WASHINGTON
UNION STATION
STATION EXPANSION

Draft Environmental Impact Statement for Washington Union Station Expansion Project

Appendix A5c –

Action Alternatives Refinement Report

Appendix B – Station Infrastructure Concept Refinement Information for Fire, MEP and Structural

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U.S. Department of Transportation
Federal Railroad Administration

January 2020

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Appendix B

Station Infrastructure Concept Refinement Information for Fire, MEP and Structural

JANUARY 2020

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Contents

INTRODUCTION

Scope of Work, Including Coordination with Terminal Infrastructure

This chapter of the AARR references the *Concept Design Report* (CDR). Refer to section 1.3.2 of the AARR for detailed information regarding coordination with Terminal Infrastructure and Cost and Constructability teams. The main outcomes from the Alternatives Refinement engineering advancement can be summarized as follows:

1. Conceptual approaches to egress have not changed (refer to CDR).
2. Above-grade structure grid in support of the SEP has been adjusted to accommodate revisions to the H Street support strategy and transfer strategy. Updates have also been made to accommodate updates to the structure for the adjacent private air-rights development (PARD) and H Street Bridge.
3. Structural design modifications have been made to include preliminary mitigation measures in relation to the SEP *Threat and Vulnerability Risk Assessment* (TVRA), which was concluded concurrent with the CDR. Due to the sensitivity of this type of information, reference is made to the TVRA for a summary of the threats, design basis risks, and other aspects.
4. Structural depth allowances have been updated to accommodate the items above.
5. Train hall ventilation strategy is consistent with the CDR; however, the sizing of ventilation elements has been updated to accommodate updates to the preliminary alternatives and the PARD.
6. Below-grade ventilation strategy is consistent with the CDR; however, the accommodations for rising shafts has been updated to accommodate updates to the preliminary alternatives and the PARD.
7. Utility loads have been updated, following coordination with the Architect of the Capitol.

Upgrades to engineering systems within the historic station and Concourse A are ongoing and do not impact the development and comparison of the range of Action Alternatives; they are therefore not included in this report.

Scope of Work in Relation to Other Adjacent Development

H-STREET BRIDGE

H Street Bridge, a six-lane vehicular bridge, spans over the rail terminal connecting North Capitol Street with 3rd Street, NE. It is an independent structure and was constructed in the 1960s and rehabilitated in the 1970s. It is a steel bridge with a concrete deck supported on structural steel beams and columns. For the majority of the bridge length, the steel columns bear on large diameter concrete piers and pile caps. The transition from steel to concrete nominally occurs at the track elevation (the H Street underpass). The large diameter (greater than six feet) concrete piers pass through the H Street underpass level. The pile caps are supported on steel encased concrete piles, approximately 50 feet deep. At the east and west ends of the bridge, the bridge girders are supported directly on concrete piers and footings.

H Street Bridge is being replaced through a parallel project being carried out by the Washington DC Department of Transportation (DDOT), and is currently being designed by DDOT's Engineering Consultants.

As the pier locations conflict with future track plans, and the pier pile caps will be undermined by the SEP, the structure is being coordinated such that:

1. Columns will be on platforms.
2. Columns may transfer through the SEP, especially in locations where they would inhibit passenger flow in concourses. The transfer structure may be installed by the SEP.
3. H Street Bridge foundations will be designed to be low enough that they are not impacted by the SEP.

Clearances and utilities for H Street bridge have been coordinated and discussed with DDOT, District agencies, the Proponents, and FRA.

AIR-RIGHTS DEVELOPMENT

The platforms and tracks are located below the air-rights for a future development, portions of which are Federally owned and portions of which are privately owned. The SEP, therefore, includes engineering systems to support the Action Alternatives.

Relationship to Coordinated Documents

TVRA

A TVRA was completed in July 2016, and has informed the planning and structural design scenarios in particular. Due to the sensitive nature of the methodology and findings, its contents are not summarized in this report.

The TVRA defines threat and performance criteria within the SEP, as well as adjacent areas including H Street, that would impact upon WUS. The demarcation is demonstrated in the graphic below.

At this stage, the following outputs of the TVRA have impacted upon these aspects of the structural design of the Project:

- Force Protection (Blast)
- Progressive Collapse

Other outcomes of the TVRA will affect other planning aspects of the SEP and will be coordinated in the subsequent phases of design.

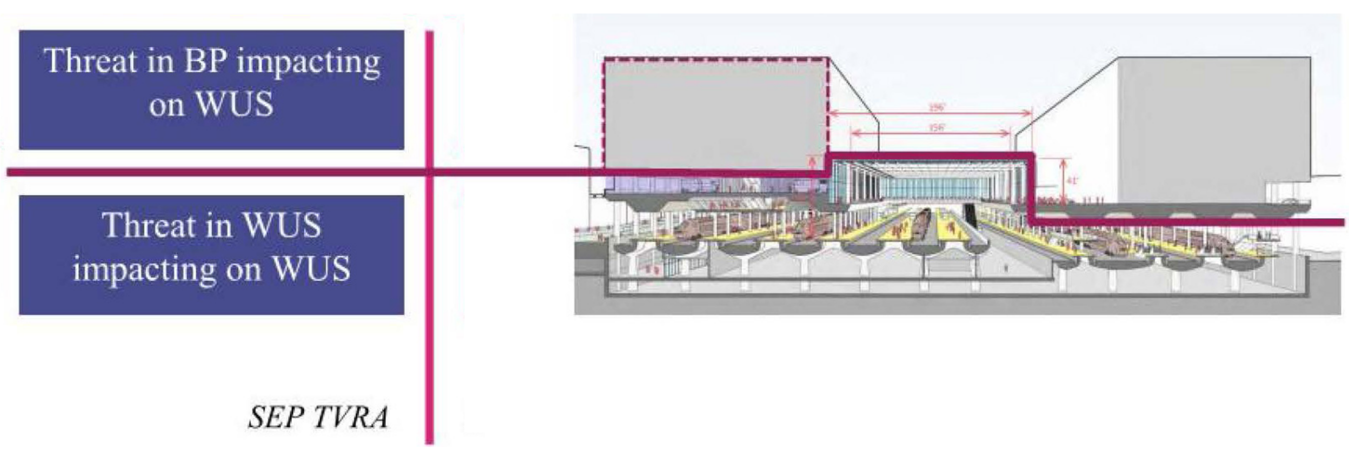
DESIGN CRITERIA REVIEW

Design Criteria Review reports are used to memorialize the Basis of Design (BoD) parameters with which the SEP Concepts should comply.

The BoD, which encompasses the Structural Engineering, Mechanical, Electrical and Plumbing (MEP), and Fire Engineering has been submitted as a separate document and contains information on the following:

1. Codes and standards
2. Owner requirements
3. Design parameters, including input from the *Final Report of Geotechnical Study*, dated December 2018, along with the *Draft Report of Aquifer Pumping Test and Seepage Analysis* dated November 2018 and subsequent discussion
4. Resilience
5. Existing conditions

The BoD establishes the criteria to which all Action Alternatives must comply. This report works alongside the BoD to describe and delineate the manner by which the Action Alternatives comply. Therefore, the BoD is an important reference document, but its findings are not duplicated in the AARR.



STRUCTURAL ENGINEERING CONCEPTS

Column Grid

A number of iterations of column grids were investigated with several factors influencing the results. It is important to note that there are several levels of column grids to consider. At the top is the Private Air-Rights Development (PARD) grid, which is transferred or otherwise superimposed onto the platform level grid. The concourse level below the track and platforms will have a different grid with the addition of columns to support the track structure. The grid at the concourse level will continue through any below-ground parking down to foundations.

PLATFORM GRIDS

The column spacing in the east-west direction is directly influenced by the track layout. Typically, the east-west spacing is approximately 55', centered on the platforms. The column spacing in the north-south direction is more flexible and spacing of 30' and 45' was investigated. Together, two grids were investigated at the platform level, approximately 55' x 30' and 55' x 45'. Refer to Figure B-3 for platform level plan.

CONCOURSE GRIDS

Spacing for track supporting columns was considered for 30' and 45' spans to coincide with the north-south spacing of the PARD supporting columns. Together, the two grids combine to create an approximately 27.5' x 30' and 27.5' x 45' typical grid at the concourse level, which continues down through any below-ground parking down to foundation. The actual grid varies considerably based on location and complexity of the building geometry above. Refer to Figure B-2 for concourse level plan.

BELOW-GRADE PARKING GRID

The column grid in any below-grade parking levels was set at an approximately 27.5' x 30' grid in most areas, including areas where a larger, approximately 27.5' x 45' grid exists above at the concourse level. This approach was considered to increase the structural efficiency in these areas where there would be minimal architectural impacts. Additionally, the tighter column spacing would make it easier to conform with TVRA requirements. Refer to Figure B-1 for typical below-grade parking level plan.

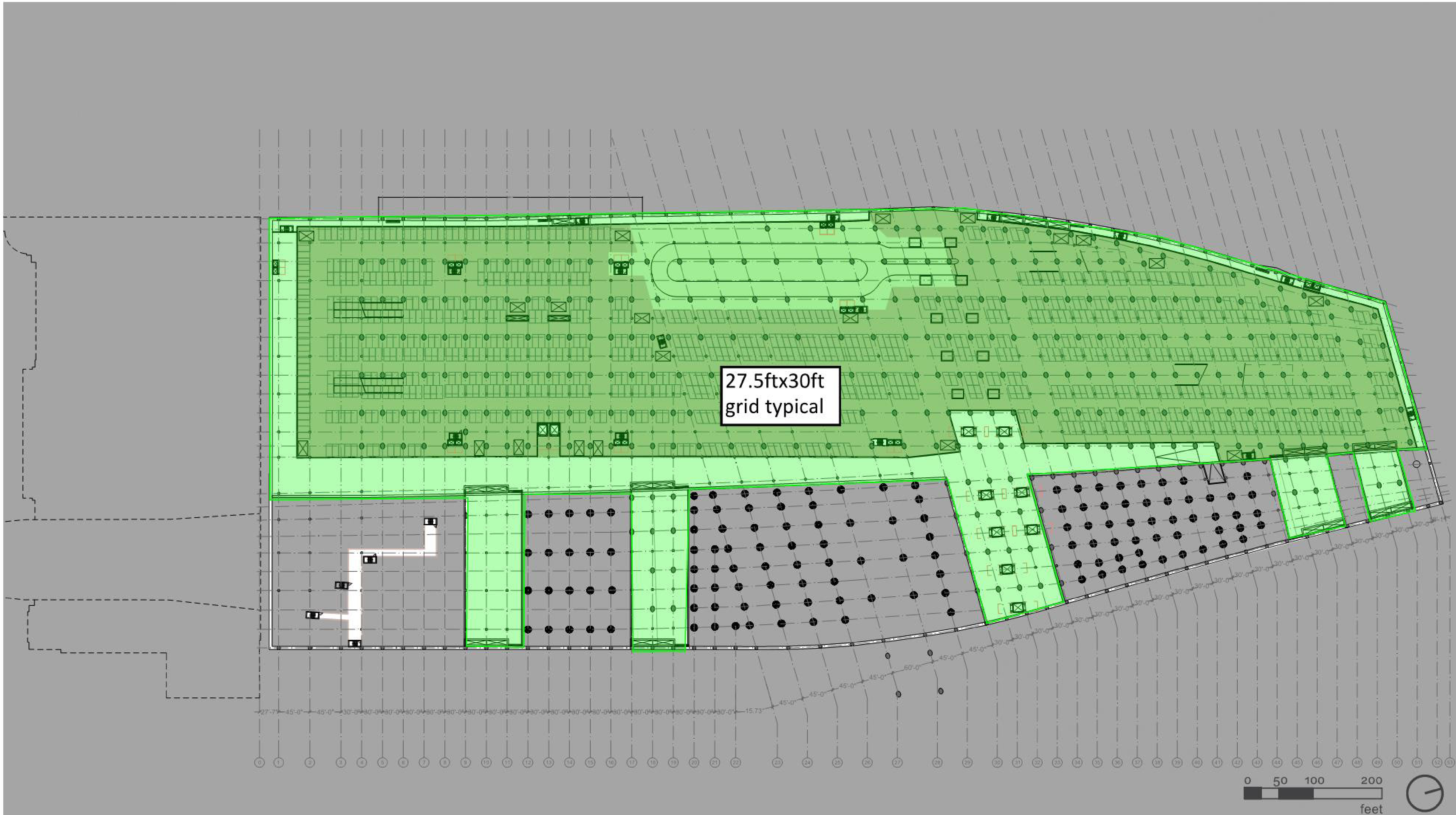
LOCAL ALTERNATE CONCOURSE GRID

The concourse level will have an approximately 27.5' x 30' typical grid in non-concourse areas. Refer to Figure B-4 for typical structural section at non-concourse areas. This column spacing is fairly conventional.

