CALIFORNIA HIGH-SPEED TRAIN

Program Environmental Impact Report/Environmental Impact Statement

ENGINEERING CRITERIA

January, 2004

Prepared for:

California High-Speed Rail Authority

U.S. Department of Transportation
Federal Railroad Administration

CALIFORNIA HIGH SPEED RAIL AUTHORITY

U.S. Department
of Transportation
**Federal
Railroad
Administration**

CALIFORNIA HIGH-SPEED TRAIN PROGRAM EIR/EIS

Task 1.11

Engineering Criteria

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January, 2004

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1.0 INTRODUCTION

1.1 BACKGROUND

In its *Business Plan*[1] adopted in June 2000, the California High-Speed Rail Authority (Authority) recommended that the state proceed with implementation of a statewide high-speed train system by initiating the formal state and federal environmental review process through preparation of a state program-level Environmental Impact Report (EIR) and a federal Tier I Environmental Impact Statement (EIS) or Program EIR/EIS. The Authority is the state lead agency for the California Environmental Quality Act (CEQA), and the Federal Railroad Administration (FRA) is the federal lead agency for the National Environmental Policy Act (NEPA). As part of the Program EIR/EIS, a number of project alternatives will be evaluated including a High-Speed Train Alternative. Within the High-Speed Train Alternative, there are a range of high-speed train alignments and station locations to be considered. To carry out the engineering and environmental work needed for the program environmental process, the state network has been divided into five regions: Bay Area-Merced, Sacramento-Bakersfield, Bakersfield-Los Angeles, Los Angeles-San Diego via the Inland Empire, and Los Angeles-Orange County-San Diego (see Figure 1.1-1).

Figure 1.1-1: High-Speed Train Corridors

1.2 PURPOSE OF ENGINEERING CRITERIA AND PARAMETERS

Through the alignment and station screening evaluation process, a number of alignment and station options were identified, evaluated and defined for further study in the Program EIR/EIS as part of the High-Speed Train Alternative. These alignment and station options were developed based on engineering criteria and parameters established for the screening evaluation. In all cases these criteria and parameters are still appropriate; however, to define the alignment and station options adequately to support the program level environmental analysis certain areas need further specificity. To guide the further definition of these options additional engineering criteria and parameters are necessary in the following three main areas: station requirements (including track/platform configuration and parking),

[1] California High-Speed Rail Authority. *Building a High-Speed Train System for California, Final Business Plan*. June 2000.

storage and maintenance requirements, and the design and operating concept for shared use (HSR and conventional passenger trains) operation in certain corridors such San Jose to San Francisco and Los Angeles to Irvine. The additional criteria and parameters are consistent with the screening methodology and previous studies, as well as the system-wide performance goals and objectives set forth by the Authority.

This report presents the engineering and operating parameters and assumptions that were used to develop and define all of the alignment and station options to be considered in this program level environmental analysis. The Regional Teams completed the definition of the alignment and station options and provided the definitions to the environmental analysis teams as the basis of their analyses.

1.3 ORGANIZATION OF THIS REPORT

In the following chapters, this report describes the range of reasonable system alternatives under consideration and those considered for further analysis in the Program EIR/EIS.

- *Chapter 2.0* describes the overall system parameters.
- *Chapter 3.0* describes the alignment design parameters.
- *Chapter 4.0* describes the station design parameters.
- *Chapter 5.0* describes the system/design parameters applied to the LOSSAN Corridor.

2.0 SYSTEM PARAMETERS

2.1 TECHNOLOGY

The design, cost and performance parameters defined in this document are based on two general technology groups; electrified and non-electrified (conventional) steel-wheel-on-steel-rail high-speed trains. The proposed high-speed train system is illustrated in terms of general alignment and technology in Figure 2.1-1.

Figure 2.1-1
High-Speed Train System

2.1.1 Electrified Steel-Wheel-on-Steel-Rail (VHS)

This type of high-speed train technology would link the San Francisco Bay Area, Sacramento, the Central Valley, Los Angeles, Orange County, the Inland Empire and San Diego (via the Inland Empire). This technology must also be capable and compatible for sharing tracks with other services at reduced speeds in heavily urbanized areas.

The electrified steel-wheel-on-steel-rail high-speed (VHS) trains must be capable of maximum operating speeds near 220 mph (350 km/h) (Figure 2.1-2) on dedicated, fully grade-separated lines with more stringent alignment requirements than those needed for lower speed lines. These trains must also be capable of integrate into existing conventional rail lines in the congested urban areas given resolution of certain equipment and operating compatibility issues. All VHS systems in operation use electric propulsion with overhead catenary and include the Train à Grande Vitesse (TGV) in France operating at 186 mph (300 km/h) and the InterCity Express (ICE) in Germany, which operates at 155 mph (250 km/h).

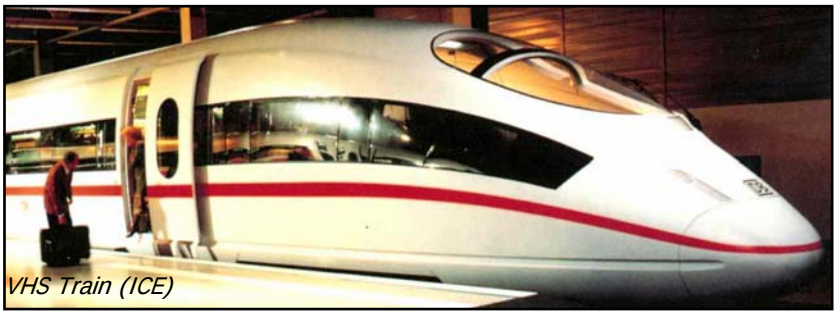

Figure 2.1-2: VHS Technology

The criteria applicable to the VHS Technology are presented in the remaining sections (2.2 and 2.3) of this Chapter, and Chapters 3 through 7.

2.1.2 Non-Electrified Steel-Wheel-on-Steel-Rail (Conventional)

This type of high-speed train technology would link LA Union Station to San Diego via Orange County. This service would require a transfer to the electrified high-speed train service (at LA Union Station or Orange County) for trips north of Union Station.

From Irvine to San Diego, <u>only</u> non-electrified steel-wheel-on-steel-rail high-speed train technology will be considered. Therefore, high-speed train service from San Diego via the LOSSAN Corridor would require a transfer to the electrified high-speed train service (at LA Union Station or Orange County) for trips north of Union Station.

<u>The criteria established for this technology is presented in Chapter 8</u>.

2.2 SHARED USE/COMPATIBILITY ISSUES

The statewide train system is being planned for dedicated high-speed service from San Jose to Sacramento to Los Angeles. For high-speed train service on the San Francisco Peninsula (San Jose to San Francisco), only integrated (shared-track) service on the Caltrain Corridor will be considered for further evaluation. The high-speed trains would need to be compatible with the other passenger trains (Caltrain) sharing the tracks. High-speed trains would also share tracks with existing services for the LOSSAN alignment alternative from Los Angeles Union Station to Irvine. Sharing tracks with existing services may be required in other heavily urbanized portions of the statewide high-speed train network, such as San Jose to Oakland, and Los Angeles to Riverside. Continued investigation of the rail corridors between Los Angeles and Riverside will include consideration of the potential for sharing tracks with Metrolink. The segments proposed for shared use operations are highly constrained in terms of urban development and alignment geometry. Operating speeds on these segments are significantly constrained, typically under 125 mph.

FRA requirements for rolling stock preclude shared use of trackage by conventional railroad equipment and available very high-speed equipment, which do not currently meet FRA structural design requirements (i.e., "buff strength"). This pertains to the amount of force that can be applied to the end of a trainset (passenger cars and locomotives or power units) without causing the cars or locomotives to crumple. A high buff strength requirement (a "crash-worthiness" standard) protects the passengers and railroad employees inside the train in the event of a collision.

Both the Federal Railroad Administration (FRA) and high-speed train manufacturers have indicated that they believe that steel-wheel-on-steel-rail trains capable of meeting the Authority's performance standards will be able to meet or exceed FRA standards for shared-track operations in California. The implementation of shared use in the California system would focus on changes to the design and manufacture of high-speed train equipment; however, it may also encompass the consideration of a variety associated solutions including changes in the type of conventional passenger and freight equipment used on the potential shared use corridors, changes in the current operating (train control, signaling, etc.) practices, and changes in the regulatory requirements. Shared use operations with conventional freight traffic would be avoided with either physical (separate tracks) or temporal (time of day) separation.

To define the extent of physical and operational characteristics of these shared use corridors, the Regional Teams, in conjunction with the Program Management Team, must apply the following basic concept of shared use operation to each applicable corridor. Shared use corridors would meet the following general criteria:

- Electrified
- Full Grade Separation
- Uniform Control/Signal System
- Four Tracks at Stations (allow for through/express services and local stopping patterns)
- May require three to Four Mainline Tracks (depending on capacity requirements of HSR and other services)
- Physical or Temporal Separation from Conventional Freight Traffic is desired.

2.3 POTENTIAL FREIGHT SERVICES ON DEDICATED HIGH-SPEED LINES

In addition to the compatibility issues described above, there are other issues associated with the potential operation of freight services with high-speed train passenger services on dedicated high-speed lines. Operating freight trains at axle loads approaching conventional U.S. axle loads would compromise high-speed train operating efficiency, maintenance standards/tolerances and strict safety requirements. Conventional U.S. freight trains also require different track geometry in terms of superelevation. In addition to the substantially higher axle loads required by the conventional railroad freight services, larger clearances due to the size of the double or piggyback cargo containers are also required. These larger clearances would impact the design of the electrification distribution system, undercrossings and tunnels. For these reasons operation of conventional full-tonnage freight trains would be incompatible with a high-speed train system in California.

Two other types of freight movement would be compatible with California high-speed trains and would provide significant growing markets.

A. Small Package/Light Container

Package/container versions of the high-speed passenger vehicles can be adapted, without compromising operating capabilities, to handle mail, express parcel, package freight, and other container freight that does not exceed the weight of typical passenger loads. Examples of this type of freight include overnight small packages and mail, distributed by such entities as Federal Express, United Parcel Service, and the U.S. Postal Service. The equipment used for these services must be completely compatible with the passenger equipment and be capable of safely traveling at the top design speeds of the entire high-speed system. This type of equipment could operate as a separate modified trainset, or one or more cars could be integrated into a passenger trainset.

B. Special Medium-Weight Freight

These high-speed (VHS technology) medium weight freight trains would have limited axle loads of about 19 metric tons[2] or less, as opposed to conventional full-tonnage U.S. freight of about 27 metric tons per axle. These freight-only trains would be designed to meet high-speed system safety and design standards but would only operate during nighttime hours, at no more than 125 mph (200 km/h). The freight-only periods would be scheduled after passenger trains were beyond the area of freight operations and would be coordinated so as not to interfere with required nighttime maintenance activities. These maintenance services could be provided on the system currently being proposed within the established parameters of cost and design By restricting these high-speed freight operations to the non-passenger service hours (night time), conflicts with the faster high-speed passenger trains can be avoided.

C. Freight Infrastructure

Freight services on the high-speed network would require operating arrangements and physical facilities to handle freight at both origin and destination points.

For small package and light container services, loading and unloading can be accomplished quickly at passenger stations. Employees would unload and load any material destined for each station quickly within the dwell times established for passenger trains. This would require interior designs that permit sorting “on the go” and fast means of accepting new packages and releasing packages from the car to the platform. Special destination specific containers may be part of the overall design for this type of service. For these types of freight, accommodations would be

[2] One metric ton equals 1.102 English tons.

required at stations for package deliveries, and for assembly into destination-specific containers and disassembly for final delivery.

For heavier freight services, which would be handled by special "freight only" trains, infrastructure requirements may be more elaborate. If these trains are handled during "freight only" operating windows when no passenger trains are on the network, passenger stations could be used to handle goods. It may be necessary to build special loading and unloading facilities either adjacent to the passenger platforms or at remote sites. These issues are freight service design issues, which need to be incorporated into whatever processes the Authority chooses, to advance the freight concepts toward business planning. The Authority has adopted the policy of excluding the cost of any special freight equipment or infrastructure as part of the initial financial and operating plans.

Due to a clear legislative mandate and limited resources, the Authority has focused their efforts on the implementation of a high-speed passenger rail service. The Authority has not undertaken the market studies necessary to define a specific freight system for consideration therefore specific freight operating plans and infrastructure will not be addressed as part of this program environmental process. However, the engineering parameters established by the Authority allow for future implementation of freight services as the market supports. Further consideration of a specific freight service proposal would be required at the project specific stage of environmental review prior to implementation.

