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TECHNICAL MEMORANDUM No.6 FINAL

ALTERNATIVES

Seattle-Tacoma International Airport

Prepared for

Port of Seattle
Seattle, Washington

October 2017

Sustainable Airport Master Plan
Seattle-Tacoma International Airport

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Introduction and Summary

This SAMP is about adding gates as quickly as possible on a land-poor airport. Achieving the Port's objectives will require a comprehensive redevelopment and relocation program before the construction of new gates can begin.

1.1 Background and Purpose

This *Technical Memorandum No. 6 – Alternatives* is the sixth in a series of memorandums which document the analyses, results, conclusions, and recommendations resulting from the Sustainable Airport Master Plan (SAMP) for Seattle-Tacoma International Airport. This Technical Memorandum summarizes the alternatives that were identified and evaluated to accommodate the requirements, documented in *Technical Memorandum No. 5 – Facility Requirements*. Alternatives were developed for the Airport's major functional areas: airfield (runways and taxiways), the passenger terminal, ground access and parking, air cargo, airline support, airport support, and general aviation.

1.2 Planning Activity Levels

Recognizing the uncertainties associated with long-range aviation activity forecasting, four planning activity levels (PALs) were identified to represent future levels of activity at which key Airport improvements will be necessary. Because, for any number of reasons, activity levels could be reached at different periods from those anticipated when the forecasts were prepared, the use of PALs allows for facilities planning that is realistically tied to milestone activity levels as they occur, rather than arbitrary years. PAL 1, PAL 2, PAL 3, and PAL 4 correspond to the forecasts for 2019, 2024, 2029, and 2034, respectively. The aviation activity forecasts associated with each PAL are summarized in Table 1-1.

Table 1-1
Aviation Activity Forecasts
Seattle-Tacoma International Airport

	Estimated 2014	PAL 1 2019	PAL 2 2024	PAL 3 2029	PAL 4 2034
Passenger enplanements (millions)	37.4	44.8	51.8	58.9	65.6
Aircraft operations	340,478	398,910	448,860	497,180	540,400
Cargo enplaned (metric tons)	319,842	351,550	383,000	413,750	441,860

Source: LeighFisher, September 2015.

1.3 Approach and Assumptions

The approach was to identify, evaluate, and refine alternative concepts for satisfying the PAL 4 (2034) requirement in each functional area of the Airport (e.g., airfield, terminal, landside, cargo). In parallel, the planning team considered alternative management and operational initiatives to satisfy the requirements.

Initial alternatives underwent high-level screening relative to the SAMP objectives. The results of the screening were summarized in decision matrices. The concepts that best achieved the objectives were refined and subsequently rescreened to determine the preferred concepts for the functional areas.

Screening criteria were selected to best enable the planning team to differentiate among alternatives. The criteria reflected the SAMP sustainability goals and objectives and were both qualitative and quantitative.

The preferred alternatives were further evaluated to ascertain they (1) can be constructed in increments as activity increases, (2) are sufficiently flexible to accommodate some limited amount of additional activity, should it materialize, and (3) are the best alternatives even if the full PAL 4 activity forecast does not occur within the planning horizon (i.e., 2034).

The most significant assumption related to the SAMP alternatives was that the Port of Seattle will not purchase additional land. The objective was to identify the best comprehensive, long-range Airport development plan with the understanding that (1) not all elements of the plan may be affordable, (2) elements of the plan that will be programmed will be determined during the implementation phase of SAMP, and (3) knowledge of the best long-range plan will inform implementation decisions.

1.4 Summary of Alternatives

The following sections summarize the most significant conclusions and recommendations from the alternatives analyses.

1.4.1 Airfield

This section summarizes the results and most significant conclusions from (1) alternatives analyses related to airfield capacity enhancement and reduce reduction, compliance with design criteria, and deice pads, and (2) an updated airfield and airspace demand-capacity analysis.

1.4.1.1 Airfield Alternatives Related to Capacity Enhancement and Delay Reduction

Six changes to existing airfield alternatives facilities or new airfield facilities were considered to potentially enhance the operational effectiveness of the airfield (i.e., increase capacity and reduce delay). .

- **Relocation of runways to permit midfield terminal development.** A runway relocation assessment was completed to determine if, by adjusting the spacing between existing runways, sufficient area could be created for midfield facilities development (i.e., a midfield passenger concourse and gates) between Runway 16C-34C and Runway 16L-34R. The conclusion was that the existing Airport area available is insufficient.

- **End-around taxiways**. Concepts for end-around taxiways to permit arriving aircraft to avoid taxiing across one or more runways to reach the terminal were explored. The conclusions were (1) end-around taxiways should be considered for long-term planning and (2) further study of end around taxiways must involve airline and FAA headquarters staff, and (3) until a comprehensive airfield/airspace study is completed following the SAMP, it will not be possible to fully assess the benefits and costs of end-around taxiways. Any drawings included in this document related to end-around taxiways depict concepts only and have not been approved by the FAA.

- **Centerfield taxiway.** The alternative of relocating Runway 16C-34C 400 feet west to allow construction of an Airplane Design Group V taxiway between Runways 16C-34C and 16R-34L was developed. This “centerfield” taxiway would be used to stage departures from Runway 16C-34C and transition arrivals on Runway 16C-34C or 16R-34L to the appropriate crossing point. FAA air traffic controllers believe the centerfield taxiway would be difficult to use and offers little benefit.

- **Additional runway crossing points.** Other airfield improvements, including additional runway crossing points and runway exits with revised geometry and locations were considered. However, those improvements will not be developed and assessed until all potential airfield improvements are assessed during a comprehensive airfield/airspace study anticipated to follow the completion of the SAMP; such study will necessarily involve appropriate airline and FAA staff. Any drawings included in this document related to runway crossing points depict concepts only and have not been approved by the FAA.

- **Dual Taxiways A and B at south end of Airport.** Staff from both the Port and FAA agree that development of dual Taxiways A and B at the south end of the Airport will improve airfield performance and should be a priority.

- **Midfield aircraft staging area.** An alternative to provide an additional aircraft parking apron located in the midfield between Runway 16C-34C and Runway 16R-34L was identified and assessed. The apron could be used for either aircraft remain overnight parking or air traffic controllers to stage and meter aircraft landing on Runway 16R-34L (the outboard runway), prior to taxiing across the center and inboard parallel runways. The FAA’s Operations Engineering Support Group concluded that the alternative is infeasible because aircraft using the staging area would obstruct the line of sight between the air traffic control tower cab and the Taxiway N movement area.

1.4.1.2 Airfield Alternatives Related to Compliance with Design Criteria

The airfield design criteria compliance review resulted in the identification of 10 instances of non-compliance with FAA design criteria. The ability to resolve instances of non-compliance ranges from relatively simple, low-cost, and non-controversial to very difficult, very expensive, and controversial.

The most controversial issue relates to the separation between the centerlines of Runway 16L-34R and Taxiway B. FAA Advisory Circular 150/5300-13A specifies that the separation required for an airplane design group V Taxiway B is 500 feet when airplanes in approach categories C, D, and E are conducting approaches with visibility minimums lower than ½ mile. The existing separation is 400 feet.

SAMP planning related to new facilities provides for the desired 500 feet separation between the centerline of Runway 16L-34R and the centerline of Taxiway B (i.e., 500 feet separation is provided south of Taxiway S and north of Taxiway L). However, the desired 500-foot separation could have a significant impact on existing passenger facilities (i.e., gates). Therefore, the alternatives explored for resolving the 500-foot separation issue were limited to operational changes rather than physical changes potentially involving decommissioning existing facilities. Potentially significant changes to passenger terminal facilities that would provide the desired 500-foot separation or changes to the airfield or airfield operations to improve compliance with design criteria and to enhance airfield performance will be explored during a comprehensive study to commence following completion of the SAMP.

1.4.1.3 Aircraft Deice Pads

Concepts for common-use aircraft deicing pads were developed. The premise for the pads is that they could share space with any aircraft apron suitable for off-gate aircraft parking. Deicing on such pads would supplement the deicing that occurs at the gates.

1.4.1.4 Updated Airfield and Airspace Demand-Capacity Analysis

The airfield and airspace demand-capacity analysis conducted for the Sustainable Airport Master Plan in 2015 was updated using the Total Airport and Airspace Modeler (TAAM) and drawing on the expertise of Port and FAA staff.

Even with the proposed airfield improvements, simulated airfield delays at the Airport exceed 20 minutes for the activity forecast at PAL 3 (2029)and 37 minutes at PAL 4 (2034). Future analyses of additional capacity-enhancing improvements should be pursued following the SAMP. Some potentially pertinent analyses include (but are not limited to): a comprehensive end-around taxiway study and a comprehensive airfield/airspace study.

1.4.2 Passenger Terminal

This section summarizes the passenger terminal alternatives analyses and the most significant conclusions and recommendations resulting from those analyses.

1.4.2.1 Overview of Alternative Development Concepts Considered and Evaluation Process

Sixteen alternatives for satisfying passenger terminal requirements were identified in a series of "Big Ideas" workshops involving both the planning team and senior Port staff. Thumbnails of the alternatives are shown in Section 3 on Figure 1-1. The alternatives were divided into two concept groups: One-Terminal and Two-Terminal. One-Terminal concepts seek to maintain all passenger-processing within the existing terminal, modifying it as necessary to accommodate the growth in passenger demand. Two-Terminal concepts seek to minimize modifications to the existing terminal by adding a second passenger terminal.

The alternatives were evaluated in three rounds of screening and a final comparison of the refined finalist alternatives.

- Round one screening was designed to eliminate alternative concepts based on "threshold" or pass/fail criteria. Six concepts failed round one screening and were rejected from further consideration.

- Round two screening was designed to identify the preferred One-Terminal and the preferred Two-Terminal concepts based on decision criteria that reflected economic and operational, environmental, and social issues. From round two, two finalist alternatives were identified—Alternative 5A for the "One-Terminal" option and Alternative 10B for the "Two-Terminal" option. Thumbnails of these concepts are shown in Section 3 on Figure 3-1.

- Round three screening was designed to identify and assess the preferred gate layout concepts for the two finalist alternatives (i.e., the One-Terminal and Two-Terminal alternatives). From round three screening, the preferred gate layout was determined to be the same for either the One-Terminal or the Two-Terminal concept.

- The refined finalist One-Terminal and Two-Terminal concepts were compared based on five criteria—total cost of ownership (TCO; i.e., total capital, operations, and maintenance and renewal costs through 2050), phasing, risk, customer service, and operational flexibility. The overarching conclusion from this final comparison was that the Two-Terminal concept is clearly superior to the One-Terminal concept.

From airfield simulation analyses completed subsequent to round three screening, it was concluded that (1) off-gate parking positions are essential for effective future airfield operations, and (2) the space currently occupied by Delta Air Lines' and Alaska Airlines' aircraft maintenance hangars and Delta Air Lines' cargo warehouse should be reserved for off-gate aircraft parking. These conclusions resulted in the refined and recommended gate layout concept shown in Section 3 on Figure 3-5.

1.4.2.2 Refined One-Terminal Concept

Functions Driving the Concept

Planning related to the One-Terminal concept focused on functions in the non-secure portions of the passenger terminal, referred to as landside functions, which have the most significant impact on the One-Terminal concept:

- **Ticketing and baggage drop**. Despite the influences of technology and the Airport's currently empty ticketing positions, there is insufficient space in the existing passenger terminal to satisfy the requirement for ticketing and baggage drop through the planning period—additional terminal space will be required to provide the desired level of service.

- **Passenger circulation**. Circulation on the ticketing and the baggage claim levels is severely restricted by elevators, escalators, and ramps to the curbside. These issues will be exacerbated as passenger activity increases and can only be resolved by enlarging the existing landside terminal building or adding a second terminal.

- **Passenger security screening check points**. Existing level of service issues associated with the constrained security screening check points will be exacerbated as passenger activity increases and can only be resolved either by enlarging the existing landside terminal building and rearranging the layout of key functions or shifting demand to a second terminal.

- **Baggage claim**. The number of claim devices and the length of the devices need to be increased by 50% and 63%, respectively, over the planning period. Baggage claim requirements and level of service objectives cannot be satisfied without increasing available space for baggage claim.

- **Ground access and curbsides**. The existing roadway and curbside system cannot accommodate forecast demand without major expansion and modification. Passenger terminal functions are linked with ground access and parking functions. Therefore, the passenger terminal and access and parking alternatives were developed in parallel.

One-Terminal Concept—Landside

Four preliminary concepts were considered for modifying the existing passenger terminal and garage to accommodate forecast activity through PAL 4 (2034):

- Concept 1—Extend the Main Terminal to the north (Section 3, Figure 3-7)

- Concept 2 (Preferred concept)— Extend the Main Terminal ticketing level façade to the east along the entire terminal face (Section 3, Figure 3-8)

- Concept 3—Extend the middle section of the Main Terminal to the east (cutting across the nose of the garage) (Section 3, Figure 3-9)

- Concept 4—Extend the middle section of the Main Terminal to the east and provide a secure/non-secure automated people mover station in the garage (Section 3, Figure 3-10)

The concepts were evaluated based on experience and professional judgement, resulting in the identification of the preferred One-Terminal concept. The preferred One-Terminal concept, Concept 2, involves expanding the passenger terminal to the east and, consequently, the following primary elements of construction:

- Remove upper drive

- Remove three upper garage levels (limited to “nose” of garage) to accommodate displaced upper level roadway functions

- Relocate bridges between garage and terminal up to garage level 5

- Build new larger elevator cores within the garage and at bridges
- Expand ticketing level exterior wall to roof drip line limits
- Realign all ticketing counters to ”island” configuration
- Reconfigure escalators between bag claim and ticketing levels
- Expand ticketing and baggage claim functions to the North

Implementing the One-Terminal concept would involve resolving substantial issues during advanced planning and design phases. Those issues include the planning and design of the (1) the modified garage and roadway structure to support fire and rescue vehicles, (2) an automated people mover (APM) system potentially needed to support international to domestic connecting passengers, and (3) a new high speed baggage system between the existing terminal and the new gates to the north.

One-Terminal Concept—Airside

Planning related to functions in the secure portions of the passenger terminal, referred to as airside functions, focused on outbound baggage makeup, Concourses A through D, and the South and North satellites. The major conclusions from this planning are summarized below;

- **Concourse A**. Concourse A, the newest of the concourses, is in excellent condition, provides a high level of service, and will only require minor improvements (e.g., concessions) in the short term.
- **Concourse B**. Some holdrooms on Concourse B are undersized for the current fleet mix and are often crowded; concessions are limited and fewer restrooms are provided than on other concourses; and passenger movement is somewhat constrained. Accordingly, at an appropriate time in the future, Concourse B should be either enlarged and reconfigured or demolished and replaced.
- **Concourse C**. Concourse C is adequate for the near-term.
- **Concourse D**. The width of Concourse D is narrow and limits passenger movements, an issue that will be exacerbated with the ultimate extension of Concourse D and connection to the southern pier of the north gates. Concourse D should be widened, moving walkways added, and concessions expanded.
- **South Satellite**. The South Satellite will be expanded and refurbished as part of the current International Arrivals Facility project.
- **North Satellite**. The North Satellite will be expanded and refurbished as part of the current NorthSTAR project.

Post-security APM System

Four APM options were considered for transporting post-security passengers (i.e., passengers having passed through the passenger security screening check points) between passenger terminal concourses and satellites and between the new International Arrivals Facility and gates. The options are depicted on Figure 1-13. Three of the options are below ground and one is elevated. The options were scored against decision criteria and the preferred post-security APM system, Option 1B, was identified as a below-ground system with six stations.

1.4.2.3 Refined Two-Terminal Concept

The Two-Terminal concept consists of two terminals—a second terminal (the North Terminal), located on the Doug Fox lot, and the existing terminal (the Main Terminal).

Two-Terminal Concept—Main Terminal

Key assumptions and features of the concept are summarized below.

- The objective of the Two-Terminal concept is to minimize the overall facilities cost by investing in the Main Terminal only as necessary to satisfy demand until the North Terminal is opened, or to renew aging infrastructure.
- Improvements planned as part of the NorthSTAR project would be relied upon to provide significant customer service enhancements.
- When the North Terminal opens, the Main Terminal may accommodate as many as 54 million annual passengers, albeit at less than desirable levels of service. Accordingly, modifications to the Main Terminal would be limited to those needed to accommodate 54 million annual passengers.
- Following the opening of the North Terminal, the Main Terminal would accommodate approximately 70% (46 MAP) of the forecast PAL 4 passenger activity.
- The modifications to Concourses A through D, the South Satellite, and the North Satellite are the same for the Two-Terminal concept as for the One-Terminal concept.

Two-Terminal Concept—North Terminal

The North Terminal concept is illustrated subsequently on Figure 3-15. Key assumptions and features of the concept are summarized below.

- The North Terminal would be constructed by about 2027, operate effectively for either a single airline or a combination of airlines, and ultimately accommodate about 30% (20 MAP) of passenger activity forecast for PAL 4 (66 MAP).
- The North Terminal will be planned to serve the North Satellite as well as the new north gates.
- Curbsides would be provided on a single level to reduce roadway complexity and cost.

- Both ticketing/bag drop and baggage claim functions will be on the same level as the roadway.
- The adjacent cemetery will not be affected.
- Adequate parking would be provided adjacent to the terminal.
- Passengers would be able to walk between the North Terminal and north gates through an enclosed pedestrian bridge that spans the North Airport Expressway and light rail right-of-way.

1.4.2.4 Comparison of the Refined One-Terminal and Two-Terminal Concepts

The refined One-Terminal and Two-Terminal concepts were compared based on five criteria—total cost of ownership (TCO; i.e., total capital, operations, and maintenance and renewal costs through 2050), phasing, risk, customer service, and operational flexibility. The conclusions from this final screening analysis were:

- TCO is less for the Two-Terminal concept than for the One-Terminal concept. This is largely attributable to the high cost of terminal, roadway, and garage modifications required for the One-Terminal concept and relatively lesser cost of new construction on a green field site for the North Terminal.
- Phasing is easier with the Two-Terminal concept than with the One-Terminal concept. The complexity of phasing necessary to maintain passenger operations, and the duration passengers would be subject to the inconveniences of major construction, are significantly greater with the One-Terminal concept than with the Two-Terminal concept.
- There are lower risks associated with the Two-Terminal Concept than with the One-Terminal Concept. With the One-Terminal concept, (a) it is much more difficult to accommodate faster than expected passenger growth than with the Two-Terminal concept, and (b) the modifications envisioned to the garage are complex and subject to the interpretation of construction codes that cannot occur until the project is designed.
- A higher level of customer service is achieved with the Two-Terminal concept than with the One-Terminal concept. Wayfinding and walking distances between security screening and gates in the North Terminal are considerably improved over the Main Terminal.
- The Two-Terminal concept has greater operational flexibility than the One-Terminal concept. The Two-Terminal concept enables (1) easier airline assignments to new gates, (2) group check-in and surge loading to be distributed between two terminals, and (3) more options for relief to stressed baggage handling systems.

The overarching conclusion from this final comparison was that the Two-Terminal concept is clearly superior to the One-Terminal concept.

1.4.3 Ground Access and Parking

This section summarizes the ground access and parking alternatives analyses and the most significant conclusions and recommendations resulting from those analyses.

1.4.3.1 Introduction

The alternatives to accommodate future access and parking requirements focused on each of two overall concepts: (1) continuing to process all passengers through the existing Main Terminal (i.e., the One-Terminal concept),or (2) developing a North Terminal located on the current Doug Fox Lot parking facility to supplement passenger processing in the Main Terminal (i.e., the Two-Terminal concept). Ground access and parking alternatives presented in this section are associated with either the One-Terminal or Two-Terminal concept.

