Sacramento Valley Station

Area Plan

Public Draft, August 26, 2020

Technical Appendix E

Technical - Constructibility

City of SACRAMENTO Perkins&Will

Administrative Draft *August 2020*

i. Platform widening memo (ARUP)

Memorandum

ARUP

To	Greg Taylor	Date	April 3, 2020
Copies	Geeti Silwal, Dennis Dornan, Christina Tung, Kimberly Orrego, Grant McInnes, Anthony Bruzzone	Reference number	252563
From	Mathew Bamm	File reference	04
Subject	Sacramento Valley Station Platform Widening Study		

Overview

This memorandum documents the geometric constraints and applicable design criteria that determine the extent to which Sacramento Valley Station's (SVS) two island platforms can be widened. This widening is part of the overall SVS Master Plan, which includes the construction of an overhead concourse spanning from H Street to the Railyards development, and from which passengers flow downwards towards the platforms. Only widening inward (i.e., between Tracks 4 and 5) was investigated as widening outward would result in a lack of compliance with UPRR track separation guidance.

The area between Tracks 4 and 5 (which have an overall separation of about 30-ft) accommodates a 22-ft wide service road. This road is proposed to be removed, allowing each of the two tracks to be realigned closer to each other in the additional right-of-way subsequently available. However, since columns supporting the elevated station concourse would also land between Tracks 4 and 5, it is necessary to ensure geometrically feasible and administratively permissible horizontal separations between tracks, columns, and platforms. After consulting Amtrak, Union Pacific, and California Public Utilities Commission design criteria, as well as initial structural consideration of minimum column thicknesses, it is probable that the platforms could be widened inward to achieve a maximum width of 30-ft each, an increase of more than 5-ft over each platform's existing width of 24'-10".

Objective and Variables

It is expected that future SVS operations will not require use of the existing service road between the center two station tracks at SVS. Conversely, additional passenger trains and passengers could result in degraded passenger experience on the current platforms. Arup was requested to investigate the feasibility of widening the platforms. As noted, only inward widening was considered.

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The repurposing of the existing service road (to accommodate wider platforms) results in an additional available gross horizontal dimension of about 21'-10". All or part of this dimension can be applied to wider platforms, resulting in moving Tracks 4 and 5 closer to each other.

The proposed elevated concourse structure perpendicular to the tracks and platforms, however, is to be supported by multiple columns landing between Tracks 4 and 5 (the existing service road). Ideally, these columns will be centered between the tracks. This central column placement eliminates the need for supporting columns and walls on the passenger platforms. However, placing the columns between the tracks results in additional design requirements related to horizontal separation between column exteriors and station tracks. These requirements limit how far inward the tracks, and therefore the platforms, can be adjusted.

Arup researched the relevant design standards, interpreted their implications for side clearances, leading to a probable increment by which both platforms may be feasibly widened. The guidelines seek to provide safety for rail operations while acknowledging the need for structures in the right-of-way. Specifically, there existed some flexibility in the following three variables.

- **Horizontal alignment of station Tracks 4 and 5:** The most straightforward variable to adjust was the relative location of each approximately thousand-foot-long tangent of Tracks 4 and 5. Shifting tracks inward, however, was limited by the dimensions of the columns between them.
- **Column Widths:** While the ideal column width was initially set at 5'-0", all columns were assumed to be reducible by up to one foot in diameter to 4'-0" to accommodate the platform widening. The precise column dimensions would be determined during detailed design, but a smaller diameter may be infeasible.
- **Side clearances between track centerline and column:** Depending on the design criteria in question, the horizontal separation between the track and the column edge could be varied.

For purposes of this study, three additional variables were assumed not amenable to change:

- **Horizontal alignment of station tracks 3 and 6:** The outer two station tracks were not subject to realignment. All station platform widening must occur towards the inner two tracks.
- **Side clearances between track centerlines and platform edge:** The existing station platforms are separated from track centerlines by 5'-4" and this horizontal clearance cannot be narrowed.
- **Upstream and downstream rail geometry:** Both shifted inner tracks are required to connect with existing No. 10 turnouts linking them with the outer station tracks (Tracks 3 and 6). The outermost UPRR tracks must remain unaffected by all impacts of the station platform widening.

