TRANSIT

RAPID TRANSIT SYSTEM EXTENSIONS
COMPENDIUM OF DESIGN CRITERIA

VOLUME III
AERIAL GUIDEWAY DESIGN CRITERIA

CHAPTER 2
CIVIL & TRACKWORK DESIGN CRITERIA

INTERIM RELEASE
REV 1

OCTOBER 30, 2008

PROGRAM MANAGEMENT CONSULTANT

– Intentionally Left Blank –

MIAMIDADE COUNTY
TRANSIT

VOLUME III – AERIAL GUIDEWAY

CHAPTER 2 – CIVIL & TRACKWORK DESIGN CRITERIA

REVISION 1

Program Management Consultant

Submitted _____ Date 5/1/09
Project Manager, Soji Tinubu

Miami-Dade Transit
Engineering Review Board Members

Approval _____ Date 5/4/09
Chief of Design & Engineering, Isabel Padrón

R. Steiner _____ Date 5/4/09
Chief of Construction, Ron Steiner

for Eric Muntan _____ Date 5/4/09
Chief of Safety, Eric Muntan

Daniel Mondesir _____ Date 5/4/09
Manager of Systems Engineering, Daniel Mondesir

Director Approval

Approval _____ Date 5/7/09
Deputy Director, Albert A. Hernandez

Approval _____ Date 06/01/09
MDT Director, Harpal Kapoor

– Intentionally Left Blank –

DOCUMENT REVISION RECORD

ISSUE NO.	DATE	REVISION DESCRIPTIONS
0	4-19-07	Interim Release
1	10-30-08	Revisions to incorporate MIC-EH design specifications that have been adopted by MDT.

ISSUE NO.	SECTIONS CHANGED
1	2.06.4.C Clearances – Stations – Horizontal gap between train and Station platform edge.

– Intentionally Left Blank –

VOLUME III - GUIDEWAY DESIGN CRITERIA

CHAPTER 2 - CIVIL AND TRACKWORK DESIGN CRITERIA

REVISION 1

Table of Contents Page No.

TABLE OF FIGURES Page No.

2.01 GENERAL

2.01.1 FOREWORD

The purpose of these design criteria is to establish the minimum civil design standards to be used in the design of the Rapid Transit System Extensions.

2.01.2 BASIS OF CRITERIA

These criteria were developed considering passenger comfort, safety, and accepted engineering practices used in currently operating rapid transit systems, and as set forth in Volume I, Systemwide Criteria of this Compendium of Design Criteria.

2.01.3 CODES AND REGULATIONS

The current adopted version of the codes, standards and regulations cited within this document shall apply, and unless otherwise directed, all addenda, interim supplements, revisions and ordinances by the respective code body shall also apply. Where conflicts exist between these, the more stringent requirement shall take precedence, unless otherwise directed by MDT.

2.01.3.1 Feeder Bus Facilities

Except as modified herein, these facilities shall be in accordance with the design concepts of the American Association of State Highway and Transportation Officials (AASHTO) and the Florida Department of Transportation (FDOT). Reference is made to these data for the pertinent design criteria of bus roadways to meet system requirements. For Traffic Design Criteria refer to Volume I - Systemwide Criteria, Chapter 3, Traffic Design Criteria.

2.01.3.2 Fixed Rapid Transit Guideway Facilities

Except as modified herein, the fixed guideway geometry, superelevation and civil design speeds for the rail vehicle shall be in accordance with current applicable requirements of the American Railway Engineering and Maintenance-of-Way Association (AREMA) "Manual for Railway Engineering", and "Portfolio of Trackwork Plans".

2.02 CONTROL

2.02.1 INTRODUCTION

The following criteria will govern the horizontal and vertical control in the design and construction of the Rapid Transit System Extensions.

2.02.2 HORIZONTAL CONTROL

The horizontal control for all alignments shall be based on the established Project Survey Control Points. All project coordinates shall be based on the Florida State Plane Coordinate System for the East Zone of Florida, North American Datum of 1983, 1990 Adjustment (NAD 83/90).

2.02.3 VERTICAL CONTROL

The vertical control for this project is based on the National Geodetic Vertical Datum of 1929 (NGVD 1929), as adopted by Miami- Dade County.

– Intentionally Left Blank –

2.03 HORIZONTAL ALIGNMENT

2.03.1 GENERAL

2.03.1.1 The horizontal alignment will consist of tangents joined to circular curves by spiral transition curves or special trackwork.

2.03.1.2 Curvature and superelevation shall be related to design speed, including a consideration for the acceleration and deceleration characteristics of the design vehicle.

2.03.1.3 Wherever possible, the geometrics shall accommodate the maximum design speed of 70 miles per hour.

2.03.1.4 Stationing and geometrics shall be denoted for centerline of the outbound track of each corridor as indicated on Figure 2-2, Line Designation. The stationing of the outbound track shall be equated to the stationing of the inbound track wherever practical however, independent track stationing shall be required but not limited to the following cases:

A. When track profiles differ.
B. In yard areas.
C. At turnouts.

Stationing for tracks initiating from a turnout shall be based upon a station equality commencing at the point of switch and carried through the PITO of the turnout.

2.03.1.5 Geometrics shall be denoted for all tracks.

2.03.2 TANGENT LENGTHS

The desirable minimum tangent length shall be 200 feet; the absolute minimum shall be 100 feet. At rapid transit stations, the horizontal alignment shall be tangent throughout the platform length; the tangent shall extend a minimum distance of 65 feet beyond each end of the future 616 foot platform as measured to a ST, TS, PC or PT. The tangent distance to a PS shall be 75 feet. Deviation from these lengths shall require approval by MDT.

2.03.3 CURVATURE

2.03.3.1 Circular Curves

Circular curves shall be defined by the arc definition of curvature, and specified by their radii. For mainline running track, the desirable minimum radius of circular curve is 1,000 feet. Radii under 1,000 feet shall require the approval of MDT. The desirable minimum radius of curvature for yard and secondary track is 300 feet. The absolute minimum radius is 250 feet and shall require the approval of MDT. The desirable minimum length of circular curve shall be 100 feet. However, if required and approved, the curve may be transitional throughout. Refer to Figure 2-3, Elements of the Transition Spiral Curve, for circular curve and spiral formulas and abbreviations.

2.03.3.2 Curve Restraining Rails

Restraining rails shall be used on the inside of the lower rail of curves where radius is less than 1000 feet (Main Line Track) and less than 300 feet (Yard & Secondary Track).

Restraining rails shall be installed horizontally, providing a flangeway opening consistent with the curve gage and extend 35 feet into the adjacent tangents.

Restraining rails will be braced and supported on every other tie or direct fixation fastener with provisions for flangeway adjustments.

2.03.3.3 Transition Spiral Curves

Transition spiral curves shall be used to connect all circular curves and tangents, except in yard and secondary track. The spiral used shall be the Barnett spiral. Spiral curve functions and abbreviations are shown on Figure 2-3. The minimum length of spiral shall be the greater of the lengths as determined by formulae (1) and (2):

(1) $L_s = 50\ E_a$

Where L_s = Minimum length of spiral, feet
E_a = Actual superelevation of rail, inches

(2) $L_s = 1.22\ E_u\ V$

Where L_s = Minimum length of spiral, feet
E_u = Unbalanced superelevation on curve, inches
Unbalanced superelevation is defined as the difference between the equilibrium superelevation and the actual superelevation.
V = Design velocity at the circular curve, mph

The absolute minimum length of spiral shall be 100 feet unless otherwise approved by MDT.

2.03.3.4 Compound Curves

Where compound circular curves are required, a spiral of sufficient length to satisfy the requirements of Section 2.3.3.2 shall be inserted between the circular curves. The formulae in Section 2.3.3.2 shall apply, modified as follows:

(1) $Ls = 50 (Ea2 - Ea1)$

Where Ls = Minimum length of spiral, feet
Ea1 = Actual superelevation of rail on the first circular curve, inches
Ea2 = Actual superelevation of rail on the second circular curve inches

(2) $Ls = 1.22 (Eu2 – Eu1) V$

Where Ls = Minimum length of spiral, feet
Eu1 = Unbalanced superelevation on the first circular curve, inches
Eu2 = Unbalanced superelevation on the second circular curve, inches
V = Design velocity at the circular curves, mph

The absolute minimum length of spiral between compound curves shall be 100 feet unless otherwise approved by MDT.

Unless otherwise approved by MDT, compound curves shall be designed for the same speed increment.

2.03.4 SUPERELEVATION

2.03.4.1 Maximum Actual Superelevation and Unbalanced Superelevation

The maximum unbalanced superelevation that the Designer may use, without receiving MDT approval, is: Eu = 4.0 inches.

The maximum actual superelevation that the Designer may use, without receiving MDT approval, is: Ea = 4.0 inches.

If Ea is less than or equal to 4.0 inches then the absolute maximum value of actual superelevation plus unbalanced superelevation shall not be exceed 8.0 inches. (Ea + Eu ≤ 8.0 inches)

The maximum actual superelevation that the Designer may use, after receiving MDT approval to exceed the limit of Ea = 4.0 inches, is: Ea = 4.5 inches.

If MDT has approved the use of an Ea greater than 4.0 inches, but less than or equal to 4.5 inches, then the absolute maximum value of actual superelevation plus unbalanced superelevation shall not exceed 8.5 inches. (Ea + Eu ≤ 8.5 inches)

2.03.4.2 Amount of Equilibrium Superelevation

Equilibrium Superelevation shall be determined by the formula:

$$Ee = Ea + Eu = 0.00070\ V^2\ D$$

Where Ee = Equilibrium superelevation, inches

Ea = Actual superelevation, inches

Eu = Unbalanced superelevation, inches

V = velocity, mph

D = degree of curve, in degrees

Expressed in terms of radius of curvature, this becomes:

$$Ee = 4.011 \frac{V^2}{R}$$

Where E_a, E_u and V are as above, and

R = Radius of circular curve, feet

The generally preferred relationship between superelevation, curvature and design speed is shown on Figure 2-4.

Curve Superelevation Design Parameters:

A. Introduction of Eu shall be used to improve curve speed within MDT and AREMA guidelines. The Designer needs to consider that a train may operate at a train speed level that is less than the intended design speed. The Designer shall examine the equilibrium superelevation for the speed level below the design speed level and, if possible, allocate the equilibrium superelevation between Eu and Ea such that Ea for the

design speed level is not greater than Ee of the next lowest speed level. A minimum Eu of 0.25 inches is desirable.

B. Calculated values of superelevation shall be rounded to the nearest one-quarter inch.

C. Superelevation values shall be based on Automatic Train Operation (ATO) fixed train speeds of 15, 28, 38, 46, 58 and 70 MPH.

D. Maximum curve speed will be consistent with speeds leading into or out of the curve or other limiting conditions.

In Figure 2-4 the majority of the combinations of curve radii and superelevation shown were developed such that a train operating at the next lowest speed increment would have at least an unbalanced superelevation of 0.25 inches (Eu = 0.25 inches). In Figure 2-4, the curve radius for the condition where Ea + Eu = 8.0 inches is provided indicating the shortest curve radius applicable without seeking MDT approval. In that case a train operating at the next lowest speed increment would have an unbalanced superelevation significantly higher than 0.25 inches (Eu > 0.25 inches).