1.4.3.2 One-Terminal Concept

All curbside, close-in parking, and commercial vehicle pickup/drop-off facilities associated with the One-Terminal concept would be located at the Main Terminal.

Off-Airport Access Roadways

Regional roadways providing access to and from the Airport are predominately outside of the control of the Port. Therefore, State and regional stakeholders and the cities in the area surrounding the Airport must work together to solve the issue of off-Airport roadway congestion.

On-Airport Access Roadways

North Airport Expressway

On the southbound North Airport Expressway (between SR 518 and South 170th Street), one additional lane (for a total of 4 lanes) is required by PAL 2, and a second additional lane (for a total of 5 lanes) is required by PAL 4. On the northbound North Airport Expressway (north of the return-to-terminal exit), one additional lane (for a total of 4 lanes) is required by PAL 3. In all cases, it appears there is sufficient right-of-way to accommodate the additional lanes.

South of South 170th Street, the southbound North Airport Expressway will be realigned to follow the alignment of the northbound lanes and SoundTransit light-rail. When realigned, the roadway should have sufficient width to allow for six lanes (the capacity required by PAL 4).

SR 518 Ramps

The Airport entrance ramp from westbound SR 518 requires one additional lane (for a total of 3 lanes) by PAL 2 and it appears there may be sufficient area to convert existing shoulder area to provide for a third lane. The Airport entrance roadway from eastbound SR 518 requires one additional lane (for a total of 2 lanes) by PAL 3, and there appears to be sufficient shoulder and adjacent area.

The Airport exit ramp to eastbound SR 518 requires one additional lane (for a total of 3 lanes) by PAL 2 and there appears to be sufficient shoulder and adjacent area.

Each of these roadways, however, is predominately outside of Airport property. Any improvements would require close coordination with the Washington State Department of Transportation (WSDOT).

South Access

Current plans for the interim South Access roadway indicate one lane in each direction. Traffic volumes appear to require that two southbound lanes be provided by PAL 2. For the South Airport Expressway (expected to open between PAL 3 and PAL 4), current plans indicate one lane in each direction. Traffic volumes appear to require two lanes in each direction by PAL 4.

Terminal-Area Circulation Roadways

Port staff modeled the on-Airport access roadway system and concluded:

- Without improvements, the on-Airport roadway system will be gridlocked by PAL 2 (2024).
- The addition of one lane for the approach to the lower drive and two lanes for the rental car buses would avoid the gridlock envisioned by PAL 2 (2024) without the additions.
- Unless more lanes are added to the approaches to the upper and lower drives and to the curbs, by PAL 4 (2034), approximately 30% of the projected demand by private vehicles cannot be accommodated.

Alternatives were identified for improving four terminal-area circulation roadways identified subsequently in Section 4 on Figure 4-1:

- **Approaches to Lower Drive and Upper Drive (Segments A and B)**: A preferred alignment was identified that would satisfy the PAL 4 (2034) requirement of 3 lanes for the approach to the Upper Drive and 5 lanes to the approach to the Lower Drive—an increase of 1 lane and 2 lanes, respectively.
- **Exit from Upper Drive to North Airport Expressway (Segment C)**: The preferred alternative to address the poor level-of-service anticipated through PAL 4 (2034) is to add a second lane. It appears the existing structure would allow for two 10-foot lanes with minimal allowance for shoulders and side rails.
- **Exit from Lower Drive to North Airport Expressway (Segment D**: Three lanes are required by PAL 3 to provide LOS C or better on this roadway. Though the deficiency could be addressed by shifting curbside demand to other facilities, this approach would deteriorate the level-of-service in the other facilities. It appears that the structure would allow for three 10-foot lanes but with minimal allowance for shoulders and side rails

Curbside Roadways

Under a One-Terminal concept, curbside alternatives are tightly linked to the terminal configurations. As discussed in Section 1.4.2.2, four general terminal concepts were considered. The following sections describe the curbside roadway alternatives associated with each terminal configuration.

Curbside Options, All Terminal Concepts

Four low-cost, operational strategies were identified to reduce demand for curbside facilities and/or better balance demand with available capacity. These potential strategies are low-cost, can improve curbside level of service, and could be implemented with any of the terminal concepts. However, operational strategies alone cannot achieve the Port's level of service goals.

A relatively minor garage reconfiguration would permit direct access from the entry roadway to Level 2 of the Main Garage using a ramp formerly used by rental cars. The objective would be to improve the attractiveness of parking in the Main Garage for drivers picking up and dropping off airline passengers and thus reduce traffic volume on the curbsides. Exiting vehicles could use the former rental car exit roadway from Level 2 to reach North Airport Expressway. This alternative could be implemented under either a O-ne or a Two-Terminal scenario.

Curbside Options, Terminal Concept 2 (Preferred Concept)

Three optional curbside configurations were developed for terminal concept 2.

- Option 1, the preferred option, is to develop multiple curb lanes on level 5 of the garage (removing sections of level 6 – 8 located above the curb lanes, raise the Lower Drive. However, the concept would result in the loss of 3,000 parking spaces, and without a detailed structural analysis, it is not clear if the garage can structurally support the concept. The structural analysis is contingent on the interpretation of building codes.

- Option 2 is the same as above, but with additional pedestrian bridges spanning above the new curbside lanes (to allow garage customers a grade-separated crossing to reach the pedestrian bridges connecting to the terminal).

- Option 3 is to develop rental car shuttle roadway on level 6 of the garage (removing sections of level 7 – 8 located above the new roadway), relocate the Upper Drive into level 5 of the garage (over height vehicles would be directed to use the Lower Drive), and raise the Lower Drive. This option would be as costly and disruptive as Option 1 without the same benefits.

Curbside Options, Terminal Concept 1

Two curbside options were developed for terminal concept 1.

- Option 1 is to construct a fifth lane on the east side of the Upper Drive. This option does not resolve the curbside deficiency and may be difficult to construct.

- Option 2 is to construct four additional lanes and an island curbside on the east side of the Upper Drive. This option would improve service on both the Lower Drive and Upper Drive but would result in a "lid" over the Lower Drive and may require the STS vent stacks to be relocated.

Commercial Vehicles

Through PAL 3, courtesy vehicles can be accommodated within the existing capacity by relocating the pickup location for airline crew vans and the Downtown shuttle into extra loading stalls currently allocated to shared-ride vans.

By PAL 4, two additional spaces would be required for courtesy vehicles. This additional capacity could be obtained by implementing the first of three curbside expansion concepts described above under *Curbside Options, Terminal Concept 2 (Preferred concept).*

Long-term charter bus alternatives developed during the IAF program definition may not be possible due to recent decisions (outside of the SAMP) that may result in the permanent loss of both the North and South GT Lots. It is suggested that charter bus alternatives are refined in advanced planning efforts to better reflect the evolving use of the current charter bus sites.

Public Transit Facilities

The One-Terminal concept retains the existing Main Terminal public transit stop comprised of two loading spaces.

The One-Terminal concept includes moving walkways in the corridor connecting the station to the Main Terminal. If, during advanced planning, it is determined the moving walkways are not feasible, the Port could continue operating the existing electric shuttle service between the station and the northernmost pedestrian bridge entering the Main Terminal.

Five strategies were identified to encourage use of public transportation modes by airline passengers: (1) reduce fares, (2) increase service area, (3) increase service frequency, (4) reduce travel times, and (5) provide attractive loading and unloading areas.

As the terminal planning components of the SAMP are refined during advanced planning, public transportation pickup and drop-off facilities will be incorporated with the goal of providing a level-of-service comparable with single-party modes while recognizing the geometric, operational, and business requirements and goals of the transportation providers.

Public Parking

While existing on-Airport public parking facilities, the Main Garage and Doug Fox Lot, have sufficient capacity to meet requirements through the planning period, the preferred One-Terminal concept would displace approximately 3,000 Main Garage spaces. To provide this capacity, a parking structure would be developed at the Doug Fox Lot providing at least 4,600 spaces (the existing Doug Fox Lot capacity plus the displaced 3,000 Main Garage spaces).

Rental Car Facility

Two sites near the existing rental car facility could be developed to provide the additional vehicle storage capacity needed by PAL 4 (2034).

Rental Car Shuttle/Pre-Security APM

Rental car shuttles are expected to require up to 15 parking positions by PAL 4T (2034). Rather than accommodate the shuttle traffic on the roadway system, the Port desires to provide a pre-security (i.e., non-secure) APM system that would provide customers convenient transportation between the Main Terminal and the Rental Car Facility (RCF).

Section 4.3.5 describes the alternatives and recommendation for a non-secure APM under a Two-Terminal scenario, with the APM connecting the Main Terminal, the new North Terminal, and the RCF. Under a One-Terminal scenario, the APM alignment options would be the same, but the system would either omit the North Terminal station or have a station serving the parking customers using the Doug Fox Lot. It is assumed that either of those variants would impact each APM alternative equally, and therefore not change the evaluation and recommendation.

Non-motorized Access

Options for pedestrians and bicyclists to access the Airport terminal are limited. The objective is to ensure that, during advanced planning and design, alternatives related to future landside facilities consider maintaining and improving non-motorized access.

1.4.3.3 Two-Terminal Concept

The Two-Terminal concept assumes that by PAL 3 (2029) passenger-processing will occur at both the Main Terminal and a North Terminal located on the site of the existing Doug Fox Lot. Accordingly, all curbside, close-in parking, and commercial vehicle pickup/drop-off facilities are also assumed to be located at both the Main Terminal and North Terminal.

Off-Airport Access Roadways

Under a Two-Terminal scenario, use of the regional roadways is slightly different from a One-Terminal scenario in that 82% of vehicles are expected to enter and exit the Airport from the north (compared with 77% under a One-Terminal scenario).

Regional roadways providing access to and from the Airport are predominately outside of the control of the Port. Therefore, State and regional stakeholders and the cities in the area surrounding the Airport must work together to solve the issue of off-Airport roadway congestion.

On-Airport Access Roadways

Section 4, Figure 4-9 depicts key on-Airport access roadways under a Two-Terminal scenario. Additional capacity is required by PAL 4 on the southbound North Airport Expressway, the northbound direction of the interim South Access roadway, and on both ramps connecting to/from SR 518 to the east. However, these deficiencies are less severe than under the One-Terminal scenario due to the amount of traffic shifted away from the Main Terminal to the North Terminal.

North Airport Expressway

On the southbound North Airport Expressway (between SR 518 and South 170th Street), one additional lane (for a total of 4 lanes) is required by PAL 2 (the 5th lane required by PAL 4 under One-Terminal scenario would not be needed under a Two-Terminal scenario). On the northbound North Airport Expressway (north of the return-to-terminal exit), one additional lane (for a total of 4 lanes) is required by PAL 3. In all cases, it appears there is sufficient right-of-way to accommodate the additional lanes.

South of South 170th Street, the southbound North Airport Expressway will be realigned to follow the alignment of the northbound lanes and SoundTransit light-rail. When realigned, the roadway should have sufficient width to allow for four lanes (the capacity required by PAL 4 and two fewer lanes than needed for the One-Terminal scenario).

SR 518 Ramps

The Airport entrance ramp from westbound SR 518 requires one additional lane (for a total of 3 lanes) by PAL 2 and it appears there may be sufficient area to convert existing shoulder area to provide for a third lane. The Airport entrance roadway from eastbound SR 518 requires one additional lane (for a total of 2 lanes) by PAL 3, and there appears to be sufficient shoulder and adjacent area.

The Airport exit ramp to eastbound SR 518 requires one additional lane (for a total of 3 lanes) by PAL 2 and there appears to be sufficient shoulder and adjacent area.

Each of these roadways, however, is predominately outside of Airport property. Any improvements would require close coordination with the WSDOT.

South Access

Current plans for the interim South Access roadway indicate one lane in each direction. Traffic volumes appear to require that two southbound lanes be provided by PAL 2. For the South Airport Expressway (expected to open between PAL 3 and PAL 4), current plans indicate one lane in each direction. Traffic volumes appear to require two lanes in each direction by PAL 4.

Two-Terminal Concept – North Terminal

Terminal-Area Circulation Roadways

The North Terminal would be served by a curbside roadway consisting of a four-lane terminal-front curb and a parallel four-lane island curbside running the length of the building.

Three alternatives were developed to provide access from the North Airport Expressway (NAE) to and from the North Terminal; the alternatives are depicted subsequently on Figures 4-10, 4-11, and 4-12, respectively, in Section 4. For each of the three alternatives, it is assumed that the southbound NAE will be realigned to the east to run parallel to the northbound NAE.

- **Alternative 1**: The objective of this alternative is to provide access to and from the new terminal from the NAE and not allow traffic (1) to use the southbound NAE to reach South 170th Street, or (2) to reach the northbound NAE from South 170th Street. Thus, the Port does not need to continue to provide for those movements and may have an interest in intentionally removing the ability for such traffic to use on-Airport roadways.

- **Alternative 2**: This alternative is similar to Alternative 1 except traffic exiting the southbound NAE would descend to cross under the NAE and light rail alignment then climb to match the elevation of the new terminal's curbside roadway.
- **Alternative 3**: The objective of this alternative is to provide access to and from the new terminal using roadway alignments similar to those for existing roadways and thus avoid roadway geometry possibly inconsistent with WSDOT code and design standards.

Alternative 3 requires less elevated roadway and less construction above active SoundTransit and freeway facilities than alternatives 1 and 2.

Curbside Roadways

The recommended curbside configuration, shown subsequently on Section 4, Figure 4-13, consists of two parallel curbside roadways of four lanes each, providing a total of 1,400 feet of curbside. Additional commercial vehicle pickup facilities would be located in the new garage that would be located adjacent to the North Terminal.

Commercial Vehicles

The recommended curbside configuration, shown subsequently on Section 4, Figure 4-13, consists of two parallel curbside roadways of four lanes each, providing a total of 1,400 feet of curbside. Additional commercial vehicle pickup facilities would be located in the new garage that would be located adjacent to the North Terminal.

Public Transit Facilities

Commercial vehicle loading areas at the North Terminal would be located on the ground (over height) floor of the parking garage, which has been sized to accommodate the projected PAL 4 demands on a single floor.

Public Parking

Approximately 87% of long-duration parking spaces currently provided on Port property (the Main Garage and Doug Fox Lot) is located "close-in" in the Main Garage. Given that the Two-Terminal concept will displace the Doug Fox Lot and there is limited property available for remote parking, it was assumed that 100% of long-duration parking spaces would be provided close-in. Public parking at the North Terminal would be provided in a parking garage constructed immediately north of the North Terminal.

Rental Cars

Alternatives for meeting rental car demand under a Two-Terminal scenario are identical to those for the One-Terminal scenario.

Non-motorized Access

Options for pedestrians and bicyclists to access the Airport terminal are limited. The objective is to ensure that, during advanced planning and design, alternatives related to future landside facilities consider maintaining and improving non-motorized access.

Two-Terminal Concept – Main Terminal

Terminal-Area Circulation Roadways

At the Main Terminal, PAL 3 and PAL 4 traffic is expected to be approximately 30% less than under the One-Terminal concept.

Alternatives were identified for improving four terminal-area circulation roadways identified subsequently on Figure 4-1 in Section 4:

- **Approach to Lower Drive (Segment A)**: An alternative was identified that would provide three lanes on the approach to the Lower Drive—an increase of 1 lane and result in LoS D. Based on microsimulation analysis conducted by Port of Seattle staff, this improvement is expected to substantially improve traffic flow as it allows two full lanes to approach the Lower Drive and provides a separate lane for vehicles bound for the 3rd floor commercial vehicle areas. To provide LOS C, which would require four lanes by PAL 1, the Upper Drive approach could be relocated another 12 feet to the west to allow a fourth lane on the Lower Drive approach. This would, however, require realignment of Air Cargo Road.

- **Approach to Upper Drive and Exit from Lower Drive (Segments B and D)**: Under a Two-Terminal scenario these two roadway segments are expected to operate at LOS C or better through PAL 4.

- **Exit from Upper Drive to North Airport Expressway (Segment C)**: The deficiency on the exit from the Upper Drive can be addressed in the same manner described in Section 4.2.3.2 for the One-Terminal scenario.

Curbside Roadways

Under the Two-Terminal concept, the existing curbsides at the Main Terminal appear to be able to accommodate the Main Terminal's share of PAL 4 activity at the desired LOS assuming (1) implementation of operational strategies (i.e., reducing average dwell times) and (2) the RCF buses can be relocated away from the Lower Drive. Under a Two-Terminal scenario, it is assumed an APM connecting the Main Terminal, North Terminal, and rental car facility would remove the rental car shuttles from the Lower Drive and allow the existing Main Terminal curbsides to meet requirements through PAL 4.

Commercial Vehicles

Under the Two-Terminal scenario, Main Terminal commercial vehicles can be accommodated within the existing facilities. As noted in Section 4.2.5, as a result of the IAF, the charter bus spaces in the

South GT Lot may be removed. It is suggested that charter bus alternatives be refined through advanced planning efforts to better reflect the evolving use of the current charter bus sites.

Public Transit Facilities

The Two-Terminal concept provides two loading positions at the Main Terminal to account for the occasional instance with two buses arrive simultaneously. Because the routes will serve both terminals, the Main Terminal will continue to provide 120 linear feet of public transit curb.

The Main Terminal under the Two-Terminal concept includes moving walkways in the corridor connecting the station to the Main Terminal.

Under a Two-Terminal concept, strategies to increase public transit use at the Main Terminal are identical as those summarized previously for the One-Terminal concept.

Public Parking

The existing capacity of the Main Garage is expected to accommodate the forecast requirements through PAL 4.

Rental Car Facility

Alternatives for meeting rental car demand under a Two-Terminal scenario are identical to those summarized previously for the One-Terminal scenario.

Non-motorized Access

Options for pedestrians and bicyclists to access the Airport terminal are limited. The objective is to ensure that, during advanced planning and design, alternatives related to future landside facilities consider maintaining and improving non-motorized access.

Automated People Mover Connecting Terminals and Remote Rental Car Facility

An APM connecting to the rental car facility is referred to as a pre-security APM because it would transport non-secure passengers (i.e., passengers not having passed through the passenger security screening check points). Five pre-security APM options were considered for transporting non-secure passengers between terminal, rental car, and light rail facilities. The options are depicted on Figure 4-16. All the options are above ground and would serve the Main Terminal, North Terminal, and RCF. One of the options offers two stations in the Main Terminal. Two of the options would extend beyond the RCF to the SoundTransit Tukwila Station. The options were scored against decision criteria and the preferred pre-security APM system, Concept 4B, was identified. Concept 4B has two stations in the Main Terminal and terminates at the RCF.

Remote Facilities

Given the limited property available on-Airport, Port staff determined that the preferred locations for employee parking, ground transportation hold facilities, and the cell phone lot (collectively referred to as “remote facilities”) are north of SR 518. The preferred locations for the remote facilities, depicted subsequently in Section 4 on Figure 4-17, are identical under either a One-Terminal or a Two-Terminal scenario.

1.4.4 Air Cargo

This section summarizes the air cargo alternatives analyses and the most significant conclusions and recommendations resulting from those analyses.

1.4.4.1 Key Concepts Influencing the Alternatives

The key concepts influencing the formulation of air cargo facility alternatives were land use priorities and the impact of future passenger facilities development on existing and future air cargo facilities.