In the primary passenger circulation areas (such as the H Street and First Street Concourses) and associated waiting areas, the design goal was to improve passenger experience by reducing the number of columns landing within them. Fewer visual obstacles would improve intuitive wayfinding and circulation, in addition to providing adequate openings in the structure for required elevators and escalators. The design team determined that an approximately 55' x 45' column grid would provide the best balance between the desired quality of service and structural demands. This column spacing is considered long span and will result in a cost premium.

Adjacent to the H Street Concourse, this grid spacing would be accomplished by transferring the supporting columns at the platform level onto the track supporting columns at the concourse level. Refer to Figure B-5 for the inverted gable transfer scheme.

The inverted gable scheme would induce unbalanced lateral thrusts at the tops of the track supporting columns. These thrusts would be mitigated through a combination of increased column size and stiffness, especially at the end columns in each line of these transfers. The width of the end columns would be increased so that they act like shear walls to resist the large lateral thrusts, which occur especially at the end bays. Refer to Figure B-6 for diagram indicating the induced horizontal thrust under gravity loads and how it could be resisted.



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B1 LEVEL PLAN - ALT A/B
PARKING ABOVE - BUS ON SOUTH-WEST WITH N-S TRAIN HALL SOUTH OF H STREET

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Figure B-1: Parking Grid Plan

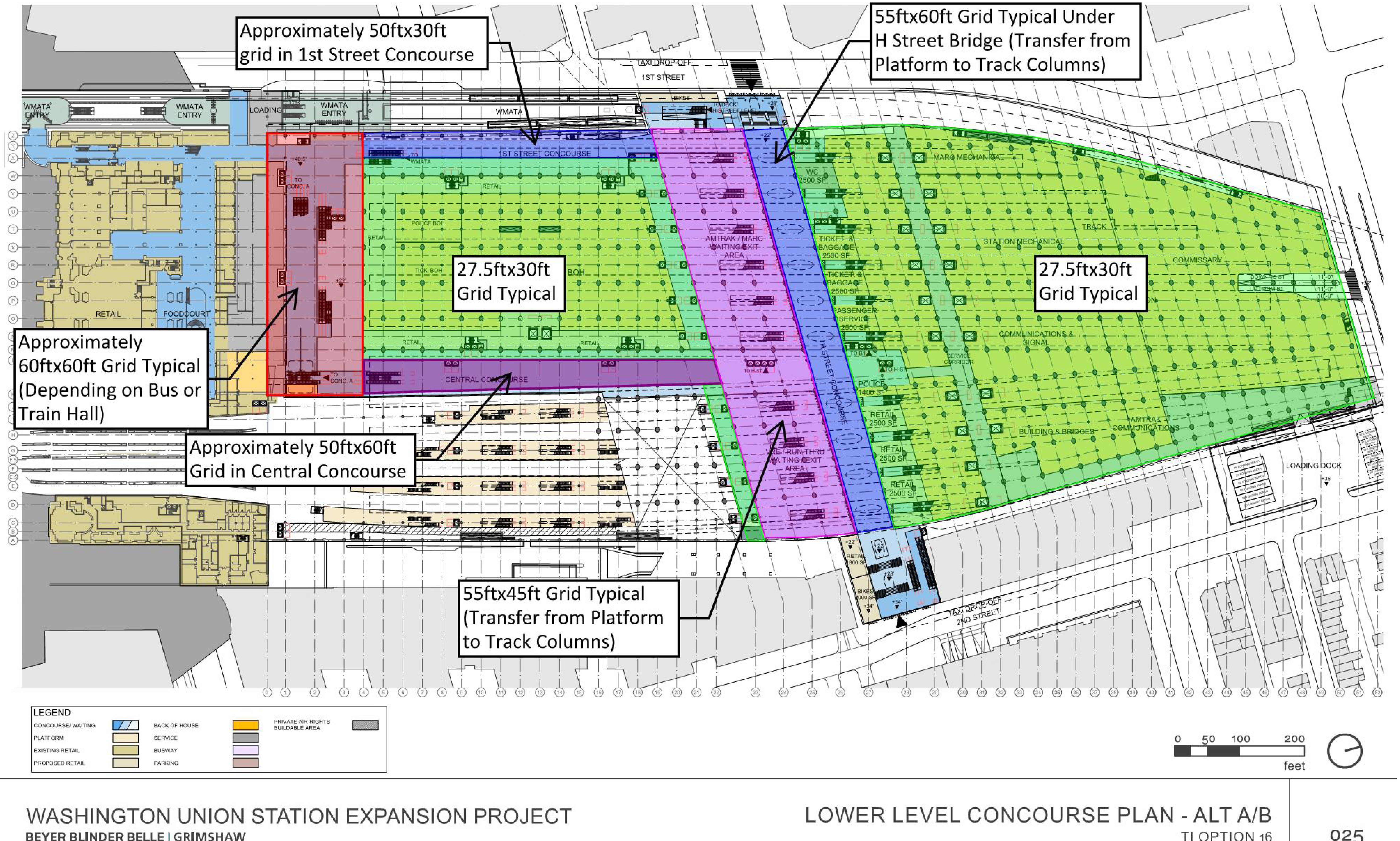
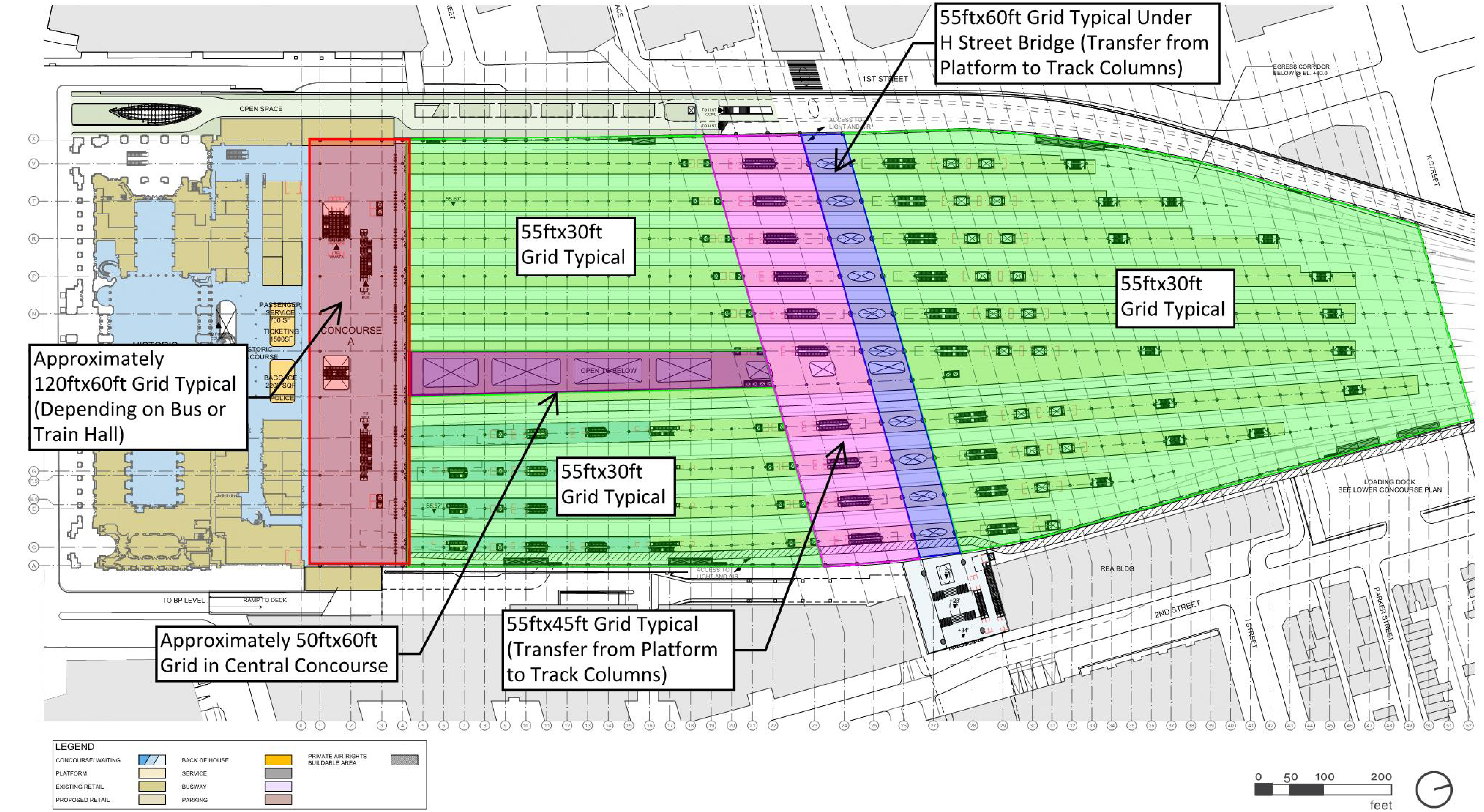


Figure B-2: Concourse Grid Plan



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STATION MAIN / PLATFORM LEVEL PLAN - ALT A/B

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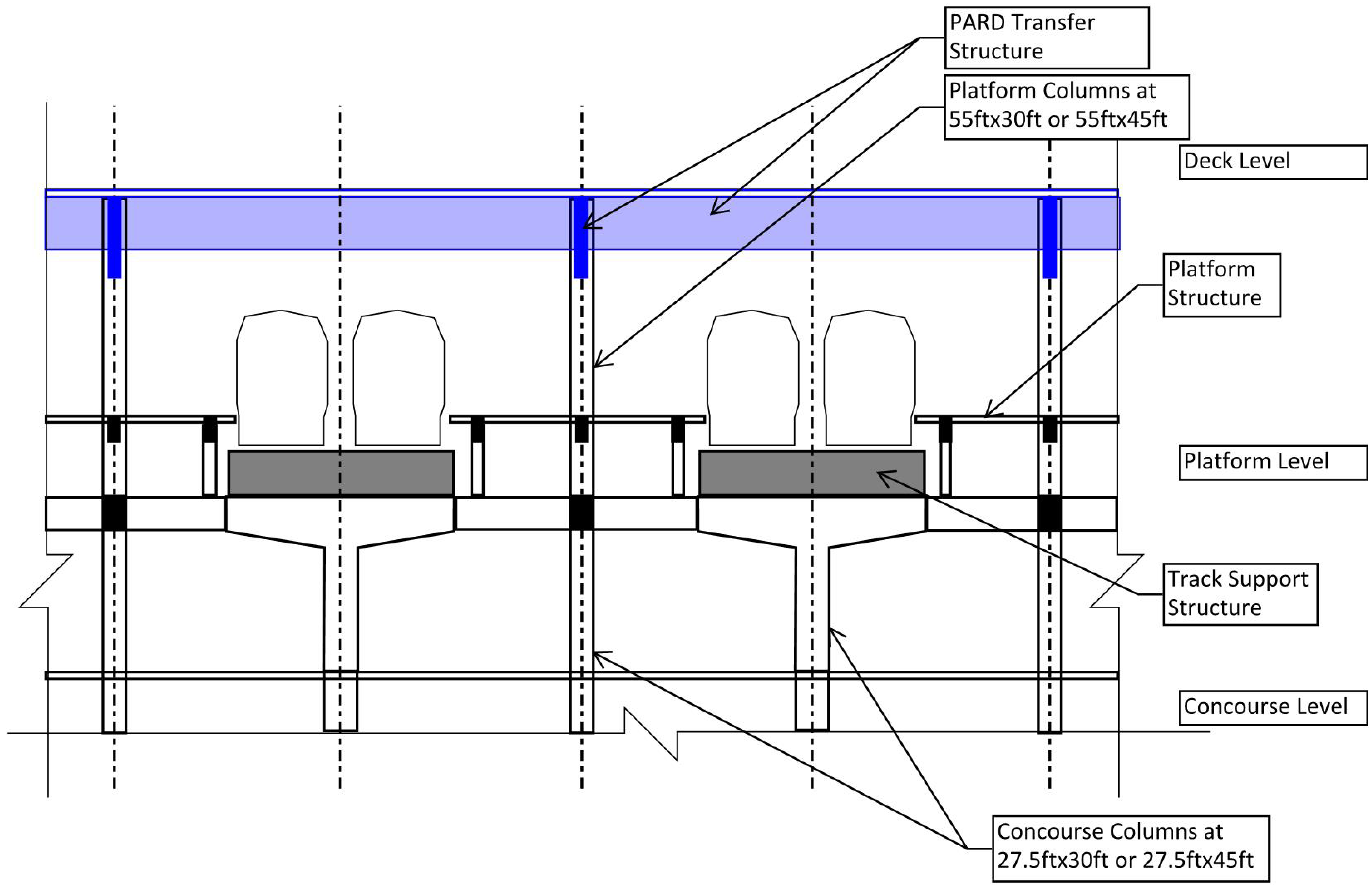
Figure B-3: Platform Grid Plan



