties regarding sign placement. In such cases, a three-centered compound curve may be used. The table at the right gives simple and compound edge-of-pavement curve data for various angles of turn and design vehicles. The designer should refer to the figure and formulae on the next page, showing computation procedures for three-centered curves.

It should be noted that a replacement of the large-radius arcs of a three-centered curve by straight-line tapers 15 to 30 meters long will produce almost the same effect as the compound curve. This alternative is recommended except when right-of-way and space limitations are so severe as to necessitate a three-centered curve.

MINIMUM EDGE OF PAVEMENT DESIGNS FOR TURNS AT INTERSECTIONS

Design Vehicle	Angle of Turn (degrees)	Simple Curve Radius (meter)	3-Centered Compound Curve Symmetric		3-Centered Compound Curve Asymmetric	
			Radii (meter)	Offset (meter)	Radii (meter)	Offset (meter)
P	30	20	—	—	—	—
SU		30	—	—	—	—
WB-50		60	—	—	—	—
P	45	15	—	—	—	—
SU		25	—	—	—	—
WB-50		50	60-30-60	1.0	—	—
P	60	10		—	—	—
SU		20		—	—	—
WB-50		—	60-25-60	2.0	60-25-80	0.6-1.8
P	75	10	30-10-30	0.6	—	—
SU		15	35-15-350	0.6	—	—
WB-50		—	45-15-45	1.8	45-15-70	0.6-3.0
P	90	10	30-10-30	0.8	—	—
SU		15	35-10-35	0.6	—	—
WB-50		—	60-20-60	1.8	35-12-60	0.6-3.0
P	105	—	30-5-30	8	—	—
SU		—	30-10-30	1.0	—	—
WB-50		—	60-15-60	2.4	45-40-65	0.6-3.0
P	120	—	30-5-30	.6	—	—
SU		—	30-10-30	1.0	—	—
WB-50		—	60-12-60	2.6	45-10-70	0.6-3.6
P	135	—	30-5-30	0.5	—	—
SU		—	30-10-30	1.2	—	—
WB-50		—	50-10-50	2.7	40-10-55	1.0-4.3
P	150	—	25-5-25	0.6	—	—
SU		—	30-10-30	1.2	—	—
WB-50		—	50-10-50	2.1	35-10-60	1.0-4.3
P	180	—	15-5-15	0.2	—	—
SU	U-Turn	—	30-10-30	.5	—	—
WB-50		—	40-10-40	2.9	30-10-60	1.8-4.0

Table 8-2



THREE-CENTERED COMPOUND CURVE

Step 1: The following quantities will be known, or can be selecten, by the designer :

- angle of turn (deflection angle) Δ (degrees)
- radii R_1, R_2 and R_3 (feet)
- offsets p and q (feet).

Step 2: Compute the intermediate deflection angles from :

$$\cos \Delta_1 = \frac{R_1 - (R_2 + p)}{R_1 - R_2} \qquad \cos \Delta_3 = \frac{R_3 - (R_2 + q)}{R_3 - R_2}$$

and $\Delta_2 = \Delta - (\Delta_1 + \Delta_3)$

Step 3: Compute the tangent lengths from the point of intersection to the beginning (B) and end (E) of the compound curve, from :

$$T_B = \frac{p \cos \Delta + q}{\sin \Delta} + R_2 \tan \frac{\Delta}{2} + (R_1 - R_2) \sin \Delta_1$$

$$T_E = \frac{p + q \cos \Delta}{\sin \Delta} + R_2 \tan \frac{\Delta}{2} + (R_3 - R_2) \sin \Delta_3$$

When $\Delta = 90^0$ (a commonly encountered case) :

$$T_B = q + R_2 + (R_1 - R_2) \sin \Delta_1$$

$$T_E = p + R_2 + (R_3 - R_2) \sin \Delta_3$$

The formulae above are for an asymmetric three-centered curve.

For asymmetric curve,

$R_1 = R_3$ and $p = q$

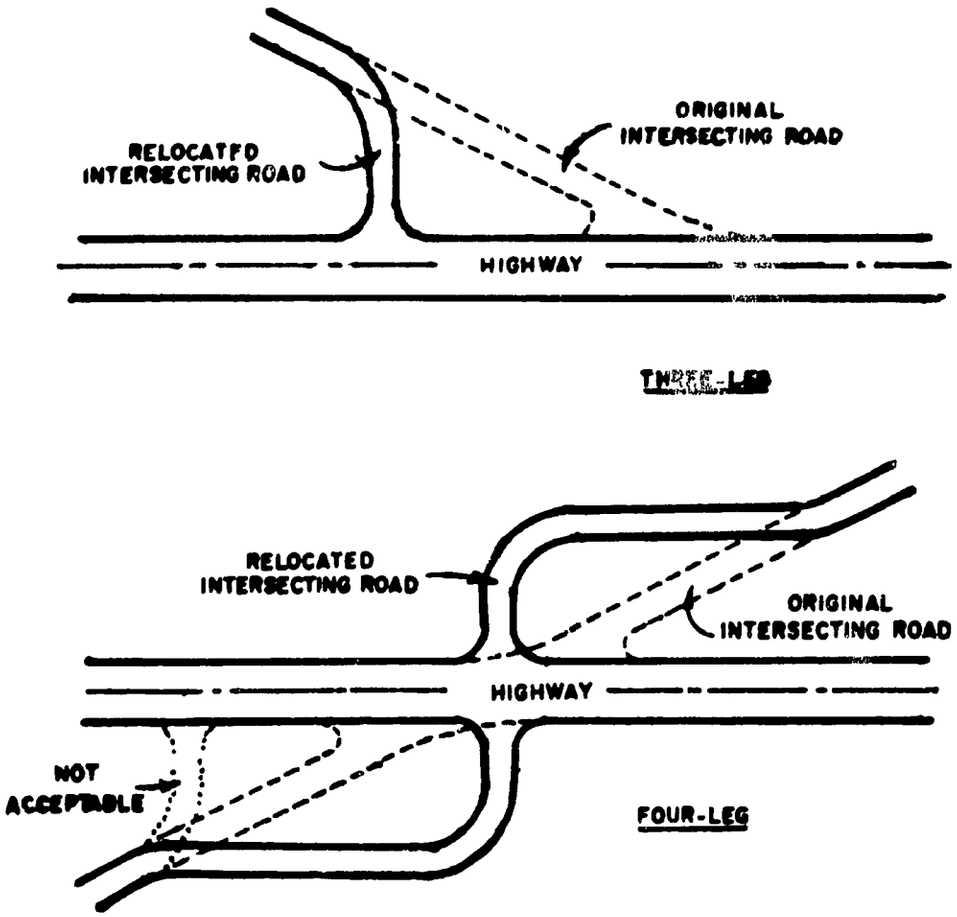
So $\Delta_1 = \Delta_3 = \cos^{1} \frac{R - (R_2 + p)}{R_1 - R_2}$

and $\Delta_2 = \Delta - 2\,\Delta_1$

and $T_B = T_E = \frac{p(1 + \cos \Delta)}{\sin \Delta} + R_2 \tan \frac{\Delta}{2} + (R_1 - R_2) \sin \Delta_1$

Skewed Intersections

Skewed intersections on major highways should be avoided where possible by means of relocations similar to those shown below :

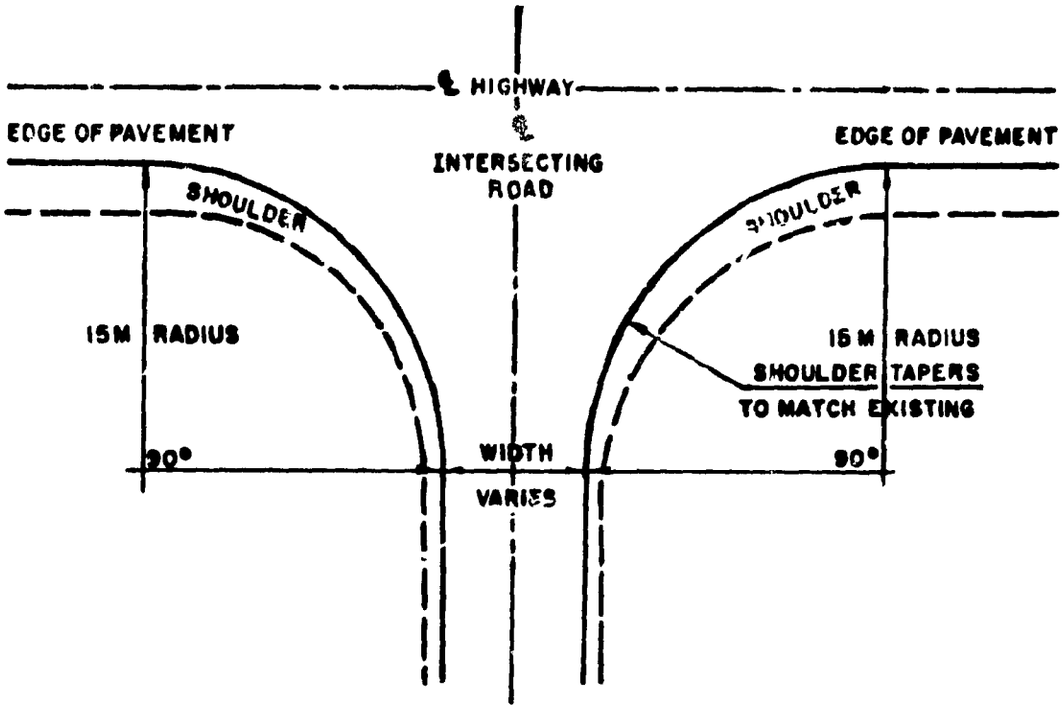


RELOCATION OF SKEWED INTERSECTIONS

Intersection angles should be skewed no more than 30° from a right angle approach.

Rural Intersections

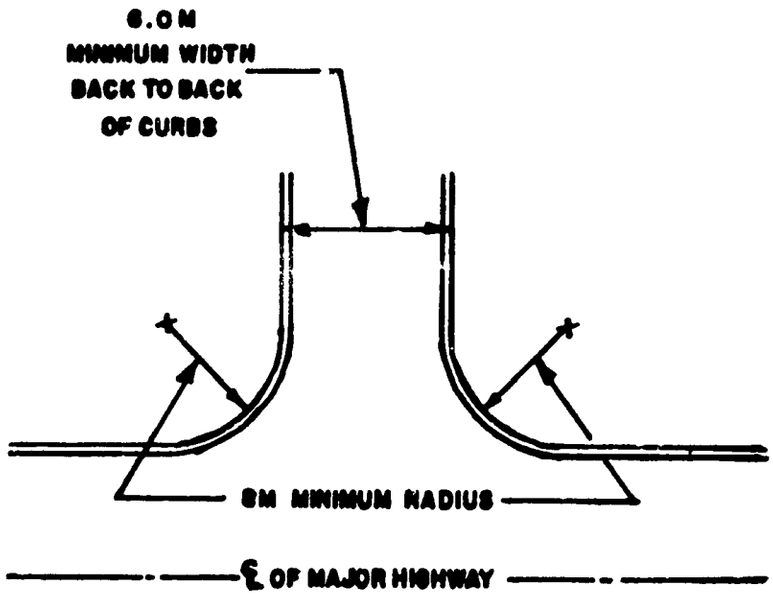
Approaches are designed for all intersections with public roads. Such roads normally carry enough traffic to make the design geometrics significant. Short relocations are often desirable. Traffic turning lanes and channelization may also be warranted. The figure below shows a typical rural intersection.



Urban Streets

There is little new location in urban areas; due to this fact, the design of urban at-grade intersections must be coordinated with and tied to the geometrics of the existing system. Grades, widths and return radii will therefore be matched with those already present, using drawings with a horizontal scale of 1 cm to 2 meters and vertical scale of 1cm to 0 2 meters.

Dimensions for paved urban intersections with minor local streets are shown in the figure below:



Urban intersections involving major streets of arterial highways usually will incorporate some form of channelization. The discussion which follows and the accompanying figure illustrate the design controls and criteria applicable to channelized intersections.

Channelization

The object of channelization is to separate or regulate conflicting traffic movements into definite paths of travel by the use of traffic islands, pavement markings or other suitable means to facilitate the safe, orderly movements of both vehicles and pedestrians.

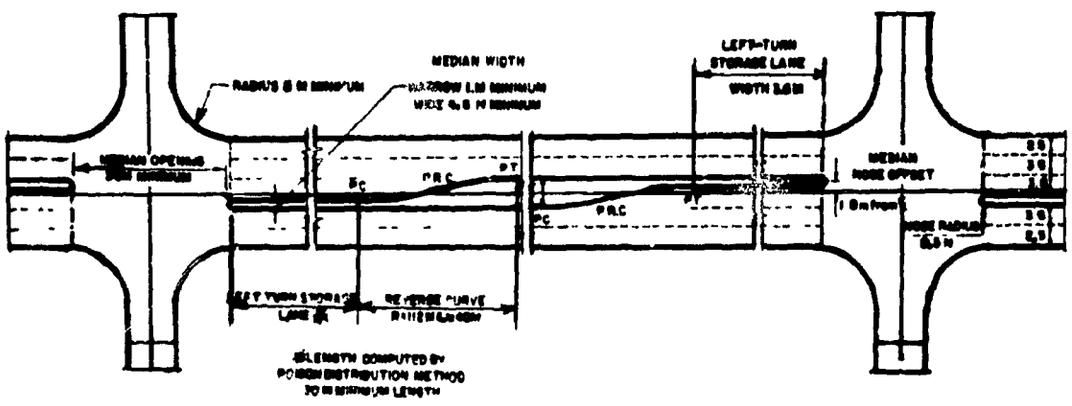
A traffic analysis generally is performed to establish the type of channelization by identifying the relative importance of conflicting movements. Giving preference to major movements is a good practice — this may require control or even elimination of minor movements such as stopping or parking. Close liaison should be maintained with the Traffic Engineer before, during and after the preliminary design phase.

It is essential that judgment be exercised during design so as not to introduce the following:

- driver confusion
- excessive restrictions
- unsafe conditions.

Complex intersections which present many choices to the driver are undesirable. Simplicity, both of movement and signalized or implicit instruction, is a desirable goal However, designs which reduce or eliminate too many movements can be unnecessarily punitive.

Determination of the lengths of left-turn and storage lanes should be made using the procedure on page 8-14.



MEDIAN LEFT-TURN CHANNELIZATION IN URBAN AREAS

Left-Turn Lanes

The length of a left-turn lane should be designed in such a maner that the number of vehicles desiring to make a left turn during any interval will exceed the left-turn lane capacity only 5 percent of the time. The following procedure, based on a probability (Poisson) distribution method, will be used for determining the length (L) of a left-turn lane. A minimum lane length of 30 meters will be used, regardless of calculated results.

Step 1 :

Calculate m, the average number of vehicles per interval, from

$$m = \frac{D \times I}{3600}$$

Where :

D = design hourly volume of vehicles making the left turn

I (interval) = 60 seconds in rural areas

= 90 seconds in urban and suburban areas.
(Other values may be used, dependent on signalization-phase periods.)

Step 2 :

Enter table 8-3 with the calculated value of m and read off the corresponding value of x, the probable maximum number of vehicles appearing the given interval. Appropriate values of x have been obtained from a Poisson distribution, so that the probability of x being exceeded is 0.05, or 5 percent.

Step 3 :

Allowing a distance of 5 meters for each stored vehicle, multiply x by 5 to obtain L, the required left-turn lane length, in meters.

TABLE — LEFT-TURN LANE LENGTH

AVERAGE NUMBER OF VEHICLES PER INTERVAL m	95% PROBABLE MAXIMUM NUMBER OF VEHICLES DURING THE SAME INTERVAL x	LENGTH OF LEFT-TURN LANE L, meters
0.1 to 0.3	2	30
0.4 to 0.8	3	30
0.9 to 1.3	4	30
1.4 to 1.9	5	30
2.0 to 2.6	6	30
2.7 to 3.3	7	35
3.4 to 4.0	8	40
4.1 to 4.7	9	45
4.8 to 5.4	10	50
5.5 to 6.2	11	55
6.3 to 7.0	12	60
7.1 to 7.8	13	65
7.9 to 8.6	14	70
8.7 to 9.4	15	75
9.5 to 10.2	16	80
10.3 to 11.0	17	85
11.1 to 11.8	18	90
11.9 to 12.6	19	95
12.7 to 13.4	20	100
13.5 to 14.2	21	105
14.3 to 15.0	22	110

Table 8-3

Example : Given DHV = 486 (left-turning vehicles)
Urban Area

Solution $m = \frac{486 \times 90}{3600} = 12.15$

Average number of vehicles per interval = 12.15
From the table, x = 19

The number of vehicles appearing during the given interval will exceed 19 only 5% of the time.

Length of left-turn lane, L = 5mtrs × 19 = *95 meters.*

Speed-Change Lanes

Speed-change lanes should be considered when designing all at-grade intersections. The use of the additional lanes will reduce the hazard and increase the capacity of the intersection by removing from the traveled way the slower moving vehicles which are entering and leaving the highway.

Warrants for the use of such additional lanes cannot be stated specifically. There are several factors, however, which should be considered, namely :

- average running speeds
- traffic volumes
- capacity
- type of highway
- arrangement and frequency of intersections
- accident experience.

Speed-change lanes are of two types: acceleration and deceleration lanes. Basic design criteria are discussed in the following paragraphs.

Deceleration lanes

The length of a deceleration lane is determined by three factors :

- average running speed on highway
- average running speed on exit curve
- deceleration rate.

Table 8-4 shows the length of deceleration lanes to be used for different combinations of highway and exit speeds. The lengths shown in this table are based on a vehicle decelerating in two steps: first, a three-second slowing down in gear without the use of brakes; and second, the comfortable breaking at a rate of 10 kph per second.

HIGHWAY DESIGN SPEED KPH (V)	AVERAGE RUNNING SPEED KPH (V_a)	L = LENGTH OF DECELERATION LANE – METER										LENGTH OF TAPER
		FOR DESIGN SPEED OF EXIT CURVE – KPH (V^1)										
		STOP CONDITION	20	30	40	50	60	70	80	90	100	
		FOR AVERAGE RUNING SPEED ON EXIT CURVE – KPH (V_a^1)										
		0	18	26	37	47	55	63	72	79	87	m
35	32	27	15	12	—	—	—	—	—	—	—	25
50	47	76	61	55	37	—	—	—	—	—	—	40
65	59	104	41	85	76	58	46	—	—	—	—	50
80	72	131	119	116	104	88	73	55	—	—	—	65
100	87	165	162	152	146	137	119	107	82	67	—	80

V DESIGN SPEED OF HIGHWAY

V_a – AVERAGE RUNNING SPEED ON HIGHWAY

V_1 – DESIGN SPEED OF EXIT CURVE

V_a^1 – AVERAGE RUNNING SPEED ON EXIT CURVE

L_t = LENGTH OF TAPER

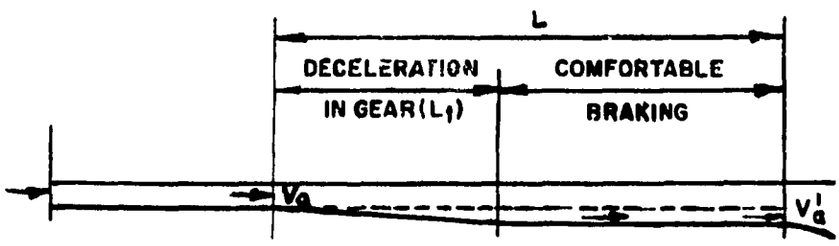


TABLE 8-4

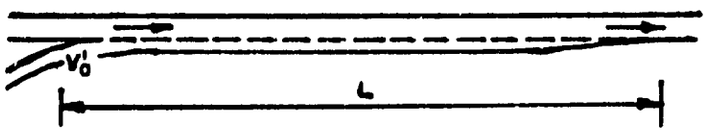
DERIVATION OF LENGTHS FOR DECELERATION LANES

Acceleration lanes

Acceleration lanes can be designed with a uniform taper, usually 20 : 1 to 50 : 1, or with a parallel lane with a more abrupt taper at the end. The taper length, regardless of the method used, is to be considered part of the lane length. The factors effecting acceleration lane length are similiar to those effecting deceleration lanes, namely :

- average running speed on highway
- average running speed on entrance curve
- acceleration rate.

The lengths shown in table 8-5 are based on an acceleration rate varying from 4kph/sec for a vehicle traveling at 10 kph to 1.5 kph/sec for a vehicle traveling at 100 kph.



HIGHWAY		L–LENGTH OF ACCELERATION LANE - METERS									
		FOR ENTRANCE CURVE DESIGN SPEED, KPH									
DESIGN SPEED, KPM	SPEED REACHED (V_0) KPH	STOP CON-DITION	20	30	40	50	60	70	80	90	100
		AND INITIAL SPEED (V_0') KPH									
		0	18	26	37	47	55	63	72	79	87
35	32	43	—	—	—	—	—	—	—	—	—
50	47	107	98	76	46	—	—	—	—	—	—
65	59	198	180	170	137	58	46	—	—	—	—
80	72	332	320	305	259	213	165	95	—	—	—
100	87	485	470	457	430	405	363	302	198	122	—

DERIVATION OF LENGTHS FOR ACCELERATION LANES

Table 8-5

Speed-Change Lane Adjustments

Tables 8-4 and 8-5 were developed without regard to the grade of the road. When the speed-change lanes are to be designed on a grade, table 8-6 must be used to modify the lane lengths.

Design speed of highway, kph	Ratio of length on grade to length on level for:	
All	3 to 4% upgrade 0.9	3 to 4% downgrade 1.2
All	5 to 6% upgrade 0.8	5 to 6% downgrade 1.35
	Acceleration Lanes	
Design speed of highway, kph	Ratio of length on grade to length on level for:	
	Design speed of turning roadway curve, kph	
	35 50 65 80	All speeds
	3 to 4% upgrade	3 to 4% downgrade
65	1.3 1.3 — —	0.7
80	1.3 1.4 1.4 —	0.65
100	1.4 1.5 1.5 1.6	0.6
	5 to 6% upgrade	5 to 6% downgrade
65	1.5 1.5 — —	0.6
80	1.5 1.7 1.9 —	0.55
100	1.7 1.9 2.2 2.5	0.5

Table 8 6

For example, from table 8-5 it is found that an acceleration lane must be 170 meters long for a highway design speed of 65 kph and an entrance curve design speed of 30 kph. Assuming the intersection is on a 3.5% upgrade, the adjustment factor is 1.3. The adjusted lane length then is 170 meters × 1.3, or 221 meters.

Private Approaches and Driveways

Generally, it is the policy of the Highway Administration to replace existing approaches where highways are to be constructed. Where highways are on new locations, approaches will be provided as required by the abutting property owners, providing that the approach is not a safety hazard.

Care should be taken to avoid an excessive number of approaches. Keep in mind that :

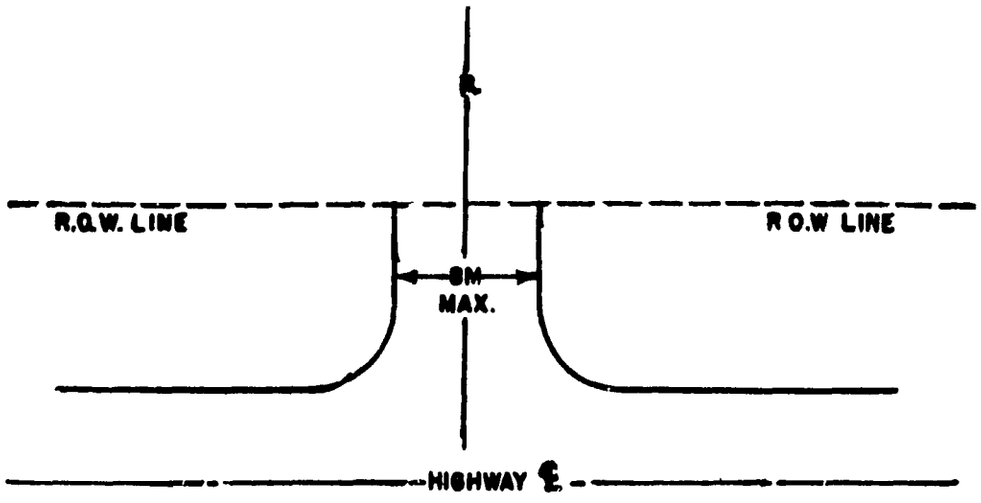
- approaches are expensive — including costs of excavation, surfacing materials and pipe culverts.
- some existing farm entrances and approaches may have outlived their usefulness and may no longer be required.
- each approach presents a potentially hazardous conflict with highway traffic, particularly when the volume of traffic is large.
- each approach represents an obstruction in the recovery area.

Recommendations for private approach locations will be made during the plan-in-hand inspection. In some cases, the need for a private approach may be obvious from the plan-sheet layout. If there is any question about the need for an approach, the situation should be investigated during the plan-in-hand or other field inspections. Final determinations of the needs for approaches will be documented at the time of right-of-way negotiations.

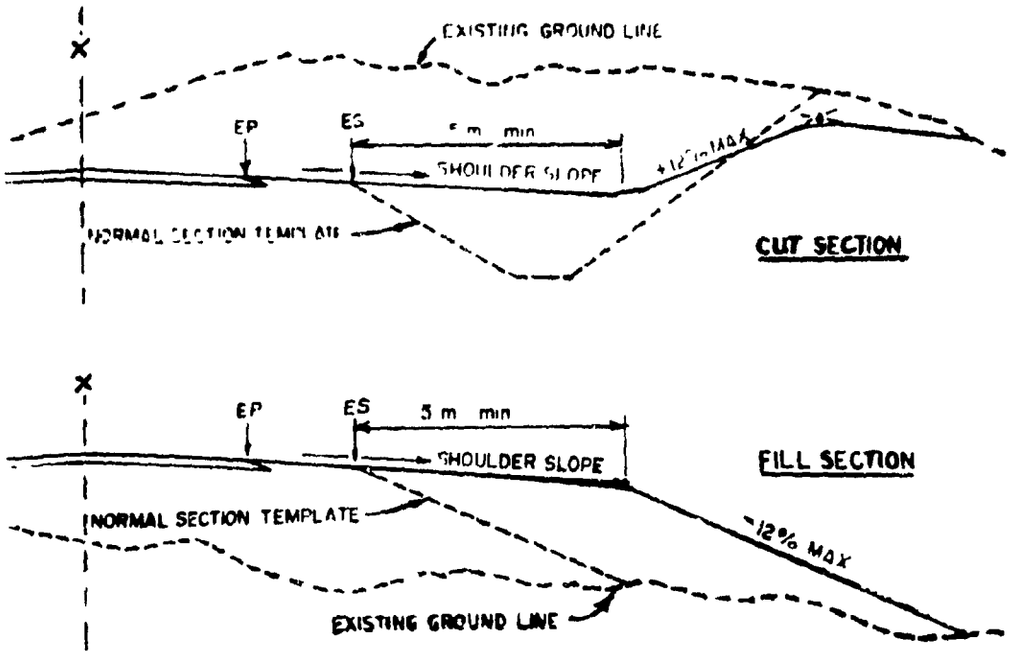
Rural Approaches

The following points should be considered when designing approaches and driveways in rural locations :

- Joint access to adjoining properties should be provided where possible, with the access opening centered on the property line. Such openings generally will be 8 meters wide, with 5 meter radii on the returns.



- Grades of rural access openings should not exceed a maximum of ±8%. An exception is in a high-cut or deep-fill situation, where a maximum grade of ±12% is allowable. In such cases the shoulder slope should be continued for a minimum of 5 meters beyond the edge of shoulder before breaking to the steeper slope, as shown in the figure below.



Wherever possible, consideration should be given to relocating the access opening to, or at least near, a roadway section where the cut changes from cut to fill, in order to avoid the situation shown above.

Urban Approaches and Driveways

In considering new driveway locations in urban areas, close liaison should be maintained with the Right-of-Way Division, which will negotiate with the property owners using the initial design as a basis for negotiation.

The major part of design work on private approaches in urban areas involves improvements on existing locations. Factors to be considered are :

- accommodation of existing approaches
- development of abutting property
- the need to keep adjacent development information up-to-date during the design phase
- location of curb inlets.

All new driveway design will be in accordance with the criteria shown in table 8-7.

DRIVEWAY WIDTH CRITERIA

	TYPE OF PROPERTY	
	Residential	Commercial
SINGLE	4m Desirable 6m Maximum	3m Desirable 10m Maximum
DOUBLE	6m Desirable 8m Maximum in existing locations only. Use single in new locations.	---
JOINT USE (Driveway on property line)	8m Desirable 10m Maximum	12m Desirable 15m Maximum

Table 8-7

Driveway geometrics are referenced to the project centerline. Returns should be located on tangents, not on curves.

Frontage Roads

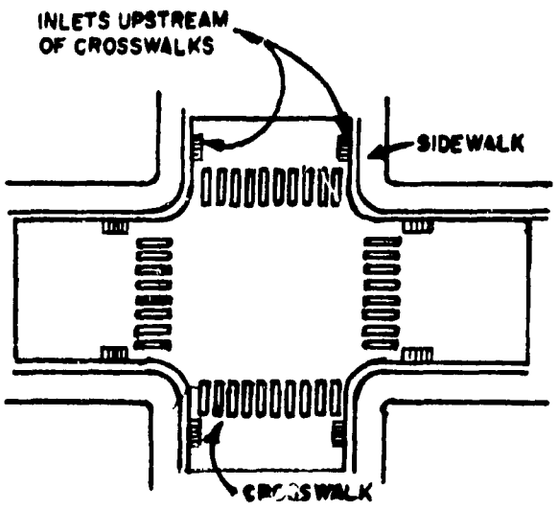
Frontage roads should be designed to provide safe and convenient access to property adjoining a major through–highway, especially one with high design speed and volume of traffic.

Signalization

The method and design of signalization at intersections are the responsibility of the Traffic Engineer. Generally, urban intersections are the only ones requiring signalization. The Design Division will furnish base plans to the Traffic Engineer.

Pedestrian Provisions

Ordinarily, little or no provision is made for pedestrian use of highways in rural areas. In urban areas, sidewalks will be provided along all highways. Sidewalks should be 1.5 meters wide and, where possible, should be set back a minimum of 1.0 meter from the curb. In cases where there is insufficient room to set the sidewalk back, the width may be increased to 1.8 meters. Consideration should be given to the relative locations of inlets and sidewalks or crosswalks to ensure that neither grates nor ponded water are hazardous to pedestrians. The following figure illustrates correct inlet locations.



INLET LOCATION
AT URBAN INTERSECTIONS

CHAPTER NINE
SURFACING

GENERAL CONSIDERATIONS

This Chapter sets forth criteria and procedures to follow in estimating quantities of highway surfacing materials.

For each project, basic decisions relative to surfacing design are formulated by the Road Design Engineer based on recommendations from the Soil Engineer. These decisions include:

- Type of finished surface
- Kinds of materials
- Thicknesses of the various courses.

Following review and approval by the Director of Engineering, the project designer is advised of the recommendations.

TYPICAL SECTION GEOMETRICS

The recommendations for structural design of the surfacing must be applied to the standard typical section selected for each project. Surfacing thicknesses will be defined to the nearest centimeter. The horizontal dimensions of the various surface courses must be determined for the purposes of :

- Computing surfacing quantities
- Construction staking in the field.

Symmetrical Sections

Most commonly used typical sections are for 2-lane highways on tangent alignment with normal crown slopes. Dimensions of the subgrade width and intermediate surfacing courses will be symmetrical about the centerline.

The finished roadway width will be shown on the standard typical section. The first computation is to establish the width of subgrade using the following formula :

$$W_s = W_f + 2\left(\frac{tZ}{1-0.03\,Z}\right)$$

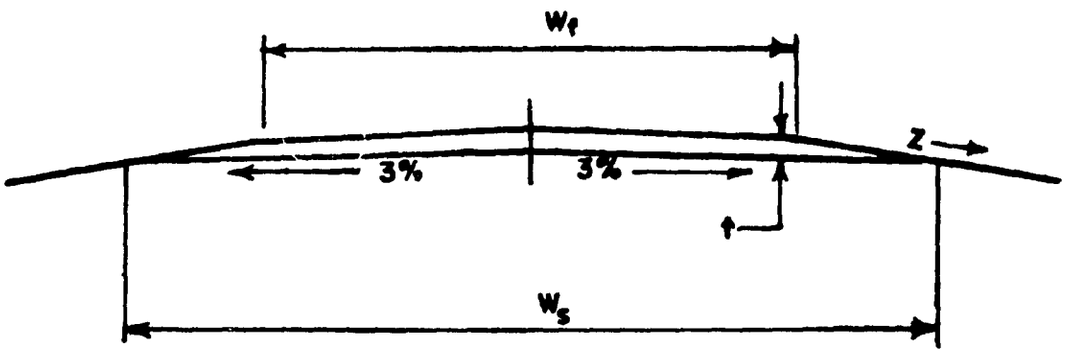
where

W_s = Width of subgrade in meters

W_f = Width of finished grade in meters

t = Total surfacing thickness at finished shoulder

Z = Horizontal proportion of the side slope i.e. $Z = 6$ for a 6:1 side slope.