There may be site specific cases where the combinations of curve radii and superelevation other than those shown in Figure 2-4 may be preferable. Curves adjacent to a passenger station and curves adjacent to special trackwork may require the Designer to consider significant changes in train speed and the Designer shall consider those conditions when selecting the combinations of curve radii and superelevation. If the Designer prefers another combination of curve radii and superelevation that is not shown in

Figure 2-4, the Designer shall advise MDT of the rationale for the Designer's selections.

2.03.4.3 Method of Attaining Superelevation

Superelevation shall be attained and removed linearly throughout the full length of the spiral transition curve, by raising the rail farthest from the curve center while maintaining the top of the inside rail at the profile grade.

After the Designer has determined the minimum spiral lengths required to comply with sections 2.3.3.2 and 2.3.3.3, the Designer shall then consider the need to adjust the length of spiral to facilitate standards for field installation and future maintenance and inspection activities.

The rate of change in superelevation will be no more than ¼ inch in a minimum distance of 12.5 feet and must be uniform over the entire spiral unless otherwise approved by MDT

2.03.4.4 Minimum Value

For a calculated Equilibrium Superelevation (Ee) of 1/2 inch or less, no superelevation need be applied (Ea = 0 inches).

2.03.4.5 Yard and secondary track will not be superelevated (Ea = 0 inches).

2.03.4.6 Operational Speeds for Turnouts

The operating speed for a turnout shall be based upon the sharpest radius of curvature inherent in the turnout geometry. The design speed shall be based upon a maximum Eu of 2¼ inches, unless otherwise approved by MDT, and

the operating speed shall be based upon the speed level which is less than or equal to the design speed.

For AREMA turnouts, (Plan No. 920-02) the following is applicable

Turnout #	Radius of centerline	Switch Entry Angle	Design Speed	Operating Speed
#10	806.09	1 – 04' – 24"	20.0 mph	15 mph
#15	1872.9	0 – 50' – 44"	30.6 mph	28 mph
#15 Equilateral	3788.57	0-25'-22"	46 mph	46 mph

In locations where MDT has determined that modified turnout designs are warranted to increase operating speeds within the physical limitations of the site, MDT will provide the alignment and geometric details for the modified turnouts. This includes the use of tangential turnout designs based upon AREMA frogs or modified turnout designs with longer switch rails, larger turnout centerline radius and curved frogs. Modified turnout designs, not based upon AREMA frogs, are generally not suitable for double crossovers where the distance between tracks is typically 14 to 15 feet and shall not be used without MDT approval.

For modified turnout designs the following is applicable

Turnout	Radius of Centerline	Switch Entry Angle	Design Speed	Operating Speed
Modified #10	1,397.61	0 – 30' – 00"	28.0 mph	28.0 mph
Modified #15	2,599.97	0 – 25' – 00"	38.0 mph	38.0 mph

The Designer shall refer to the MDT Directive Drawing CDT11 for additional information on design geometry of the modified turnouts.

If MDT has approved the use of modified turnout designs, the Designer shall immediately assess whether there are any issues related to unacceptably long gaps in the contact rail to rail car interface. MDT must be notified of any gaps over 30 feet in length measured from the tips of the end approaches or other points of electrical contact or any contact rail sections (one contact rail or overlapping contact rails) with any overall effective length less than 72 feet measured from the tips of the end approaches or other points of electrical contact. Refer to Volume VII Chapter 2, Contact Rail and Coverboard for additional information on contact rail configurations at turnouts areas.

The track gage through #10 and #15, lateral and equilateral, turnouts shall be 4 feet 8.5 inches.

2.04 VERTICAL ALIGNMENT

2.04.1 GENERAL

Profile grade shall represent the elevation of the top of the low rail. When only one track profile is given for curved alignment, the profile of the second track shall be adjusted uniformly to accommodate the difference in length through the curve.

2.04.2 GRADES

2.04.2.1 Except through the Station, the desirable maximum grade for mainline running track shall be 3.0 percent. In exceptional circumstances, the maximum grade may be increased up to 4.0 percent but shall require the approval of MDT. There is no minimum grade for at-grade or aerial construction. A maximum grade of 0.35 percent may be held through Stations if required. Under exceptional circumstances, grades through Stations may be increased to 1.0 percent with approval of MDT.

2.04.2.2 Yard and Secondary Track Areas

In yard and secondary tracks, the maximum grade shall be 1.0 percent. The minimum grade desired shall be 0.35 percent, except for storage tracks, where the desirable grade shall be 0.20 percent. Permanent stub end tracks should be sloped away from the turnout. On yard lead tracks and test track, mainline grade criteria will govern.

2.04.2.3 Miscellaneous

Pocket tracks and turnback tracks may have a sag curve if approved by MDT, and should be placed at zero profile grade whenever possible. Introduction of a vertical curve between the interlockings, because of special conditions or

restraints, shall require the approval of MDT. The zero profile grades were used in Stage 1 construction.

2.04.3 VERTICAL CURVATURE

All changes in grade shall be connected by parabolic vertical curves. The desirable length of vertical curve shall be determined by the formula:

$$V.C. = (G_1 - G_2)\ 200$$

Where V.C. = Length, feet

$(G_1 - G_2)$ = Algebraic difference of grades connected by the vertical curve, in percent

The minimum length of vertical curve, unless otherwise approved by MDT, shall be determined by the formula:

$$V.C. = (G_1 - G_2)\ 100$$

The Designer should be liberal when establishing length of vertical curve, allowing up to twice the minimum if possible. The absolute minimum length of vertical curve shall be 200 feet.

The Designer shall consider drainage conditions and avoid sag vertical curves in locations such as mid span on aerial structures where effective drainage can be difficult to achieve.

2.04.4 MINIMUM LENGTH OF GRADE

The desirable minimum length of constant profile grade between vertical curves shall be 100 feet.

No compensation of grade is required for horizontal curvature.

– Intentionally Left Blank –

2.05 TRACKWORK CONFIGURATION

2.05.1 GENERAL

Rapid transit track materials and special trackwork shall comply with MDT directive drawings, design criteria and standard drawings and the current editions of American Railway Engineering Maintenance-of-Way Association (AREMA) "Manual of Railway Engineering" and "Portfolio of Trackwork Plans" unless otherwise approved by MDT.

2.05.2 DIRECT FIXATION RAIL FASTENERS

Running track and special trackwork shall be fastened directly to the concrete trackbed of non-ballasted aerial structures.

All special trackwork on aerial structure shall be installed using direct fixation rail fastener to reduce the transmission of noise and vibrations.

The rail fasteners required in the special trackwork units shall be the same basic rail fastener used in running track construction.

2.05.3 GAGE AND RAIL CANT

Track gage is the perpendicular distance between the inner sides of the head of the running rails measured at a point 5/8 inch below the top of rails.

Track gage shall comply with the gage criteria shown in Figure 2-5, Track Gage Criteria.

Running rails shall be installed with 1:40 cant towards the centerline of the track except for special trackwork areas which will have zero cant. For direct

fixation trackwork, the transition from 1:40 cant to zero cant shall be made in a length no less than 10 feet.

2.05.4 RAIL

2.05.4.1 Running Rail

All rails shall be 115RE section, control-cooled carbon steel as per AREMA Specifications as modified by MDT. Mainline rails shall be welded into continuous lengths, with insulated joints at interlocking locations. Jointed rail shall be used in the yard. Specially treated control-cooled rail should be used as follows:

A. End Hardened Rail

End hardened rail (end heat treated) shall be used for all the yard tracks and for the manufacture of insulated joints, except where either surface heat treated rail (head hardened) or fully heat treated rail is to be used.

B. Heat Treated Rail

Heat treated rail shall be used at the following locations:

- All special trackwork
- Both rails of curves
- Through station areas which includes a distance of 1,344 feet on either side of the station.
- Unusually steep grades where either the uphill or downhill grade is greater than or equal to 3%.
- Any areas where frequent braking and/or accelerating is expected.

2.05.4.2 Restraining Rail and Emergency Guard Rail

Restraining rails shall be heat treated rail and the Designer shall submit to MDT for approval the details for the proposed restraining rail system.

The design of the Emergency Guard Rail shall be to limit the movement of a derailed rail car in the field direction. The Emergency Guard Rail shall only be used in locations to be determined by MDT and shall be installed as noted below.

- On aerial guideways with only one track located on the guideway structure, Emergency Guard Rails shall be installed adjacent to both running rails.

- On aerial guideways with two adjacent tracks located on the guideway structure, Emergency Guard Rails shall be installed, on both tracks, adjacent to the running rail closest to the centerline of the aerial guideway. The running rails on the field side do not require an Emergency Guard Rail.

- On aerial guideways with three or more adjacent tracks located on the guideway structure, Emergency Guard Rails shall be installed, on both exterior tracks, adjacent to the running rail closest to the centerline of the aerial guideway. The running rails on the field side do not require an Emergency Guard Rail and Emergency Guard Rails are not required on the interior tracks.

The design of the Emergency Guard Rail shall be submitted to MDT for approval.

2.05.5 SPECIAL TRACKWORK

Special trackwork shall be located on tangent track and on constant profile grades. The installation of special trackwork on a vertical or horizontal curve may be considered, but will require approval of MDT.

Double crossovers shall be used on the non-ballasted aerial portions of the system to reduce the overall length of special structure. Double crossovers shall be located on parallel tracks only. Single crossovers shall be used in the at-grade portion of the system unless space limitations are prohibitive. Special trackwork shall comply with the following criteria.

The Designer shall immediately assess whether there are any issues related to unacceptably long gaps in the contact rail to rail car interface. MDT must be notified of any gaps over 30 feet in length measured from the tips of the end approaches or other points of electrical contact or any contact rail sections (one contact rail or overlapping contact rails) with any overall effective length less than 72 feet measured from the tips of the end approaches or other points of electrical contact. When designing any double crossover the use of an unbridgeable gap requires MDT approval.

The Designer shall immediately assess whether there are any issues related to location of special trackwork relative to the location of expansion joints on the aerial structure. The Designer shall coordinate with the structure engineer with respect to the rail/structure interaction analysis.

2.05.5.1 Main Line

All turnouts and crossovers shall be No. 10 turnouts, except for corridor junctions where No. 15 turnouts shall be used, unless otherwise approved by MDT. The Designer shall meet with MDT to determine the whether to design the alignment for a turnout based on standard AREMA, tangential, or modified turnout geometry.

2.05.5.2 Yards

In yard locations use No. 6 turnout, minimum and No. 8 crossovers. Self guarded frogs shall be used.

2.05.5.3 Scissors crossovers (double crossovers) on wide track centers shall consist of modified No. 10 turnouts and an AREMA Manganese steel insert crossing unless otherwise approved by MDT.