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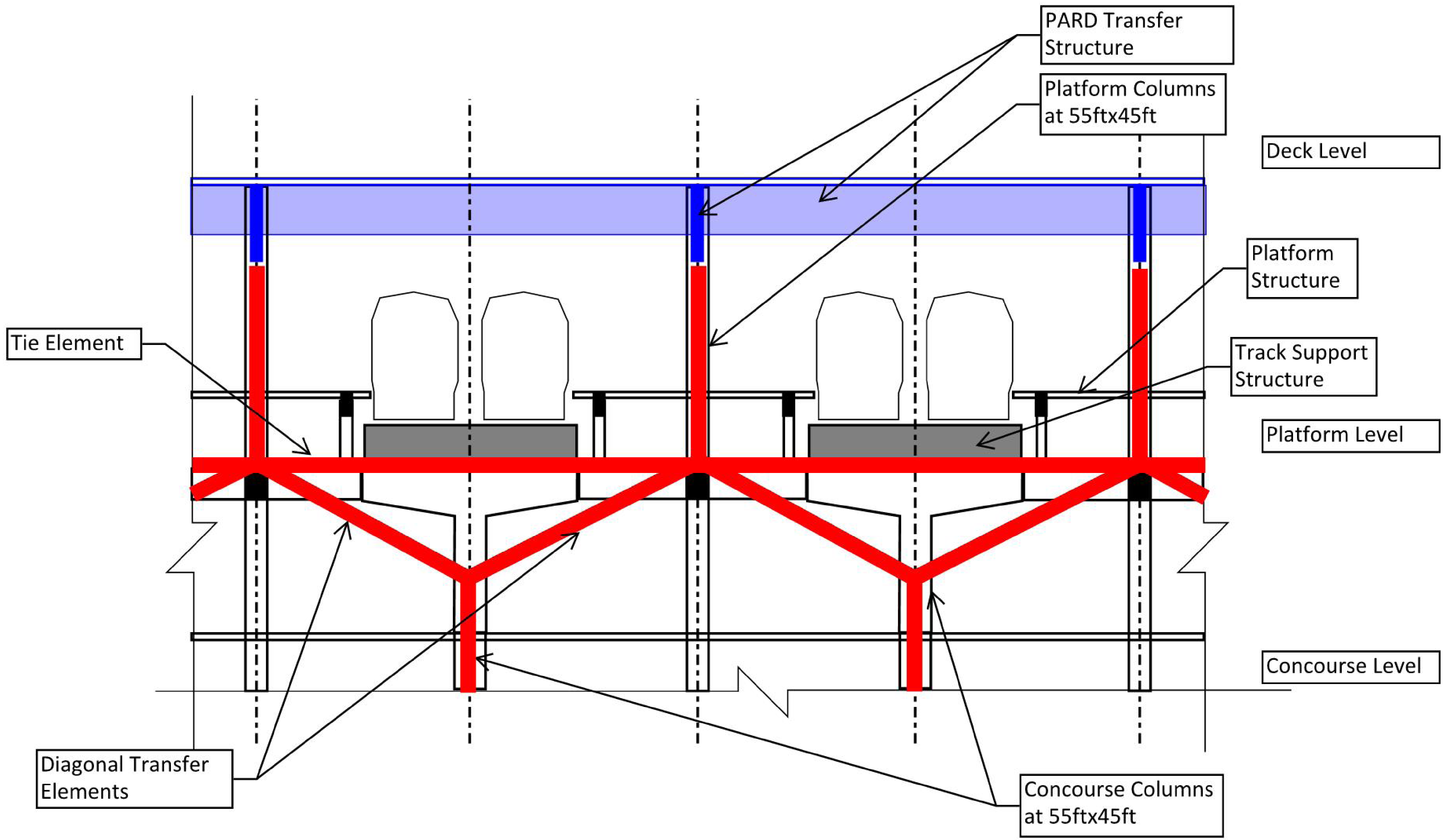
TYPICAL STRUCTURAL SECTION AT NON-CONCOURSE AREAS

Figure B-4: Typical Structural Section at non-concourse areas



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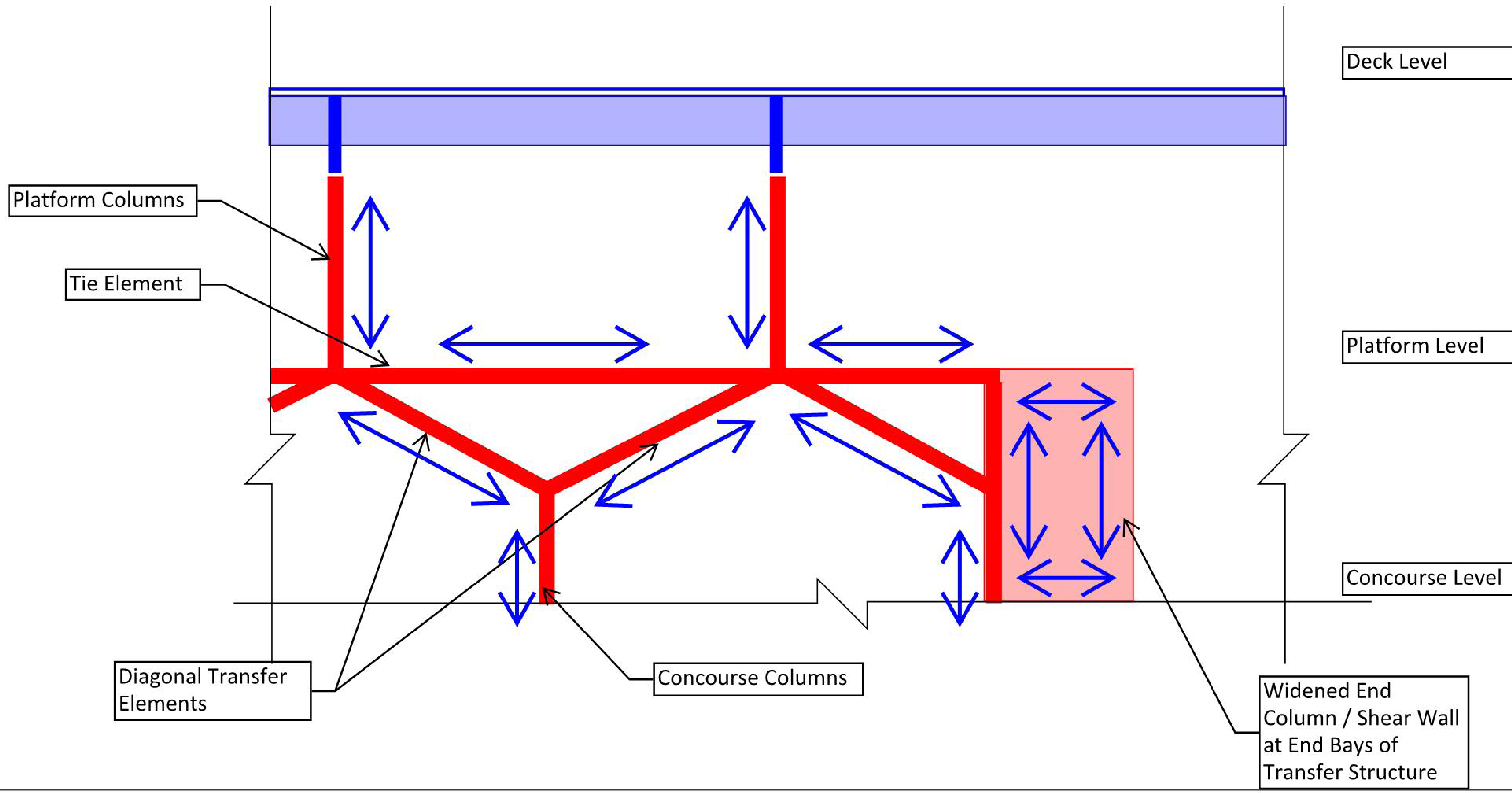
INVERTED GABLE TRANSFER SECTION

Figure B-5: Inverted Gable Transfer



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INVERTED GABLE FORCE DIAGRAM

Figure B-6: Inverted Gable Force Diagram

Lateral System

The Lateral Force Resisting System (LFRS) for the SEP needs to resist lateral loads applied directly to the station as well as those imposed from any PARD structures.

A preliminary study of the wind and seismic demands at the site found that seismic demands and requirements would generally be greater than that of wind, and thus drive the design. Further study of wind and seismic demands will be performed for selected Action Alternatives in future phases and after a geotechnical site-specific seismic evaluation is completed.

The Seismic Force Resisting System (SFRS) would consist of moment frames in each direction, which would provide the required clearances over the tracks and architectural flexibility in the lower levels. It may be possible to transition the structural materials over the height of the structure with a primarily steel structure at the top transitioning down to a primarily concrete structure at the bottom.

The lateral system would transition from steel to composite to concrete moment frames from top to bottom of the structure. Simple 2D plane models were used to assess the forces and drifts. Refer to Figure B-8 through Figure B-10 for sample analysis outputs.

Alternatively, it may be desirable to carry the same system down to foundation.

