

EXHIBIT A

SEC PROJECT LIGHT RAIL TRANSIT (LRT) CROSSING LOCATIONS

The following is a complete listing of the public highways, including on-ramps and off-ramps and pedestrian walkways and bike paths, that will be crossed (hereinafter, an “LRT Crossing”) by the proposed Southeast Corridor Project’s fully grade-separated LRT element. This listing of LRT Crossings is organized directionally (except where otherwise indicated), as follows: as the SEC Project proceeds south on I-25, starting from the Broadway Station to Lincoln Avenue; and, then north on I-225, from I-25 to Parker Road. Further, this listing of LRT Crossings is also organized such that, where practicable, 2 or more actual crossings have been combined into 1 LRT Crossing (as noted below) when multiple roadways were crossed by a single structure or when, geographically, multiple roadway crossings all had the same clearance evaluation components.

LRT CROSSINGS ALONG WEST SIDE OF I-25

- | | |
|--|---------------------------------|
| 1) Over Broadway Blvd. & over Kentucky Ave. | City and County of Denver (CCD) |
| 2) Under Logan St. | CCD |
| 3) Under SB I-25 off-ramp at Washington St. and under Washington St | CCD |
| 4) Under Louisiana St. | CCD |
| 5) Under Emerson St. and under SB I-25 on-ramp at Emerson. | CCD |
| 6) Under Downing St. | CCD |
| 7) Under Franklin St. | CCD |
| 8) Over SB I-25 off-ramp at University Blvd. (SH 177), over University, and over SB I-25 on-ramp at University | CCD |
| 9) Under Steele/St. Paul | CCD |
| 10) Under Colorado Blvd. (SH 2) and under Colorado Center Dr. | CCD |
| 11) Under Birch ST. | CCD |
| 12) Under SB I-25 off-ramp at Evans Ave., under Evans and | CCD |

- under SB I-25 on-ramp at Evans
- 13) Over SB I-25 off-ramp at Yale Ave., over Yale and over SB I-25 on-ramp at Yale CCD
- 14) Over the Highline Canal Service Road CCD
- 15) Under SB I-25 off-ramp at Hampden Ave. (SH 30), under Hampden, and under SB I-25 on-ramp at Hampden. CCD
- 16) Under Quincy Ave. CCD
- (I-25/I-225 INTERCHANGE - See # 25 below)
- 17) Under Union Ave. CCD
- 18) Over SB I-25 off-ramp at Belleview Ave. (SH 88), over Belleview, over SB I-25 on-ramp at Belleview CCD
- 19) Over SB I-25 off-ramp at Orchard Rd., over Orchard, over SB I-25 on-ramp at Orchard Greenwood Village (GV)
- 20) Under Yosemite St. GV
- 21) Over SB I-25 off-ramp at Arapahoe Rd. (SH88), over Arapahoe, over SB I-25 on-ramp at Arapahoe GV
- 22) Over SB I-25 off-ramp at Dry Creek Rd., over Dry Creek, over SB I-25 on-ramp at Dry Creek Arapahoe County
- 23) Over SB I-25 off-ramp at County Line Rd., over County Line, over SB I-25 on-ramp at County Line Arapahoe County
- 24) I-25/C-470 INTERCHANGE including:
- Under SB I-25 off-ramp to WB C-470 Douglas County
 - Under NB I-25 off ramp to WB C-470 Douglas County
 - Over C-470 Mainline Douglas County
 - Under EB C-470 off ramp to NB I-25 Douglas County
 - Under EB C-470 off ramp to SB I-25 Douglas County
- 25) I-25/I-225 INTERCHANGE including:
- SB I-25 to NB I-225 structure which goes over: CCD

- SB I-25 Mainline
 - NB I-25 Mainline
 - Ramp, SB I-25 to NB I-225
 - Ramp, SB I-225 to SB I-25
 - Ulster St.
-
- SB I-225 to NB I-25 structure which goes over: CCD
 - SB I-25 Mainline
 - NB I-25 Mainline
 - Ramp, SB I-25 to NB I-225
 - Ramp, SB I-225 to SB I-25
 - Ulster St.
-
- SB I-225 to SB I-25 structure which goes over: CCD
 - Ulster St
 - Ramp, SB I-25 to NB I-225
 - Ramp, SB I-225 to SB I-25
 - NB I-25 Mainline
 - SB I-25 Mainline
 - Ramp, SB I-25 to Belleview
-
- NB I-25 to NB I-225 structure which goes over: CCD
 - Ulster St
 - Ramp, SB I-25 to NB I-225
 - Ramp, SB I-225 to SB I-25
 - NB I-25 Mainline
 - SB I-25 Mainline
 - Ramp, SB I-25 to Belleview

LRT CROSSINGS ALONG I-225 MEDIAN

- 26) Over DTC Parkway CCD

27) Under Yosemite St.

CCD

28) Under Dayton St. (Undedicated St.)

City of Aurora

29) Over Parker Road (SH 83)

City of Aurora

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1.2 Basic Configuration

Basic Configuration shall be as defined in Book One, and as follows:

1. The general termini shall be as shown in the Reference Drawings.
2. The LRT alignment shall be grade separated from the highway and cross streets. No at-grade crossings will be allowed.
3. The Highway and Fixed Guideway horizontal and vertical alignments shall be as shown in the Reference Drawings. Additionally, the following shall be allowed without being considered a change to the Basic Configuration.
 - A. The vertical alignment for the Highway can be changed up to 2 feet down or 5 feet up, except for the Southmoor area (defined as the area between Hampden Avenue and Quincy Avenue) which can be changed up to 2 feet down or 2 feet up.
 - B. The vertical alignment grade for the Fixed Guideway can be changed up to 0.25 percent.
 - C. The horizontal alignment for the Highway and Fixed Guideway can be changed up to 10 feet, or within the proposed right-of-way limits as shown in Book 4, whichever is less.
 - D. The minimum vertical clearance for the fixed guideway between the top of the rail and overhead structures can be changed up to 2 feet, but shall not be less than minimum criteria.
7. The number of Fixed Guideway tracks, including turnout sizes and special trackwork locations/configurations, shall be as shown in the Reference Drawings. Additionally, the locations of special trackwork can be changed up to 50 feet along the longitudinal axis of the Fixed Guideway alignment.
8. The LRT connection at the I-25/I-225 interchange shall be a wye connection with two (2) tracks on each leg. All track to track crossings shall be grade separated.
9. The LRT connection at the Broadway Station shall be a wye connection with two tracks on the Central to Southeast and Central to Southwest legs. The Southwest to Southeast leg may be one track. A pocket track shall be provided south of the Broadway Station. The number of tracks at the Broadway Station shall be as shown in the Reference Drawings.
10. The location of the stations shall be as shown in the Reference Plans, except as follows:
 - A. Design of the station sites shall be as shown in the Contract Drawings.
 - B. The station site location can be changed, in its entirety, a distance of up to 100 feet along the longitudinal axis of the fixed guideway alignment.
12. The number and locations of wayside signals and signal box units shall be as shown in the Contract Drawings. Additionally, the locations of wayside signals or signal box units can be changed up to a distance of 50 feet along the longitudinal axis of the fixed guideway alignment, provided that the change does not increase the design headway to greater than 130 seconds and that adequate breaking distance is maintained as given in the Contract.