For example, where $W_f = 12.20\text{m}$

$t = 0.55\text{m}$

$Z = 6:1$

$$W_s = 12.20 + 2 \times \left(\frac{0.55 \times 6}{1 - .03\,Z}\right)$$

$$= 12.20 + 8.04 = 20\,24$$

$$= 20\,2 \text{ (Round to nearest 0.1 meter).}$$

Because of the rounding process, the side slope through the surfacing courses will not be exactly 6:1, but the difference is negligible and the even dimension facilitates staking of the subgrade.

The second computation is to establish the width of the intermediate surfacing courses. Each horizontal dimension shall be computed in proportion to the thickness.

For example, the width at the top of any surfacing course may be determined by the following formula :

$$W_x = W_f + \frac{t_x}{t}\left(W_s - W_f\right)$$

Where :

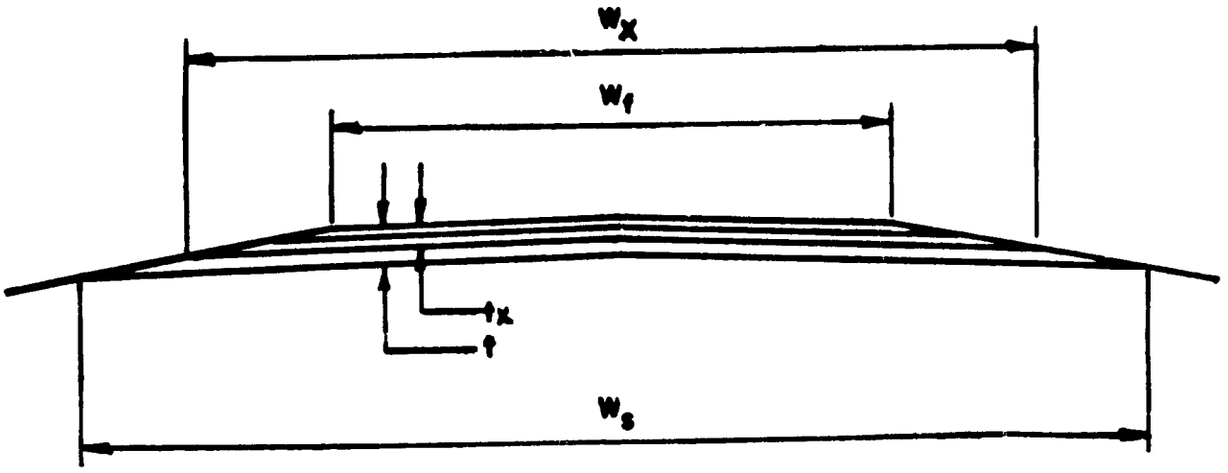
W_x = Top width of intermediate surfacing course

W_f = Width of finished grade

W_s = Width of subgrade

t = Total surfacing thickness at finished shoulder

t_x = Accumulative thickness of courses above W_x



All dimensions are in meters.

All computed intermediate widths (W_x) will be rounded to the nearest 0.05 meters.

Unsymmetrical Sections

When sections are not symmetrical about the centerline, the widths to the left and right of centerline must be computed and shown separately. This situation exists with all superelevated sections and with divided highways where the inside and outside shoulders are different widths.

To compute subgrade widths for superelevated sections, the following formulae will be used :

Low Side

$$W_{sl} = W_f \text{ (low side)} + \frac{tZ}{1-SZ}$$

High Side

$$W_{sh} = W_f \text{ (high side)} + \frac{tZ}{1+SZ}$$

Where :

W_{sl} = Width from centerline to edge of subgrade on low side of superelevation in meters

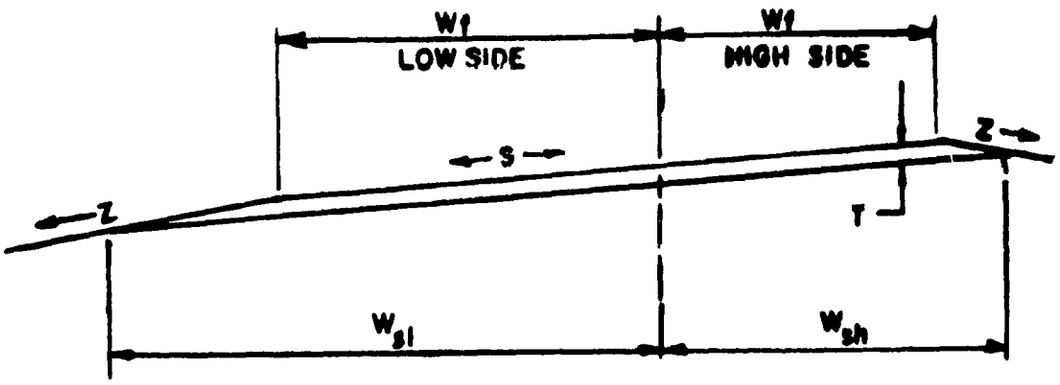
W_{sh} = Width from centerline to edge of subgrade on high side of superelevation in meters

W_f = Width of finished grade in meters

t = Total thickness of surfacing in meters

S = Slope of superelevation (m/m)

Z = Horizontal proportion of the side slope.



The computed values for W_{sl} and W_{sh} will each be rounded to the nearest 0.1 meter.

For divided highways on tangent or curve sections, the subgrade widths left and right of centerline are computed as follows :

TANGENT

$$W_s \text{ (inside)} = W_f \text{ (inside)} + \frac{tZ}{1 - 0.03Z}$$

$$W_s \text{ (outside)} = W_f \text{ (outside)} + \frac{tZ}{1 - 0.03Z}$$

Curve Sections

Subgrade widths on curves are determined using one of the following four formulae. A formula was derived for each different situation as listed below:

FORMULA	SITUATION
W_s (outside) $= W_f$ (outside) $+ \frac{tZ}{1 + SZ}$	Outside Roadway, Outside Width
W_s (inside) $= W_f$ (inside) $+ \frac{tZ}{1 - SZ}$	Outside Roadway, Inside Width
W_s (inside) $= W_f$ (inside) $+ \frac{tZ}{1 + SZ}$	Inside Roadway, Inside Width
W_s (outside) $= W_f$ (outside) $+ \frac{tZ}{1 - SZ}$	Inside Roadway, Outside Width

Inside roadway refers to the roadway closest to the curve's radius point. Outside roadway refers to the roadway farthest from the curve's radius point.

Both Ws (inside) and Ws (outside) will be rounded to the nearest 0.1 meter.

The widths of intermediate surfacing courses for unsymmetrical sections will be computed in the same manner as for symmetrical sections in proportion to the thicknesses, except that widths will be computed and recorded separately for each side of the centerline.

In order to speed computation of subgrade widths, the following table has been developed for the most common situations-tangent and full curve. The table shows subgrade widths beyond the edge of finished shoulder for a one-meter thick surface.

S \ Z	1:1	2:1	3:1	4:1	5:1	6:1
− 3%	1.03	2.13	3.30	4.55	5.88	7.32
− 8%	1.09	2.38	3.95	5.88	8.33	11.54
+ 8%	.93	1.73	2.42	3.03	3.57	4.05

To use the table, first locate the correct factor using the superelevation rate and sideslope. This factor is then multiplied by the total thickness of surfacing. The example on the next page demonstrates this procedure.

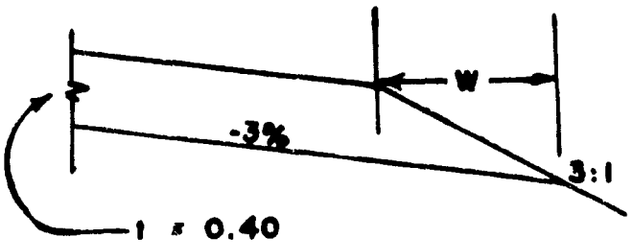
Example

For cross section at right, $t = 0.40m$;

$Z = 3:1$; $S = 3\%$

from table, factor is 3.30

$W = 3.30 \times 0.40 = 1.32m.$



COMPUTING SURFACING QUANTITIES

For each typical section, computations will be made to determine the required quantities per station of each type of surfacing material. Subsequently, these values will be used to compute total surfacing quantities for the entire project To assure consistency and uniformity, the computation steps described below must be followed.

Gravel Quantities

1. For estimating purposes the cross-section area for each course may be computed by multiplying the thickness (nearest 0.01 meter) by the average of the top and bottom widths. End areas should be rounded and recorded to the nearest 0.01 square meter.
2. Compute the cubic meters per 100 meters with this formula :

   C.M./100m = End Area (sq. m.) × 100m

   Round the answer to the nearest 0.1 cubic meter.
3. Compute tons per 100 meters. Unless otherwise directed, use 2200 kilos per cubic meter for conversion.

   $$\text{Metric Tons/100m} = \text{C.M./100m} \times \frac{2200}{1000} = \text{C.M /100m} \times 2.2^*$$

   Round the answer to the nearest 0.1 ton. Specific unit weights for gravel may be given for individual projects.

Check your answer for each step before proceeding to the next step. Values should be recorded on the typical section sheet as illustrated on the model sheet in Chapter Fourteen.

* NOTE. The conversion factor of 2.2 may be modified if the District Engineer determines that another factor is more appropriate.

Plant Mix Quantities

1. Compute cross-section areas. If the plant mix course is of uniform thickness, the procedure is the same as for gravel courses. If cross slopes are steepened, special computation must be made to allow for variable thickness. Round the answers to the nearest 0.01 square meter.
2. Compute cubic meters per 100 meters in the same manner as for gravel quantities.
3. Compute tons per 100 meters on the basis of a weight of 2320 kilograms per cubic meter.

$$\text{Tons/100m} = \frac{2320}{1000} \times \frac{\text{C.M.}}{\text{100m}}$$

This value includes the weight of all materials.

All rounding of computations should be performed in sequence by steps as directed.

Bituminous Material Quantities

For estimating purposes, all bituminous material is assumed to weigh 1.00 kilogram per liter.

Plant Mix Asphalt — Quantities to be estimated at 6.5 percent of the computed weight of plant mix and recorded to the nearest 0.1 ton per 100 meters.

For plant mix bituminous base, the asphalt quantity will be computed as 5.0 percent of the total weight.

Prime Asphalt — Prime Asphalt will be estimated at the rate of 1.5 liters per square meter of surface area of top course gravel. Quantities will be recorded as tons per station. For computation purposes, the rate of application should be converted to 0.001385 tons/sq.m. Round the answer to the nearest 0.1 ton.

Tack Asphalt — Tack asphalt will be estimated at the rate of 0.50 liter per square meter between lifts of plant mix material and between plant mix surfacing and bituminous-stabilized base courses. The square meters of surface area computed for prime asphalt should be used also for estimating tack asphalt quantities — even though the area is not precisely correct. Quantities should be computed and recorded in liters per 100 meters and rounded to the nearest liter. Quantities should also be converted into tons per 100 meters using 0.9 kilograms per liter as a conversion factor. Round the answer to the nearest 0.1 ton.

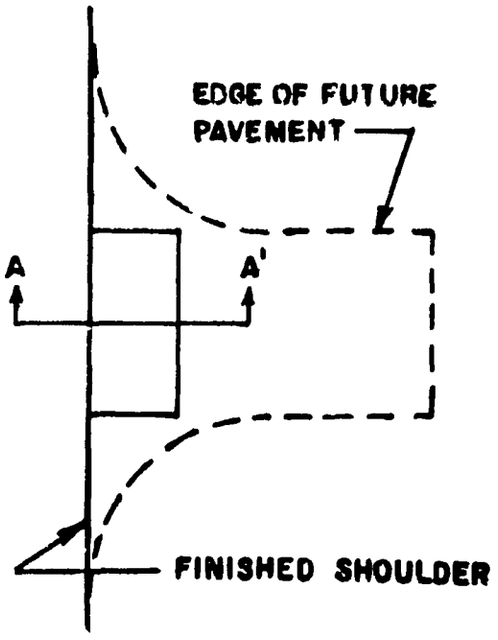
Macadam

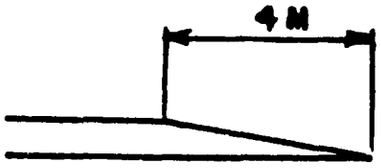
When macadam surfaces are specified, the rates of application for the various materials involved will be provided by the pavement designer.

Approach Surfacing

On bituminous-surfaced projects, all private approaches will be surfaced to the right-of-way line unless other wise directed. Seldom used approaches, which warrant gravel sufaces only, will be identified at the time of plan-in-hand inspection.

In roads where plant mix base is a part of stage construction, quantities for approaches should e estimated based on using a 4-meter transitional tapered section from the finished shoulder › the road approach. This tapered section is illustrated below.





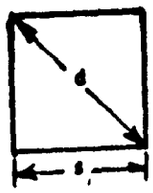
SECTION A-A'

Summary of Quantities

Total quantities of surfacing materials will be computed and summarized in the format shown in Chapter Fourteen. Computed quantities should be rounded as follows:

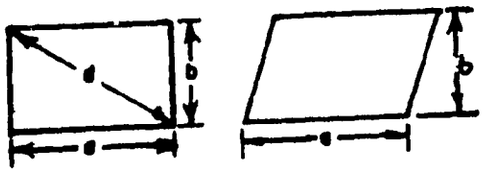
- Gravel and plant mix — nearest ton
- All bituminous material — nearest 0.1 ton
- Sand surfacing and pit run material — nearest C.M.

Formulae are shown on the following pages as an aid to computation of surface areas.



Square

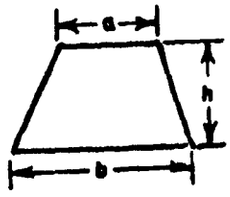
Area $= S^2 = {}^1/_2 d^2$



Rectangle and Parallelogram

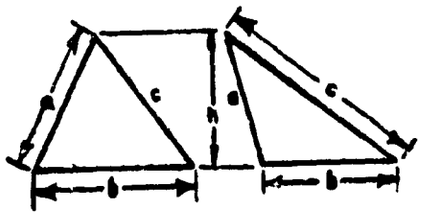
Area $= ab$

$= b\sqrt{d^2 - b^2}$



Trapezoid

Area $= {}^1/_3 h\ (a + b)$

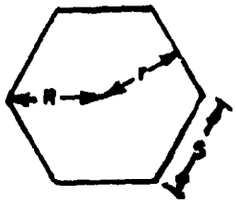


Triangle

Area $= {}^1/_2 bh$

$= \sqrt{S\ (S - a)\ (S - b)\ (S - c)}$

Where $= S = {}^1/_2\ (a + b + c)$



n = number of sides

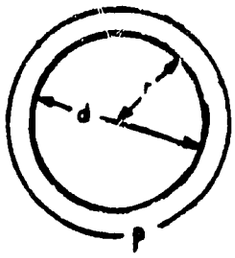
Regular Polygon

$$\text{Area} = \frac{n}{4}\ S^2 \cos \frac{180^0}{n}$$

$$= \frac{n}{4}\ R^2 \sin \frac{360^0}{n}$$

$$= nr^2 \tan \frac{180^0}{n}$$

Circle

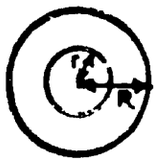


$$\text{Area} = \pi r^2 = \frac{\pi d^2}{4} = \frac{p^2}{4\pi}$$

Perimeter

$$= p = \pi d = 2\pi r$$

Circular Ring (Annulus)



$$\text{Area} = \pi (R^2 - r^2)$$

$$= \pi (R - r)(R + r)$$

Sector

$$\text{Area} = \tfrac{1}{2} br = \pi r^2 \frac{\theta}{360^0} \qquad \text{Arc } b = \frac{\pi r \theta}{180^0}$$

Quadrant ($\theta = 90^0$)

$$\text{Area} = \frac{\pi r^2}{4}$$

Segment

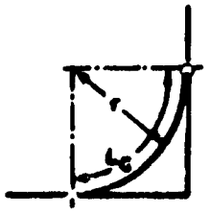
$$\left.\begin{aligned} \text{Area} &= \tfrac{1}{2}[br - c(r - h)] \\ &= \pi r^2 \frac{\theta}{360^0} - \tfrac{1}{2} c (r - h) \end{aligned}\right\} \theta < 180^0$$

$$\left.\begin{aligned} &= \tfrac{1}{2}[br - c(h - r)] \\ &= \pi r^2 \frac{\theta}{360^0} + \tfrac{1}{2} c (h - r) \end{aligned}\right\} \theta > 180^0$$

Fillet or Spandrel

$$\text{Area} = r^2\left(\tan\frac{\alpha}{2} - \frac{\pi\alpha}{360^0}\right) = r^2\left(\tan\frac{\alpha}{2} - 0.008727\alpha\right)$$

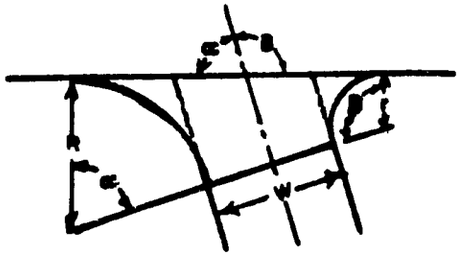
$$\text{Length of return, } L_c = \frac{\pi r\alpha}{180^0} = 0.0174533r\alpha$$



90° Fillet

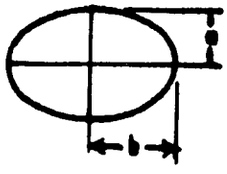
$$\text{Area} = r^2\left(1 - \frac{\pi}{4}\right) = 0.214602r^2$$

$$\text{Length of return, } L_c = {}^1/_2\pi r = 1.570796r$$



Driveway Surface

$$\text{Area} = R^2\left(\tan\frac{\alpha}{2} - \frac{\pi\alpha}{360^0}\right) + r^2\left(\tan\frac{\beta}{2} - \frac{\pi\beta}{360^0}\right) + {}^1/_2w\left(R\tan\frac{\alpha}{2} + r\tan\frac{\beta}{2}\right)$$



Ellipse

$$\text{Area} = \pi ab$$

$$\text{Perimeter} = 2\pi\sqrt{\frac{a^2 + b^2}{2}}$$

(approximately)

Parabola

$$\text{Area} = 2/3\,sh$$

CHAPTER TEN

RIGHT-OF-WAY

GENERAL CONSIDERATIONS

Right-of way plans must be prepared in ways to clearly define the land needed for highway construction. Development of right-of-way plans and the data shown on them requires the cooperative effort of many persons, including :

- Field survey crews
- Title researchers
- Highway designers
- Right-of-way designers
- Right-of-way appraisers

This Chapter is written for the right-of-way designer and sets forth policies and procedures for his guidance in coordinating the preparation of right-of-way plans.

A typical set of right-of-way plans will consist of a title sheet and a series of plan sheets showing alignment, basic topography, coordinate system used, property lines, property owners and a description of the required land.

The base maps for this information should be prepared as soon as possible — even before the specific right-of-way requirements are known. Tracings prepared by the highway designer for construction plans can be readily adapted for right-of-way plans.

RIGHT-OF WAY DESIGN PROCEDURE

The Right-of-Way designers are to follow the basic steps as outlined below in the preparation of right-of-way drawings.

1. After the alignment has been determined by the Road Design Division, the Right-of-Way Division designers prepare initial right-of-way plans. This set of plans is prepared using the Road Design plan and profile sheets. All alignment information, including PC, PT, PI stationing, length and bearing of tangent and curve data, as well as construction limits are traced onto the initial right-of-way plan sheets. Only the plan portion of the plan and profile sheets are used. After this is done, the right-of-way limits are added. These limits are predetermined for the several classes of highways and are shown in Table 10-1. The right-of way limits are then checked against the construction limits. All conflicts are noted. These conflicts will be discussed at the preliminary plan-in-hand (P.I.H.) inspection. For a complete discussion of the plan-in-hand inspection, refer to Chapter Thirteen of this manual.

2. With the initial right-of-way plans complete and possible problem areas noted, the right of-way designer is ready to attend the P.I.H. inspection The right-of-way designer will participate in all P.I.H field inspection trips All right-of-way problems will be discussed at this time Possible problems would be sensitive right-of-way takings, such as choice farmland, graveyards and developed urban areas. Another problem area would be in those areas where the construction limit extends past the standard right-of-way limit.

3. Following the P.I H. inspection, the right-of-way designer should make all corrections to the initial right-of-way plans as found necessary during the inspection. Additional right-of-way takings beyond the standard limits should be fully described.

4. After the initial right-of-way plans are modified to include all changes made during the P I.H. inspection, a land surveyor certified by the Land Bureau will obtain all necessary property ownership data to complete the right-of-way plans. The certified land surveyor, whether a private consultant or a HA employee, is responsible for reducing all property survey notes and preparing final ownership maps. These maps must meet criteria presented later in this Chapter. He is also responsible for obtaining the Land Bureau's official acceptance of the maps prior to their being turned over to the right-of-way designers.

5. After ownership maps are prepared, work on the final right-of way plans can begin. Criteria for preparation of final right-of-way plans are presented later in this Chapter.

6. During steps 4 or 5, a second P.I.H. inspection is normally held. This inspection is held when the road design is about complete. Its purpose is to discuss final details of the project before the construction plans are finalized. Normally, no changes in right-of-way occur. If changes do occur, the certified land surveyor will again have to be contacted and modifications to the ownership maps made before final right-of-way plans are completed.

OWNERSHIP MAPS

Ownership maps are prepared by a certified land surveyor and approved by the Land Bureau. Approval of the ownership maps is obtained by the certified land surveyor and must be obtained prior to their being submitted to the right-of-way designer.

The ownership maps serve as the most important source of ownership data during right-of-way plans preparation. For this reason an effort must be made by the right-of-way designer to ensure that the certified land surveyor includes on the ownership maps all data necessary for completion of the plans.

The ownership maps will consist of two parts. First, the maps themselves are prepared using the initial right-of-way plans for guidance. All property ownership lines are shown using a solid line New parcels created by the right-of-way lines are clearly identified with parcel numbers. These parcel numbers are assigned according to Land Bureau policy. Typical parcel numbers and their meaning are shown later in this Chapter. Coordinates for control points, such as PC, PT, PI and Point on Tangent (POT), are converted into the local land coordinate system.

A full description of the coordinate systems used and any other Land Bureau documents used in the preparation of the maps should appear on each ownership map. These ownership maps are prepared in the same scale as the initial right-of-way plans.

The second document prepared by the certified land surveyor is a compilation of ownership data. The following list shows the data necessary.

- Owner's name and address
- Original property parcel number
- Area of original property
- Class of land
- Parcel number of property taken
- Area of property taken
- Parcel number of remaining property
- Area of remaining property.

This list of data must also be approved by the Land Bureau prior to being turned over to the right-of-way designer.

INITIAL RIGHT-OF-WAY PLANS

Initial right-of-way plans are traced from the plan portion of the Plan and Profile sheets of the construction plans, as prepared by the Road Design Division.

All alignment information, such as tangent bearings complete curve data and match lines, are placed on the plans All P.C., P.T., P.I and P.O.T. coordinates are also placed on the plans. Items that are important during negotiations with the owners will be shown on the right-of-way plans. Examples of such items are trees, hedges, bushes, sidewalks, paved driveways, underground utilities and waterwells. Buildings are always shown. These data are normally shown on the roadway design topographic plans and can merely be transferred onto the initial right-of-way plans.

FINAL RIGHT-OF-WAY PLANS

Right-of-Way Plan Set Organization

Right-of-way plans will contain three different types of sheets. These sheets are, in order of their appearance, the title sheet, ownership summary sheets, and plan sheets.

A description of their contents and layout is discussed below. The size of the original sheets and title blocks will be the same as for construction drawings as discussed in Chapter Fourteen.

Title Sheet

The title sheet is normally a modified construction plan title sheet. Typical right-of-way symbols and a table of contents appear on the title sheet.

A typical completed right-of-way title sheet is shown at the end of this Chapter.

Ownership Summary Sheets

Ownership summary sheets are placed immediately after the title sheet. These sheets are similar to the summary sheets in the construction plan set. A summary of ownership information appearing on the summary sheet contains the following items.

- Owner's name and address
- Original property parcel number
- Area of original property
- Class of land
- Parcel number of property taken
- Area of property taken
- Parcel number of remaining property
- Area of remaining property.

A typical completed ownership summary sheet is shown at the end of this Chapter.

Plan Sheets

Plan sheets are normally prepared by tracing the ownership maps directly. In the event the ownership maps were not prepared using the same scale as the initial right-of-way plans, plan sheets will be prepared using one of the following scales.

Urban Areas	1cm = 5m
Rural Areas	1cm = 10m

These scales are the same as those used for plan and profile sheets prepared by the Road Design Division.

Additional information which must be added to these sheets is discussed in the next section of this Chapter entitled "Right-of-Way Design Criteria."

A typical completed right-of-way plan sheet is shown at the end of this Chapter.

RIGHT-OF-WAY DESIGN CRITERIA

This section sets forth policies and criteria to guide the right-of-way designer in establishing and documenting right-of-way requirements.

Construction Limits

The principal guide for design of right-of-way is the identification of actual construction limits established by the roadway designer.

When highway design has progressed to a point that construction limits can be identified with a reasonable degree of certainty, the right of-way designer will receive the highway plans showing the limits of construction and other construction orientation guidelines. These data are then sketched onto the initial right-of-way plans, using a light, dashed line for top of cut and a light, dotted line for toe of fill. The area of "slope rounding" should be included as a part of the construction limits.

Right-of-Way Widths

Obviously, the right-of way must be wide enough to accommodate the identified construction limits.

Minimum values apply only to rural areas and to situations where high R.O.W. cost is not a significant factor. No set rules can be established governing R.O.W. widths in urban areas. Sound judgment must be used to obtain a logical balance between R.O.W. costs and widths.

Existing Right-of-Way

Where the proposed alignment is fairly close to the present traveled way or where it intersects with other highways, the right of-way lines defining previously acquired land should be drawn as a light, dashed line. This information is available from previous right-of-way maps. These lines should be labelled "Existing R/W".

Right-of-Way Breaks

Try to design R.O.W. lines with a few breaks and changes of width as possible. A large number of breaks complicates the writing of R.O.W. descriptions.

The following general criteria should apply :

- A right-of-way width parallel to the centerline should be maintained uniformly for at least 100 meters.
- Except for changes at property lines or extremely large changes (10 meters), changes in right-of-way width should be accomplished with a taper of 4:1.
- Where the width changes between adjacent property owners, the breaks should follow the property line.
- Where widths change close to P.C.'s or P.T.'s, try to make the breaks coincide with the curve points.
- Where width changes are required both left and right, try to make the break-points coincide at the same stationing.
- Take the ownership boundaries into consideration. Sometimes it is advisable to run the right-of-way along the property line, either to avoid leaving a narrow strip of property or to avoid negotiating with another owner.

Beginning or Ending of Project

When right-of way is designed at the beginning and ending of a project, and those points are within the limits of an individual ownership, consideration should be given to acquiring right-of-way through the ownership for future connecting projects so that the owner will not have to be contacted again.

Construction Permits and Easements

Under certain conditions it may not be necessary to obtain permanent possession of land on which construction work is to be performed. Instead, a construction permit should be obtained.

The following general criteria should apply:

- Private irrigation ditches should be designed outside the right-of-way. A construction permit or a construction easement should be obtained. (See Figure 1.)

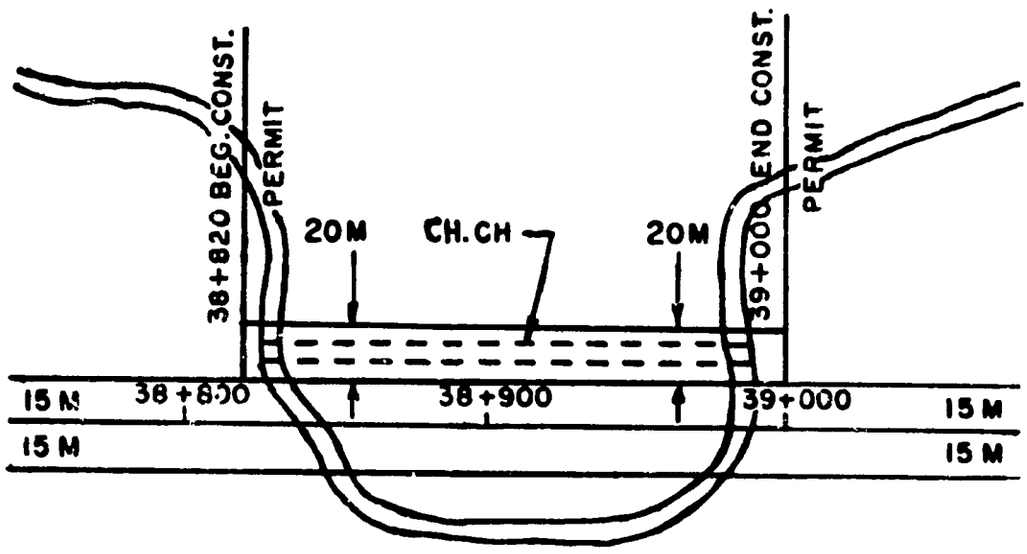


Figure 1

- When Government-furnished borrow pits are outside the limits of right-of-way, a construction easement for the haul road must be obtained. The land for the actual pit will either be leased or purchased. (See Figure 2.)

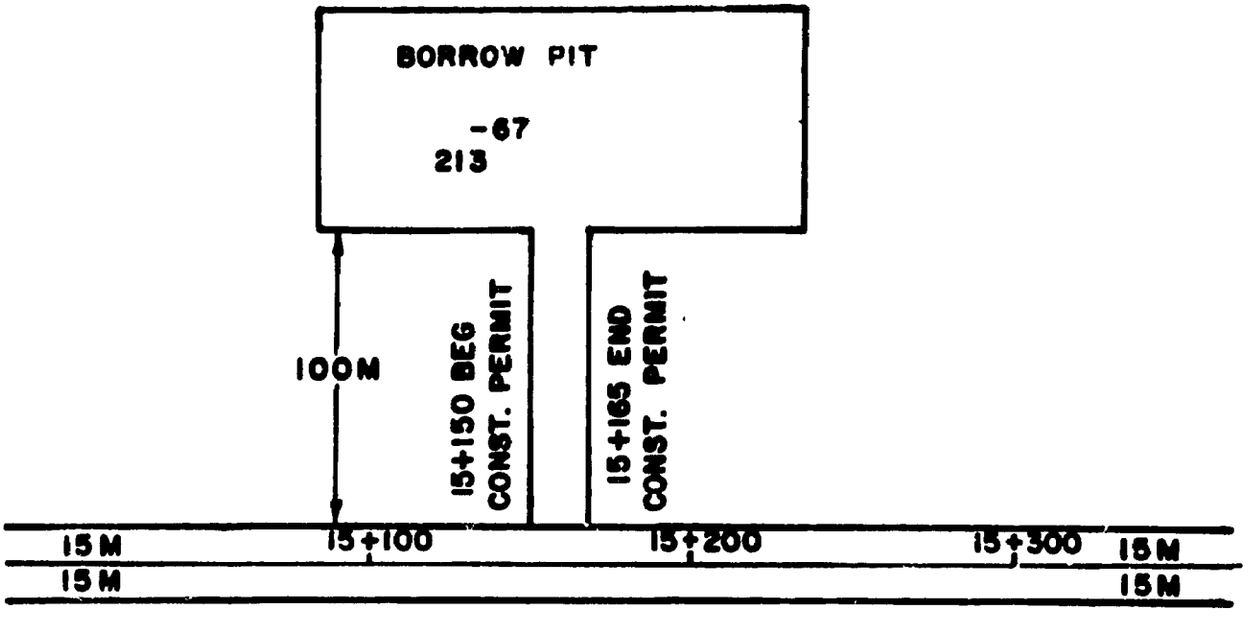


Figure 2

- Right-of-way should be designed to include channel changes for drain ditches, streams or rivers. (See Figure 3.)