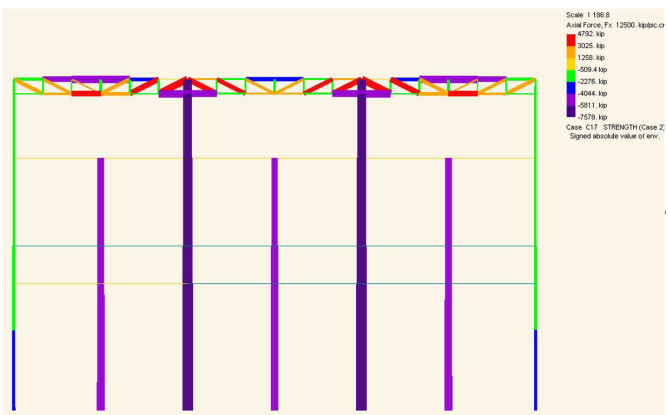


Figure B-8: Envelope Strength including Overbuild and Lateral – Axial Force Diagram

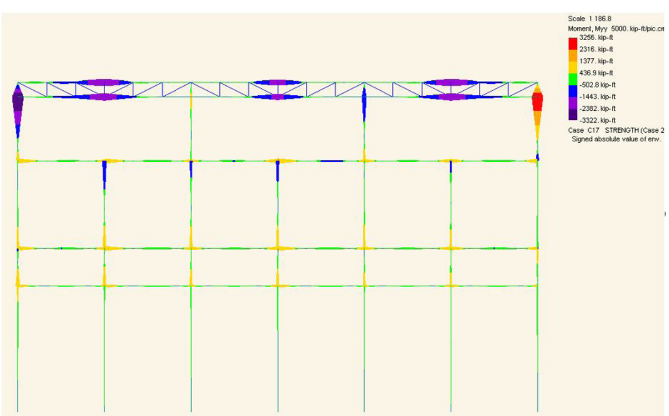


Figure B-9: Envelope Strength including Overbuild and Lateral – Moment Diagram

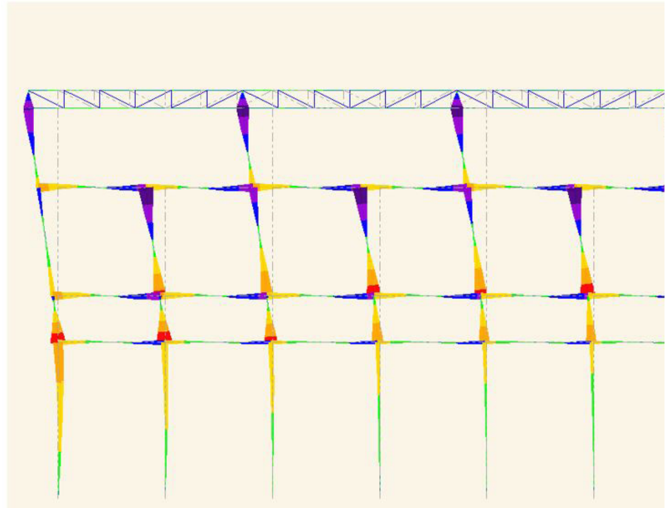


Figure B-10: Seismic Drift – Moment Diagram and Deflected Shape

Platform Column Sizes

The PARD supporting columns passing through the platform were identified as a critical element in the overall design due to their long, unbraced length; large gravity loads; large lateral moments and stiffness requirements; and width limitations.

The columns are limited to 36" total width including finishes. This dimension allows the columns to fit between the VCEs. It may be possible to relax the maximum width requirement of the columns in areas away from the VCEs in order to increase the structural efficiency. The columns were assumed to be braced at the track supporting pier level, as opposed to at the high platform level which lacks the lateral stiffness required to brace the columns.

For the 55' x 30' grid, the columns could be concrete encased heavy W14 rolled sections with additional welded plates or built-up box sections as needed to support loads imposed by the PARD. For the 55' x 45' grid, the columns would require additional plate thickness, potentially on the order of 6" or more to support the increased demands resulting from the larger tributary area. Solid steel sections, built up from several laminations of welded plates, may also be considered where axial loading dominates the column design. The sizes discussed above are for columns that are supporting PARD. Columns that do not support PARD will generally be of the same type, but with potentially significant reductions in required plate thicknesses.

In any case, the use of higher strength steel, 65-70ksi, would slightly reduce the overall steel weight of the columns. This slight reduction in material per column may prove significant when extrapolated over the entire site.

Track Supporting Structure

The track supporting structure is designed for Cooper E80 loading and consists of girders spanning between hammerhead piers. The piers would typically be spaced at 30’ on center with local areas of 45’ on center spacing in the vicinity of the H Street Concourse. Refer to Figure B-1 through Figure B-3 for typical platform, concourse, and below-ground parking plans showing extent of each grid spacing at each level.

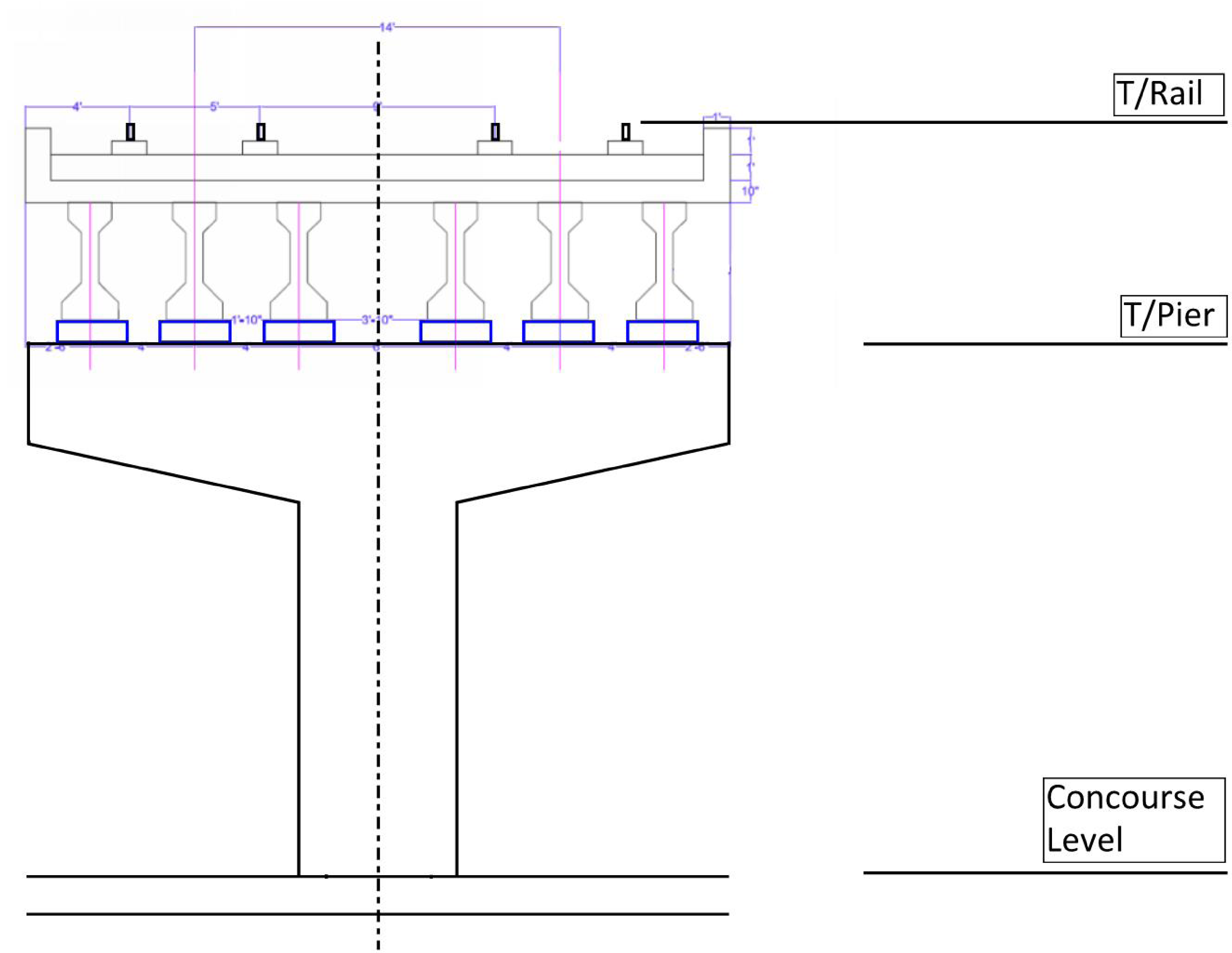
The diameter of the piers is governed by longitudinal train loading and seismic demands. The tops of the piers would be braced laterally in the east-west direction to the platform columns, and the bracing beam would act as part of the moment frame in that direction. The piers would consist of large diameter concrete columns approximately 6’ in diameter. Steel sections may be embedded to reduce the required diameter.

The piers are assumed to act as cantilevers up from the level below. It may be desirable to add bracing or moment frame beams between piers in the north-south direction along the tracks to distribute longitudinal train demands between multiple piers, and potentially reduce the required diameters.

Girders would span between the piers to support the tracks. For preliminary design we have considered using simple spans, as preferred by Amtrak, with girder depth on the order of span/10 to span/12. It may be possible to reduce the girder depth to span/14 or span/16 for continuous spans. The girders would be either steel or precast/ pre-stressed concrete. The use of steel, rather than concrete, girders may be preferable due to the potential weight savings, ability to prefabricate the deck and girder system, and for greater possible span to depth ratio.

Allowance is made for floating track slabs, which may be required to meet vibration and noise criteria. Refer to Figure B-11 for a section showing a typical track support structure in non-concourse areas.

In order to improve the station and passenger experience along the First Street Concourse, the outer tracks would not be supported on piers spaced along the length of the track. Instead, floor beams will span east-west to girders spanning between the adjacent PARD supporting columns and the exterior structural wall. This will open up the First Street Concourse below.



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TYPICAL NON-CONCOURSE AREA TRACK SUPPORT STRUCTURE

Figure B-11: Typical Track Support Structure Section (In non-public / non-concourse areas)

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Above-ground Parking

A number of Action Alternatives include new above-grade parking. Typically, the new parking is proposed to be located above and as part of a new bus structure. The new parking structure would have a typical uniform grid at approximately 30' x 30', which transfers onto a larger bus grid. Alternatively, the bus grid could be maintained continuously through the parking levels, in which case a transfer level would not be required.

The new parking may be subject to TVRA requirements which would dictate the design and be resolved in a later phase of design.

The structure would consist of composite steel framing, or Cast-In-Place (CIP) concrete framing. Alternatively, the use of pre-cast, pre-stressed, or post tensioned concrete may be considered.

Bus Structure

The new bus structure is proposed to consist of one level above grade. In several Action Alternatives, above-grade parking and/or air-rights development (in the areas that are Federally or privately owned) is indicated above, supported on the bus structure.

The bus supporting structure would consist of composite steel framing spanning between concrete encased steel columns, or CIP concrete framing spanning between CIP concrete columns. CIP columns may need to be oversized or require embedded steel sections to comply with TVRA requirements. The use of pre-cast, pre-stressed, or post tensioned elements may be considered.

A transfer structure will be required for any construction above the bus structure as column landing zones through the bus level will be limited. The column grid within the bus structure varies depending on location considered and layout. A second transfer structure may also be required between the bus grid and the station columns. Alternatively, it may be possible to arrange columns through the bus level in such a way as to avoid needing a second transfer structure.

Action Alternatives A, B, C, and A-C incorporate parking or overbuild above the bus deck and will likely require transfer structural above and below the bus level. Action Alternatives D and E require columns supporting the train hall roof to be transferred at bus level onto a different column grid through the concourse level where a number of the columns may need be transferred a second time over the run-through tracks if those columns are not able to be coordinated all the way down to foundation.

Train Hall

All Action Alternatives include a train hall south of H Street. The train hall structures would typically consist of long-span steel roof structure, likely plate girders, although trusses, or complex AESS shapes may also be considered. The lateral system would consist of moment frames in each direction, although there may be opportunity to add diagonal bracing in the perimeter walls or tie the roof diaphragms into adjacent SEP structures depending on the various Action Alternatives. Diagonal bracing may also be added within the roof to stiffen the diaphragm, if required.

Foundations

A preliminary site-wide geotechnical investigation has been completed by Wood Environmental & Infrastructure Solutions (Wood) to establish criteria for the design of foundations, retaining walls, and other subgrade elements. Refer to *Final Report of Geotechnical Study*, dated December 2018.

The following description of foundations is consistent with the Cost and Constructability analysis. Please refer to the *Cost and Constructability Final Report* for a more detailed description of the effect of foundation types on cost and schedule.