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3.3 LRT DESIGN

3.3.1 Track Geometry and Trackwork

3.3.1.5 Clearance Requirements

3.3.1.5.1 General

1. The criteria developed in this Section apply to the design of the entire system. All designs shall provide not less than the minimum clearances as specified in this Section.

3.3.1.5.2 Track Spacing

Track spacing will vary, depending on the type of construction used for the particular section.

1. Minimum center-to-center track dimensions for parallel tracks with center catenary poles shall be 14.0 feet.
2. Minimum center-to-center track dimensions for parallel tracks without center catenary poles shall be 13.0 feet.
3. Increased center-to-center dimensions may be required through curved sections.

3.3.1.5.3 Clearance Envelope

The Clearance Envelope (CE) is defined as the space occupied by the vehicle dynamic envelope plus the effects of Other Wayside Factors (OWF) including construction, fabrication, and maintenance tolerances and additional Running Clearance (RC). This relationship can be expressed mathematically as:

$$CE = VDE + OWF + RC$$

$$CE = (5 \text{ feet, } 9\text{-}1/2 \text{ inches}) + (1.5 \text{ inches} + 1.0 \text{ inches} + CW) + (2.0 \text{ inches})$$

$$CE = 6 \text{ feet } 2 \text{ inches minimum for tangent track}$$

$$CE = 6 \text{ feet } 2 \text{ inches} + CW \text{ minimum for outside curves}$$

3.3.1.5.3.1. Vehicle Dynamic Envelope

The dynamic outline of the design vehicle shall be developed in accordance with data as described in RTD's Light Rail Design Criteria, Section 4.2.4.2 - Clearance Envelope.

3.3.1.5.3.2 Other Wayside Factors

Other Wayside Factors is the sum of certain Construction Tolerances (CT) and Maintenance Tolerances (MT), and a chorded wall construction factor (CW)

$$CT = \text{Allowable deviation from the design position}$$

$$CT = 0.5 \text{ inches for ballasted, paved or direct fixation track plus } 1.0 \text{ inches for poles, signal equipment or walls}$$

$$CT = 1.5 \text{ inches}$$

$$MT = \text{Maintenance tolerance (allowable deviation in position from the as constructed position)}$$

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- MT = 1.0 inches for ballasted track or
0.5 inches for direct fixation or paved track
- CW = Additional width for chorded construction of walls, catenary poles, signal poles or other obstructions to be constructed outside of curves
- CW = Distance as shown on Figures 4.4 and 4.5 of RTD's LRT Design Criteria
- OWF = Other wayside factors
- OWF = CT + MT + CW

3.3.1.5.3.3 Running Clearances

Running clearances are the clearance contingency added after the inclusion of all factors which define the vehicle, vehicle tolerances, construction tolerances and maintenance tolerances. Running clearances are specific to the right-of-way condition encountered and shall be as follows:

| <u>Condition</u> | <u>RC</u> |
|---------------------------------|-----------|
| Traction power poles | 2 inch |
| Conduit | 2 inch |
| Signals | 2 inch. |
| Other non-structural elements | 2 inch |
| Walkway edge | 2 inch |
| Pantograph electrical clearance | 3 inch |
| Structural members | 6 inch |
| Adjacent LRVs | 0 inch |

3.3.1.5.3.4 End and Middle Ordinate Displacement

For design purposes, the end overhang and middle ordinate of the vehicle on curved tracks shall be considered. Rounding of car corners shall not be considered.

3.3.1.5.3.5 Effect of Superelevation

1. It is the intent of these criteria to provide facilities which will permit changing the operating speeds of the trains during the life of the system by changing the actual superelevation (E_a). Because some horizontal clearances are a function of superelevation, it is necessary that the facilities be designed for a maximum value of E_a , not to exceed 6 inches, toward the center of the curve, and for a minimum value E_a away from the center of the curve unless physical conditions restrict the operating speed in a given area.
2. A superelevation correction of 2.15 inches per inch of actual superelevation (E_a) at the car mirror, not to exceed 10 inches for outside end overhang, and 1.15 inches per inch of E_a at 5.5 feet above the top of rail shall be applied to the clearance envelope.

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3.3.1.5.4 CLEARANCES

3.3.1.5.4.1 Horizontal Clearances

Minimum horizontal clearances measured from centerline of track shall be as follows:

| <u>Condition</u> | <u>Horizontal Clearance</u> |
|---|-----------------------------|
| Adjacent parallel tracks | See 3.3.1.5.2 Track Spacing |
| Intermittent columns and point restrictions | 7.5 feet minimum (Note 1) |
| Retaining walls or continuous restrictions | 8.5 feet minimum |

NOTES:

1. Each such restriction shall be considered independently and submitted to the SEC Representative for prior Approval.
2. In addition to the clearance envelope, an emergency access/maintenance walkway shall be provided adjacent to each track. The walkway shall extend 2 feet, 6 inches from the edge of the clearance envelope and shall extend 6 feet, 6 inches above the top of rail. The walkways shall be provided along the outside edges of the guideway and shall permit unobstructed egress from the guideway. With prior SEC Representative Approval the walkway may be located between the LRT tracks. For walkway clearance calculations only, traction power poles and the LRV mirrors need not be considered.