Applicable Design Criteria

While Amtrak design criteria is the apparent controlling standard, Arup consulted three potential sources of design criteria for each organization whose authority extends over the SVS rail right-of-way.

- **Union Pacific Guidelines for Railroad Grade Separation Projects:** According to Section 4.3, governing *structure separation,* a 25'-0" side clearance is desirable to a non-railroad structure. Subsequently, however, in section 5.2.2(b)(1) governing *permanent horizontal clearances,* it is explicitly noted that "where it is impracticable to clear span the Railroad right-of-way," those seeking a design exception may "provide written justification and request for variance for the proposed design." However, since Union Pacific freight trains would not be operating on the innermost station tracks, it is not clear that UPRR criteria control this realignment, and if the standards did apply, it could be reasonable to expect a design exception.
- **California Public Utilities Commission General Order No. 26-D:** For surface tracks, a side clearance of 8'-6" is required for "all structures and obstructions above the top of the rail."
- **Amtrak 70050.001.08 Minimum Roadway Clearances:** While a side clearance of 9'-0" is stated as required for structures such as columns, 8'-0" side clearances are permitted for building walls, and 6'-0" for elements of inter-track fencing. It is possible that the SVS concourse columns could be classified as a building wall, rather than strictly as columns, however it is not reasonable to expect Amtrak to accept defining the columns as a fence.

Existing Geometry

Figure 1 depicts section view of the existing station platforms, showing the centerline-to-centerline width of 30'-4.8" between centerlines of Tracks 4 (center left) and 5 (center right). Also illustrated in Figure 1 are the existing symmetrical platform widths of 24'-10" each. The CAD drawings on file contained platforms 25'-4" wide. In light of the discrepancy, this study conservatively assumes the narrower width as documented by Union Pacific in its 2013 *Sacramento Track Relocation Record Drawings.* A field survey of the tracks and platforms should be prepared to confirm the above findings at preliminary engineering stage.

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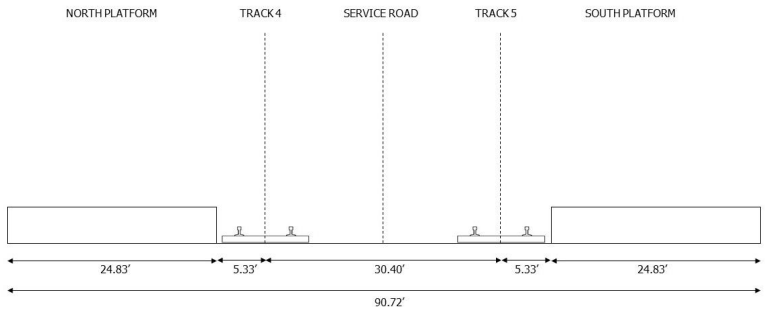
Figure 1: Existing Station Section, Facing East at SVS along Tangent Section of Track/Platform



Proposed Widening Alternatives

Two platform widening configurations were evaluated. First, as illustrated in Figure 2, Arup tested a 5'-0" column diameter and the 8'-6" side clearance designated by CPUC. Under these conditions, the platforms can be widened inward to a maximum of 29'-0" each. The second configuration considered is illustrated in Figure 3; if columns are narrowed to 4'-0" and horizontal separation to track centerline also reduced to 8'-0", then both island platforms can be widened to 30'-0" with all gained width, as in Figure 1, towards the center two tracks.

Narrowing the columns to less than 4'-0" would, in addition to requiring more complex structural analysis, likely require the construction of a crash wall to sustain a potential impact with a derailed train. Since a crash wall would add six inches to both sides of the column, there is effectively zero or rapidly diminishing return in pursuing additional platform width through column reduction alone.

The widening shown in Figure 2 requires reclassification of columns as elements of a trackside building, to achieve the 8'-0" permitted side clearance from Amtrak. Furthermore, it requires a design exception from CPUC due to its narrower side clearance than the designated 8'-6". The following section lists the possible design exceptions raised by each agency, and the rationale for requesting that the exception be granted.