COLUMN FOUNDATIONS

Based on the completed geotechnical investigations and anticipated SEP and PARD reactions, we anticipate that most pile foundations can be supported in the Potomac layer with depth at approximately -115'. Existing grade elevation is 52' (per NAVD 88). Relatively few foundations in the vicinity of the H Street Concourse may need to be socketed into bedrock with depth at approximately -192'. The foundation reactions in the vicinity of the H Street Concourse are larger due to larger grid spacing including transferring the PARD supporting columns onto the track supporting columns at platform level. These transfers are required for the SEP station experience. Representative foundation reactions for PARD and track supporting columns at different spacing are given in Table B-1.

Table B-1: Representative Column Foundation Reactions

COLUMN	GRID/SPACING	SERVICE REACTIONS D+L (KIPS)	FACTORED REACTIONS 1.2D+1.6L (KIPS)
PARD Supporting	55 FT x 30 FT over 27.5 FT x 30 FT	4664	6196
PARD Supporting	55 FT x 45 FT over 27.5 FT x 45 FT	6996	9294
Track Supporting	55 FT x 30 FT over 27.5 FT x 30 FT	2702	4662
Track Supporting	55 FT x 45 FT over 27.5 FT x 45 FT	3822	6589

The PARD-supporting column reactions are calculated for an 11-story overbuild and two stories of below-grade public parking under the concourse level. The track supporting column reactions are calculated for two trains over a pier, located for maximum effect, with two stories of below-grade public parking under the concourse level.

Live load reduction was considered only at the overbuild levels and below-grade parking levels. Live load reduction was not considered at the deck, platform, or concourse levels. The use of live load reduction does not appear to result in a significant reduction in foundation demands.

Representative foundation reactions have reduced somewhat from the Concept Design phase. Maximum grid spacing has been reduced as a compromise between station experience and structural and foundation demands, below-grade parking has been reduced to a maximum of two levels, and train loads have been refined.

Based on the anticipated representative column reactions and recommendations by Wood, we have tabulated the following expected drilled shaft sizes based on column type.

Table B-2: Expected Drilled Shaft Foundations

COLUMN	DRILLED SHAFT DIAMETER (FT)	BOTTOM OF SHAFT ELEVATION (FT)
27.5 FT x 30 FT PARD supporting column	6 FT	-140 FT
27.5 FT x 45 FT PARD supporting column	8 FT	-140 FT
27.5 FT x 30 FT Track supporting column	4.5 FT	-140 FT
27.5 FT x 45 FT Track supporting column	6 FT	-140 FT
55 FT x 45 FT Inverted Gable Transfer Supporting Column	12.5 FT*	-140 FT*

*Drilled caissons supporting inverted gable transfer columns may need to be socketed into rock at elevation -192 FT

The use of micropiles rather than drilled shafts was also investigated. The recommended skin friction values from Wood were used to determine pile capacities, with a maximum limit of 400kips per micropile. The expected number of 12" diameter micropiles based on column type is tabulated below.

Table B-3: Expected Micropile Foundations

COLUMN	NO. 12" DIAMETER MICROPILES REQUIRED	BOTTOM OF MICROPILE ELEVATION (FT)
27.5 FT x 30 FT PARD supporting column	16	-90 FT
27.5 FT x 45 FT PARD supporting column	24	-90 FT
27.5 FT x 30 FT Track supporting column	12	-90 FT
27.5 FT x 45 FT Track supporting column	17	-90 FT
55 FT x 45 FT Inverted Gable Transfer Supporting Column	43*	-90 FT

*Micropile solution not feasible for inverted gable transfer supporting columns

Considering the results of the *Report of Aquifer Pumping Test and Seepage Analysis* (Wood), the use of a mat foundation should be considered in subsequent stages of detailed design (post 10% design). With the more shallow excavation Action Alternatives, such as Alternative A, where excavation extends minimally below the water table, the use of a mat foundation could provide savings on cost and schedule relative to the deep foundations options considered to date.

COMPARISON OF TRAIN LOAD

It is understood that the K Street Bridge is to remain in place. Per a cursory SEP preliminary assessment, the K Street Bridge appears to have been designed to support E50 loading as opposed to E80 and it is located such that all trains entering the station will cross over it.

Recalculating the foundation reactions listed in Table B-1 above for E50 loading as opposed to E80 reduces the factored dead + live reaction for the 30' and 45' spaced track supporting columns by 766kips and 1061kips, respectively. This represents approximately 16% total foundation load reduction at those locations.

Given the magnitude of the load difference, further consideration may be warranted in the design stages beyond the 10% level. However, provision for E80 loading is maintained for the SEP at this time so as to not preclude the heavier weights of potential future dual mode locomotives, and the Norfolk-Southern track rights in the terminal.

SUPPORT OF EXCAVATION (SOE)

Criteria for Support of Excavation (SOE) has been established by the soil investigation and report by Wood from December 2018. The description of methods for SOE below provides only a high-level summary based on the Cost and Constructability Analysis. Please refer to the *Cost and Constructability Report* for a more detailed description of specific systems and the resultant effects on cost and schedule.

FRA has considered a range of possible approaches for the SOE that utilize different wall systems to effectively cut off the water, such as slurry walls, sheet piles, and secant walls. The specific approach varies per Action Alternative and is based on the depth of excavation required.

Based on groundwater data, the Action Alternatives with two levels of below-grade parking (Alternatives B and E) require the deepest excavation, and therefore cut off wall foundations to bedrock. Whereas Action Alternatives with only one layer of parking below grade (Alternatives C and D) or no below-grade parking (Alternatives A and A-C) require only cut off wall foundations to the shallower clay layer.

The *Cost and Constructability Report* provides more detailed information on the specific recommended approaches for cut off walls in each Action Alternative.

Care will need to be taken adjacent to the WMATA Metrorail Station and other structures around the site. Monitoring will be required during construction.

Assuming the use of perimeter slurry walls down to bedrock around the SEP, the perimeter SOE walls would be used to vertically support the edge of the SEP structure. A line of structural columns would be embedded along the perimeter wall as required to support the edge of the SEP structure.

Note that the SOE along the southern edge of the site, adjacent to the historic station building, will be offset nominally towards the north to avoid any conflicts with the existing foundations for the historic station building. A similar offset may be required adjacent to the K Street Bridge and along the WMATA right-of-way.

Interface between Private Air-Rights Development and SEP Structure

The platform columns would support gravity and overturning loads resulting from PARD. PARD would need to coordinate exactly how their structure would transfer to the station structure with the SEP team. The private overbuild would also be required to conform to the TVRA requirements. Refer to Figure B-12 for typical scope demarcation.

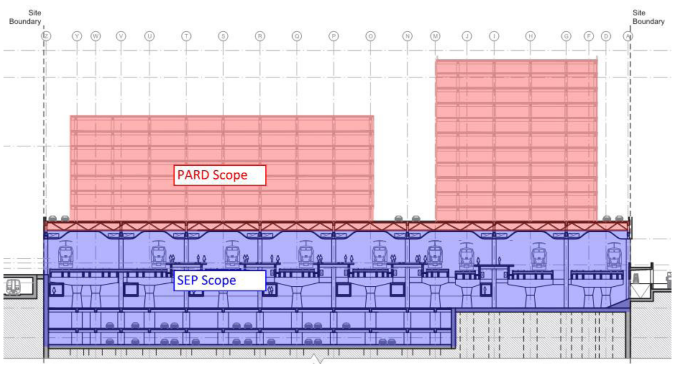


Figure B-12: Section Delineating Private Air-Rights Development from SEP Scopes

VERTICAL LOAD TRANSFER

A number of schemes have been explored to transfer the vertical loads of the PARD onto the station columns. All are feasible and work with the proposed Action Alternatives.

1. Below deck two-way transfer structure
   a. No or minimal restriction on PARD column grid
   b. Two-way beam and girder transfer system below the deck consisting of trusses in each direction to transfer vertical reactions to SEP columns

2. Below deck one-way transfer structure
   a. PARD columns in the east-west direction land on the north-south running grid lines of the SEP columns. No restriction on north-south PARD column spacing
   b. One-way girder transfer system below the deck consisting of trusses spanning north-south along the length of the platform, where there is less restriction on truss depth than over the tracks
      i. Results in more efficient truss design

3. Above deck transfer structure/no transfer
   a. Transfer structure located within the PARD structures to land the PARD columns directly on the SEP columns below
   b. Alternately provide no transfer structure and instead have the PARD columns match the SEP column layout below.

Scheme 1 as discussed above is reflected in the SEP documentation, as it would provide the most flexibility for the PARD, and is seen as the most likely choice. The final choice of system would be verified together by the SEP and PARD design teams at a later date.

INTEGRATION OF LATERAL SYSTEMS

The station LFRS would consist of moment frames as discussed previously. The LFRS for any overbuild could consist of either moment frames, braced frames, or core walls.

The choice of LFRS for the PARD and how to transfer it into the station structure would be verified by the PARD design team in coordination with the SEP design team at a later date.

Interface Between H Street Bridge and SEP Structure

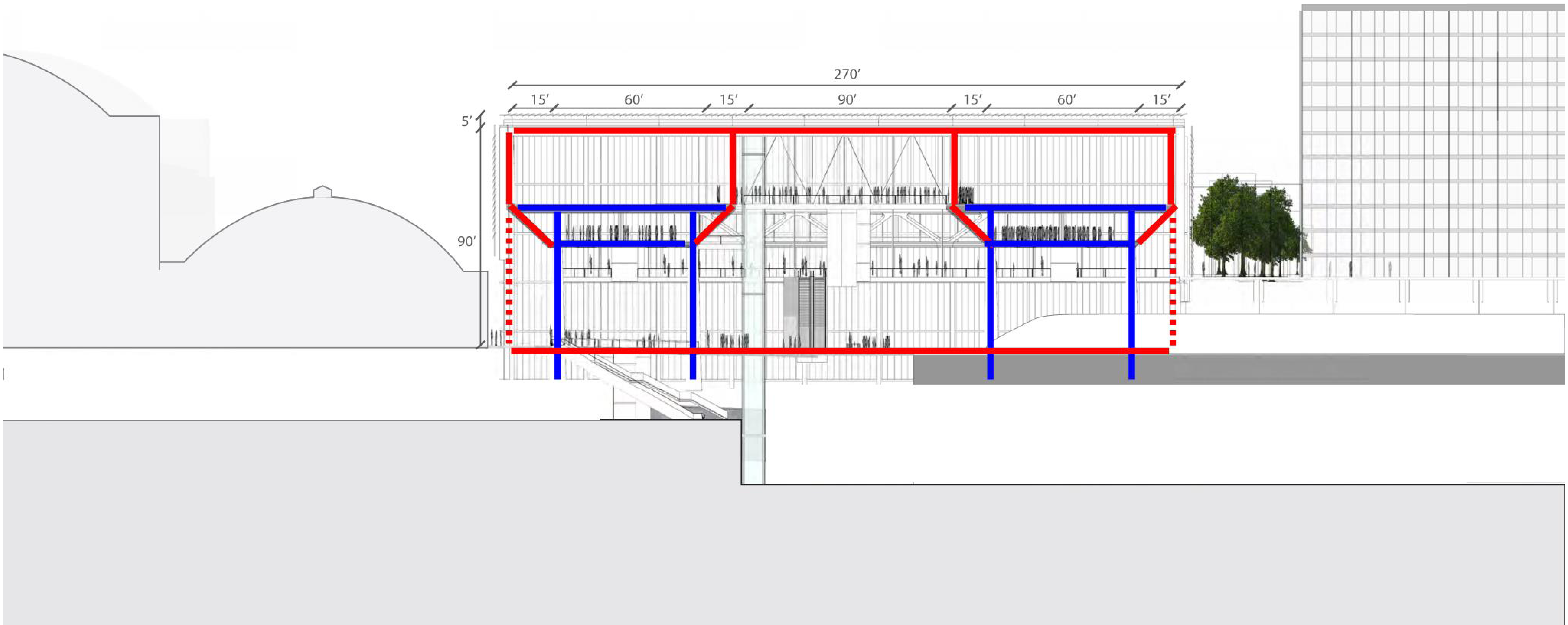
H Street Bridge spans east to west over the rail terminal and bisects the site. It is an independent structure with a steel superstructure supported on steel columns which transition to large diameter concrete piers at track elevation (the H Street underpass) and are supported on pile caps. The pile caps are supported on steel encased concrete piles, approximately 50 feet deep.