3.0 ALIGNMENT DESIGN PARAMETERS

This section presents the design parameters including speeds, geometry, and clearances to be applied in defining the alignment options for the program level environmental analysis. The criteria presented are consistent with the criteria applied in the previous Alignment and Station Screening Evaluation study and are based on accepted engineering practice, the criteria and experiences of other railway and high-speed train systems, and recommendations of high-speed train manufacturers. The alignment criteria and clearances, as set forth, were established with the following objectives:

- Maximum system safety,
- Acceptable passenger comfort,
- Minimum wear on rails and wheels for rail technologies,
- Compatibility with railcar characteristics, and
- Maximum operating speed and efficiency.

The main engineering design parameters and criteria are summarized in Table 3.0-1 and described below for VHS.

Table 3.0-1
Summary of Engineering Design Parameters

Parameter	Very High-Speed
Double Track	Full
Power Source	Electric
Grade Separations	Full
Potential for Shared Use	Yes
Corridor Width ❑ **Desirable** ❑ **Minimum**	 100 ft (30.4 m) 50 ft (15.2 m)
Top Speed	220 mph (350 km/h)
Average Speed	125-155 mph (200-250 km/h)
Acceleration	0.4-1.3 mph/s[3] (0.6-2.1 km/h/s[4])
Deceleration	1.2 mph/s (1.9 km/h/s)
Minimum Horizontal Radius	500-650 ft (150-200 m)
Minimum Horizontal Radius (At top speed)	15,600 ft @ 220 mph (4,750 m @ 350 km/h)
Superelevation ❑ **Actual (Ea)** ❑ **Unbalanced (Eu)**	 7 in (180 mm) 5 in (125 mm)
Grades ❑ **Desirable Maximum** (sustained grade) ❑ **Absolute Maximum** (limited length)	 3.5% 5.0%
Minimum Vertical Radius Crest Curve (at top speed)	157,500 ft @ 220 mph (48,000 m @ 350 km/h)
Minimum Vertical Radius Sag Curve (at top speed)	105,000 ft @ 220 mph (32,000 m @ 350 km/h)
Horizontal Clearance (Centerline of track to face of fixed object)	10 ft 4 in @ 220 mph (3.1 m @ 350 km/h)
Vertical Clearance (Top of rail to face of fixed object)	21 ft (6.4 m)
Track Centerline Spacing	15 ft 8 in @ 220 mph (4.7 m @ 350 km/h)
Notes: 1- mph/s – miles per hour-second 2- km/h/s – kilometers per hour-second	

3.1 SPEEDS

The proposed technology is focused on the next generation of high-speed rail trains to provide both frequent service and fast travel times. It is anticipated that trains would travel at maximum operating speeds near 220 mph (350 km/h). Average operating speeds would of course, be lower, around 155 mph (250 km/h). Speeds in urban areas are typically constrained to a maximum of approximately 125 mph (200 km/h) due to physical (curve radius) and environmental constraints (visual or noise/vibration). These speeds allow for express travel times consistent with the travel time goals.

Existing high-speed train systems in Europe and Japan currently operate at speeds of 187 mph (300 km/h) to 200 mph (325 km/h) and are testing speeds 220 mph (350 km/h). The operators and manufacturers concur that speeds of 220 mph (350 km/h) are or would be obtainable within the implementation period of the California system. All of the system operators agree that there are significant obstacles to implementing the higher speeds. Specifically, the higher speeds are associated with increased maintenance of infrastructure and vehicles, higher maintenance costs, higher noise levels and higher energy usage and costs. Decisions have been made in Germany to limit the maximum operating and design speeds to 187-200 mph (300-320 km/h) due to the economic viability of the increased maintenance and energy usage costs. However, France is currently testing higher operating speeds of mph (320 km/h) and currently designs new lines for potential operation at 220 mph (350 km/h). Japan does not plan to increase speeds beyond 187 mph (300 km/h), due to existing infrastructure limitations and strict environmental requirements concerning noise; however, they are manufacturing and testing equipment at speeds of 220 mph (350 km/h) and higher. In addition, Spain is currently implementing new lines for operation at 220 mph (350 km/h).

Given the technical viability of 220 mph (350 km/h) high-speed train operating speeds and the strong advantages of lower travel times on California's long intercity markets, it is prudent to continue to accommodate these speeds in the design and development of the alignments considered for this system.

Table 3.1-1 presents the range of maximum operational speeds and acceleration/deceleration characteristics assumed for the two technology groups under consideration, allowing for expanded capabilities in the next generation of VHS equipment. Because of variations in performance and equipment characteristics, each group has its own geometric design criteria.

Table 3.1-1
Design Speeds

	VHS	
Top Speed	220 mph (350 km/h)	
Average Speed	125 – 155 mph (200 – 250 km/h)	
Acceleration	mph/s[1]	(km/h/s[2])
0 – 62 mph	1.3	2.1
62 – 124 mph	1.0	1.6
124 – 186 mph	0.6	1.0
186 + mph	0.4	0.6
Deceleration	mph/s	(km/h/s)
	1.2	1.9

Note: 1- mph/s – miles/hour-second
2- km/h/s – kilometers/hour-second

3.2 ELECTRIFICATION

An electrical propulsion system is necessary to provide the performance characteristics (e.g. speed and acceleration) required to be competitive with other modes of travel in California. The power supply would consist of a 2x25KV overhead catenary system for all electrified portions of the statewide system. Supply stations would be required at approximately 30 mile intervals. Based on the estimated power needs of this system, these stations would need to be approximately 20,000 square feet (200' X 100'). Switching stations would be required at approximately 15 mile intervals. These stations would need to be approximately 7,500 square feet (150' X 50'). Paralleling (booster) stations would be required at

approximately 7½ mile interval. These stations would need to be approximately 5,000 square feet (100' X 50'). Each station includes a control house that would need approximately 800 square feet (40' X 20'). These facilities would not be sited as part of this Program EIR/EIS. However, a generic analysis of these facilities would be included. The facilities defined fall well within the potential impact areas defined for the environmental analysis methods for the program level study. All facility sizing and spacing to be verified by simulation based on planned headways, speed and specific equipment specifications at the project specific level of analysis.

3.3 DOUBLE TRACK

The high-speed rail technology requires a dual track mainline system to safely support the ridership volumes, frequency of service, scheduling flexibility and delay recovery required for the proposed system. In addition, the dual track mainline must be maintained through station areas to allow for run-through or express services. Off-line stopping tracks would be provided at all intermediate stations (See Chapter 5).

3.4 GRADE SEPARATION

Due to the safety and performance requirements, there would be no grade crossings permitted on the dedicated high-speed train lines. No unauthorized vehicles or pedestrians would be permitted to enter the corridor or cross the tracks at grade, which would expose them to a possible collision with a train. In addition, the right-of-way would be fully access controlled (fenced) in areas of high-speed operation to avoid intrusion by pedestrians, wildlife and livestock. This requirement applies to both the dedicated and shared use operation alternatives.

3.5 HORIZONTAL ALIGNMENT

The horizontal alignment design parameters are based on passenger comfort; limiting the lateral force on the passenger. To limit the discomfort caused by excessive lateral force, the track is superelevated (tilted) toward the inside of the curves. Minimum lengths of tangents and curves are required, and spiral transition curves are applied to assure a gradual introduction of lateral force. The steady state lateral forces are limited to 0.1g or 3.2 ft/s^2 (1 m/s^2) in the design parameters described below. Table 3.5-1 includes formulae for determining superelevation and minimum lengths of tangents, curves, and transition curves for the two technology groups.

Table 3.5-1
Horizontal Alignment Criteria

	VHS (English) (1)	VHS (Metric) (2)
Minimum tangent length (Lt)	2.22 V (>500')	0.42 V (>152.4 m)
Equilibrium superelevation (Ee)	$\frac{4.01\ V^2}{R}$	$\frac{1.199\ V^2}{R}$
Unbalance superelevation (Eu)	Ee-Ea	Ee-Ea
Max Ea	7 "	17.8 cm
Max Eu	5 "	12.7 cm
Minimum length of circular curve (Lc)	2.22 V	0.42 V
Minimum radius (absolute @ minimum speed)	500-650ft	150-200m
Spiral length (Le) (greater of) none required if Ls<0.01 R	I.38 Ea V 0.98 Eu V 62 Ee	0.103 Ea V 0.073 Eu V 7.44 Ee

Notes: (1)- **Ea** = actual superelevation (inches), **Ee** = equilibrium superelevation (inches), **Eu** = unbalanced superelevation (inches), **Lc** = minimum length of circular curve (feet), **Le** = spiral length (feet), **Ls** = minimum length of transition spiral (feet), **Lt** = minimum tangent length (feet), **R** = radius (feet), **V** = velocity (mph)

(2)- **Ea** = actual superelevation (centimeters), **Ee** = equilibrium superelevation (centimeters), **Eu** = unbalanced superelevation (centimeters), **Lc** = minimum length of circular curve (meters), **Le** = spiral length (meters), **Ls** = minimum length of transition spiral (meters), **Lt** = minimum tangent length (meters), **R** = radius (meters), **V** = velocity (kph)

3.6 VERTICAL ALIGNMENT

The vertical alignment, also known as the profile, traces the elevation of the top of rail. Maximum profile gradients are based on trainset performance. The length of vertical curves is governed by the vertical force that passengers can comfortably experience in profile crests and sags. According to standard U.S. passenger rail practices, the allowable forces in sags (downward 0.03g) are slightly greater than that for crests (upward 0.02g) and are practically the same from a standpoint of minimum and desirable criteria. There is also a minimum length of profile tangent and vertical curves, which prevent a roller coaster effect in profiles.

Table 3.6-1 lists recommended maximum gradients for main lines, secondary tracks and yards, and stations. Also included are formulae for computing radii of vertical curves and minimum curve and tangent lengths.

Table 3.6-1
Vertical Alignment Criteria

	VHS (English) (1)	VHS (Metric) (2)
Length of constant grade (Lt)		
Desirable	4.38 V	0.829 V
Minimum	2.22 V (<500')	0.42 V (<152.4 m)
Gradient (in %)		
Mainline Tracks:		
(desirable maximum)	3.5	3.5
(absolute maximum)	5.0	5.0
Station Tracks: (desirable minimum)	0.0	0.0
(absolute maximum)	0.25	0.25
Yards and secondary tracks:	0.0	0.0
Storage and transfer tracks:	0.0	0.0
Vertical curve radius (R)		
Crest	3.33 V^2	0.392 V^2
Sag	2.22 V^2	0.261 V^2
Length of vertical curve (LVC)		
Desirable	4.38 V	0.829 V
Minimum	2.22 V	0.42 V
(increase 50% if in horizontal curve)		

Notes:
(1) **Lt** = length of constant grade (feet), **LVC** = length of vertical curve (feet), **R** = vertical curve radius of circular curve (feet), **V** = velocity (mph)
(2) **Lt** = length of constant grade (meters), **LVC** = length of vertical curve (meters), **R** = vertical curve radius of circular curve (meters), **V** = velocity (kph)

Combined effects of steep grades and horizontal curves on passenger comfort would need to be considered in design phase of project.

3.7 CLEARANCE REQUIREMENTS

Adequate clearances assure the safe passage of trains, access to disabled trains, and safe conditions for maintenance personnel and passenger evacuation. Minimum clearances are listed below in Table 3.7-1.

Table 3.7-1
Clearances

	VHS
Centerline of Track to Face of Fixed Object (horizontal)	10 ft 4 in (3.1 m) @ 220 mph (350 km/h)
Top of Rail to Face of Fixed Object (minimum vertical)	21 ft (6.4 m)
Double Track Center to Center Distance (horizontal)	15 ft 8 in (4.7 m) @ 220 mph (350 km/h)(1)
Minimum Clear (horizontal)	30 in (76.2 cm)

Notes:
1-TGV system requires 4.5 m, ICE requires 4.7m @ 350 km/h.

3.8 RIGHT-OF-WAY REQUIREMENTS

The minimum right-of-way limits for typical operating sections of the high-speed train system are shown in Table 3.8-1. These limits represent the minimum right-of-way required for basic implementation of a specific operating section. In many cases additional requirements apply which are also noted in the table. Other factors such as topography, soils, groundwater levels, noise receptors, cut-and-fill slopes, drainage, retaining walls, service roads, utilities, operating speeds, and construction methods also influence the extent of the required right-of-way envelope. Typical cross-sections for each general mainline section are included in Appendix A.

For the definition of alignment options, three general parameters should be followed as guidelines with consideration given to constraint information identified in the screening evaluation: (1) a minimum right-of-way corridor of 50 feet (15.2 meters) should be assumed in congested corridors; (2) a 100-foot (30.4-meter) corridor should be assumed in less developed areas to allow for drainage, future expansion and maintenance needs; and (3) a wider corridor should be assumed in variable terrain to allow for cut and fill slopes and twin-bore tunnel. In these wider sections, the width should be determined according to the minimum cross sectional requirements, as defined in Table 3.8-1, and the general assumption of 2:1 cut and fill slopes. For shared use corridors, widths would vary depending on the number of tracks required.