Figure 2: Section View, 29'-0" Platforms, 5'-0" columns

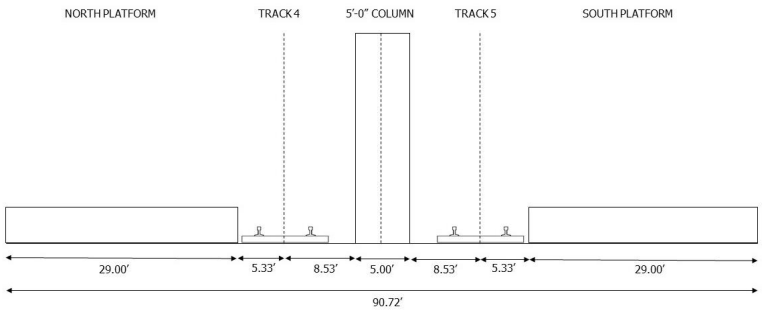
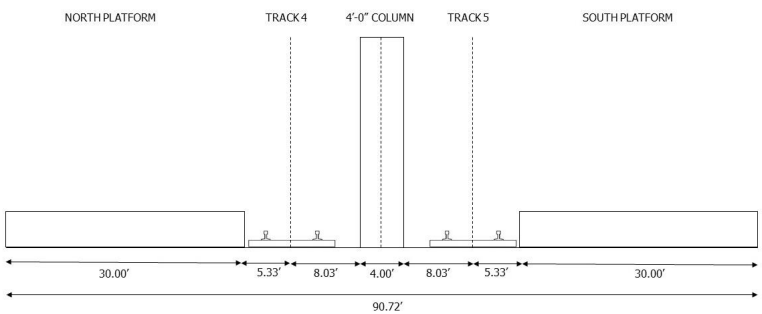


Figure 3: Section View, 30'-0" Platforms, 4'-0" columns



Impacts on Platform and Track Geometry

To accommodate the shifted platforms and adjacent central tracks, no relocation is expected for the four existing No. 10 turnouts from which Tracks 4 and 5 diverge from and rejoin Tracks 3 and 6, respectively.

Sharper horizontal curves, however, are necessary to realign the extended existing turnouts with the 5'-2" offset tangent tracks. Specifically, the curved sections alongside the flared ends of the platforms would exhibit 8 to 10 degrees of curvature, rather than the 7 to 8 degrees of the existing tracks. This would reduce the design speed from 25mph to 20mph, but this reduction in speed is of limited operational relevance on tracks that only serve stopping passenger trains. The sharper curves tying into

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the turnouts would increase the rate at which both platforms narrow near their ends; in these flared sections, like in the flared sections on the existing platforms, the platforms do not achieve the same width as along the tangent sections. This study shows that, even with the increased degree of curvature at the ends, both platforms can still retain tangent sections of over 1,000 feet along both Tracks 4 and 5.

Anticipated Design Exception Rationale, by Agency

- **UPRR**: *Should the columns require a 6" crash wall?* Since freight trains are not anticipated to use either track, and since all Amtrak trains slow and stop, the collision risk is reduced and the mitigatory effect of a crash wall is already achieved by the low impact of a potential derailment.
- **Amtrak**: *Are columns genuinely classifiable as a building wall?* Given the number and thickness of columns, coupled with the slow train speed, derailments pose limited risk to structure supported by column. Future research may identify precedents in which Amtrak permitted structural elements to be placed adjacent to a track with 8'-0" side clearance.
- **CPUC**: *Side clearance is 6-inches narrower than the criteria.* Similarly, an exception could be sought based on slow train speeds, coupled with the acceptability under a different agency. CPUC could also theoretically be requested to honor Amtrak's 8'-0" horizontal clearance requirement, if granted for this design, in lieu of imposing its own standards.

A common rationale for all design exceptions, and indeed the objective that informed this platform widening study in the first place, is the elimination of a need for columns, shear walls, or any supports on the passenger platforms themselves. The centrally placed columns between Tracks 4 and 5 contribute to an open design and circulatory efficiency of passenger movements, as boarding and alighting Amtrak riders would not be queuing or maneuvering around concourse columns.

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ii. Rail tracks vertical clearance memo (ARUP)

Public Draft, August 26, 2020

File Note

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Project title	Sacramento Valley Station	Job number	
Cc		File reference	
Prepared by	Emma Burkhardt	Date	December 19, 2019
Subject	Railway Vertical Clearance Requirements		

1 Summary

This report documents regulatory design guidance for overhead clearances in the railroad operational area of the Sacramento Valley Station. The purpose of this note is to provide reasonable design guidance relating to vertical clearances in structures spanning the freight, passenger, and light rail system. Upon analysis of the relevant design criteria, it is recommended that 24'-6" of vertical clearance is provided from top of rail to bottom of structure within the shared track area, and 19'-6" within the area occupied by light rail only. However, in exclusive right of way areas where unauthorized access to the right of way is prevented, the vertical clearance may be reduced to 14'-6".