DDOT is planning major rehabilitation of the H Street Bridge in the near future. Any reconstruction must be coordinated with the updated track layouts and future below-grade spaces as part of the SEP. In the No-Action Alternative, it is assumed that DDOT would only rehabilitate the H Street Bridge. However, in light of the ongoing planning of the SEP, DDOT is planning a larger reconstruction of the Bridge to facilitate the SEP and PARD.

All Action Alternatives include one or more stories below the top of the existing bridge pile cap. As a result, in all instances, the existing bridge foundations will need to be removed and relocated prior to completion of the SEP. Subsequent coordination with DDOT is required to coordinate the interface between SEP and H Street Bridge. The approach for supporting the new bridge must respect the required rail and platform clearances of the SEP. Furthermore, it must address the envelope requirements of the SEP. It should be constructed without joints, and should have an adequate waterproofing strategy to prevent leakage onto the tracks and platforms and into the H Street Concourse below. Special detailing will be required along the interface of the SEP deck and bridge superstructure to seal that joint.

Interface Between K Street Bridge and SEP Structure

The K Street Bridge structure may need to be modified to facilitate rail support access into the SEP from the north side. A number of options were studied for removing existing columns and adding transfer girders in order to accommodate turning radii from the K Street underpass. It was found that likely a maximum of two consecutive columns could be removed without detrimental impact to overhead clearances caused by adding a transfer girder to support the bridge structure in lieu of the columns. It will need to be verified that the existing bridge foundations can support the increased loads or if strengthening is required. Further column protection may also need to be considered.



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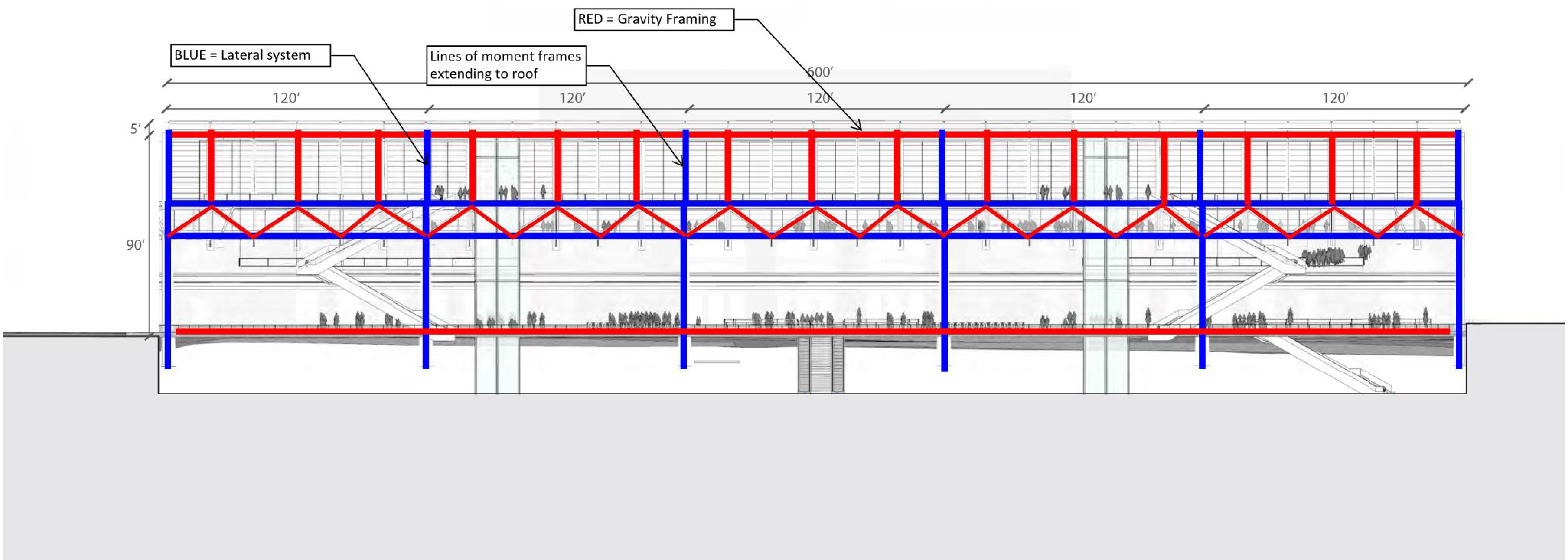
BUS ON SOUTH WITH MEZZANINE LEVEL SECTION

Figure B-13: Bus on South with Mezzanine Level Structural Section



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BUS ON SOUTH WITH MEZZANINE LEVEL ELEVATION

Figure B-14: Bus on South with Mezzanine Level Structural Elevation

MECHANICAL, ELECTRICAL, AND PLUMBING CONCEPTS

Track and Platform Ventilation

Track ventilation system basis of design assumes that the system will be designed to approximately six air changes per hour. This assumption would be tested during a design phase (beyond the 10% stage of design).

Ventilation ducts will exhaust air from above the tracks, from a large plenum created by two downstand barriers at the platform edge. Additional supply air may be required to a few locations, which will be reviewed in future phases.

The total air flow rate to the track area has been assessed using the above criteria, and fan rooms, plenums, and major ductwork have been sized on the basis of:

1. Exhaust Fans, rated for high temperature air would generally be located in fan plant rooms above the tracks. Fan rooms would be located in four quadrants of the SEP, separated by a notional north-south axis and the H Street bridge in the middle.
2. Each fan room would be approximately, 19,200 sf and will include one spare fan.
3. Ductwork runs north-south over the platforms, to reduce any impact on the Overhead Catenary System (OHS) clearances.
4. The overall plenum and ductwork size will be dependent upon the final configuration, most notably if the fan room is located at the platform ends, then the platform ducts will be sized for the full flow. If the fan room is located more centrally, then ductwork can branch and reduce in size.
5. In the train hall, where the roof is significantly higher, this portion will have exhaust fans or ductwork located at high level.

Both sets of exterior louver locations will need to be coordinated in design phase (beyond the 10% stage of design), with respect to clearance from egress doors and to ensure that any smoke and pollutants disperse safely. The key criteria for this is included within the *Basis of Design Report.*

Ventilation of Under-Track Areas

Mechanical ventilation will be provided to all areas. At this stage, the most significant aspect is in reviewing how the intake and exhaust shafts would be incorporated at platform level, and in establishing appropriate louver locations. The requirements are as follows:

Interior Comfort Strategy

The strategy for thermal comfort and resultant compartmentalization of public areas of the SEP are described in the previous sections of this report related to "Refinements to Design to Enhance Passenger Experience," as well as more technical detail in the Compendium.

Occupant comfort is generally informed by the following parameters:

- Dry bulb temperature
- Relative humidity
- Air velocity
- Radiant temperature (e.g. whether sunlight directly lands on an occupant)
- Clothing
- Occupant activity levels

Adaptive comfort strategies also include other parameters, such as:

- Spaces are designed to a permit a wider range of conditions. They become partially conditioned.
- Perception of comfort difference from a prior state. As an example, in summer occupants entering a partially conditioned space from outside space will feel more comfortable than they previously were.
- Length of period that occupants will be exposed to that particular environment
- Giving occupants an opportunity to control the environment (e.g. removal/ addition of clothing or ability to open windows)

The summary of the strategy for regulating thermal comfort and air movement in the SEP includes the following:

- Public circulation concourses will vary by alternative. In Alternatives C, D, E, and A-C, the Central Concourse (featuring an east-west train hall) would be partially conditioned, whereas in Alternatives A and B (featuring a north-south train hall), it would be fully conditioned due to the full-height glazed walls of the train hall envelope. The First Street and H Street Concourses will be partially conditioned in all Action Alternatives.
- Public waiting concourses within expanded WUS and the Bus Facility, lounges and retail will be fully conditioned, as individuals will dwell in these areas. This will include Concourse A and waiting areas adjacent to H St Concourse.
- Platforms and parking will be unconditioned. Internal temperature will be controlled by ventilation systems, which will introduce outside air into these areas.

In order to maintain the internal environment and provide separation from diesel exhaust and comply with Building Code requirements, all conditioned rooms will be separated from non-conditioned and partially conditioned spaces. As a consequence, the Action Alternatives incorporate the following features:

1. Full height glazed wall separating Concourse A from platforms
2. Walls/ doors at lower concourse level, separating the north-south concourses, from the lower level of Concourse A
3. The H Street waiting areas will be separated from the H Street Concourse, and from the platforms above. Glazed walls will therefore be provided within H-Street Concourse, and the waiting area VCEs will be enclosed, with options including:
    a. At platform level (e.g. a hood and doors over the stairs)
    b. At waiting areas, enclosing each VCE from the waiting area
4. Retail, which may be conditioned, would be enclosed.
5. Waiting areas within the bus facility will be separated from the bus parking areas.

Partially conditioned spaces will have some openings to platform level; however, these openings will be detailed to reduce any impacts from diesel exhaust and brake dust and improve the acoustics of the circulation spaces.

Approaches reviewed include the following:

1. Partial height walls at the top of the Central Concourse adjacent to the tracks
2. Glazed floor at platform level for complete separation

Utilities

Architect of the Capitol (AOC) supplies chilled water and steam to WUS. The AOC has confirmed that they can increase the quantities available.

The capacity increase has been calculated based on the enlarged floor area and can be summarized in the table below:

WUS Current Use	Pro-rata future load (Less 10%)	Pro-rata future load (Add 20%)
Chilled water 2760 GPM 870Tons	1800 Tons, consisting of: AOC 1500 Tons WUS New Plant 300Tons	2400 Tons, consisting of: AOC 1500 Tons WUS New Plant 900 Tons
Steam 7000 lb/hr	14,500 lb/Hr AOC 20,000 lb/Hr WUS Not required	19,400 lb/Hr AOC 20,000 lb/Hr WUS Not required

Cooling towers would generally be located above the tracks. Each cooling tower is approximately 1,000 SF and needs to be exposed to a perimeter wall 30' away from adjacent buildings, or be located atop a roof. See Figure B-27.

STORMWATER STRATEGY

The District Department of Energy and Environment (DOEE) regulates the management of Storm water within the District of Columbia. Construction and redevelopment projects in Washington, DC must install runoff-reducing Green Infrastructure (GI) if they trigger the District of Columbia's stormwater management regulations. This requirement, called the Stormwater Retention Volume (SWRv), is calculated by determining the volume of stormwater runoff from the site, in this case from the PARD deck.