2.05.5.4 Center pocket tracks shall consist of No. 10 turnouts and special No. 5 equilateral turnouts unless otherwise approved by MDT.

2.05.5.5 All turnouts shall have guarded Samson switch points with undercut stock rails according to AREMA Plan No. 221-62, point detail 5100. Any deviation from the Special Trackwork Directive Drawings and the sizes indicated above shall require the approval of MDT.

Limiting factors to be considered in designing the horizontal and vertical alignment adjacent to special trackwork units are:

Turnout No.	Type of Track Construction	Minimum Distance from Point of Switch thru Turnout to: *T.S. or T.C.	*P.V.C.	End of Turnout Unit
5 E.Q.	Direct Fixation	52'	52'	58'
5 E.Q.	Ballasted	52'	64'	64'
6	Ballasted	59'	73'	73'
8	Ballasted	70'	89'	89'
10 or 10 E.Q	Direct Fixation	97'	97'	102'
10 or 10 E.Q	Ballasted	97'	117'	117'
15 or 15 E.Q	Direct Fixation	140'	140'	147'
15 or 15 E.Q	Ballasted	140'	165'	165'

* These are the absolute minimum values that may be used. The desired minimum values are those listed in the "Point of Switch" to "End of Turnout Unit" column. The use of the absolute minimum values is subject to the approval of MDT. The minimum vertical or horizontal tangent distance preceding a point of switch shall be at least 10 feet.

Special trackwork shall not be located within 200 feet of a transition between direct fixation and ballasted track construction. The minimum tangent length between a point of switch and the end of a station future platform extension shall be 75 feet.

The separation distances required between switch points of various combinations and directions where contact rail is required shall be as shown on Figures 2-6A through 2-6F inclusive unless otherwise approved by MDT. Contact rail end approaches shall be provided as follows:

9'-0 ” ramp (10’-9½” rail) end approaches for main line track over 15 MPH and 5'-0 ” ramp (6’-9½” rail) end approaches for yard, secondary, and storage tracks 15 MPH or under.

2.05.6 DERAILS

Derails shall be installed on access tracks to railroads and on any yard or secondary track normally used for the storage of unattended vehicles if this track is directly connected to the main track and its prevailing grade is descending to the main track.

2.05.6.1 Derails shall be located as follows:

A. At the downgrade end of the yard and secondary track.

B. To derail equipment away from the main track, if possible.

C. To derail equipment away from the contact rail.

The location of derails shall be coordinated with MDT.

2.05.7 TIE SPACING

Concrete ties shall be used in ballasted main line track. Monolithic concrete ties shall be spaced 30 inches maximum center-to-center.

Either wood or concrete ties shall be used in ballasted yard or secondary track. Wood ties shall be spaced 24 inches maximum, center-to-center. Monolithic concrete ties shall be spaced 30 inches maximum center-to-center.

Wood ties may be used in ballasted yard and secondary special trackwork units with MDT approval and they shall be spaced in accordance with the trackwork Contract, Standard or Directive Drawings.

Special concrete ties shall be used in ballasted main line special trackwork units and they shall be spaced in accordance with the Contract, Standard or Directive Drawings.

In special trackwork units contact rail tie spacing will be in accordance with Contract Drawings. Every fourth tie shall be a contact rail tie where concrete ties are and every fifth tie where wood ties are used, with a maximum spacing of 10 feet.

2.05.8 DIRECT FIXATION RAIL FASTENER SPACING

2.05.8.1 Direct Fixation Rail Fastener Spacing

The longitudinal reinforcing steel of the concrete track structure shall be designed to provide a minimum anchorage clearance envelope of 5 inches squared, in such manner as to avoid the direct fixation fastener anchors as much as possible. The nominal direct fixation rail fastener spacing shall be 30 inches. The absolute maximum will be 33 inches. The spacing of fasteners in any 50 feet of track shall average 30 inches.

2.05.8.2 Direct Fixation Rail Fastener Longitudinal Restraint

The load range of the longitudinal restraint of the Direction Fixation Fastener, based upon the acceptance testing under static conditions, shall be within the envelope defined in the table below.

Description	Deflection	Load
	(inches)	(pounds)
Lower Boundary	0.0	0.0
	0.3125	2,500
	> 0.3125	2,500
Upper Boundary	0.0	1,000
	0.05	3,500
	>.05	3,500

When determining the loads and rail break gaps as part of the rail/structural interaction analysis, the above longitudinal load conditions, as well as any other trackwork or structural conditions pertinent to the rail/structure interaction analysis as deemed necessary by the Designer, shall be applied.

2.05.9 END OF TRACK RESTRAINING DEVICES

A sliding bumping post, sand box, or other MDT approved end of track restraining device shall be used at the end of each stub-end track.

2.05.9.1 Mainline Tracks Tail Tracks at Terminal Stations

For tail track on the mainline or similar situations, the preferred end of track restraining device is the sliding bumping post. The sliding bumping post system is designed to absorb energy from a train which is traveling at a speed of 15 mph or less, in either coasting or braking mode. It is assumed that the train does not apply any tractive effort after passing the signal mast located in front of the bumping post. The spatial requirements for this equipment, including a signal mast located ahead of the sliding bumping post, are:

A. The preferred distance from the end of the track to the face of the bumping post is 80 feet. The minimum distance is 50 feet unless otherwise approved by MDT.

B. The preferred distance from the face of bumping post to the location of the signal mast which is also the end of a stored train is 20 feet. The minimum distance is 10 feet unless otherwise approved by MDT.

C. The design distance for stopping an AW2 train depends upon track grade, train length, train speed, characteristics of the train control system, and whether the sliding bumper system is assisting in the stopping of the train. The following criteria are based upon the characteristics of the Stage I Metrorail train control system.

- On level track the distance required to stop a six-car train loaded to AW2 conditions and traveling at 28 mph under ATO conditions without assistance by the sliding bumper, is 1,004 feet.
- On level track the distance required to stop a six-car train loaded to AW2 conditions and traveling at 15 mph under ATO conditions without assistance by the sliding bumper, is 484 feet.
- The above distances of 1,004 feet and 484 feet can be reduced to 894 feet and 374 feet respectively, if the full capacity of the sliding bumper system is utilized. However, the reduced distances shall not be used without approval by MDT.
- For track installed on a grade other than 0%, longer train lengths, different train control systems, or for different ATO speeds, the Designer shall request guidance from MDT.

D. The Designer shall locate a pair of insulated joints at both ends of the station platform zone. The insulated joints will be installed directly

opposite of each other without a longitudinal offset. The design distance for stopping an AW2 train, as per paragraph C above, shall be increased by the distance from the antenna of the rail car to the face of coupler. For Stage 1 Metrorail passenger cars, this distance is approximately 6 feet.

E. The distance between two trains stored on the stub end track shall be 10 feet. The distance of a stored train from the end of the station platform shall be at least 20 feet.

F. The Designer shall determine the distance from the end of track to the physical end of the guideway based upon needs for access, drainage, railings, or other site specific requirements.

The Designer shall determine the minimum length of tail track by selecting the longest tail track requirement from the following two cases:

1) The total length of track required for ATO operation consisting of the sum of distances in paragraphs A, C & D.
2) The total length of track for train storage consisting of the sum of the distances in paragraphs A, B, & E plus the length of each train to be stored on the track.

The total length of guideway shall be equal to the total length of track plus the distance required in paragraph F.

Unless otherwise approved by MDT, the entire tail track shall be on tangent track.

The sliding bumping post assembly shall consist of a friction bumping post equipped with hydraulic shock absorbers supporting the striking face designed to mate with the MDT Vehicle anti-climber.

2.05.9.2 Yard Tracks

Fixed Bumping posts may be used on stub-end yard tracks and will be equipped with a shock absorbent head of multiple spring and shock bed design.

2.05.10 APPROACH SLABS

An approach slab, as shown on Directive Drawings, shall be provided at all transitions between direct fixation and tie-and-ballasted track construction.

2.05.11 BOLTED JOINT BARS

Bolted joints shall be used on yard tracks and in special trackwork on primary track where it is impractical to use field welds. In primary track bolted joints shall be epoxy bonded to the rail and fastened with pin bolts. In yards or in special trackwork unbonded bolted joints shall be used. Bolted joints, unbo

The standard bar shall be the six-hole, 36-inch-long, AREMA joint bar with recommended head easement for 115 RE rail and AREMA recommended rail drillings and bar punchings. Joint bars shall be located in special trackwork and at other locations as necessary.

2.05.12 INSULATED JOINT BARS

Insulated joint bars shall be used in special trackwork and at other locations as necessary to comply with the automatic train control criteria. Insulated joints shall comply with the following track criteria:

A. They shall have the same drilling pattern as standard joint bars.

B. They shall be compatible with the standard rail fasteners used on the System.

C. They shall comply with the general requirements of a rail joint as defined by the AREMA "Manual for Railway Engineering".

D. They shall be epoxy bonded to the running rail and fastened with pin bolts.

E. They shall be located as close as possible to the center of the spans and away from possible high stress areas.

F. In station areas, miter cut bonded insulated joints will be used.

2.05.13 SPECIAL ITEMS

Specialty devices, such as retarders, wheels stops, trip stops, drag detectors, and rail lubricators shall be used only at locations specified by MDT.

– Intentionally Left Blank –

2.06 CLEARANCES

2.06.1 GENERAL

The following clearances shall be provided in the design documents and checked after construction. All vertical and horizontal clearance requirements shall be verified with the appropriate authorities by the Designer during the time of final design.

2.06.2 HORIZONTAL TRACK CENTERS AND CLEARANCES

2.06.2.1 Standard Track Centers and Clearance Requirements

The following horizontal clearances are applicable for tangent alignment. These clearances will be compensated for curvature and superelevation when required. In addition, the dimensions shown on the contract documents shall include appropriate allowances for construction tolerances such that the as built condition meets the minimum clearance requirements. The dimensions for Composite Vehicle Dynamic Envelope and the Composite Maximum Vehicle Dynamic Envelope are shown on Directive Drawing VPD001.

***Commentary**: Stage I information showed some evolution in the vehicle data. Stage I drawings refer to a vehicle clearance outline which is the same outline referred to herein as the Composite Maximum Vehicle Dynamic Envelope. Although most Stage I drawings do not identify the vehicle data as a composite of the outline of several heavy rail cars, a detailed review indicates that the Stage I data used for vehicle envelopes and clearances is not the actual vehicle data for the Stage I rail car. The Composite Vehicle Dynamic Envelope contains all vehicle motions for a new rail car with new wheels on new rail. The Composite Maximum Vehicle Dynamic Envelope factors in new construction rail alignment,*

gage face rail wear, and wheel flange wear. The difference between the two envelopes is due to additional vehicle yaw (1.21 inches) caused by the wear and alignment condition. This does not include the effects of other maintenance factors cited in section 2.6.2.2.)

For all guideway sections constructed after 2006, the Designer shall provide a walkway envelope of 2' – 6", at a point measured vertically 6' – 6" above the walkway surface. Any intrusions into the walkway envelope space requires MDT approval.