Arup considered the criteria of the following agencies: UPRR, Amtrak, Caltrans, California High Speed Rail Authority (CHSRA), and Sacramento Regional Transit District (Sac RT). In addition, Caltrans and California Public Utilities Commission (CPUC) criteria were reviewed, as CPUC establishes legal minimum railway clearances for the state of California, and Caltrans establishes highway clearances to railways.

UPRR and Amtrak currently operate trains in Sacramento Valley Station. According to the Capitol Corridor Vision Implementation Plan (2016), the ROW in question may be electrified in the future. Sac RT operates adjacent to, but not within, the UPRR and Amtrak corridor, and shall also impose clearance requirements on proposed overhead structures. CHSRA is anticipated to use the station in the future.

File Note

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2 Design Criteria

The following subsections list the vertical clearance design standard for each railroad operator and relevant agency.

2.1 Union Pacific

According to Union Pacific Railroad/BNSF Railway Guidelines for Railroad Grade Separations Projects (2016), the minimum permanent vertical clearance shall be 23'-4" measured from the top of the highest rail to the lowest obstruction under the structure.

2.2 Amtrak

According to Amtrak Standard Track Plan AM 70050 (2000), the minimum vertical clearance requirements are as follows:

- 23'-0" for overhead bridges and other structures in non-electrified territory
- 24'-3" for overhead bridges and other structures in electrified territory for 22'-0" trolley wire
- 26'-9" for overhead bridges and other structures in electrified territory for 24'-6" trolley wire height

2.3 California Public Utilities Commission

According to CPUC General Order (GO) No. 26-D (1981), the minimum overhead clearance above railroad and street railroad tracks are as follows:

- 22'-6" for freight cars
- 14'-0" for non-freight cars

2.4 Caltrans

According Caltrans Highway Design Manual (HDM) 2018 Sixth Edition, Section 309.2, federal aid participation requires that the following vertical clearances are provided over railroad facilities:

- 23'-4" over the top of rails for non-electrified rail systems
- 24'-3" over the top of rails for 25 kV electrification

According to Section 309.5, the Caltrans minimum vertical clearance requirements to "highway overhead and other structures including through railroad bridges" are as follows:

- 23'-4" above the highest rail for normal freight

- 19'-0" above the highest rail for tracks with no freight cars operated

2.5 California High-Speed Rail Authority

All CHSRA proposed systems are electrified. According to California High-Speed Train Project Civil Directive 904 (2015), the minimum vertical clearance requirements are as follows:

- 27'-0" for new structure over both dedicated HST and shared used track
- 27'-0" for existing structure over dedicated HST track
- 24'-6" for existing structure over shared used track
- 24'-0" for existing structure over dedicated HST track operating less than or equal to 125 mph

2.6 Sacramento Regional Transit District

All Sac RT systems are electrified. According to Sacramento Light Rail Design Criteria (1993), Section 3.2.3, the minimum distance from the top of the high rail to an overhead obstruction is as follows:

- 19'-6" if the trackway is paved and mixed traffic is probable
- 14-6" in exclusive right of way areas where unauthorized access to the right of way is prevented

3 Recommendation

Since the pedestrian concourse structure shall be built before the construction of California High-Speed Rail, the CHSRA vertical clearance requirement of 24'-6" for existing structure over shared used track is recommended. Furthermore, 24'-6" vertical clearance satisfies vertical clearance requirements of the relevant agencies:

- UPRR requirement of 23'-4"
- Amtrak requirement of 24'-3" for overhead bridges and other structures in electrified territory for 22'-0" trolley wire
- CPUC General Order (GO) No. 26-D (1981), requirement of 22'-6" for freight cars
- Sac RT requirement of 19'-6"
- CHSRA requirement of 24'-0" for existing structure over dedicated HST track operating less than or equal to 125 mph
    - It should be noted that the speed of trains entering SVS will be greatly reduced and well under 125 mph. In addition, all trains will stop or terminate at SVS; therefore, passing under the pedestrian concourse structure at very low speeds (<30 mph).