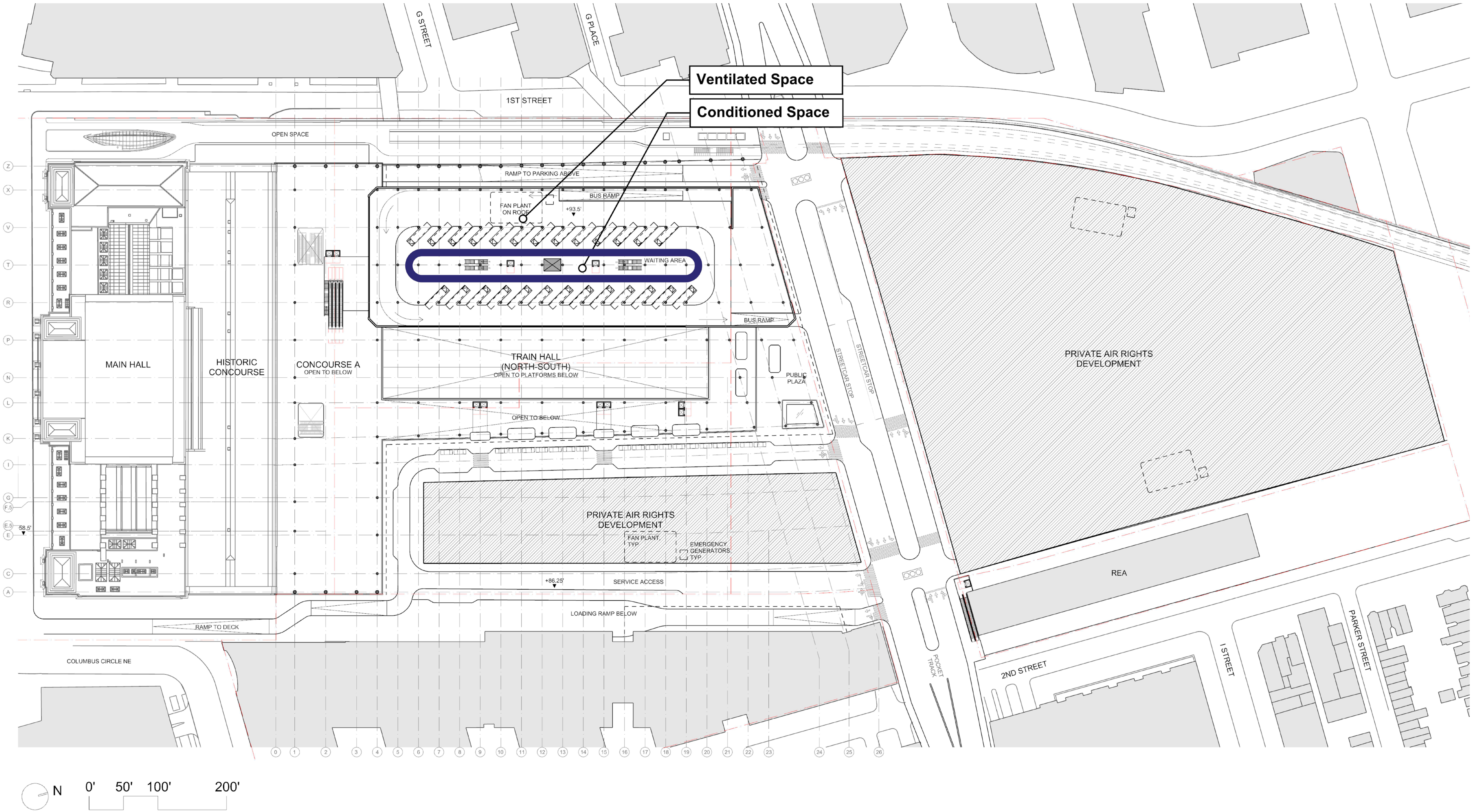
Currently, various options are available for compliance, including a combination of the following options:

1. On-site stormwater management strategies including:
    i. Attenuation tanks
    ii. Bioretention, e.g. bioswales, planting, permeable paving
    iii. Green roofs
    iv. Blue roofs, where rainfall on the roofs is stored to reduce outflow rates
2. Off-site retention
3. Purchasing either stormwater retention credits or in-lieu fee

Due to the uncertainty of purchasing credits on the market within the protracted nature of the current project schedule and the complexity of pursuing credit for retention offsite, on land owned by others, the current planning assumes that the first approach will be taken. Approximately 135,000 cu.ft of storm water storage is required for both the PARD and SEP. In the future, an economic assessment can be made to review Options 2 and 3, and also to determine whether some of this storage may be located within the PARD.

Fire Engineering

The fire strategy has not changed from the CDR. Please refer to the CDR.



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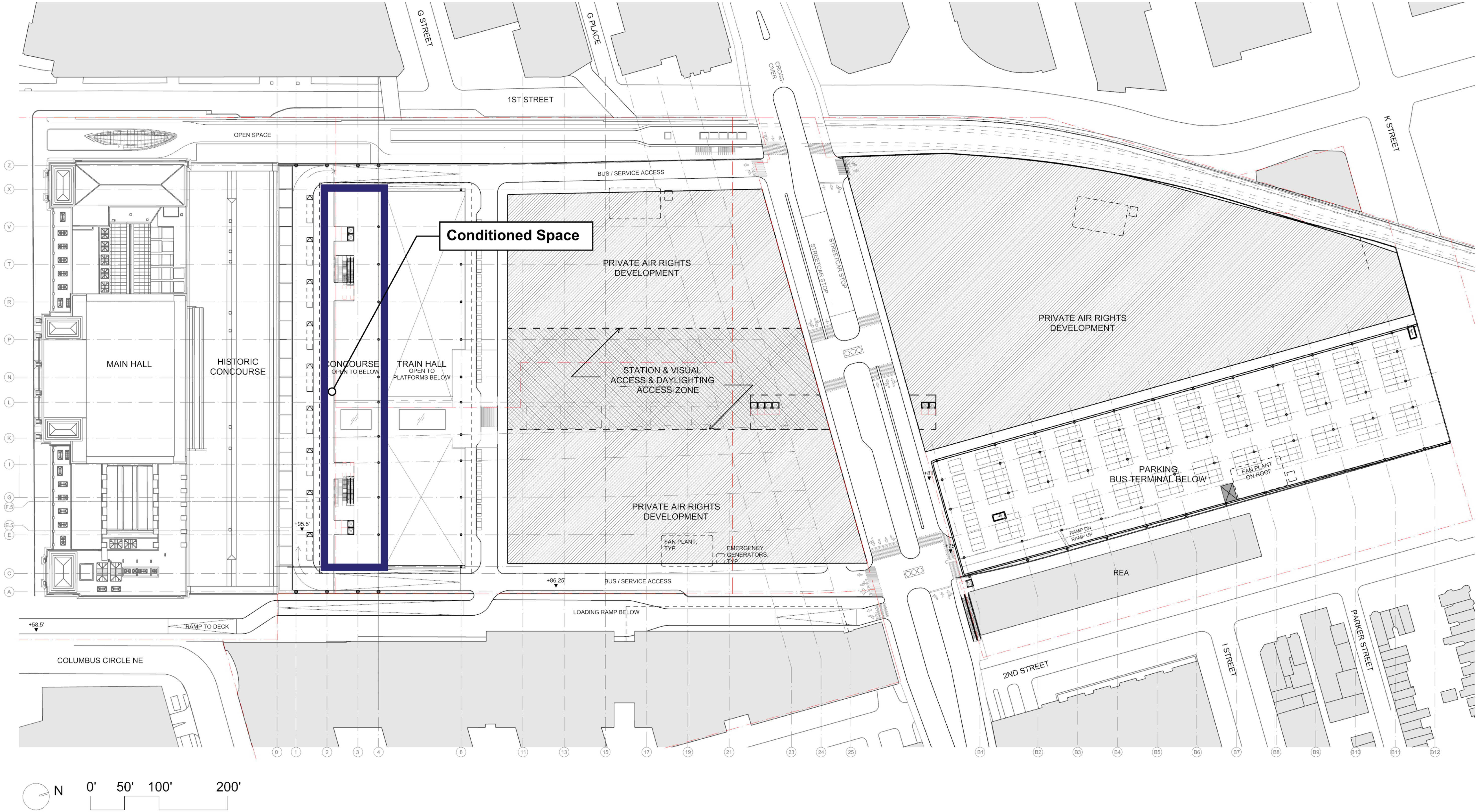
DECK LEVEL TWO PLAN - ALT A

COMFORT ZONE STRATEGY PLAN

Figure B-15 - Comfort Strategy, Typical for all Alternatives



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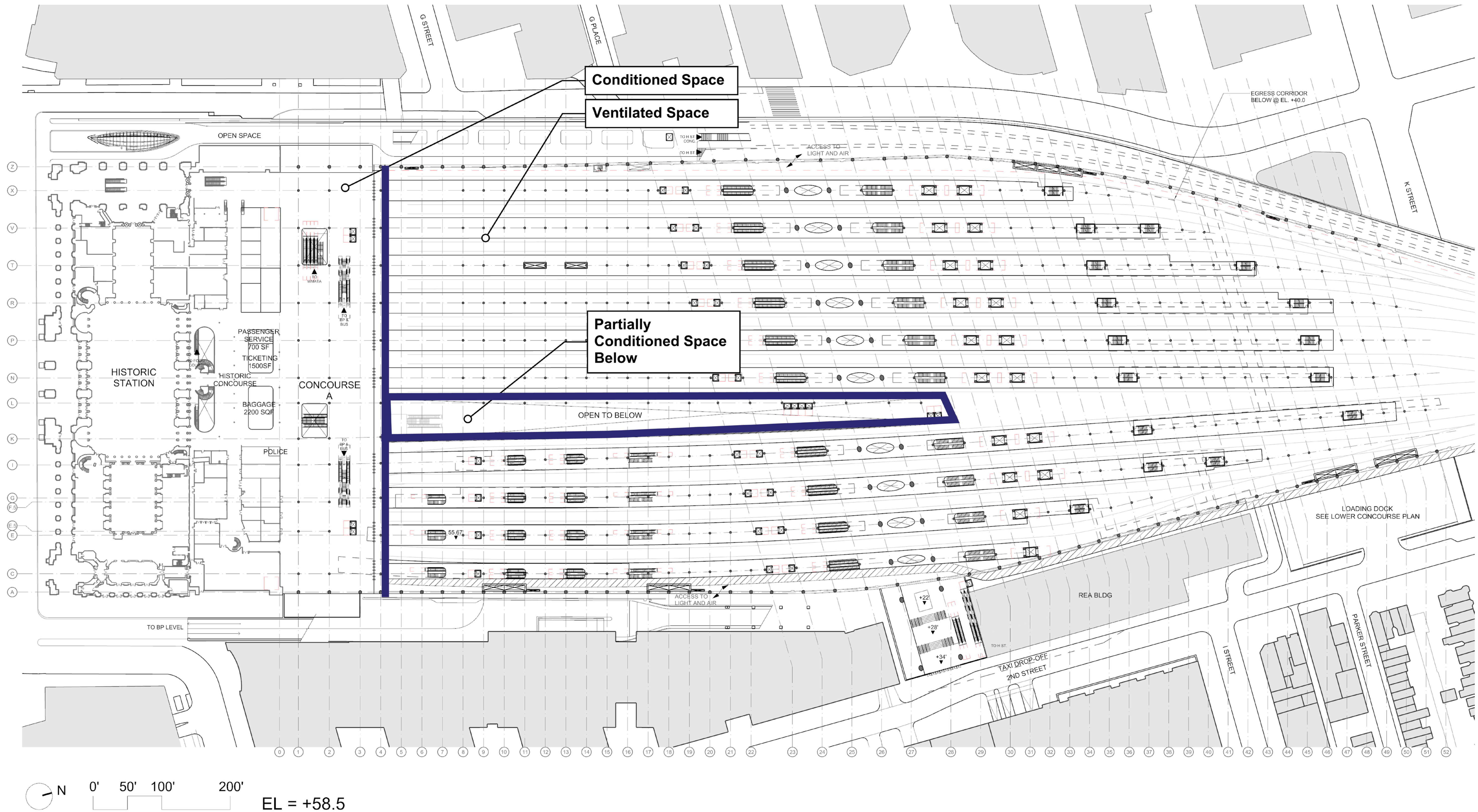
DECK LEVEL TWO PLAN - ALT C EAST