For the purposes of allocating scarce land, the priorities among the Airport's key functions are:

1. Passenger
2. Airfield
3. Landside
4. Cargo
5. Airline support
6. Airport support
7. General aviation

A significant number of air cargo and other facilities (e.g., aircraft remain overnight parking positions and aircraft maintenance hangars) will be displaced to permit construction of the necessary PAL 4 passenger facilities requirements. These displaced facilities may be competing for the same scarce Airport land.

The best use of developable Airport land bounded to the south by the existing FedEx facility, to the north by State Route (SR) 518, to the west by Taxiway A, and to the east by Air Cargo Road is for air cargo. This area, referred to as the north cargo area, is identified subsequently on Figure 5-4.

A total site area of approximately 92.5 acres is needed to accommodate the forecast PAL 4 cargo requirements. The area available in the north cargo area is approximately 68 acres, leaving a gap between the area required and the area available of 24.5 acres. This gap must ultimately be satisfied by (1) expanding the existing north cargo area to the south of the FedEx facilities, (2) supplementing the facilities in the north cargo area with another, non-contiguous area, or (3) relocating all cargo functions to a new location.

1.4.4.2 Identification and Assessment of Alternative Cargo Sites

Five potential sites for cargo development were identified, assessed, and screened relative to economic/operational, environmental, and social criteria. The potential cargo sites are shown subsequently on Figure 5-5. From the assessment and screening, it was concluded that the preferred sites for cargo development are Site #1 – the north cargo area, and Site #4 – SASA.

1.4.4.3 Identification and Assessment of Alternative Site Development Concepts

Alternative concepts for cargo development at Site #1 (north cargo area) and Site #2 (SASA) were developed, assessed, and screened relative to economic/operational, environmental, and social criteria. The concepts for developing Site #1 and their objectives, descriptions, and assessments are summarized subsequently on Figure 5-7. The concepts for developing Site #2 and their objectives, descriptions, and assessments are summarized subsequently on Figure 5-8.

From the assessment and screening, we concluded that the preferred long-term cargo development concept is Concept #2, which is to develop Site #1, the North Cargo Area, for air freight and to develop Site #4, SASA, for integrator freight.

1.4.5 Airline Support

Airline support facilities include aircraft maintenance hangars, flight kitchens, ground handling service facilities, fuel storage and distribution facilities, and office space.

1.4.5.1 Aircraft Maintenance Hangars

From the airfield simulation analyses, it was concluded that Alaska Airlines' two aircraft maintenance hangars and Delta Air Lines' single aircraft maintenance hangar must be relocated to provide the space necessary for higher-priority off-gate aircraft parking (to accommodate arriving aircraft awaiting gates, departing aircraft awaiting their departure sequence, and aircraft with long dwell times that must be towed from contact gates). From analyses related to on-Airport land development, it was concluded that two areas exist for potentially locating replacement aircraft maintenance hangars—the north cargo area and SASA. Three alternatives for developing aircraft maintenance hangars were considered—all replacement hangars in the vicinity of the north cargo area, some replacement hangars in the north cargo area and some in SASA, and all replacement hangars in SASA.

The preferred alternative concept is to construct all replacement aircraft hangars in SASA. This allows the most effective use of the space available and permits the Port to achieve its objective of reducing noise generated by aircraft engine testing with a single engine run-up facility. The most significant assumption related to the alternatives for aircraft maintenance functions was that those functions cannot be accommodated at another airport. Both Alaska Airlines and Delta Air Lines representatives stated that the hangars are essential to their passenger operations at the Airport.

1.4.5.2 Flight Kitchens

There are currently three providers of aircraft food and beverage services to the airlines (i.e., flight kitchens) operating at the Airport—Gate Gourmet, Flying Foods and Sky Chef. For the purposes of SAMP it was concluded that (1) the Gate Gourmet flight kitchen (located adjacent to the Doug Fox lot) will be demolished to make available space for the north terminal and associated parking and (2) the Flying Foods and Sky Chef flight kitchens (located to the north of the North Cargo Area) will be permitted to remain as long as the properties are not needed for higher-priority functions (e.g., cargo).

1.4.5.3 Ground Handling Services Facilities

Airline ground handling services include aircraft cargo and baggage loading and unloading, fueling, de-icing; baggage sorting, ground power service, aircraft push-back and towing, aircraft cleaning, aircraft security, and ground service equipment repair and maintenance. Because the Airport is land-poor, most facilities from which ground handling services are currently provided will be demolished to allow the development of additional gates. The specific requirements and alternatives for replacement facilities will be determined during advanced planning, which will occur after the SAMP is complete.

1.4.5.4 Fuel Storage and Distribution Facilities

The key conclusions related to the analysis of fuel storage alternatives were (1) sufficient land is available adjacent to the existing fuel farm to permit the requirements to be satisfied, (2) decisions related to the volume and timing of incremental fuel storage facilities will be driven by airlines, and (3) an additional pipeline between the Airport fuel farm and the Olympic Pipeline's Renton Terminal should be considered to provide redundancy in the case of a failure or maintenance issues related to the existing pipeline.

The existing underground fuel hydrant system (i.e., the fuel distribution system) is well maintained and should be expanded to meet future fueling needs as the Airport's gate facilities are expanded. Decisions related to the fuel distribution system should be made during advanced planning and design.

1.4.5.5 Office Space

It is assumed that (1) the amount of space available for airline offices will increase in the future as additional passenger terminal and gate facilities are provided, (2) the specific needs for office space will be programmed as part of advanced planning that will occur following completion of the SAMP, and (3) the Port will continue to reallocate existing office space to meet changing future needs.

1.4.6 Airport Support

Airport support facilities include aviation maintenance facilities, aircraft rescue and firefighting facilities, and an aircraft ground run-up enclosure.

1.4.6.1 Aviation Maintenance Facilities

Seven sites were assessed to determine their suitability to satisfy the requirements for aviation maintenance facilities. The location of the sites is shown subsequently on Figure 7-1. From the assessment, it was concluded that the west-side construction trailer site is the only viable site to accommodate the relocated maintenance functions.

1.4.6.2 Aircraft Rescue and Firefighting Facilities

The Airport's existing aircraft rescue and firefighting facility (i.e., the fire station) must be relocated to permit the construction of more gates. Seven potential fire station locations were identified and evaluated resulting in the conclusions that (1) the existing station must be replaced with two stations—one on the east side of the Airport and one on the west side of the Airport, (2) the east side station should be integrated with extended Concourse D, and (3) the west side station should be located on the site currently occupied by the Weyerhaeuser hangar. The program and design for the new fire-fighting facilities on these sites will be developed during advanced planning.

1.4.6.3 Aircraft Ground Run-up Enclosure

The ground run-up enclosure must be located nearby the aircraft maintenance hangars. Therefore, the preferred alternative location for the ground run-up enclosure is SASA. The program and concept for this facility will be developed during advanced planning.

1.4.6.4 Centralized Receiving Warehouse

The program and plan for a centralized receiving warehouse should be developed in advanced planning.

1.4.6.5 Trash, Recycling, and Compost

The program and plan for a centralized trash, recycling, and compost processing facility should be developed in advanced planning.

1.4.6.6 Utilities

The Airport's existing utility infrastructure and the supply of supporting regional infrastructure (e.g., power, water, and sewerage) are generally adequate to meet current and future needs. The recommended approach to satisfying project-specific requirements is to conduct the appropriate analyses during detailed planning and design efforts that will follow the SAMP.

1.4.7 General Aviation

It is recommended that the site utilized to accommodate itinerant GA aircraft (i.e., the site accommodating both the FBO building and itinerant GA aircraft apron) be retained; it is adequate to accommodate demand through PAL 4 (2034); no increase in size is recommended. It is recommended that the Weyerhaeuser Corporation's lease be terminated and the area made available for the west side fire station.

1.4.8 Comprehensive Airport Development

The preferred alternatives for the individual functional areas of the Airport were combined, resulting in the identification of the recommended comprehensive plan for Airport development, shown subsequently on Figure 9-2.

The estimated cost to implement the comprehensive plan for Airport development is sufficiently large that it is not certain if all elements can be afforded. Issues related to affordability, specific elements of the plan to be carried forward, and the timing of projects to be carried forward will be resolved during subsequent tasks (i.e., financial feasibility and long-range strategy).

Airfield

The development and operation of the Airport's airfield facilities are constrained by both a lack of developable land and airspace operating rules.

2.1 Introduction

This chapter identifies the alternative concepts considered for satisfying the Airport's airfield requirements, documented in *Technical Memorandum No. 5 – Facility Requirements*, summarizes the results of an updated airfield and airspace demand-capacity analysis, and is organized in four parts:

- A description of alternative concepts related to capacity enhancement and delay reduction
- An explanation of alternative concepts to mitigate instances of non-compliance with design criteria
- A summary of the concept for remote aircraft deice pads
- A summary of recently updated airfield and airspace capacity analyses.

Our approach involved considerable coordination with FAA planning and air traffic personnel.

2.2 Airfield Alternatives Related to Capacity Enhancement and Delay Reduction

The following sections describe six changes to existing airfield facilities or new airfield facilities that were considered to potentially enhance the operational effectiveness of the airfield (i.e., increase capacity and reduce delay).

2.2.1 Relocation of Runways to Permit Midfield Terminal Development

One alternative assessed for reducing delay is a shift of the existing runways, which would create space to construct midfield passenger facilities. Such facilities would reduce the number of runway crossings, thereby increasing airfield capacity and reducing delay.

Assumptions

The objective of the runway relocation assessment was to determine if, by adjusting the spacing between existing runways, sufficient area could be created for midfield facilities development between Runway 16C-34C and Runway 16L-34R. Key assumptions for developing the preliminary concepts were:

- The location of Runway 16R-34L remains fixed.
- The locations of Runway 16C-34C and Runway 16L-34R could be adjusted consistent with airport design criteria in Federal Aviation Administration Advisory Circular 150/5300-13A, *Airport Design*.

Alternative

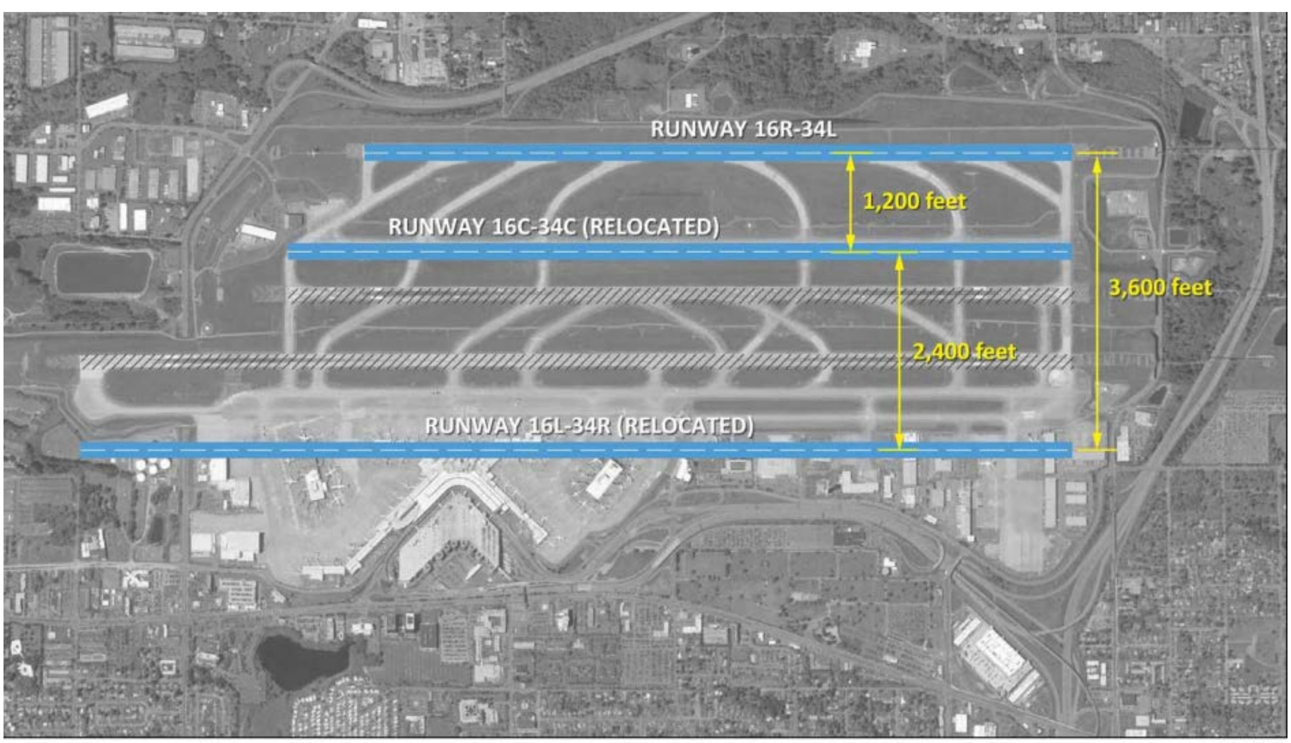
For the purposes of developing the alternative, the maximum spacing between existing Runway 16R-34L and relocated Runway 16L-34R was set at 3,600 feet (the existing separation is 2,500 feet) based on existing property boundaries and FAA design criteria. The parallel runway spacing of 3,600 feet is the new minimum standard for conducting simultaneous independent instrument approaches with existing radar and high-resolution color monitor displays with alerts (i.e., a final monitor aid — FMA).

The location of Runway 16R-34L would be unchanged. Runways 16C-34C and 16L-34R would be relocated to increase their separation to 2,400 feet. The alternative is shown on Figure 2-1.

Evaluation

The alternative would increase the capacity of the outboard-inboard runway pair (Runway 16R-34L and Runway 16L-34R) but does not provide adequate space for midfield terminal facilities development, including the necessary taxiways. Further, the impact of the alternative on existing facilities is unacceptable. Nearly all facilities currently located on the east side of the Airport, including the terminal facilities, would require relocation. In addition, the costs associated with the relocation of runways and facilities would be prohibitive.

Figure 2-1
Alternative for Adjusting Runway Spacing to Permit Midfield Terminal Development
Seattle-Tacoma International Airport



Source: LeighFisher, May 2015.

Evaluation

The feasibility of the runway alternatives to accommodate midfield facilities development was assessed based on airport design criteria as stated in Federal Aviation Administration Advisory Circular 150/5300-13A, *Airport Design*, and Federal Aviation Regulations Part 77—Safe, Efficient Use, and Preservation of the Navigable Airspace.

2.2.2 End-Around Taxiway(s)

Airports operating parallel runway systems to one side of a passenger terminal typically use the inboard runway for departures and the outboard runways for arrivals. In this configuration, arriving aircraft must cross the inboard departure runway, which creates a runway crossing, thereby decreasing capacity, increasing delay, and increasing the chance of a runway incursion.

Recently, airports have designed and constructed taxiways that circumvent the end of the departure runway, referred to as "End-Around Taxiways (EATs)." EATs allow arriving aircraft to avoid crossing one or more runways, thus reducing the risk of incursions and increasing airfield departure capacity.

Two EATs were considered—one on the northern end of the airfield and one on the southern end. The northern EAT would circumnavigate Runways 16C/34C and 16L/34R. The southern EAT would circumnavigate Runway 16C/34C and cross Runway 16L/34R. Operationally, both EATs would allow for the free flow of Aircraft Design Group (ADG) III aircraft with a maximum 45' tail height. The free flow of taxiing aircraft would occur under both departures and arrivals to maximize the airport's runway use options while decreasing runway crossings.

Assumptions

Alternative locations and configurations for the EATs were identified based on the topography of the airfield and surrounding areas and criteria included in FAA Advisory Circular 150/5300-13A *Airport Design* (e.g., criteria related to taxiway design, runway imaginary surfaces, visual screens, approach light systems, and localizer antennas). Two key assumptions influencing the alternatives considered were (1) the EATs would be sited on or directly adjacent to the existing airfield platform, and (2) Interstate 518 will not be relocated.

Preliminary Alternatives

The preliminary alternatives for the north and south EATs are shown on Figures 2-2 and 2-3, respectively. Based on the Airport's existing runway configuration, in particular the staggered runway ends, a southern EAT that circumnavigates 16C/34C and 16L/34R was considered and dismissed.

Preliminary Evaluation

The conclusions from the preliminary evaluation were

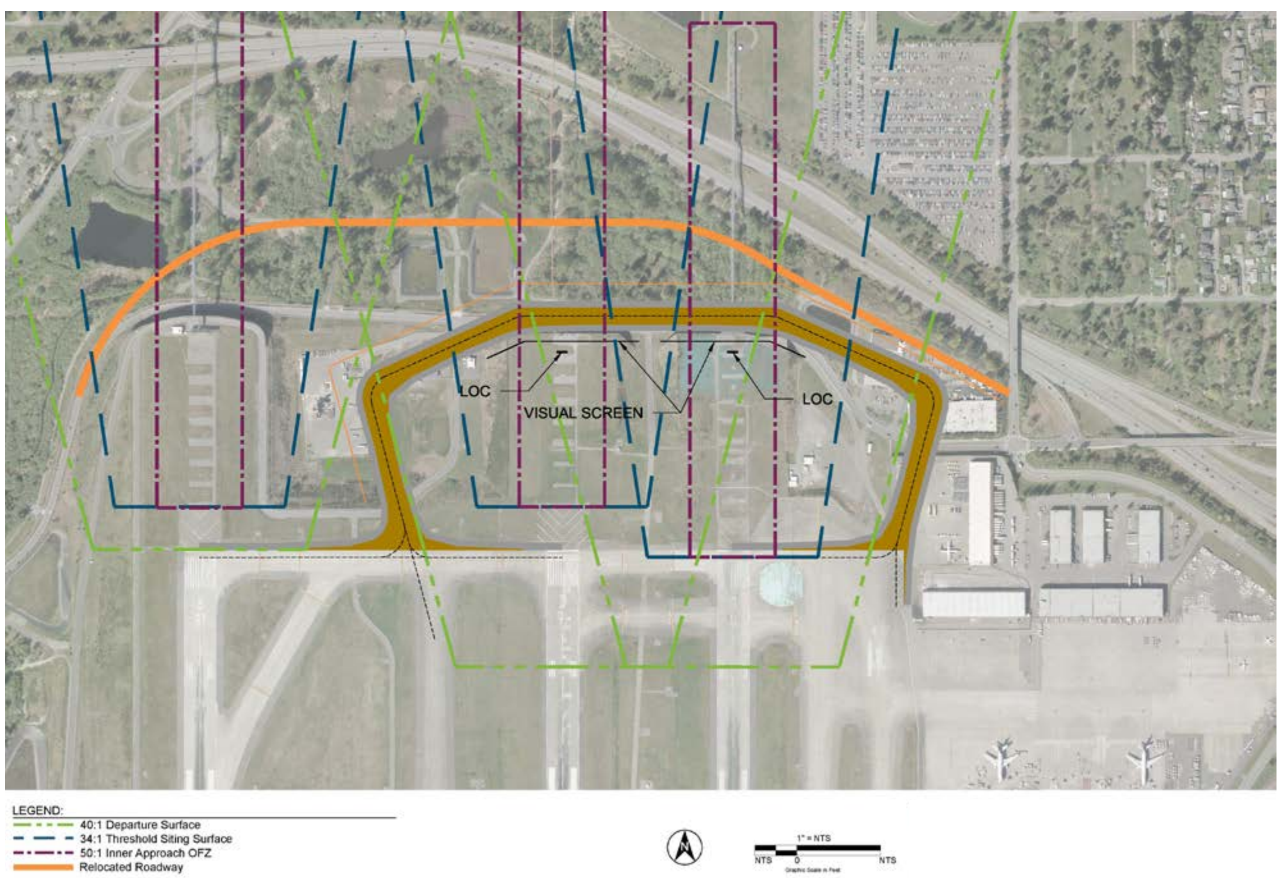
- Designing the EATs will involve declared distances concepts and may require reductions in takeoff run available or landing distance available. Accordingly, close coordination with the FAA and airlines will be required before any EAT concept can be finalized. Until the configurations can be identified and fully evaluated, such coordination will not yield effective results.