3.3.1.5.4.2 Vertical Clearances

Minimum vertical clearances, measured from the top of high rail, shall be as follows:

| <u>Condition</u> | <u>Required Vertical Clearance</u> |
|--------------------|------------------------------------|
| Structure over LRT | 17 feet |
| LRT in long tunnel | 15 feet |

Prior SEC Representative Approval will be required to use 15 foot clearance.

3.3.1.5.4.3 Chorded Construction

1. When chorded construction is specified, walls and walkways shall be constructed in chords whose lengths shall be measured along the inside face of the wall nearest the curve center. The maximum allowable lengths of chord shall be:
 - A. For curves with radii 2500 feet or greater: 50 feet
 - B. For curves with radii less than 2500 feet: 25 feet
2. Values to be used for allowances for chorded construction in clearance calculations are shown in Figures 4.4 and 4.5 of RTD's LRT Design Criteria.
3. In chorded construction, the horizontal dimensions from centerline of track to inside face of wall shall be measured normal to the centerline of track between adjacent chorded elements.

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3.3.1.5.4.4 Widening on Curves

1. The required increase in width of clearance envelope between a tangent section of track and a curved section of track shall be applied or removed linearly. The transition from tangent width to curved width shall begin at a point 50 feet before the TS (or 50 feet after the ST) and end at a point 25 feet before the TS (or 25 feet after the ST) For horizontal curves without spirals, the PC and PT shall be used in lieu of the TS and ST.
2. The clearance envelope through turnouts shall be determined using the turnout centerline radius.

3.3.1.5.4.5 Structure Width

The minimum structure width shall be determined by the sum of the dynamic total width, required clearances, construction tolerances, allowance for chorded construction, where applicable, allowance for superelevation of the tracks, where applicable, and requirements for safety walks.

3.3.1.5.4.6 Station Clearances

Horizontal clearances at platforms shall be 4 feet, 7 inches from the centerline of the track to the edge of the platform.

3.3.1.5.4.7 Highway

The following vertical clearances (rapid transit structure over highway) shall apply to possible future developments as well as existing conditions.

1. Over roadways under Colorado Department of Transportation jurisdiction:
Minimum vertical clearance, 16.5 feet
2. The above-listed vertical clearances, vertical clearance requirements in all other jurisdictions, and all horizontal clearance requirements shall be verified with the appropriate authorities. For structures under the jurisdiction of agencies other than those listed above, the design shall be coordinated with the appropriate owner or agency involved.

3.3.1.5.4.8 Undercar Clearance

The minimum vertical clearance envelope under the car shall be 3 inches.

23.3.1.7 LRT Design Variances

3.3.1.7.1 General

The following design variances have been Approved by RTD.

3.3.1.7.2 Curves not meeting 60 mph design speed

| Curve No. | Design Speed | Meet | Comment |
|---------------|--------------|---------------------|---------|
| | | Accel/Decel Curves? | |
| SE1 SB to SW2 | 40 | Yes | |

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| Curve No. | Design Speed | Meet Accel/Decel Curves? | Comment |
|-----------------|--------------|--------------------------|--|
| SE1 SB to SW3 | 55 | Yes | |
| SE1 NB from SW1 | 55 | No | Constrained wye track configuration |
| SE1 NB from SW2 | 55 | No | Quickly shifting track centers to reuse bridge |
| | | Meet | |
| SE1 NB from SW3 | 55 | No | Quickly shifting track centers to reuse bridge |
| SE1 POCKET1 | 20 | No | Pocket track will not see 60 mph operations |
| SE1 POCKET2 | 44 | No | Pocket track will not see 60 mph operations |
| SE1 WYENB1 | 15 | No | Non-revenue track |
| SE1 WYESB1 | 20 | No | Non-revenue track |
| SE1 NB1 | 20 | No | Constrained wye track configuration |
| SE1 SB1 | 20 | No | Constrained wye track configuration |
| SE1 NB2 | 25 | No | Minimize property impact (Gates building) |
| SE1 SB2 | 25 | No | Minimize property impact (Gates building) |
| SE1 NB4 | 55 | Yes | |
| SE1 SB4 | 55 | No | Minimize ramp structure length |
| SE1 NB5 | 50 | Yes | |
| SE1 SB5 | 50 | Yes | |
| SE1 NB6 | 50 | Yes | |
| SE1 NB10 | 45 | Yes | |
| SE1 SB10 | 45 | Yes | |
| SE1 NB11 | 45 | Yes | |
| SE1 SB11 | 45 | Yes | |
| SE1 NB15 | 40 | No | Minimize property impact |
| SE1 SB15 | 40 | No | Minimize property impact |
| SE1 NB17 | 35 | No | Minimize property impact |
| SE1 SB17 | 35 | No | Minimize property impact |
| SE1 NB18 | 35 | No | Minimize property impact |
| SE1 SB18 | 35 | No | Minimize property impact |
| SE2 NB2 | 45 | Yes | |
| SE2 NB3 | 45 | No | Minimize property impact |
| SE2 SB3 | 45 | Yes | |
| SE2 NB10 | 45 | Yes | |
| SE2 NB19 | 45 | Yes | |
| SE4 NB1 | 55 | Yes | |
| SE4 NB2 | 45 | Yes | |
| SE4 SB2 | 55 | Yes | |
| SE4 NB3 | 55 | No | Compromise between speed and structure cost |
| SE4 SB3 | 55 | Yes | Compromise between speed and structure cost |
| SE4 NB4 | 55 | No | Compromise between speed and structure cost |
| SE4 SB4 | 55 | Yes | Compromise between speed and structure cost |
| SE4 NB5 | 55 | No | Compromise between speed and structure cost |
| SE4 SB5 | 55 | No | Compromise between speed and structure cost |
| SE4 NB7 | 45 | Yes | |
| SE4 SB7 | 45 | Yes | |
| SE4 SB8 | 45 | Yes | |
| SE4 NB13 | 40 | No | Minimize property impact |
| SE4 SB13 | 40 | No | Minimize property impact |
| SE4 NB14 | 40 | No | Minimize property impact |
| SE4 SB14 | 40 | No | Minimize property impact |
| SE4 SB17 | 55 | No | Minimize property impact |
| SE4 NB18 | 45 | Yes | |