COMFORT ZONE STRATEGY PLAN

Figure B-16 - Comfort Strategy, Typical for all Alternatives



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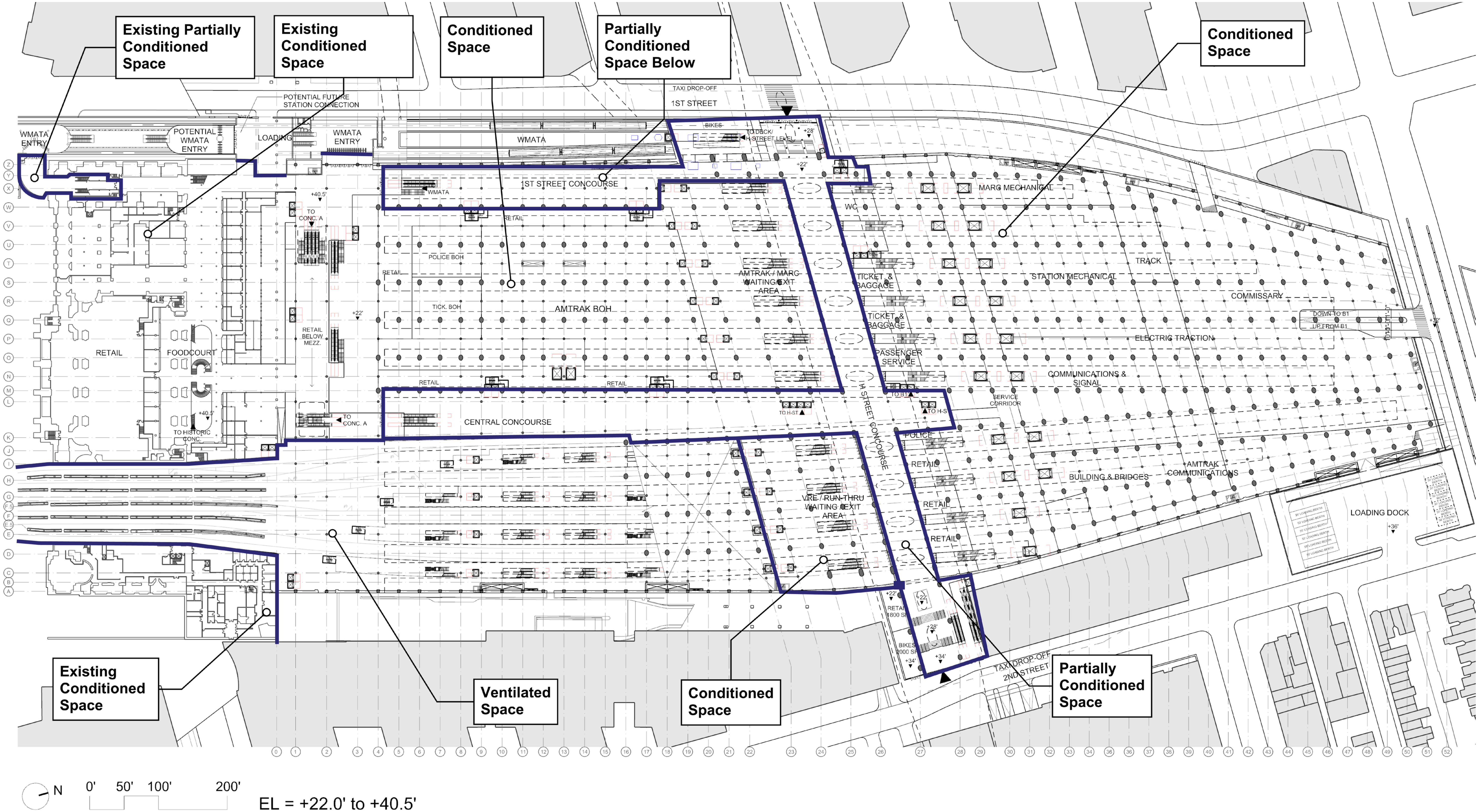
STATION MAIN / PLATFORM LEVEL PLAN - ALT C

COMFORT ZONE STRATEGY PLAN

Figure B-17 - Comfort Strategy, Typical for all Alternatives



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LOWER LEVEL CONCOURSE PLAN - ALT A/ B/ A-C

COMFORT ZONE STRATEGY PLAN

Figure B-18 - Comfort Strategy, Typical for all Alternatives

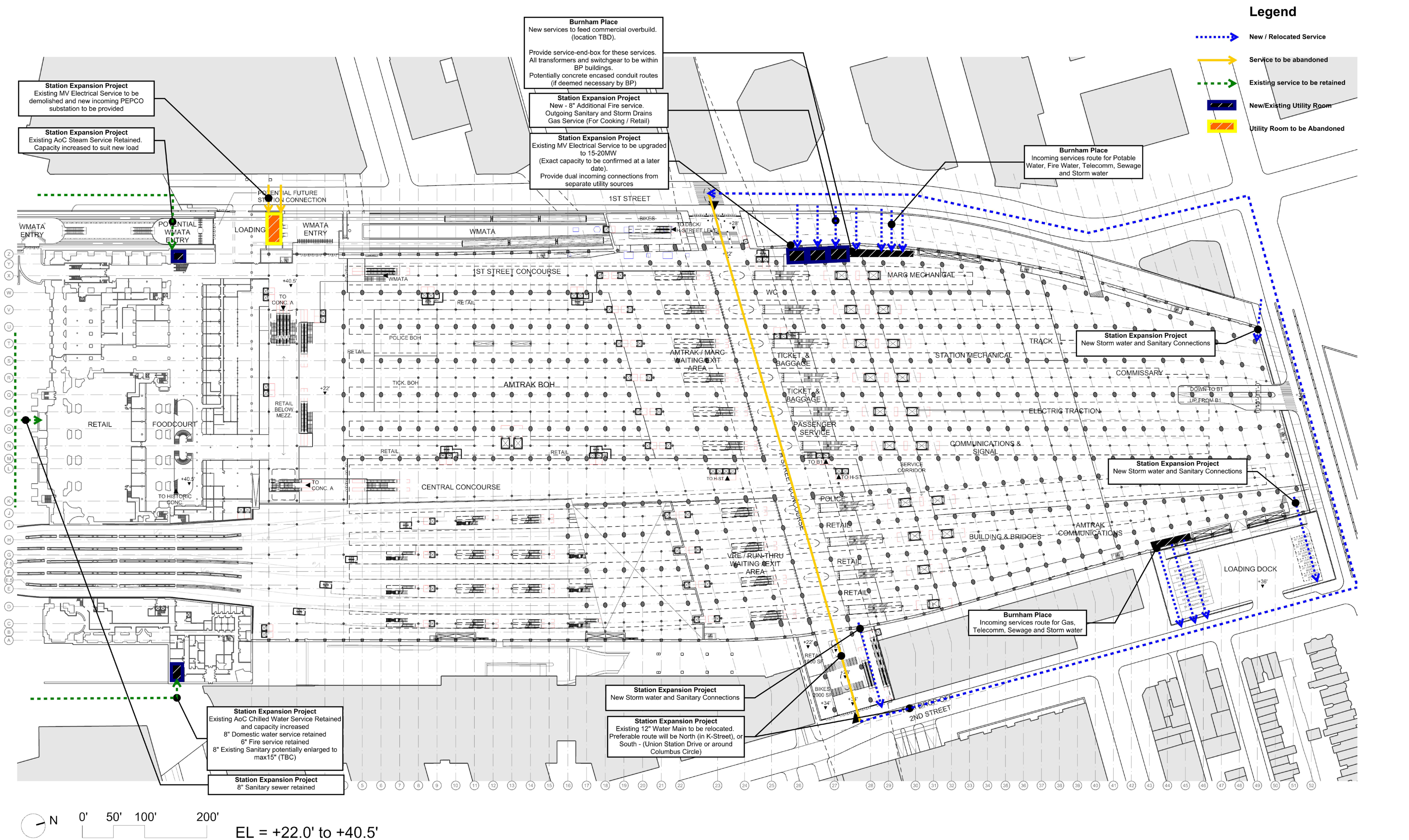
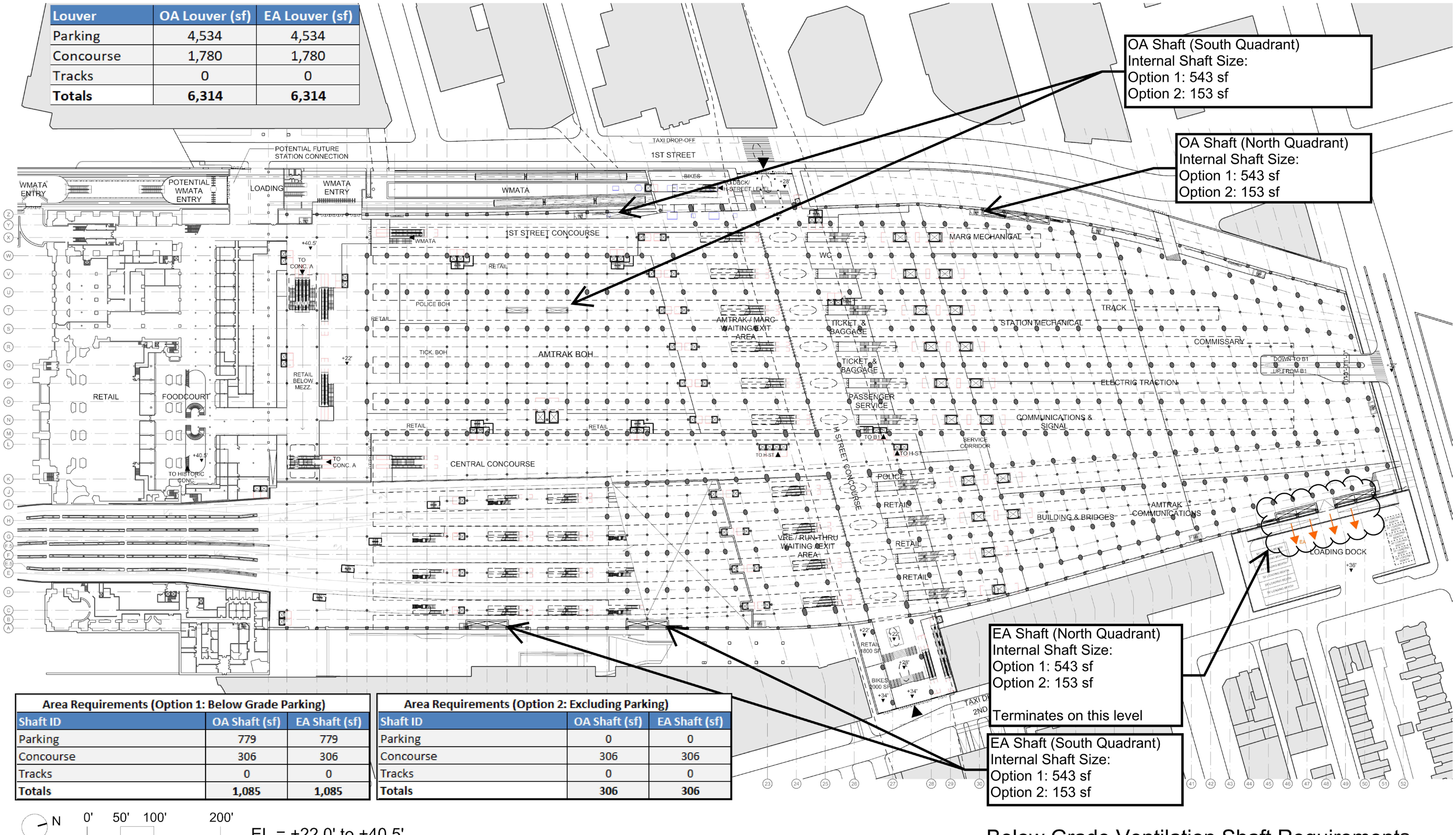


Figure B-19 - Utilities Coordination Sketch

Louver	OA Louver (sf)	EA Louver (sf)
Parking	4,534	4,534
Concourse	1,780	1,780
Tracks	0	0
Totals	**6,314**	**6,314**



Area Requirements (Option 1: Below Grade Parking)		
Shaft ID	OA Shaft (sf)	EA Shaft (sf)
Parking	779	779
Concourse	306	306
Tracks	0	0
Totals	**1,085**	**1,085**

Area Requirements (Option 2: Excluding Parking)		
Shaft ID	OA Shaft (sf)	EA Shaft (sf)
Parking	0	0
Concourse	306	306
Tracks	0	0
Totals	**306**	**306**

N 0' 50' 100' 200'

EL = +22.0' to +40.5'

Below Grade Ventilation Shaft Requirements

Figure B-20 - Below-grade Ventilation Shafts and Louver Areas