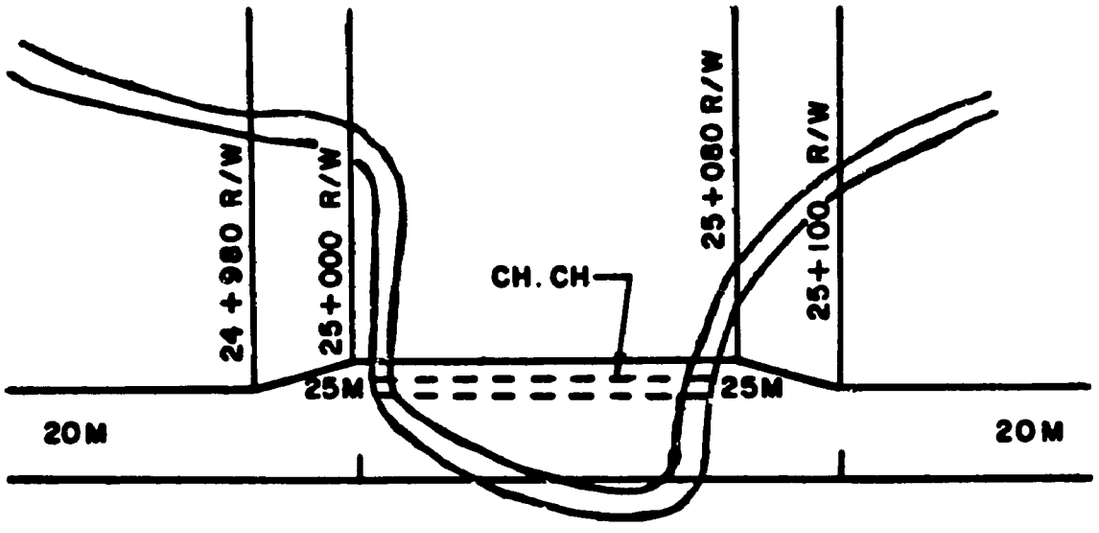


Figure 3

- A construction permit normally will be adequate for minor inlet and outlet ditches outside the regular highway right-of-way. If a concrete spillway is to be built or considerable rip rap is to be placed, additional right-of-way should be obtained to include the spillway. (See Figure 4.)

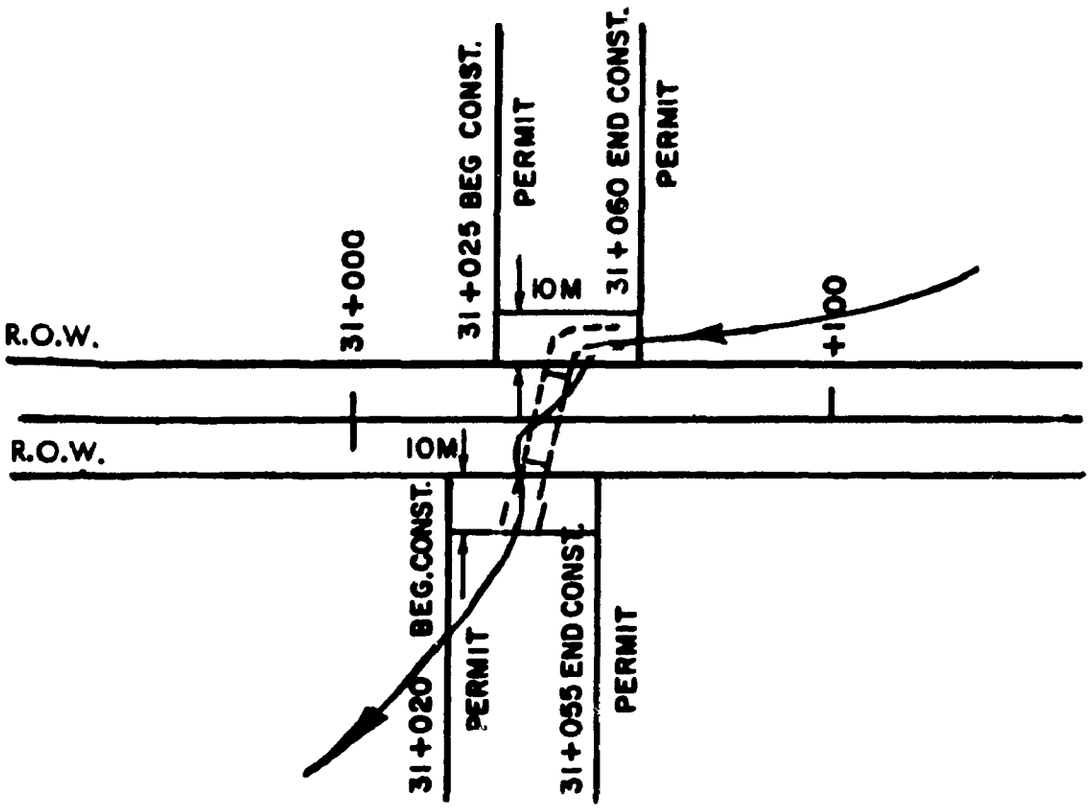


Figure 4

- Construction permits or easements may be required in the case of railroad crossings or encroachments that occur when the alignment is parallel to the railroad. In cases where the highway centerline crosses the railroad centerline, it is necessary to show both the RR stationing and the highway stationing at the point of intersection, the angle between the two lines, and the railroad and highway stationing and offsets from centerline of each point of R.O.W. intersection. (See Figure 5.)

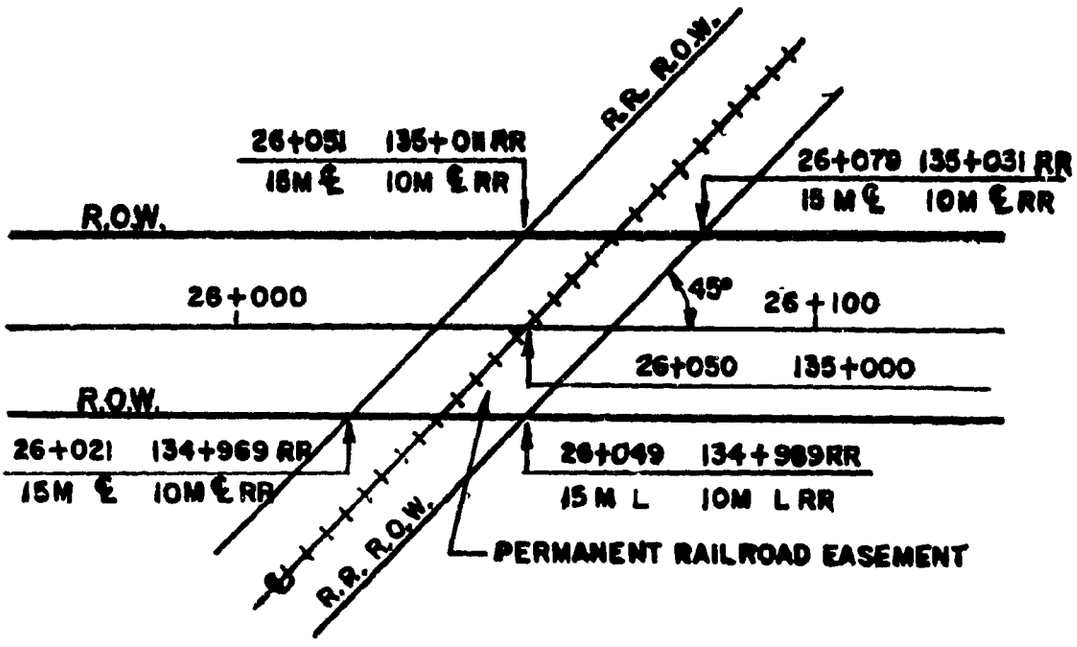


Figure 5

- On a parallel encroachment it is necessary to show the railroad and highway stationing and offsets from centerlines of each right-of-way break. (See Figure 6.)

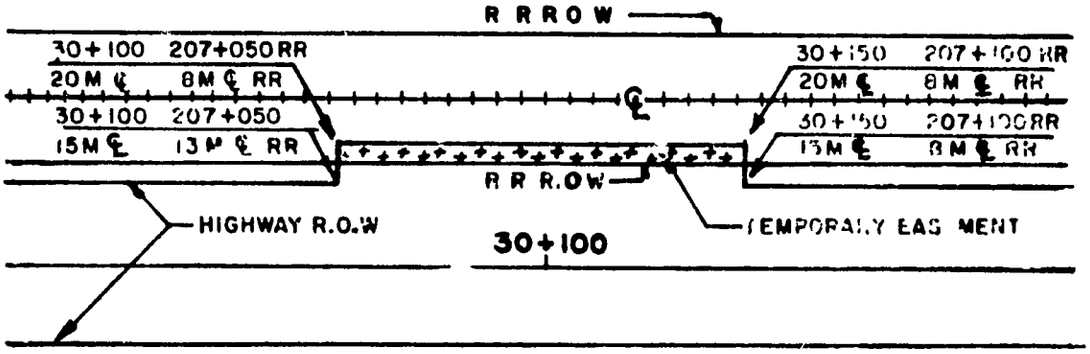


Figure 6

Parcel Numbers

A parcel number can be a single number or letter or a combination of two or more numbers or letters. Typical parcel numbers are shown below:

— 57	— 34
— 183	— C
207	A

The original parcel numbers are 57 and 34. Each time the property is divided, a new number is added. The above examples are for parcels which have been divided twice.

Parcel numbers are for convenience in identifying the different land parcels to be acquired for a specific project. Parcel numbers for right-of-way takings are numbered consecutively, starting at the beginning of the project. These numbers are assigned by the Land Bureau.

The following criteria should be kept in mind :

- Where there is a complete severance as shown by the cross-hatched area in figure 6, the separated portions of property belonging to the same owner are given different parcel numbers. (See Figure 7.)

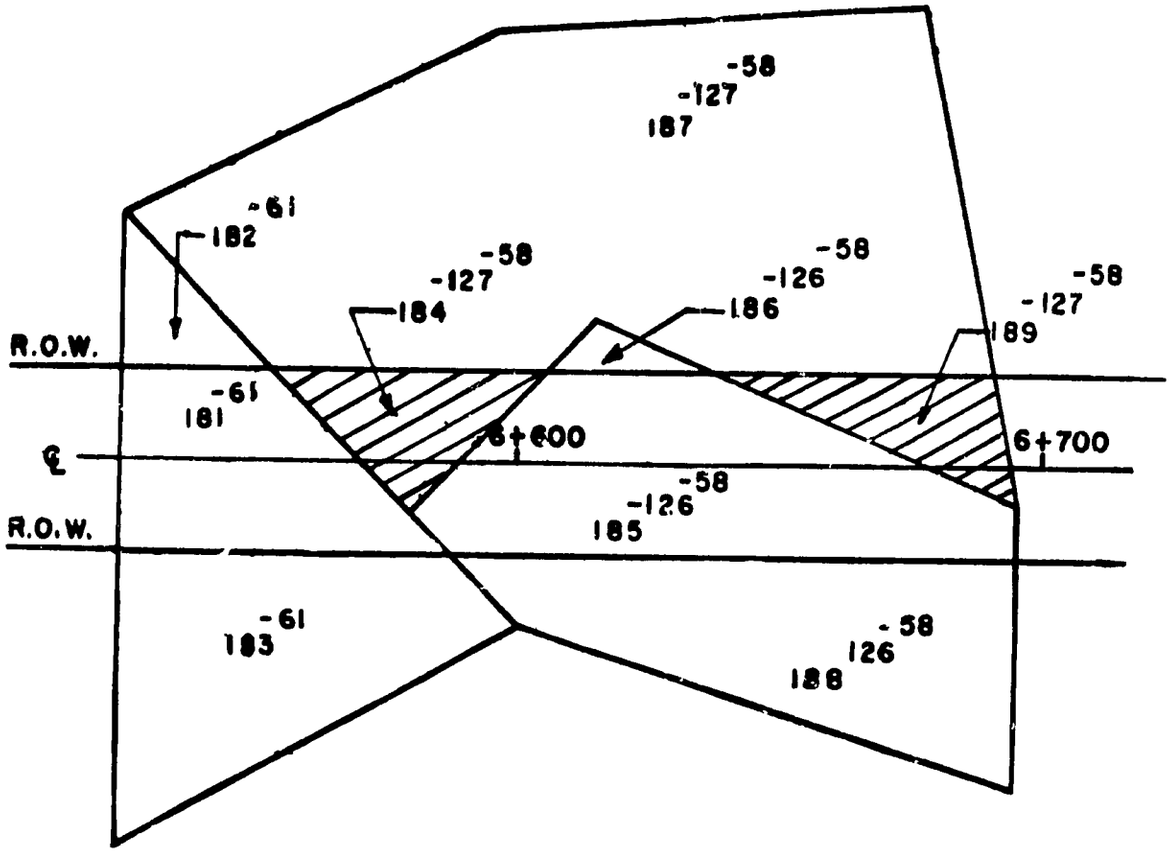


Figure 7

- Different parcel numbers for the same owner are necessary where a dedicated street or alley separates the lots of that owner.
- Different parcel numbers for the same owner are necessary where a project runs from one province into another.
- Where existing right of-way is adequate, it is not necessary to assign a parcel number unless the grade change may cause damage to the property.
- Where additional width or length of a tract is acquired subsequent to acquisition of the original tract, and a second deed is required from the same owner, the additional tract should be identified with a supplemental tract number.
- An addition in width or length of a parcel *prior* to acquisition of the original right-of-way requires revision of the description and retention of the original parcel number.
- A parcel originally under one ownership, but which is divided into two or more ownerships prior to acquisition, requires treatment as two or more individual parcels. The original parcel number will be retained for that portion still under the original ownership Portions under new ownership will be given the same parcel number, but with *an additional number*, such as

  $$\frac{-27}{153}, \quad \frac{-27}{154}, \quad \frac{-7}{155}, \quad \text{etc.}$$

- Temporary construction permits require a parcel number unless acquired with another parcel.

Area Determination

When computing the areas taken and the areas which remain, compute and record them to the nearest square meter. This applies both in urban and rural areas.

Examples of Right-of-Way Plans

The following pages illustrate examples of a typical title sheet, ownership location map and right-of-way plan sheet.

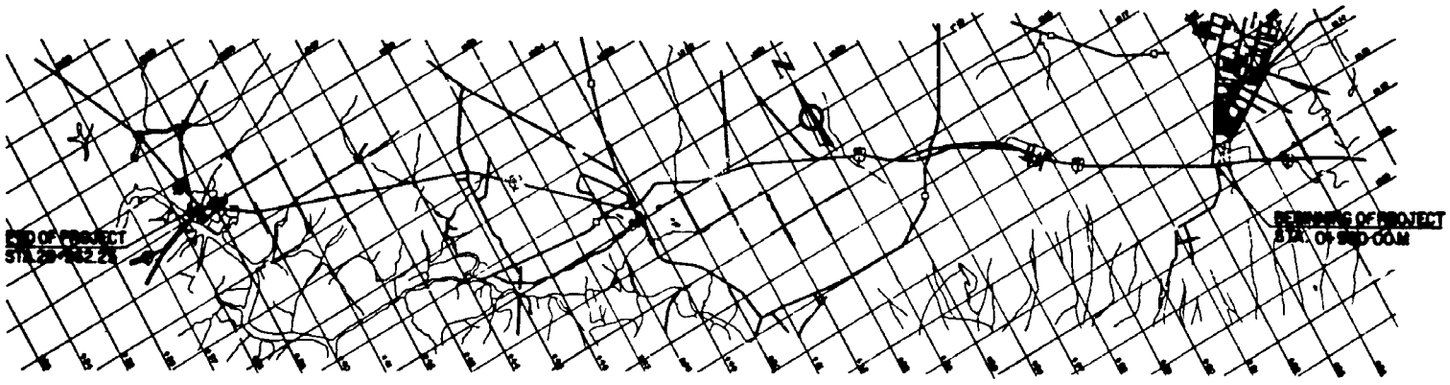
MINISTRY OF PUBLIC WORKS & COMMUNICATION
HIGHWAY ADMINISTRATION

PROJECT NO 01(02)000+960 LG
RIGHT OF WAY

LENGTH 28.0 KILOMETERS

RIGHT OF WAY SYMBOLS

RIGHT OF WAY LINE	
EXISTING ROW	
INTERNATIONAL BORDER	
PROVINCE BORDER	
CITY OR VILLAGE LIMIT	
CERRECL DE	
RAILROAD	
RAILROAD ROW	
FENCE	
PROPERTY LINE	
TELEPHONE POLE	
POWER POLE	
TEL AND POWER POLE TO BE REMOVED	
FILL SLOPE	
CUT SLOPE	
PARCEL NUMBER	
NEW PIPE	
OLD PIPE TO PLACE	
DITCH	
OUTLET DITCH	
INLET DITCH	
CHANNEL CHANGE	
STRUCTURE	
TEMPORARY EASEMENT	



PREPARED BY	SUBMITTED	APPROVED
CHIEF RIGHT OF WAY ENGINEER DATE	DIRECTOR OF ENGINEERING DATE	DATE

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OWNERSHIP SUMMARY SHEET

OWNER	ADDRESS	ORIGINAL PROPERTY		CLASS OF LAND	AMOUNT TAKEN		REMAINDER	
		PARCEL #	AREA HECT		PARCEL #	AREA HECT	PARCEL #	AREA HECT
PLAN SHEET NUMBER 14								
		232-172	3 0000	RICE FIELD	244 232 172	0 1040	232-72	"
		174	2 4000		243 174	0 7200	174	"
		173	1 1030		245-173	0 0830	173	"
		180	7 558		246-9	1 4470	180	"
		97-180	3000		247 197 60	0 3620	97-180	"
		183	5 0740		248-183	0 6380	183	
							238-183	
		205-186	38560		249 205 186	1 2160	205 186	
							243 205 186	"
		204	1 0400		250-204 156	0 0210	204-186	"
		186	2 1120		251-186	1 5920	186	"
							240-186	
		188	1 9840		252-188	0 1750	188	"
		87	0 4000		253-187	0 3550	137	
							187	
							241	
		13	2 2560		255 13	0 1840	13	
		7	2 6400		254-7	0 0100	7	
		12	2 4800		256-12	1 3650	12	
							236 2	
		11	4 6400		257 11	1 5950	11	"
							233 11	"
		17	4 0480		258 7	1 3760	17	
		8	4 8000		259 8	7290	18	
							236 18	
		2	5 2480		260 21	1 3440	21	
							237	
		2	5 8080		261	0 1600	22	
PLAN SHEET NUMBER 15								
		48	0 0420	RICE FIELD	93 48	0 0200	18	0 2020
		62 47	6110		99-62 47	0 1090	62 47	1 5020
		63 47	1 3306		28 63 47	0 0466	63 47	1 2840
		64 47	1 4 75		9 63 47	0 0055	64 47	4120
		65 48	0 2469		5 48	0 2488		
		68-48	1 2094		68 48	0 2094		
		69-48	1 1985		95 69-48	0 940	67-48	
		70 48	0 2644		95 70 48	0 8199	7 48	
		7 48	0 1602		94 71 48	0 0922	48	"
		36	0 0900	GARDENING LAND	367 16	0 1030	36	
		37	0 8 50	PINE APPLE	368 37	0 6 90	37	
		57	0 2700		372 57	0 1900	57	
		58	0 6050		371 58	0 2340	58	
		59	0 5700		370 59	0 4695	59	
		60	0 3568		369 60	0 0788	60	
		62	0 7800		374 62	0 4 90	360 6	"
							62	
		64	1 1600		373-64	0 0010	64	
		108	1 2150		375 108	0 0210	108	"
		44	0 4050	RICE FIELD	383-144	0 0190	104	"

OWNER	ADDRESS	ORIGINAL PROPERTY		CLASS OF LAND	AMOUNT TAKEN		REMAINDER	
		PARCEL #	AREA HECT		PARCEL #	AREA HECT	PARCEL #	AREA HECT
PLAN SHEET NUMBER 15 (Con t)								
		148	0 0900	PINEAPPLE	389 148	0440	148	0 4100
							382-148	0 1410
		149	0 4850		382-149	0 4090	149	0 0760
		152	1 6550		383 152	0 7620	152	0 8250
							381 152	0 0480
		153	0 8950		382 153	0 3140	153	0 5810
		154	0 2050	RESIDING LAND	384 154	0 0350	154	0 1700
		157	1 2850	PINEAPPLE	380 157	0 2780	157	1 0070
		158	0 0040					
				"	377-158	0 2800	158	0 6650
		372						
		159	"		376-159	0 6610	159	0 1840
		160			378 160	1 1600	160	0 3930
		161	"		381-161	0 4990	161	0 0360
		62			337 162	0 2260	162	0 7790
		167	"		386 167	0 1680	167	0 6170
		168	"		387 168	0 0070	168	0 8180
		169	"		389 169	0 0880	169	0 2570
		170			390 170	0 0060	170	1 290
		172	"	GARDENING AN	391-17	0 6150	172	0 1100
		173	"	RESIDING LAND	392 173	0 0480	173	0 0020
		174		GARDENING LAND	396-174	0 5450	4	0 3850
		75		RESIDING LAND	397-175	0 0250	175	0 0100
		176		GARDENING AND	176	0 0300		
				RESIDING LAND	177	0 3750		
		178		GARDENING AND	395 178	0 340	178	0 7 0
		79		RICE FIELD	98 179	0 820	179	0 3530
		83		RESIDING LAND	394-183	0 0 10	83	0 2930
		267			4 7 267	0 2705	267	0 2545
		68	BAR	RUBBER	4 0 268	0 652*	268	0 0075
		269			4 9 269	3275	269	0 1715
							363 269	0 0110
		270	MAX		420 270		270	1 2430
		272	"	RESIDING LAND	418 272 274	36	272	0 3550
		363		RICE FIELD	407-364		364 74	0 0465
		275	"	GARDENING LAND	409 275		275	0 0330
		276	"	RESIDING LAND		"		-
		2	"	"	4 6 277	"	277	0 1600
		286	"	GARDENING LAND	4 5 286	-	286	0 1780
		287	"	RESIDING LAND	414 287	"	287	0 2 00
		288	"		288	"		
		289	"		413-289		289	0 0860
		290			412-290	33 x1	290	0 0800
		293	"	RICE FIELD	411-293	"	293	0 3770
		294			399-294		294	0 0215

REVISIONS		RIGHT OF WAY OWNERSHIP SUMMARY SHEET
		PROJECT NO OR 1021003+980 LB

LOCATION TABULATION

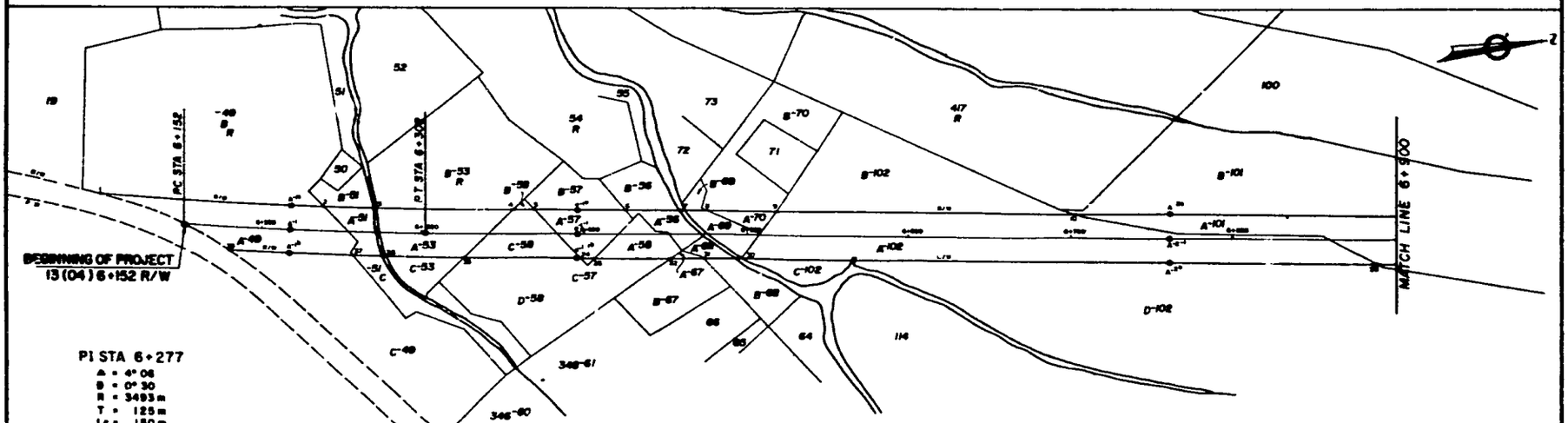
PARCEL	AREA	CLASS OF LAND	NORTHWEST	SOUTHEAST	NORTHEAST	SOUTHWEST	REMARKS
A-48	5891 m²	River Front	Adjacent to A-51	Adjacent to C-49	Adjacent to B-49	Adjacent to TL 24	River and Regulation No. 150
B-49	17900 m²		Adj. to B-50 and B-51	Adj. to A-49	Adjacent to 47 and 19	Adj. to 19	
C-49	7700 m²		Adj. to C-51	Adj. to 348-49	Adj. to A-49	Adj. to TL 24	
Parcel 49	30 30 m²						
A-51	720 m²	River Channel	Adj. to B-51	Adj. to River Channel	Adj. to A-49	Adj. to C-51	River Reg. No. 34
B-51	900 m²		East Adj. to River Channel	West Adj. to B-49 and 50	South Adj. to B-51	North Adj. to 47 and new channel	
C-51	900 m²		East Adj. to River Channel	West Adj. to C-49	South Adj. to B-49	North Adj. to A-51	
Parcel 51	0 500 m²						
A-52	30 00 m²	River Front	Adj. to C-52	Adj. to C-53	Adj. to B-53	Adj. to B-52 River Channel	River Front Reg. No. 107
B-52	37800 m²		Adj. to 54	Adj. to A-53	Adj. to 52	Adj. to River Channel	
C-52	0652 m²			Adj. to B-52 and 50	Adj. to A-53	Adj. to River Channel	
Parcel 52	0700 m²						
A-53	0 1 m²	River Front	Adj. to A-52	Adj. to A-57	Adj. to A-57	Adj. to B-53	River and Reg. No. 64
B-53	22 m²			Adj. to B-57	South Adj. to C-53	Adj. to B-53	
C-53	2100 m²		Adj. to B-53	Adj. to A-57	Adj. to A-53	Adj. to B-53	
B-54	4030 m²		Adj. to C-52 C-57 and B-55	Adj. to A-57 B-57 and 348-61	Adj. to C-52	Adj. to 55	
Parcel 53	0000 m²						
A-57	1271 m²	Dredged	Adj. to B-53 and B-53	Adj. to C-57	Adj. to B-57	Adj. to C-53	Dredging Reg. No. 64
B-57	1030 m²		Adj. to 54	Adj. to B-53	Adj. to B-53	Adj. to B-53 and B-57	
C-57	30 m²			Adj. to B-53	North Adj. to A-57	Adj. to B-53	
Parcel 57	0000 m²						
A-58	40 m²	Residential Land	Adj. to River Channel	Adj. to A-59	Adj. to B-57	Adj. to 7 17 and A-59	Residential Land Registration No. 44
B-58	494 m²		Adj. to 55 and River Channel	Adj. to A-58	Adj. to 5	Adj. to B-57	
Parcel 58	230 m²						
A-67	36 m²	River Front		Adj. to A-69	South Adj. to B-67	Adj. to A-69	River Front Reg. No. 142
B-67	2 24 m²		Adj. to B-68	Adj. to 66	Adj. to A-67	Adj. to A-69	
Parcel 67	2 69 m²						
A-68	63 m²	Water Courses	Adj. to River Channel	Adj. to B-68	Adj. to A-96	Adj. to A-67	Water courses Reg. No. 142
B-68	897 m²		Adj. to B river Channel	Adj. to 64	Adj. to A-68	Adj. to B-67 64 and 65	
Parcel 68	060 m²						
A-69	556 m²	Water Courses	Adj. to A-70	Adj. to A-72	Adj. to B-69	North Adj. to River channel	Water courses
B-69	204 m²		Adj. to B-70	Adj. to B-70	Adj. to 72	Adj. to A-69	
Parcel 69	50 m²						
A-70	324 m²	Single cons	North Adj. to B-70	Adj. to A-101		Adj. to A-69	Single cons Reg. No. 57
B-70	26 6 m²		Adj. to 417	Adj. to B-102 and 71	Adj. to 73 and 72	Adj. to B-69 and A-69	
Parcel 70	2940 m²						
A-102	8964 m²	River Front	Adj. to B-102 and A-101	Adj. to A-101	Adj. to A-70 and A-69	Adj. to C-102 B-101 and river Channel	River Front Reg. No. 80-140
B-102	53 6 m²			Adj. to 417	South Adj. to A-102	Adj. to B-70 and 7	
C-102	94 m²		North Adj. to A-102	Adj. to River Channel		Adj. to River Channel	
B-101	32973 m²		Adj. to A-101 and C-101	Adj. to C 03 and 108 109	Adj. to A-102	Adj. to River Channel and 113	
Parcel 101	40 00 m²						
A-101	7081 m²	River Front	Adj. to River Channel and A-103	Adj. to C-101	Adj. to B-101 and 417	Adj. to A-102	River Front Reg. No. 127
B-101	12436 m²		Adj. to 100	Adj. to River Channel	A. to	Adj. to A-101	
C-101	4613 m²		Adj. to C 105	Adj. to A-101	Adj. to D-102		
Parcel 101	9900 m²						

LAND COORDINATE

POINT NO.	E	N	NOTES
A-[illegible]	827 70	3172 04	Reinforced concrete monument (R/W)
A	942 6	73 83	Transmission power
A-[illegible]	957 04	3472 40	Reinforced concrete monument (R/W)
[illegible]	940 07	3436 86	
[illegible]	963 09	3949 4	Transmission power
[illegible]	979 09	3347 35	Reinforced concrete monument (R/W)
A-[illegible]	993 96	4220 33	
A-[illegible]	916 72	4389 3	Transmission power
A-[illegible]	923 74	42 6 64	Reinforced concrete monument (R/W)

RIGHT OF WAY COORDINATE

POINT	E	N	NOTES
	1003 66	3353 35	Stone monument (corner)
2	03 2	3507 30	
3	1035 09	3720 01	
4	044 33	30 22	
5	1046 54	3913 14	
6	105 47	3970 10	
7	1057 30	30 9	
8	1060 30	3930 30	
9	1062 07	3972 19	
10	1064 32	4 40 30	
20	1130 35	4330 17	
30	109 10	3946 00	
3	1090 78	3922 15	
32	1096 47	3907 33	
33	1102 35	3890 47	
34	1114 30	3840 02	
35	1172 60	3770 9	
36	1166 62	373 30	
37	1163 19	3760 37	
38	1140 68	3620 49	



GRAPHIC SCALE

SCALE

REVISIONS

SYMBOL	DESCRIPTION	DATE	APPROVAL

RIGHT OF WAY

PROJECT NO 13 (04) 6+152 LS

SH NO 3 of 9

-152-

CHAPTER ELEVEN

MISCELLANEOUS DESIGN

Several highway design criteria are not directly related to the major topics covered elsewhere in this manual. These miscellaneous criteria are presented in this Chapter.

AIRWAY HIGHWAY CLEARANCES

Within 5 kilometers of airports, highways must be designed to provide minimum clearances between the highways and the navigable airspace. Navigable airspace, minimum clearances and related criteria are discussed below.

Navigable Airspace

Navigable airspace at the ends and to the sides of runways is illustrated in the following figures. Navigable is defined as the space above the approach surfaces and transition surfaces adjacent to a paved or unpaved runway. Highway appurtenances such as overhead signs and light standards must not penetrate navigable airspace.