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| Curve No. | Design Speed | Meet Accel/Decel Curves? | Comment |
|---------------|--------------|--------------------------------|-------------------------------------|
| SE2 SB225-NB1 | 40 | No | Constrained wye track configuration |
| SE2 SB225-NB1 | 40 | No | Constrained wye track configuration |
| SE2 NB225-NB1 | 40 | No | Constrained wye track configuration |
| SE2 SB225-SB1 | 40 | No | Constrained wye track configuration |

3.3.1.7.3 Tangent length less than 200' desirable length

| Station | Length | Criteria Met | Comment |
|-----------------------|--------|--------------|---|
| <u>SE1 SB to SW</u> | | | |
| 318+01.93 | 111.88 | 50'abs min | Constrained wye connection |
| <u>SE1 NB from SW</u> | | | |
| 328+90.08 | 104.22 | 50' abs min | Constrained wye connection |
| <u>SE1 POCKET</u> | | | |
| 418+29.71 | 134.34 | 50' abs min | Constrained wye connection |
| <u>SE1 NB</u> | | | |
| 23+00.45 | 179.37 | 3V min | Constrained wye connection |
| 55+58.84 | 168.83 | 3V min | Minimize ramp structure length |
| 68+85.26 | 128.59 | 50' abs min | Minimize ramp structure length |
| 168+90.59 | 180.65 | 3V min | |
| 183+95.38 | 118.49 | 50'abs min | Constrained geometry at Colorado tunnel |
| 206+95.05 | 113.99 | 50' abs min | Constrained geometry at Evans tunnel |
| 212+15.98 | 182.77 | 3V min | |
| 217+84.45 | 183.05 | 3V min | |
| <u>SE1 SB</u> | | | |
| 55+65.60 | 170.16 | 3V min | Minimize ramp structure length |
| 168+90.61 | 180.62 | 3V min | |
| 183+90.70 | 153.08 | 50' abs min | Constrained geometry at Colorado tunnel |
| 207+28.12 | 118.07 | 50' abs min | Constrained geometry at Evans tunnel |
| 217+85.95 | 183.05 | 3V min | |
| <u>SE2 NB</u> | | | |
| 264+80.36 | 103.36 | 50' abs min | Minimize impact to residences |
| 323+66.41 | 189.93 | 3 V min | Minimize impact to residences |
| 330+84.16 | 147.70 | 50' abs min | Minimize impact to residences |
| 370+81.92 | 144.79 | 50' abs min | Minimize impact to residences |
| 383+66.61 | 128.18 | 50' abs min | Constrained interchange geometry |
| 397+14.26 | 139.53 | 50' abs min | Constrained interchange geometry |
| 437+78.24 | 101.20 | 50' abs min | Minimize property impacts |
| <u>SE2 SB</u> | | | |
| 246+83.73 | 154.33 | 50' abs min | Minimize property impacts |
| 312+21.50 | 190.13 | 3V min | Minimize impact to residences |
| 323+66.02 | 179.64 | 50' abs min | Minimize impact to residences |
| 370+82.15 | 120.10 | 50' abs min | Constrained interchange geometry |

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| Station | Length | Criteria Met | Comment |
|---------------|--------|--------------|------------------------------------|
| 437+77.70 | 101.75 | 50' abs min | Minimize property impacts |
| <u>SE4 NB</u> | | | |
| 543+75.64 | 173.15 | 3V min | Minimize property impacts |
| 569+81.97 | 180.12 | 3V min | Minimize length of narrow shoulder |
| 650+53.54 | 112.28 | 50' abs min | Minimize property impacts |

3.3.1.7.4 Tangent length less than 200 feet desirable length

| Station | Length | Criteria Met | Comment |
|------------------|--------|--------------|------------------------------------|
| <u>SE4 SB</u> | | | |
| 515+48.79 | 184.78 | 3V min | Minimize property impacts |
| 543+77.80 | 172.75 | 3V min | Minimize property impacts |
| 569+33.33 | 189.05 | 3V min | Minimize property impacts |
| 580+87.97 | 190.54 | 3V min | Minimize property impacts |
| 588+65.34 | 145.04 | 50' abs min | Minimize property impacts |
| 650+50.75 | 155.21 | 50' abs min | Minimize property impacts |
| 732+12.56 | 184.02 | 3B min | Constrained by geometry |
| <u>SE3 NB225</u> | | | |
| 516+74.92 | 180.13 | 3V min | Maximize length of narrow shoulder |
| 520+57.90 | 186.60 | 3V min | Maximize length of narrow shoulder |

3.3.1.7.5 Curve length less than 3V

| Curve No. | Length | Comment |
|-----------------|--------|--|
| SE1 SB to SW2 | 107.36 | Quickly shifting track centers to reuse bridge |
| SE1 SB to SW3 | 117.51 | Quickly shifting track centers to reuse bridge |
| SE1 NB from SW1 | 129.91 | Constrained wye track configuration |
| SE1 NB from SW2 | 115.28 | Quickly shifting track centers to reuse bridge |
| SE1 NB from SW3 | 115.28 | Quickly shifting track centers to reuse bridge |
| SE1 SB10 | 134.21 | Minimize property impacts |
| SE1 SB11 | 131.97 | Minimize property impacts |
| SE1 SB19 | 153.49 | |
| SE2 SB2 | 169.92 | Minimize property impacts |
| SE2 SB9 | 105.90 | Minimize property impacts |
| SE2 NB13 | 143.12 | Constrained interchange geometry |
| SE2 SB13 | 143.36 | Constrained interchange geometry |
| SE2 NB14 | 118.42 | Constrained interchange geometry |
| SE2 SB14 | 118.42 | Constrained interchange geometry |
| SE2 NB15 | 39.96 | Constrained interchange geometry |
| SE2 NB17 | 159.16 | Constrained interchange geometry |
| Curve No. | Length | Comment |
| SE2 SB21 | 168.98 | Minimize property impacts |
| SE4 NB12 | 166.32 | Minimize property impacts |
| SE4 SB12 | 163.64 | Minimize property impacts |