For design purposes the standard track spacing and clearance conditions for tangent track shall be:

A. Between adjacent main line parallel tracks without a center walkway, center-to-center, 14'-0" minimum. Track centers shall be established in increments of 3 inches.

B. Between main line and pocket or turnback tracks center-to-center, 17'-11" desirable, 14'-0" minimum without a center walkway, 14'- 6" minimum with a center walkway. Designer shall confirm that the minimum 2'-6" walkway envelope is maintain throughout the transition area between tangent and curved track.

C. Between main line tracks at center platform stations, center-to-center 35'-10" unless otherwise approved by MDT.

D. Between parallel yard tracks, center-to-center, as follows:

		Minimum	Desirable
1.	Lead track to a ladder track	20'-0"	
2.	Running track to a ladder track	20'-0"	20'-0"
3.	Drill track to a body track (Storage)	18'-0"	20'-0"
4.	Body track to a body track (Storage); alternating spaces of	14'-0" & 18'-0"	
5.	Repair shop tracks	20'-0"	
6.	Wayside storage tracks	40'-0"	50'-0"
7.	Transfer zone tracks	14' -0"	17' -11"

E. Fixed structure, measured from centerline of track to nearest point of fixed structure:

Minimum = 8'-0" Desirable = 8'-6"

F. Between acoustical barrier or handrail and centerline of nearest track;

Minimum = 6’ 1 1/8”

G. Fences parallel to track, measured from centerline of track;

At-grade section; Minimum =10'-0"

Retained fill or embankment; Minimum = 8'-6"

H. Clearances of guideway structure adjacent to streets or expressways shall be in accordance with the latest edition of the Florida Department of Transportation Manual of Uniform Minimum Standards for Design, Construction and Maintenance of Streets and Highways and/or standards of local agencies having jurisdiction over the roadway affected.

2.06.2.2 Determining Minimum Clearance Requirements

In cases where the standard track centers and clearances provided in section 2.6.2.1 or 2.6.3 do not provide the minimum running clearances specified in this section, the standard dimensions shall be adjusted as provided below:

Minimum offsets shown by dimensions on the Contract Drawings shall be determined by the following formula:

DO = MVDE + OWF + RC

Where:

DO = Design Offset
MVDE = Composite Maximum Vehicle Dynamic Envelope
OWF = Other Wayside Factors
RC = Running Clearance

The MVDE consists of the following:

- The offsets shown or calculated from the Composite Maximum Vehicle Dynamic Envelope as shown on the Directive Drawing VPD001

***Commentary**: The Stage I drawings focused on three points on the vehicle body with only graphical interpretations of other points. For the new line extensions three similar points are shown. These three points basically represent the side sill of the rail car, the widest portion of the rail car that protrudes into the walkway (maximum width of the car), and the furthest protrusion of the vehicle body near the roof line.)*

OWF factors consist of the following:

- The horizontal effects due to curvature = 0.75 inches per degree of curvature plus any effect attributable to gage widening.
- The horizontal effects due to superelevation = (Height above top of rail (inches)/59) X Ea). The effects of Ea are only applied on the inside of a curve and any increase in clearance derived from Ea on the outside of a curve is ignored unless otherwise approved by MDT.
- Maintenance tolerances for direct fixation or other non-ballasted track = 1.0 inch in the horizontal direction.
- Maintenance tolerances for ballasted track = 2.0 inches in the horizontal direction.
- The horizontal effects due to maintenance tolerances for cross level for direct fixation or other non-ballasted track = 0.5 inches in the vertical direction using the above formula for superelevation where Ea= 0.5 to determine the additional horizontal clearance requirements.
- The horizontal effects due to maintenance tolerances for cross level for ballasted track = 1.0 inches in the vertical direction using the above formula for superelevation where Ea= 1.0 to determine the additional horizontal clearance requirements.
- Construction tolerance for minor structures such as noise walls, ancillary precast concrete, fences and wayside installations = 1.0 inch unless the Designer or MDT determines additional construction tolerance is required.
- Construction tolerance for major structures, including aerial structures, retained cut, retained fill, and cut and cover = 2.5 inches unless the Designer or MDT determines additional construction tolerance is required.
- Construction tolerance for tunnels – to be determined by the tunnel engineer.

- Allowance for resurfacing of ballasted track = 3.0 inches in the vertical direction
- The effects of chorded construction for walls and other wayside elements as necessary = function of track radius and chord length to be determined by the Designer.
- The effects of superelevation and vertical curves in vertical direction. Note that the effects of superelevation shall only be included for points on the outside of the curve and any increase in vertical clearance derived from Ea on the inside of a curve is ignored unless otherwise approved by MDT.
- Space allowances for future installations such as designing a noise wall so that in the future a surface applied acoustical material can be added if needed. The Design Offset must include all space allowances in the current design without a reduction in the minimum running clearances.

Note when determining the OWF, the above items are generally additive and some items such as noise walls installed on the aerial guideway may be subject to the combined effects of construction tolerance for the noise wall and the aerial structure to which it is attached.

The Minimum Running Clearances, unless otherwise approved by MDT consist of the following:

- Wayside signs, closed cabinets, and breakable items = 4.0 inches
- High walkways used in tunnels or other areas = 4.0 inches.
- Sound walls, ancillary precast concrete, pipes, cableways, and minor structures = 6.0 inches. The minimum running clearance with MDT approval = 4.0 inches.

- Major structures such as concrete walls and bridge piers where frequent maintenance activity is anticipated = 2'-6". In locations where maintenance activities are infrequent = 2'-0".
- For underground or retained cut structures, the Designer shall develop cross sections using design offsets and running clearance criteria consistent with similar underground structures for other heavy rail transit system in the U.S. and submit for MDT approval.
- Any conductive element not part of the traction power distribution system, from the third rail shoe = 3.0 inches
- Walkway envelope for single track guideway = 2 feet – 6 inches
- Walkway envelope for walkways located in between two tracks = 2 feet – 6 inches.
- Vehicle to vehicle envelope between rail cars on adjacent tracks without other envelope requirements = 1 foot -0 inches.
- Vertical running clearance to fixed obstructions from the top of the Rail Car dynamic envelope but ignoring the antenna = 6.0 inches.
- Vertical running clearance measured from the bottom of the roof slab of a cut and cover structure to the top of the Rail Car dynamic envelope but ignoring the antenna, where ventilation requirements may be an issue. = 1 foot – 0 inches minimum unless additional space is required for ventilation purposes.

The Designer shall refer to Directive Drawings VPD002 and VPD003 for additional information on clearance requirements.

Field acceptance of the as-built condition shall be based upon field measurements from the centerline of the track which provide a clearance of

no less than the distance determined by the Design Offset minus the construction tolerances unless otherwise approved by MDT.

The minimum clearance requirement that establish the minimum track centers on tangent track may be effected may the clearance requirements needed for adjacent curves. The increased clearance requirement for the curved track shall be transition as follows:

- The minimum running clearance for curved track shall be set from a point 25 feet before the spiral to curve point (SC) and 25 feet beyond the curve to spiral point (CS).
- The longitudinal location of the minimum running clearance needed for tangent track shall be set from a point 50 feet before the tangent to spiral point (TS) and 50 feet beyond the spiral to tangent point (ST).
- Between these points the change in running clearance shall be linear.
- The clearance required at the TS or ST point, due to the curve clearance requirements shall be checked against the clearance provided on the tangent track.
- If the track centers on the tangent track require an increase to achieve the minimum running clearance throughout the tangent to curve transition zone, then the track centers shall be increased to the next 3 inch increment until adequate running clearance is achieved.

The above requirements for minimum running clearances are not applicable to the edge of the station platform.

The above running clearances and other wayside factors are minimum values and if, in the judgment of the Designer, additional clearance is required then

the Designer shall clearly denote the DO and the field measurements required to provide the desired running clearance.

The Designer shall review wayside installations such as wayside cabinets and consider the location of maintenance personnel when assessing the cabinets and the position of the opened cabinet doors such that wherever practical, the designed clearance condition for maintenance personnel working with open cabinet doors shall meet the requirements for a walkway and a cabinet with closed doors.

2.06.3 VERTICAL CLEARANCES

A. Transit structures over public highways shall be in accordance with the Florida Department of Transportation. Minimum vertical clearance shall be 16'-6".

B. Vertical clearance, guideway structure over local public roads and streets, as required by the authority having jurisdiction over the roads. Minimum vertical clearance shall be 16'-6".

C. Vertical clearance, guideway structure under a fixed structure, shall be 13'-0" minimum, measured from top of rail to the nearest point of the obstruction.

D. Vertical clearance, guideway structure over other areas not covered under (A), (B), and (C) to be established by Designer and verified with MDT.

2.06.4 STATIONS

The minimum horizontal dimensions shall be as follows:

A. Length of platform - 456 feet initially and 616 feet future unless otherwise approved by MDT.

B. Reserved paragraph (Commentary - The Stage I Design Criteria did not have the correct relationship for the platform edge.)

C. For new stations, Americans with Disabilities Act (ADA) requires a maximum gap, as measured horizontal in the field between the edge of the rail car threshold and the platform edge, no greater than 3 inches. To allow for free play, wheel flange wear and construction and maintenance tolerances, the Contract Drawings shall show a gap of 2.75 inches and a centerline of track to edge of platform distance of 5 feet 4.25 inches (Based upon the actual width of the Stage I rail car floor at the threshold of 10’ - 3”).

D. For new stations, Americans with Disabilities Act (ADA) requires a maximum gap, as measured vertically in the field between the edge of the rail car threshold and the platform edge, no greater than 5/8 inches. To allow for wheel thread wear, and rail wear, the contract drawings shall show a platform elevation which is 0.5 inches below the rail car threshold and a top of rail to top of platform distance of 3 feet 7 inches. The top of the platform, for this measurement, is the top surface of the finished floor ignoring the bumps on the platform edge warning strip.

E. Other station clearances and allowances for finishes shall be as described in Volume II, Station Criteria, Chapter I, - Architectural Design Criteria, of this Compendium of Design Criteria.

The minimum vertical clearances shall be as follows:

Vertical clearance above top of rail to any obstruction in the Station area:

Minimum = 13'-0".

2.06.5 RAILROADS

All railroad clearances and trackwork shall comply with current plans and specifications of the respective railroad. In the absence of such plans and specifications, trackwork shall comply with the current AREMA "Manual for Railway Engineering" and "Portfolio of Trackwork Plans" and shall be approved by a responsible office of the affected railroad company. The minimum standards for Railroad clearances are established in the Florida Administrative Code Chapter 14-57.003.

– Intentionally Left Blank –

2.07 DRAINAGE

2.07.1 INTRODUCTION

This section establishes criteria for drainage facilities which cross or are relocated or modified because of Rapid Transit System Construction. These criteria apply to facilities which are constructed before, during or after completion of construction.

Due to hydrological conditions which exist in South Florida, drainage criteria will be a prime consideration in the total design.