- The configuration of the EATs is related to other potential airfield changes that will be evaluated in a comprehensive study of the airfield/airspace system following the completion of the SAMP. Until the EAT configurations are known, the costs cannot be estimated.

- The full benefit of the EATs, primarily to departing aircraft, is not achievable given current airspace procedures. These benefits also will be evaluated in a comprehensive study of the airfield/airspace system following the completion of the SAMP.

Until a comprehensive airfield/airspace study and technical feasibility analysis are completed following the SAMP, it will not be possible to fully assess the benefits and costs of the EATs and reach final conclusions related to their implementation. Accordingly, we recommend including the EAT concepts shown on Figures 2-2 and 2-3 on the ALP as conceptual and subject to further coordination, planning, and design.

Figure 2-2
North End-Around Taxiway Concept
Seattle-Tacoma International Airport

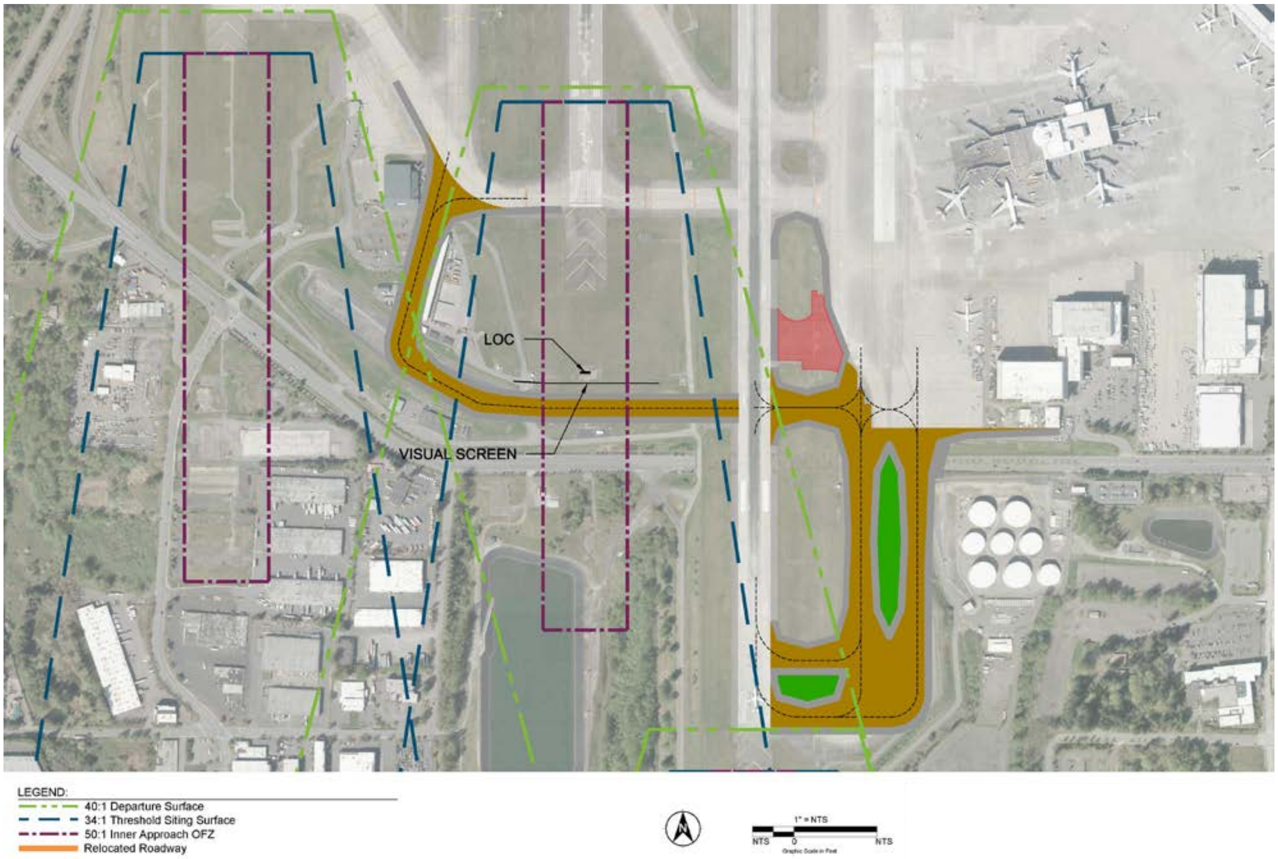


Source: Port of Seattle, May 2017.

Figure 2-3

South End-Around Taxiway Concept

Seattle-Tacoma International Airport



Source: Port of Seattle, July 2017.

2.2.3 *Centerfield Taxiway*

One alternative provides a centerfield taxiway between Runway 16L-34R and Runway 16C-34C.

Assumptions

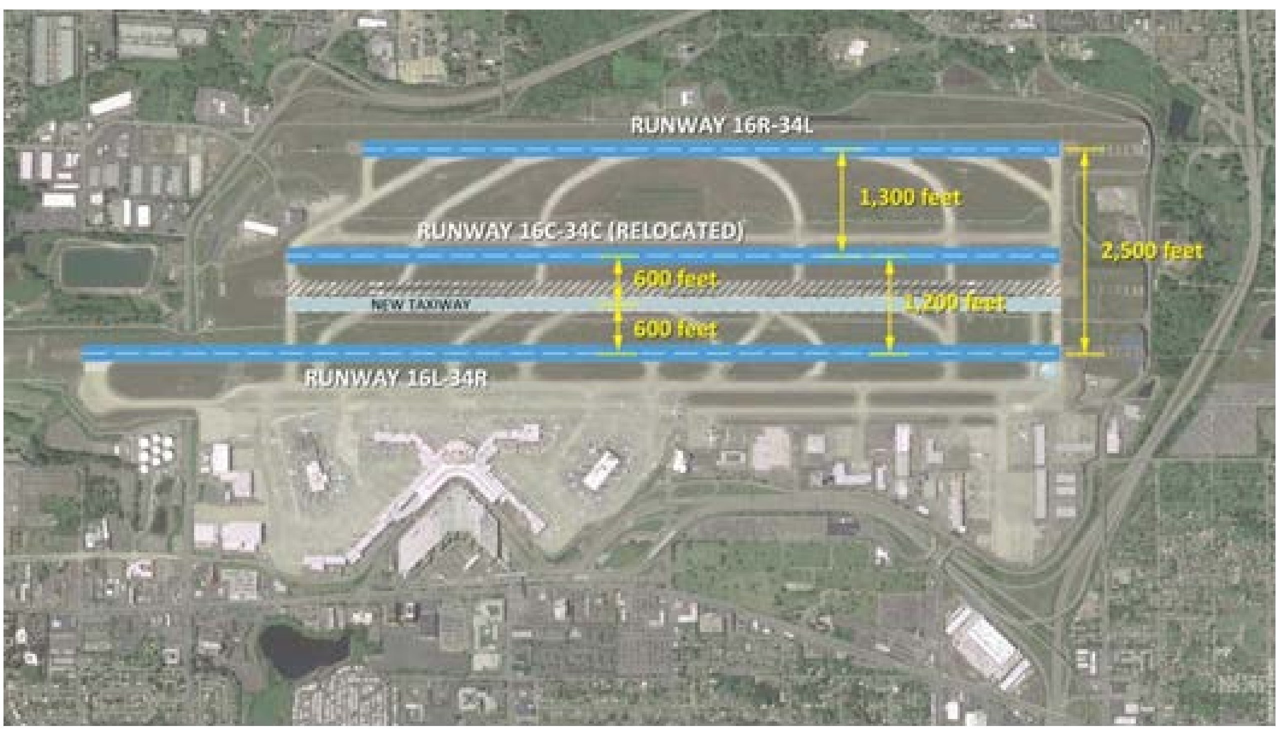
The purpose of the alternative is to allow a centerfield taxiway between Runways 16L-34R and 16C-34C. The taxiway would accommodate aircraft in Airplane Design Group V and Taxiway Design Group 5/6/7 (e.g., A330, B767, B777, B747 aircraft, respectively). The existing 800-foot separation between Runway 16L-34R and Runway 16C-34C is too small to allow a Group V taxiway. The minimum separation needed for Group V taxiway is 1,000 feet; 1,200 feet allows for reverse turns to a centerfield taxiway. Since runway relocation is required for either, the alternatives analysis included only the 1,200-foot separation, as it provides a greater benefit at a similar cost.

The centerfield taxiway would be used to stage departures from Runway 16C-34C and transition arrivals on Runway 16C-34C or 16R-34L to the appropriate crossing point.

Alternative

As shown on Figure 2-4, the centerfield taxiway alternative would require Runway 16C-34C to be shifted 200 feet to the west to accommodate a centerfield Group V taxiway.

Figure 2-4
Centerfield Taxiway
Seattle-Tacoma International Airport



Source: LeighFisher, May 2015.

Evaluation

FAA air traffic controllers believe the centerfield taxiway would be difficult to use and offer little benefit.

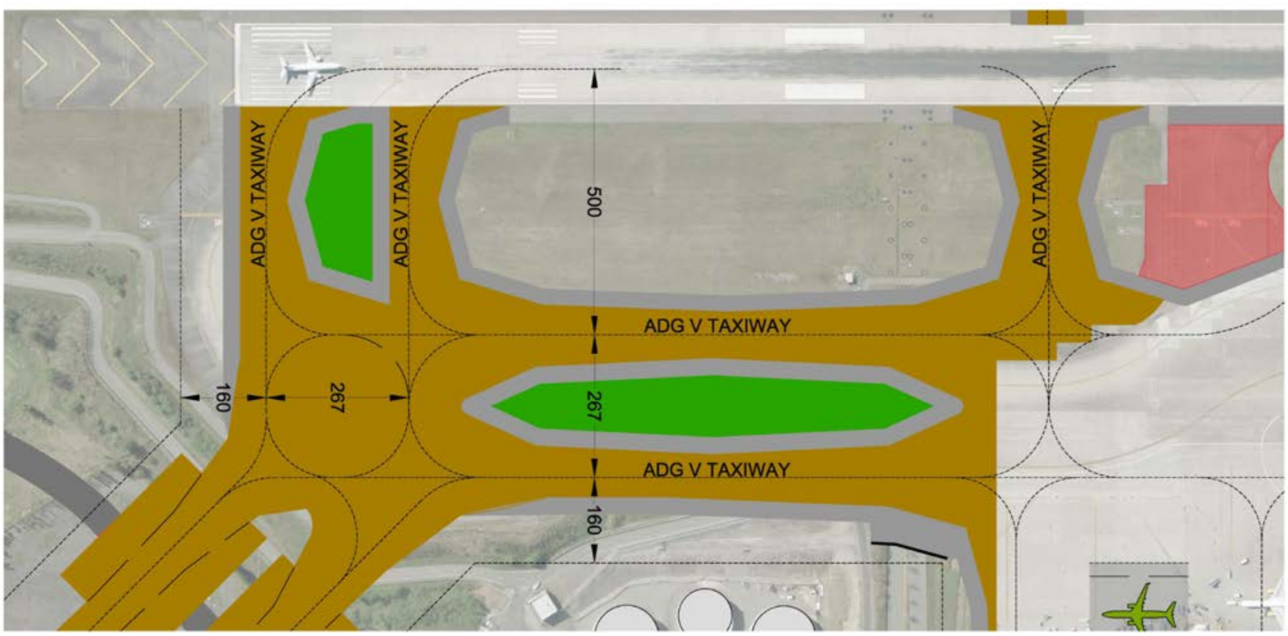
2.2.4 Additional Runway Crossing Points

Other airfield improvements, including additional runway crossing points and optimized runway exits are being considered. However, those improvements will not be developed and assessed until all potential airfield improvements are assessed during the comprehensive airfield/airspace study anticipated to follow the completion of the SAMP.

2.2.5 Dual Taxiways A and B at South End of Airport

The alternative to develop dual Taxiways A and B at the south end of the Airport is illustrated on Figure 2-5. Staff from both the Port and FAA agree that development of dual Taxiways A and B at the south end of the Airport will improve airfield performance and should be a priority.

Figure 2-5
Dual Taxiways A and B at South End of Airport
Seattle-Tacoma International Airport



Source: Port of Seattle, October 2017.

2.2.6 Midfield aircraft staging area

An alternative that would provide an additional aircraft parking apron located in the midfield between Runways 16C-34C and Runway 16R-34L was identified and assessed. The apron could be used for either aircraft remain overnight parking or air traffic controllers to stage and meter aircraft landing on Runway 16R-34L (the outboard runway), prior to taxiing across the center and inboard parallel runways. As shown on Figure 2-6, the proposed area would be located adjacent to Taxiway T, and between Taxiways N and J.

Figure 2-6
Midfield Aircraft Staging Area Location
Seattle-Tacoma International Airport

Source: CH2M Hill, Engineers, May 2015.

Assumptions

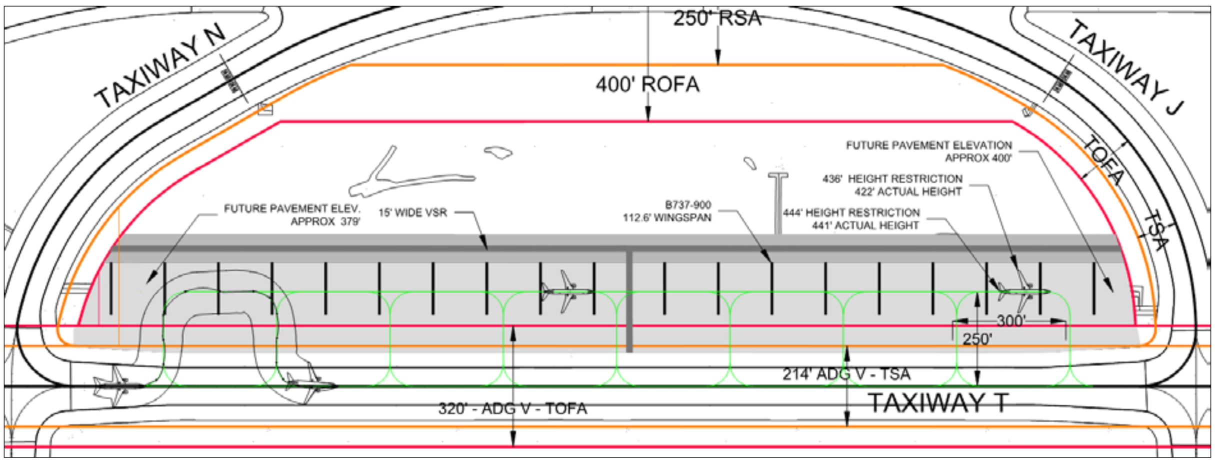
Assumptions related to the alternatives developed for the midfield staging area include the following:

- The flow-through area would be sized for Group III aircraft (e.g., B737-900).
- A 15-foot-wide vehicle service road would be provided on the west side of the site.
- Aircraft must be parked 250 feet from the Taxiway T centerline to ensure holding aircraft remain outside of the taxiway Object Free Area (OFA) and wings and tails clear Part 77 and TERPS surfaces.
- Aircraft would be able to power in and power out of the holding positions.

Alternatives

Alternative 1, shown on Figure 2-7, would accommodate eight Group III aircraft (e.g., the Boeing 737-900) parked parallel to Taxiway T. The holding positions would be independent (i.e., each could be accessed when the adjacent positions are in use) and would be accessed from Taxiway T.

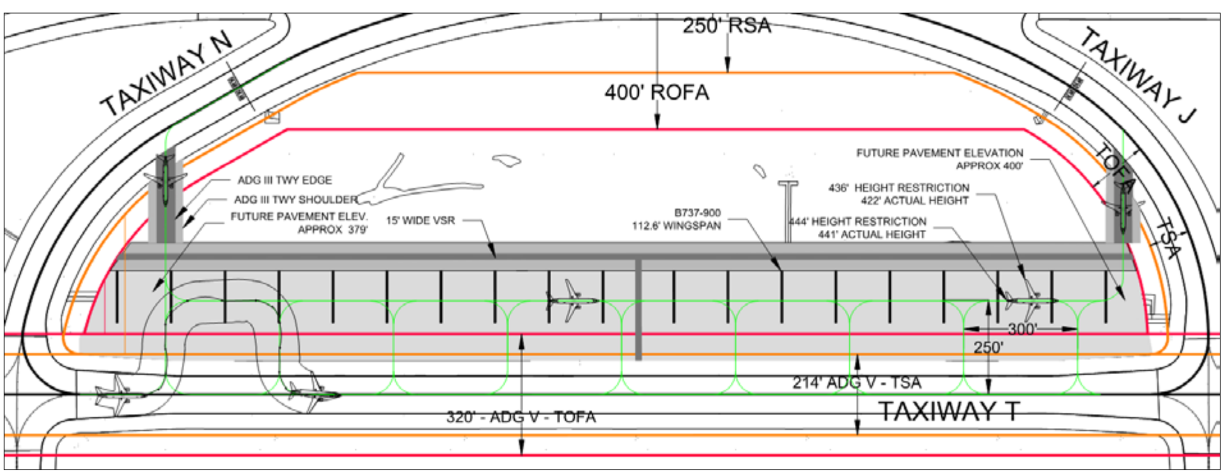
Figure 2-7
Midfield Aircraft Staging Area Alternative 1
Seattle-Tacoma International Airport



Source: CH2M Hill, Engineers, May 2015.

Alternative 2, shown on Figure 2-8, is the same as Alternative 1 except for the provision of restricted access to the holding apron from Taxiways N and J (access would be restricted depending on which hold positions are occupied).

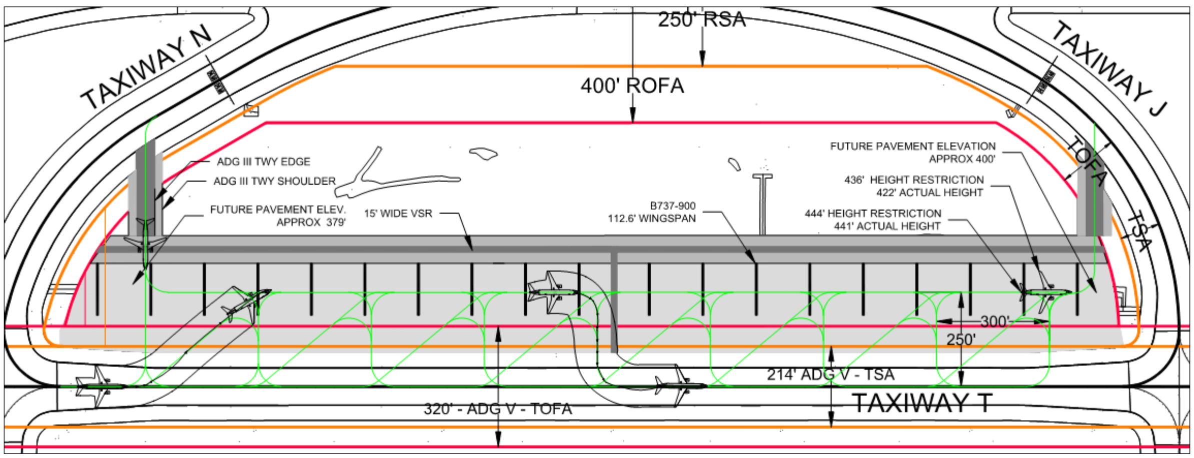
Figure 2-8
Midfield Aircraft Staging Area Alternative 2
Seattle-Tacoma International Airport



Source: CH2M Hill, Engineers, May 2015.