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3.3.1.7.6 Curves with no spirals

| Curve No. | Radius | Calculated Spiral Length | Meets Ls/Rc < 1/100 Criteria? | Comment |
|---------------|--------|--------------------------------|--|---------------------------------------|
| SE1 POCKET1 | 2250 | 95 | No | Spirals not needed for storage tracks |
| SE1 NB16 | 8750 | 85 | Yes | |
| SE1 SB16 | 8764 | 85 | Yes | |
| SE2 NB1 | 8014 | 80 | Yes | |
| SE2 SB1 | 8000 | 80 | Yes | |
| SE2 NB6 | 9014 | 85 | Yes | |
| SE2 SB6 | 9000 | 85 | Yes | |
| SE2 NB11 | 17500 | 40 | Yes | |
| SE2 SB11 | 17500 | 40 | Yes | |
| SE2 NB12 | 18000 | 40 | Yes | |
| SE2 SB12 | 16500 | 40 | Yes | |
| SE2 NB13 | 8200 | 75 | Yes | |
| SE2 SB13 | 8214 | 75 | Yes | |
| SE2 NB18 | 8000 | 80 | Yes | |
| SE2 SB18 | 8000 | 80 | Yes | |
| SE2 NB19 | 5500 | 55 | Yes | |
| SE4 NB1 | 12950 | 45 | Yes | |
| SE4 SB1 | 8000 | 80 | Yes | |
| SE4 NB2 | 5500 | 55 | Yes | |
| SE4 SB2 | 7500 | 75 | Yes | |
| SE4 NB6 | 8000 | 80 | yes | |
| SE4 SB6 | 8000 | 80 | Yes | |
| SE4 NB7 | 5500 | 55 | Yes | |
| SE4 SB7 | 5500 | 55 | Yes | |
| SE4 SB8 | 5500 | 55 | Yes | |
| SE2 NB225-NB2 | 5000 | 40 | Yes | |
| SE2 SB225-NB2 | 5000 | 40 | Yes | |
| SE3 NB1 | 16250 | 40 | Yes | |
| SE3 NB2 | 16250 | 40 | Yes | |
| SE3 NB3 | 16250 | 40 | Yes | |
| SE3 NB4 | 16250 | 40 | Yes | |
| SE3 SB1 | 10000 | 70 | Yes | |
| SE3 SB2 | 8000 | 80 | Yes | |

3.3.1.7.7 Reverse curves with no tangent track between them

| Curve No. | Comment |
|-----------|--------------------------------|
| SE2 SB3 | Minimize impacts to residences |
| SE2 SB4 | |

3.3.1.7.8 Vertical grades exceeding the desirable maximum

Mainline Track (desirable maximum grade = 3.5 percent maximum grade = 6 percent)

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| Begin Station | End Station | Grade | Meets Max Grade Criteria | Comments |
|-----------------|-------------|-------|--------------------------|--|
| <u>SE1 WYE</u> | | | | |
| 220+47.50 | 224+66.79 | 5.00% | Yes | Over Broadway, minimize structure length |
| <u>SE1 NB</u> | | | | |
| 20+45.00 | 24+75.00 | 5.00% | Yes | Over Broadway, minimize structure length |
| 120+50.00 | 123+00.00 | 5.00% | Yes | Over Broadway, minimize structure length |
| 132+50.00 | 134+75.00 | 4.00% | Yes | Over Broadway, minimize structure length |
| 213+50.00 | 216+17.50 | 4.96% | Yes | Minimize retained cut length |
| <u>SE2 NB</u> | | | | |
| 327+25.00 | 329+75.00 | 4.60% | Yes | Minimize retained cut length |
| New interchange | | | | |
| <u>SE4 NB</u> | | | | |
| 584+85.00 | 588+00.00 | 6.00% | No | Over Arapahoe, minimize structure length Does not meet Gc=Gt-230/Rc criteria |
| 609+75.00 | 611+50.00 | 4.41% | Yes | Over Arapahoe, minimize structure length |
| 620+00.00 | 629+40.00 | 3.71% | Yes | Match existing grade, minimize earthwork |
| 693+50.00 | 695+60.00 | 6.00% | No | Over County Line, minimize structure length Does not meet Gc=Gt-230/Rc criteria |
| 706+60.00 | 708+77.50 | 4.33% | Yes | Over County Line, minimize structure length |
| 747+50.00 | 750+00.00 | 3.60% | Yes | Weave through C-470 interchange |
| 757+00.00 | 765+00.00 | 4.48% | Yes | Minimize retained cut length |
| <u>SE3 NB</u> | | | | |
| 637+65.00 | 640+75.00 | 5.00% | Yes | Minimize retained fill length |

3.3.1.7.9 Vertical grades exceeding the desirable maximum

Special Trackwork (desirable maximum grade = 1.0 percent maximum grade = 4.5 percent)

| Begin Station | End Station | Grade | Meets Max Grade Criteria | Comment |
|-----------------|-------------|-------|--------------------------|---|
| <u>SE1 NB</u> | | | | |
| 23+00 | 24+79.82 | 5.00% | No | 5.00% Grade needed to match grade at Broadway Station and get over Broadway |
| 228+76.55 | 243+06.50 | 1.01% | Yes | |
| <u>SE2 NB</u> | | | | |
| 341+80.00 | 350+48.88 | 1.25% | Yes | Match existing grade to minimize earthwork |
| New interchange | | | | |
| <u>SE4 NB</u> | | | | |
| 508+70.31 | 513+30.82 | 2.27% | Yes | Minimize retained fill length |
| 783+26.17 | 786+92.69 | 1.50% | Yes | Match existing grade to minimize earthwork |
| 791+92.69 | 795+59.22 | 1.50% | Yes | Match existing grade to minimize earthwork |

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| Begin Station | End Station | Grade | Meets Max Grade Criteria | Comment |
|---------------|-------------|-------|--------------------------|--|
| <u>SE3 NB</u> | | | | |
| 631+93.39 | 633+98.54 | 3.01% | Yes | Match existing grade to minimize earthwork |

Station Platform (desirable maximum grade = 0.5 percent, maximum grade = 1.5 percent)

| Station Name | Grade | Meets Max Grade Criteria | Comment |
|--------------|-------|--------------------------|---------|
| Louisiana | 0.87% | Yes | |
| Colorado | 0.97% | Yes | |
| Southmoor | 1.25% | Yes | |
| Belleview | 1.50% | Yes | |
| Orchard | 1.50% | Yes | |
| Lincoln | 1.50% | Yes | |