2.07.2 CODES AND REGULATIONS

Drainage design criteria shall be in accordance with the Miami-Dade County Public Works Manual, Section D4 - Water Control and regulations of Miami-Dade County Department of Environmental Resource Management (DERM) and the South Florida Water Management District (SFWMD).

Erosion control design shall be in conformance with the requirements of the National Pollutant Discharge Elimination System (NPDES) as administered by the Florida Department of Environmental Protection (FDEP) and Miami-Dade County DERM.

2.07.3 HYDROLOGY

A. Storm Frequency

Design storm frequencies shall be in accordance with the requirements of the agencies with jurisdiction over the project. In addition, the design shall also meet the following minimum requirements:

- Parking Lots And Roadways: 10 year design storm

- Guideway Structure: 50 year design storm

After preliminary selection of drainage facility sizes, evaluation should be made of the drainage that would be caused by flooding resulting from more intense and less intense storms. Upgrading of criteria, if indicated, shall require approval of the MDT`.

B. Rainfall Intensity

Design rainfall intensity shall be in accordance with the requirements of the agencies with jurisdiction over the project. In addition, the design shall also meet the following minimum requirements:

- A minimum 10 minute time of concentration for rainfall intensity shall be utilized.

C. Runoff

Design runoff shall be in accordance with the requirements of the agencies with jurisdiction over the project.

In addition, the "rational formula" below shall be used for the design of all drainage facilities for drainage areas less than ten acres. Flood routing models shall be used where the drainage area exceeds 10 acres.

$$Q = CIA$$

Where Q = Design Runoff in cubic feet per second
C = Runoff coefficient
I = Rainfall intensity in inches per hour
A = Area of watershed in acres

2.07.4 HYDRAULICS

The design of drainage facilities shall be based on sound hydraulic principles in order to affect an optimum combination of efficiency and economy. For detailed design criteria in the Miami-Dade County Area, refer to Section D-4 - Water Control, of the Miami-Dade County Public Works Manual, and the requirements of the South Florida Water Management District.

2.07.5 CONDUITS

2.07.5.1 Closed Conduits

A. The minimum diameter pipe to be used for storm sewers shall be 18 inches.

B. Manhole spacings along storm sewers shall conform to the following limits:

Pipe Diameter (Inches)	Manhole Spacing (Feet)
less than 24	300
24 or more	400

2.07.5.2 Culverts

A. The minimum allowable diameter pipe shall be 24 inches.

B. Culverts longer than approximately 300 feet shall be designed as storm sewers.

C. For detailed design criteria, refer to Section D-4 – Water Control, of the Miami-Dade County Public Works Manual.

2.07.5.3 Seepage Storm Drainage System

A. An underground storm water disposal system, hereinafter called Exfiltration Trenches, shall be used in all cases where tests show this method to be feasible. Surface retention basin systems shall only be used where tests show the above to be impractical. Trenches shall be designed in accordance with Section D-4 Water Control - Section 4 of the Miami-Dade County Public Works Manual.

B. The Engineer of Record shall determine the location of percolation tests for tests to be performed by the Engineer of Record's Geotechnical Specialty Engineer to develop the hydraulic conductivity of the soil used in establishing the length of Exfiltration Trench required. Percolation tests shall be the SFWMD "usual open-hole test". Exfiltration trenches and tests shall be 15 feet deep.

It is intended that the water from the guideway be channeled through swales along and under the guideway to utilize as much of the water as possible for irrigation before being discharged into the Exfiltration Trenches. The location of these Swales shall be coordinated with the landscape plans.

2.07.5.4 Guideway Drainage

Volume III, Chapter 3 Structural Design Criteria for Aerial Guideways address the drainage details regarding deck drains, downspouts, and other requirements regarding drainage on structures. See Section 3.04.

2.08 STREET AND PARKING AREAS

2.08.1 GENERAL

This section establishes criteria for the design of streets and parking areas which are to be maintained by the governing agency.

In general, design standards should be in compliance with the policies of the American Association of State Highway and Transportation Officials and the Florida Department of Transportation. All detailed roadway design shall meet the criteria as set forth in the Miami-Dade County Public Works Manual or Miami-Dade County Building and Zoning Code, as applicable.

Maintenance or access roads shall have grades, visibility and width compatible with traffic and maintenance vehicle dimensions to ensure safety from impact and shock.

2.08.2 PORTLAND CEMENT CONCRETE PAVEMENT

Portland cement concrete pavement shall be used in the area of the bus bays and shall extend at least 40 feet beyond the end bays. The Portland Cement Association Design Method shall be used for design.

Expansion joints shall be used where pavement abuts structures. At least one longitudinal joint shall be used with transverse and keyed joints used as required. Pavement shall be unreinforced (except for joint tie-bars) and have thickened edges as required. Transverse joints shall be spaced to be compatible with joint spacing used in sidewalks and buildings.

2.08.3 ASPHALTIC CONCRETE PAVEMENT

Asphaltic concrete pavement shall be used in all other areas of street and parking areas where portland cement concrete pavement is not used. The minimum pavement section shall consist of 2 inch asphalt concrete surface, 8 inch limerock base and 12 inch stabilized sub-base, as required.

2.09 FENCING

2.09.1 GENERAL

Fencing shall be provided in order to protect the public and maintain security by preventing unauthorized entrance into the right-of-way or other protected facilities. Fencing shall be provided as shown by details and schedules shown on standard drawings.

2.09.2 AT-GRADE SECTIONS

Fencing shall be provided continuously along each side of all at-grade and retained fill sections.

2.09.3 AERIAL SECTIONS

No fence shall be provided along aerial structures where the bottom of the structure is at least 10 feet above the ground elevation below.

2.09.4 YARDS AND TRACTION POWER SUBSTATIONS

Fencing, other than along at-grade sections of the trackway, shall be provided to deny unauthorized access to high voltage installations and areas containing Rapid Transit System property, and to define other areas where so required.

– Intentionally Left Blank –

2.10 LANDSCAPING AND ENVIRONMENTAL CONSIDERATIONS

2.10.1 GENERAL

Design criteria requirements for landscaping are set forth in Volume V, "Landscape Design Manual", of this Compendium of Design Criteria.

The civil work shall be coordinated with the landscape work to assure that the placement of landscape planting is accomplished in an ecologically advantageous way.

– Intentionally Left Blank –

2.11 DESIGN SURVEY DATA

2.11.1 FOREWORD

The purpose of this criteria is to establish requirements and minimum standards of surveys performed for Design Data of the facilities in the Engineer of Record's Work Areas. The Design Surveys include the field and office data developed for topographical features, utilities, tree surveys and boring locations, and exclude property surveys. The Design Surveys shall be conducted in accordance with the following requirements and standards.

2.11.2 HORIZONTAL CONTROL

The Horizontal Control for all Design Surveys shall be based on the established Project Survey Control Monuments. All Project Coordinates are based on the Florida State Plane Coordinate System (Transverse Mercator) East Zone, referenced to NAD 83/90 (North American Datum of 1983, 1990 Adjustment).

2.11.3 VERTICAL CONTROL

The Vertical Control for all Design Surveys shall be based on the Project Survey Control Monuments. All Project Vertical Control is based on the National Geodetic Vertical Datum of 1929.

2.11.4 SURVEY CONTROL MONUMENTS

After Survey Control have been established, the Engineer of Record shall have the responsibility of notifying the MDT, in writing, of any MDT Survey Control Monuments that have been disturbed or destroyed. Either MDT or the Engineer of Record shall reset those Monuments and provide the all involved parties with the Revised Horizontal and Vertical Control.

2.11.5 STANDARD OF ACCURACY

The minimum Standard of Accuracy for Design Surveys shall be Second Order Class I for Horizontal Control with a minimum accuracy of 1:50,000 and Third Order for Vertical Control with a minimum accuracy of $0.050\sqrt{M}$, where M = distance in miles, in accordance with the "Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys".

2.11.6 FIELD BOOKS

All field survey information will be entered in hard covered and bound cross section field books of nominal 6-l/2" x 8-l/2" size, together with all electronic data if applicable. The field books will be indexed, pages numbered and kept in a legible and orderly manner. All field books will be numbered on the front cover by showing the field book number and contract number. Upon completion of the Engineer of Record's design, all field books and applicable electronic data will be transmitted to MDT.

2.12 RIGHT-OF-WAY DATA

2.12.1 FOREWORD

The criteria for transit right-of-way is basically identified as the minimum requirements of space and estates in property necessary for the construction, operation, maintenance and security of the system and the separation distances for compatibility of the system with the community. Minimum acquisition is desirable to reduce displacement of persons and commerce and to conform to local and federal government constraints. Sufficient acquisition is necessary to construct, operate, maintain and protect the transit facility. The appropriate acquisition estate and geographical space are influenced by the topography, drainage, ditches, retaining walls, access roads, utilities, the nature of the structure, and side slopes selected.

2.12.2 PROPERTY IMPACT STATEMENTS

The Engineer of Record shall prepare Property Impact Statements, if requested, for partial acquisitions. As a minimum, Property Impact Statements shall address the following items:

A. Parcel Identification Number.

B. Reference to Right-of-Way Certification Map.

C. Ownership of Parcel.

D. Location: A general description of the property location with respect to the surrounding streets.

E. Description of the physical characteristics, improvements and present uses of the property from an external observation.

F. Vehicular and Pedestrian Access.

G. Definition of the type of right-of-way required: i.e., Fee Simple, Utility Easement, Permanent Easement, Temporary Construction Easement. The required rights for any easement shall be specified as indicated under "Property Rights".

H. Construction Impacts: A general narrative description of how the proposed construction will affect the remainder of the property from the standpoint of construction, engineering, access, proximity to the facility and future property utilizations.

2.12.3 ADVERSE IMPACT STATEMENTS

The Engineer of Record shall prepare Adverse Impact Statements, if requested, providing the description of the impact of the system construction and operation on those properties lying in close proximity to the project, upon which no physical encroachment occurs and, therefore, there is no property acquisition certification. As a minimum, Adverse Impact Statements shall address the following items:

A. Construction Description: A general narrative description of the Construction Impact on property affected by street reconstruction and/or temporary closing or detours, i.e., Loss of Access, Change of Access, etc.

B. Reconstruction: A general narrative description of those streets to be reconstructed, the type of reconstruction and its effect on pedestrian/vehicular traffic.

C. Construction Impact: A general narrative of the construction impact where facilities will be in close proximity to existing structures and the subsequent loss or reduction in air, light or vision.

D. Temporary Street Closing: A general discussion of the effects of detouring traffic from one street to another.

E. Permanent Street Closing: A general discussion of the permanent relocation of traffic from one street to adjacent streets.

2.12.4 PROPERTY RIGHTS

Right-of-way is the composite total requirements of all interests and uses of real property needed to construct, maintain, protect and operate the fixed guideway system. While some uses are temporary and reversionary in nature, other interests are permanent ones. The philosophy of rapid transit engineering is to certify the minimum right-of-way required consistent with the engineering requirements of the system and good right-of-way practice. The following list of property rights is set forth as a guide and shall be included, as needed, in the Property Impact Statements.