Table 3.8-1
Minimum Permanent Right-of-Way Requirements

Type of Section	Minimum Width	Minimum Requirements
At-Grade/Cut-and-Fill/Retained Fill	50 ft (15.2 m)	Fee purchase of entire width Cut & Fill section requires additional width to accommodate drainage and 2:1 slopes
Aerial Structure	50 ft (15.2 m)	Fee purchase required for column foundations Fee purchase or aerial easement required for full width of structure plus 3.5 feet (1 m) on each side for maintenance purposes. Allows for ongoing use of land area under the structure (parking, streets, other rail services, etc.) with appropriate lease for private entities or agreement with public entities. This arrangement must allow for ongoing access to columns for maintenance and proper protection for columns if area is used for street or rail purposes.
Tunnel (Double Track)	67 ft (20.4 m)	Fee purchase or underground easement of entire width. Fee purchase allows for ongoing use of land area above the structure (parking, streets, open space, etc.) with appropriate lease for private entities or agreement with public entities.
Tunnel (Twin Single Track)	120 ft (36.6 m)	Fee purchase or underground easement of entire width. Fee purchase allows for ongoing use of land area above the structure (parking, streets, open space, etc.) with appropriate lease for private entities or agreement with public entities.
Trench Section (open or closed)	50 ft (15.2 m)	Fee purchase of entire width Closed section allows for ongoing use of land area over the structure (parking, streets, open areas, etc.) with appropriate lease for private entities or agreement with public entities.

Note: Widths do not include temporary easements required for construction purposes.

3.9 TUNNELING

3.9.1 TECHNICAL CONFERENCE

To provide a forum to address the issues associated with the tunneling required for the statewide high-speed train system, a technical conference was held on December 3 and 4, 2001, in the Los Angeles area. The conference was attended by seven representatives of major tunneling contractors, nine specialized tunneling consulting engineers, two geologists/geotechnical engineers, and representatives of the Program Management and Regional Study Teams as well as Authority staff. In addition, the conference was observed by two Authority Board Members. The conference was held over a two day period providing sufficient time for extensive discussion in the three main areas: past assumptions and requirements, construction methods and cost estimating.

The conference focused on gaining insights/input regarding feasibility, construction methods and cost assumptions associated with the proposed tunneling. This information would be used to avoid making planning decisions that are not based on the current construction capabilities or those reasonably expected within the implementation timeframe of this project. The attendees were provided with background information on the studies to date, system requirements, previous assumptions, and previous findings as a basis for participation in the technical conference. As part of the conference, attendees participated in discussions and cost estimating exercises to identify and explore the key issues.

3.9.2 CONFERENCE CONCLUSIONS

Based on the outcome of the discussions held throughout the conference, numerous specific conclusions were formalized with all of the attendees. Several of the key conclusions are summarized below.

- Confirmed the overall feasibility of the tunneling proposed for the statewide high-speed train system. No 'fatal flaws' were identified in the tunneling assumptions applied to date.
- Tunnel boring machines should be assumed as the excavation method for all tunnels with the exception of specific areas identified during the conference that have difficult geology.
- Twin single track tunnels should be assumed for lengths of 0-6 miles. For lengths greater than 6 miles a third tunnel is required for ventilation, evacuation and construction access.
- There is no significant difference in the tunneling requirements (methods or cost) at sustained 2.5% or 3.5% vertical grades.
- The cost of tunneling using Tunnel Boring Machines versus Drill and Blast methods was not as significant as the difference in construction time. Drill and Blast methods require significantly more time.
- All tunnels should be fully lined for structural, water tightness and aerodynamic reasons.
- Considerable geologic exploration is required prior to construction.
- Consider reducing the cross-sectional area of tunnels approaching terminal stations and evaluate potential reductions in other areas.
- Confirmed the desirability of crossing of major fault zones at grade.
- Confirmed the objective of minimizing the amount of tunneling required, due to cost, time of construction and potential for delay.
- Limit the use of long tunnels (over 12 miles in total length).

The conclusions reached at the conference generally confirm and support the studies completed to date.

3.9.3 TUNNELING CRITERIA / ASSUMPTIONS

To define the alignment options for consideration in the program environmental analysis, the following criteria and assumptions have been followed in the development of plans and profiles for the northern and southern mountain crossings, which would be provided by the Program Management Team:

- The extent of tunneling should be minimized. Tunnels lengths should be limited to less than 6 miles, where possible and not to exceed 12 miles overall length.
- Tunnel boring machines should be the assumed excavation method for all tunnels with the exception of specific areas such as fault crossings that have very difficult geology
- Twin single track tunnels should be assumed for lengths of 0-6 miles. For lengths greater than 6 miles a third tunnel is required for ventilation, evacuation and construction access. The typical sections included in Appendix A reflect these assumptions.
- Tunnels should be fully lined as reflected in the unit costs included in Chapter 6.

4.0 STATION DESIGN PARAMETERS

Several key factors must be considered in the identification of potential station stops along the system, including ability to maintain approach and through service speed; cost; ridership potential; operating policy; local access times; intermodal connectivity; and the distribution of population and major destinations along the route. All intermediate stations incorporate siding tracks for stopping trains, allowing through movement of express trains. In general, stations are spaced following the pattern of urban centers (about 50 miles [80.5 kilometers] apart in rural areas), with overall average spacing at approximately 30 miles (48.3 kilometers), and an average spacing in metropolitan regions of 15 miles (24.1 kilometers). Closer spacing would have significant impacts on the ability to operate express and local traffic on the same dual track system in these areas, due to substantial differences in operating speeds.

There are two principal types of stations: terminus and intermediate. Terminus stations are those where all trains are planned to stop and perhaps lay-over during non-peak periods. San Diego, Los Angeles Union Station, LAX, San Francisco, Oakland, and Sacramento are all planned as terminus stations; however, Los Angeles Union Station would also have the characteristics of an intermediate station and is treated separately in this section. All other potential stations are intermediate stations. Intermediate stations would provide off-line passenger platforms allowing for pass-through express services on the dual track mainline. Each Regional Team is responsible for proposing station configurations that best meet the criteria defined herein for any shared use options considered in their region. Table 4.0-1 illustrates the forecasted daily boardings for each station in the year 2020 high scenario, based on Sensitivity Analysis Scenario 6B by Charles River Associates. This scenario represents the assumed conditions for the purposes of the environmental process.

Table 4.0-1
Forecasted Daily Intercity Boardings/Alightings

Station Name	Average Daily Boardings/Alightings[1]	Station Name	Average Daily Boardings/ Alightings [1]
Sacramento	29,504	Sylmar	8,790
Stockton	3,760	Burbank	13,306
San Francisco	43,046	Los Angeles Union Station	37,476
San Francisco Airport	5,770	East San Gabriel Valley	25,544
Redwood City/Palo Alto	12,506	Ontario Airport	5,270
Oakland Airport	1,192	Riverside/San Bernardino	9,750
Oakland	20,400	Temecula	4,962
Fremont/Union City	5,410	Escondido	6,698
San Jose	24,188	Mira Mesa	3,350
Gilroy	5,504	Qualcomm Stadium/San Diego	26,622
Los Banos	386	LAX Airport	8700
Modesto	3,370	Norwalk	7,242
Merced	1,028	Anaheim	13,752
Fresno	7,092	Irvine	6,170
Tulare/Kings-Visalia or Hanford	316		
Bakersfield - Downtown	5,348		
Palmdale	4,016		

4.1 STATION PLATFORMS

Most high-speed train equipment vendors design their equipment for high-level boarding platforms to facilitate loading and unloading of passengers as well as to meet requirements for disabled passengers per the Americans with Disabilities Act (ADA). At least one potential equipment vendor designs their equipment exclusively for low platform boarding. The platform height would not be specified at this program level of analysis. Station platforms are assumed to have a minimum length equivalent to that of a two multi-car trains, approximately 1,300 feet (400 meters). This platform length allows for flexibility in operations by allowing for variation in trainset composition and potential temporary storage at station platforms. Station platforms are assumed to have a width of 30 feet (9 meters), inclusive of vertical access. Some flexibility with these dimensions may be required at terminal locations and would be considered on an individual basis, based on the capacity needed at that location and the effect of any sizing deviations on the operational performance of the rest of the system. Ridership forecasts would be analyzed to define more specific platform widths during the subsequent more detailed analysis.

4.2 TRACK AND PLATFORM CONFIGURATION

To study the potential impacts of station areas in the Program EIR/EIS, it is necessary to define the elements of station infrastructure and configuration that would be necessary to accommodate the assumed train volumes and frequency required to serve the forecasted demand. To this end the Program Management Team has developed and applied the California High-Speed Rail System simulation model to determine basic track and platform configurations necessary to meet the demand according to the Business Plan ridership forecasts and the associated conceptual service plan identified in the Corridor Evaluation Study. These basic configurations do not account for specific site conditions or constraints at each potential station location. Instead, they are intended to provide a benchmark for the required station infrastructure and guidance to the regional teams in defining the station area to be studied in the Program EIR/EIS.

Certain elements of the basic configurations described in this section can be modified or adapted to address more specific site conditions; however, in most cases modifications would influence the capacity and other aspects of the operating performance of the station. In some cases these changes in the basic configuration may have a profound effect on the ability of the station to process the assumed train volume, which in turn may affect the system as a whole.

The configuration and dimensions defined in this section are “desirable” values that Regional Teams should strive to achieve for the station options. However, reasonable options were not disregarded based solely on their ability to meet these guidelines. Instead, the Regional Teams reviewed the basic configuration and identify potential modifications based on the site conditions. This information was used by the Program Management Team in order to address the operational impacts. In this manner the potential operational impacts can be determined and discussed in the context of the potential physical and environmental impacts to fully understand and document the “trade-offs”, prior to defining the station area for further study. In most cases it would not be prudent to make limiting decisions at this stage of study, but instead conservative assumptions should be made that allow for flexibility in the station area studied. Subsequently, these factors can be considered in following phases of technical analysis, when the potential impacts of not achieving these dimensions can be more thoroughly evaluated.

4.3 TERMINAL STATIONS

Stations identified as potential terminal stations include San Francisco, Oakland, Sacramento, Los Angeles International Airport (LAX), and San Diego. Depending upon the examination of shared use issues on the LOSSAN Corridor and policy decisions affecting the high-speed rail system configuration end points and associated service, a location in Irvine or Anaheim may be identified as a terminal station. The California High-Speed Train DRAFT Engineering Criteria report dated July 2, 2002 proposed a concept for terminal stations in dedicated high-speed train service (San Francisco, Oakland, Sacramento, San Diego and Anaheim or Irvine). This configuration specified four tracks and two island platforms as presented in Figure 4.3-1. This layout includes data on track geometry and platforms and provides overall dimensions based upon operations analysis utilizing the California High-Speed Rail System Business Plan simulation model developed by the Program Management Team for this purpose. As shown in Figure 4.3-1, the *desirable* terminal station track and platform configuration is estimated to require a total area of 7.5 hectares (18.6 acres). Additional area would be required for access, parking and ancillary uses.

The Business Plan simulation model tested different terminal station configurations to determine an arrangement which provided results that validated the feasibility of reliably processing the number and type of trains specified in the conceptual service plan (from the *Corridor Evaluation Study*). Specific assumptions governing the dynamics of train movements applied to the modeling within the terminal stations are shown below in Table 4.3-1. These assumptions are based on current U.S. passenger rail services and international high-speed rail practice that is appropriate and feasible for the service levels defined. It is important to note that all terminal station configurations are defined with a "run-through" capability; that is, the ability to position arriving (from the main track or the storage yard) trains at the platform, dwell to allow passengers to alight or board and then dispatch the train in its original direction of travel either in revenue service onto the main track or as a deadhead trainset moving to a storage yard facility in proximity to the station. This "run-through" configuration is the desirable layout and should be assumed as a significant success factor in reliably delivering the levels and frequencies of service specified in the conceptual service plan and providing the capacity to accommodate the future growth of the California High-Speed Train System.

Table 4.3-1
Trainset Turnaround Time at Terminal Stations
(based on "run-through" configuration with inspection and cleaning at off-site yard)

Train Operation	Elapsed Time
Train Dwell Time in Station for Passengers Disembarking	5 Minutes
Travel Time from Station to Yard	5 Minutes
Contact Time in Yard for Inspection and Interior Cleaning	25 Minutes
Travel Time from Yard to Station	5 Minutes
Dwell Time in Station for Passengers Boarding	5 Minutes
Total Elapsed Time for Trainset Turn-around	45 Minutes

As the Regional Teams examined potential station locations, physical and environmental constraints were identified that had a direct impact on the ability to accommodate the *desirable* track and platform configuration at each site. In particular, the size and configuration of the San Francisco terminal station was expected to vary depending on the development of the Transbay Station concept plan with the city of San Francisco and Caltrain as well as the level of train service that can be supported in the shared use arrangement with Caltrain. Consequently, further refinement of these basic configurations occurred as more detailed analysis of the potential sites was completed by the Regional Teams. The results of this

analysis and subsequent review by the Program Management Team yielded Terminal Station layouts that differed significantly from those previously defined in the DRAFT Engineering Criteria Report. These revised configurations are described below.