Storage Track (desirable maximum grade = 0.0 percent, maximum grade = 0.25 percent)

| Location | Grade | Meets Max Grade Criteria | Comments |
|-----------------|-------|--------------------------|--|
| SE1 POCKET | 0.21% | Yes | Match existing grade to minimize earthwork |
| SE2 POCKET | 1.25% | No | Match existing grade to minimize earthwork |
| SE4 END OF LINE | 0.87% | No | Match existing grade to minimize earthwork |
| SE3 END OF LINE | 1.50% | No | Match existing grade to minimize earthwork |

3.3.1.7.10 Length of constant profile grade less than 3V

| Begin Station | End Station | Length | Comment |
|------------------|-------------|--------|------------------------------|
| New intersection | | | |
| <u>SE4 NB</u> | | | |
| 609+75.00 | 611+50.00 | 175.00 | Minimize retained cut length |

3.3.1.7.11 Minimum tangent prior to PS less than desirable (45 feet)

| Station | Criteria Met | Comment |
|-----------------|--------------|---------|
| <u>SE1 NB</u> | | |
| <u>SE2 NB</u> | | |
| New interchange | | |

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3.3.1.7.12 Vertical clearance less than desirable (17 feet)

| Begin Station | End Station | Length | Comment |
|-----------------------------|-------------|--------|--|
| <u>SE4</u> <u>739+35</u> | 740+65 | 130' | Meets 15 foot minimum clearance criteria |

RTD LIGHT RAIL DESIGN CRITERIA

Regional Transportation District
October 2000

PREFACE

4.2.4 Clearances

4.2.4.1 General

The criteria developed in this section apply to the design of the entire system. All designs shall provide not less than the minimum clearances as specified in this section.

Assurance of adequate and appropriate clearance for the passage of light rail vehicles throughout the mainline trackage, switches and special trackwork, stations, storage yards and operations facilities is one of the most fundamental concerns inherent in the design process and must be rigorously monitored during the construction phase. Design criteria for clearances are complex and are based on numerous assumptions and interfaces.

It is in the development of clearance requirements that the build-up of concurrent, multiple tolerances must be scrutinized and balanced with the practicality of available space and other functional requirements. The clearance requirements in this section seek to make that balance.

4.2.4.2 Clearance Envelope

The Clearance Envelope (CE) is defined as the space occupied by the Vehicle Dynamic Envelope (VDE) plus the effects of Other Wayside Factors (OWF) including construction, fabrication, and maintenance tolerances for certain track and facilities plus Running Clearances (RC). Simplistically this relationship can be expressed as follows:

$$\begin{aligned} \text{CE} &= \text{VDE} + \text{OWF} + \text{RC} \\ &= (5 \text{ feet-}9\text{-}1/2 \text{ inches}) + (1.5 \text{ inches} + 1.0 \text{ inch} + \text{CW}) + (2.0 \text{ inch}) \\ &= 6 \text{ feet-}2 \text{ inch minimum (centerline track to pole face, tangent track)} \end{aligned}$$

Add CW correction from Figure 4.4 for outside curves (6 feet-2 inches + CW).

Generally speaking, the clearance envelope represents the space in or into which, other than the light rail vehicle, no physical part of the system may be placed or constructed or may protrude. The clearance envelope is normally referenced from, or represented by its relationship to, the theoretical centerline of track at Top of Rail (TOR).

a) Vehicle Dynamic Envelope

In addition to the LRV static dimensions, the vehicle dynamic envelope (VDE) includes all possible vehicle movements from vehicle tolerances and from certain closely-related rail/track tolerances. More specifically, the VDE is based upon the following assumptions:

- Static geometry of the vehicle
- Roll angle of $\pm 4^\circ$
- Suspension lateral travel (per side) of 1.340 inch
- Wheel gauge construction tolerance (per side) of 0.031 inch
- Lateral wheel wear (per side) of 0.300 inch
- Radial wheel wear of 1.000 inch
- Rail gauge construction tolerance (per side) of 0.125 inch
- Lateral rail wear (per side) of 0.500 inch
- Wheel-to-rail sideplay (per side) of 0.375 inch

b) Other Wayside Factors

The clearance envelope (CE) can be determined by adding other wayside factors (OWF) for certain construction and maintenance tolerances plus running clearance to the vehicle dynamic envelope. Other Wayside Factors is the sum of certain construction tolerances (CT) plus certain maintenance tolerances (MT) plus a corded wall construction factor (CW) to account for the effects of certain wall construction, all where applicable.

$$\text{OWF} = \text{CT} + \text{MT} + \text{CW}$$

The following defines the Other Wayside Factors and are applicable to and included in the horizontal component of the CE:

CT = Construction tolerances (allowable deviation from design position)

Track = 0.5 in open, paved, and direct fixation

Plus:

poles or signals equipment = 1.0 in, or
walls = 1.0 in, or

MT = Maintenance tolerances (allowable deviation from as constructed condition)

Track = 1.0 in open track (each track), or
= 0.5 in paved and Direct Fixation track

CW = Additional width for chorded construction of walls, catenary poles, signal poles, other obstructions to be constructed outside of curves. (See Figure 4.4 and 4.5)

c) Running Clearances

In addition to the vehicle dynamic envelope and the other wayside factors, the clearance envelope includes an allowance for running clearances (RC). Running