A. Permanent Surface Easements

1) Rights to unobstructed and unimpaired use of the surface of the property.

2) Rights to construct, operate, maintain, restore, replace and remove transit and transit related structures and facilities in, upon, over, under or across the described property.

3) The upper limit of the surface easement shall be 18 feet above top of rail, except in those areas of critical clearance under expressways.

4) The surface easement shall have no lower limit.

5) The surface easement should contain wording which reserves the following rights:
   a) The right to install subsurface utilities in and across the right-of-way.

   b) The right to approve any plans of any structures which would be built on the easement after installation of the tracks.

   c) The right to fence the right-of-way to prevent access to the third rail.

   d) The right to prevent the transference of any load on or to any structures.

B. Aerial Easements

1) Right of unobstructed and unimpaired use of the aerial envelope.

2) Support rights for foundations, piers and other structural members.

3) Right to prevent transfer of loads to any part of structure or foundation.

4) Access rights for periodic inspection and maintenance of structure and footings.

5) Right to approve or disapprove use of and construction of any structure under the aerial envelope.

6) Right to prevent storage of flammables, explosives or other hazards under or adjacent to the aerial envelope.

7) Rights for installation and maintenance of transit utilities below the surface of the ground under the aerial easement.

8) Right to use the area under the aerial easement as a contractor's work area during construction.

9) The upper limit of the aerial envelope shall be 18 feet above top of rail.

C. Temporary Construction Easements

1) Right to occupy the described property and enjoy its undisturbed use for a specified period of time.

2) The right of ingress and egress through, across and over the property through a specified location to be agreed upon.

3) The right to modify existing fencing.

4) The easement would have no vertical limits.

5) Property will be returned to owner in substantially the same condition existing at the date of initial use.

D. Utility Easements

1) Right to transfer or assign title to the easement to another party.

2) Right to install, maintain, remove, replace and protect the specified utility.

3) Right to prevent the construction of a permanent structure over the easement.

4) Right of access to the surface of the easement.

2.12.5 RIGHT-OF-WAY REQUIREMENTS

The following criteria are provided for the limits of the right-of-way for guideway and station structures. The dimensions given are for minimum requirements and must be modified where system clearances and engineering requirements dictate additional needs. All right-of-way limits shall be vertical or horizontal planes.

The following minimum clearances shall be utilized to establish the right-of-way requirements for the project. Encroachment into these minimum limits requires prior approval from MDT:

- Outside Edge of Guideway Structure and Components: 5 feet minimum.
- Outside Face of Station Structures and Ancillary Facilities: 30 feet minimum.

2.12.6 DEFINITIONS

A. Certification - The establishment and definition of the real estate acquisition requirements.

B. Certification Revision - The reestablishment or adjustment of previously certified parcels due to design changes or refinements.

Construction Easement - Area required for by the contractor during construction. This area will be defined by an envelope, including its upper, lower and side limits.

C. Decertification - The cancellation of a previous certification due to design changes or refinements.

D. Engineer of Record - An architect/engineering firm responsible for the preliminary and/or detail design of a particular Construction Contract Unit.

E. Full Parcel Acquisition - The total permanent acquisition of an entire parcel of property.

F. Partial Parcel Acquisition - The acquisition of a portion of a parcel of property for either permanent or temporary use.

G. Permanent Aerial Easement - Area required for aerial sections of the transit facility. This area will be defined by an envelope, including its upper, lower and side limits.

H. Permanent Drainage Easement - An easement required for the retention, release and/or flow of surface water.

I. Permanent Needs - Property required for the construction of the rapid transit facility which will be occupied by a permanent facility. This permanent facility will be the rapid transit system and its appurtenances or an adjacent street, highway, railroad or utility.

J. Permanent Slope Easement - A permanent right to construct and maintain a slope within a defined area adjacent to a street or rail right-of-way. Upon completion of the construction of the slope, possession of the property will be restored to the owner of the fee title for any use not inconsistent with the continued existence of the slope. The property owner's right to construct improvements within the slope easement area is severely limited.

K. Permanent Subsurface Easement - Area below ground surface required for construction and maintenance of portions of the transit facility, such

as subway box, retaining wall footings, etc. This area shall have definite upper, lower and side limits defined dimensionally and utilizing elevations.

L. Permanent Utility Easement - An easement required for location and maintenance of various utility facilities, as well as storm drainage and traffic signal facilities. Upon completion of construction, easements will be transferred to the agency responsible for maintenance of the facility.

M. Property Certification Map - This map shall delineate and mathematically define the permanent and temporary real estate acquisition requirements based on engineering determination.

N. Preliminary Right-of-Way Map - This map will be prepared from the photogrammetric manuscripts, and will show parcel numbers, owners' names, total areas of parcels, property lines and deed or plat dimensions relative to individual properties. These maps will be developed from recorded deeds and/or plats.

O. Right-of-Way Map - A map prepared using previously prepared Preliminary Right-of-Way Maps and Property Certification Map as the basis for development. This map shall delineate the limits of temporary and permanent needs by the use of appropriate control dimensions and will be incorporated into the Contract Drawings.

P. Sever and Restore (Cut and Reface) - The removal of a portion or section of building and the reconstruction of the building face.

Q. Temporary Construction Easement - A right to use a defined area for a limited period of time, for specific purposes related to construction. Upon the termination of the easement, the property will be returned as nearly as possible to its original condition, and all rights of ownership will revert to the owner.

R. Temporary Slope Easement - A right to construct a slope within a defined area. This right will be limited to a specific period of time. At the termination of the easement, the property will be returned, as nearly as possible, to its original condition and all rights of ownership will revert to the owner. Such easement should not be used where a permanent slope is necessary to support adjoining facilities.

2.13 UTILITIES

2.13.1 GENERAL

2.13.1.1 Foreword

These criteria shall govern new utility construction outside buildings; the support, restoration, maintenance, and relocation of existing utilities encountered or affected by construction of the Rapid Transit System; and the restoration of structures, pavement, sidewalks, and landscaping disturbed by such construction. In the performance of work, consideration shall be given to the needs of the transit system, the requirements and obligations of the utility organizations, the requirements of the governmental authorities, traffic requirements, and the requirements and service needs of abutting properties.

All contacts with utility companies require prior approval from MDT.

2.13.1.2 Basic Goals

All interruptions of utility service to abutting property shall be kept to a minimum and, if temporarily relocated, shall be restored upon completion of the work. Replacements for any existing utilities shall be designed to provide service essentially equal to that offered by the existing installation. No betterments shall be included unless specifically directed or approved by MDT and Miami-Dade County.

2.13.1.3 Codes and Regulations

All new outside construction beyond the five foot line of buildings and the support, maintenance, restoration, and relocation of existing utilities shall be in strict conformance to the latest specifications and practices of the public and private utility companies, as well as the Florida Building Code, the Miami-

Dade County Public Works Manual, and the Florida Department of Transportation Utility Accommodations Manual.

All new design and construction under existing or proposed track locations shall be in conformance with Chapter I, Part 5 of the American Railway Engineering and Maintenance-of-Way Association's "Manual for Railway Engineering".

2.13.1.4 Pre-Design Conference

The Engineer of Record shall develop preliminary design drawings showing foundation locations, footing details and elevations, facility elevations and drainage structures noting possible utility conflicts. These drawings shall be submitted for review by the utility companies. The Engineer of Record shall conduct a pre-design conference with all affected utility companies to coordinate on-site relocation requirements with the utility companies.

2.13.2 UTILITY SYSTEMS

2.13.2.1 Sanitary Sewer Systems

The Engineer of Record shall contact the affected utility company where the Rapid Transit System design affects existing sanitary sewer facilities.

Design and construction of new sanitary service outside the transit right-of-way line will be done by the utility company. From the transit right-of-way line to within five feet of a building, new service shall be designed and constructed by the Engineer of Record and General Contractor respectively, in accordance with all applicable codes and regulations.

2.13.2.2 Storm Sewer Systems

The design and construction of new storm sewer lines, permanent to temporary relocations, and support and maintenance of storm sewer facilities shall be by the Engineer of Record and General Construction Contractor respectively.

The design of storm sewer lines shall be based on the drainage section of these Design Criteria.

2.13.2.3 Water Lines

The Engineer of Record shall contact the affected utility company where the Rapid Transit System design affects existing water lines.

Design and construction of new water service outside the transit right-of-way line will be done by the utility company. Within the transit guideway right-of-way new service shall be designed and constructed by the Engineer of Record and General Construction Contractor respectively, in accordance with all applicable codes, regulations, and fire/life/safety criteria.

2.13.2.4 Natural Gas Lines

The Engineer of Record shall contact the affected gas company where the Rapid Transit System design affects existing gas lines.

All design and construction, either permanent or temporary, including support and maintenance of affected gas lines, manholes and valves will be by the gas company affected.

2.13.2.5 Electric Facilities

The Engineer of Record shall contact the affected electric company where the Rapid Transit System design affects existing electrical facilities.

All design and construction, either permanent or temporary, including support and maintenance of affected existing electrical facilities will be by the electrical utility company affected.

2.13.2.6 Communications Systems

The Engineer of Record shall contact the affected utility company where the Rapid Transit System design affects existing communications.

All design and construction, either permanent or temporary including support and maintenance of affected existing communication lines will be by the communication company.

2.13.3 RESTORATION

2.13.3.1 General

All restoration (streets, sidewalks, etc.) shall be of like materials and conform to widths and thicknesses prevailing, prior to any utility construction. No street, sidewalk, or alley widening or other improvements shall be included without the written consent of MDT.

2.13.3.2 Codes and Regulations

All restoration in public right-of-way (streets, sidewalks, etc.) shall be in conformance with the current standards of the Miami-Dade County Public Works Department, the State of Florida Department of Transportation, and other municipal agencies affected. All utilities to be relocated and/or new

construction to be placed within the Rapid Transit System right-of-way shall be in accordance with the criteria of the governing transit agency and the American Railway Engineering and Maintenance-of-Way Association's "Manual for Railway Engineering".

2.13.4 STREET LIGHTS

2.13.4.1 General

The design of any temporary street lighting, permanent removal of existing street lighting and restoration of permanent existing street lights shall be by the utility company or public works body having jurisdiction over these items.

The construction of any temporary street light, permanent removal of any street light and the relocation and restoration of any existing street light systems owned and maintained by a public works body shall be by the General Construction Contractor.

The construction of any temporary street light systems, permanent removal of any street light system and the relocation and restoration of any existing street light systems owned by a utility company shall be done by that company.