- Sacramento: the configuration for the Sacramento Terminal Station was revised to conform with the physical and environmental constraints identified by the Regional Team. The new concept is "stub-ended"; that is, the tracks in the station terminate in proximity to the end of the platforms and every train that enters the station must stop, dwell (to disembark, inspect, clean and board) and turn back in the direction from which it came in order to depart the station; there is no "run-through" capability as previously described for the *desirable* configuration. This layout integrates several of the basic maintenance and cleaning functions formerly defined for the Storage Yard in the "run through" concept and consists of six tracks, four passenger platforms and four "bi-level" maintenance platforms. The six station tracks are of a pedestal type to provide access to the underside of the trainset for inspection and light repairs. The floor level maintenance platforms provide access to the interior of the train for expeditious "turnaround" cleaning (to minimize dwell time), and the exterior of each car for inspection/light repair of components located from floor to ceiling height levels. The roof level maintenance platforms provide access for inspection and light repair of roof mounted apparatus, including the electric propulsion power collection system. There is an open area underneath all platforms to allow for inspection of the wheels, trucks and other components located between the track and floor levels on both sides of the trainset. As shown in Figure 4.3-1A, the revised Sacramento Terminal Station concept is estimated to require a total area of 10 hectares (24.7 acres). Additional area would be required for access, parking and ancillary uses.

- San Diego: the configuration for the San Diego Terminal Station was revised to conform with the physical and environmental constraints identified by the Regional Team. The new concept is "stub-ended"; that is, the tracks in the station terminate in proximity to the end of the platforms and every train that enters the station must stop, dwell (to disembark, inspect, clean and board) and turn back in the direction from which it came in order to depart the station; there is no "run-through" capability as previously described for the *desirable* configuration. This layout integrates several of the basic maintenance and cleaning functions formerly defined for the Storage Yard in the "run through" concept and consists of four tracks, two passenger platforms and three "bi-level" maintenance platforms. The four station tracks are of a pedestal type to provide access to the underside of the trainset for inspection and light repairs. The floor level maintenance platforms provide access to the interior of the train for expeditious "turnaround" cleaning (to minimize dwell time), and the exterior of each car for inspection/light repair of components located from floor to ceiling height levels. The roof level maintenance platforms provide access for inspection and light repair of roof mounted apparatus, including the electric propulsion power collection system. There is an open area underneath all platforms to allow for inspection of the wheels, trucks and other components located between the track and floor levels on both sides of the trainset. As shown in Figure 4.3-1B, the revised San Diego Terminal Station concept is estimated to require a total area of 4.4 hectares (10.9 acres). Additional area would be required for access, parking and ancillary uses.

- Oakland: the configuration for a Terminal Station in Oakland was revised to conform with the physical and environmental constraints identified by the Regional Team. The new concept is "stub-ended" with "tail-tracks"; that is, the tracks in the station continue approximately one train length beyond the end of the platforms before terminating. A train entering the station may either stop, dwell (to disembark, clean and board) and turn back in the direction from which it came in order to depart the station or; stop, dwell for passengers to disembark, "run-through" to a tail track, clean and inspect (repair if necessary) on the tail track, move back to the station for a brief dwell for boarding passengers and then depart the station. This layout provides limited "run-through" capability and integrates several of the basic maintenance and cleaning functions formerly defined for the Storage Yard in the "run through" concept. The Terminal consists of four station tracks extending into four "tail tracks" with two passenger platforms and three "bi-level" maintenance platforms. This

configuration provides limited "run-through" capability (to the tail tracks) and the tail tracks provide the storage capacity for four trainsets. As shown in Figure 4.3-1C, the revised Oakland Terminal Station concept is estimated to require a total area of 7.8 hectares (19.3 acres). Additional area would be required for access, parking and ancillary uses.

- San Fracisco/Transbay Terminal: the overall configuration of the proposed Transbay Terminal was in the developmental process during the completion of this analysis. Consequently, in defining a component of the Transbay Terminal station layout to be dedicated to serving California High Speed Rail Trains, the low-end assumption is that a minimum of two tracks and one island platform would be provided for this purpose. As shown in Figure 4.3-1D, the current assumption for the section of the proposed Transbay Terminal that would support California High Speed Rail Train service is estimated to require a total area of 2.6 hectares (6.4 acres). Further study in cooperation with Caltrain would be necessary to determine a shared operating plan for the Transbay terminal tracks and platforms.

The *Revised* Business Plan simulation model tested these terminal station configurations (Sacramento, San Diego, Oakland and San Francisco) to validate the feasibility of reliably processing the number and type of trains specified in the conceptual service plan (from the *Corridor Evaluation Study*). The assumptions governing the dynamics of train movements applied to the modeling within the terminal stations were modified to conform with the operational constraints inherent in the "stub-ended" configurations and are shown below in Table 4.3-1A. These assumptions are based on reasonable, but operationally challenging compromises to current U.S. passenger rail services and international high-speed rail practice that is appropriate and feasible for the service levels defined.

Table 4.3-1A
Trainset Turnaround Time at Terminal Stations

Train Operation	Elapsed Time
Train Dwell Time in Station for Passengers Disembarking	5 Minutes
Contact Time in Terminal Station for Inspection and Interior Cleaning	10 Minutes
Dwell Time in Station for Passengers Boarding	5 Minutes
Total Elapsed Time for Trainset Turn-around	20 Minutes

An additional Terminal Station configuration alternative, each with trail tracks, was developed for both Sacramento and San Diego in the event that the physical and environmental constraints would accommodate the space required for this infrastructure. These station layouts offer the advantage of improved operational flexibility (with limited run-through capability) contributing to a more consistent, reliable service and allow for some growth in the long term. Furthermore, the tail tracks would provide important train staging and train storage capacity in close proximity to the station as shown in Figures 4.3-1E (13.1 hectares/32.4 acres) and 4.3-1F (7.8 hectares/19.3 acres) respectively.

The configuration for a potential Terminal Station at either Anaheim or Irvine is assumed to be "stub-ended" with four tracks and two platforms. This concept is "stub-ended"; that is, the tracks in the station terminate in proximity to the end of the platforms and every train that enters the station must stop, dwell (to disembark, inspect, clean and board) and turn back in the direction from which it came in order to depart the station; there is no "run-through" capability as previously described for the *desirable* configuration. This layout integrates several of the basic maintenance and cleaning functions formerly defined for the Storage Yard in the "run through" concept and consists of six tracks, four passenger platforms and four "bi-level" maintenance platforms. The four station tracks are of a pedestal type to provide access to the underside of the trainset for inspection and light repairs. The floor level

maintenance platforms provide access to the interior of the train for expeditious "turnaround" cleaning (to minimize dwell time), and the exterior of each car for inspection/light repair of components located from floor to ceiling height levels. The roof level maintenance platforms provide access for inspection and light repair of roof mounted apparatus, including the electric propulsion power collection system. There is an open area underneath all platforms to allow for inspection of the wheels, trucks and other components located between the track and floor levels on both sides of the trainset. As shown in Figure 4.3-1G, the revised Anaheim/Irvine Terminal Station concept is estimated to require a total area of 4.4 hectares (10.9 acres). Additional area would be required for access, parking and ancillary uses.

4.3.1 Los Angeles

In the conceptual service plan (from the *Corridor Evaluation Study*), Los Angeles Station is a high volume passenger terminal that provides service to 132 trains (66 trains in each direction equivalent to 77% of the total service in the plan). It is a "run through" station for service originating in San Diego, Sacramento and San Francisco as well as originating four trains at the startup of the service day.

The desirable configuration for Los Angeles Station is an arrangement of six tracks and three platforms as presented in Figure 4.3-2. The desirable layout includes data on track geometry and platforms, and provides overall dimensions based upon operations analysis utilizing the California High-Speed Rail System simulation model developed by the Program Management Team for this purpose. As shown in Figure 4.3-2, the desirable Los Angeles Station configuration is estimated to require a total area of 28.8 hectares (71.3 acres).

An optional configuration that accommodates train storage capacity for six trainsets as an integral element of Los Angeles Station is presented in Figure 4.3-3. This arrangement provides the train storage requirements to support the service defined in the conceptual service plan (from the *Corridor Evaluation Study)* within the immediate spatial footprint of Los Angeles Station if a train storage facility proves to be infeasible at a location that is 300 meters to 1500 meters away from the Los Angeles Station area. As shown in Figure 4.3-3, the Los Angeles station configuration with the train storage option is estimated to require a total area of 31.0 hectares (76.6 acres).

4.3.2 San Jose

In the conceptual service plan (from the *Corridor Evaluation Study*), San Jose Station provides service to 106 trains (53 trains in each direction equivalent to 62% of the total service in the plan). It is a "run through" station for service originating in San Diego, Sacramento and San Francisco. Although there are no trains originating at San Jose to support the start up of the service day in the conceptual service plan, several significant considerations contribute to defining San Jose with a unique distinction.

Based upon the modeling and analysis of the conceptual service plan (from the *Corridor Evaluation Study*) the Intermediate Station configuration shown in Figure 4.4-1 is adequate to support the number of trains specified to serve San Jose Station. However, it is important to consider an alternative configuration that would be capable of supporting both future growth and potential modifications to the conceptual service plan. The operations analysis indicated that with modest growth in the levels and frequency of service, an additional station siding track would likely be necessary to support the increased volume of train movements, particularly during peak hourly periods when trains operate at closer headway intervals. Furthermore, the configuration and operating assumptions associated with the San Francisco Terminal and Storage Facility may change as a result of further study, having a profound effect on the operations plan for the segment between San Jose and the Bay Area. Finally, additional analysis of shared use in this corridor, currently ongoing, could have a significant impact on the operations and

service plan overall. For example, San Jose may have to be configured as a prominent facility to support train service to the Bay Area considering the potential challenges and constraints for developing facilities in San Francisco.

Consequently, the desirable configuration for San Jose Station is an arrangement of four tracks and two platforms as presented in Figure 4.3-4. The four station tracks are "off-line" with the two main tracks of the High-Speed Rail Corridor passing in between. The desirable layout includes data on track geometry and platforms, and provides overall dimensions based upon operations analysis utilizing the California High-Speed Rail System simulation model developed by the Program Management Team for this purpose and a provision for growth, and changes in operating and service plan (as described above) As shown in Figure 4.3-4, this configuration is estimated to require a total area of 27 hectares (66.7 acres).

4.3.3 Los Angeles Airport

The potential for providing high-speed train service directly to and from Los Angeles Airport (LAX) is being examined. If the results of this evaluation determine that it is desirable to include LAX as an integral component of the high-speed rail network, a terminal type station facility is desirable. Although a ridership demand forecast is not yet available, nor was this service included in the operations analysis, a conceptual configuration has been developed in order to describe the likely characteristics of a terminal station facility to serve LAX. As shown in Figure 4.3-5, this configuration is "stub-ended" and includes four station tracks and two island platforms. The estimated required area required for this facility is 5.5 hectares (13.6 acres).

4.4 INTERMEDIATE STATIONS

Intermediate stations are defined as "line" stations providing service along the dedicated high-speed rail route and located between San Diego, Los Angeles, Sacramento and San Francisco. The desirable configuration for intermediate stations is an arrangement of two "off-line" platforms as presented in Figure 4.4-1. This configuration represents only the track and platform needs. Overall station size would also be a factor of access facilities, parking facilities and passenger facilities according to the forecast passenger volumes at each potential station.

It is important to note that although Fresno and Bakersfield are, by definition, intermediate stations, these two locations originate service at the startup of the "service day" and require the addition of two train storage tracks at each station as presented in Figure 4.4-2. In addition, there are some cases where off-line station areas are being considered. In these cases separate tracks are diverted from the mainline dual track alignment to provide service to urban areas that cannot support the more rigid mainline geometric design requirements. For example, there are potential station locations serving communities in the San Joaquin valley, such as Stockton, where the main trunk of the High-Speed Rail Corridor would not pass directly through the town center. An optional configuration for these locations, as presented in Figure 4.4-3, is a grade separated, "off-line" double track alignment seamlessly connected (including flyovers) to the dual main tracks of the High-Speed Rail Corridor trunk. This alignment would support speeds up to 174 kph positioned strategically to provide train service to an island platform located in, or near, the town center.

The desirable layout for intermediate stations includes data on track geometry and platforms and provides overall dimensions based upon operations analysis utilizing the California High-Speed Rail System simulation model developed by the Program Management Team for this purpose. As shown in Figure 4.4-1, the desirable intermediate station configuration is estimated to require a total area of 20 hectares (49.5 acres). As shown in Figure 4.4-2, the optional station configuration applicable to Fresno

and Bakersfield is estimated to require a total area of 21.4 hectares (52.8 acres). As shown in Figure 4.4-3, the optional "off-line" station configuration for locations such as Stockton is estimated to require a total area of 15.2 hectares (37.6 acres).