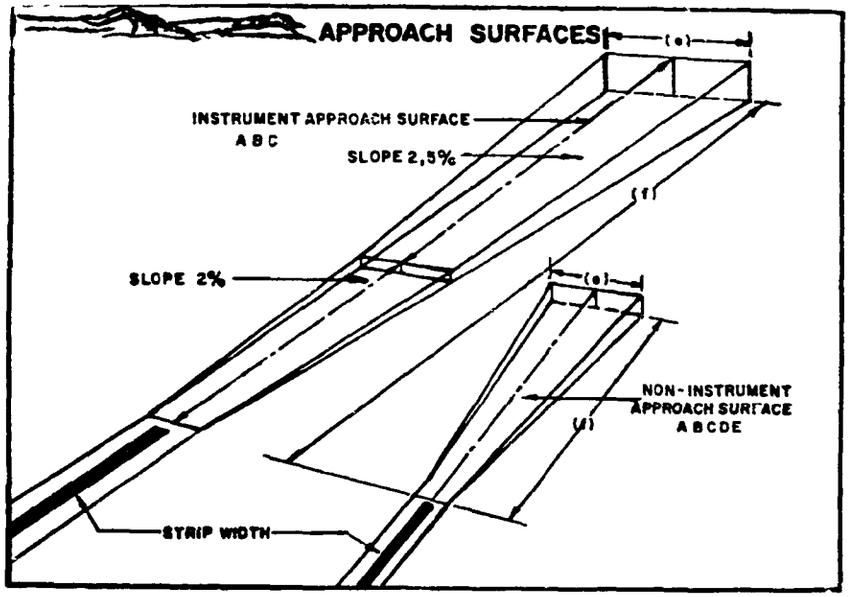
Minimum Clearances

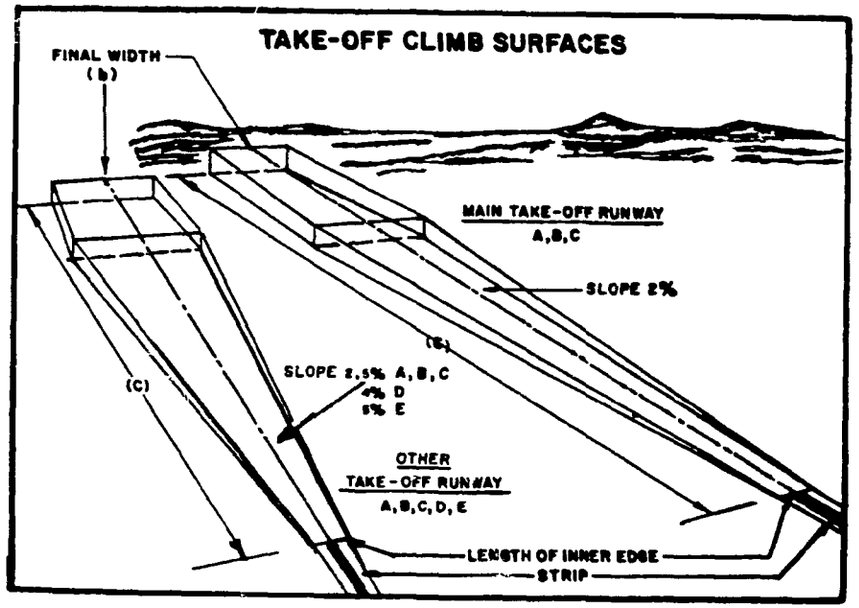
The minimum vertical clearances between the near road shoulder and the navigable airspace are set forth in the following table. These criteria apply to military and civil airfields. The designer should take into account:

- future surfacing overlays which will reduce clearance.
- future growth of the airport which may necessitate highway relocation.

References

For detailed airway-highway clearance regulations, the designer should contact the Directorate of Air Bases. Due to the frequent changes in regulations, the above agencies should be contacted early in the design phase if there is an airport within 5 kilometers of the project.





RUNWAY CODE LETTER	TRANSI-TIONAL SURFACES	BASIC RUNWAY LENGTH M	MINIMUM HORIZONTAL CLEARANCE M	TAKE OFF CLIMB AREAS AND SURFACES			
				LENGTH OF INNER EDGE, M(a)	FINAL WIDTH M(b)	LENGTH M(c)	SLOPE
A,B,C, MAIN TAKE-OFF SURFACES	—	—	250	180	1200	15000	2% (1 50)
A	14 3% (1 7)	2100 AND OVER	200	180	1200	12000	2.5% (1 40)
B	14 3% (1 7)	1500 AND OVER	200	180	1200	12000	2 5% (1 40)
C	14 3% (1 7)	900 AND OVER	200	180	1200	12000	2.5% (1 40)
D	20% (1,5)	750 AND OVER	150	80	580	2500	4% (1 25)
E	20% (1 5)	600 AND OVER	100	60	380	1600	5% (1 20)

RUNWAY CODE LETTER	APPROACH AREA AND SURFACES				
	LENGTH OF INNER EDGE, M(d)	FINAL WIDTH M(e)	LENGTH M(f)	SLOPE OF INNER 3000 M	SLOPE BEYOND 3000 M
A,B,C, INSTRUMENT APPROACH AREAS	300	4800	15000	2% (1 50)	2 5% (1 40)
A	150	750	3000	2 5% (1 40)	—
B	150	750	3000	2 5% (1 40)	—
C	150	750	3000	3.3% (1 30)	—
D	80	580	2500	4% (1 25)	—
E	60	380	1600	5% (1 20)	—

Data Conform to International Standards and Recommended Practice
AERODROMES, Annex 14 Sixth Edition – Sept 1971

POWERLINE CLEARANCES

During the design of a highway minimum clearances for powerlines and poles must be observed. For high voltage powerlines the following minimum clearances are to be used.

Powerlines carrying	Vertical	Horizontal
15,000 Volts or less	7.5 meters	30 meters
over 15,000 Volts	8.5 meters	30 meters

For more detailed information concerning electrical clearances the designer should contact the Power Company.

GUARDRAILS GUIDE POSTS AND MEDIAN BARRIERS

The purpose of guardrail is to protect traffic from hazardous conditions along the roadside. The designer must be aware that guardrail is hazardous in itself, and should not be used when it is a greater hazard than the object or condition being "protected". This section discusses the various types of guardrail and median barrier in use, warrants for their use, and their location and place.

Safety Beam Guardrail

Safety beam guardrail consists of a steel W beam offset by wooden blocks from mounting posts spaced between 2 and 4 meters apart. It is designed such that a vehicle striking it at a flat angle will slide along the rail — consequently, there should be no obstructions or points of discontinuity to impede the movement of the vehicle. Posts should be of adequate strength to resist the force against them without failing, although some degree of deflection or "give" is desirable to cushion the impact. Generally, a maximum deflection of 0.5 meters is expected. The rail element itself should be adequately anchored to withstand tensile forces resulting from the drag of the sliding vehicle along the rail and to prevent buckling and pocketing of the rail. Proper design of the rail termination should be realized to alleviate the danger of the end itself.

Reinforced Concrete Guardrail

Reinforced concrete guardrail is used most commonly on bridges and bridge approaches. This type of guardrail consists of concrete posts and rails. Both posts and rails should be of adequate strength to resist the forces acting against them. For more information, refer to Section 513 of the Standard Specifications for Highways and Bridges.

Steel Pipe Guardrail

Steel pipe guardrail consists of posts and rails made of steel pipes 15 centimeters in diameter. The posts will be spaced approximately 2 meters apart and embedded in the embankment sufficiently deep to overcome any overturning force developed during impact.

Wooden Guardrail

Wooden guardrails consisting of square posts and rectangular shaped rails are usually used at temporary bridge sites and as barricades.

Concrete Median Barrier

A reinforced concrete median barrier, originally developed by the New Jersey Department of Transportation, is constructed in an inverted Y section. Usage of this and similar zero-deflection median barriers is primarily between opposing roadways on high volume freeways where neither vehicle movement nor barrier deflection across the narrow median is allowable.

Guide Posts

Guide posts are generally used to mark abrupt changes in shoulder width, at approaches to structures, at drop inlets and at cut sections to provide warning. Guide posts are used to outline horizontal curves and otherwise show the direction of the road Using a reflective surface, such a white paint, and reflector buttons, greatly improve their visibility at night, when it is needed most. Guide posts are also desirable in areas subject to fog.

The choice of providing guardrails or guide posts largely is a matter of hazard involved. Guardrails are designed to resist impact by deflecting the vehicle along the length of the guardrail at reduced speed. Guide posts are not intended to resist impact. If they are designed to resist impact they will not be as effective as guardrail and their cost will greatly increase.

Sources of Information

Information regarding guardrail and median barriers may be found in the following publications :

- NCHRP Report No. 54 : Location, Selection and Maintenance of Highway Guardrails and Median Barriers (1968)
- HRB Special Report No. 81 : Highway Guardrail, Determination of Need and Geometric Requirements (1964)
- A Policy on Geometric Design of Rural Highways (AASHO, 1965).

Warrants For Use

Three warranting features are considered in establishing guardrail placement : (a) embankment geometry, (b) roadside obstacles, and (c) impenetrable roadside hazards in close proximity to the roadway.

Embankment geometry

On low, flat fills it is safer for out-of-control vehicles to "ride out" a slope than to strike a guardrail. On high, steep fills there is less hazard in being redirected by a guardrail than where the vehicle is allowed to travel down the slope.

Chart A plots an equal severity curve for the two conditions mentioned above. This Chart is to be used in determining the need for guardrail.

Roadside obstacles

A great many of all highway fatalities occur when vehicles inadvertently leave the roadway and strike fixed objects. If these objects are removed the vehicle operators would have the opportunity to regain control. Chart B shows a plot of off-the-road incidents occurring within given distances of the edge of the traffic lane. From the Chart it is seen that 80% of the uncontrolled vehicles did not travel more than 8.5 meters from the edge of the traffic lane.

For warranting purposes, an 8-meter zone next to the traveled way is considered the minimum for being kept clear of obstacles. If this zone cannot be cleared due to practical or economic reasons, guardrail may be warranted for these areas.

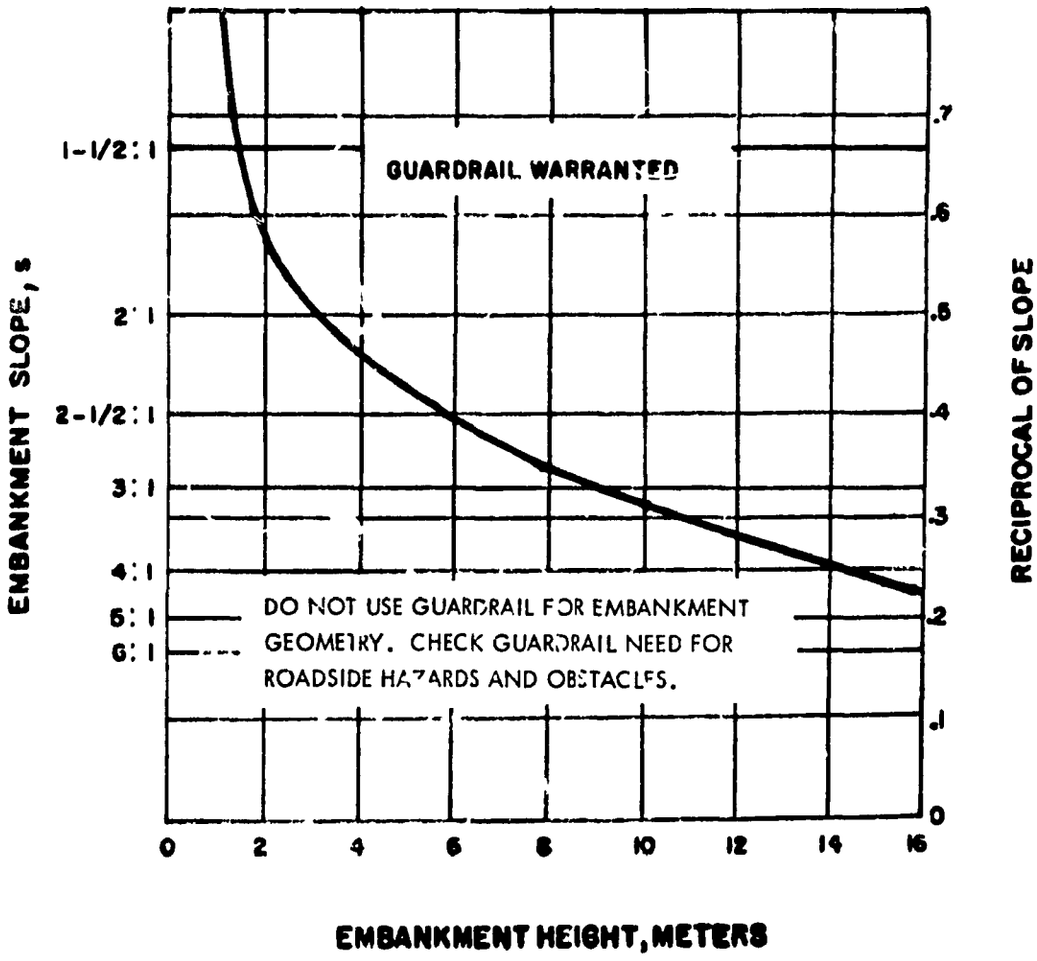
Impenetrable roadside hazards

Roadside hazards are those which are located along a roadway for a considerable distance. Examples of hazards are: (1) rough-rock cuts, (2) large boulders, (3) permanent bodies of water with depth greater than 60 centimeters, (4) dropoffs having a slope greater than 1:1 and depth greater than 60 centimeters, and (5) lines of large trees. Because these hazards occur for some distance along the roadway, the possibility of uncontrolled vehicles striking one of these hazards is greater than that of a vehicle hitting a roadside obstacle. For this reason, guardrail may be needed at hazards located more than 8 meters from the traveled way.

Median Barriers

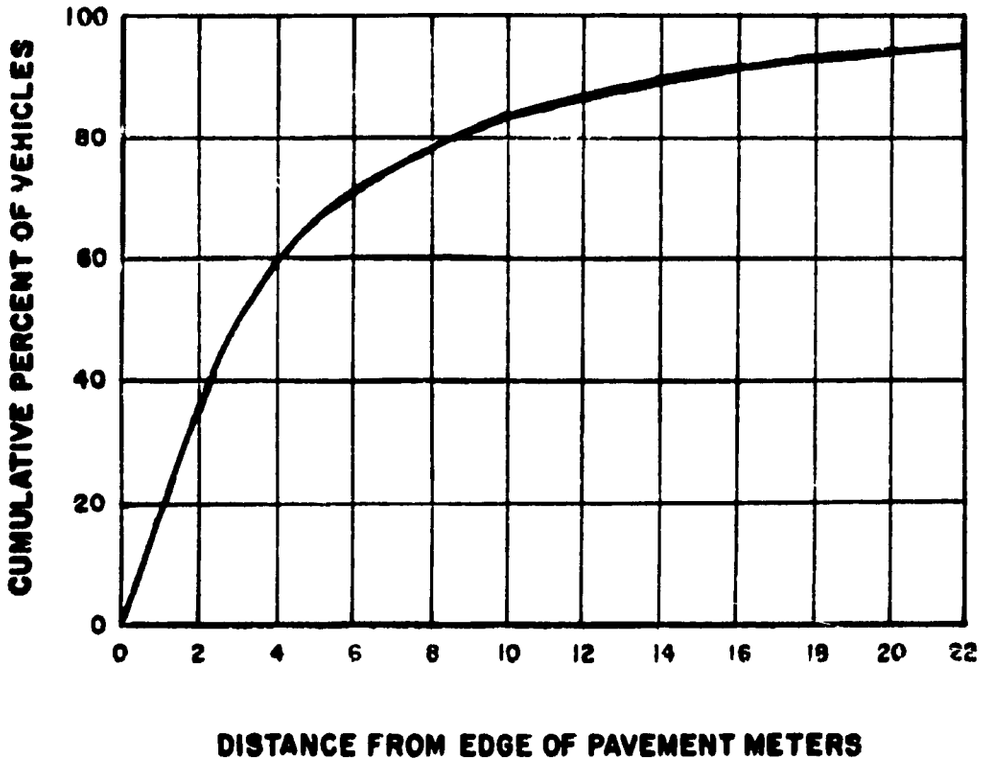
Warrants for median barriers are determined by median widths and traffic volume. Chart C should be used for guidance in determining barrier need.

On all divided highways, regardless of median width and traffic volume, the median roadside must be examined for guardrail warrants, as discussed earlier.



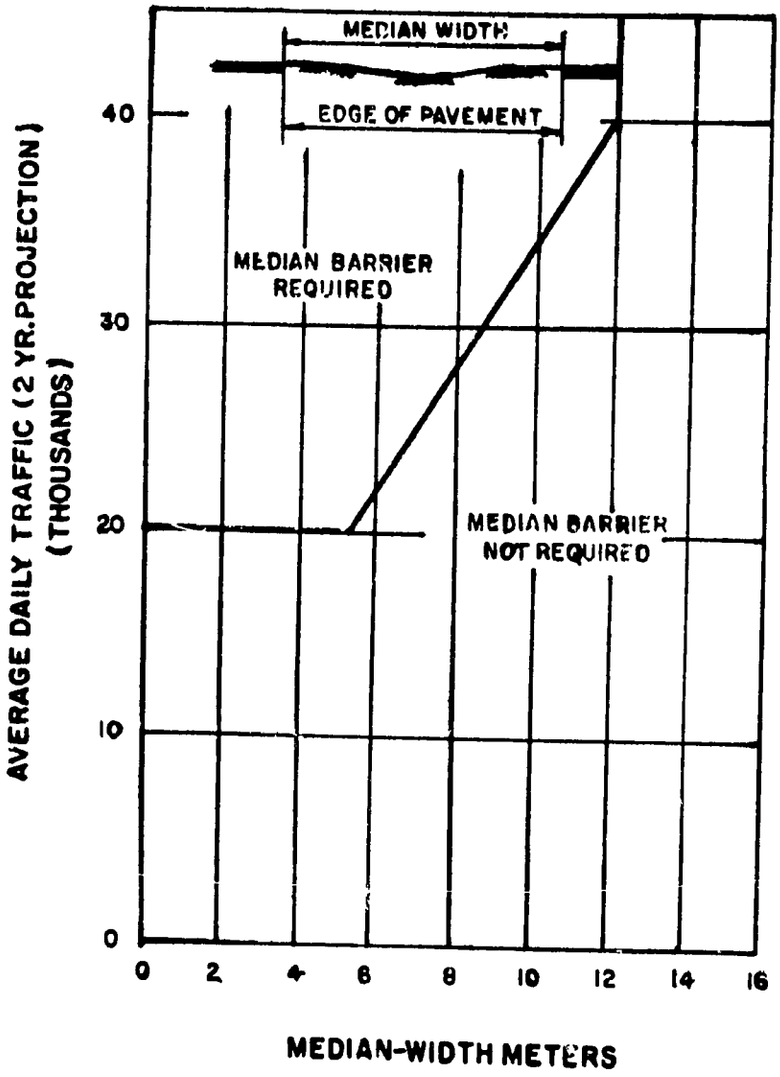
GUARDRAIL REQUIREMENTS FOR EMBANKMENT GEOMETRY

CHART A



DISTRIBUTION OF OFF-THE-ROAD INCIDENTS

CHART B



MEDIAN BARRIER REQUIREMENTS

CHART C

ROADSIDE DEVELOPMENT

The part played by landscaping the roadway in making highways aesthetically pleasing, safer and easier to maintain, should not be overlooked. Careful consideration of landscaping factors should be made during all phases of design. The following discussion lists some of the points which should be borne in mind by the designer — imagination and a sense of totality of the highway function will suggest many more.

- The eventual landscaping of the highway and surrounding area should be taken into account as early as possible, preferably during the preliminary location survey.
- Harsh geometric lines parallel to the highway can be broken and softened by continuing existing tree masses through these lines onto the right-of-way.
- Driver awareness of horizontal and vertical curvature is increased by careful planning of tree lines and hill slopes to give advance warning of directional changes.
- Slopes and cross sections should be designed to blend into the natural lines of the terrain.
- The location of borrow pits and other material sites should be planned with a view to their eventual incorporation into the landscape.
- Vegetative cover around structures is essential for erosion control, enhancing the natural lines of the structure, and by selection of slow-growing shrubs and grasses, maintenance will be reduced.

DETOURS

On almost all projects, detours will be required to maintain traffic flow during construction. Recommendations for possible detour routes should be made by the District Engineer during the plan-in-hand inspection. The designer should be aware of the arrangements made, and will be required to compute quantities of gravel surfacing and other construction necessary to make the proposed detour suitable for traffic.

STAGE CONSTRUCTION

So that projects may be completed in an orderly fashion, the scheduling of construction projects will have to occur during the planning and design phase. In such cases, designs and specifications are prepared for one stage of construction at a time One example of this would be designing a roadway without the final gravel course or asphalt surface. These final items would be added later under a different contract. Stage construction works well when considerable roadway settlement and stabilization are expected. Stage construction is also used when financial constraints limit the scope of the original design.

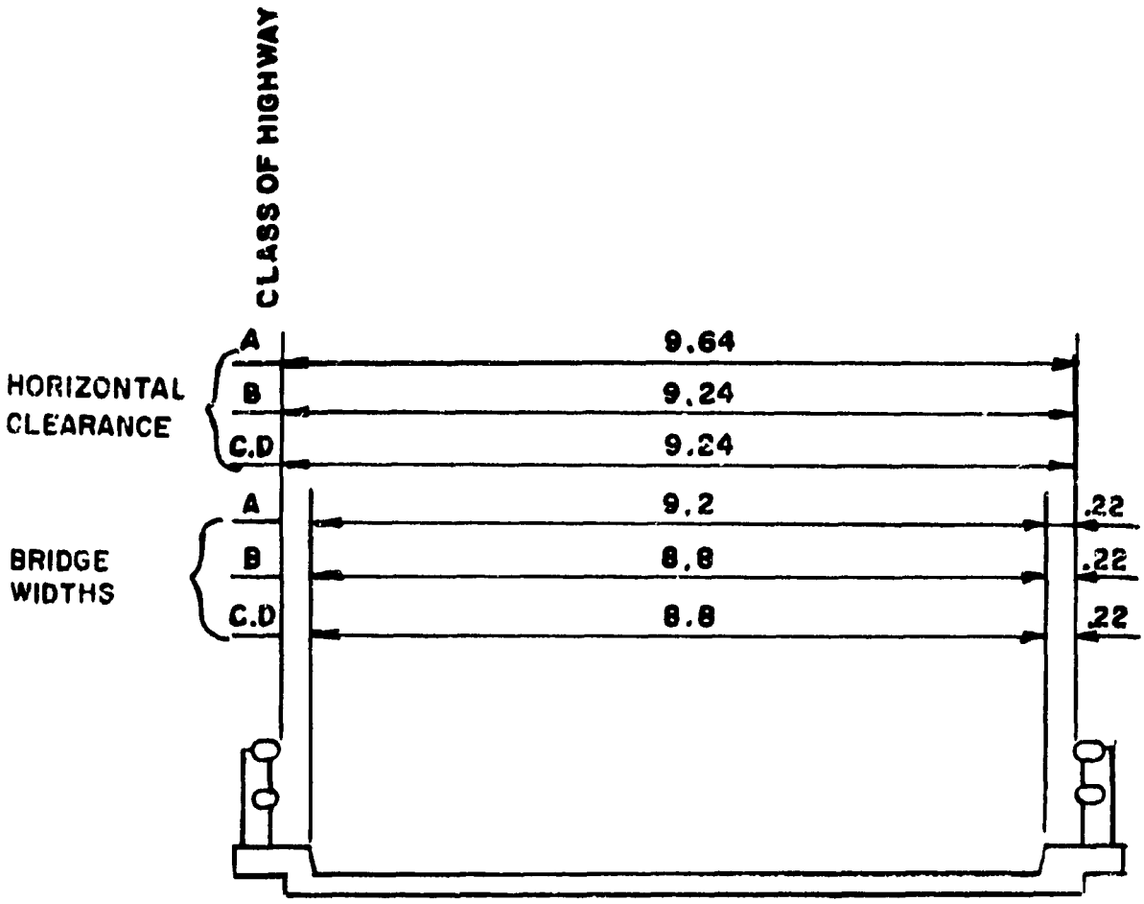
STRUCTURE WIDTHS AND HORIZONTAL CLEARANCES

Roads with wide shoulders, wide gutters and flat slopes are safe and give a sense of freedom. Poles, walks, bridge columns and parapets set close to the pavement are potential hazards and cause drivers to shy away from them. Many drivers move out of their normal lane or change speed abruptly where there is constriction, either actual or apparent, in the roadway ahead. For this reason the clear width on bridges should be as great as feasible, preferably as wide as the approach pavement and shoulders, in order to give drivers a sense of openness. On the other hand, bridges that are long are costly, and on them some compromise from the desirable usually is necessary.

On long bridges, particularly on long-span bridges, where cost per square meter is greater than on short-span bridges, widths less than ideal may be acceptable because restriction in width is compensated somewhat by the tendency of drivers to be alert, to become accustomed to reduced clearance and to drive cautiously. The presence of structural elements, a marked change in the roadside, or a change in the pavement which results in a different appearance and sound, tend to alert drivers. The lighting of bridges at night also affects driver reaction favorably. On the other hand, short bridges are less costly relatively and on them there is less justification for a narrow roadway.

In making conclusions as to the width of roadway over a bridge in determining the dimensions, location and design of the structure as a whole, and in detailing features adjacent to the road, one should aim to provide a facility on which driver reaction and vehicle placement will be essentially the same as elsewhere on the intersecting roads. The width should not be so great as to result in the high cost of structure without proportionate value in utility and safety.

The minimal and desirable bridge widths based on Article 1.1.7 of the AASHO Design Specifications and related to the HA-accepted road pavements and shoulder widths are shown on the following figures.

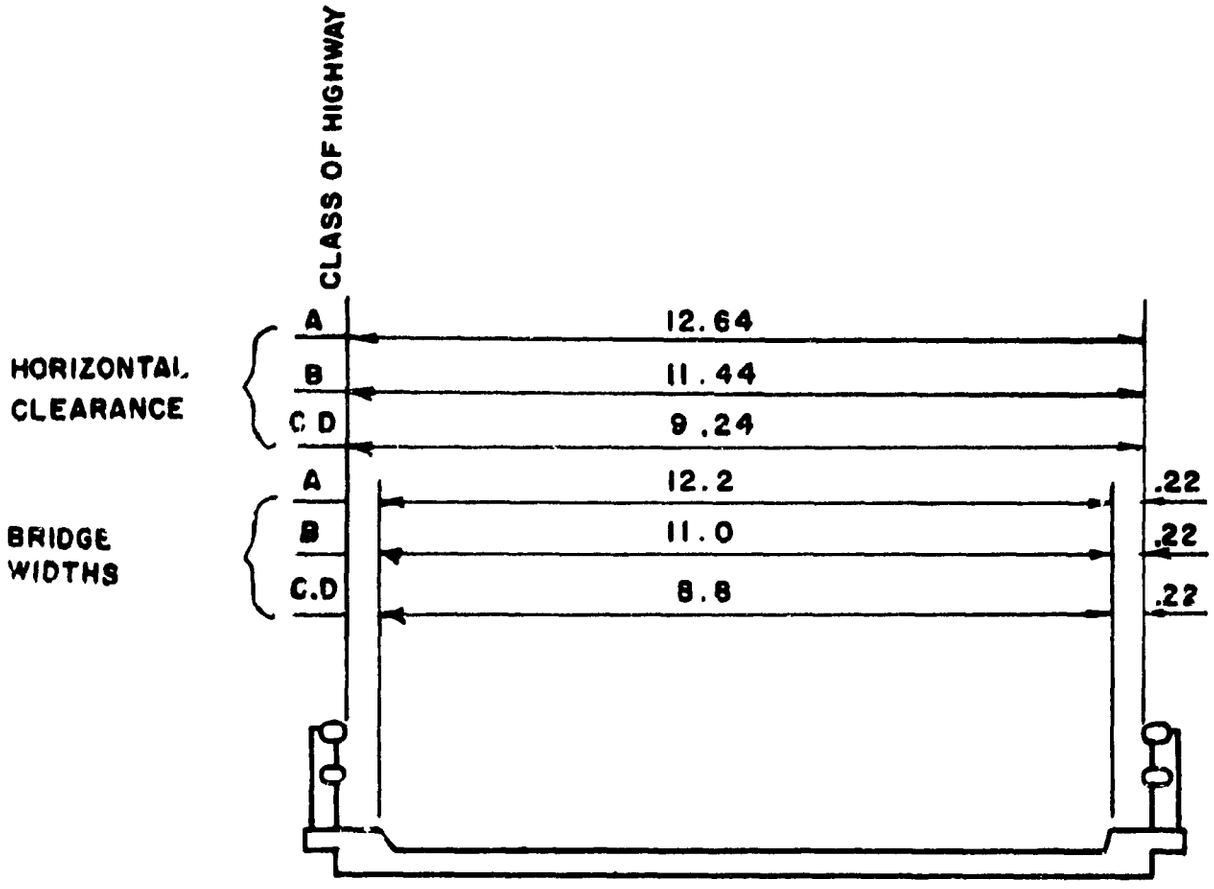


MINIMAL

HORIZONTAL CLEARANCE EQUALS APPROACH PAVEMENT WIDTH PLUS 2.44 METERS

BRIDGE CROSS SECTIONS (WITH BRUSH CURB)

ALL DIMENSIONS IN METERS



DESIRABLE

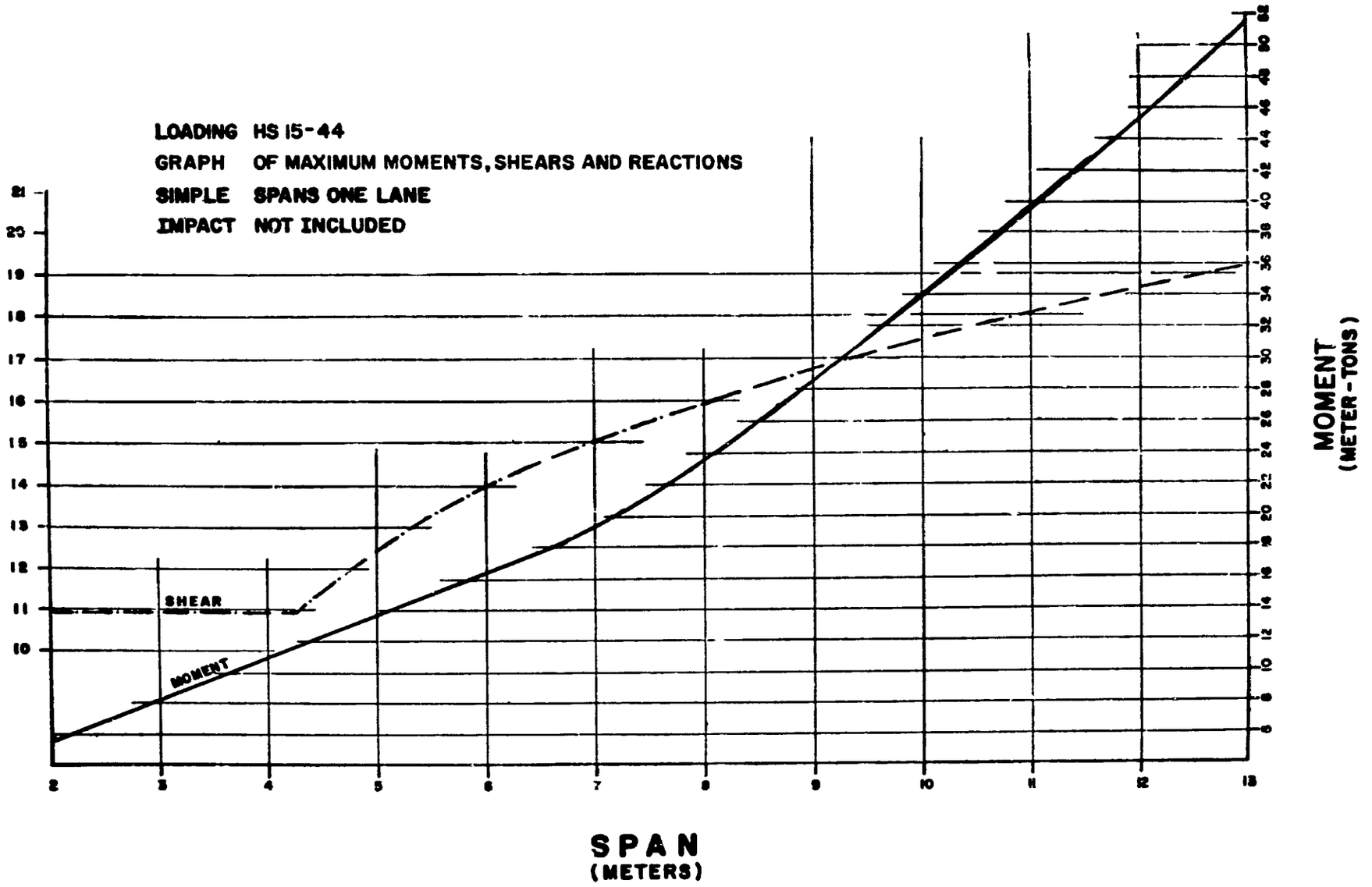
BRIDGE ROADWAY WIDTH EQUALS FULL SHOULDER WIDTH OF APPROACH ROADWAY

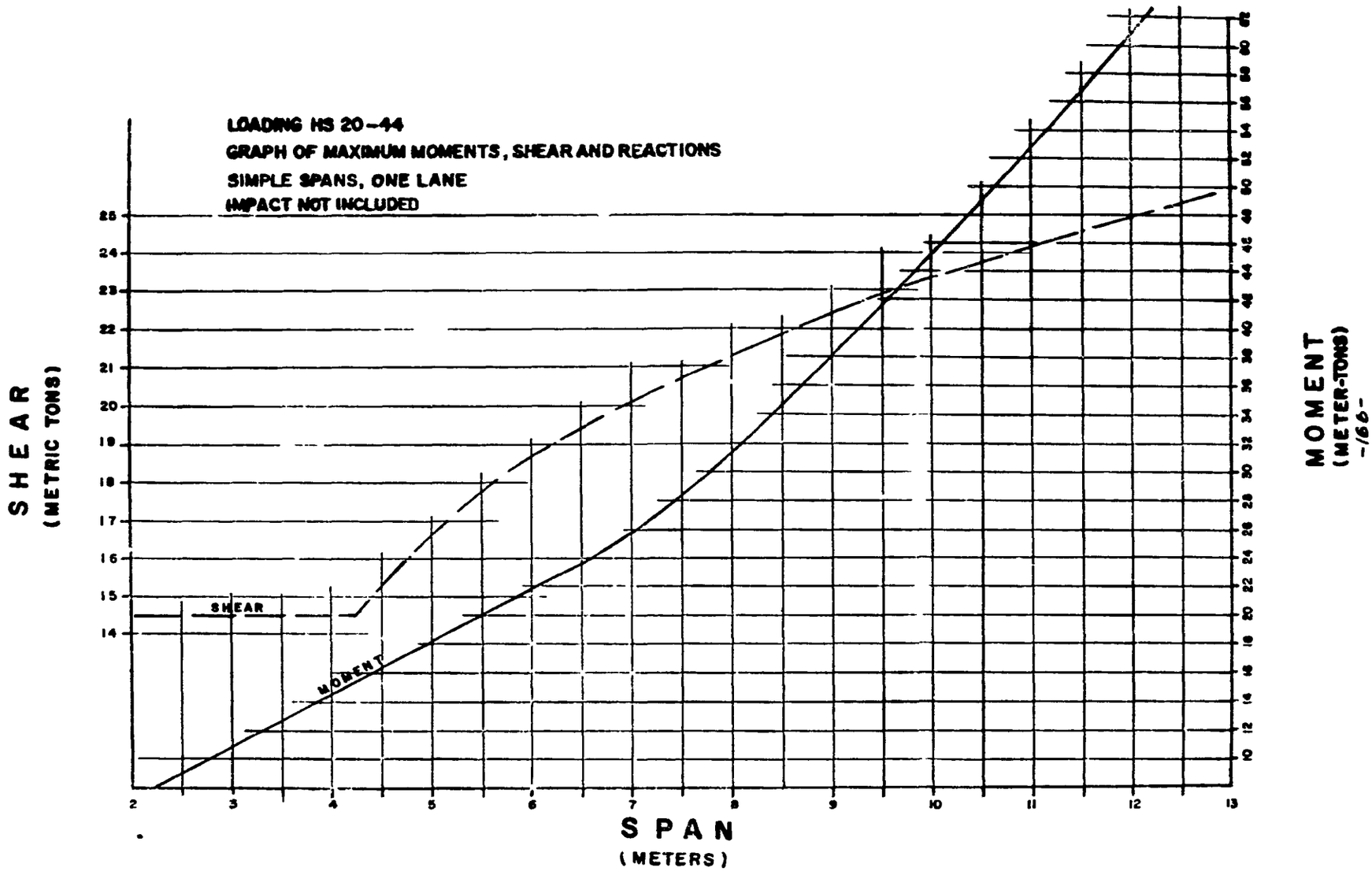
BRIDGE CROSS SECTIONS (WITH BRUSH CURB)

ALL DIMENSIONS IN METERS

AASHO H -- LOADING GRAPHS

The following graphs of maximum moments, shears and reactions for HS-15 and HS-20 are included in this Chapter for use primarily of the District offices. Two graphs for the HS-15 and HS-20 are for spans up to 70 meters. It should be noted that these AASHO loadings are for one lane of traffic and for simple spans. Impact is not included.