Figure 2-1 – Reserved

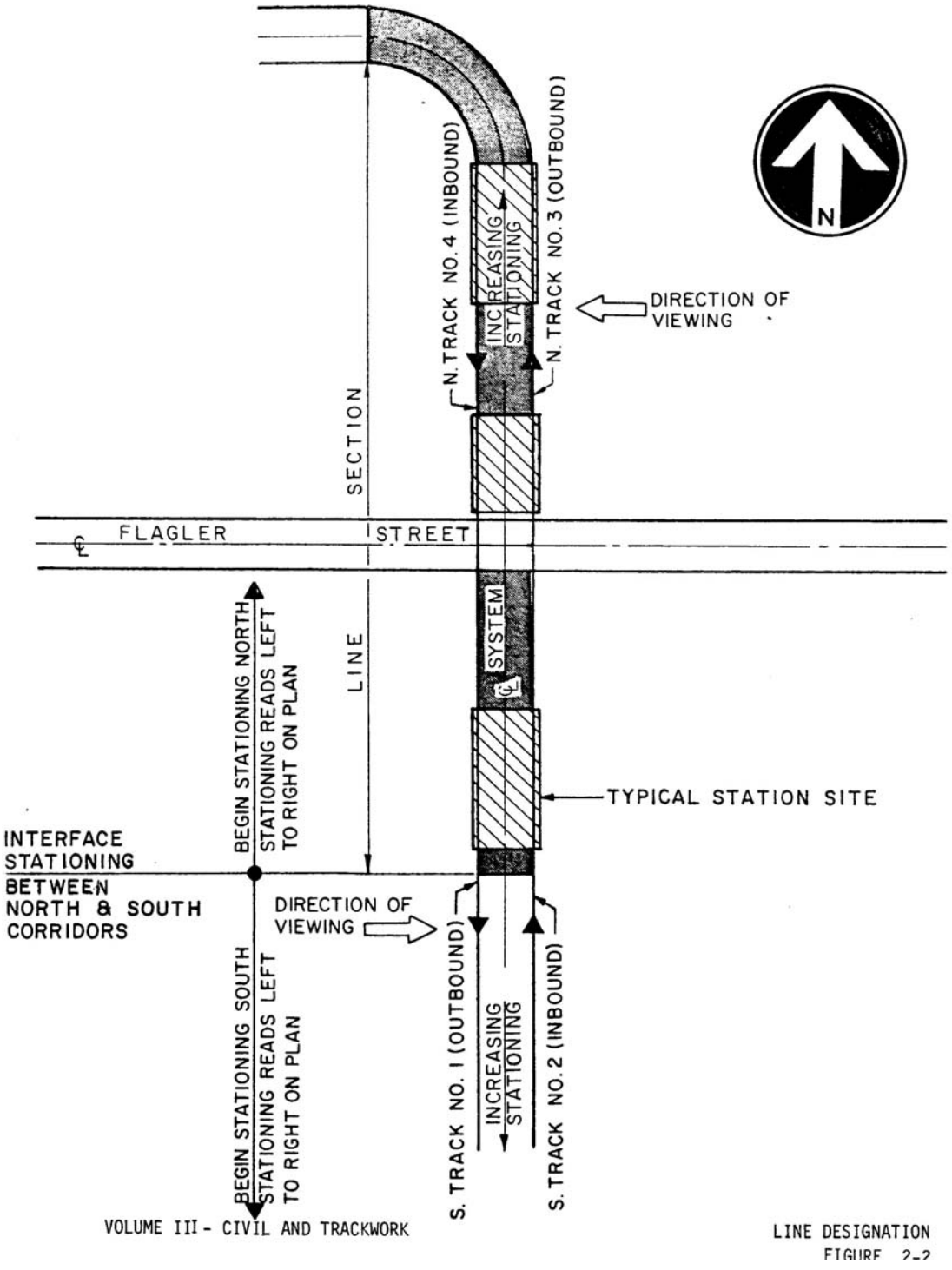
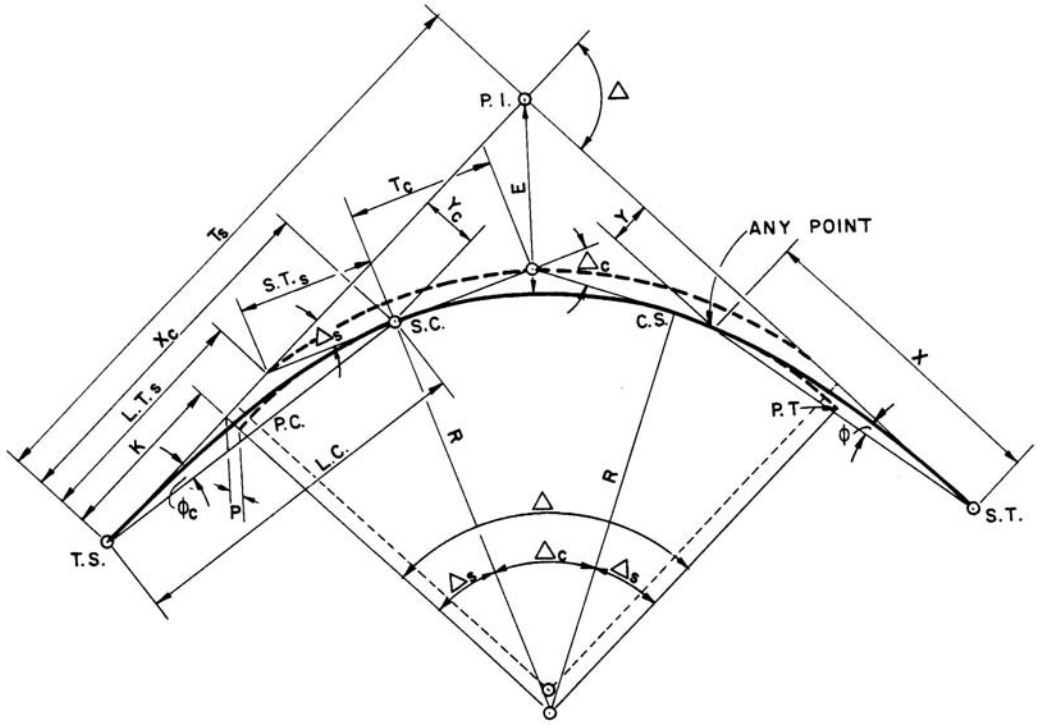


Figure 2-2 – Line Designation



P.I. = POINT OF INTERSECTION MAIN TANGENTS
R = RADIUS OF CIRCULAR CURVE
$T_s = (R + P)\,TAN\,\frac{\Delta}{2} + K$ = TANGENT LENGTH
$P = Y_c - R\,(1 - COS\,\Delta_s)$
$K = X_c - R\,SIN\,\Delta_s$
S.T. = SPIRAL TO TANGENT
T.S. = TANGENT TO SPIRAL
S.C. = SPIRAL TO CURVE
C.S. = CURVE TO SPIRAL
P.C. = POINT OF CURVATURE
P.T. = POINT OF TANGENCY
$L.C. = \sqrt{X_c^2 + Y_c^2}$ = STRAIGHT LINE CHORD DIST.
$E = (R + P)\,EXSEC\,\frac{\Delta}{2} + P$

Δ = TOTAL INTERSECTION ANGLE
Δ_c = CENTRAL ANGLE OF CIRCULAR CURVE
$\Delta_s = \frac{L_s\,D}{200}$ = SPIRAL ANGLE
D = DEGREE OF CIRCULAR CURVE (ARC DEFINIT
L_s = LENGTH OF SPIRAL
$L.T._s$ = LONG TANGENT $= X_c - \frac{Y_c}{TAN\,\Delta_s}$
$S.T._s$ = SHORT TANGENT $= \frac{Y_c}{SIN\,\Delta_s}$
T_c = TAN LGTH. OF CIR. CURVE $= R\ TAN\ \frac{\Delta_c}{2}$
L_c = LGTH. OF CIR. CURVE $= \frac{\Delta_c}{180}\,\pi R$
$X_c = L_s\,COS\,\phi_c$
$Y_c = \frac{D\,(Rad.)\,L_s^2}{600}$
$\phi_c = \frac{\Delta_s}{3}$

VOLUME III- CIVIL AND TRACKWORK

ELEMENTS OF THE TRANSITION SPIRAL CURVE
FIGURE 2-3

Figure 2-3 – Elements of the Transition Spiral Curve

70 MPH Generally Preferred Alignment Parameters			
Radius	**Ea**	**Eu**	**Ls (Min)**
2,457	4.00	4.00	342
3,170	4.00	2.20	200
3,370	3.75	2.08	188
3,600	3.50	1.96	175
3,860	3.25	1.84	163
4,150	3.00	1.74	150
4,500	2.75	1.62	138
4,910	2.50	1.5	128
5,400	2.25	1.39	119
6,000	2.00	1.28	109
6,750	1.75	1.16	100
7,710	1.5	1.05	100
9,000	1.25	0.93	100
10,790	1.00	0.82	100
13,490	0.75	0.71	100
17,990	0.50	0.59	100
26,990	0.25	0.48	100
39,310	0.00	0.50	Not Required

58 MPH Generally Preferred Alignment Parameters			
Radius	**Ea**	**Eu**	**Ls (Min)**
1,687	4.00	4.00	283
2,000	4.00	2.75	200
2,120	3.75	2.61	188
2,260	3.50	2.47	175
2,420	3.25	2.33	165
2,610	3.00	2.17	154
2,830	2.75	2.02	143
3,090	2.50	1.87	132
3,390	2.25	1.73	122
3,770	2.00	1.58	112
4,240	1.75	1.43	101
4,850	1.5	1.28	100
5,660	1.25	1.13	100
6,790	1.00	.99	100
8,490	0.75	.84	100
11,320	0.50	.69	100
16,970	0.25	.55	100
26,990	0.00	0.50	Not Required

Notes: (1) Radii requiring an Ea + Eu greater than 8.0 inches requires MDT approval
(2) Ea greater than 4 inches requires MDT approval.
(3) Radii less than 1,000 feet requires MDT approval.
(4) Ls (min) to be adjusted as per Section 2.3.4.3

Figure 2-4a – Generally Preferred Alignment Parameters (70 MPH and 58 MPH)

46 MPH Generally Preferred Alignment Parameters			
Radius	**Ea**	**Eu**	**Ls (Min)**
1,061	4.00	4.00	224
1,360	4.00	2.24	200
1,450	3.75	2.10	188
1,540	3.50	2.01	175
1,650	3.25	1.89	163
1,780	3.00	1.77	150
1,930	2.75	1.65	138
2,110	2.50	1.52	125
2,320	2.25	1.41	113
2,570	2.00	1.3	100
2,900	1.75	1.18	100
3,310	1.5	1.06	100
3,860	1.25	.95	100
4,630	1.00	.83	100
5,790	0.75	.72	100
7,720	0.50	.60	100
11,580	0.25	.48	100
16,970	0.00	0.50	Not Required

38 MPH Generally Preferred Alignment Parameters			
Radius	**Ea**	**Eu**	**Ls (Min)**
1,000	2.75	3.04	141
1,050	2.75	2.77	138
1,140	2.50	2.58	125
1,260	2.25	2.35	113
1,400	2.00	2.14	100
1,570	1.75	1.94	100
1,800	1.5	1.72	100
2,100	1.25	1.51	100
2,520	1.00	1.30	100
3,140	0.75	1.09	100
4,190	0.50	.88	100
6,290	0.25	.67	100
11,580	0.00	.50	Not Required

28 MPH Generally Preferred Alignment Parameters			
Radius	**Ea**	**Eu**	**Ls (Min)**
1,000	.75	2.39	100
1,200	.50	2.12	100
1,800	.25	1.50	100
6,290	0.00	.50	Not Required

Notes: (1) Radii requiring an Ea + Eu greater than 8.0 inches requires MDT approval
(2) Ea greater than 4 inches requires MDT approval.
(3) Radii less than 1,000 feet requires MDT approval.
(4) Ls (min) to be adjusted as per Section 2.3.4.3

Figure 2-4b – Generally Preferred Alignment Parameters (46 MPH, 38 MPH, 28 MPH)

HORIZONTAL TRACK ALIGNMENT	TRACK GAGE
TANGENT MAIN TRACK	4 - 8 1/4"
CURVE OF RADIUS > 1500'	4 - 8 1/2"
CURVE OF 1500' > RADIUS>1000'	4 - 8 3/4"
CURVE OF 1000 > RADIUS	4 - 9"

NOTE:
1. THESE GAGES APPLY ONLY WITH STANDARD AAR WHEEL GAGES OF 4'-7 11/16" AND VEHICLE AXLE SPACING BETWEEN 7'-0" AND 8'-6" INCLUSIVE.