File Note

December 19, 2019

- CHSRA requirement of 24'-6" for existing structure over shared use track
    - It should also be noted that a shared use scenario is likely within the station.

4 References

American Railway Engineering and Maintenance-of-Way Association. *AREMA Manual for Railway Engineering*. 2012.

Amtrak. *Standard Track Plan AM 70050*. 2000.

California Department of Transportation. *Highway Design Manual, U.S. Customary Units, Sixth Edition.* 2018. https://dot.ca.gov/-/media/dot-media/programs/design/documents/hdm-complete-14dec2018.pdf

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California High-Speed Rail Authority. *Technical Memorandum 3.2.1 – OCS Requirements.* 2010. https://www.hsr.ca.gov/docs/programs/eir_memos/Proj_Guidelines_TM3_2_1R01.pdf

Capitol Corridor Vision Implementation Plan. 2016. https://images.capitolcorridor.org/wp-content/uploads/2016/12/CCVIP-FINAL-REPORT.pdf

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Union Pacific Railroad – BNSF Railway. *Guidelines for Railroad Grade Separation Projects – General Overhead Structure Drawing*. 2016.

DOCUMENT CHECKING (not mandatory for File Note)

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[Status]

City of Sacramento Public Works

Sacramento Valley Station Concourse Architecture Concept

Structural Design Narrative

4-05 Reports & Memos

Issue | April 3, 2020

Job number 252563-00

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Contents

Document verification

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Job title		Sacramento Valley Station Concourse Architecture Concept		**Job number** 252563-00
Document title		Structural Design Narrative		**File reference**
Document ref		4-05 Reports & Memos		
Revision	**Date**	**Filename**	04.03.2020_SVS Structural Narrative_Station Architecture Concept.docx	
Draft 1	Mar 27, 2020	**Description**	First draft	
			Prepared by	Checked by	Approved by
		Name	Kion Nemati	John Worley	Mathew Bamm
		Signature			
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		Description			
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Issue Document verification with document					✓

1 Introduction

The purpose of this report is to present the development of the structural design scheme in support of the Architect's Concourse Station concept for the Sacramento Valley Station Master Plan Bus Facility. The focus on the Concourse structure will also include relevant commentary on associated existing and new/proposed structure in the vicinity of the Concourse. The primary focuses of this report are to present the following: developed structural column grid in coordination with tracks platforms and the bus plaza, define structural criteria and scheme for the Concourse structure, and identify areas for future coordination.

The Sacramento Valley Station Master Plan Concourse connects a handful of different modes of transport including the proposed Bus Facility, Amtrak, Light Rail, and multiple points of pedestrian access. It spans over the existing Union Pacific railway and is approximately 800ft long by 130ft wide. It is an open-air structure with an elevated & covered Lower Concourse area to the south, near the Bus Facility, and an elevated & covered Upper Concourse area to the north that primarily spans over Amtrak and the Union Pacific railways. The structure's touchdown to grade is heavily site constrained as it must traverse over a handful of existing and proposed elements. As such, determining a feasible column grid is of significant importance.

The structure's gravity system are steel beams and trusses with concrete topped (floor) and untopped (roof) metal deck, supported on concrete columns. For the section of Concourse North of the Bus Terminal, the use of a full floor-height Vierendeel and Pratt Bridge Truss combination enables the Concourse to achieve long spans of up to 150ft over numerous constraints. The lateral system from the Concourse roof to floor is a mix of moment and braced frames which transfer into concrete shear walls that extend down to pile caps.

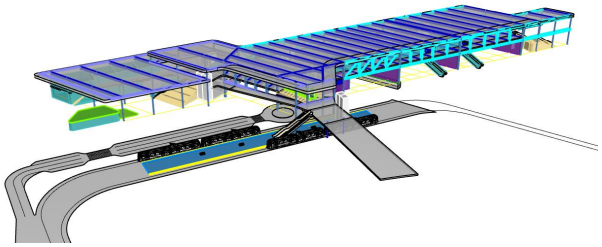

Figure 1 South East Perspective of Concourse Concept with Structure from Project Rhino Model

2 Design Criteria

2.1 Codes and Standards

The governing code is not yet known as the permitting schedule of the facility is not known. However, for the purposes of schematic sizing, the following codes are referenced:

- IBC 2018: International Building Code
- ASCE 7-16: Minimum Design Loads for Buildings and Other Structures
- ACI 318-14: Building Code Requirements for Structural Concrete
- ANSI/AISC 360-16: Specifications for Structural Steel Buildings
- ANSI/AISC 341-16: Seismic Provisions for Structural Steel Buildings.