LOADING HS 15-44
GRAPH OF MAXIMUM MOMENTS, SHEARS AND REACTIONS
SIMPLE SPANS ONE LANE
IMPACT NOT INCLUDED
SHEAR
MOMENT
SHEAR (METRIC TONS)
MOMENT (METER-TONS)
SPAN (METERS)


LOADING HS 20-44
GRAPH OF MAXIMUM MOMENTS, SHEAR AND REACTIONS
SIMPLE SPANS, ONE LANE
IMPACT NOT INCLUDED
SHEAR
MOMENT
SHEAR (METRIC TONS)
MOMENT (METER-TONS)
SPAN (METERS)
14
15
16
17
18
19
20
21
22
23
24
25
2
3
4
5
6
7
8
9
10
11
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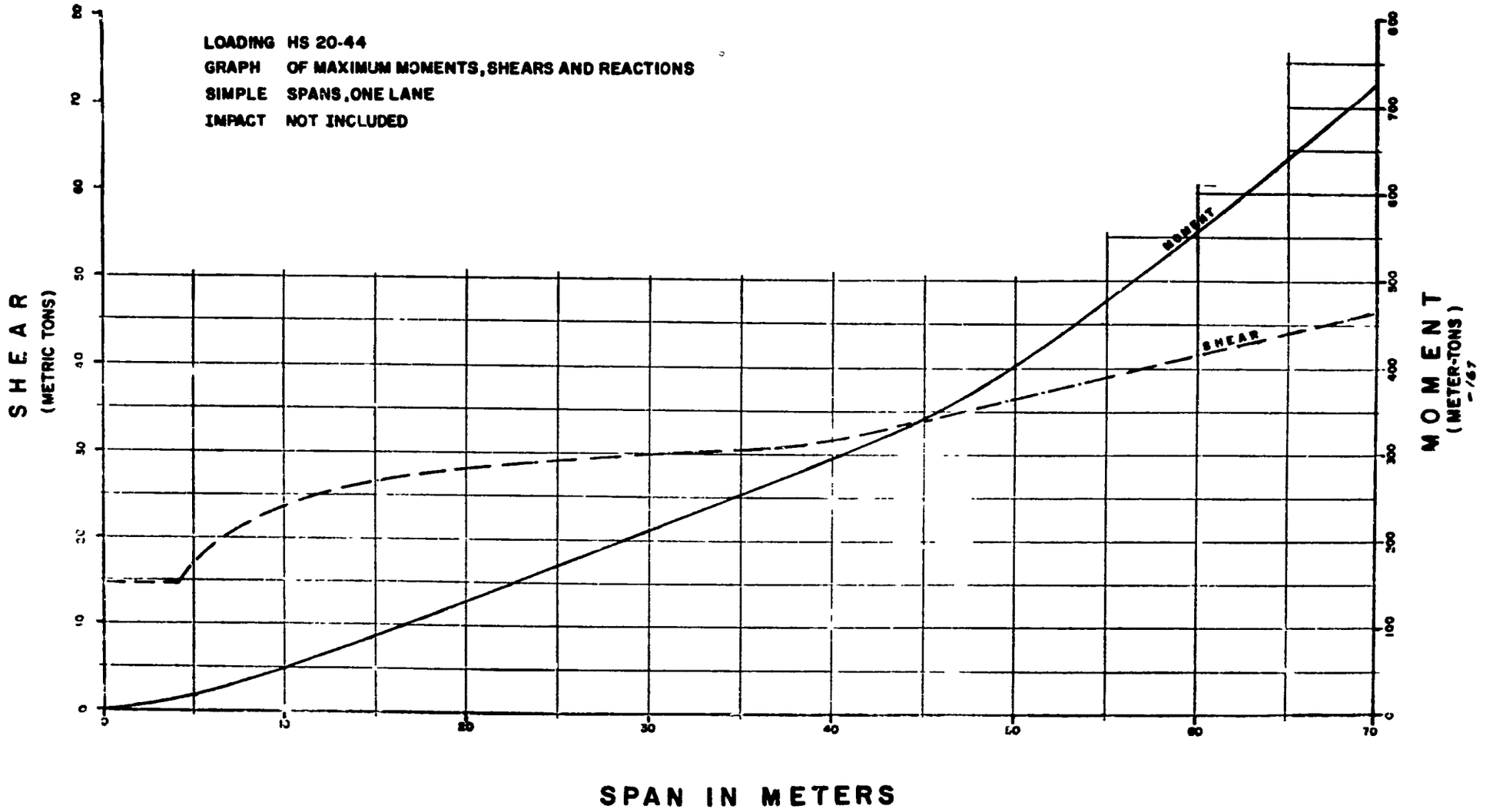

LOADING HS 20-44
GRAPH OF MAXIMUM MOMENTS, SHEARS AND REACTIONS
SIMPLE SPANS, ONE LANE
IMPACT NOT INCLUDED
MOMENT
SHEAR
SHEAR (METRIC TONS)
MOMENT (METER-TONS)
SPAN IN METERS
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
700
800

TIMBER

The following tables of the physical properties of native woods are intended to supplement Table 1.10.1 of Structural Lumber in the AASHO Standard Specifications for Highway Bridges.

They are not as complete or workable as desirable and in some instances single values are given rather than a range of values. These singular values represent only one test specimen and should be treated as such.

For the most part, the values are from the work of Paul Maurand's "L'Indochine Forrestiere," and were obtained at a moisture content of 15 percent.

The values would be applicable for timber used under continuously dry conditions, as in a covered structure. For other conditions in which the moisture content of the wood is at or above the fiber saturation point, approximately 23.5 percent, the values of compression of parallel to the grain and static bending should be further reduced by 10 percent.

The following notes apply to the tables as noted :

1/ Maximum crushing strength, parallel to the grain.

2/ Modulus of rupture.

3/ A comparative measure of toughness.

4/ Maximum tensile strength, perpendicular to the grain.

1/ 2/ 4/ A factor of safety of 3 to 5 must be applied to these values to obtain allowable working stresses.

Note: The following tables are samples only and must be developed for each country.

SCIENTIFIC NAME	HOPEA PIERRAI	PARASHOREA STELLATA	TERRETIA COCHINCHINESIS	SHOREA OBTUSA	XYLIA DOLABRIFORMIS
FAMILY NAME	DIPTEROCARPACEAE	DIPTEROCARPACEAE	STERCULIACEAE	DIPTEROCARPACEAE	LEGUMINOSAE
DENSITY	0.87 TO 0.89	0.75 TO 0.89	0.63	1.05 TO 1.15	1.10 TO 1.20
SHRINKAGE COEFFICIENT	0 50 TO 0.70	0 48	0 25 TO 0.50	0.47	0.50 TO 0 56
COMPRESSIVE STRENGTH kg/Cm² 1/	764	482	400 TO 500	650 TO 750	730 TO 870
STATIC BENDING kg/Cm² 2/	1970	1233	1100 TO 1300	1700 TO 1800	1200 TO 1900
SHOCK RESISTANCE kgm 3/	0,68 TO 0.89	0.43	0.26 TO 0.64	0.84	0.48 TO 0.53
TENSILE STRENGTH kg/Cm² 4/	34	30	26 TO 35	35	31
SPLITTING RESISTANCE Kg/Cm	17	19	15 TO 23	12 TO 16	21
REMARKS	PALE YELLOW TURNS BROWN WITH LONG EXPOSURE, IS RESISTANT TO WEATHERING USED IN CONSTRUCTION WORK, BOAT BUILDING, HAS FINE TEXTURE, WORKS EASILY.	THICK FIBEROUS SAPWOOD GRAYISH WHITE HEARTWOOD. USED FOR HOUSE FRAMES, CABINET WORK AND BOAT BUILDING. WORKS EASILY.	SAPWOOD GRAY, HEARTWOOD RED. NOT DURABLE USED FOR CABINET WORK	REDDISH BROWN, FINE TEXTURE, DURABLE TO WOOD DESTROYING ORGANISMS. CONSTRUCTION BEAMS AND POSTS RAILROAD CROSSTIES. BOAT BUILDING.	SAPWOOD THIN PALE PINK; HEARTWOOD REDDISH. DURABLE, RESISTANT TO DECAY AND MARINE BORERS. USED FOR CONSTRUCTION, BOAT BUILDING, RAILROAD CROSSTIES

SCIENTIFIC NAME	SINDORA COCHINCHINENSIS	PINUS MERKUSII	SHOREA VULGARIS	LITSEA VANG	SANDORICUM INDICUM
FAMILY NAME	LEGUMINOSAE	PINACAE	DIPTOCARPACEAE	LAURACEAE	MELICEAE
DENSITY	0.87 TO 1.125	0.55 TO 0.90	0 80 TO 0.93	0.59 TO 0.75	0.53 TO 0.56
SHRINKAGE COEFFICIENT	—	—	0 40 TO 0.65	0.40 TO 0.50	0.24 TO 0.32
COMPRESSIVE STRENGTH kg/Cm² 1/	600 TO 800	400 TO 560	600 TO 630	370 TO 450	347
STATIC BENDING kg/Cm² 2/	1500 TO 1700	1000 TO 1200	1750 TO 1980	970 TO 1350	820
SHOCK RESISTANCE kgm 3/	0.35	0.25 TO 0.45	0.88 TO 1.17	0.35 TO 0.45	0.2
TENSILE STRENGTH kg/Cm² 4/	22. TO 28.	20 TO 30	31 TO 34	22 TO 32	20
SPLITTING RESISTANCE Kg/Cm	12 TO 19	12 TO 16	18 TO 20	12 TO 16	11 TO 17
REMARKS	SAPWOOD WHITE, SEPARATES FROM HEARTWOOD; HEARTWOOD TURNS REDDISH. DURABLE. USED FOR CONSTRUCTION AND CABINET WORK. FINE TEXTURE.	LIGHT COLORED WITH DARK RED AND BROWN VEINS. INTERIOR CONSTRUCTION, PACKING CASES.	GRAYISH ROSE WITH YELLOW UNDERTONE. USED FOR CONSTRUCTION AND BOAT BUILDING	SEMIHARDWOOD YELLOWISH BROWN; FRAGRANT WHEN GREEN. RESISTS WEATHERING AND AND INSECTS. USED FOR CONSTRUCTION FRAMING AND CABINETWORK	PALE RED, COARSE GRAIN NOT DURABLE. USED FOR PACKING CASES AND CHEAP FURNITURE.

SCIENTIFIC NAME	HOPEA ODARATA	LAGERSTROEMIA SPP.	SHOREA COCHINCHINENSIS	MESUA FERREA	DIPTEROCARPUS SPP
FAMILY NAME	DIPTEROCARPACEAE	LYTHRACEAE	DIPTEROCARPACEAE	GUTTIFERAE	DIPTEROCARPACEAE
DENSITY	0.71 TO 0.89	0.64 TO 0.78	0.82 TO 0.93	1.05 TO 1.17	0.66 TO 0.93
SHRINKAGE COEFFICIENT	0.39 TO 0.55	0.40 TO 0.55	—	0.57	0.35 TO 0 60
COMPRESSIVE STRENGTH kg/Cm² 1/	500 TO 750	400 TO 560	550 TO 575	757 TO 860	450 TO 550
STATIC BENDING kg/Cm² 2/	1100 TO 1450	1100 TO 2500	1350 TO 1540	1900 TO 2000	1100 TO 1500
SHOCK RESISTANCE kgm 3/	0.55 TO 0.66	0.40 TO 0.60	0.47 TO 0.77	0.43 TO 0 90	0.30 TO 0.45
TENSILE STRENGTH kg/Cm² 4/	29 TO 39	24 TO 29	27 TO 33	36	25 TO 35
SPLITTING RESISTANCE Kg/Cm	15 TO 26	18 TO 21	15 TO 17	21	17 TO 22
REMARKS	YELLOWISH TURNING BROWN ON EXPOSURE RESISTANT TO INSECTS AND WEATHER. USED FOR CROSSTIES, BOATS, CABINET WORK.	THIN GRAY SAPWOOD; WHITISH TO PINK HEARTWOOD. TOUGH AND FLEXIBLE. EASILY SHAPED BY STEAMING. SIMILAR TO HICKORY.	SAPWOOD NOT USEABLE; HEARTWOOD DARK CREAMY YELLOW USED FOR HOUSE CONSTRUCTION; DOES NOT TAKE PAINT READILY.	DARK RED; EASY TO WORK WHEN GREEN; DIFFICULT WHEN DRY. USED FOR FURNITURE AND CONSTRUCTION. DURABLE UNDER WATER.	SAPWOOD GRAY; HEARTWOOD REDDISH; COARSE GRAIN. IS SUSCEPTIBLE TO INSECTS AND WEATHERING. USED FOR GENERAL CONSTRUCTION AND BOAT BUILDING.

SCIENTIFIC NAME	AGLAIA GIGANTEA	TOONA FEBRIQUGA	TALAUMA GIOI	SHOREA HYPOCHRA	ANISOPTERA COCHINCHINENSIS
FAMILY NAME	MELIACEAE	MELIACEAE	MAGNOLIACEAE	DIPTEROCARPACEAE	DIPTEROCARPACEAE
DENSITY	0.68 TO 0.76	0.45 TO 0.65	0.53 TO 0.66	0.66	0.61 TO 0.71
SHRINKAGE COEFFICIENT	0.40 TO 0.50	0.32 TO 0.38	0.30 TO 0.50	0.50	0.50 TO 0.70
COMPRESSIVE STRENGTH kg/Cm² 1/	440 TO 530	280 TO 450	360 TO 480	463	750 TO 860
STATIC BENDING kg/Cm² 2/	850 TO 1450	730 TO 1000	965 TO 1330	1326	800 TO 1285
SHOCK RESISTANCE kgm 3/	0.4 TO 0.8	0.12 TO 0.37	0.24 TO 0.29	0.70	0.25 TO 0.43
TENSILE STRENGTH kg/Cm² 4/	19 TO 33	17 TO 20	19 TO 26	19	22 TO 36
SPLITTING RESISTANCE Kg/Cm	14 TO 16	12 TO 17	11 TO 16	12	17 TO 21
REMARKS	SAPWOOD THIN, PALE PINK, HEARTWOOD REDDISH; DARKENS UPON EXPOSURE. USED FOR HOUSE FRAMING.	GROWTH RINGS DISTINCT; YELLOWISH HEARTWOOD; COARSE GRAIN. TURNS MAHOGANY COLOR. NOT DURABLE. USED ONLY FOR CABINET WORK. AROMATIC.	DARK YELLOW, FINE TEXTURE, DURABLE. WORKS EASILY; USED FOR CABINET WORK AND FLOORING, INTERIOR TRIM AND FURNITURE.	BRIGHT YELLOW, SIMILAR TO SAO WOOD, SUSCEPTIBLE TO INSECT ATTACK. USED FOR BOAT BUILDING AND CONSTRUCTION.	HEARTWOOD AND SAPWOOD ARE CREAM YELLOW; DURABLE UNDER WATER AND BELOW GROUND. USED FOR CONSTRUCTION FRAMING AND BOAT BUILDING.

SCIENTIFIC NAME	ADINA CARDIFOLIA	PINUS KHASYA	EUGENIA SPP		
FAMILY NAME	RUBIACEAE	PINACAE	MYRTACEAE		
DENSITY	0.48 TO 0.74	0.61 TO 0.75	0 90 TO 1.00		
SHRINKAGE COEFFICIENT	—	0.55	0.59		
COMPRESSIVE STRENGTH kg/Cm² 1/	540 TO 607	450 TO 540	644		
STATIC BENDING km/Cm² 2/	1190 TO 1460	1100 TO 1300	1346		
SHOCK RESISTANCE kgm 3/	0.24 TO 0.36	0.32 TO 0.47	0.61		
TENSILE STRENGTH kg/Cm² 4/	23 TO 30	23 TO 27	33		
SPLITTING RESISTANCE Kg/Cm	14 TO 17	10 TO 12	22		
REMARKS	YELLOWISH WHITE; USED FOR VENEER AND PLYWOOD.	SALMON COLORED; IS SUSCEPTIBLE TO INSECTS USED FOR PLANKING, CABINETS AND GRATES SIMILAR TO AND SAME USES AS U.S. SOUTHERN YELLOW PINE.	REDDISH GRAIN, NOT STRAIGHT; NOT DURABLE. USED FOR CONSTRUCTION.		

CHAPTER TWELVE

QUANTITY ESTIMATES

GENERAL CONSIDERATIONS

When making quantity estimates, the designer should consider the following items :

- Rounding procedures
- Degrees of accuracy
- Cost Estimates.

These items are discussed below.

ROUNDING PROCEDURES

For estimating purposes, all quantities are rounded using the following procedure:

1. Determine the last digit to be used.
2. If the digit following the last digit used is 4 or less, drop it and all that follows it. Do not change the last digit used.
3. If the digit following the last digit used is 5 or more, drop it and all that follows it. Add 1 to the last digit used.

DEGREES OF ACCURACY

Quantity estimates are rounded to the nearest whole unit used as the basis for payments. These units are set forth in the Standard Specifications.

Exceptions to this general rule are given in the following table. These items will be estimated to the nearest one-tenth of a unit.

SPECIFICATION SECTION	ITEM	UNIT
401	Bituminous Concrete	Ton
407	Bituminous Materials	Ton
502	All Sheet Pile	Square Meter
503	Bearing and Friction Pile	Linear Meter
504	Concrete	Cubic Meter
507	Mortar Rubble Masonry	Cubic Meter
512	Steel Grid Flooring	Square Meter
513	Railings	Linear Meter
515	Loose Rip Rap for Slopes	Square Meter, Cubic Meter, or Ton
	Mortar Rip Rap for Slopes	Square Meter
	Stone Rip Rap for Foundation Protection	Ton
	Concrete Rip Rap in Bags	Cubic Meter
	Concrete Slab Rip Rap	Square Meter
516	Concrete Cribbing	Cubic Meter
520	Lumber	Cubic Meter
	Timber	Cubic Meter
522	Timber Cribbing	Cubic Meter

COST ESTIMATES

The designer will complete the second, third and fourth columns of the cost estimate form only. Contract Administration Division personnel are responsible for developing cost data and will complete the cost estimate.

A detailed quantity estimate is prepared following final P.I.H. inspection revisions. This estimate includes all quantities in the project.

Close coordination with the Contract Administration Division cost estimaters is important during this period of time in order to achieve an accurate and timely cost estimate.

A cost estimate form with the second, third and fourth column completed is shown on the next page.

CONSTRUCTION COST ESTIMATE SHEET 1 OF 1

PROJECT

NUMBER (02) 000 + 960 DA DATE 1 APRIL 1974

ITEM NO.	QUANTITY	UNIT	DESCRIPTION	UNIT PRICES	AMOUNT
	1,273	C.M.	STRUCTURE EXCAVATION		
	165,450	C.M.	BORROW-CONTRACTOR SOURCE		
	38,217	TONS	BITUMINOUS CONCRETE PAVEMENT		
	86,158	TONS	BITUMINOUS CONCRETE BASE		
	421,678	S.M.	PROCESSING LIME-TREATED SUBGRADE		
	8,434	TONS	HYDRATED LIME (FOR LIME-TREATED SUBGRADE)		
	6,189	TONS	RC-100 ASPHALT CEMENT (FOR ASPHALT CONCRETE SURFACING)		
	2,063	TONS	RC-70 ASPHALT CEMENT (FOR ASPHALT CONCRETE BASE)		
	419	TONS	LIQUID ASPHALT (FOR PRIME)		
	113	L.M.	0.6 M R.C.P. CLASS II		
	393	L.M.	0.8 M R.C.P. CLASS II		
	246	L.M.	1.0 M R.C.P. CLASS II		
	1	EACH	RELOCATED EXISTING 1.30M × 25M R.C.P		
	704	L.M.	CURB AND GUTTER TYPE 2		
	38.4	C.M.	CONCRETE CLASS "B"		

CHAPTER THIRTEEN

DESIGN REVIEW

GENERAL CONSIDERATIONS

During the design phase of each project, one or more plan-in-hand field inspections will be made to resolve design problems.

Designers will participate in plan-in-hand (P.I.H) inspections only when specifically requested by the Road Design Division Chief. Others in attendance include :

- District Engineer
- Construction Division Representative
- Right-of-Way Representative
- Specialists in hydraulics, traffic, bridges, utilities, etc., as requested
- Persons representing private and governmental interests that will be significantly affected.

One P.I.H. inspection should be adequate for projects when the major alignment, grade, drainage and access features appear to be rather simple. On more complex projects, two P.I.H. inspections will be expected . a preliminary and a final inspection.

The P.I.H. inspection is usually conducted by the Road Design Division Chief or, in his absence, by the designer, since the designer is responsible for preparation of the plans and is most familiar with the problems involved.

On more complex projects, the P.I.H. inspection could require several days. It is wise then to prepare a schedule of subjects to be covered, their order, and the persons to be present. From the list of persons above, only the first three are present during the entire inspection. The others need be present only when specific problems in their areas are involved.

PRELIMINARY P.I.H. INSPECTIONS

Objective

Preliminary P.I.H. inspections will be made to establish the alignment and grades to be used.

Preparation

To prepare for the preliminary P.I.H., the designer should review the proposed alignment and make a list of the problems to be resolved. Some areas where problems commonly arise are :

- drainage
- access
- traffic maintenance during construction.

The plans to be taken on the preliminary P.I.H. are as follows :

- Title sheet
- Typical sections
- Plan and profile showing proposed alignment, grade and drainage
- One-page mass diagram with a grading summary attached
- Preliminary layouts of interchanges and other facilities.

The above titled sheets need to be completed, as described below, for use on the preliminary P.I.H inspection.

Title Sheet

The title sheet designates the name and length of the project, shows design data, traffic count, design speed, and includes a location map showing the location of the project and the proposed alignment.

Typical Sections

These sheets show all proposed typical sections, including the station limits for each section. The sections show the thickness of material for each course in the roadway structure along with dimensions for the side slopes.

Plan and Profile Sheets

These are the most important drawings and will be used most frequently during the P.I.H. inspection. For this reason, great care should be used to be sure all available data have been included on the plans as accurately as possible.

Profiles will be completed to the point of showing grades and vertical points of intersection elevations. Locations and lengths of vertical curves and equations will be shown. The plan drawings show the proposed alignment, including bearing of each tangent section and a full description of each curve. Drainage structures will be described and locations shown.

Mass Diagram

A one-page mass diagram will show the quantity of earthwork involved in the project. At the time of preliminary P.I.H, the mass diagram will be a rough approximation, furnishing an indication of the amount of borrow required or material to be wasted.

Interchange and Other Facilities

Plan drawing will be prepared in sufficient detail to fully describe the layout of the interchanges or facilities.

Preliminary P.I.H. Report

Following the preliminary P.I.H. inspection, a preliminary P.I.H. report will be prepared setting forth the revisions agreed to during the inspection. The report will be prepared by the designer if he participates in the inspection, or by the Road Design Division Chief if the designer does not participate. The report, when concurred in by the participants of the preliminary P.I.H inspection, will be used as the basis for further development of the plans.

Revising the Plans

Revisions to the plans, as specified in the approved preliminary P.I.H. report, will be made by the designer before continuing with the detailed design. Upon completion of the revisions, any grade changes which affect structures must be sent to the Bridge Design Division Chief

FINAL P.I.H. INSPECTIONS

Objectives

Final P.I.H. inspections will be made to establish all details needed to complete the design of the project. Decisions made during preliminary P.I.H. inspections relative to alignment, grades and other items will not be reviewed unless major problems arise.

Preparations

To prepare for the final P.I.H. inspection, the designer should again review the project plans and make a list of the problems to be resolved.

The plans should be prepared in detail, with the details ready to trace. Right-of-way lines and grade lines will be drawn in pencil, and all summaries must be complete.

All special provisions should be written in draft form and approved by the Road Design Division Chief. These provisions will then be submitted to the Contract Administration Division for final preparation and incorporation into the contract documents for that project. When writing special provisions, designers will prepare them according to HA guidelines.

Final P.I.H. Report

Following the final P.I.H. inspection, a final P.I.H. report will be prepared setting forth the revisions agreed to during the inspection. The report will be prepared by the designer, if he participates in the inspection, or by the Road Design Division Chief if the designer does not participate. The report, when concurred in by the participants of the final P.I.H. inspection, will be used as the basis for revising the plans.

Revising the Plans

The designer will revise the plans, based on the approved final P.I H. report, before tracing the final details.

CHAPTER FOURTEEN

CONTRACT PLANS ASSEMBLY

GENERAL CONSIDERATIONS

This Chapter presents guidelines for preparing contract plans in a clear, concise and uniform manner. The designer should ensure that the plans contain the information that is required by contractors, material suppliers and construction inspection personnel. Contract plans are also a permanent record of the design criteria for which the road was designed. The designer should remember that many highway employees use the contract plans in the performance of their duties. Thus, the plans must contain the data necessary for the various personnel to accomplish their portion of the work. The use of duplicate data and cross references should be avoided, as it complicates the task of assembling, checking and revising plans.

In circumstances not covered by these guidelines, designers should establish their own guidelines to be used consistently throughout the plans.

Plan Set Organization

Depending on the size and type of a specific project, each set of contract plans will contain sheets selected from, and arranged in order of the following list :

ROADWAY PLANS	SHEET CODES
1. Title Sheet	
2. Table of Contents	
3. Symbols and Abbreviations	
4. Notes Sheet	
5. Typical Section Sheets	
6. Summary Sheets	
7. Detail Sheets	
8. Right-of-Way Plans	
9. Plan and Profile	C
10. Lighting Sheets	L
11. Signing Sheets	S
12. Utility Plans	U
13. Standard Drawings	
14. Cross Sections	

STRUCTURE PLANS

1. Survey Sheet
2. Layout Sheet, if not included on Survey Sheet
3. Approach Roadway Typical Sections and Project Cross-Sections
4. Soils Report Sheet — Borings, Soundings etc.
5. Substructure Details including Pile Layout & Details, if applicable
6. Beam or Girder Details
7. Superstructure Details
8. Slope Protection
9. Reinforcing Steel Schedule.

Size and Layout of Original Sheets

Original sheet size will be determined by the Highway Administration. Borderlines on all sheets will p a 8cm binding margin on the left edge and 2cm margins elsewhere, except that on cross-section sheets the borderlines may be omitted if sufficient space is allowed for a 8cm binding margin.

Sheet Codes

A number of sheets are provided with additional identification. This identification is a combination of letters and numbers using the codes shown in the section entitled "Plan Set Organization". The numbers are determined by sequentially numbering the sheets within that particular group Typical examples of this system are; C-2, the second plan and profile sheet, and S-8, the eighth signing sheet.

Abbreviated Plans

Abbreviated or short plans may be used for limited scope projects, such as surfacing or surface widening.

Abbreviated plans contain title sheets, typical sections, summaries of quantities, general notes and plan sheets. Profile sheets are included to show changes in grade.

Sheet Identification

The sheet title identification block is preprinted in the lower right hand corner of all sheets except title sheets. A sample title block is shown below.

DESIGNED	MINISTRY OF PUBLIC WORKS AND COMMUNICATION **HIGHWAY ADMINISTRATION**		
DRAWN			
CHECKED			
SUBMITTED BY DATE			
APPROVED DATE			OF

Revisions

Revisions to existing sheets should be made on the original sheets whenever practical. Major revisions, which cannot be made on the original sheet, should be shown on a new sheet placed immediately after the original. Its sheet number is modified by adding a letter: for example, revised sheet No. 26-A would be placed immediately following original sheet No. 26.

Revision descriptions, symbols and dates are listed in the space provided immediately to the left of the title block, as in the example below :

REVISIONS			
SYMBOL	DESCRIPTION	DATE	APPROVAL
R/1	DELETE APPROACH ROAD STA. 153+056 LEFT	9-6-72	
R/2	CHANGE CULVERT SIZE STA. 153+325 TO 1.0M CLASS 2	9-6-72	

The revision symbol is also shown near the revised data on the drawing.

Additions

Sheets, other than revised sheets added to a set of plans after final numbering, are placed at the end of the plan set and numbered sequentially, continuing with the number following the last sheet number in the plan set.

Deletion

Sheets which are to be cancelled or deleted from the plans will remain in their position within the plan set but are marked "VOID" and crossed out.

All changes to the plan set, such as revisions additions and deletions, are recorded in a revised table of contents.

Scales

The use of nonstandard scales is noted to the left of the revision block. Standard scales are discussed in the appropriate sections throughout the manual.

The format and content of all sheets are described in the following pages, and model plan sheets are shown, where appropriate.

Reduced Plans

When reduced plans are used, a note showing the appropriate percent reduction will be placed immediately above the title block. A sample of this note is shown below.

NOTICE PLANS REDUCED APPROXIMATELY 50%

TITLE SHEET

General Requirements

The title sheet will be the front page for a set of plans Title sheets identify the projects and their locations as described below and illustrated on the model sheet.

Location Map

A large scale map placed in the upper left corner of the title sheet shows the general location of the project in relation to the other roads within the highway district.

Title Information

Title information is shown on the top center of the title sheet in the following order :

- Highway Administration
- Project name
- Project number
- Types of work covered by the set of plans (see below)
- Highway district.

Types of Work

The specific types of work identified on the Title Sheet are as follows :

Grading	Traffic Signals
Detour	Bridge(s)
Base Course	Roadside Improvements
Paving	Guardrail
Culverts	Fencing
Lighting	

Project Length

The project length is shown to the nearest tenth of a kilometer immediately below the title information.