Alternative 3, shown on Figure 2-9, is similar to Alternative 2 with the exception that aircraft would park at an angle, rather than parallel, to Taxiway T. With this alternative, adjacent holding positions would be dependent—an aircraft could not exit a hold position until the position ahead is vacated.

Figure 2-9
Midfield Aircraft Staging Area Alternative 3
Seattle-Tacoma International Airport



Source: CH2M Hill, Engineers, May 2015.

Evaluation

The FAA's Operations Engineering Support Group reviewed the midfield aircraft staging area concept and determined:

- Instrument landing systems (ILS): The aircraft would have a minimum effect on the localizer signals from the Airport's four instrument landing systems. Parked aircraft would be static and should be positioned at a 90 degree angle in relation to the runway (plus/minus 10 degrees) to minimize reflected energy.
- Air traffic control tower line of sight: Aircraft will obstruct the line of sight between the air traffic control tower cab and the Taxiway N movement area.

Therefore, the FAA's Operations Engineering Support Group concluded that the alternative would be rejected in a formal FAA airspace review—line of site obstructions are unacceptable.

2.3 Airfield Alternatives Related to Compliance with Design Criteria

The airfield design criteria compliance review resulted in the identification of several instances of non-compliance with FAA design criteria (i.e., issues) and, therefore, required airfield improvements. This section describes the alternatives and potential mitigation measures for ensuring compliance with FAA design criteria. This section is organized according to the 10 compliance issues identified in *Technical Memorandum No. 5 – Facility Requirements*.

2.3.1 Compliance Issue #1: Separation between Runway 16L-34R and Taxiway B

FAA Advisory Circular 150/5300-13A requires a separation of 500 feet between the centerline of Runway 16L-34R and the centerline of Taxiway B. The existing separation is 400 feet. The basis of the requirement is Aircraft Design Group V aircraft approaching Runway 16L in visibility conditions less than 2,400 feet (runway visual range).

Meeting the required 500-foot separation over the full length of Taxiway B would have significant impacts on the airfield and existing passenger concourses:

- It would affect the separation between Taxiway B and Taxilane W (i.e., Taxilane W would have to be shifted to the east)
- Shifting Taxilane W to the east would subsequently impact existing aircraft parking (e.g., on Concourse B and Concourse C)

SAMP planning adjacent to new facilities (north of Taxiway L and South of Taxiway S) has accounted for the desired 500 feet separation between the centerline of Runway 16L-34R and the centerline of Taxiway B. However, the desired 500 feet separation between Taxiways L and S could have a significant impact on existing passenger facilities (i.e., gates and hold rooms). Therefore, the alternatives explored for resolving the issue favored operational changes rather than physical changes that involve decommissioning existing facilities. Through consultation, the Port and FAA agree to develop a path forward to meet the standard along the entire length of the runway. Given current planning constraints, however, the Port and FAA recognize that the long-term solution to meet the requirement would need to be addressed as part of a subsequent study. In the meantime, the Port and FAA agree that:

1. There will be no further expansion, beyond what has already been approved by the Seattle Airports District Office, to impede Runway 16L-34R from meeting the permanent runway-to-taxiway separation distance standard of 500 feet.
2. As opportunities arise to reduce the existing penetrations of the 500-foot standard, the Port will take steps to implement the standard separation distance at those locations.
3. Until the permanent separation distance standard is met for the full length of the runway and parallel taxiway, the Port will use operational procedures documented by an FAA Modification of Standard to meet the separation standard.

4. Within 3 years, the Port shall initiate a study specifically designed to develop a plan for fully meeting this separation standard in the long term.

2.3.2 Compliance Issue #2: Existing Airfield Intersection Geometry for Design Aircraft

Some of the Taxiway intersections require fillet widening to provide the 15-foot Taxiway Edge Safety Margin (TESM) required for the turning movements of the B777-300 design aircraft.

No alternative was developed for this compliance issue. The Airport will meet standards when reconstruction projects are required in areas where intersections with deficient fillets have been identified. Wider fillets will be depicted as a future condition on the Airport Layout Plan.

2.3.3 Compliance Issue #3: Runway Blast Pad Geometry

Runway 16R-34L blast pads require enlargement (each of the blast pads is 200 feet wide and 200 feet long rather than the required 240 feet wide and 400 feet long). No alternative was developed for this compliance issue. The proposed mitigation measure is correction of this non-standard blast pad geometry with the next FAA-funded project for Runway 16R-34L. Larger blast pads will be depicted as a future condition on the Airport Layout Plan.

2.3.4 Compliance Issue #4: Runway Incursion Mitigation & Hot Spot Locations

The FAA has identified three Runway Incursion Mitigation (RIM) locations at the Airport, two of which overlap the two Airport/user identified Hot Spots. The third RIM location, which is not identified as a Hot Spot, is located at the confluence of Taxiways A, B, C, and D in the northeast corner of the movement area.

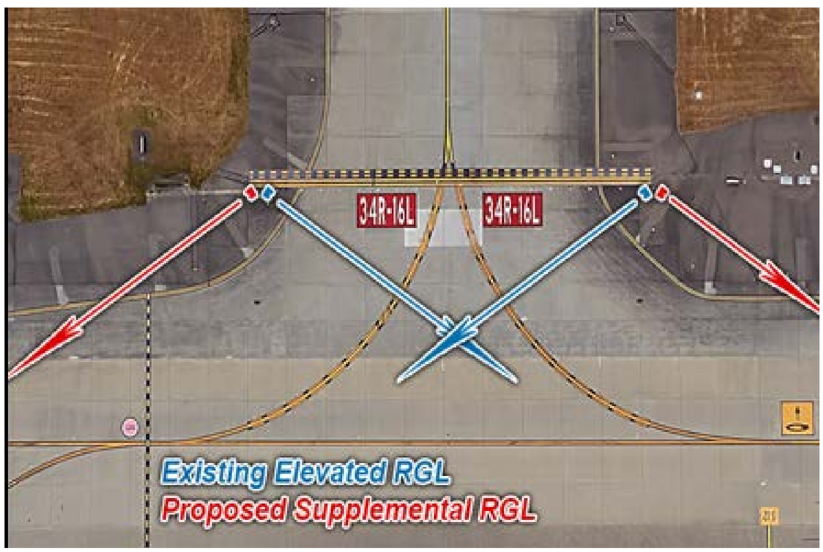
2.3.4.1 FAA RIM SEA-HS 1

Four concepts were developed to mitigate RIM SEA-HS 1.

Mitigation Concept 1: Supplemental Runway Guard Lights

This concept, shown on Figure 2-10, supplements the two existing Runway Guard Lights (RGL) with two additional RGLs on each side of Taxiway Q holding point to increase visibility for aircraft taxiing from Taxiway B. There would be no impacts to operations during construction. However, the ability of the additional RGLs to adequately mitigate the Hot Spot was questioned.

Figure 2-10
RIM SEA-HS 1 Mitigation Concept 1
Seattle-Tacoma International Airport

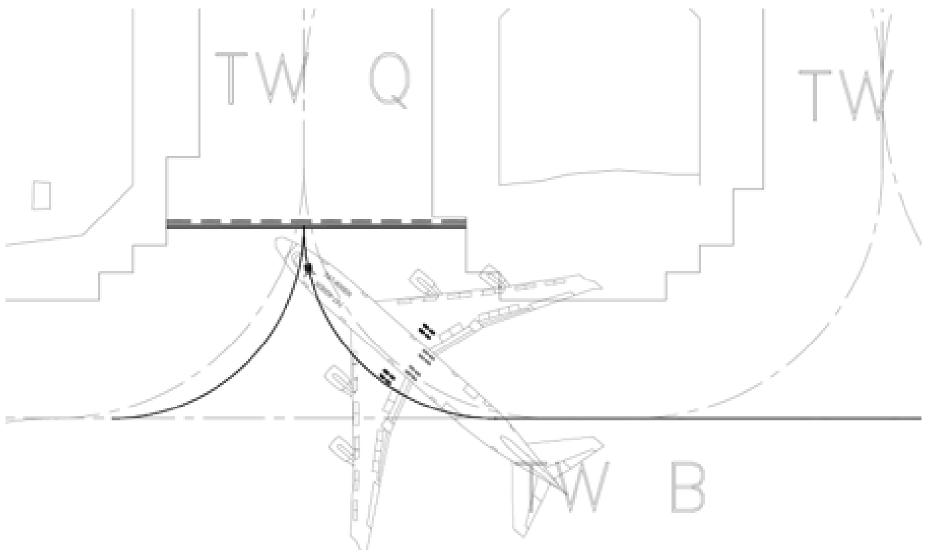


Source: CH2M Hill, Engineers, February 2016.

Mitigation Concept 2: Merge Centerline Radii Prior to Hold-bar

Under Concept 2, shown on Figure 2-11, the Taxiway Q centerline radii are shifted slightly to end at the crossing hold line. There would be impacts to operations during construction as it requires restriping and realigning the centerline lights. However, this alternative mitigates what has been expressed as the primary factor that results in runway incursions, the confluence of the radii beyond the hold line and the inability to align aircraft perpendicular to the runway.

Figure 2-11
RIM SEA-HS 1 Mitigation Concept 2
Seattle-Tacoma International Airport

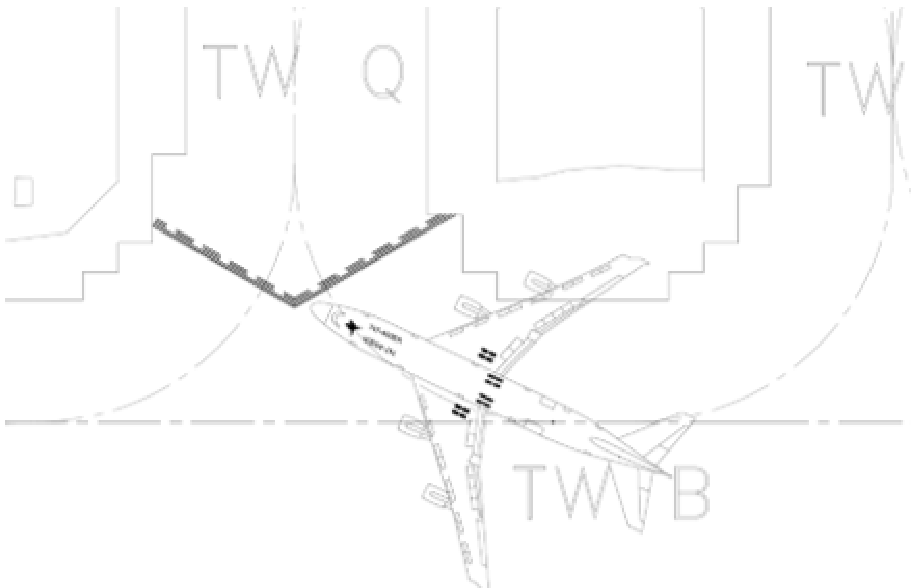


Source: CH2M Hill, Engineers, February 2016.

Mitigation Concept 3: Angled "V" Hold-bars

Concept 3, shown on Figure 2-12, includes the installation of two angled hold-bars to improve visibility from each direction. This alternative attempts to alert the pilot to the hold line prior to beginning the turn. However, the non-standard hold-bar configuration is not ideal. There would be impacts to operations during construction as it requires restriping and realigning the centerline lights.

Figure 2-12
RIM SEA-HS 1 Mitigation Concept 3
Seattle-Tacoma International Airport

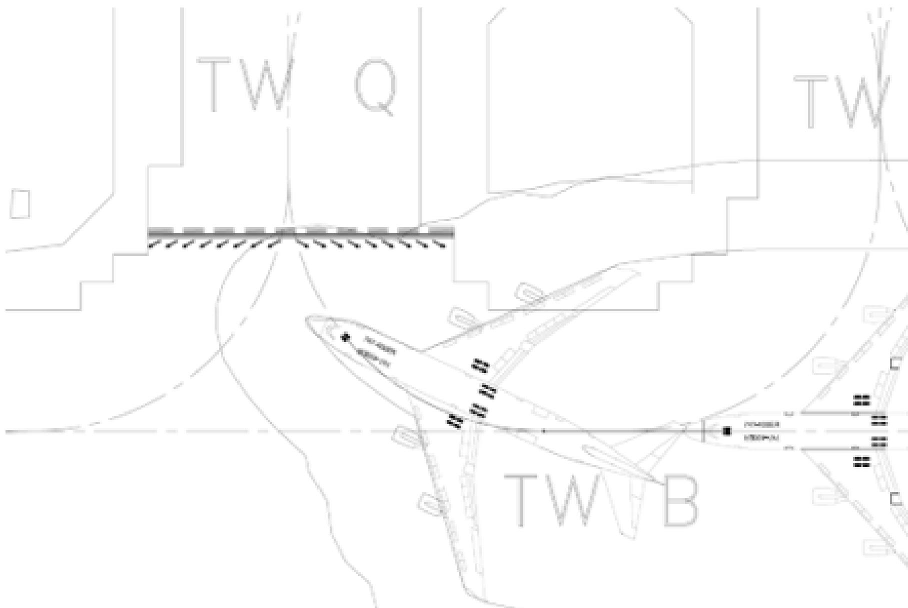


Source: CH2M Hill, Engineers, February 2016.

Mitigation Concept 4: Angled Hold-bar Lighting

Concept 4, shown on Figure 2-11, includes angled hold-bar lighting with directional lighting to make the holding point more conspicuous to approaching aircraft. Airport Operations viewed this alternative as unacceptable due to the non-standard hold-bar and uncertain benefit. This alternative would not have any impacts to operations during construction.

Figure 2-13
RIM SEA-HS 1 Mitigation Concept 4
Seattle-Tacoma International Airport



Source: CH2M Hill, Engineers, February 2016.

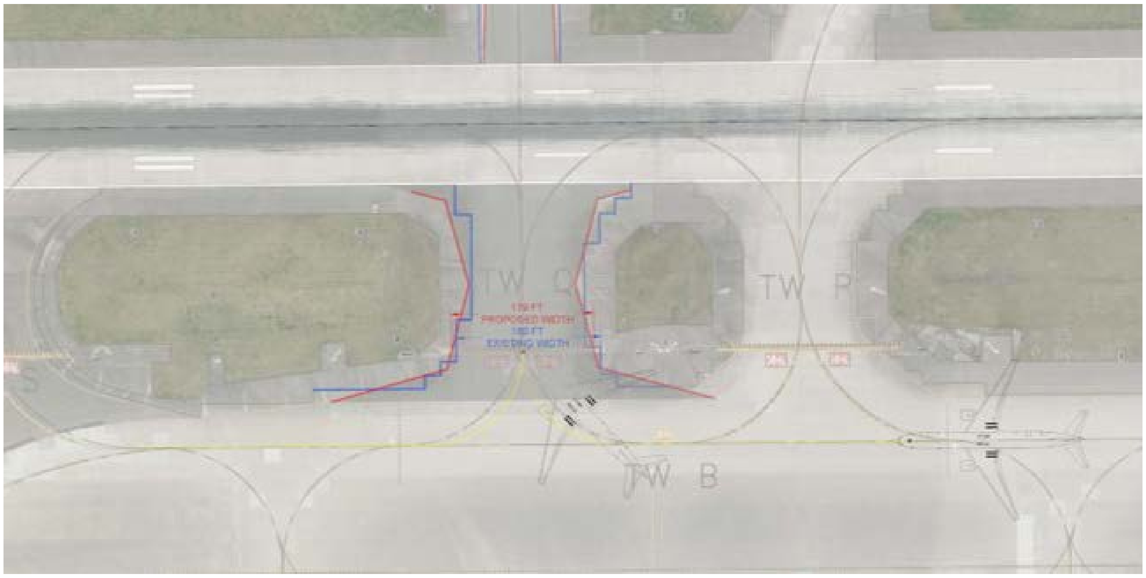
RIM SEA-HS 1 Preferred Mitigation Concept

Mitigation Concepts 1, 3, and 4 were dismissed by Airport operations staff and the FAA because of the limited and/or uncertain benefits anticipated. The preferred alternative is to combine mitigation Concept 2 with modifications to operational procedures and lighting.

The preferred RIM SEA-HS 1 mitigation concept, shown on Figure 2-14, includes a reduction of Taxiway Q pavement width to 75 feet, and a reduction of the centerline radii so it ends at the crossing hold line. In addition, the preferred concept includes restriped marking and new/relocated Taxiway lights at the reduced radii.

The Port is proceeding with the implementation of this preferred concept. The concept has been reviewed by the FAA will be completed by the end of 2018. Upon completion of the project, Airport staff will continue to monitor the Hot Spot to ensure the modifications mitigate existing safety concerns.

Figure 2-14
RIM SEA-HS 1 Preferred Mitigation Concept
Seattle-Tacoma International Airport



Source: CH2M Hill, Engineers, July 2016.

2.3.4.2 FAA RIM SEA-HS 2

FAA RIM-SEA HS 2 is located on Taxiway F. The recommended solution, agreed to by the FAA Office of Runway Safety, is to remove the HS designation due to a change in use of this location by FAA air traffic controllers. This location will still be monitored as part of the RIM program.

2.3.4.3 RIM Additional Location

The third FAA RIM location is in the vicinity of the Runway 16L threshold. Aircraft may be crossing the Runway 16L hold line as a result of the wide expanse of pavement or angled sweeping nature of Taxiway A.

The preferred alternative to compliance issue #8 (Three-node Concept, discussed later in this section) includes improvement to this area of the airfield. As part of this project (1) Taxiway B will be shifted to obtain a 500 feet separation with the Runway 16L-34R centerline, (2) Taxiway A will also be shifted, and (3) the sweeping connection between Taxiway A and Taxiway D will be removed. In addition, wide expanses of pavement will be limited with the introduction of new green no-taxi islands. It is anticipated this solution will improve pilots' awareness in this area. Once the preferred alternative is implemented, this RIM location should be monitored and alternatives to improve situational awareness should be reevaluated if runway incursions persist.

2.3.5 Compliance Issue #5: High Energy Intersections

Taxiways K, M, and N each cross Runway 16L-34R in the high energy zone (i.e., the middle third of the runway) and Taxiway J is just within the middle third of Runway 16C-34C.

This compliance issue was examined as part of the entire airfield analysis in combination with compliance issues #6, 7, and 9. Results of this analysis are presented in Section 2.3.11.

2.3.6 Compliance Issue #6: Right Angle Intersections

This compliance issue was examined as part of the entire airfield analysis in combination with compliance issues #5, 7, and 9. Results of this analysis are presented in Section 2.3.11.