The simulation model was used to test three different typical intermediate station configurations to identify the appropriate track geometry and siding length. Sidings measuring 5, 7 and 9 kilometers long were examined in combination with the track geometrics which provided results that validated the feasibility of reliably processing the number and type of trains specified in the conceptual service plan (from the *Corridor Evaluation Study*). The speed of trains executing a diverging movement from the main track to the passenger station siding was the most prominent performance characteristic applied to the simulation analysis. As presented in Figure 4.4-1*,* a siding length of 5 kilometers was determined to be the desirable arrangement. This arrangement allows for diverging speeds of 174 kph (108 mph) and allows for safe and efficient processing of both stopping and through movements with negligible impact to travel times and system capacity.

Horizontal and vertical alignments should remain on tangent where possible through as much of the length of the 5 kilometer segment of the station siding and mainline tracks. If absolutely necessary curves can be introduced at a distance greater than twenty meters on either side of the platform. The objective is to insure that the physical relationship between the track and platform would be without deformation and would minimize the gap between the platform edge and the door sills of the train.

In some cases, land use and other limitations may necessitate a deviation from the desirable (desirable) typical intermediate station configuration. In these cases, a shorter station siding track length may be considered to decrease the spatial area requirements influenced by this dimension. Four examples of shorter siding lengths are presented in Figures 4.4-4, 4.4-5, 4.4-6 and 4.4-7 where diverging speed assumptions are decreased to 145 kph (90 mph), 130 kph (81 mph), 100 kph (62 mph), and 90 kph (56mph) respectively. The estimated area requirements are 13.6 hectares (33.7 acres) for the 145 kph option (3350m siding length), 9.9 hectares (24.4 acres) for the 130 kph option (2430m siding length), 5.2 hectares (12.8 acres) for the 100 kph option (1280m siding length), and 3.8 hectares (9.4 acres) for the 90 kph option (940m siding length). It is important to note that these options configured with siding lengths for intermediate stations that are shorter than 5000m have not been examined in the operations analysis/simulation modeling process. Consequently, the specific impacts that these shorter siding lengths and slower diverging speeds would have on system performance and service delivery is unknown. It is anticipated that this analysis would occur at a later date as the Regional Teams identify and present specific exceptions to the 5000m typical intermediate station configuration concepts.

4.5 STORAGE AND MAINTENANCE REQUIREMENTS / CONFIGURATION

To study the potential impacts in the Program EIR/EIS, The California High-Speed Train DRAFT Engineering Criteria report dated July 02, 2002 defined the storage and maintenance facility configuration and requirements that would be necessary to accommodate the assumed levels of high-speed train service. To this end, the Program Management Team utilized the California High-Speed Rail System simulation model to determine an overall operating and maintenance concept that meets the demand according to the Business Plan ridership forecasts and the associated conceptual service plan identified in the Corridor Evaluation Study. In addition, conceptual facilities were defined for general station locations in terms of track and infrastructure configurations to guide the identification of potential sites for consideration in the program level analysis.

The *desirable* general concept for storage and maintenance requirements described in the DRAFT Engineering Criteria Report dated July 2, 2002 was comprised of storage, cleaning and inspection, and light maintenance facilities positioned at or in very close proximity to each terminal station and a major repair and maintenance facility located (either near the Los Angeles "hub" station or near the center of

the system (e.g., Bakersfield or Fresno). The optimal location for the maintenance facility depends on a number of variables, some of which may not be fully addressed at this program level of analysis. Thus, it is important that potential sites in both general locations are identified and considered in this analysis. The evaluation by the Regional Teams identified three potential locations for the main maintenance and repair facility; two in Los Angeles and one in Bakersfield; one location would ultimately be selected from these three.

The facilities sizing was based on the greatest potential need (fleet size) associated with various operating scenarios. These operating scenarios are based on the Business Plan Sensitivity Analysis ridership forecasts, which represent the highest reasonable forecasted ridership and the conceptual service plan from the Corridor Evaluation. These forecasts and various operating scenarios relate to a potential fleet of from 38 up to 61 trainsets (including a 15% spare ratio) depending on train consist size, mix of services and specific start-up assumptions. This conservative estimate of fleet size is further divided into storage needs at each terminal location based on potential operating scenarios. For the purposes of defining these general facilities, we have assumed the following trainset storage requirements: Sacramento (9 trains), San Francisco/Oakland (15 trains), San Diego (21 trains), Los Angeles (4 trains), Fresno and Bakersfield (2 trains).

The Regional Teams reviewed the basic parameters described in this section and applied them in identifying potential sites for consideration in the regional environmental analyses. As with the station configurations, the basic storage and maintenance facility configurations described below did not account for specific site conditions or constraints at each potential facility location. Instead, they were intended to provide a benchmark for the required facilities infrastructure and guidance to the regional teams in defining the station area to be studied in the Program EIR/EIS.

Certain elements of the basic configurations described in this section were expected to be modified or adapted to address more specific site conditions; however, in most cases modifications would influence the capacity and other aspects of the operating performance of the facility. In some cases these changes in the basic configuration may have a profound effect on the ability of the station to process the assumed train volume (such as San Francisco Terminal Station as described in Section 4.3), which in turn may affect the system as a whole.

As with the conceptual station drawings, the configurations and dimensions listed in the descriptions below are “desirable” values that Regional Teams attempted to achieve for the storage and maintenance facilities options. Options were not being screened out based solely on their ability to meet these guidelines. Instead, the Regional Teams reviewed the basic configuration and identified potential modifications based on the site conditions. This information was presented to the Program Management Team in order to address the operational impacts. Consequently, potential operational impacts were determined using the *Revised* Business Plan simulation model and discussed in the context of the potential physical and environmental impacts to fully understand and document the “trade-offs”, prior to defining the storage and maintenance facilities area for further study. In some cases we may not make limiting decisions at this stage of study but would make conservative assumptions that allow for flexibility in the storage and maintenance facilities area studied. Subsequently, these factors can be considered in following phases of technical analysis, when the potential impacts of not achieving these dimensions can be more thoroughly evaluated.

4.5.1 Train Storage, Service & Inspection and Light Maintenance Facilities

For each of the terminal stations a location, a general configuration was developed for a maintenance and storage yard facility to support the service defined in the conceptual service plan (from the *Corridor Evaluation Study*). The desirable configuration for this facility includes tracks for “lay-up” (parking) for trainsets, a Service and Inspection (S&I) facility for inspection and light maintenance, and a train washer

located on the yard approach track for exterior cleaning prior to daily train storage. In addition, adjacent to the S&I facility, on a separate track, is a wheel truing facility capable of accommodating two cars at a time. There is also provision for an employee administrative and comfort area.

Two options were developed for the desirable configuration to provide flexibility in examining land use opportunities and alternatives:

Option 1 – *Wide* Configuration: This arrangement is based upon track lengths that accommodate one 400 meter trainset or two 200 meter trainsets on each track. It provides the configuration which supports the conceptual service plan (from the *Corridor Evaluation Study)* with dimensions that are a combination of the shortest length and greatest width.

Option 2 – *Long* Configuration: This arrangement is based upon track lengths that accommodate two 400 meter trainsets on each track. It provides the configuration which supports the conceptual service plan (from the *Corridor Evaluation Study*) with dimensions that are a combination of the greatest length and smallest width.

In the previous section, the desirable station configurations defined the capability for trains to arrive at the station and then "run-through" to a storage yard facility. For each of the storage and maintenance facilities, we had assumed that the distance of the two tracks connecting the terminal station and the storage yard is between 300 meters and 1500 meters. The desirable width for the right of way to accommodate these tracks is 12 meters.

General configurations for the storage and maintenance facilities for each of the potential terminal locations (Sacramento, San Francisco/Oakland, Anaheim, Irvine, San Diego and Los Angeles) are included in Figures (4.5-1 through 4.5-5). Note that Figure 4.5-4 presents a configuration for Los Angeles that assumes dedicated high-speed rail service to San Diego as described in the Corridor Evaluation Report. In contrast, Figure 4.5-5 presents a configuration for Los Angeles that assumes that Los Angeles Station would be the terminus and end point for the high-speed rail system and that the network would extend no further than Los Angeles.

It was anticipated that physical and environmental constraints would directly impact the ability to accommodate the basic track configuration within a reasonable distance from each potential station site. In particular, the size and configuration of the facility required for San Francisco was expected to vary depending on the level of train service that can be provided in the shared use arrangement with Caltrain. Further refinement of these basic configurations and assessment of remote location of facilities would continue to be necessary as more detailed analysis of the potential sites is completed. For each location the drawings depict basic track, infrastructure and right of way area requirements.

A Service and Inspection (S&I) facility for inspection and light maintenance, a wheel truer and a train washer were not included in the configuration for Los Angeles Union Station, LAX and San Francisco/Oakland due to the acute land use challenges assumed for this area. Furthermore, initial operations analysis indicated that it is feasible to structure train movement cycles so that the required inspection, light maintenance, wheel repairs and train washing can be performed at Sacramento, San Diego or the Main Repair and Maintenance Facility.

The results of the analysis by the Regional Teams and subsequent review by the Program Management Team yielded potential Storage Yard layouts that differed from those previously defined in the DRAFT Engineering Criteria Report. These revised configurations, although providing the same static capacity as the concepts described in the DRAFT Engineering Criteria Report, are located some distance from the proposed Terminal Stations and do not provide "run-through" capability. The revise storage yards concepts are described below.

- Sacramento: the configuration for the storage yard to support service for the Sacramento Terminal Station was revised to conform with the physical and environmental constraints identified by the Regional Team. The new storage yard concept is located approximately 13_km from Sacramento Terminal Station (south of Alpine Avenue, north of Elder Creek Road, east of Power Inn Road, west of Florin Perkins and parallel to the UPRR main track alignment). This arrangement is based upon track lengths that accommodate one 400 meter trainset or two 200 meter trainsets on each track. It provides the configuration which supports the conceptual service (nine trainsets) plan (from the *Corridor Evaluation Study)* with dimensions that are a combination of the shortest length and greatest width. As shown in Figure 4.5-1A, the revised storage yard concept is composed of eleven tracks, and includes a wheel truer, train washer and S&I facility. This configuration is estimated to require a total area of 13.8 hectares (34.1 acres).

- Los Banos/Merced: the configuration for the storage yard to support service for the San Francisco and Oakland Terminal Stations was revised to conform with the physical and environmental constraints identified by the Regional Team. The new storage yard concept is located approximately 200 – 300 km from San Francisco Terminal Station in the Central Valley. This arrangement is based upon track lengths that accommodate one 400 meter trainset or two 200 meter trainsets on each track. It provides the configuration which supports the conceptual service (fifteen trainsets) plan (from the *Corridor Evaluation Study)* with dimensions that are a combination of the shortest length and greatest width. As shown in Figure 4.5-2A, the revised storage yard concept is composed of sixteen tracks, and includes a wheel truer, train washer and S&I facility. This configuration is estimated to require a total area of 13.1 hectares (32.4 acres).

- San Diego: the configuration for the storage yard to support service for the San Diego Terminal Station was revised to conform with the physical and environmental constraints identified by the Regional Team. The new storage yard concept is located approximately 8km from San Diego Terminal Station (Qualcomm option; immediately north of the Soledad Freeway and parallel to the Escondido Freeway). This arrangement is based upon track lengths that accommodate one 400 meter trainset or two 200 meter trainsets on each track. It provides the configuration which supports the conceptual service (twenty-one trainsets) plan (from the *Corridor Evaluation Study)* with dimensions that are a combination of the shortest length and greatest width. As shown in Figure 4.5-3A, the revised storage yard concept is composed of twenty three tracks, and includes a wheel truer, train washer and S&I facility. This configuration is estimated to require a total area of 16.2 hectares (40 acres).

The *Revised* Business Plan simulation model tested these storage yard configurations (Sacramento, Los Banos and San Diego) to validate the feasibility of operating and storing the number and type of trains specified in the conceptual service plan (from the *Corridor Evaluation Study*). The operational characteristics and dynamics of train movements that emerged from the modeling for the revised terminal stations concepts were applied to dispatching trains to and from the revised storage yard concepts at the beginning and end of the service day.