Design Data

Project design data are included in a block in the upper right hand corner. When projects have two or more road segments with different design data, prepare separate design data blocks for each segment.

Letting Date

The letting date is recorded in the space provided in the upper right corner. This date will be recorded by the Contract Administration Division. This date is the actual letting date, not a proposed letting date.

Project Approval Block

A project approval block is located at the center of the title sheet below the layout map.

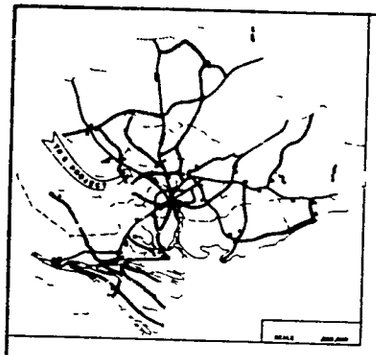
Layout Map

The layout map located in the center of the title sheet provides details of the following:

- The location of the project roadway in relation to true North, towns, existing roads, major drainage systems such as rivers and canals, government-optioned borrow and surfacing sources, railroads and buildings.
- The beginning and ending stations of the project.
- The numbers and stations of adjoining projects.
- Bridges on the project. A single station number is used to designate the center stationing of each structure. Data shows the bridge length and if it is to be constructed under this contract.
- Route numbers.
- Enlarged insert maps of cities and towns when construction is contemplated through those areas.

Related Projects

A block for related projects is located in lower left-hand corner of the title sheet. Data in this block list the numbers of projects not covered by the contract plans and projects financially related to the main project.



MINISTRY OF PUBLIC WORKS & COMMUNICATION
HIGHWAY ADMINISTRATION

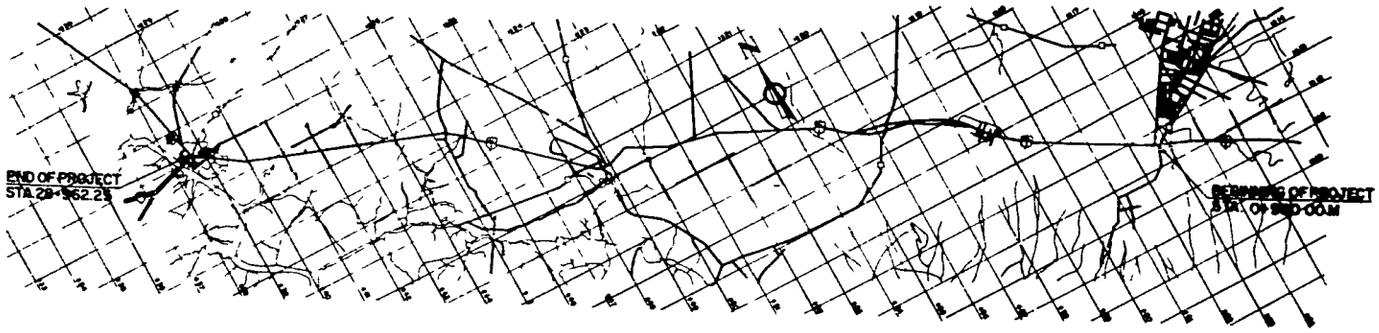
PROJECT NO 01(02)000+960 DA
GRADING, CULVERTS, PAVING

LENGTH 28.0 KILOMETERS

DESIGN DATA

	1970	1990
ADT/VU	7000	13000
DHV	450	800
T = 17	%	
D = 55	%	
V = 80	KPH	

LETTING DATE _____



DESIGNED BY	SUBMITTED	APPROVED
CHIEF DESIGN ENGINEER DATE	DIRECTOR OF ENGINEERING DATE	DIRECTOR GENERAL HIGHWAY ADMINISTRATION DATE

TABLE OF CONTENTS SHEET

General Requirements

A table of contents as shown on the next page is the second sheet in each set of contract plans One sheet will be used solely for the table of contents, except in plans so brief that the tabl of contents and the notes can be placed on the same sheet.

Where the table of contents is combined with the notes, each group information is clearly labele "TABLE OF CONTENTS" and "NOTES," using the same letter size as for sheet leadings.

Sheet Sequence

Table of contents will list the major groups of sheets and those subgroups necessary to facilitat locating each item in the plans. The major groups, and the sequence of sheets within eac group are shown at the beginning of this chapter.

Addenda

The addenda to the table of contents list any sheets which are revised added or deleted i the contract plans after final numbering of sheets is completed. Each addition to the addendu requires a new revision of the table-of-contents sheet.

Sheet Numbers

The title sheet is considered as page one but is not numbered. All other sheets will have shee numbers shown in the title blocks at the lower right corner.

Road plans sheets will be individually numbered in sequential order. Signing, lighting an bridge plans will be individually numbered within each group and have letter prefixes, c shown on the example sheet. Cross-section sheets will be individually numbered in sequenti order beginning with 1. Sheets added to plans after final numbering (addenda) will be numbere in sequential order within each major group, as shown in the example.

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REVISIONS			
SYMBOL	DESCRIPTION	DATE	

DESIGNED
DRAWN
CHECKED
SUBMITTED DATE
APPROVED DATE

TABLE OF CONTENTS

PROJECT NO. 01102 000+880 DA

Sh No 2 of 53

SYMBOLS AND ABBREVIATIONS SHEET

A sheet of symbols and abbreviations is the third sheet in each set of plans. The following items are shown on this sheet :

- All standard symbols adopted by the HA, except those symbols used only for signing and lighting plans.
- All the standard abbreviations which could be misinterpreted by the contractor or inspection personnel.
- A skew–line diagram for drainage structures. The skew of a structure is oriented with respect to a line perpendicular to the project centerline drawn through the point of intersection of the structure flowline with project centerline The skew is defined as the angle, to the right or left ahead, between this perpendicular and the structure flowlines.

The standard symbols and abbreviations should be used consistently in all contract plans.

Use standard abbreviations only where room restricts the writing of complete words.

Preprinted symbols and abbreviations sheets will be available for use in preparing contract plans.

SYMBOL AND ABBREVIATIONS

TITLE SHEET

- PROPOSED ROUTE
- PAVED ROAD
- GRAVEL ROAD
- UNIMPROVED ROAD
- INTERCHANGE
- PRIMITIVE ROAD
- STRUCTURE
- RAIL ROAD
- FERRY TERMINAL
- CITY OR VILLAGE LIMIT
- PROVINCE LINE
- INTERNATIONAL BORDER
  - -NUMBERED HIGHWAY
  - -NUMBERED HIGHWAY
  - -NUMBERED HIGHWAY
  - -NUMBERED HIGHWAY
  - -NUMBERED HIGHWAY
- BUILDING

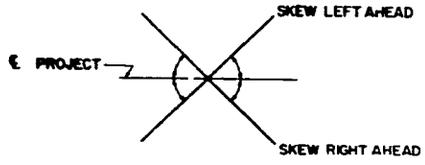
PROFILE

- P I ON VERTICAL CURVE
- GRADE LINE & PC OR PT
- NATURAL GROUND
- SPECIAL DITCH

PLAN

- INTERNATION BORDER
- PROVINCE LINE
- CITY OR VILLAGE LIMIT
- DEFLECTION ANGLE
- POINT OF INTERSECTION
- CENTERLINE WITH CIRCLE FOR POT, PC. OR PT
- OLD ROW
- NEW ROW
- RAIL ROAD
- CONCERTINA WIRE
- FENCE
- TREES
- RICE
- MARSH
- GUARDRAIL
- CENTERLINE
- PROPERTY LINE
- CULVERT
- TELEPHONE POLE
- POWER POLE
- ROW MARKER
- FILL SLOPE
- CUT SLOPE

CULVERT SKEW DIAGRAM



ABBREVIATIONS

Abut	ABUTMENT
Az	AZIMUTH
Bit Conc.	BITUMINOUS CONCRETE
BM	BENCH MARCH
Brg	BEARING
CB	CATCH BASIN
C-C	CENTER TO CENTER
C&G	CURB & GUTTER
CI	CAST IRON
CL	CLEARANCE
CMP	CORRUGATED METAL PIPE
Const	CONSTRUCTION
Ctr	CENTER
D	DEGREE OF CURVATURE
DI	DROP INLET
DS	DOWN STREAM
Ea	EACH
EF	EACH FACE
EL	ELEVATION
EP	EDGE OF PAVEMENT
ES	EDGE OF SHOULDER
Eq	EQUATION
Exist	EXISTING
Exp	EXPANSION
Ext	EXTERIOR
E	EXTERNED DISTANCE
FETS	FLARED END TERMINAL SECTION
FF Fix	FAR FACE FIXED
FL	FLOW LINE
FP	FENCE POST
HHW	HIGH HIGH WATER
Hor	HORIZONTAL
Hse	HOUSE
Ht	HEIGHT
ID	INSIDE DIAMETER
IF	INSIDE FACE
Int	INTERIOR
Inv EL	INVERT ELEVATION
Jt	JOINT
Lc	LENGTH OF CURVER
LLW	LOW LOW WATER
LOC	LIMIT OF CONSTRUCTION
LS	LUMP SUM
Lt	LEFT
Max	MAXIMUM
Min	MINIMUM
MH	MANHOLE
MHT	MEAN HIGH TIDE
MLT	MEAN LOW TIDE
MO	MIDDLE ORDINATE
NF	NEAR FACE
No	NUMBER
NTS	NOT TO SCALE
PVRC	POINT OF VERTICAL REVERSE CURVE
OD	OUTSIDE DIAMETER
PC	POINT OF CURVE
PCC	POINT OF COMPOUND CURVE
PG	PROFILE GRADE
PI	POINT OF INTERSECTION
POT	POINT OF TANGENT
PRC	POINT OF REVERSE CURVE
Prefab	PREFABRICATED
Prestr	PRESTRESSED
PT	POINT OF TANGENT
PVC	POINT OF VERTICAL CURVE
PC	POLYVINYL CHLORIDE
PVI	POINT OF VERTICAL INTERSECTION
PVT	POINT OF VERTICAL TANGENT
Q50	DESIGN DISCHARGE BASED ON 50-YEAR FLOOD RECORD
R	RADIUS
RCP	REINFORCED CONCRETE PIPE
RCSP	REINFORCED CONCRETE SEWER PIPE
Rdway	ROAD WAY
RP	REFERENCE POINT
Rt	RIGHT
R/W	RIGHT OF WAY
Sta	STATION
Std	STANDARD
Shdr	SHOULDER
e	SUPERELEVATION
T	TANGENT
TBM	TEMPORARY BENCH MARK
TC	TOP OF CURB
Tel	TELEPHONE
Temp	TEMPORARY
TR	TOP OF RAIL
Typ	TYPICAL
US	UP STREAM
VC	VERTICAL CURVE
Vert	VERTICAL
WP	WORK POINT

SYMBOLS AND ABBREVIATION

PROJECT NO 01(08)0004-660 BA

NOTES SHEET

General Requirement

A sheet of notes similar in format to the model sheet is included in each set of contract plans. One sheet is used solely for notes, except when the notes can be placed on the same sheet with the table of contents.

Contents

Notes sheets provide general information necessary for plan users to obtain an understanding of the contract plans. The following type of information is included, when applicable:

- Description of work to be done by noncontractor personnel.
- Instructions for the contractor regarding items not to be disturbed.
- General instructions for the contractor.
- Waste areas for excess excavation.
- Bases for plan quantities for surfacing materials.
- Description of work items absorbed in the costs of bid items.

NOTES

MISC TO BE MOVED OR REMOVE BY OTHERS

LOCATION	DESCRIPTION
4+050	GRAVE
18+435	GRAVE
27+735	1000 GAL GASOLINE TANK

ALL PRIVATELY OWNED SIGNS TO BE REMOVED BY OWNERS
ALL GUARDRAIL GUIDE POSTS AND GOVERNMENT OWNED SIGNS TO BE REMOVED BY GOVERNMENT FORCES

CONSTRUCTION NOTE

CONTRACTOR IS TO USE EXTREME CAUTION IN THE AREA SURROUNDING THE BRIDGE AT STATION 15+663 WHERE UNEXPLODED ORDNANCE AND MINE FIELDS ARE LOCATED CONTRACTOR WILL CONTACT LOCAL MILITARY AUTHORITY IN ORDER TO HAVE AREA CLEARED

CLEARING AND GRUBBING

TO BE ABSORBED IN UNIT PRICE BID FOR EXCAVATION
CLEARING AND GRUBBING TO CONSTRUCTION LIMITS PLUS 2 METERS

DO NOT DISTURB

STA. 8+065 RT DO NOT DISTURB GRAVEYARD WITHIN RIGHT OF WAY

BASIS OF PLAN QUANTITIES

(QUANTITIES FOR ESTIMATING PURPOSES ONLY)

GRAVEL WEIGHT ESTIMATE	= 2200 KILOS PER CM
PLANT MIX WEIGHT	= 2320 KILOS PER CM
PLANT MIX BIT MAT'L	= 6.5% WEIGHT OF PLANT MATERIAL
PRIME	= 1.5 LITERS PER SQUARE METER
BITUMINOUS MATERIAL	= 0 KILO PER LITER
TACK	= 0.4 LITERS PER SQUARE METER

REVISIONS			
SYMBOL	DESCRIPTION	DATE	APPROVAL

DESIGNED
DRAWN
CHECKED
SUBM.
APPD

NOTES

PROJECT NO
U.S. 2 DUCHODA

TYPICAL SECTION SHEETS

General Requirements

One or more sheets are used to show all the typical sections. Mainline typical sections are shown, first followed by other typical sections in the order they appear along the mainline stationing. All typical sections will be numbered in sequential order. The first typical section is number one, the second typical section, number two, and so on.

Contents

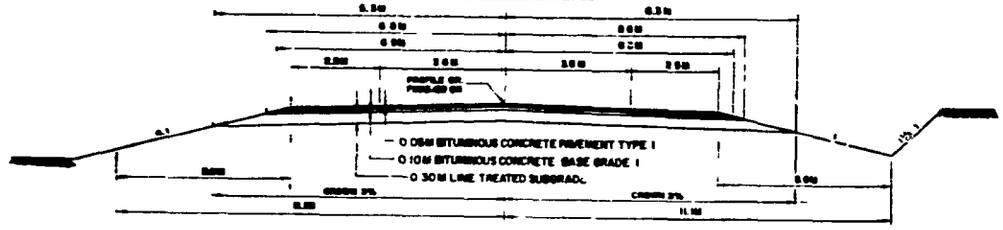
Items to be shown for each typical section are listed below.

- The typical section number.
- The name of the road to which the typical section applies is placed directly below the typical section number.
- The locations of frontage and access roads not parallel with the mainline are shown directly below the names. The locations are referenced to the mainline stationing.
- Beginning and ending stations for the typical section are shown in the upper right corner of each typical section.
- A cross-section view of the typical section to show the following :
  - + The grading template, including any nonstandard slope design.
  - + Profile grade.
  - + Surfacing template for immediate development.
  - + Ultimate section for all stage construction.
  - + Types, thicknesses and widths of surfacing materials
  - + Slopes and dimensions necessary to define the typical section. The fixed point on the inslope at which the embankment slope changes is defined on surfacing sections as well as on grading sections.
- Quantities of gravel and bituminous materials represented by the typical sections are shown to the nearest tenth of a unit.
  - + Gravel quantities are expressed as "area in square meters", "cubic meters per 100 meters" or "tons per 100 meters".
  - + Bituminous material quantities are expressed as "square meters per 100 meters," "tons per 100 meters", and "liters per 100 meters."
- Notes pertinent to that specific typical section.
- A note stating "NOT TO SCALE", if applicable.

TYPICAL SECTION NO 1

MAINLINE

STA 0+[illegible] TO STA [illegible]

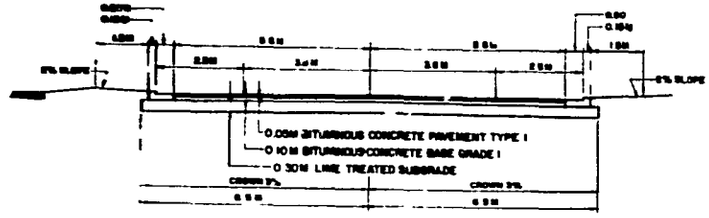


QUANTITIES						
MATERIAL	UNIT	BITUMINOUS CONCRETE PAVEMENT TYPE I	BITUMINOUS CONCRETE BASE GRADE I	LIME TREATED SUBGRADE	PRIME	TACK
GRAVEL	TONS / 100 M	196.7	300.0			
BITUMINOUS	TONS / 100 M	9.9	30.1		1.9	0.6
LIME	[illegible]			1010		
UNSURFACED LIME	TONS / 100 M			30.2		

TYPICAL SECTION NO 2

MAINLINE

STA 20+[illegible] TO STA [illegible]



QUANTITIES						
MATERIAL	UNIT	BITUMINOUS CONCRETE PAVEMENT TY I	BITUMINOUS CONCRETE BASE GRADE I	LIME TREATED SUBGRADE	PRIME	TACK
GRAVEL	TONS / 100 M	129.9	198.0			
BITUMINOUS	TONS / 100 M	6.4	19.9		1.3	0.4
LIME	[illegible]			1300		
UNSURFACED LIME	TONS / 100 M			20		

REVISIONS			
SYMBOL	DESCRIPTION	DATE	APPROVAL

TYPICAL SECTIONS 1 AND 2

PROJECT NO.

SUMMARY SHEETS

General Requirements

One or more summary sheets will be included in each set of contract plans. Summary sheets show all quantities of work and materials required by the plans. No other data are shown on the summary sheets. The quantities are shown in the same format as on the model sheet.

Stationing within each summary frame will be in sequential order whenever possible. To prevent unnecessary redrafting, last minute changes may be lettered at the bottoms of frames out of sequence. At least 3 centimeters will be left at the bottoms of frames to permit last minute additions. A horizontal reference line will be drawn after each tenth entry of information in the summary frames.

Separate summaries for the following groups of pay items are shown, when applicable.

- Grading items
- Detour items
- Pavements items
- Drainage structures
- Roadside-improvements items
- Guardrail
- Base courses
- Seeding
- Topsoil
- Curbs & gutters
- Right-of-way markers
- Items to be removed by contractor.

SUMMARY

GRADING

STATION	CUBIC METERS EXCAVATION	CUBIC METERS EMBANKMENT		REMARKS
0+960 28+96025	15 340	165 450		MAINLINE
TOTALS	15 340	165 450		

CULVERTS

STATION	LINEAR METERS 0 50M CLASS II	LINEAR METERS 0 80M CLASS II	NEW RCP 1 00M CLASS II	HEIGHT OF COVER METERS	SKEW ANGLE	CONCRETE END SECTION CUBIC METERS LT	CONCRETE END SECTION CUBIC METERS RT	C M BEDDING MATERIAL	C M CULVERT EXCAVATION	REMARKS
1 + 712			60 00	0 60		1 43	1 73	72	98	3-1 00M X 20 00
2 + 564		18 50		0 50		86	86	18	24	
2 + 815	18 00			0 50		76	76	10	17	
3 + 840		57 0		0 55		1 14	1 14	42	64	3 08 M X 19 00
6 + 022	35 00			0 55		86	86	18	26	2 06 M X 17 50
6 + 998			54 00	1 40		1 25	1 56	103	147	2-1 0 M X 27 00
10 + 022			48 00	1 00		1 25	1 56	90	118	2-1 0 M X 24 00
12 + 700		38 00		0 50		1 00	1 00	26	41	2-0 8 M X 19 00
13 + 754		54 00		0 50		1 14	1 14	32	48	3-0 8 M X 18 00
20 + 817			84 00	1 50		1 43	1 73	108	209	3-1 0 M X 28 00
24 + 544				0 70				70	109	2 1 30M X 25 00 RAISE
26 + 167		20 00		0 60		86	86	23	32	
26 + 300	20 00			0 70		76	76	20	30	
26 + 645		22 50		0 75		86	86	25	40	
27 + 188		42 00		0 65		1 00	1 00	34	53	2 0 8 M X 21 00
27 + 650		43 00		1 00		1 00	1 00	42	83	2-0 8 M X 21 50
27 + 981	10 00			0 70		86	86	25	36	EXTEND EXISTING 0.6M CULVERT
4 + 450		40 50		0 60		1 00	1 00	30	44	2-0 8 M X 20 25
5 + 094		57 00		0 55		1 14	1 14	36	54	3 0 8 M X 19 00
TOTALS	83 00	392 50	246 00			18 60	19 82	824	1275	

SURFACING

STATION FROM	STATION TO	LINEAR METERS GROSS	LINEAR METERS NET	+	-	USED FOR	TONS A C SURFACING TYPE 2	TONS A C BASE GRADE		LIME TREATED BASE SQ METERS AREA	LIME TREATED BASE TONS LIME		SHOULDERS MATERIAL TONS A C SURF TYPE 1	A C SURF TYPE 2	PRIME	TACK	REMARKS
0+98000 13+65012					25 88	EXISTING BRIDGE											
28+610 25	28+61 0 25 28+962 25	27650 25 350 00	27624 36 350 00				37 762 5 454 7	85 248 8 909 3		417 127 8 4 550	8342 6 91		2624 3 29 4	5552 8 45 5	414 4 46	138 1 1 8	TYP SECTION NO 1 TYP SECTION NO 2
TOTALS		28 000 25	27974 36		25 88		38217 2	86 1581		421 677 8	8433 6		2653 7	5598 0	4190	139 9	

REVISIONS			
SYMBOL	DESCRIPTION	DATE	APPROVAL

DESIGNED
DRAWN
CHECKED
SUBMITTED DATE
APPROVED DATE

SUMMARY

PROJET NO 3H0E)000+88DDA

SHEET NO 1 OF 1

DETAIL SHEETS

General Requirements

Detail sheets are included in contract plans to show:

- Nonstandard items
- Mass diagrams.

Requirements for each type of detail sheet are presented below

Nonstandard Items

One or more detail sheets may be used to show details of nonstandard items They are used for items requiring more specific information than shown on the plan and profile sheets. For example, detail sheets may be required to show hydraulic details for structures.

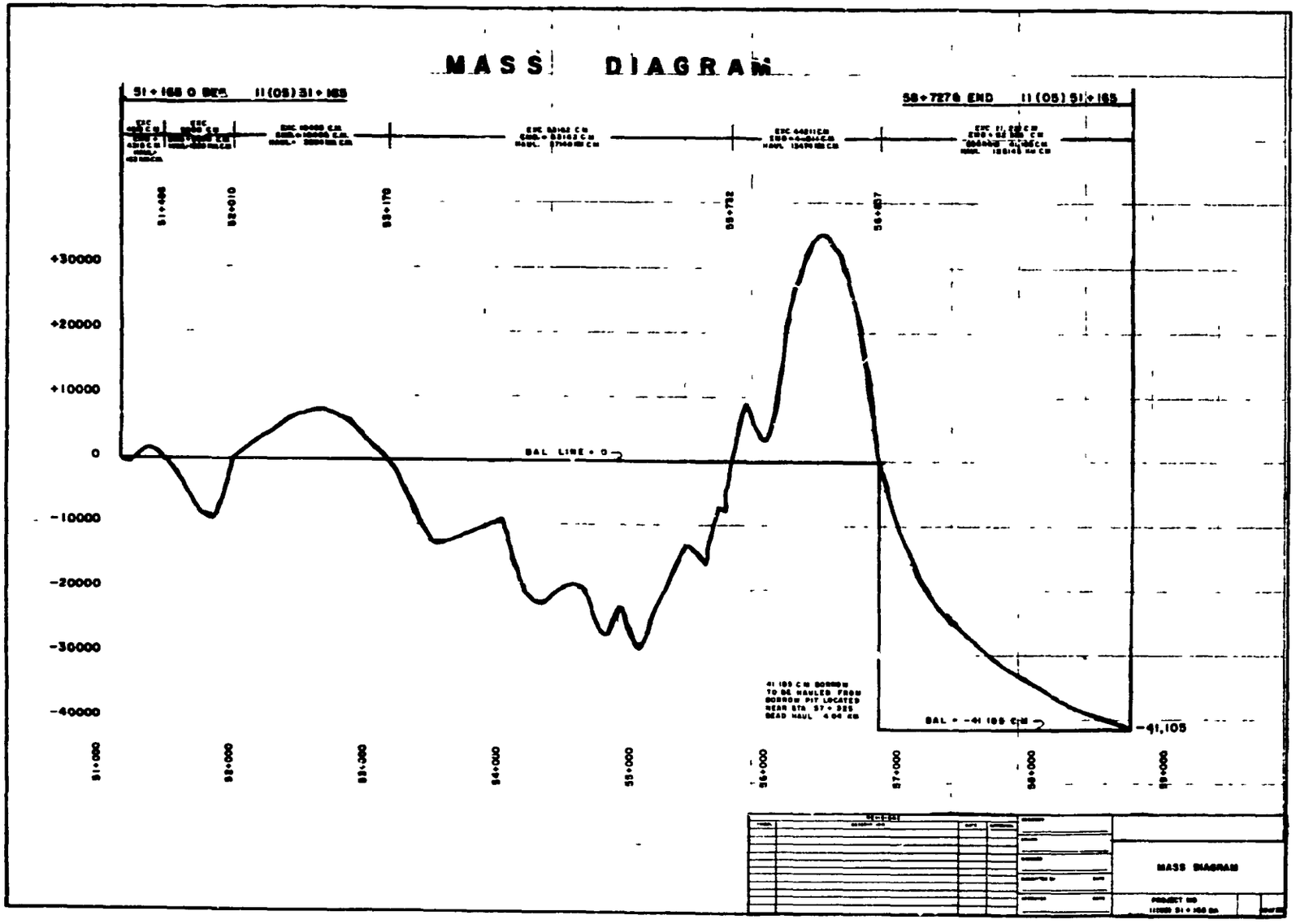
Each detail sheet is clearly labeled in the title box at the lower right corner of the detail drawing. The title box will show the name of the detail, the station where it is applicable and the scale to which it is drawn.

Mass Diagram

A single-sheet mass diagram is included in contract plans with earthwork. The mass diagram provides an overall view of the earth quantities and where they are to be placed.

Balance points, cubic meters of earth, and haul quantities are shown.

A scale is used that places the mass diagram on one sheet. Where practicable, the mass diagram should be continuous, with no breaks.


MASS DIAGRAM
51+168.0 BEG
11(05)31+165
58+727.8 END
11(05)51+165
+30000
+20000
+10000
0
-10000
-20000
-30000
-40000
BAL LINE = 0
BAL = -41,105 CYS
-41,105
51+000
52+000
53+000
54+000
55+000
56+000
57+000
58+000
MASS DIAGRAM

RIGHT-OF-WAY SHEETS

In order to provide supplemental right-of-way information to that appearing on plan and profile sheets, the ownership summary sheets of the final right-of-way plans will be inserted in the contract plans.

PLAN AND PROFILE SHEETS

General Requirements

Plan and profile sheets show the horizontal and vertical alignment and depict the construction items and the topography necessary for construction.

Sequence of Sheets

Mainline plan and profile sheets are shown first, in the order of increasing stationing. The continuous stationing of mainline plan and profile sheets is not interrupted by special sheets showing features on or near the mainline.

Special plan and profile sheets showing connections, interchanges, intersections, detour roads, frontage roads, railroads and so on, appear after the mainline plan and profile sheets in the order they appear along the mainline.

Special plan and profile sheets for each feature are grouped together.

Labeling Special Sheets

Special plan and profile sheets are clearly labeled on their right sides so that any plan user can readily determine what special feature is shown.

Use of Notes

Notes on plan sheets should be brief, clear, and consistent. Installations and removals are noted by station and a brief description. Detailed descriptions are included in summary sheets, but should not be included on plan and profile sheets.

Typical notes for some common items are presented below:

Items	*Typical Note*
Existing sign	SIGN
New culvert	865 + 000 NEW 0.8M RCP
Existing culvert to be removed	870 + 300 0.5M RCP. REMOVE
New road approach	875 + 205 RD. APP. RT.
New metal guardrail	882 + 000 to 882 + 030 NEW METAL G.R. LT.
New rip rap	892 + 035 to 892 + 045 PLACE 30 SQ M OF ONE TON RIP RAP

North Arrows

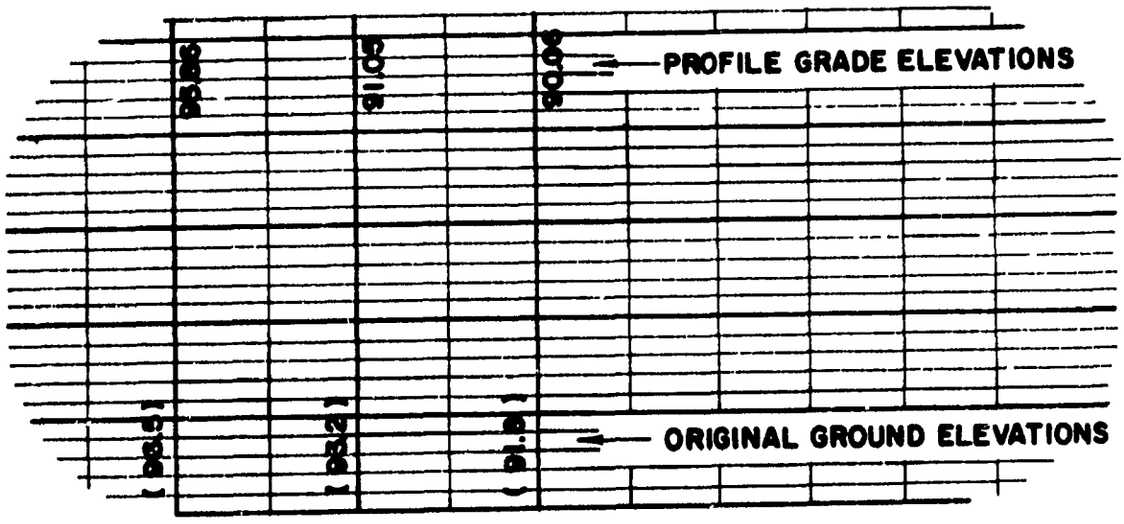
North arrows are shown on plan views and should be uniform in size and shape within each set of plans.

Orientation of Notes

All notes and dimensions for road plans are written horizontally, with the following exceptions:

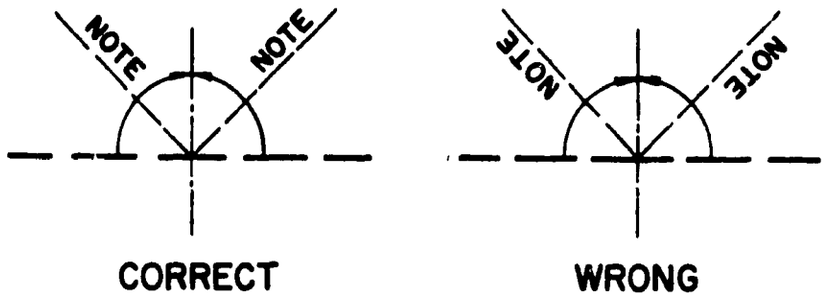
- *Plan views*: Pipe installation notes, equations and right-of-way breaks should be written vertically.
- *Profile views*: Equations are written diagonally. Full stations and elevations of vertical curve P.I.'s, P.C.'s and P.T.'s are written vertically.

Original ground elevations are written with the bottom of the number touching the vertical line representing the station; and profile grade elevations, with the top of the number touching the vertical line. For further clarification, the original ground elevations are placed in parentheses. The figure below explains this orientation.



- *Special considerations*: Where limited space for notes makes horizontal placemen detrimental to the readability of the plans, notes may be place vertically.

No notes or dimensions are written from right to left in an inverted position.



ainline Plan and Profile Sheets

ecific guidelines for the preparation of mainline plan and profile sheets are presented low.

ales

e scales for mainline plan and profile sheets should be as follows:

- Rural projects — Plan 1cm = 10m
  Profile 1cm = .5m Vertical
  1cm = 10m Horizontal
- Urban projects — Plan 1cm = 5m
  Profile 1cm = .25m Vertical
  1cm = 5m Horizontal

ight-of-Way and Land Information

nd information shown on the plan sheets should be limited to map coordinate numbers.

ght-of-way information provided on the plan sheets should depict the relationship of the new O.W. to project centerline.

pography

pography to be shown includes utilities, irrigation and drainage facilities, buildings and ner items pertinent to construction operations.

here overhead utilities cross the centerline, notes indicate the centerline stations, the types of lities, the numbers of wires, the angle at which they cross the centerline, and the clearances ove the present ground. Where underground utilities cross the centerline or come within construction limits, notes will reference these utilities to centerline as well as give the types utilities and the sizes and depths of pipe.

adway Alignment Data

rizontal alignment data should be provided as follows:

- Staked and projected alignments are represented, showing equations. The staked centerline within projections should be dashed. Nonparallel projections should show ties between staked and projected lines.
- Bearings are written near the lines to which they apply.
- Identify the P.I., P.C. and P.T. by station.
- Place lists of curve data, including full superelevation, near the P.I.'s. Full superelevation is expressed as a percentage.