2.3.7 Compliance Issue #7: Direct Access to Runway from an Apron

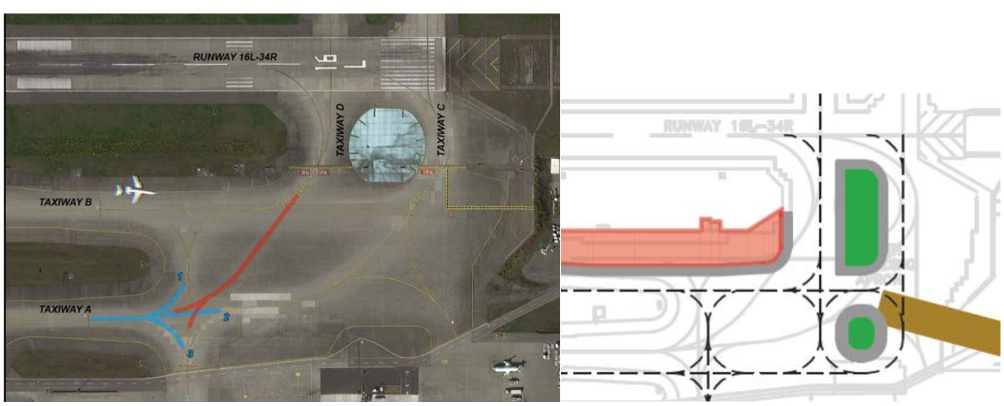
Taxiway N and Taxiway L provide direct access from the apron to Runway 16L-34R. The preferred alternative[1] is to relocate both Taxiways L and N.

Taxiway L relocation will be implemented as part of a 2018 capital improvement project. The relocation has been reviewed by the FAA and the FAA has completed NEPA reviews. It is anticipated this project will be completed by the end of 2018. The relocation of Taxiway N was examined as part of the entire airfield analysis in combination with compliance issues #5, 6, and 9. Results of this analysis are presented in Section 2.3.11.

2.3.8 Compliance Issue #8: Three-Node Concept

The intersection of Taxiway A with Taxiways C and D near the Runway 16L threshold is inconsistent with the FAA's "three-node concept." Because the Airport's taxiway system is constrained by the limited availability of developable land, options involving major taxiway system redesign were not considered. Accordingly, the alternative, shown on Figure 2-15, is to remove the Taxiway centerline leading from Taxiway A to Taxiway D to reduce the intersection to three nodes. The alternative is consistent with the proposed shift of Taxiway B described in compliance issue #1.

Figure 2-15
Three-Node Concept Preferred Alternative
Seattle-Tacoma International Airport



Source: CH2M Hill, Engineers, February 2016.

[1] The preferred alternative refers to a preference by the Port and FAA during meetings to review alternative concepts.

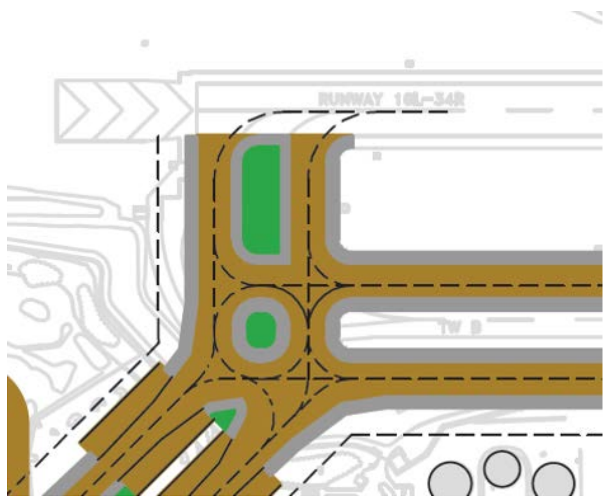
2.3.9 Compliance Issue #9: High Speed Exit Placement

This compliance issue was examined as part of the entire airfield analysis in combination with compliance issues #5, 6, and 7. Results of this analysis are presented in Section 2.3.11.

2.3.10 Compliance Issue #10: No-Taxi Islands

Although Runway 34R is accessed both by an entrance taxiway and a bypass taxiway, these taxiways are not separated by a no-taxi island. The solution to this issue is straightforward—current design criteria specify that taxiways providing access to a roadway be separate and distinct. Therefore, the preferred alternative, shown on Figure 2-16, is to install a no-taxi island and designate the entrance and bypass taxiways by separate names.

Figure 2-16
No-Taxi Island Preferred Alternative
Seattle-Tacoma International Airport



Source: CH2M Hill, Engineers, February 2016.

2.3.11 Comprehensive Airfield Alternatives Analysis Related to Compliance Issues #5, 6, 7, and 9

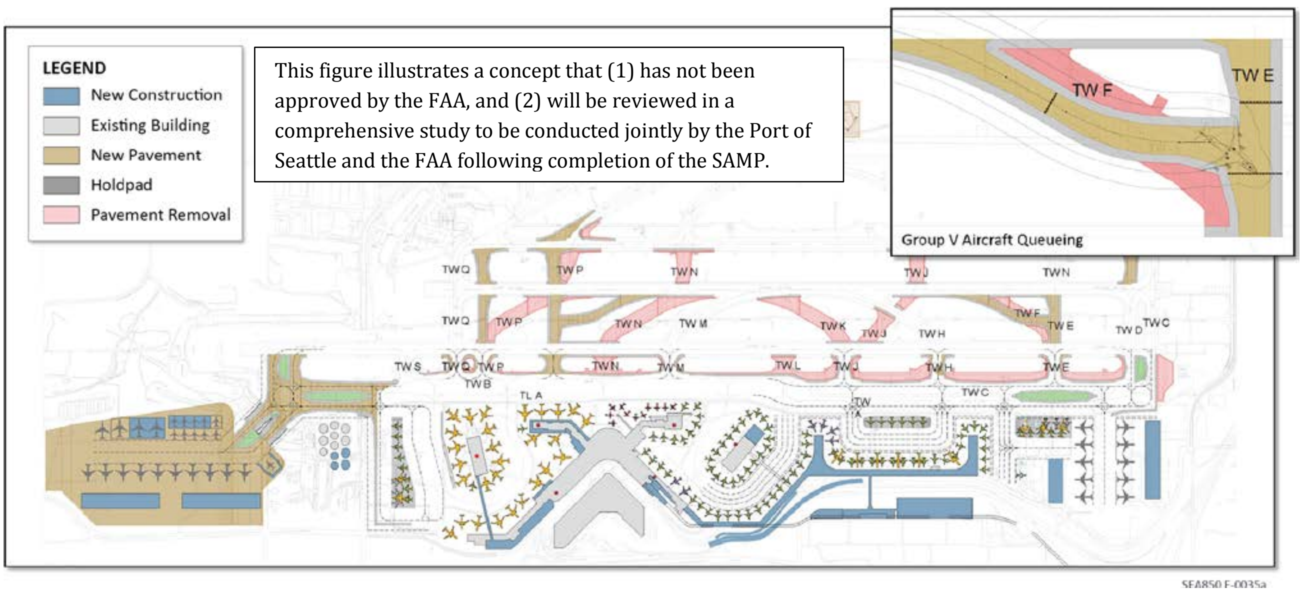
Seven alternative concepts, including a minimal action concept, were prepared—from the perspective of overall airfield operations— to identify the preferred alternative to mitigate compliance issues #5, 6, 7, and 9 (high-energy intersections, right-angle intersections, direct access to a runway from an apron, and high-speed exit placement, respectively).

Concept 1: "T" High-Speed Exits, Maintain Two Existing High-Speed Exits

Under Concept 1, shown on Figure 2-17, most of the taxiway crossings within the high-energy area (middle third of the runway) of Runway 16C-34C and Runway 16L-34R are removed, including Taxiways J and K, to solve compliance issue #5. It also removes Taxiway P, which does not intersect Runway 16L-34R at a right angle, to partially solve compliance issue #6. However, this alternative does not completely solve compliance issues 5 and 6 as it maintains Taxiways M and H at their current locations.

This concept also reconfigures two existing high-speed exits, Taxiway F and Taxiway N, and relocates Taxiway N outside of the high-energy area. The reconfiguration of Taxiways F and N with T-shaped high speed exits allows for queuing of aircraft between the runways. Although intersections between the taxiways and the runway are at right angles, aircraft queuing within the T are not at a right angle with the runway when at the holding point.

Figure 2-17
Concept 1: Maintain Two Existing High-Speed Exits
Seattle-Tacoma International Airport



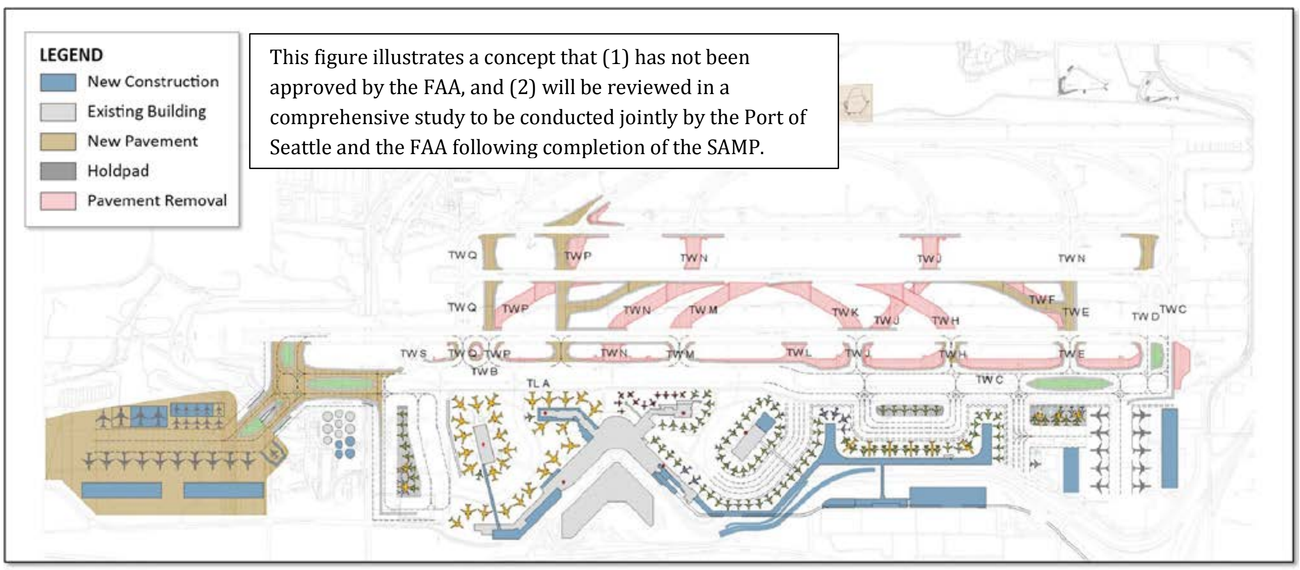
Source: CH2M Hill, Engineers, July 2016.

Concept 2: "T" High-Speed Exits, Remove all Existing High-Speed Exits

Concept 2, shown on Figure 2-18, is similar to Concept 1, but includes the removal of additional high-speed taxiways. All taxiway crossings within the high-energy area are removed, including Taxiways J, K and M, to solve compliance issue #5. It also removes Taxiways P and H, which do not intersect with the runway at a right angle, to solve compliance issue #6.

This concept reconfigures two existing high-speed exits, Taxiway F and Taxiway N, and relocates Taxiway N outside of the high-energy area. Similar to Concept 1, the reconfiguration of Taxiway F and N with T-shaped high speed exits allows for queuing of aircraft between the runways. Although intersections between the taxiways and the runway are at a right angle, aircraft queuing within the T are not at a right angle at the holding point.

Figure 2-18
Concept 2: Removal of Existing High-Speed Exits
Seattle-Tacoma International Airport



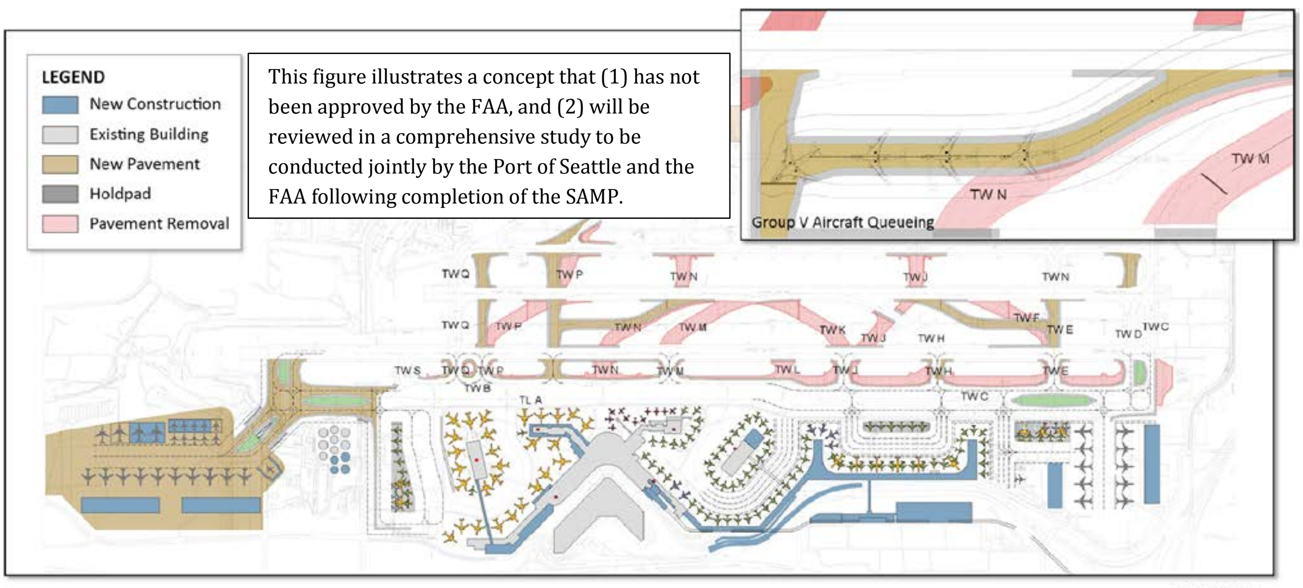
Source: CH2M Hill, Engineers, July 2016.

Concept 3: Longer "T" High-Speed Exits, Maintain One Existing High-Speed Exit

Under Concept 3, shown on Figure 2-19, all taxiway crossings within the high-energy area are removed, including Taxiways J, K, and M, to resolve compliance issue #5. It also removes Taxiway P, which does not intersect with the runway at a right angle, to partially solve compliance issue #6, but maintains Taxiway H at its current location and shape.

This concept reconfigures two existing high-speed exits, Taxiway F and Taxiway N, and relocates Taxiway N outside of the high-energy area. This reconfiguration is similar to the T-shape reconfiguration, with a longer portion parallel to the runway to allow for more aircraft queuing. The separation between the taxiway and the runway is 400 feet. Similarly to the previous two concepts, aircraft queuing at the holding points are not at a right angle with the runway.

Figure 2-19
Concept 3: Maintain One Existing High-Speed Exit
Seattle-Tacoma International Airport

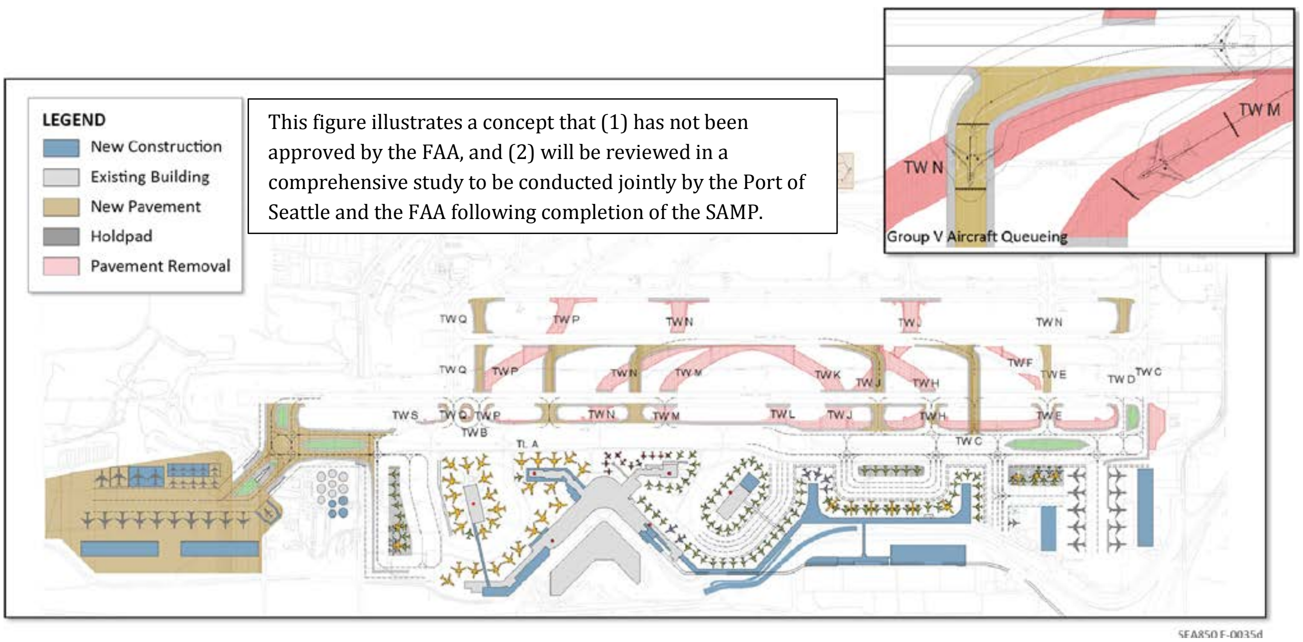


Source: CH2M Hill, Engineers, July 2016.

Concept 4: "Curved" High-Speed Exits

Under Concept 4, shown on Figure 2-20, Taxiways J, K, and M are removed to solve compliance issue #5. Taxiways H, N, and P are also reconfigured with partial curved exits, and the concept relocates and reconfigures Taxiway H with the partial curved exits concept. This concept allows for aircraft to be lined up at a right angle with Runway 16L-34R at the holding point to solve compliance issue #6. However, Concept 4 does not allow for sufficient queuing between the runways.

Figure 2-20
Concept 4: Curved High-Speed Exits
Seattle-Tacoma International Airport



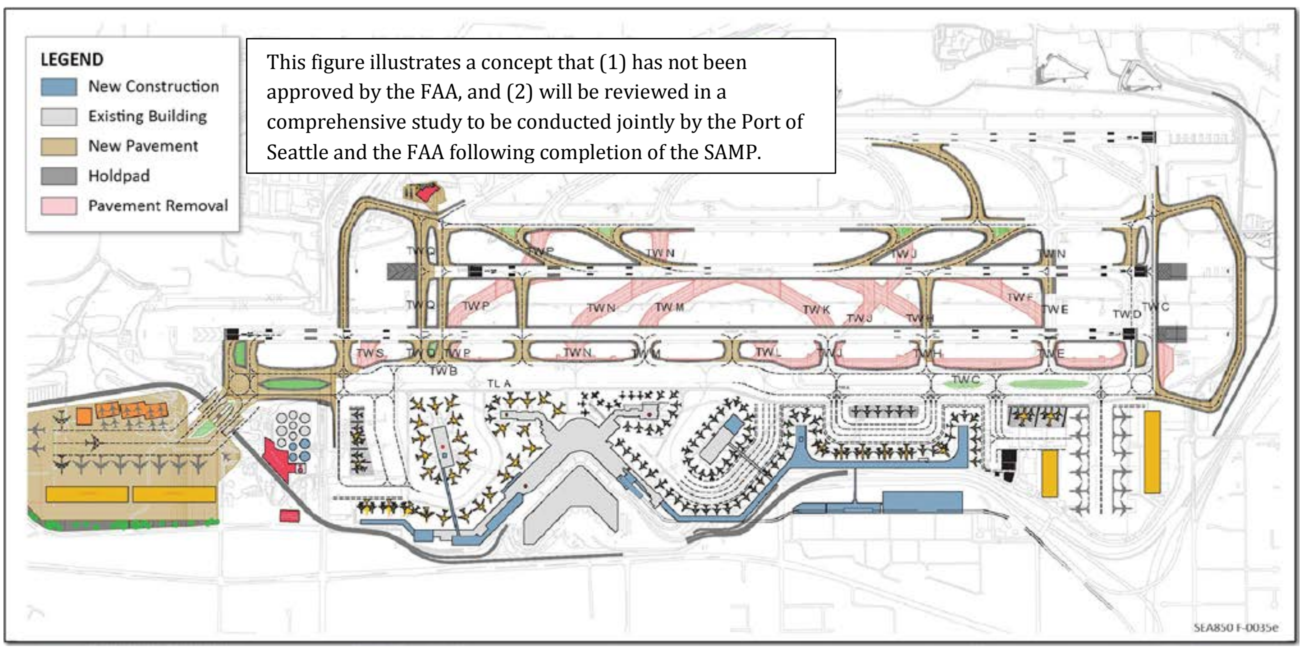
Source: CH2M Hill, Engineers, July 2016.