4.5.2 Main Repair and Maintenance Facility

The location for the Main Repair and Maintenance Facility is desirable to be on the main trunk line of the system in the Central Valley, possibly near Bakersfield, Fresno or Merced, or in the Los Angeles area. As presented in Figure 16, the conceptual configuration for this heavy maintenance complex includes a Wheel Truing Area, a Service and Inspection (S&I) Area, a Running Repair facility, Support Shops, Material Inventory and Distribution, Component Change-Out Area, Overhaul Shop, Heavy Repair facility and Exterior Maintenance Shop. The facility size and configuration associated with this concept is based upon the fleet size necessary to support the reliable delivery of the conceptual service plan (from the *Corridor Evaluation Study) and the Business Plan Sensitivity Analysis ridership forecast.* The following

descriptions are examples of the types of areas, shops and functions that have been considered for the conceptual configuration of the Main Repair and Maintenance Facility:

Wheel Truing Area

The wheel truing facility is configured to accommodate two cars. It is utilized to return wheel diameter parity and profile due to the stresses of track wear, drift, spalling, and wheel flat spots. The wheel truing machine is mounted under the floor for ease of operation. Rail cars are pulled over the machine to expedite turn around time. Candidate vehicles for wheel truing are typically identified during a programmed maintenance inspection.

Service and Inspection Area

The service and inspection area is configured as a two track "run-through" facility. Tracks are equipped with observation pits and door level platforms for ease of inspection and light repair, providing access to under car, interior floor, and roof levels. Located between this area and the main maintenance area is a "runaround" track that would allow direct access/egress to both sides of the shop. The service and inspection area has a sixteen car capacity on each track.

The Running Repair Area

The running repair area is configured with raised rail mounted on post structures and observation pits with depressed side floors. The posted, raised rail provides access to under car components requiring repair or replacement. Side floor and roof height platforms are also assumed in this configuration. The observation pit is equipped with a lift device to facilitate the removal and replacement of larger, heavier component units. Platforms provided at the car body side height provide access to glass, door, and interior and exterior repair requirements. A platform at the roof level provides access to the pantograph, resistor grids and a/c components for servicing activities as required.

Support Shops

Based on the needs of specific fleet design parameters examples of shop areas and functions include the following:

Truck Shop: equipped with a storage track and two turntables for the efficient transition of trucks requiring service and trucks ready for installation. Direct access is provided to the Component Cleaning Area, (located on an exterior wall) to prepare the trucks for overhaul/heavy repair. This area includes eight truck hoists to facilitate efficient repair, disassembly and reassembly. The additional turntables and connecting tracks in this area provide for the required maneuverability of truck assemblies.

Component Cleaning Area: This enclosed work area, located on an exterior wall, is used to pre-clean large components such as rail vehicle trucks, air compressors and air conditioning units (condensers and evaporators) prior to disassembly and repair or shipment.

Brake Shop: This area is used to clean, disassemble, repair, reassemble and test brake units and all brake actuators.

Air Room: This facility is used to clean, inspect, troubleshoot, repair, rebuild, paint, and test all types of brake valves and brake system components. The work area would be divided into four separate sections; the valve cleaning room, the repair area, the valve painting area and the valve test area. The repair and test operations are performed in enclosed, temperature-controlled rooms. Repair operations are performed in individual workstations.

Clean Room/Electronics Shop: This enclosed, temperature controlled room is equipped to clean, troubleshoot, repair and test trainset electronic components such as panels, relays, inverters,

battery chargers, circuit cards and selected control units. Repair activities are generally performed at individual workstations using specialized electronic test equipment.

HVAC Unit Repair Shop: This area is used to repair the components, associated with air conditioning units.

Pantograph Repair Area: This area is located on a suspended platform at the roof level of a rail car for the removal and installation of electric propulsion energy collection components.

Battery Room: This area supports the disassembly, cleaning, testing and reassembly of multi-cell battery units.

Wheel Shop: This area supports the fabrication and repair of wheel and axle sets. Machine technology resident in this shop includes a mounting press, demount press, wheel bore, and axle lathes.

Material Inventory and Distribution Area
This area serves as the distribution point in the Main Maintenance and Repair Facility for the material required to maintain, repair, clean, service, and provide for the state of good repair of the high-speed rail fleet. The area includes a loading dock for highway vehicles, space for the storage of transitional components (wheel sets, air compressors, etc.), and equipment (cranes, forklifts, pallet shelving etc.) associated with the efficient storage and distribution of rail car components and equipment.

Component Change-Out Area
This area is configured as a four track "run-through" facility. The hoist section of this area has the capacity to lift eight coupled rail cars on two separate tracks. Located between these tracks, are two tracks configured for the removal and installation of rail car trucks. Car body posts hold the rail vehicle in place while the trucks are removed and positioned on one of the four available truck turntables for efficient transition into the Truck Shop.

Overhaul Area
This area is utilized in the life cycle maintenance program. Rail cars undergo rebuild and major component replacement on either a time or mileage based cycle. Systems and subsystems are removed, rebuilt and replaced.

Heavy Repairs
This area accommodates repairs to a rail car that requires it to be out of service for an extended length of time.

Exterior Maintenance Shop
This area provides for the cosmetic and minor body damage repair, touch-up and periodic re-painting of vehicle exteriors.

As shown in Figure 4.5-6, the estimated area for this facility, including trackage requirements is 39.8 hectares (98.3 acres).

4.6 PARKING REQUIREMENTS

Depending on the station location, ridership demand, availability of intermodal connections, mix of trip purposes served, local land use and parking policies, and other site specific factors, passenger parking facilities may require a significant amount of land area. Thus, general assumptions and parameters must be determined to estimate the amount of parking and associated infrastructure/land area needed at each

potential station location. The Program Management Team has compiled the available information regarding passenger demand at each general station location and roughly estimated parking demand. These estimates are intended to be used as a baseline to guide the definition and evaluation of station options during the program environmental process. The factors and estimates applied are simply initial assumptions to provide a general sense of the parking and access requirements at each general station location, based on the results of the previous corridor evaluation studies and ridership analyses. The regional teams should to refine/revise these factors/estimates to reflect local conditions and policies and document their assumptions.

Worksheets were developed and applied to prepare this initial estimate of station parking requirements for forecast intercity and commute trips. The worksheets are presented as Table 4.6-1 and 4.6-2. The assumptions applied in the tables are discussed below.

The forecasted daily intercity boardings for each station were taken from Sensitivity Analysis Scenario 6B for the Year 2020 prepared for the Authority by Charles River Associates. These boardings represent the "worst case" ridership for environmental analysis. The forecasted daily commute boardings for each station are based on the commute ridership analysis completed for the Business Plan by Charles River Associates. In order to relate the forecasted boardings to parking and access requirements, it was necessary to roughly estimate the mode split for HSR passengers arriving at the station. The potential arrival modes include: air, rail, bus/shuttle, taxi, auto: self-park, auto: drop-off, walking (pedestrian).

Taking into account the potential intermodal connections, mode splits were roughly estimated for each category of station, based on the aforementioned *Environmental Constraints Analysis* as well as data from two research documents: *Parking* by Weant and Levinson for the Eno Foundation for Transportation and *United States Airports Parking Statistics Analysis* by Larry Donoghue presented in *The Parking Professional* (February 1997). Data on parking demand from both transit stations and airports was reviewed, however, it is anticipated that parking demand at HSR stations would more closely resemble that of airports given that the HSR system provides intercity service. The mode splits utilized reflect the anticipated higher level of intermodal connectivity at airport and urban stations.

The number of parking spaces was estimated using the mode's daily boardings, percent of passengers in the peak hour, average passengers per vehicle, vehicle headways and a length of stay factor. The peak parking demand for drop-off activity (buses, shuttles, taxis, and auto drop-off) assumed 15% of the daily boardings as the peak hour boarding. The self-parking demand assumed 100% of the daily boardings for that mode. The assumed headway for buses and shuttles was 10 minutes while the assumed headway for taxis and auto drop-off was 5 minutes. The assumed factors for each mode are presented in table 4.6-1.

Table 4.6-1

Parking Estimation Factors

Mode Type	Percent Daily Pass in Pk Hr	# Pass Per Veh	Headway (minutes)	Length of Stay Factor
Bus	15%	20	10	1.15
Shuttle	15%	7	10	1.15
Bus/Shuttle	15%	14	10	1.15
Taxi	15%	2.5	5	1.15
Self	NA	1.9	NA	1.5
Drop-off	20%	1.9	5	1.15

Note: Based upon data presented in "Parking" by Weant and Levinson for the Eno Foundation for Transportation and, data from Walker Parking Consultants in Los Angeles, CA.

Basic information and procedures for estimating the land area required and cost efficiency various parking structure configurations are included in Appendix B. The Regional Teams should apply this information to define parking area requirements for each potential station area based on the forecast ridership and passenger arrival assumptions as defined by the Regional Teams based on the information in Table 4.6-2 and 4.6-3.

Table 4.6-2

Estimated Station Parking Requirements – Intercity Trips

	Average	Mode Split							Daily Boardings - By Mode							Parking Space Requirements				Peak Veh
	Daily			Bus/		Auto					Bus/		Auto			Bus/		Auto		Arriving/
Station Name	Boardings	Air	Rail	Shuttle	Taxi	Self	Drop-off	Ped	Air	Rail	Shuttle	Taxi	Self	Drop-off	Ped	Shuttle	Taxi	Self	Drop-off	Hour
Sacramento	14,752	0%	10%	20%	15%	15%	30%	10%	-	1,475	2,950	2,213	2,213	4,425	1,475	6	13	1,747	45	1,165
Stockton - Downtown	1,880	0%	5%	15%	10%	35%	30%	5%	-	94	282	188	658	564	94	1	1	519	6	346
Stockton - Suburban Manteca	1,880	0%	0%	15%	5%	60%	20%	0%	-	0	282	94	1,128	376	0	1	1	890	4	594
San Francisco	21,523	0%	30%	15%	20%	0%	10%	25%	-	5,381	3,228	4,305	2,152	2,152	4,305	7	25	0	22	1,133
San Francisco Airport	2,885	40%	10%	15%	15%	10%	10%	0%	1,154	288	433	433	288	288	0	1	2	228	3	152
Redwood City/Palo Alto	6,253	0%	10%	10%	10%	35%	30%	5%	-	625	625	625	2,189	1,876	313	1	4	1,728	19	1,152
San Jose	12,094	0%	10%	20%	15%	15%	30%	10%	-	1,209	2,419	1,814	1,814	3,628	1,209	5	10	1,432	37	955
Gilroy	2,752	0%	5%	15%	5%	40%	30%	5%	-	138	413	138	1,101	825	138	1	1	869	8	579
Los Banos	193	0%	0%	15%	5%	60%	20%	0%	-	0	29	10	116	39	0	0	0	91	0	61
Modesto - Downtown	1,685	0%	5%	15%	10%	35%	30%	5%	-	84	253	169	590	506	84	1	1	466	5	310
Modesto - Sub - Briggsmore	1,685	0%	0%	20%	10%	40%	30%	0%	-	0	337	169	674	506	0	1	1	532	5	355
Merced - Downtown	514	0%	5%	15%	10%	35%	30%	5%	-	26	77	51	180	154	26	0	0	142	2	95
Merced - Suburban	514	0%	0%	15%	5%	50%	30%	0%	-	0	77	26	257	154	0	0	0	203	2	135
Fresno - Downtown	3,546	0%	5%	15%	10%	35%	30%	5%	-	177	532	355	1,241	1,064	177	1	2	980	11	653
Fresno - Suburban	3,546	0%	0%	20%	10%	40%	30%	0%	-	0	709	355	1,418	1,064	0	1	2	1,120	11	747
Tulare/Kings-Visalia or Hanford	158	0%	0%	10%	5%	50%	30%	5%	-	0	16	8	79	47	8	0	0	62	0	41
Bakersfield - Downtown	2,674	0%	5%	15%	10%	35%	30%	5%	-	134	401	267	936	802	134	1	2	739	8	492
Bakersfield - Suburban Fruitvale	2,674	0%	0%	20%	10%	40%	30%	0%	-	0	535	267	1,069	802	0	1	2	844	8	563
Sylmar	4,395	0%	0%	20%	5%	40%	30%	5%	-	0	879	220	1,758	1,318	220	2	1	1,388	13	925
Burbank	6,653	20%	5%	15%	10%	20%	25%	5%	1,331	333	998	665	1,331	1,663	333	2	4	1,050	17	700
Los Angeles Union Station	18,738	0%	15%	15%	10%	20%	32%	8%	-	2,811	2,811	1,874	3,748	5,996	1,499	6	11	2,959	60	1,972
East San Gabriel Valley	12,772	0%	5%	15%	10%	35%	30%	5%	-	639	1,916	1,277	4,470	3,831	639	4	7	3,529	39	2,353
Ontario Airport	2,635	20%	5%	15%	10%	20%	25%	5%	527	132	395	263	527	659	132	1	2	416	7	277