The lists of curve data show the following items in this order:

P I.	(P.I Number)
Δ	(Delta angle)
D	(Degree of curvature)
R	(Radius of curve)
T	(Tangent length)
L_c	(Length of curve)
E	(External distance)
e	(Rate of full superelevation)

Vertical alignment data should be provided as follows:

- Profile grade lines are shown in relation to original ground lines. Record the elevations of these lines in two rows along the bottom of the profile — original ground elevations on the bottom row, profile grades on the top row. The drawn ground line reflects all centerline elevations provided by the survey. Recorded ground line elevations should be at 25-meter intervals for rural areas. Profile grade elevations are recorded at 25-meter intervals.
- P.C.'s and P T.'s are depicted with small circles on the grade line. Show the vertical curve length and middle ordinate.
- P.I.'s are depicted by small triangles at the intersections of the dashed tangent lines. Notes at P.I.'s indicate P I. stations and elevations.
- Tangent gradients are shown.
- Place bench-mark notes in the bottom part of the profile near the stations to which they apply.
- Record reference elevations at 1-meter intervals in the columns on each side of the profile.

Right-of-Way, Easements, and Control of Access

Right-of-way limits are shown. Describe breaks in right-of-way alignments by centerline stations and offsets Stations are written as plus stations and offsets will be expressed in meters. Easement areas and control of access limits, as applicable, should be clearly defined. Where control of access limits does not coincide with right-of-way limits, label each clearly.

Items to be Installed or Constructed

Show items to be installed or constructed using standard symbols wherever standard symbols are applicable. The symbols are supplemented by notes indicating station locations and brief descriptions of the items. Refer to the section on "Use of Notes".

Items to be Removed

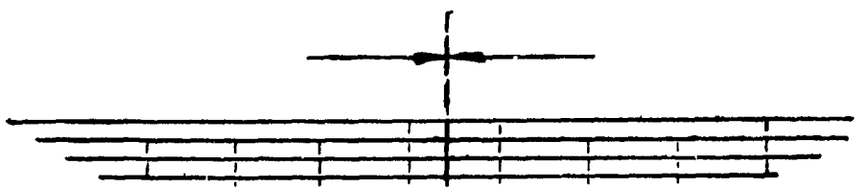
ihow items within the right-of-way limits to be removed. Those items to be removed by ioncontractor personnel should be clearly noted.

Earthwork Data

'he following earthwork data for each balance are recorded at the top of the profile view iear the station which represents the center of the balance area :

- the beginning and ending stations of the balance area
- the in-place quantities of roadway excavation and embankment
- the total in-place quantities of excavation and embankment.

arthwork balance points are represented by vertical lines and short arrows, at the appropriate tations, drawn just above the profile portion of the sheet thus:



lan Views of Geometric Layouts

lan views of geometric layouts are used where mainline-plan and profile sheets cannot dequately show horizontal alignment details of large or complex facilities, such as interchanges nd major intersections.

ie contents of geometric layouts are generally the same as the contents of plan views on ainline-plan and profile sheets, with these exceptions :

- Topography is not shown.
- The names of the features are clearly shown on the right side of the sheets.

Supplemental Profiles

Supplemental profiles are used to show vertical alignment of improvements other than mainline roadways, such as frontage roads and ramps.

Supplemental profiles should be drawn on cross-section paper.

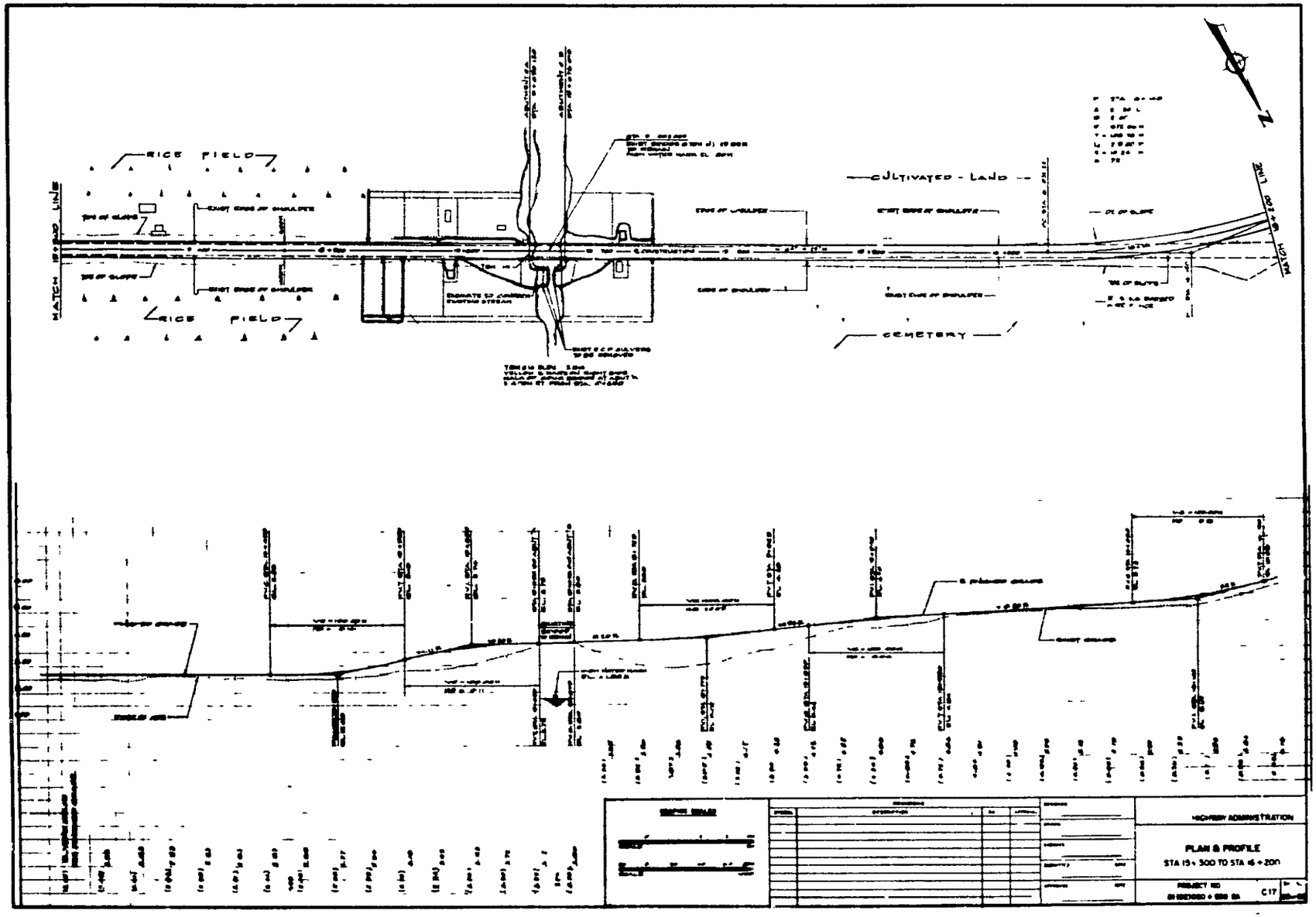
Supplemental profiles contain the same types of information as shown on profile views of mainline-plan and profile sheets. In addition, the names of the supplemental profiles are shown on the right sides of the sheets.

Contour Grading Plans

Contour grading plans should be prepared for all interchanges. These plans show the final shape of the finished ground, using contour lines and elevations.

Contour grading plans should show the following items:

- Centerlines and station marks for mainlines, crossroads and frontage roads
- Base lines and station marks for ramps
- Object lines showing traffic lanes, shoulders and drainage structures
- Arrows showing the direction of flow through drainage structures
- Names or other identification for crossroads, ramps, and frontage roads
- Elevation lines at 0.5-meter intervals with elevations noted at 2-meter intervals
- Names and scales of interchanges on the right side of the sheets.


RICE FIELD
RICE FIELD
CULTIVATED - LAND
CEMETERY
MATCH LINE
MATCH LINE
HIGHWAY ADMINISTRATION
PLAN & PROFILE
STA 15+500 TO STA 16+200
C17

LIGHTING, SIGNING AND UTILITY SHEETS

Symbol Legend

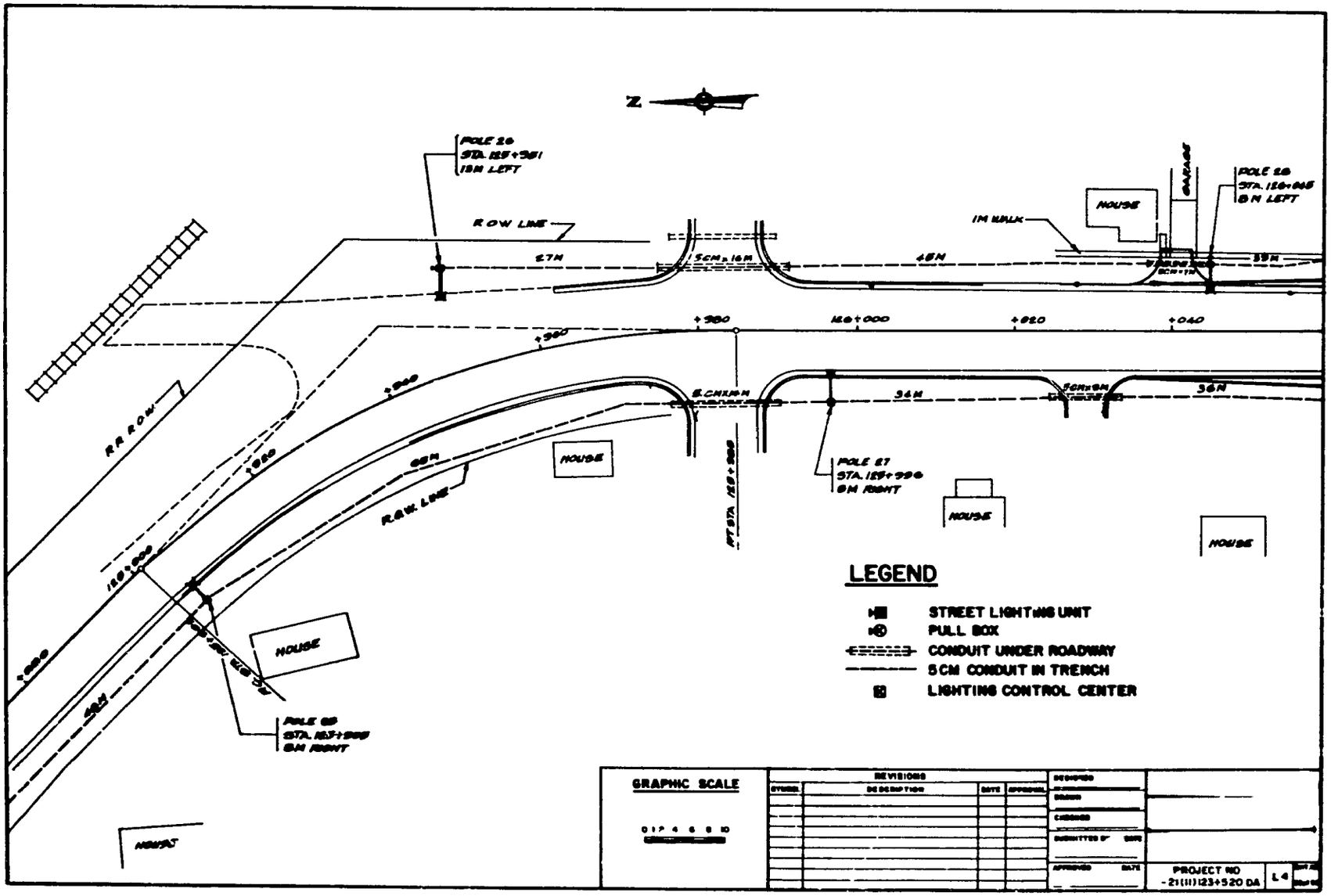
The first sheet of each of these speciality plans will contain a complete legend of symbols as used on those plans.

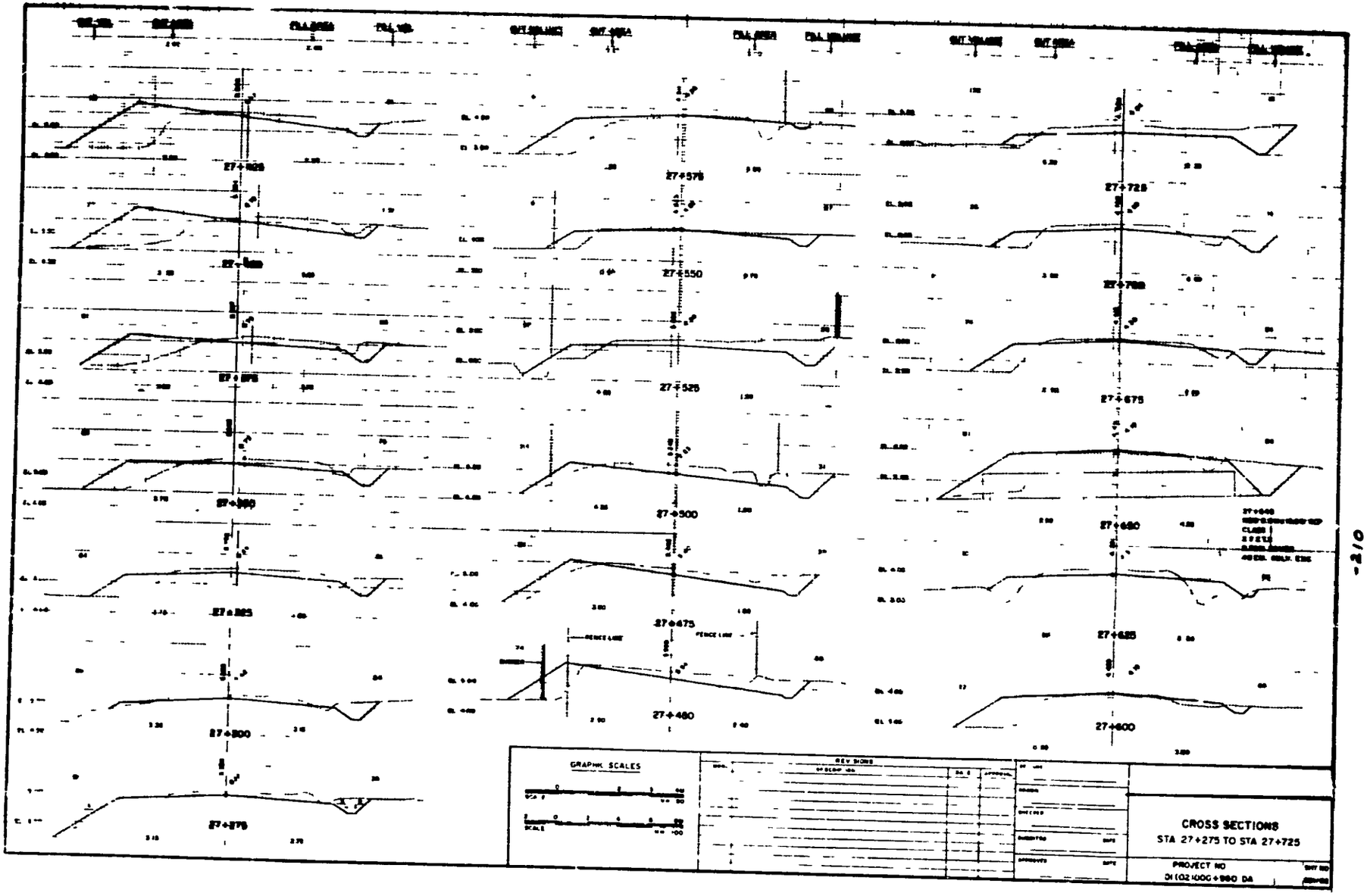
Sheet Identification

The normal sheet-numbering system used throughout the plans will be used on these speciality plans. In addition to this number, a sheet code number using a letter prefix will be used. For explanation of the sheet code, refer to the section entitled "Sheet Codes" earlier in this Chapter.

Scales

These sheets are prepared in the same scale as the plan portions of the plan and profile sheets.


N
POLE 26
STA. 125+941
19M LEFT
ROW LINE
27M
15CM x 16M
48M
1M WALK
HOUSE
GARAGE
POLE 28
STA. 126+065
8M LEFT
39M
+980
126+000
+020
+040
+900
+940
+960
R.R. ROW
E.CHIAPAN
34M
50M x 9M
36M
68M
R.O.W. LINE
HOUSE
PT STA. 125+999
POLE 27
STA. 125+996
8M RIGHT
HOUSE
HOUSE
HOUSE
125+900
+920
+880
HOUSE
POLE 25
STA. 125+999
8M RIGHT
HOUSE
LEGEND
STREET LIGHTING UNIT
PULL BOX
CONDUIT UNDER ROADWAY
5CM CONDUIT IN TRENCH
LIGHTING CONTROL CENTER
GRAPHIC SCALE
0 1 2 4 6 8 10
REVISIONS
DESCRIPTION
DATE
DESIGNED
DRAWN
CHECKED
SUBMITTED BY
APPROVED
DATE
PROJECT NO
-21(11)123+520 DA
L 4


27+275
27+300
27+325
27+350
27+375
27+400
27+425
27+450
27+475
27+500
27+525
27+550
27+575
27+600
27+625
27+650
27+675
27+700
27+725
FENCE LINE
GRAPHIC SCALES
CROSS SECTIONS
STA 27+275 TO STA 27+725
PROJECT NO
DI 02 100G + 980 DA

MODEL BRIDGE PLANS

The following model bridge plans are intended to be used as a guide in the preparation of contract plans. As in most bridge projects, any definite plan set organization cannot be followed exactly and this set of plans is no different in that respect.

The highway and existing bridge shown are nonexistent.

All lettering has been done with a Leroy–lettering set for clarity, whereas in actual practice, freehand lettering of most small print will be found to be much faster. In freehand lettering, extreme care should be taken to ensure that figures and letters are clearly written and cannot be mistaken for something other than what is intended.

Some portions of the plans, such as the reinforcing steel schedule, are not complete in that all the reinforcing required for a bridge of this size is not shown. To detail more would be repetitious and nothing would be gained in furthering the purpose of these plans.

It should be noted that the total number of bars are shown in the reinforcing-steel schedule, and only one schedule is used. This method should assist both the steel fabricator in supplying the correct amounts of steel and the project engineer in computing the correct weights for payment

The cross-section sheet also shows only a model number of sections to cover most of the situations encountered on a typical bridge project. In practice, more sections would be required to determine quantities with the accuracy necessary for an engineer's estimate.

Some of the sheets showing details of the prestressed beams could normally be reproductions of standard sheets. Standard sheets are being developed for all the prestressed beams, precast piles and for any other bridge component that is used repetitiously.

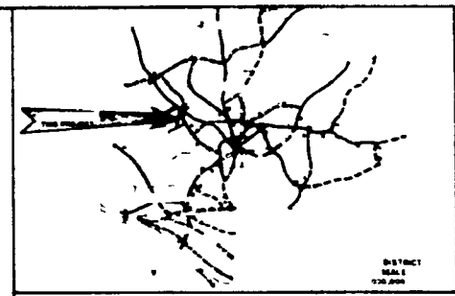
MINISTRY OF PUBLIC WORKS AND COMMUNICATIONS

HIGHWAY ADMINISTRATION

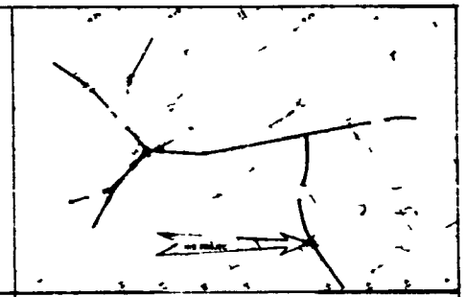
RECONSTRUCTION OF PEACE BRIDGE

PROJECT NO. 00 (01) CA

INDEX

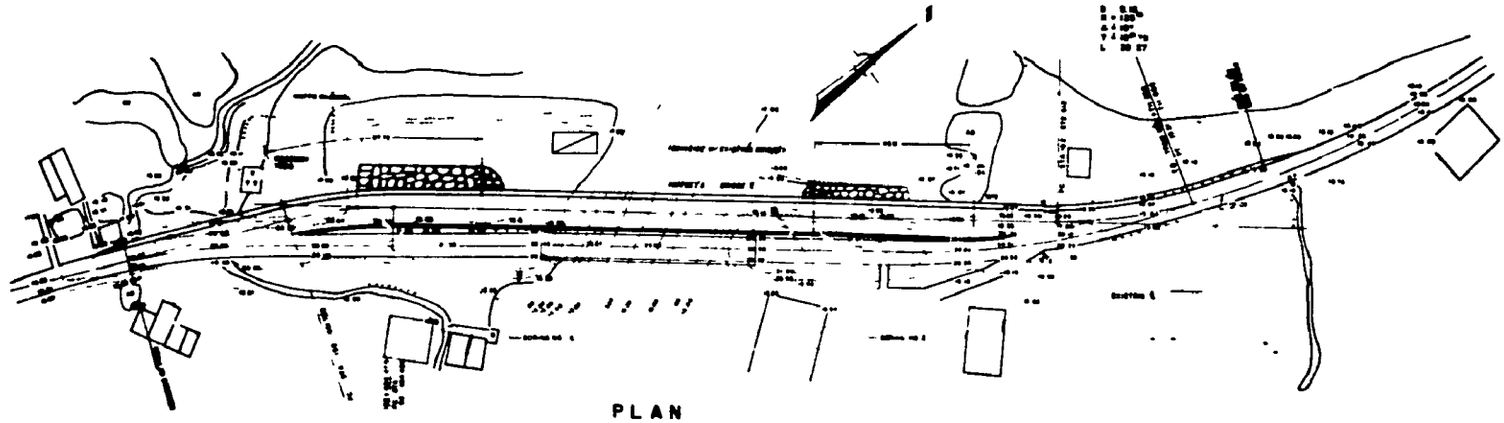


LOCATION MAP



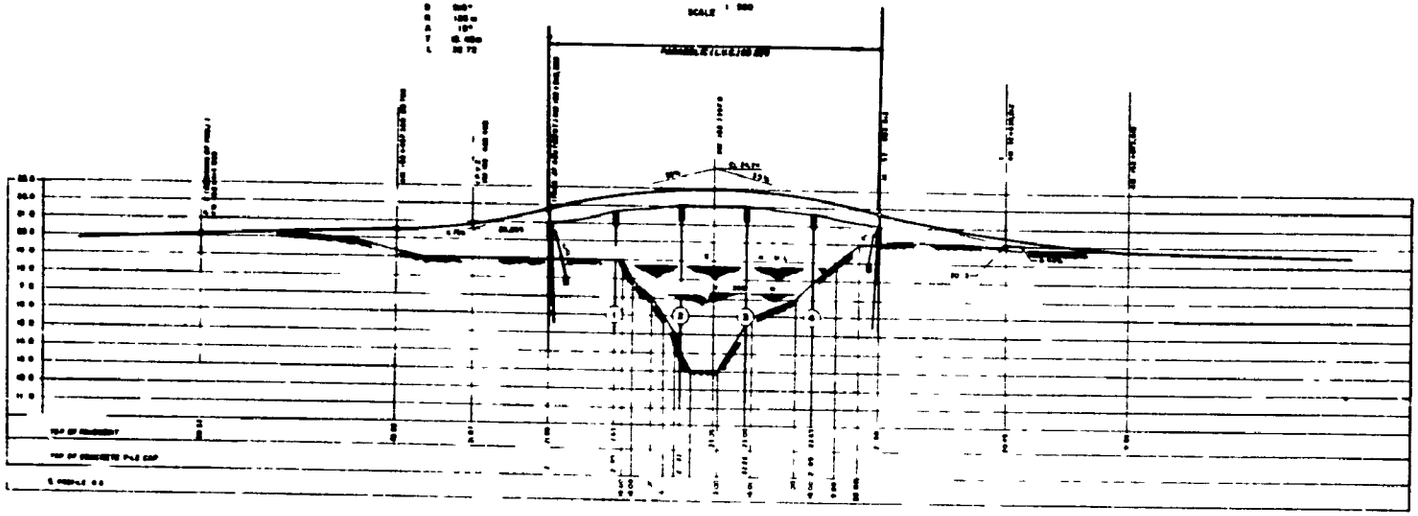
VICINITY PLAN

-212-



PLAN

SCALE 1:500



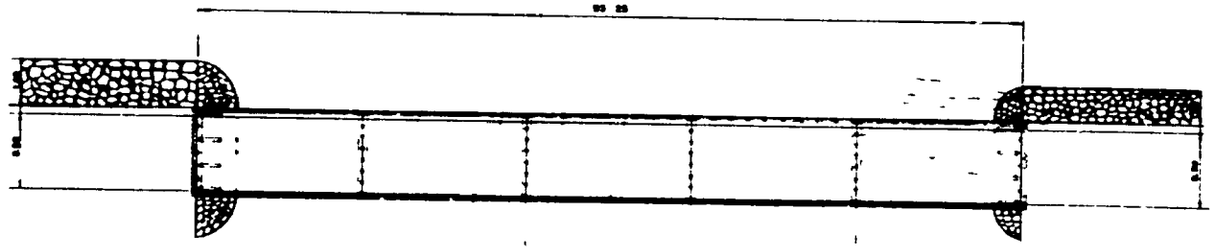
(PROFILE)

SCALE HORIZONTAL 1:500
VERTICAL 1:100

GRAPHIC SCALES

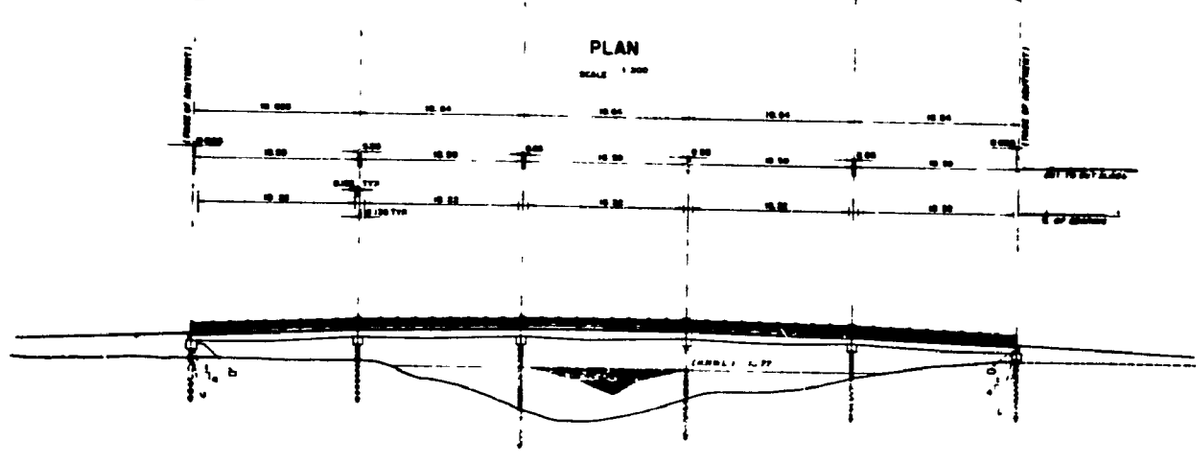
SCALE 1:100

SCALE 1:500



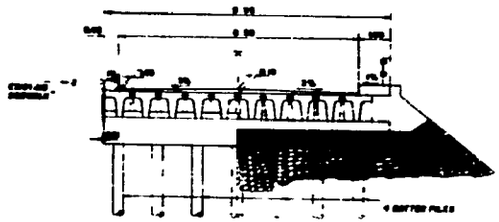
PLAN

SCALE 1:200



ELEVATION

SCALE 1:200

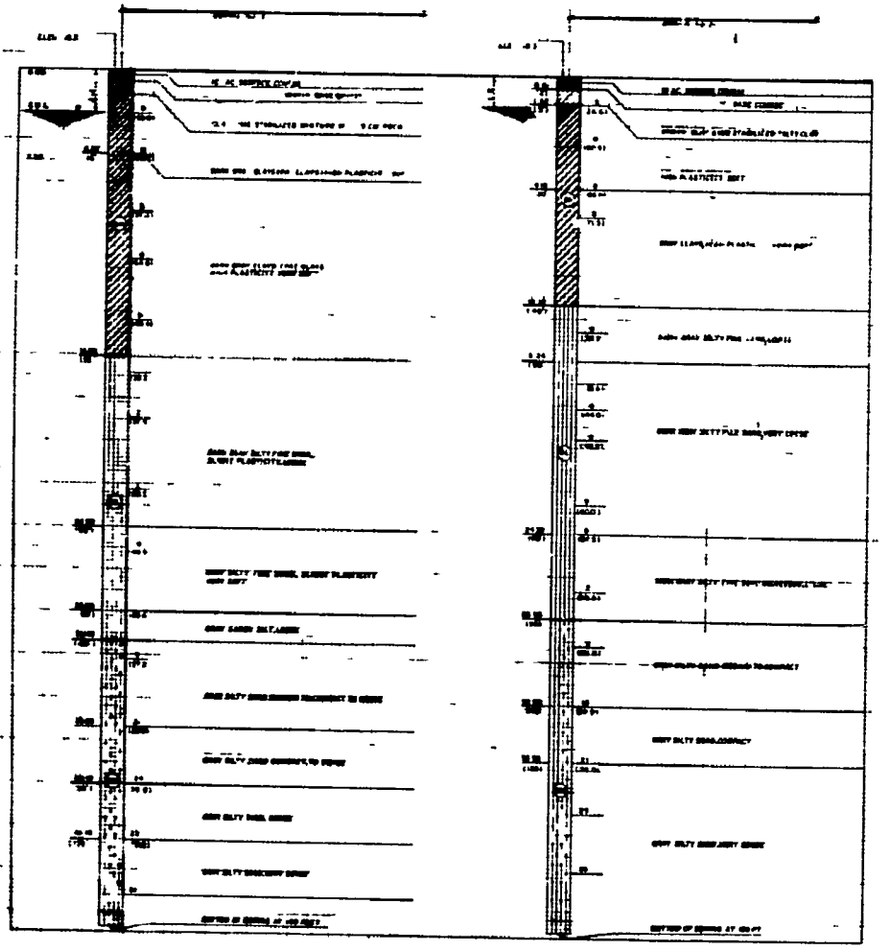


(SECTION)