Concept 5: Western High-Speed Exits

Under Concept 5, shown on Figure 2-21, all the eastbound high speed exits from Runway 16C-34C, including Taxiways F, H, J, K, M, N, and P, are removed. The high speed exits F, H, K, and M are reconfigured to exit towards Taxiway T (exit toward the west in south flow). This utilizes end-around taxiways on each side of the airfield for aircraft crossings up to Group III. Aircraft larger than Group III would use the other perpendicular taxiways (C, D, E, P, or Q depending on the performances) to cross Runway 16C-34C and 16L-34R.

The southern end-around taxiway bypasses Runway 16C-34C and crosses Runway 16L-34R using a relocated Taxiway S. The northern end-around Taxiway bypasses both Runway 16C-34C and Runway 16L-34R, and does not require an active runway crossing.

Figure 2-21
Concept 5: Western High-Speed Exits
Seattle-Tacoma International Airport



Source: CH2M Hill, Engineers, July 2016.

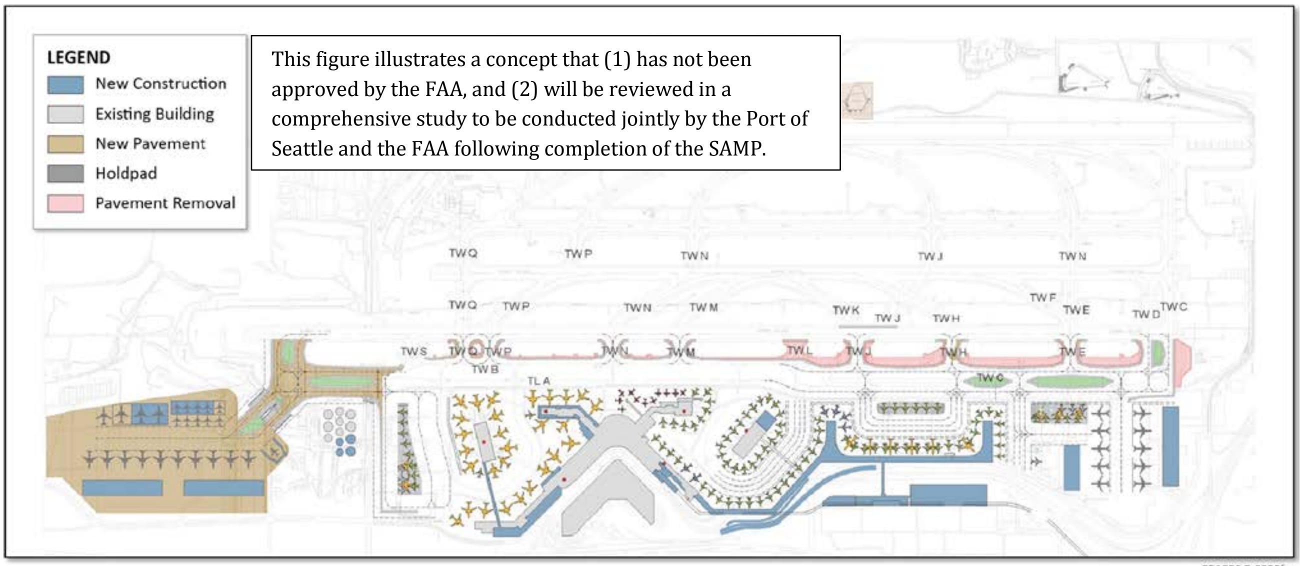
Concept 6: Minimal Action

Concept 6, shown on Figure 2-22, is a minimal action concept. It maintains the changes proposed to solve compliance issues 7 and 8 east of the inboard runway, with the reconfiguration of Taxiway B and removal of Taxiway L, but does not include changes to the airfield west of the inboard runway.

Concept 7: Shift Runway 16C-34C

Concept 7 includes a shift of Runway 16C-34C to provide greater separation between Runway 16C-34C and Runway 16L-34R and solves compliance issues 5, 6, and 9. However, this concept has significant impacts on the existing facilities. In addition, Runway 16C-34C was recently constructed. Therefore, this concept was removed from detailed consideration.

Figure 2-22
Concept 6: Minimal Action
Seattle-Tacoma International Airport



Source: CH2M Hill, Engineers, July 2016.

Alternative Analysis Summary and Preferred Alternative

Each alternative concept was assessed and ranked based on the following evaluation criteria:

- **Meets FAA standards:** This criterion reflects the ability to meet FAA design and safety standards. If an alternative did not meet this criterion, it was dismissed from further consideration.

- **Ability to queue between runways:** This criterion reflects the ability for aircraft to queue between runways, or to hold between the center and inboard runway, providing more ATC flexibility.

- **Operational flexibility during construction:** This criterion reflects the ability to allow for flexible operations during construction.

- **Impact on runway capacity:** This criterion reflects the ability to maximize runway capacity.

- **Sustainability considerations:** This criterion reflects the ability to minimize environmental impact.

- **Project costs:** This criterion reflects subjective judgments of the relative costs of the alternatives.

The concepts were analyzed using a tiered approach. Tier 1 evaluates each concept on the ability to meet FAA design and safety standards. The most important criterion is to meet FAA design and safety standards, and any concept that did not meet this criterion was removed from further consideration. Then, concepts that passed Tier 1 evaluation were evaluated on Tier 2 criteria, which are various operational considerations and project costs. Table 2-1 summarizes the scoring process described below.

In Tier 1 evaluation, Concepts 1, 2, and 3 were removed from consideration because they do not meet FAA AC 150/5300-13A design and safety standards. These three concepts introduce new taxiway pavement at a 400 foot separation with Runway 16L-34R and do not allow aircraft to be aligned at a right-angle with the runway when lined up on the taxiways. Concept 6 does not resolve compliance issues around taxiway crossings within the middle third of the runway and taxiways are not at a right angle, and was removed from further consideration.

Concepts 4, 5, and 7 were further analyzed for Tier 2 evaluation. Concept 7 was dismissed because of the significant impacts on the existing facilities, as described in Section 2.3.11. Concept 4 significantly limits the ability to queue between runways, and was removed from further consideration. Concept 5 has a higher cost than Concept 4, but all compliance issues are resolved. Concept 5 includes only right angle intersections, and exits within the middle-third of the runways are removed.

Thus, Concept 5 was selected as the preferred concept. However, it has not been accepted by the FAA and will be reviewed in a comprehensive study to be conducted jointly by the Port of Seattle and the FAA following completion of the SAMP.

Table 2-1
Rank and Score Summary – Alternative Concepts for Mitigating Design Criteria Compliance Issues
Seattle-Tacoma International Airport

	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6	Concept 7
Tier 1 Criteria							
1. Meets FAA design/safety standards	Red	Red	Red	Green	Green	Red	Green
Tier 2 Criteria							
2. Ability to queue between runways	Yellow	Yellow	Green	Red	Yellow	Yellow	Green
3. Operational flexibility during construction	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Red
4. Impact on runway capacity	Yellow	Red	Yellow	Yellow	Yellow	Green	Green
5. Sustainability considerations	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Red
6. Project Costs	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Red
Score	-1	-2	0	0	1	3	0

Ranking: Red -1, Yellow 0, Green +1

Source: CH2M Hill, July 2017.

2.4 Aircraft Deice Pads

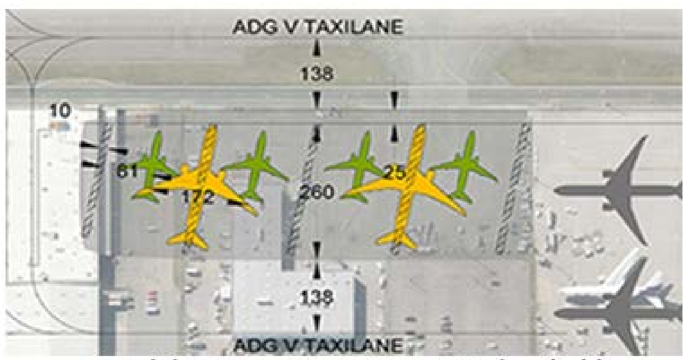
Aircraft deicing currently occurs at the gates. The airlines desire to transition to centralized deicing operations at locations convenient to the departure runway thresholds to (1) increase gate utilization during deicing conditions by "clearing" departing aircraft from the gates faster (by eliminating at-gate deicing), (2) consolidate the areas where glycol is collected into more confined areas, and (3) reduce the occurrences when departing aircraft must return to the point of deicing fluid application because the fluid is no longer effective due to time spent in taxi queues. The key planning assumptions are that the deice pads would:

- Supplement deicing at the gates (there is insufficient space to permit all deicing at centralized locations)
- Operate as a common use facility
- Permit flow through operations (i.e., taxi in, taxi out)
- Accommodate a range of aircraft types
- Provide sufficient space for deicing equipment and personnel
- Utilize space also used to accommodate remain overnight aircraft
- Be planned subsequent to the completion of the SAMP during advanced planning

The priority is a deice pad adjacent to the Runway 16L threshold. It is recommended that during advanced planning, opportunities to "overlay" off-gate aircraft parking positions with deice pads be explored and implemented. The concept is illustrated on Figure 2-23 for both north and south deicing pad locations.

Figure 2-23
Remote Aircraft Deice Concept
Seattle-Tacoma International Airport

North location near Runway 16L threshold



South location near Runway 34R threshold

Source: Port of Seattle, 2017.

2.5 Updated Airfield and Airspace Demand-Capacity Analysis

2.5.1 Background

This section provides a summary of the airfield and airspace demand-capacity analysis conducted for the Sustainable Airport Master Plan in 2016 and 2017. In 2015, an initial demand-capacity analysis was conducted in cooperation with the FAA and Port of Seattle using the Airport Cooperative Research Program (ACRP) Prototype Airfield Capacity Spreadsheet Model, which is based on the industry-standard FAA Airfield Capacity Model (ACM). Considering the Airport's three-runway system and a runway use pattern similar to that observed in 2014, the results of this analytical spreadsheet model suggested that average annual aircraft delays could exceed 20 minutes by Planning Activity Level 3 (PAL 3, or 2029).

However, the ACRP model mainly considers runway capacity constraints. Other sources of potential airfield capacity constraints, such as runway crossings, the taxiway system, the airspace structure, and the apron/gate area, are not included in this model. To better understand how the airfield and airspace system as a whole may affect future delays, the planning team conducted a detailed airfield simulation effort using the Total Airport and Airspace Modeler (TAAM). TAAM is a fast-time airfield and airspace simulation software program that simulates individual aircraft operations from origin to destination. It enables the user to explicitly consider how the Airport's runway system, taxiway system, apron/gate area, and airspace could affect airfield capacity and aircraft delay. The results of the simulations, coupled with other analytical tools, were used to evaluate whether the airfield infrastructure changes proposed in the SAMP would enable the Airport to accommodate forecast demand at a reasonable level of delay.

2.5.2 Approach

The simulation effort began with a model calibration process. A calibrated model is one that produces performance measures that are similar to historical data. To develop a calibrated model, airport operations were simulated using a historical schedule and the model was validated by comparing the performance measures of the simulated airport (hourly runway throughput, runway use, taxi times, and gate use) with observed historical performance. Following calibration, proposed airfield improvements and future-year design day flight schedules were applied to these calibrated models and the performance of the simulated airfield was evaluated.

The following two sections describe key input assumptions for the simulations and present a summary of the simulated results. Additional assumptions and more detailed results for both the calibration process and the future-year models are provided in Appendix G.

2.5.3 Key Assumptions

2.5.3.1 Design Day Flight Schedule

A design day flight schedule (DDFS) is a schedule of matched flight arrivals and departures used in simulation. Four DDFS were used as part of this simulation exercise; a baseline DDFS that was used for calibration purposes, and three future-year DDFS. The baseline DDFS was constructed from Official

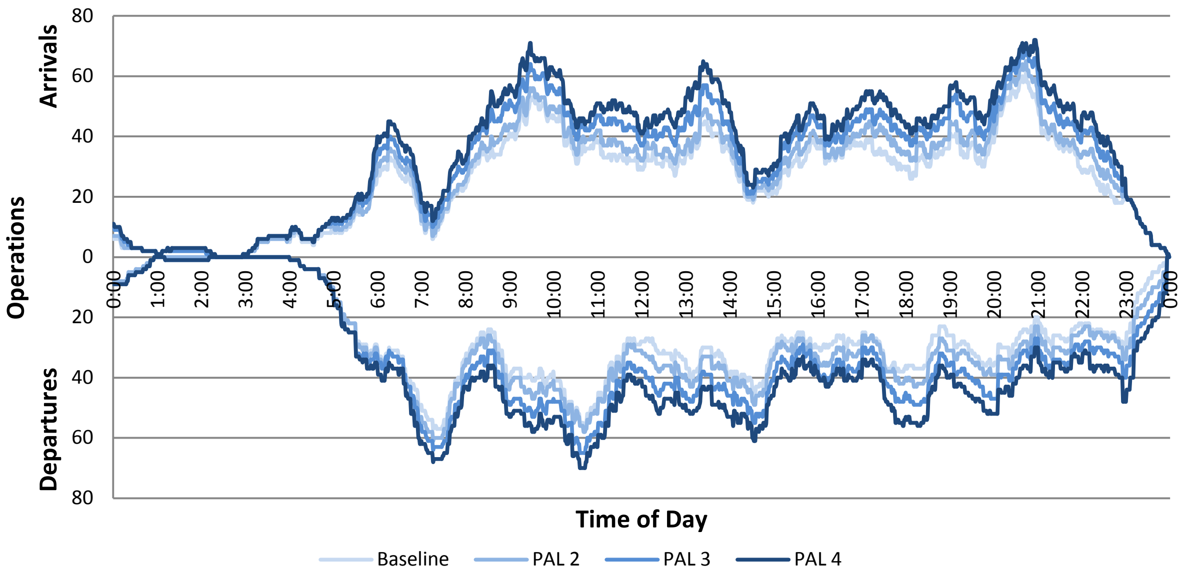
Airline Guide (OAG) data selected using Average Day of the Peak Month (ADPM) methodology for August 2016. In addition to passenger operations, cargo, and general aviation (GA) operations were added to the DDFS based on historical operations obtained from the FAA Aviation System Performance Metrics (ASPM) database. Future-year DDFS were developed by adjusting the baseline schedule in accordance with annual activity forecasts. Table 2-2 and Figure 2-24 summarize the total and rolling hour operations, respectively, of the four DDFS used in the simulations.

Table 2-2
Summary of Operations Contained in Design Day Flight Schedules
Seattle-Tacoma International Airport

	Baseline DDFS			PAL 2 DDFS			PAL 3 DDFS			PAL 4 DDFS		
	Arrival	Departure	Total	Arrival	Departure	Total	Arrival	Departure	Total	Arrival	Departure	Total
Operations												
DDFS Operations	612	620	1232	670	677	1347	769	774	1543	850	856	1706
Peak Hour Ops	61	57	94	65	61	103	69	65	115	72	70	127
Peak Hour Start	8:44 PM	7:16 AM	9:31 AM	8:44 PM	7:16 AM	9:31 AM	8:44 PM	10:36 AM	9:29 AM	8:55 PM	10:36 AM	9:29 AM
Fleet Mix												
Wide Body	46	46	92	49	49	98	59	59	118	61	63	124
Narrow Body	343	349	692	383	389	772	444	449	893	488	493	981
Regional Jet	101	102	203	111	111	222	130	130	260	156	156	312
Turboprop	122	123	245	127	128	255	136	136	272	145	144	289
Market Segment												
Passenger	595	603	1198	651	658	1309	749	755	1504	829	835	1664
Cargo	15	14	29	17	16	33	18	16	34	19	18	37
GA	2	3	5	2	3	5	2	3	5	2	3	5

Source: LeighFisher, 2016.

Figure 2-24
Rolling Hour Design Day Flight Schedule Profiles
Seattle-Tacoma International Airport



Source: LeighFisher, 2016.

2.5.3.2 Airspace Structure

The Airport's three runways lie parallel to each other in a north-south orientation. The Airport generally operates in one of two flow directions, North flow or South flow, primarily depending on the prevailing wind direction. In North flow, operations may use runways 34R, 34C, and 34L; in South flow, operations may use 16L, 16C, and 16R. South flow is the preferred configuration for a number of reasons, including predominant winds, fewer interactions with nearby airports (i.e., Boeing Field - BFI), and a more favorable taxiway pattern to feed the primary departure runway.

For the purposes of historical analysis, the Airport is assumed to be operating in North flow during a particular hour if at least 10 operations occur in that hour, and if at least 90% of these operations use runways 34L, 34C, or 34R. Similarly, the Airport is assumed to be operating in South flow during a particular hour if at least 10 operations occur in that hour, and if at least 90% of those operations use runways 16R, 16C, or 16L. The Airport is assumed to be operating in a bi-directional flow during a particular hour if at least 10 operations occur in that hour, and if fewer than 90% of these operations use the same runway orientation. The Airport is assumed to be in a period of low demand if fewer than 10 operations occur in a given hour. Analysis of data provided by the Port of Seattle Noise Office for January 1, 2012 to November 29, 2016 revealed that the Airport operates in South flow approximately 70.9% of the time and North flow 29.1% of the time. These percentages exclude bi-directional flow hours, low demand hours, or hours with missing data.

An important characteristic of the Airport's airspace is the single departure waypoint in both flow directions. Both Conventional and Area Navigation (RNAV) Standard Instrument Departure Procedures (SIDs) call for all jet departures to converge on this waypoint. Furthermore, jet noise-abatement procedures confine departures to narrow corridors. Turboprop aircraft departures are exempt from these rules and may make an immediate, divergent turn. This single waypoint precludes the possibility of conducting parallel simultaneous departure streams. Standard instrument departure and arrival routes for north flow and south flow are shown on Figure 2-25.