Table 4.6-2

Estimated Station Parking Requirements – Intercity Trips

	Average	Mode Split							Daily Boardings - By Mode							Parking Space Requirements				Peak Veh
	Daily			Bus/		Auto					Bus/		Auto			Bus/		Auto		Arriving/
Station Name	Boardings	Air	Rail	Shuttle	Taxi	Self	Drop-off	Ped	Air	Rail	Shuttle	Taxi	Self	Drop-off	Ped	Shuttle	Taxi	Self	Drop-off	Hour
Riverside/San Bernardino	4,875	0%	5%	20%	10%	30%	30%	5%	-	244	975	488	1,463	1,463	244	2	3	1,155	15	770
Temecula	2,481	0%	0%	15%	5%	50%	25%	5%	-	0	372	124	1,241	620	124	1	1	979	6	653
Escondido	3,349	0%	0%	15%	5%	50%	25%	5%	-	0	502	167	1,674	837	167	1	1	1,322	8	881
Mira Mesa	1,675	0%	0%	20%	10%	40%	25%	5%	-	0	335	167	670	419	84	1	1	529	4	353
Qualcomm Stadium	13,311	0%	15%	20%	5%	30%	30%	0%	-	1,997	2,662	666	3,993	3,993	0	5	4	3,153	40	2,102
University Town Center	4,975	0%	5%	20%	10%	35%	30%	0%	-	249	995	498	1,741	1,493	0	2	3	1,375	15	916
Oakland Airport	596	30%	5%	10%	10%	20%	25%	0%	179	30	60	60	119	149	0	0	0	94	2	63
Oakland	10,200	0%	15%	15%	15%	15%	20%	20%	-	1,530	1,530	1,530	1,530	2,040	2,040	3	9	1,208	21	805
Fremont/Union City	2,705	0%	5%	15%	5%	40%	30%	5%	-	135	406	135	1,082	812	135	1	1	854	8	569
Palmdale	2,008	20%	0%	10%	10%	30%	30%	0%	402	0	201	201	602	602	0	0	1	476	6	317
LAX Airport	4,350	40%	10%	15%	15%	10%	10%	0%	-	0	0	0	0	0	0	0	0	0	0	0
Norwalk	3,621	0%	5%	15%	5%	40%	30%	5%	-	181	543	181	1,448	1,086	181	1	1	1,143	11	762
Anaheim	6,876	0%	10%	10%	10%	35%	30%	5%	-	688	688	688	2,407	2,063	344	1	4	1,900	21	1,267
Irvine	3,085	0%	10%	10%	10%	35%	30%	5%	-	309	309	309	1,080	926	154	1	2	852	9	568

Notes:

1. Based on Final Business Plan, June 2000
2. Number of Bus/Shuttle drop-off spaces = Daily Boardings X Percent Passengers in Peak Hour / Avg No. of Passengers Per Vehicle / (60 min/hr / Headway) X Length of Stay Factor.
3. Number of Self Parking Spaces = Daily Boarding / Avg No. of Passengers Per Vehicle X Length of Stay Factor
4. Number of Drop-Off Parking Spaces = Daily Boarding X Percent Daily Passengers in Peak Hour / Avg No. of Passengers Per Vehicle/(60 min/hr/Headway) X Length of Stay Factor
5. Based upon data from in "Parking" prepared for the Eno Foundation For Transportation, the Boarding Passengers/Parking Space at selected rail transit stations ranged from 1.4 to 32.0 with an average rate of 7.5.
6. Amtrak data on method of travel to station used where available

Table 4.6-3

Estimated Station Parking Requirements – Commute Trips

Commute Station Name	Average Daily Boardings1	Mode Split							Daily Boardings - By Mode							Parking Space Requirements				Peak Veh Arriving/ Hour
		Air	Rail	Bus/ Shuttle	Taxi	Auto Self	Auto Drop-off	Ped	Air	Rail	Bus/ Shuttle	Taxi	Auto Self	Auto Drop-off	Ped	Bus/ Shuttle	Taxi	Auto Self	Auto Drop-off	
San Francisco	3,300	0%	25%	15%	20%	10%	10%	20%		825	495	660	330	330	660	1	4	261	3	174
San Francisco Airport	450	40%	10%	15%	15%	10%	10%	0%	180	45	68	68	45	45	0	0	0	36	0	24
Redwood City/Palo Alto	1,150	0%	10%	10%	10%	35%	30%	5%	-	115	115	115	403	345	58	0	1	318	3	212
San Jose	800	0%	10%	20%	15%	15%	30%	10%	-	80	160	120	120	240	80	0	1	95	2	63
Gilroy	150	0%	5%	15%	5%	40%	30%	5%	-	8	23	8	60	45	8	0	0	47	0	32
Los Banos	100	0%	0%	15%	5%	60%	20%	0%	-	0	15	5	60	20	0	0	0	47	0	32
Palmdale	3,280	0%	0%	20%	10%	40%	30%	0%	-	0	656	328	1,312	984	0	1	2	1,036	10	691
Sylmar	4,280	0%	0%	20%	5%	40%	30%	5%	-	0	856	214	1,712	1,284	214	2	1	1,352	13	901
Burbank	990	20%	5%	15%	10%	20%	25%	5%	198	50	149	99	198	248	50	0	1	156	2	104
East San Gabriel Valley	650	0%	5%	15%	10%	35%	30%	5%	-	33	98	65	228	195	33	0	0	180	2	120
Ontario Airport	2,000	20%	5%	15%	10%	20%	25%	5%	400	100	300	200	400	500	100	1	1	316	5	211
Riverside/San Bernardino	750	0%	5%	20%	10%	30%	30%	5%	-	38	150	75	225	225	38	0	0	178	2	118
Temecula	3,740	0%	0%	15%	5%	50%	25%	5%	-	0	561	187	1,870	935	187	1	1	1,476	9	984
Escondido	300	0%	0%	15%	5%	50%	25%	5%	-	0	45	15	150	75	15	0	0	118	1	79
Mira Mesa	100	0%	0%	20%	10%	40%	25%	5%	-	0	20	10	40	25	5	0	0	32	0	21

Notes:

1. Based on Final Business Plan, June 2000
2. Number of Bus/Shuttle drop-off spaces = Daily Boardings X Percent Passengers in Peak Hour / Avg No. of Passengers Per Vehicle / (60 min/hr / Headway) X Length of Stay Factor.
3. Number of Self Parking Spaces = Daily Boarding / Avg No. of Passengers Per Vehicle X Length of Stay Factor
4. Number of Drop-Off Parking Spaces = Daily Boarding X Percent Daily Passengers in Peak Hour / Avg No. of Passengers Per Vehicle/(60 min/hr/Headway) X Length of Stay Factor
5. Based upon data from in "Parking" prepared for the Eno Foundation For Transportation, the Boarding Passengers/Parking Space at selected rail transit stations ranged from 1.4 to 32.0 with an average rate of 7.5.
6. Amtrak data on method of travel to station used where available

4.7 PASSENGER FACILITIES REQUIREMENTS

As with the parking requirements, the configuration of station facilities would depend upon a multitude of variables including station location, ridership demand, interaction with intermodal connections (if available), mix of trip purposes served and local land use and building codes requirements. Consequently, a set of assumptions had to be developed to describe the functional use areas within a station facility and establish a method with which the order of magnitude size of a station facility could be using a combination of the functional use area descriptions and the numbers of passengers using the facility during a peak hour period (peak hour passengers = PHP). The Program Management Team has utilized the available information for passenger demand for each station and the conceptual descriptions of the functional use areas to define a reasonable, order of magnitude estimate for the size of a station facility applicable to each potential station location. The results of this process represent a general framework to describe station facility requirements based upon previous corridor evaluation studies and ridership analyses. The Regional Teams should modify these estimates to reflect local codes, conditions and policies and document their assumptions.

The following general descriptions are examples of the types of major functional use areas that have been considered for the conceptual configuration of a high-speed rail station facility:

Waiting Room

A waiting room is an area where passengers (and in some instances, “visitors” who might be accompanying them) wait for trains prior to queuing or proceeding to the platform to board a train. Waiting areas are typically located away from the principal travel path between the ticket counter (or electronic ticket and check-in vending area) and the boarding areas. Passengers proceeding directly from a station entrance or ticketing area should follow a route that precludes disturbing passengers seated in a waiting area.

Concourses

Concourses may be one or more areas where passengers walk to or from trains or queue in anticipation of boarding trains. In stations that typically serve only one train at a time a separated concourse is not provided. However, larger stations, such as terminals located in major cities, may have several concourses particularly if arriving and departing passengers are separated. Furthermore, if boarding queue areas for many tracks are employed, a concourse should have adequate depth and length to accommodate approximately seventy five percent of the normal peak passenger count for each train.
Where concourses are used exclusively for travel paths a minimum width of fifteen feet is typically provided to allow for passengers carrying luggage or pushing luggage carts.

Ticketing

The ticketing area is where passengers, who have not procured their transportation documents, queue and secure these documents. A ticketing area can be manned (configured with ticket counters) or unmanned (in which case electronic ticket and check-in vending machines would be utilized) or have a combination of ticket counters and electronic vending machines. It is assumed that passenger checking of baggage would be accomplished at the ticket counter (where applicable) to expedite the movement of passengers though the pre-boarding process. Space allocation for service staff (where applicable), storage areas for document stock, an area for placement of communications and computer hardware apparatus has also been considered.

Baggage Facilities

Baggage facilities within a high-speed station are assumed to include provision to respond to the following activities:

- Receipt and checking of outbound baggage
- Receipt of inbound baggage from the train and dispensing these items to passengers
- Storage of unclaimed and connecting baggage
- Storage of baggage tractors and carts (as applicable)
- Storage of cleaning and maintenance supplies

The movement of outbound baggage from the ticket counter area to the baggage "make-up" area may be either manual or automated depending upon the distance and quantities involved.

Restrooms

It is assumed that public restrooms would be provided at each high-speed rail station to accommodate passengers waiting for trains (and "visitors" who might be accompanying them) or connecting modes of transportation. Public restrooms are typically configured according to local codes, ordinances and/or regulations.

Support Facilities

The requirements for support facilities would depend on the volume of trains and ridership, type of station, and potential station location. A provision for these support functions has been considered in the overall order of magnitude estimate for the various station facilities' sizing. Descriptions of examples of support facilities areas include:

- Vendor services for food, beverages, newspapers, magazines etc.
- Public telephones
- Passenger services office (stations over 300 peak hour passengers)
- Administrative
- On board services
- Commissary
- Mechanical
- Security

Two tables were developed to present order of magnitude estimates of station facilities spatial requirements based upon the passenger volume from the forecast intercity trips.

These tables are identified as Table 4.7-1; Station Categories for Peak Hour Boardings/Alightings and Table 4.7-2; Station Spatial Area Requirements by Category. The assumptions applied to these tables are described as follows.

Table 4.7-1, Station Categories for Peak Hour Boardings/Alightings, were developed by first using the forecasted daily intercity and commute Boardings/Alightings for each station taken from Sensitivity Analysis Scenario 6B for the Year 2020. These data represent the "worst case" ridership for environmental analysis.

Next, the daily volume of trains defined in the conceptual service plan (from the Corridor Evaluation Study) was used to develop the number of trains during the peak hour (the largest number of trains in a sixty minute period) for each station. The ratio of the number of peak hour trains to total daily trains was

computed (for each station) and applied to the daily forecast of boardings/alightings (for each station) to estimate the number of peak hour passengers (PHP). The PHP were than used to identify the Station Category (I, II, III or IV) for each station.

Table 4.7-2, Station Spatial Area Requirements by Category, were developed by estimating the size of the area required to support functional use for different ranges of PHP. These general functional use areas have been previously described in this section. Area sizes were estimated using existing intercity and high-speed rail station configurations as a benchmark with references from AREMA's (American Railway Engineering and Maintenance-of-Way Association) Design Criteria for Railway Passenger Stations, Part 8, 2001.

The Regional Teams used the Tables 4.7-1 and 4.7-2 to develop area requirements for Station Facilities. It is important to note that these guidelines, presented as square footage requirements in the tables, apply only to the total estimated area not the type of structure. Consequently, the configuration of each Station Facility would depend on specific land use challenges and local codes, conditions and policies. Based upon the aforementioned, the Regional Teams have the latitude to utilize different configurations such as a mezzanine (connecting the two platforms at an Intermediate Station), one story or multiple story structures provided that the overall spatial area required for the appropriate Station Category has been accommodated.