2.2 Dead Loads

Design dead loads include the self-weight of all structural elements plus the superimposed load (SDL) of architectural floor finishes, cladding, services/utilities and fixed equipment. The following SDL criteria (not including the weight of structure) is assumed for initial member sizing.

Table 1: Concourse Floor - Assumed SDL

Parking Level Slab	Superimposed Load
MEP + Misc	20 psf
3.25in LWC o/ 3in Metal Deck	47 psf

Table 2: Concourse Roof - Assumed SDL

Bus Level Slab – Under Buses	Superimposed Load
MEP + Roofing + Misc	12 psf
Untopped Metal Deck	3 psf

2.3 Live Loads

As the design is still in concept, a detailed space layout is yet to be developed. The primary purpose of the structure however is as a walkway and elevated platform. Based on this assumption the minimum design live load (LL) per the provisions of ASCE 7-16 are tabulated in the following tables. It is expected that as design develops, discreet locations may have larger live load demands, however the majority of the space is still expected to be designated as a walkway and elevated platform.

Table 3: Concourse Floor - Assumed LL

Occupancy	Live Load
Walkways and elevated platforms (other than exitways)	60 psf

Table 4: Concourse Roof - Assumed LL

Occupancy	Live Load
Ordinary flat pitched and curved roof	20 psf

In addition to the loading shown above, a final design should be checked against loading and patterning defined by the most current version of the AASHTO Bridge Design Specifications.

2.4 Seismic Loads

The following is taken directly from the Sacramento Valley Station Bus-Mobility Center 30% Design, Geotechnical Design Narrative. See the full memorandum for additional information.

The 2019 California Building Code refers to the design code by American Society of Civil Engineers ASCE 7-16 (2016) for the development of site-specific response spectra. The Wallace and Kuhl (2013) report classified the site as Site Class F, specified where soils are vulnerable to potential collapse i.e. liquefaction, which requires a site response analysis be carried out. The Engeo (2008) report classified the site as Site Class E as they estimated a lower liquefaction potential. According to ASCE 7-16 Section 20.3.1 any structure with a fundamental period less than 0.5s is exempt from Site Class F. We understand that the fundamental period of the structure is expected to be below 0.5s, so we have assigned Site Class E. This may need to be reevaluated at a later stage when the concourse is added. – *Note: This has been written in terms of the bus facility, the Concourse is in too early of a design phase to assess whether its fundamental period is below or above 0.5 seconds, it is anticipated to be around this value however. With that being said, for the Concourse, it is not anticipated that the increase in force demands from a site specific response spectrum will significantly change the structural scheme because it will not be a long period structure.*

Since S_1 is greater than 0.2s and the site is classified as Site Class E, the site-specific ground motion procedures specified by ASCE7-16 Chapter 21.2 are required. This is beyond the scope of this memorandum. Presented below are the seismic design parameters from Chapter 11, assuming an F_v value of 4. While not directly compliant with ASCE7-16, this is assumed adequate at this stage of design as it is likely to be conservative once the analysis specified in Chapter 21.2 is carried out. Table **5** presents the seismic design parameters determined from ASCE 7 online hazard tool.

Table 5: Seismic Parameters Site Class E

Latitude: 38.58363º N Longitude: 121.49945º W	Factor/ Coefficient	Value
Seismic Importance Factor, I_e		1.25
Mapped Peak Ground Acceleration MCEG	PGA	0.24
Short-Period MCER at 0.2s	S_s	0.57
1.0s Period MCER	S_1	0.254
Soil Profile Type	Site Class	E
PGA Site Coefficient	F_{PGA}	1.783
Short Period Site Coefficient	F_a	1.587
1.0s Period Site Coefficient	F_v	4.0[1]
Adjusted MC Spectral Response Parameters	PGA_M	0.426
	S_{MS}	0.905
	S_{M1}	1.016[1]
Spectral Acceleration Parameters	S_{DS}	0.604
	S_{D1}	0.677[1]
Long-Period Transition Period	T_L	12
[1]Assumed F_v value of 4.0.		