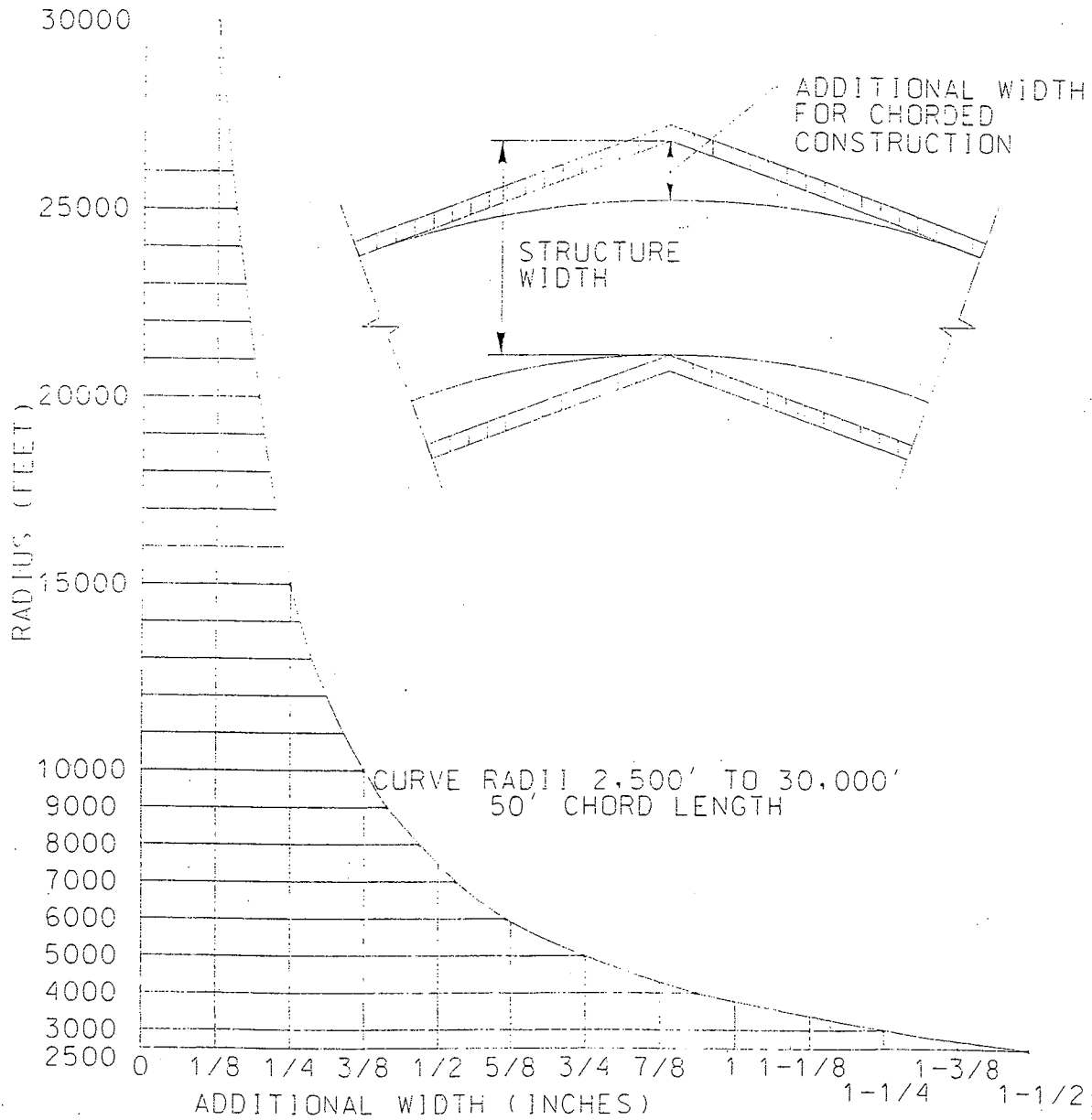
clearances can be considered as the RTD clearance contingency after the inclusion of all factors purporting to define the vehicle, the vehicle tolerances, the construction tolerances, and the maintenance tolerances.

Running clearances are specific to the ROW conditions encountered and shall include one of the following in any direction:

- 2 inch For traction power poles, conduit, signals, signs, and other non-structural members, or
- 2 inch For walkway edge, or
- 3 inch For pantograph electrical clearance, or
- 6 inch For structural members, or
- 0 inch For adjacent LRV.

For horizontal curves with spirals, the tangent clearance envelope shall end 50 feet before the point of Tangent-to-Spiral (TS) and 50 feet after the point of Spiral-to-Tangent (ST). The full curvature clearance envelope shall begin 25 feet prior to the point of Spiral-to-Curve (SC) and end 25 feet beyond the point of curve-to-spiral (CS). The horizontal component of the vehicle dynamic envelope between these two offset points (i.e., 50 feet before TS and 25 feet before SC) shall be considered to vary linearly with distance between the two points. Horizontal offsets at intermediate locations shall be calculated with straight line interpolation. For horizontal curves that do not include spiral transition curves, the full curvature clearance envelope shall begin 50 feet prior to the Point of Curvature (PC) and extend to 50 feet beyond the Point of Tangency (PT). More detailed computer simulations with more precise geometry may be used, subject to RTD approval, to define the clearance envelope in place of these 25 foot and 50 foot locations and straight line interpolations. The clearance envelope through turnouts shall be calculated based on the turnout centerline radius.

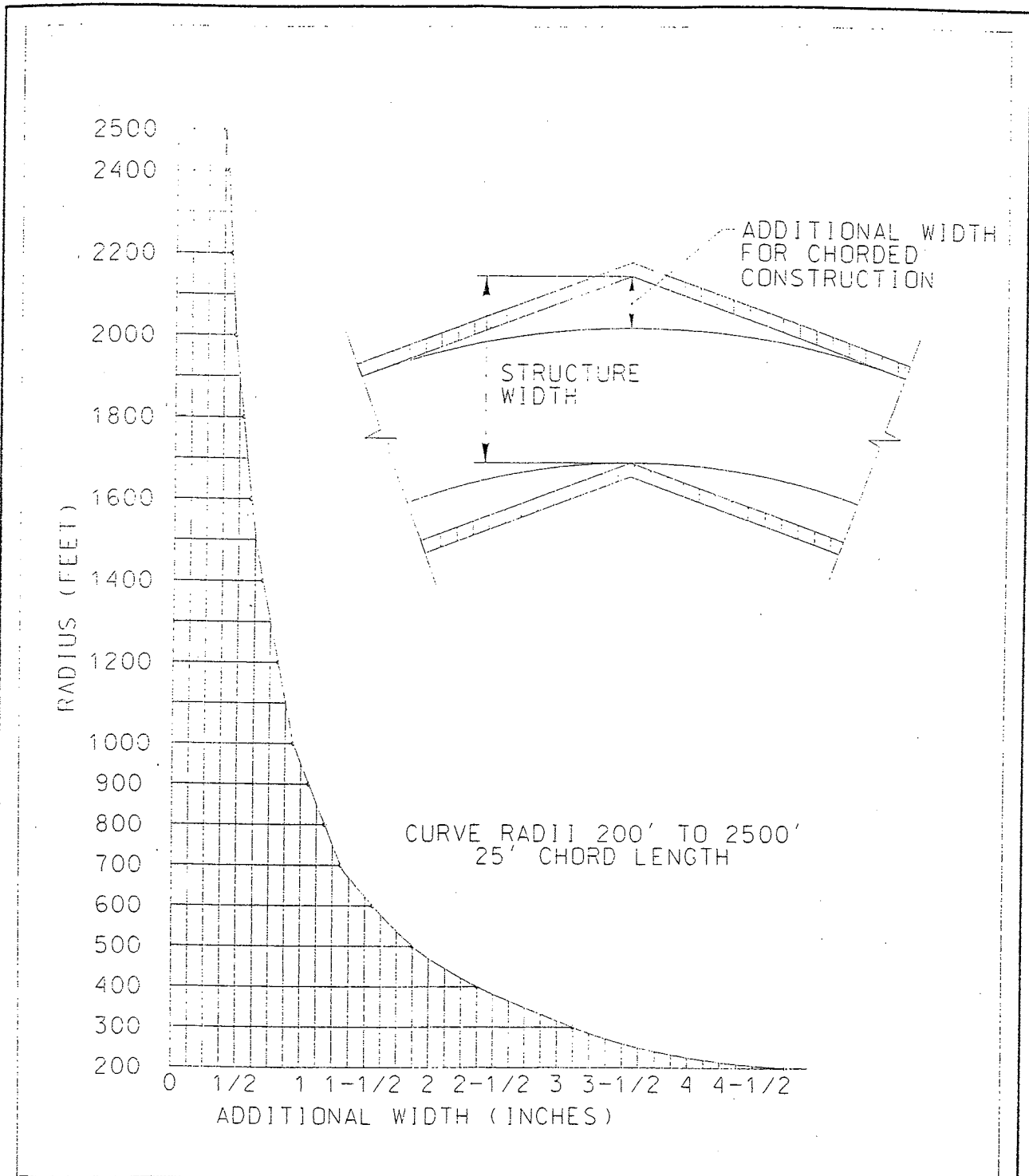
Superelevation correction (e) = 2.15 inches per inch of actual Superelevation (Ea) at car mirror, but not to exceed 10 inches for outside end overhang, 1.15 inches per inch of Ea at 5.5 feet above TOR.