Table 4.7-1

Station Categories for Peak Hour Boardings/Alightings

Station	Boardings /Alightings for Intercity & Commute Service		Station Configuration	Station Category
	Daily	Per Peak Hour		
Sacramento	29504	2868	Terminal	I
San Francisco	49646	3009	Terminal	I
Los Angeles Union Station	37476	2839	Run through terminal	I
East San Gabriel Valley	26844	2789	Intermediate	I
San Jose	25788	2190	Run through terminal	II
Qualcomm Stadium/San Diego	26622	1775	Terminal	II
Oakland	20400	2200	Terminal	II
Sylmar	17350	1200	Intermediate	III
Redwood City/Palo Alto	14806	1089	Intermediate	III
Burbank	15286	1124	Intermediate	III
Riverside/San Bernardino	11250	1023	Intermediate	III
Anaheim	13752	1000	Terminal	III
Temecula	12442	970	Intermediate	III
Palmdale	10576	881	Intermediate	III
Ontario Airport	9270	843	Intermediate	III
University Town Center	9950	800	Intermediate	III
Stockton-Suburban Manteca	3760	427	Intermediate	IV
Stockton-Downtown	3760	427	Intermediate	IV
Gilroy	5804	512	Intermediate	IV
Fresno-Suburban	7092	601	Intermediate	IV
Fresno-Downtown	7092	601	Intermediate	IV
Santa Clarita*	6000	529	Intermediate	IV
Escondido	7298	663	Intermediate	IV
Norwalk	7242	600	Intermediate	IV
Irvine	6170	600	Terminal	IV
LAX Airport	8700	600	Terminal	IV
Modesto-Suburban Briggsmore	3370	396	Intermediate	V
Modesto-Downtown	3370	396	Intermediate	V
San Francisco Airport	6670	392	Intermediate	V
Bakersfield-Suburban Fruitvale	5348	388	Intermediate	V
Bakersfield-Downtown	5348	388	Intermediate	V
Mira Mesa	3550	277	Intermediate	V
Fremont/Union City	5410	380	Intermediate	V
Merced-Suburban	1028	158	Intermediate	VI
Merced-Downtown	1028	158	Intermediate	VI
Los Banos	586	62	Intermediate	VI
Tulare/Kings-Visalia or Hanford	316	26	Intermediate	VI
Oakland Airport	1192	160	Terminal	VI
San Diego				

Table 4.7-2

Station Spatial Area Requirements by Category

Station Category	PHP Range	Total No.	Area	
			sq. ft	ha
I	2500 to 3500	4	60000	0.56
II	1500 to 2449	3	35000	0.33
III	750 to 1499	9	29800	0.28
IV	400 to 749	10	22320	0.21
V	200 to 399	7	18972	0.18
VI	up to 199	5	11880	0.11

5.0 CONVENTIONAL NON-ELECTRIC (LOSSAN CORRIDOR) SYSTEM/DESIGN PARAMETERS

Of the five corridors being studied by the Authority, the Los Angeles – Orange County – San Diego corridor is unique in that it contains, from end to end, an existing intercity passenger rail corridor – the Los Angeles to San Diego (LOSSAN) corridor. In terms of passenger volumes, the LOSSAN corridor is Amtrak's second-busiest corridor in the nation, after the Northeast Corridor connecting Washington, D.C. to New York City. It is used by Amtrak for the State-supported Pacific Surfliner Service between Los Angeles and San Diego, by the Southern California Regional Rail Authority for its Metrolink commuter rail service in Los Angeles and Orange Counties, and in San Diego County by the North County Transit District for its Coaster commuter rail service. The Burlington Northern Santa Fe also uses the corridor for freight service.

The presence of the LOSSAN corridor provides an excellent opportunity, as it raises the possibility of building a high-speed train system by incrementally improving an existing service, including the possibility of using conventional fossil-fuel trains rather than electrically powered steel-wheel-on-steel-rail technologies. However, the corridor also poses some considerable constraints. It passes through one of the most densely populated areas of the State, and in southern Orange County and San Diego County, traverses ecologically sensitive coastal areas. Due to these significant environmental and community constraints, the LOSSAN options fall into two categories: shared-use scenarios where high-speed trains would mix with conventional services (no further south than Irvine), and conventional-only scenarios which provide an upgraded "feeder" service that would require a transfer to the rest of the high-speed network, at LA Union Station or in Orange County.

For the shared–use scenarios north of Irvine, the high-speed rail engineering criteria discussed in the preceding sections would be applied. For the conventional-only scenarios, this study examines two scenarios of incremental improvements to the LOSSAN corridor that would support different levels of service and frequencies. These, as alternative "build" options, would serve as a feeder line to the statewide high-speed rail system. The incremental improvements would construct the necessary track capacity to meet projected demand and increase passenger speeds to 110 mph throughout the corridor. In selected segments of the corridor, the criteria allow for passenger speeds up to 125 mph at the most.

5.1 TECHNOLOGY

SHARED USE SCENARIOS

Within the LOSSAN corridor itself, options are being examined that would allow high-speed trains to share tracks with existing Amtrak intercity, commuter rail, and freight rail services as far south as Irvine. The intent is not to mix high-speed trains traveling at more than 200 up to 125 mph (320 200 km/h) with other rail traffic; in urban areas, the speeds of high-speed trains would be approximately the same as other passenger services. However, by sharing tracks, the intent is to minimize community and environmental impacts while creating a feeder rail system allowing travelers easy access the statewide system.

CONVENTIONAL SCENARIO A - (110 MPH)

This scenario assumes the diesel electric locomotive, General Motors Electromotive Division's, F59 PHI currently used within the corridor with conventional "Bi-level California" cars. This locomotive is capable of accelerating quickly to speeds of 90 mph, but its acceleration drops off rapidly as it nears its top speed of 108 mph This locomotive complies with the Federal Railroad Administration's (FRA) high Crash Energy

Management (CEM) requirements and is in shared-use operations with freight and other passenger service.

CONVENTIONAL SCENARIO B - (125 MPH)

This scenario assumes a vehicle similar to the diesel-turbine version of Bombardier's Acela HS locomotive, which is not yet in revenue service. This locomotive is currently under FRA testing at Pueblo, Colorado test track. It is capable of accelerating to top speeds in the 125-150 mph (200-240km/h) range and has been designed to meet FRA CEM requirements. Fossil fuel locomotives typically have slower acceleration rates than electric vehicles. This technology may be marginally slower than the electric AEM-7 used in Amtrak's Acela Regional Service, but travel times would be comparable in this corridor.

5.2 CONVENTIONAL SYSTEM CONFIGURATION OPTIONS

The final system configuration would involve incremental upgrading of the corridor for improved conventional operations. The first scenario would upgrade the existing LOSSAN corridor to FRA Class 6 standards, increasing operating speeds to a maximum of 110 MPH (117km/h) with full double tracking. The second scenario would upgrade the corridor to FRA class 7 standards with full double-tracking and grade-separations to allow rail services to operate at up to 125 mph (200 km/h). The grade separations would provide a greater level of safety and access. All existing Amtrak stations would continue to be served. Both scenarios assume a conventional fossil-fuel train system that would not be compatible with the rest of the statewide network. This would require passengers to transfer to and from the rest of the statewide train system at LA Union Station in Los Angeles or at a new terminus station in Anaheim or Irvine.

The mixing of slower conventional commuter and freight services, which typically operate at top speeds of 90 mph and 70 mph, would require the development of a new operating plan that would allow for the existing Amtrak/Caltrans intercity trains to operate at higher speeds on an express schedule.

For the sake of simplicity the two scenarios are discussed throughout this report as two distinct options. However, they should be seen as two bookends in what is in fact a continuous spectrum of design options. By drawing selectively from different elements of the two scenarios in different parts of the corridor, it would be possible to configure a large number of distinct options between the two extremes discussed in this report.

The basic characteristics of the two incremental LOSSAN scenarios are summarized in Table 5.1-2, on the following page.

Table 5.1-2
Summary of Engineering Design Parameters (LOSSAN)

Parameter	Scenario A	Scenario B
Double Track	Full	Full
Power Source	Fossil-Fuel	Fossil-Fuel
Grade-Separations	Partial (1)	Full
Potential for Shared-use	Yes	Yes
Corridor Width ❑ **Desirable** ❑ **Absolute Minimum**	 100 ft (30.4 m) 50 ft (15.2 m)	 100 ft (30.4 m) 50 ft (15.2 m)
Top Speed	110 mph (177 km/h)	125 mph (200 km/h)
Average Speed	TBD	TBD
Acceleration	TBD	TBD
Deceleration	TBD	TBD
Maximum Superelevation ❑ **Actual (Ea)** ❑ **Unbalanced (Eu)**	 BNSF Territory: 5 in (127 mm) SCRRA & NCTD Territory: 6 in (152 mm) Conventional Non-Tilt: 4 in (102 mm)	 BNSF Territory: 5 in (127 mm) SCRRA & NCTD Territory: 6 in (152 mm) Passive-Tilt: 8 in (203 mm) Active-Tilt: 9 in (229 mm)
Minimum Horizontal Radius (absolute @ minimum speed)	460 ft (140 m)	460 ft (140 m)
Minimum Horizontal Radius (at top speed)	At 5 in Ea: 5,392 ft @ 110 mph (1,643 m @ 177 km/h) (2) At 6 in Ea: 4,856 ft @ 110 mph (1,480 m @ 177 km/h) (2)	At 5 in Ea: 4,821 ft @ 125 mph (1,469 m @ 201 km/h) (2) At 6 in Ea: 4,476 ft @ 125 mph (1,364 m @ 200 km/h) (2)
Minimum Horizontal Clearance (centerline of track to face of fixed object)	8 ft 6 in (2.6 m) (3)	8 ft 6 in (2.6 m) (3)
Minimum Vertical Clearance (Existing Structures) (top of rail to face of fixed object)	22 ft 6 in (6.9 m) (3)	22 ft 6 in (6.9 m) (3)
Minimum Vertical Clearance (Proposed Structures) (top of rail to face of fixed object)	26 ft 0 in (7.9 m) (4)	26 ft 0 in (7.9 m) (4)
Minimum Track Centerline Spacing	15 ft 0 in (4.6 m)	15 ft 0 in (4.6 m)
Minimum Right-of-Way Requirements At-Grade/Cut-and-Fill/Retained Fill Aerial Structure Tunnel (Double Track) Tunnel (Twin Single Track) Trench/Box Section	 50 ft (15.2 m) 50 ft (15.2 m) 67 ft (20.4 m) 120 ft (36.6 m) 70 ft (21.3 m)	 50 ft (15.2 m) 50 ft (15.2 m) 67 ft (20.4 m) 120 ft (36.6 m) 70 ft (21.3 m)
Minimum Station Platform Length	820 ft (250 m)	820 ft (250 m)
Minimum Station Platform Width	25 ft (7.6 m)	25 ft (7.6 m)

Notes:
(1) Full-Closure is required for operations between 110 mph and 125 mph. This can be accomplished with 4-quadrant gates. At grade crossings are prohibited for operations over 125 mph.
(2) Class 6 operations assumes the use of conventional non-tilt trainsets, limiting underbalance to 4", and the resulting max speed for any given radius. Class 7 Operations assumes utilizing passive tilt-technology trainsets that allow the use of higher underbalance superelevation (8") resulting in higher speeds for any given radius. If active-tilt trainsets are utilized, shorter radii would result based on an allowable 9" underbalance (FRA approved limit in NEC Corridor)
(3) From California Public Utilities Commission General Order 26-D
(4) From American Railway Engineering and Maintenance-of-Way Association, Manual for Railway Engineering (2001), Volume 4, Chapter 28, Section 1.8 (Assumes 50 kV system)

Table 5.1-3
Horizontal and Vertical Alignment Criteria (LOSSAN)

Parameter	Class 6	Class 7
Minimum Tangent Length (Lt) ❑ **Desirable** ❑ **Minimum**	 3.0V 100 ft	 3.0V 200 ft
Equilibrium Superelevation (Ee)	$\sin^{-1}(0.07V^2/R)$	$0.0007V^2D$
Maximum Actual Superelevation (Ea)	5 in	5 in
Maximum Unbalance Superelevation (Eu)	4 in	8 in
Minimum Length of Circular Curve ❑ **Desirable** ❑ **Minimum**	 3.0V 100 ft	 3.0V 200 ft
Spiral Length (Le) (greater of)	1.22 Eu V (1) 124 Ea (1)	0.85 Eu V (2) 124 Ea (1)
Minimum Length of Vertical Curve (LVC)	$2.15(D)(V^2)/A$ (3)	$2.15(D)(V^2)/A$ (3)
Grades ❑ **Desirable Maximum – Extended Grades** ❑ **Absolute Maximum – Limited Grades**	 1.2% 2.5%	 1.2% 2.5%
Length of Constant Grade (Lt) ❑ **Desirable** ❑ **Minimum**	 3.0V 100 ft	 3.0V 200 ft

Notes:
(1) From National Railroad Passenger Corporation MW1000, Limits and Specifications for the Safety, Maintenance, and Construction of Track
(2) Minimum spiral length formula based on Eu is dependent on rolling stock characteristics. 0.85 Eu V is an industry accepted assumption for passive tilt technology trainsets.
(3) D=absolute value of the difference in grades (decimal); V=train speed (mph); A=acceptable vertical acceleration (0.60 for passenger operations) (PROPOSED AREMA FORMULA)

APPENDICES

APPENDIX – A
Typical Cross Sections

APPENDIX – B
Parking Facility Sizing Guidelines