The analysis method used for the code-based design of the primary lateral force-resisting system will likely be a response spectrum analysis. With special reinforced concrete shear walls from grade to first floor of the concourse, and a combination of ordinary moment frames and ordinary braced frames from the concourse floor to roof.

2.5 Wind Loads

Wind loading parameters for the building structure according to ASCE 7-16 are given in Table 6. The exposure category for wind loads is based on the ground surface roughness surrounding the site. Open terrain with scattered obstructions (surface roughness C) prevails upwind of the site. Note that the structure is conservatively assumed to have a Risk Category of III.

Table 6: Wind Load Parameters

Parameter	Design Value
Basic Wind Speed, V	105 mph
Wind Importance Factor, I_w	1.25

3 Design Concept

3.1 Overview, Layout, & System

As stated in the introduction, the Concourse's design needs to account for a handful of different site constraints. As a result, the design team agreed that most efficient manner to produce a concept design was to do so via 3d modeling. This was done in Rhino in a back and forth model sharing process. The most, up to date, grids, member geometry and sizing is contained within the Rhino model titled *S-SK-010 - MODEL_CHANGES FROM PLATFORM TO PUDO.3dm*. That key information is described within further detail in this report. For a layout of major structures and site constraints around the Concourse see Figure 2.

The Concourse's overall structural system is described in the Introduction. On the left-hand side of Figure 3 the Lower Concourse portion can be seen, its floor elevation is at +20'-0" above grade, while its roof elevation is at +39'-0". The right-hand side of the image makes up the Upper Concourse with floor and roof elevations of +32'-0" and +55'-0", respectively. A set of ramps, stairs and escalators connect the Lower and Upper Concourses.

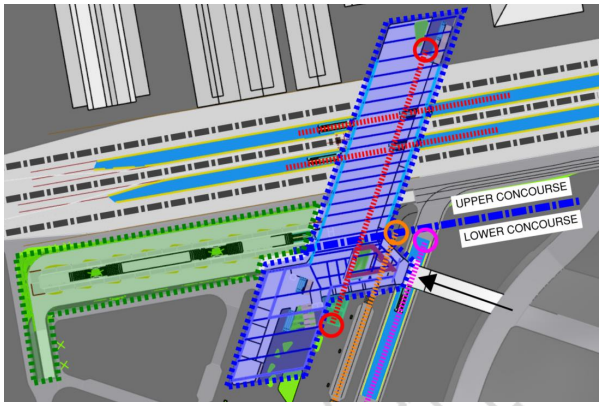

Figure 2 Diagrammatic plan view of SVS Concourse and surrounding elements; blue region – Concourse, green region – Bus Facility, black dash-dot line – Amtrak and Union Pacific tracks, red dotted line – Pedestrian Tunnel, orange dotted line, pick-up drop-off route (PUDO), pink dotted line – light rail (LRT), black arrow – LRT platform

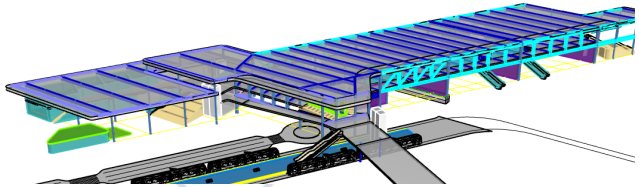

Figure 3 Concourse perspective. For reference, the left-hand side of the image is project south-east. Key structural elements: blue - floor and roof trusses, cyan – bridge truss, teal – columns, purple, shear walls.

3.2 Gravity System

The floors for the Concourse are concrete topped metal deck spanning plan east-west to steel wide-flange beams which then span to steel trusses that are 4 to 6ft deep, see Figure 4. The Lower Concourse columns are on a 45ft grid running plan north-south, and a 30 to 60ft grid running East-West. The Upper Concourse columns are spaced out much farther, ranging from 130 to 150ft in both major directions. See Figure 5, for the diagrammatic column layout. Reinforced concrete columns range from 2 to 4ft in diameter and are categorized by location in the Rhino model.