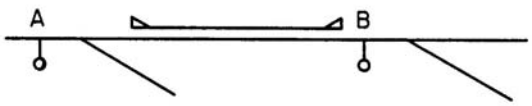
2. THE 1/4" CHANGE IN TRACK GAGE SHALL BE MADE IN A TRANSITION LENGTH OF NOT LESS THAN 31' NOR MORE THAN 62'. In general, the transition length for a change in gage shall be achieved within the spiral portion of a curve and uniformly distributed between the Ts and Sc (Cs and St) points wherever practical. The centerline of track is defined as 2 feet 4 1/8 inches from the gage face of the outside (high) rail and the inside (low) rail shall be shifted towards the center of the curve to accommodate the wider gage.

3. IN YARD AND SECONDARY TRACK THE BASIC TRACK GAGE FOR TANGENT SECTIONS AND FOR CURVES OF RADIUS GREATER THAN OR EQUAL TO 1,500’ SHALL BE 4' - 8½".

Figure 2-5- Track Gage Criteria

BACK-TO-POINT TURNOUTS OF SAME HAND

TURNOUT & HAND		9'-0" END APPROACH	5'-0" END APPROACH
A	B		
6 R	6 R	N. A.	84.58'
6 L	6 L	"	"
6 R	8 R	"	"
6 L	8 L	"	"
8 R	8 R	"	112.44'
8 L	8 L	"	"
8 R	10 R	"	"
8 L	10 L	"	"
10 R	10 R	140.35'	140.35'
10 L	10 L	"	"
10 R	15 R	"	N. A.
10 L	15 L	"	"
15 R	15 R	210.23'	"
15 L	15 L	"	"



NOTE: CONTACT RAIL IS REQUIRED IN ALL OF THE ABOVE CASES.

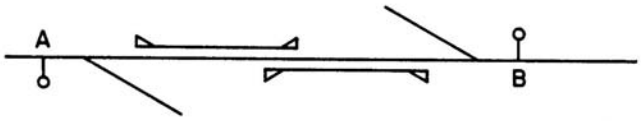
VOLUME III- CIVIL AND TRACKWORK REQUIRED DISTANCES BETWEEN SWITCH POINTS

FIGURE 2-6A

Figure 2-6a – Back-to-Point Turnouts of Same Hand

BACK – TO – BACK TURNOUTS OF SAME HAND

TURNOUT & HAND		9'-0" END APPROACH	5'-0" END APPROACH
A	B		
6 R	6 R	N.A.	198.00'
6 L	6 L	"	"
6 R	8 R	"	220.00'
6 L	8 L	"	"
8 R	8 R	"	242.00'
8 L	8 L	"	"
8 R	10 R	"	275.00'
8 L	10 L	"	"
10 R	10 R	312.00'	308.00'
10 L	10 L	"	"
10 R	15 R	376.00'	N.A.
10 L	15 L	"	"
15 R	15 R	440.00'	"
15 L	15 L	"	"



NOTE: CONTACT RAIL IS REQUIRED IN ALL OF THE ABOVE CASES.

VOLUME II I- CIVIL AND TRACKWORK REQUIRED DISTANCES BETWEEN SWITCH POINTS

Figure 2-6b – Back-to-Back Turnouts of Same Hand

BACK-TO-POINT TURNOUTS OF OPPOSITE HAND
(LARGER FROG ANGLE LEADING)

TURNOUT & HAND		9'-0" END APPROACH		5'-0' END APPROACH	
A	B	MINIMUM	DESIRED	MINIMUM	DESIRED
6 R	6 L	N.A.	N.A.	79.25	80.42
6 L	6 R	"	"	"	"
6 R	8 L	"	"	"	"
6 L	8 R	"	"	"	"
8 R	8 L	"	"	97.00'	97.00'
8 L	8 R	"	"	"	"
8 R	10 L	"	"	"	"
8 L	10 R	"	"	"	"
10 R	10 L	123.25'	136.00'	123.25'	136.00'
10 L	10 R	"	"	"	"
10 R	15 L	"	"	N.A	N.A.
10 L	15 R	"	"	"	"
15 R	15 L	173.82'	180.29'	"	"
15 L	15 R	"	"	"	"

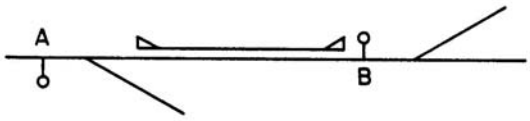
NOTE : CONTACT RAIL IS REQUIRED IN ALL OF THE ABOVE CASES..

VOLUME III- CIVIL AND TRACKWORK REQUIRED DISTANCES BETWEEN SWITCH POINTS

Figure 2-6c – Back-to-Point Turnouts of Opposite Hand (Larger Frog Angle Leading)

BACK-TO-POINT TURNOUTS OF OPPOSITE HAND
(SMALLER FROG ANGLE LEADING)

TURNOUT & HAND		9'-0" END APPROACH		5'-0" END APPROACH	
A	B	MINIMUM	DESIRED	MINIMUM	DESIRED
6 R	6 L	N.A.	N.A.	79.25'	80.42'
6 L	6 R	"	"	"	"
8 R	6 L	"	"	97.00'	97.00'
8 L	6 R	"	"	"	"
8 R	8 L	"	"	"	"
8 L	8 R	"	"	"	"
10 R	8 L	"	"	123.25'	136.00'
10 L	8 R	"	"	"	"
10 R	10 L	123.25'	136.00'	"	"
10 L	10 R	"	"	"	"
15 R	10 L	173.82'	180.29'	N.A.	N.A.
15 L	10 R	"	"	"	"
15 R	15 L	"	"	"	"
15 L	15 R	"	"	"	"



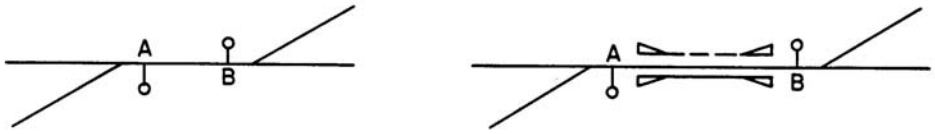
NOTE: CONTACT RAIL IS REQUIRED IN ALL OF THE ABOVE CASES.

VOLUME III- CIVIL AND TRACKWORK REQUIRED DISTANCES BETWEEN SWITCH POINTS

Figure 2-6d – Back-to-Point Turnouts of Opposite Hand (Smaller Frog Angle Leading)

POINT-TO-POINT TURNOUTS OF SAME HAND

TURNOUT		REQ'D. DIST. W/O SPACER RAIL OR CONTACT RAIL (MINIMUM)	MINIMUM DISTANCES WITH SPACER RAIL & CONTACT RAIL	
A	B		9'-0" APPROACH	5'-0" APPROACH
5 EQ.	5 EQ.	N.A.	71.00'	N.A.
5 EQ.	6 L	"	N.A.	59.00'
5 EQ.	8 L	"	"	59.00'
5 EQ.	10 L	"	"	59.00'
5 EQ.	15 L	"	"	N.A.
6 R/L	6 R/L	12.83'	"	59.00'
6 R/L	8 R/L	"	"	59.00'
8 R/L	8 R/L	"	"	59.00'
8 R/L	10 R/L	N.A.	"	59.00'
10 R/L	10 R/L	"	71.00'	59.00'
10 R/L	15 R/L	"	"	N.A.
15 R/L	15 R/L	"	"	"



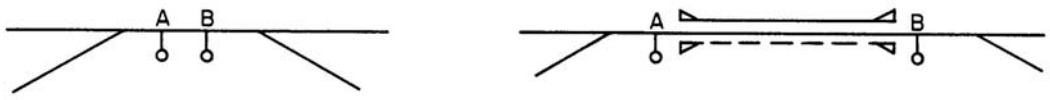
NOTE: SPACER RAIL IS THE SECTION OF RAIL PLACED BETWEEN THE STOCK RAILS OF THE POINT-TO-POINT TURNOUTS. IT'S MINIMUM LENGTH IS 19'-0".

VOLUME III- CIVIL AND TRACKWORK REQUIRED DISTANCES BETWEEN SWITCH POINTS

Figure 2-6e – Point-to-Point Turnouts of Same Hand

POINT - TO - POINT TURNOUTS OF OPPOSITE HAND

TURNOUT A	TURNOUT B	REQ'D DIST. W/O SPACER RAIL OR CONTACT RAIL (MINIMUM)	MINIMUM DISTANCES WITH SPACER RAIL & CONTACT RAIL 9'-0" APPROACH	MINIMUM DISTANCES WITH SPACER RAIL & CONTACT RAIL 5'-0" APPROACH
5 EQ.	5 EQ.	N.A.	71.00'	N.A.
5 EQ.	6 R	"	N.A.	59.00'
5 EQ.	8 R	"	"	59.00'
5 EQ.	10 R	"	"	59.00'
5 EQ.	15 R	"	"	N.A.
6 R/L	6 L/R	12.83	"	59.00'
6 R/L	8 L/R	"	"	59.00'
8 R/L	8 L/R	"	"	59.00'
8 R/L	10 L/R	N.A.	"	59.00'
10 R/L	10 L/R	"	71.00'	59.00'
10 R/L	15 L/R	"	"	N.A.
15 R/L	15 L/R	"	"	"



NOTE: SPACER RAIL IS THE SECTION OF RAIL PLACED BETWEEN THE STOCK RAILS OF THE POINT - TO - POINT TURNOUTS. IT'S MINIMUM LENGTH IS 19'-0".

VOLUME III- CIVIL AND TRACKWORK

REQUIRED DISTANCES BETWEEN SWITCH POINTS

FIGURE 2-6F

Figure 2-6f – Point-to-Point Turnouts of Opposite Hand

– Intentionally Left Blank –