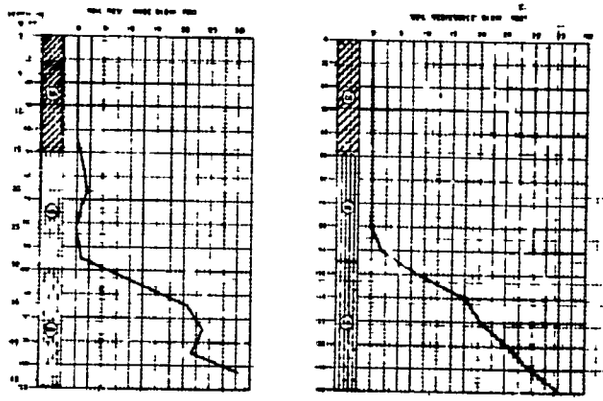
NOT TO SCALE

GRAPHIC SCALE

SCALE 1:200



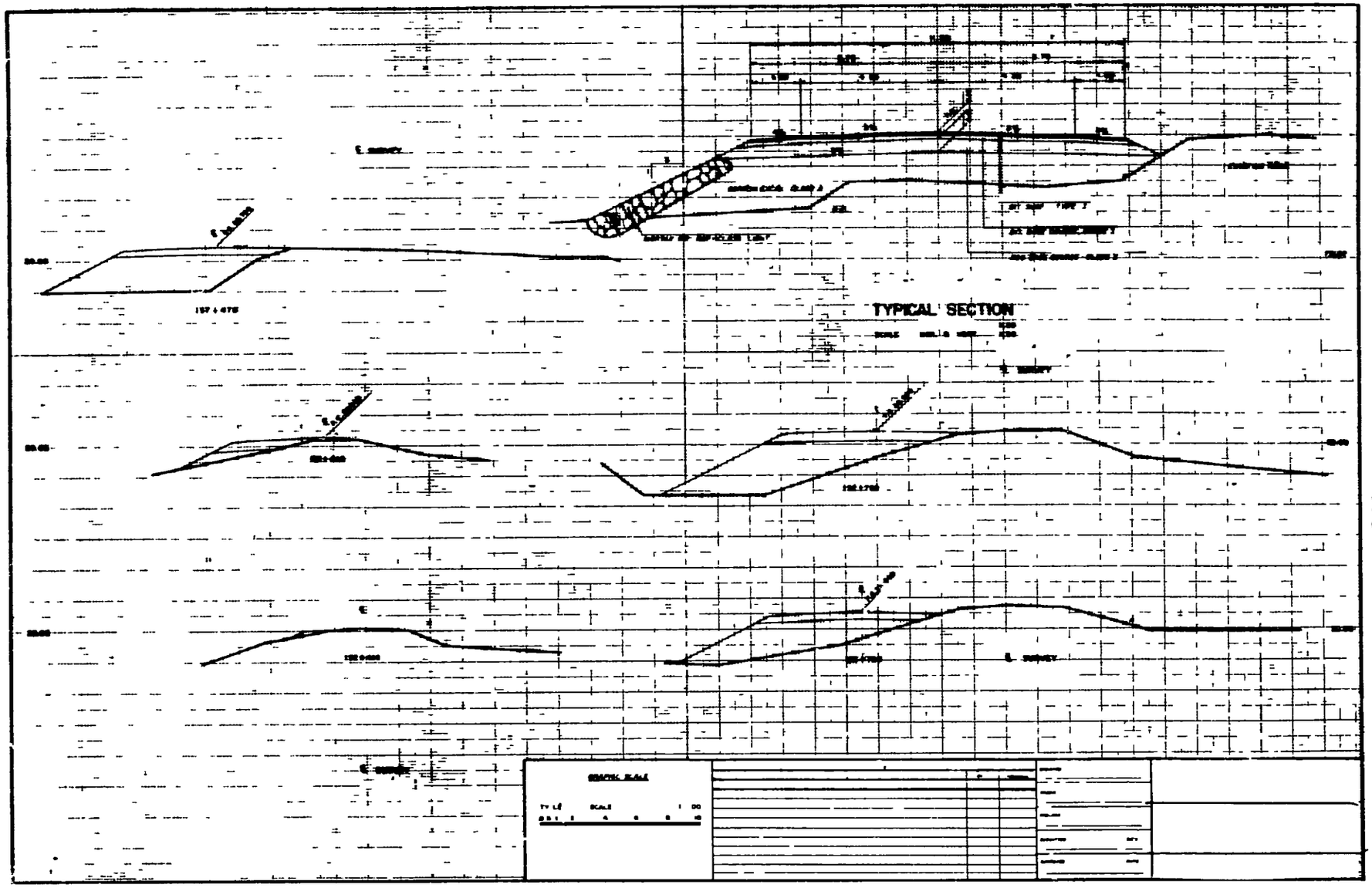
DEEP BORING LOGS

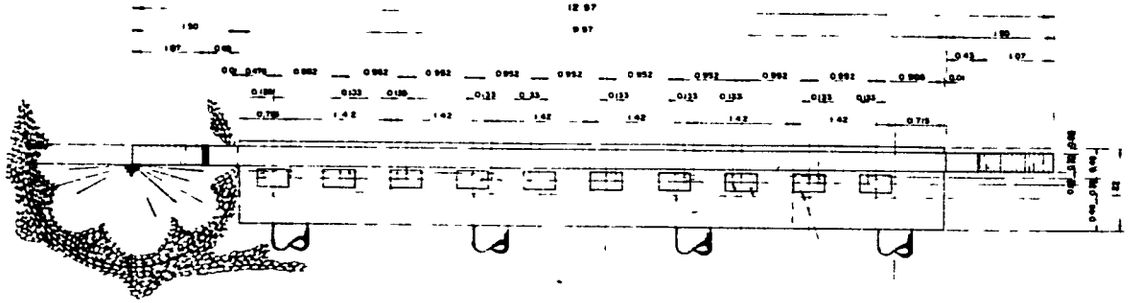


STANDARD PENETRATION RESULTS

NOTES

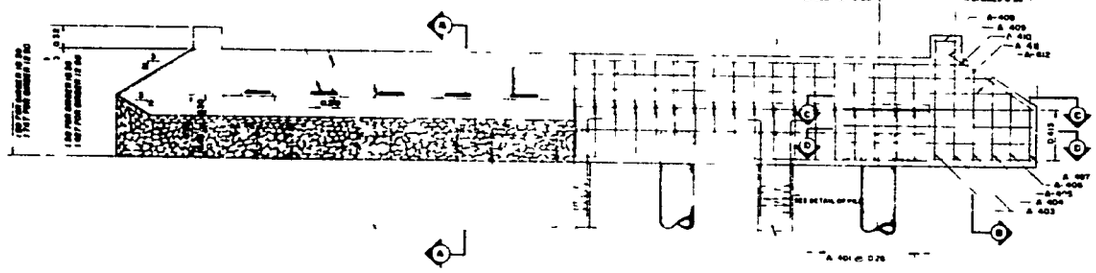
1. SOILS BORINGS WERE TAKEN BETWEEN THE MONTHS OF [illegible] AND [illegible] 1974 BY THE [illegible]
2. SOILS ARE CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOILS CLASSIFICATION SYSTEM ([illegible])
3. THE NUMBER OF THE BLOWS REQUIRED TO DRIVE A 140 LBS HAMMER FALLING 30 INCHES [illegible] A 1 3/8 INCH INSIDE DIAMETER SPOON. NUMBERS ENCLOSED IN PARENTHESIS REPORT MOISTURE CONTENT EXPRESSED AS PERCENT DRY SOIL WEIGHT
4. THE NUMBER ON LEFT OF BORING LOGS DENOTES THE DEPTH IN METERS, THOSE ENCLOSED IN PARENTHESIS DENOTES THE DEPTH IN FEET
5. [illegible] INDICATES THE GROUND WATER LEVEL ENCOUNTERED DURING THE TIME OF DRILLING


TYPICAL SECTION



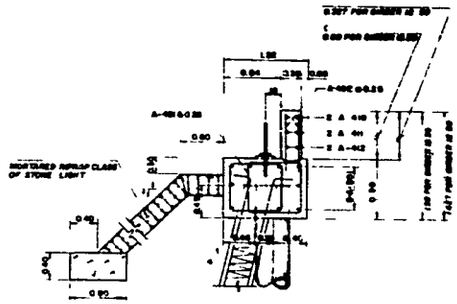
PLAN

SCALE 1:25



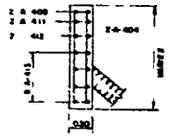
ELEVATION SECTION

SCALE 1:25



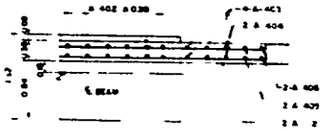
SECTION "AA"

SCALE 1:25



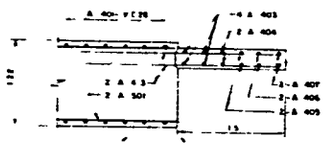
SECTION "BB"

SCALE 1:25



SECTION "CC"

SCALE 1:25



SECTION "DD"

SCALE 1:25

GRAPHIC SCALE

SCALE 1:25

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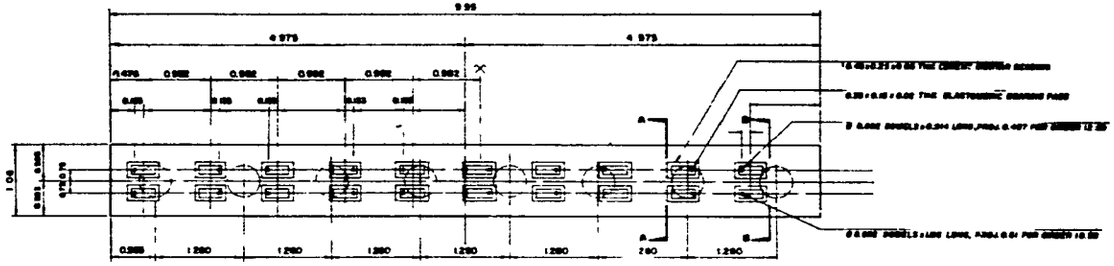
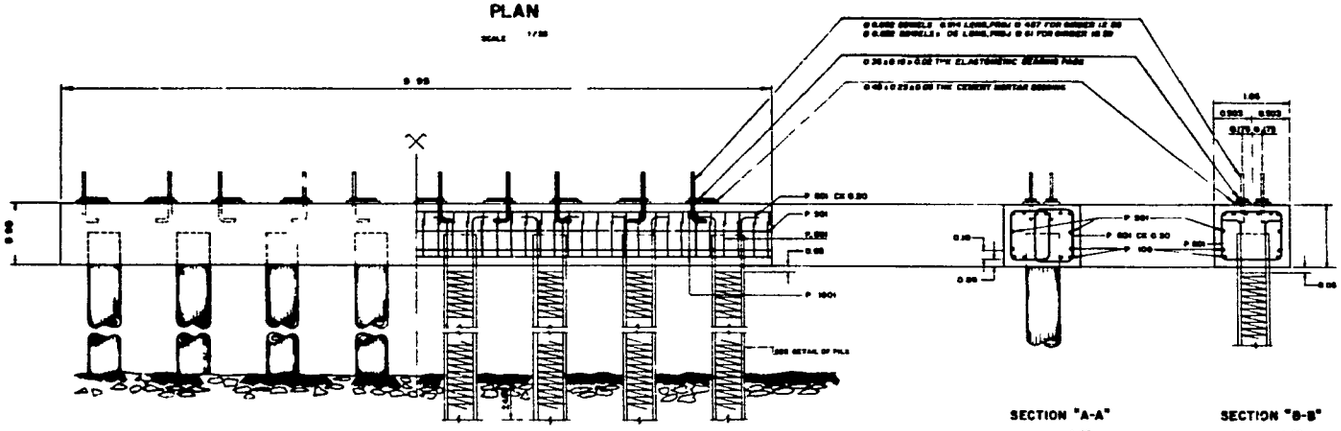


PLAN

SCALE 1/25



SECTION "A-A"

SCALE 1 25

SECTION "B-B"

SCALE 1 25

HALF PIER ELEVATION

SCALE 1 25

HALF PIER SECTION

SCALE 1 25

(NOTE)

PILE TO BE DRIVEN TO BEARING CAPACITY OF 45 TONS

GRAPHIC SCALE

SCALE 1 25

0 50 1 2 3

REVISION

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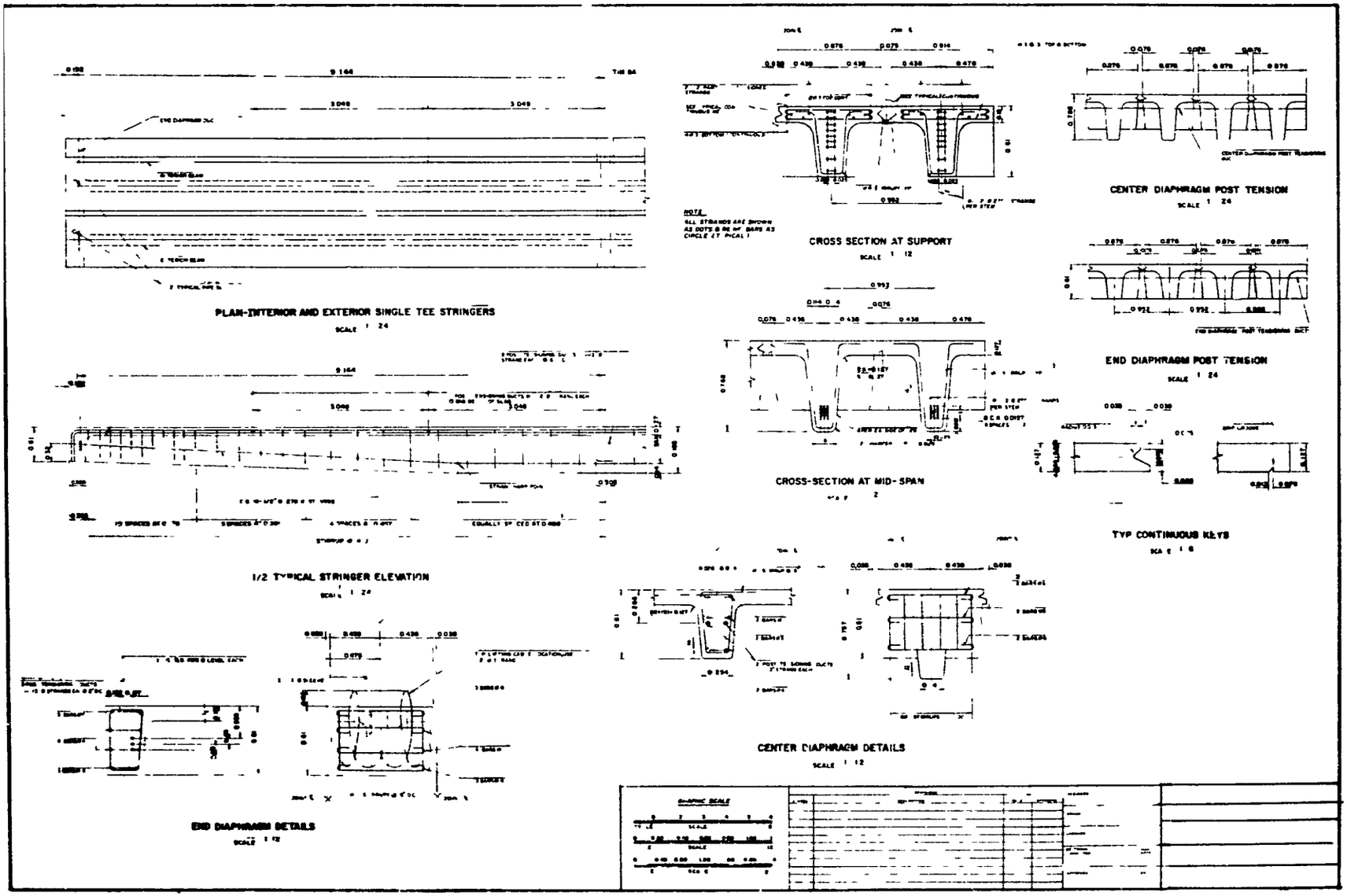
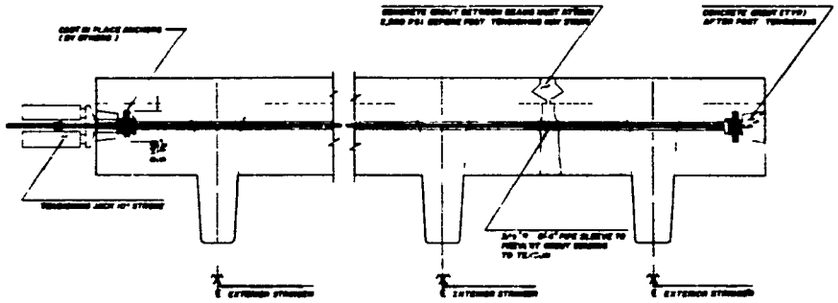
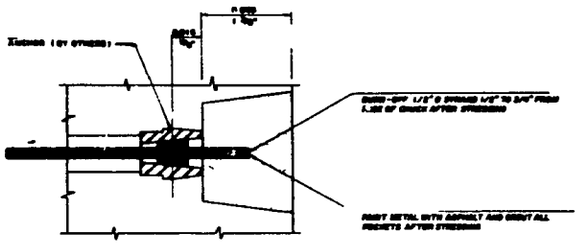

PLAN-INTERIOR AND EXTERIOR SINGLE TEE STRINGERS
SCALE 1 24
CROSS SECTION AT SUPPORT
SCALE 1 12
CENTER DIAPHRAGM POST TENSION
SCALE 1 24
END DIAPHRAGM POST TENSION
SCALE 1 24
CROSS-SECTION AT MID-SPAN
TYP CONTINUOUS KEYS
1/2 TYPICAL STRINGER ELEVATION
CENTER DIAPHRAGM DETAILS
SCALE 1 12
END DIAPHRAGM DETAILS
GRAPHIC SCALE



TYPICAL LATERAL POST-TENSIONING

SCALE 1:24



DETAIL OF POST-TENSIONING ANCHOR

NO SCALE

POST-TENSIONING NOTES

VERIFY That BEAM CAMBERS furnished by others are correct and that the beam placing sequence is optimum

STRANDS Shall be 1/2" ϕ 240 KS galvanized 7 wire strands
Thoroughly clean the strands at the ends prior to placing the anchors

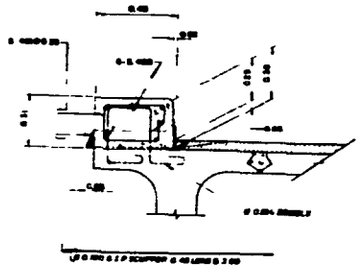
INSTALL Post-tensioning strands & grout sleeves as each beam is being set into position

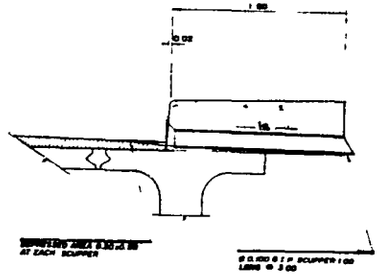
DECK GROUTING Verify that the grout sleeve is fully preventing bond at the joints
Grout shall have a 28 day f'c = 3,000 psi 3/8 max aggregate & 2" max slump thoroughly shaken
Grout key before placing grout. Grout shall be free of voids, deck pockets, etc. conc. shall be cured with pigmented membrane curing compound or by being kept continuously wet for 28 days

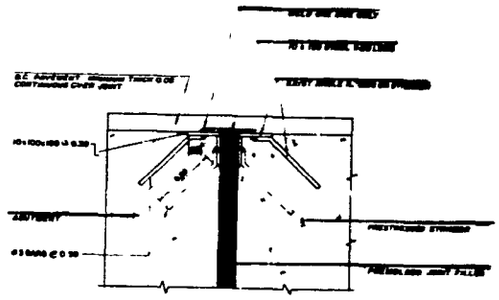
STRESSING Not commence after the grout has attained 2,500 psi. Strands shall be stressed as the work progresses from the span 1 to 9 then end elongation measurement shall kept being until after all slack has been removed and the proper end bearing load has occurred. Slack in the strands and end bearing loads shall be removed by applying a jacking force of 10,000 ± 10,000 psi to the strands and released to 500 psi prior to commencing post tensioning. The strands shall be considered fully stressed at a gage reading of approx 170,000 psi & elongation of 2.1 ± 0.10. Inspect anchorage 24 hours after stressing and if any slippage has occurred replace the wrapper & restress the strands

SAFETY The post tensioning strands shall be carefully inspected for broken wires, nicks, scratches, welds, or excessive rust and if any of the above or any found the strands shall be replaced. Grips shall be inspected before use to insure that the proper retaining end is in place and in good condition. Test the jaws are the same size for 1/2 ϕ strands that the jaw teeth are in perfect condition, that the anchor body is free of nicks, burrs, etc. that could damage the post tensioning strands. Ducts shall be thoroughly cleaned just before use to ensure that all cement, concrete, etc. collected during prestress beam fabrication is removed & core interior is absolutely free of all foreign matter. Absolutely no personnel will be in front of either end of the post tensioning strands while it is being jacked. No unnecessary personnel shall be present during the jacking operation

BURN OFF Strands no closer than 1/2" to the chuck to prevent heat from the cutting operation damaging the chuck jaws or strands. Paint all metal with 2 coats of asphalt and grout pocket grout per the operation. Shall be 2 parts sand to 1 part cement by weight, 6 gal max slump shaken dry. Surface conditions and concrete shall be cured with pigmented membrane forming curing compound or by being kept continuously wet for 28 days



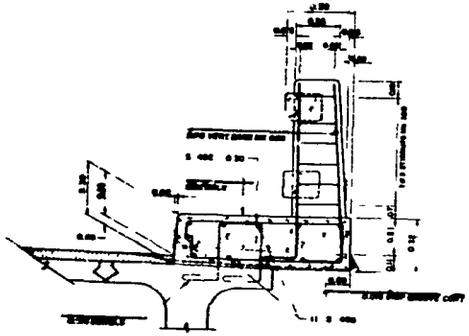


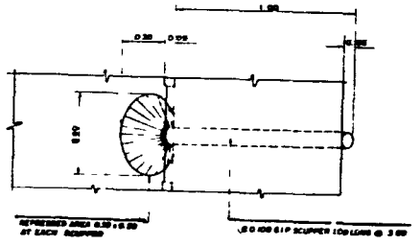


AT ABUTMENT & PIER

DECK EXPANSION JOINT DETAILS

SCALE





SIDEWALK DETAILS

SCALE

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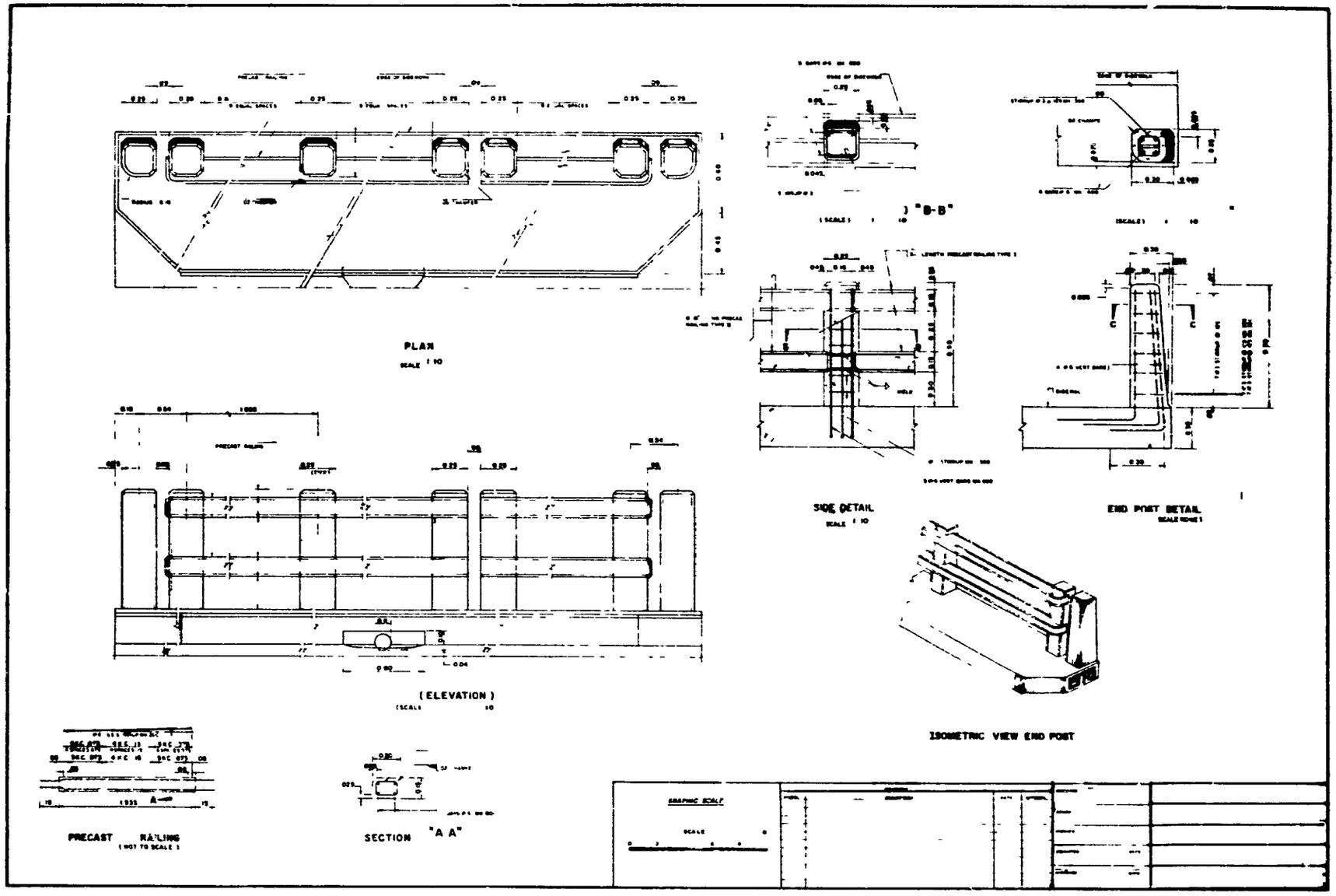
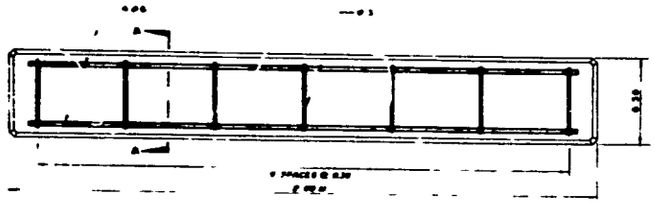
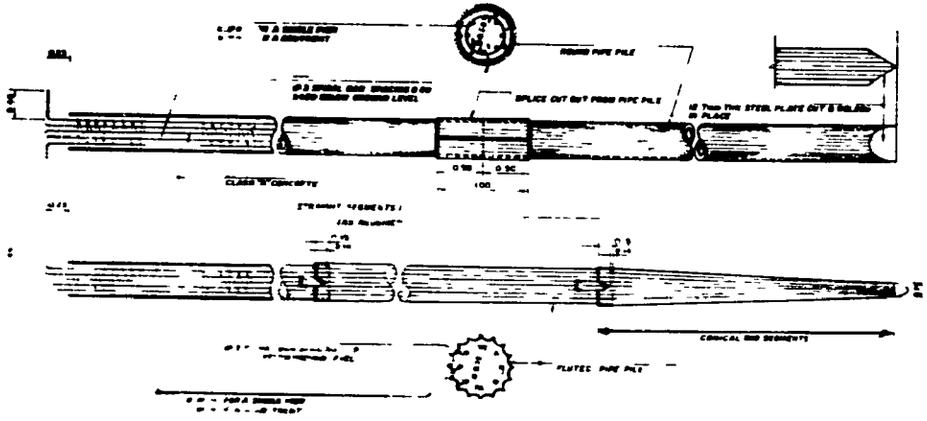

PLAN
SCALE 1:10
"B-B"
SIDE DETAIL
SCALE 1:10
END POST DETAIL
(ELEVATION)
ISOMETRIC VIEW END POST
PRECAST RAILING
(NOT TO SCALE)
SECTION "A A"
GRAPHIC SCALE
SCALE

(GUARD POST)



(PLAN)

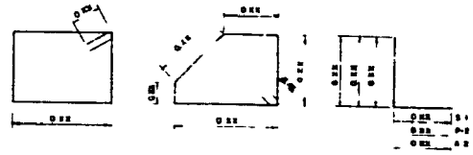
(SECTION) A-A



DETAILS OF Ø 0.46 STEEL PIPE PILE

REINFORCING BAR SCHEDULE

BENT BARS



MARK	SIZE	NUMBER	LENGTH	LOCATION
P 1	5	40		PIER CAPS
A-1	6	46	0.XX	ABUTMENTS
A 2	4	20	0.XX	ABUTMENTS
P 2	4	10	0.XX	PIER CAPS
S-1	4	140	0.XX	SUPERSTRUCTURE SUBSTABLE

STRAIGHT BARS

MARK	SIZE	NUMBER	LENGTH	LOCATION
A 3	6	26	0.XX	PIER CAPS
A-4	4	44	0.XX	ABUTMENTS
P 3	4	62	0.XX	PIER CAPS
S 1	6	114	0.XX	PIER CAPS
S-2	6	230	0.XX	ABUTMENTS

CHAPTER FIFTEEN

PAVEMENT STRUCTURE DESIGN

GENERAL CONSIDERATIONS

Pavement structure design refers to the design of the wearing course, base and subbase courses. These layers when properly designed and constructed are capable of transmitting wheel loads to the subgrade soil beneath without causing undue distortion of the pavement structure or the subgrade. In addition to considering the short-term effects, such as settlement caused by inadequate pavement thickness and strength, the designer must also consider the potential maintenance problems. Since repairs or replacement would be expensive and disruptive of traffic, the road must be built to last a reasonably long period of time with a minimum of maintenance.

This Chapter contains design criteria and a guide to reference material necessary for the designer to develop the most economical structural section consistent with HA goals and policies.

PAVEMENT SELECTION COMMITTEE

General Consideration

During the initial design stages of all road projects many decisions are made which will have an effect on the ultimate design of the project. One such decision is the type of pavement to be used. A pavement selection committee is established by the Director of Engineering in order to make this decision.

Committee Membership

Committee membership is made up of Engineers from the following divisions within the HA:

- Road Design
- Construction
- Maintenance
- Materials.

The Director of Engineering or his representative acts as chairman of the committee with the Road Design Division responsible for reporting and carrying out the committee's final recommendations. Besides these committee members, the designer who will be responsible for the actual pavement design will sit on the committee as a nonvoting member.

Pavement Selection Factors

The decision as to which type of pavement to use is primarily one of economic. Which type of pavement will provide the best roadway for the least amount of construction and maintenance money is the question the committee must answer. This is not an easy question For example, a rigid pavement may cost more to construct than a flexible pavement but be cheaper to maintain. A rigid pavement when built on a weak subgrade, however, may break up excessively, causing maintenance costs to go up. In this case, would it be more economical over the life of the road to build a flexible pavement on an existing surface or slightly improved subgrade and pay higher maintenance costs, or build a rigid pavement on a much improved subgrade and possibly pay less maintenance costs? This and similar questions must be answered before a decision on pavement types can be made.

The principal factors which influence pavement selection are listed below.

Road Design

- Class of road
- Traffic
- Cost of different pavement types
- Hydrology data

Construction

- Availability of contractors to do work
- Competence of contractors

Maintenance

- Direct cost of repairs
- Road user cost when road is closed or partially closed for extensive repairs
- Indirect cost of serious failures (accidents, build-up of traffic, etc)

Materials

- Availability of materials
- Cost of materials
- Suitability of materials.

These factors, together with facts about the actual project, will, when properly used, provide enough information so that an intelligent, economical decision can be made.

After a decision has been made, the Pavement Selection Committee's report which has been approved by the Director of Engineering is forwarded to the designer in charge of the pavement design. This report will contain all data necessary to begin pavement design, namely: traffic counts, strength of subgrades, strengths and suitability of the materials to be used, hydrologic data and other specific information and recommendations which will effect the pavement design.

FLEXIBLE PAVEMENT

Sources of Information

The design procedures used for flexible pavement design are fully described in the Asphalt Institute manuals found in the HA research library. The most frequently used of these manuals are: (1) *Thickness Design-Full Depth Asphalt Pavement Structures for Highways and Streets*, Manual Series No.1 (MS-1); (2) *Soils Manual for Design of Asphalt Pavement Structures*, Manual Series No.10 (MS-10); (3) *Asphalt Surface Treatments*, Manual Series No.13 (MS-13); and (4) *Asphalt Overlays and Pavement Rehabilitation*, Manual Series No.17 (MS-17).

Outline of the Asphalt Institute Design Procedure

The design process as described in MS-1 consists of three parts. The first step is to perform a traffic analysis in order to determine a Design Traffic Number (DTN). Next, the strength of the subgrade is determined using the California Bearing Ratio (CBR), Resistance Value (R), or Bearing Value Determination (Plate Bearing Test). Finally, the traffic factor and subgrade support factor are used in a nomograph to determine the total thickness of asphalt concrete pavement necessary.

At this point the designer has two options. He can either specify that the entire thickness be asphalt concrete pavement or he can design an equivalent thickness using an asphalt wearing course and a granular base course. Both methods are fully described in MS-1.

RIGID PAVEMENT

Sources of Information

Rigid pavement design will be in accordance with the Portland Cement Association's design procedures. The three principal manuals used are *Thickness Design for Concrete Pavements*, *Subgrades and Subbases for Concrete Pavements* and *Joint Design for Concrete Pavements*. These and other pavement design manuals are located in the HA research library.

Outline of PCA Design Procedures

In the PCA design procedure as in the flexible design procedure, a traffic analysis is performed and a subgrade support factor is determined.

A trial-depth of pavement is then assumed and a concrete-fatigue analysis is performed to determine the pavement's ability to withstand the expected repetition of axle loadings. The fatigue analysis provides a percentage which is a measure of the fatigue resistance used during the design period by the expected axle loadings. This percentage can then be used in comparing different combinations of pavement depths, concrete strengths and subgrade support factors.

PCA Tables of Information

Several of the tables which appear throughout the PCA manuals were developed for conditions in the United States. Most notable is table 8 in the manual entitled *Thickness Design for Concrete Pavements* This table was prepared from data obtained at 12 loadometer stations in the United States In the absence of corresponding data from HA station, the table may be used. When local loadometer data have been recorded, similar charts, more appropriate should be prepared.

ADDITIONAL INFORMATION

Besides the publication discussed in the preceding sections, many other books and manuals on asphalt and concrete pavements are located in the HA research library. The manuals include a complete set of Asphalt Institute manuals and many PCA publication. The *AASHO Interim Guide for Design of Pavement Structures 1972* is also available in the research library. This publication provides the designer with additional design procedures for asphalt and concrete pavement and presents much of the theory surrounding pavement design.