In contrast to the gravity system of the lower concourse where floor and roof trusses span to columns, the upper concourse spans these truss elements to a perimeter steel bridge truss which then transfers load to the columns. The bridge truss allows the concourse to achieve long spans up to 150ft. The horizontal elements of the bridge truss are 4ft deep while the vertical elements are 3ft 6in deep. Over the longest span, 150ft, diagonal elements were added to keep the truss top and bottom horizontal element depth to a minimum.

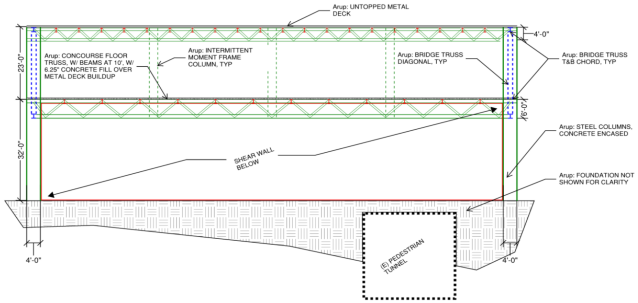

Figure 4 Section through Upper Concourse in the location containing the Bridge Truss, showing steel wide-flange beams in red (being cut in section) spanning to steel floor and roof trusses.

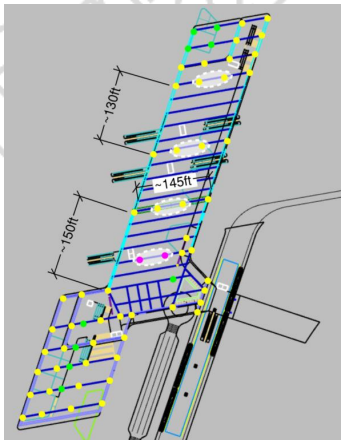

Figure 5 Concourse column grid. Yellow - columns from grade to Concourse Roof, green - from grade to Concourse floor, pink - from concourse floor to roof. Columns enclosed in a dotted white oval are moment frame columns to resist lateral load transverse to the bridge truss.

3.3 Lateral System

The lateral system for the Upper Concourse has seen further refinement over that of the Lower concourse. This is primarily due to the Upper Concourse design having a closer focus to date, and also it being more site constrained which essentially requires the lateral system to be in certain locations.

The lateral system from the roof to floor of the Upper Concourse in the direction transverse to the bridge truss (approximately plan east-west), are steel moment frames to allow for open circulation. These include added columns beyond what was primarily needed for the gravity system and can be seen in white ovals in Figure 5. In the longitudinal direction (approximately plan north-south), the system is a combination of steel moment and braced frames. Some of these frames transfer load directly down into a concrete shear wall, which is the lateral system from grade to the Concourse floors. Other frames with no shear wall directly below need to transfer lateral loads directly into the Concourse floor diaphragm which then redistributes it to the shear walls. The shear walls are 18in thick special reinforced concrete shear walls, their locations are the purple lines in Figure 6. Additional lateral system locations are also required, as shown by the orange lines in Figure 6, but are more flexible in their exact location, allowing them to better integrate with future programming development. These orange lines represent the approximate length and orientations required in each white region and can be either a concrete shear wall or steel braced frame.

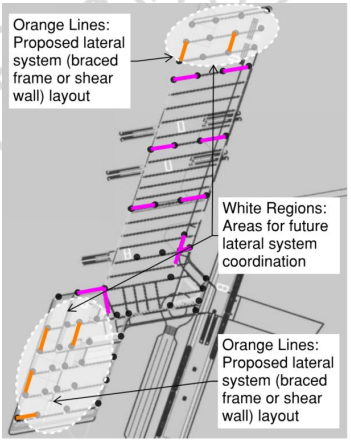

Figure 6 Concourse lateral system layout.

3.4 Key Provisions for Future Design Development

Note that the concept design is not fully vetted and coordinated, some of the key outstanding structural tasks are:

- Coordination of lateral system layout, especially at the North and South ends of the Concourse, as indicated in Figure 1.
- Study to determine where seismic joints are necessary, for example, between: Upper and Lower Concourse, and between the LRT Platform.
- Continued coordination to determine whether entire bridge truss can be simplified into a Vierendeel and still accommodate various spatial constraints such as escalator clearances.
- Foundation layouts near and over existing tunnel.
- Desired Concourse ramp and stair support scheme and connection details.

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