RTD

DESIGN CRITERIA

TITLE: ADDITIONAL WIDTH FOR CHORDED CONSTRUCTION
 FIGURE: 4.4

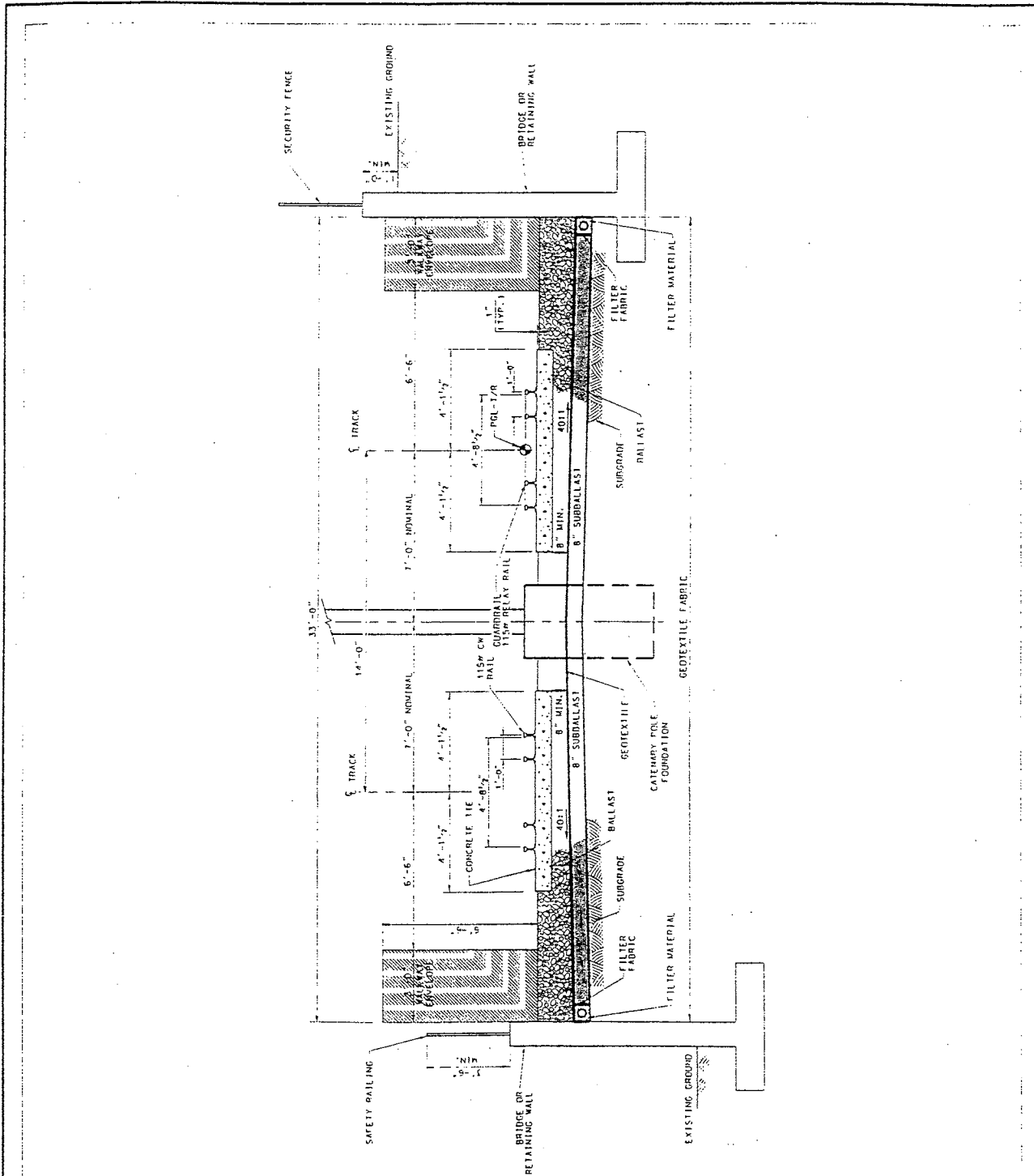


RTD

DESIGN CRITERIA

TITLE: ADDITIONAL WIDTH FOR CHORDED CONSTRUCTION

FIGURE: 4.5



RTD

DESIGN CRITERIA

TITLE: TYPICAL RETAINED TRACK - TANGENT

FIGURE: 4.10