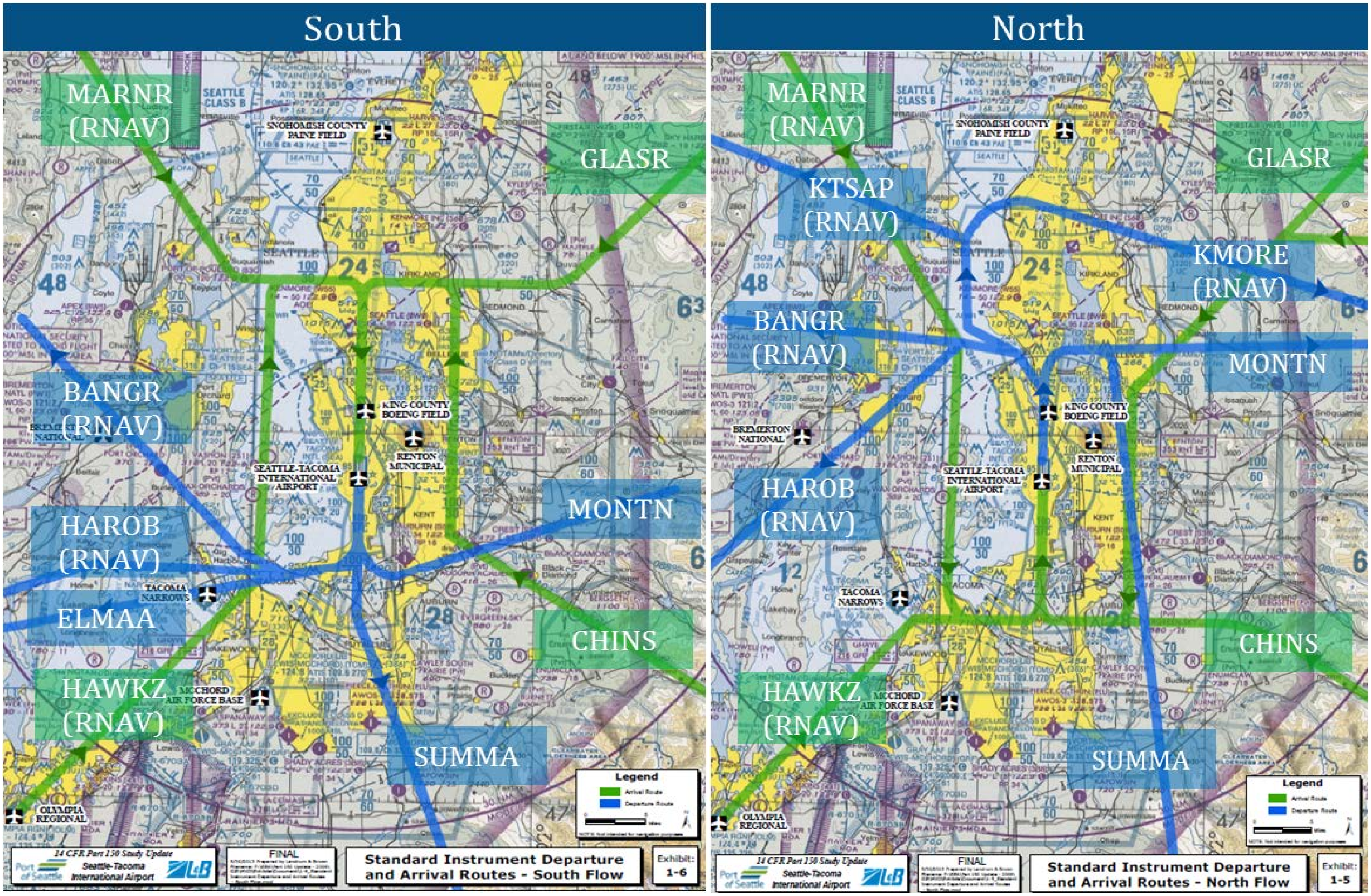
2.5.3.3 Weather Conditions

The Airport is characterized by various operating conditions generally defined by atmospheric ceiling and visibility. For the purposes of simulation, weather conditions at the Airport were classified as one of three conditions:

- Visual Meteorological Conditions (VMC): generally favorable weather conditions at the Airport and on the final arrival approach path. The Airport can achieve high throughputs due to the high visibility.
  - South flow: defined as a cloud ceiling of at least 5,000 feet and visibility of at least 5 miles.
  - North flow: defined as a cloud ceiling of at least 5,000 feet and visibility of at least 5 miles.
- Marginal Meteorological Conditions (MMC): weather conditions that are less severe than under Instrument Conditions but worse than Visual Conditions.
  - South flow: defined as a cloud ceiling between 3,000 and 5,000 feet and visibility between 3 and 5 miles.
  - North flow: Not defined.
- Instrument Meteorological Conditions (IMC): generally poor weather conditions at the Airport and on the final approach path. Throughputs are reduced due to the lower visibility.
  - South flow: defined as a cloud ceiling less than 3,000 feet or visibility less than 3 miles.
  - North flow: defined as a cloud ceiling less than 5,000 feet or visibility less than 5 miles.

The definitions of each weather state differ from North flow to South flow because of the runway stagger in North flow and the missed approach thresholds (4,000 feet in South flow; 3,000 feet in North flow).

Figure 2-25
Standard Instrument Departure and Arrival Routes for North and South Flows
Seattle-Tacoma International Airport



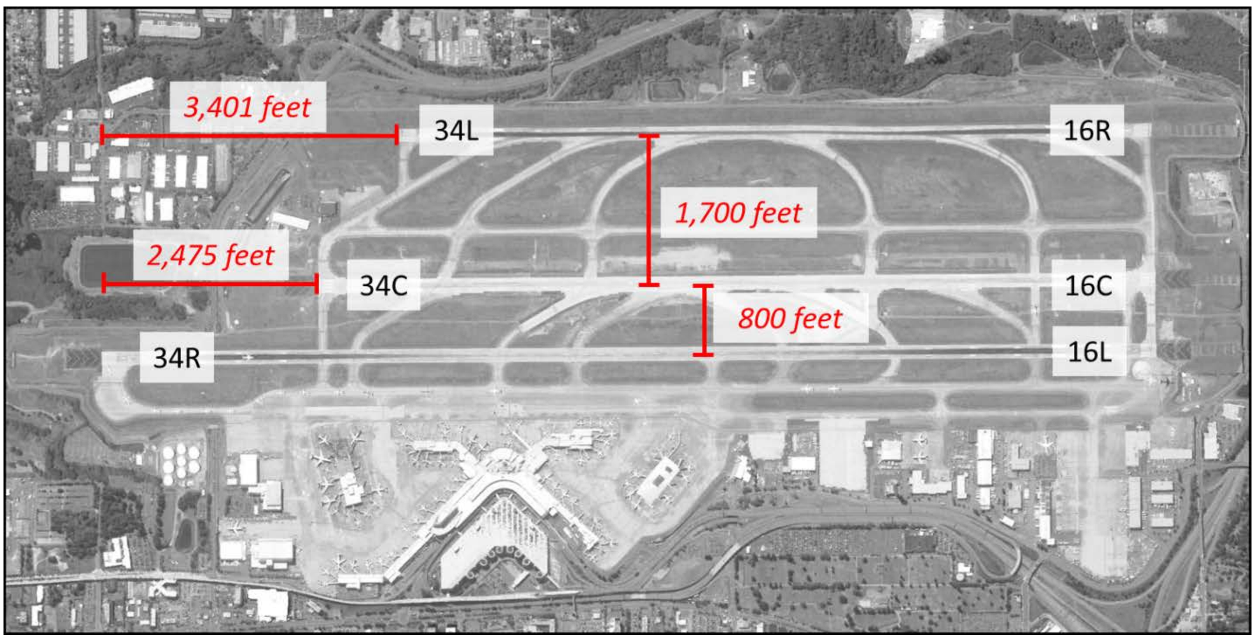
Source: 14 CFR Part 150 Study Update, October 2013.

2.5.3.4 Runway Use

Layout

The centerlines between Runways 16L-34R and 16C-34C are 800 feet apart; the centerlines between Runways 16C-34C and 16R-34L are 1,700 feet apart; and the centerlines between Runways 16L-34R and 16R-34L are 2,500 feet apart. The South flow runways—16L, 16C, and 16R—are not staggered; that is, their thresholds are not offset from each other. In North flow, however, the thresholds of the inboard runway (34R) and the outboard runway (34L) are offset by 3,401 feet; the thresholds of the inboard runway (34R) and the center runway (34C) are offset by 2,475 feet; and the thresholds of the center runway (34C) and the outboard runway (34L) are offset by 926 feet. These runway centerline separations and runway threshold offsets are shown on Figure 2-26.

Figure 2-26
Runway Centerline Separations and Runway Threshold Offsets
Seattle-Tacoma International Airport



Source: LeighFisher, September 2017.

Historical Runway Use

In IMC, the Air Traffic Control Tower (ATCT) at the Airport prefers to assign arrivals to the outboard and the inboard runways. Their centerlines are spaced 2,500 feet apart; therefore, a full wake turbulence separation is not required between arrivals to these runways.

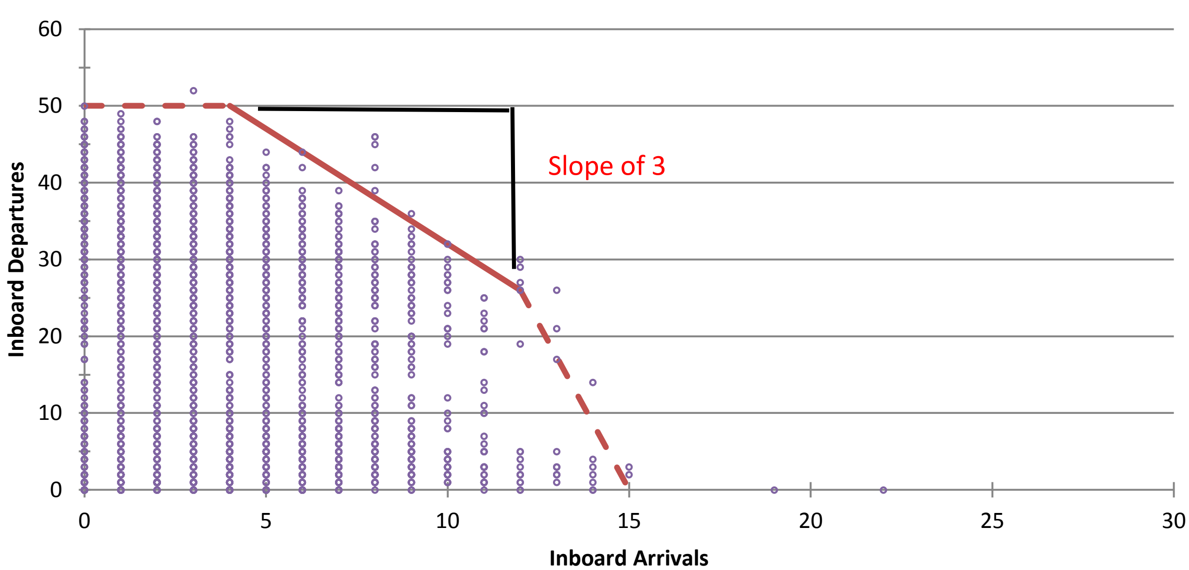
Pilots of heavy arriving jets often request to land on Runway 16L-34R, the inboard runway, which is the primary departure runway. Pilots typically make this request to utilize the length of the runway (11,901 feet) to decelerate rather than the shorter center and outboard runways. Additionally, the inboard runway is adjacent to the terminal area, so the pilot can reduce taxi-in time and avoid crossing active runways.

However, ATCT controllers at the Airport estimate that every heavy inboard arrival results in the loss of up to 3-4 inboard runway departure slots. The reduction of departure throughput is attributable to the increased runway occupancy time of inboard arrivals, which may occur for the following reasons:

- The inboard runway does not have high-speed exits, so arrivals must come to nearly a complete stop on the runway before making a 90-degree turn to exit the runway.
- An inboard runway departure may not begin its roll if an arrival to that runway is within 2 nautical miles (n mi) of the runway threshold (referred to as the "capture distance").
- In South flow, inboard arrivals typically decelerate to taxiing speed around Taxiway M or N; however, because traffic on Taxiway B flows in the opposite direction, the arrival must travel at taxi speed on the runway to exit further south at Taxiway Q or S.
- When arrivals exit the inboard runway, they would ideally turn onto Taxiway B and then contact ground control. However, some international carrier pilots do not turn off before contacting ground control due to ICAO rules specifying that ground control must first approve entry into a taxiway prior to the movement.

Data from the Noise Office of the Port of Seattle from June 29, 2016 to November 29, 2016 reveal an approximately one-to-three tradeoff between inboard arrivals and departures, as shown on Figure 2-27.

Figure 2-27
Relationship between Arrivals and Departures on Runway 16L-34R
Seattle-Tacoma International Airport



Source: LeighFisher, based on data provided by Port of Seattle Noise Office, 2017.

In South flow VMC, ATCT controllers assign almost all departures to the center runway. This practice keeps the longer inboard runway available for heavy jet arrivals. If the Airport operates in this manner, then arrivals can land on the inboard runway without restricting departure throughput. Departures also occasionally use the center runway in South flow MMC.

In North flow, it is impractical to use the center runway as the primary departure runway. Departures would need to cross the active inboard runway to reach the center runway. In addition, there is little to no space for departure queuing for the center runway due to the proximity of the inboard runway to the main passenger terminal.

Simulated Conditions

Based on an analysis of historical operations and weather data at the Airport (detailed in Appendix G), and on discussions with ATCT personnel, five models representing the most frequent combinations of operating configurations and weather conditions were developed for simulation.

- South flow VMC (36.5% frequency): Arrivals on Runways 16R (primary) and 16L; departures on Runways 16C (primary) and 16L.
- South flow MMC (12.0% frequency): Arrivals on Runways 16R (primary) and 16L; departures on Runways 16L (primary) and 16C.
- South flow IMC (22.1% frequency): Arrivals on Runways 16R (primary) and 16L; departures on Runway 16L.
- North flow VMC (27.2% frequency): Arrivals on Runways 34L (primary) and 34R; departures on Runway 34R.
- North flow IMC (2.2% frequency): Arrivals on Runways 34L (primary) and 34R; departures on Runway 34R.

Dependencies

The following relationships were assumed between the runways for each of the models.

- South flow VMC
  - Visual approaches are independent of each other.
  - Departures on Runway 16C are independent of arrivals on Runways 16R and 16L.
  - Jet departures from different runways are fully dependent on each other.
  - Mixed operations runway
    - A departure on Runway 16L cannot roll if the next Runway 16L arrival is within the runway capture distance of 2 nmi.
    - A departure on Runway 16L cannot roll until the previous Runway 16L arrival has cleared the runway.

- South flow MMC
  - ILS approaches and instrument departures; no “2-increasing-to-3” rule.
  - Arrivals to Runways 16L and 16R are dependent and must maintain a minimum 1 nmi diagonal separation.
  - Departures on Runway 16L are independent of arrivals on Runway 16R.
  - Departures on Runway 16C are independent of arrivals on Runways 16R and 16L.
  - Jet departures from different runways are fully dependent on each other.
  - Mixed operations runway
    - A departure on Runway 16L cannot roll if the next Runway 16L arrival is within the runway capture distance of 2 nmi.
    - A departure on Runway 16L cannot roll until the previous Runway 16L arrival has cleared the runway.

- South flow IMC
  - Arrivals to Runways 16L and 16R are dependent and must maintain a minimum 1 nmi diagonal separation.
  - Departures on Runway 16L are independent of arrivals on Runway 16R (see FAA JO 7110.65W, which allows for independent arrivals and departures on runways separated by at least 2,500 feet with no stagger).
  - Mixed operations runway:
    - A departure on Runway 16L cannot roll if the next Runway 16L arrival is within the runway capture distance of 2 nmi.
    - A departure on Runway 16L cannot roll until the previous Runway 16L arrival has cleared the runway.

- North flow VMC
  - Visual approaches are independent of each other.
  - Departures on Runway 34R are independent of arrivals on Runway 34L.
  - Mixed operations runway
    - A departure on Runway 34R cannot roll if the next Runway 34R arrival is within the runway capture distance of 2 nmi.
    - A departure on Runway 34R cannot roll until the previous Runway 34R arrival has cleared the runway.

- North flow IMC
  - Arrivals to Runways 34R and 34L are dependent and must maintain a minimum 1 nmi diagonal separation.
  - Departures on Runway 34R are dependent on arrivals to Runway 34L (see FAA JO 7110.65W, which precludes independent arrivals and departures on staggered runways separated by 2,500 feet).
    - The departure must begin its roll before the next Runway 34L arrival reaches the runway capture distance of 2 nmi + 3,401 foot stagger.
  - Mixed operations runway
    - A departure on Runway 34R cannot roll if the next Runway 34R arrival is within the runway capture distance of 2 nmi.
    - A departure on Runway 34R cannot roll until the previous Runway 34R arrival has cleared the runway.

2.5.3.5 Taxi Flows

In South flow, aircraft move about the airfield in a predominantly counter-clockwise direction. In North flow, aircraft move about the airfield in a predominantly clockwise direction. Taxilane W in front of the main passenger terminal is primarily reserved for towing operations, while arriving and departing operations utilize Taxiway B.

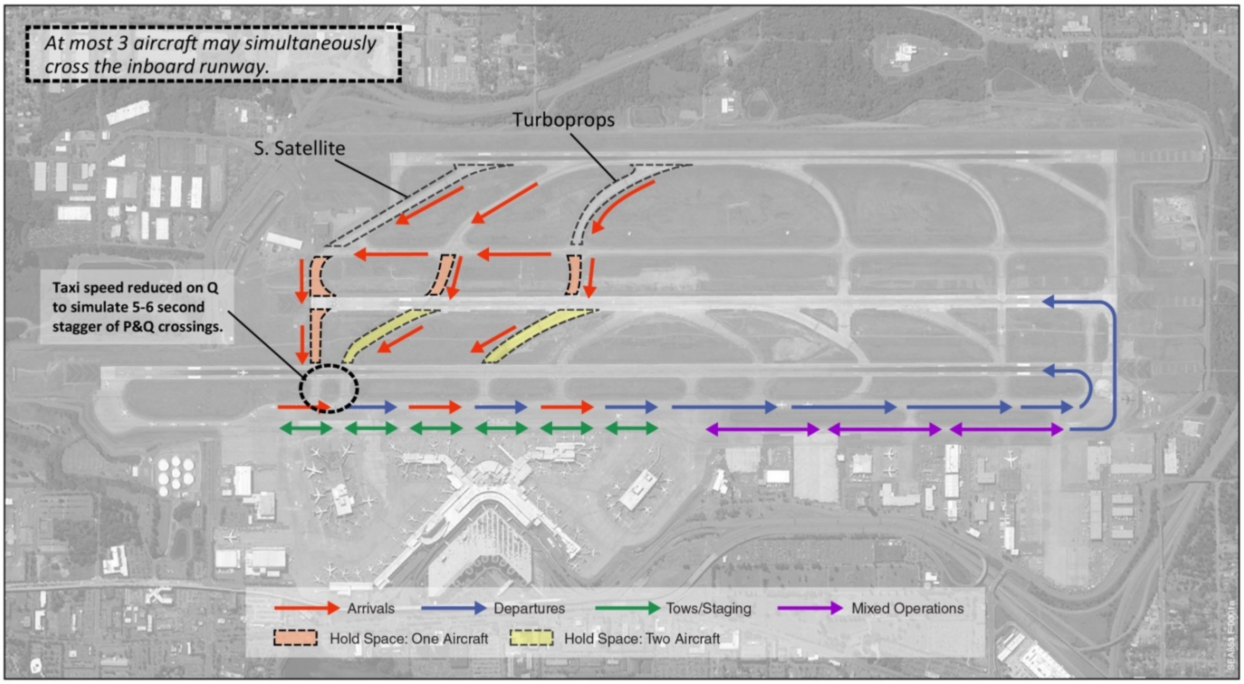
Taxiway flows for the existing airfield layout were used to calibrate the models, and are illustrated on Figure 2-28.

Figure 2-28

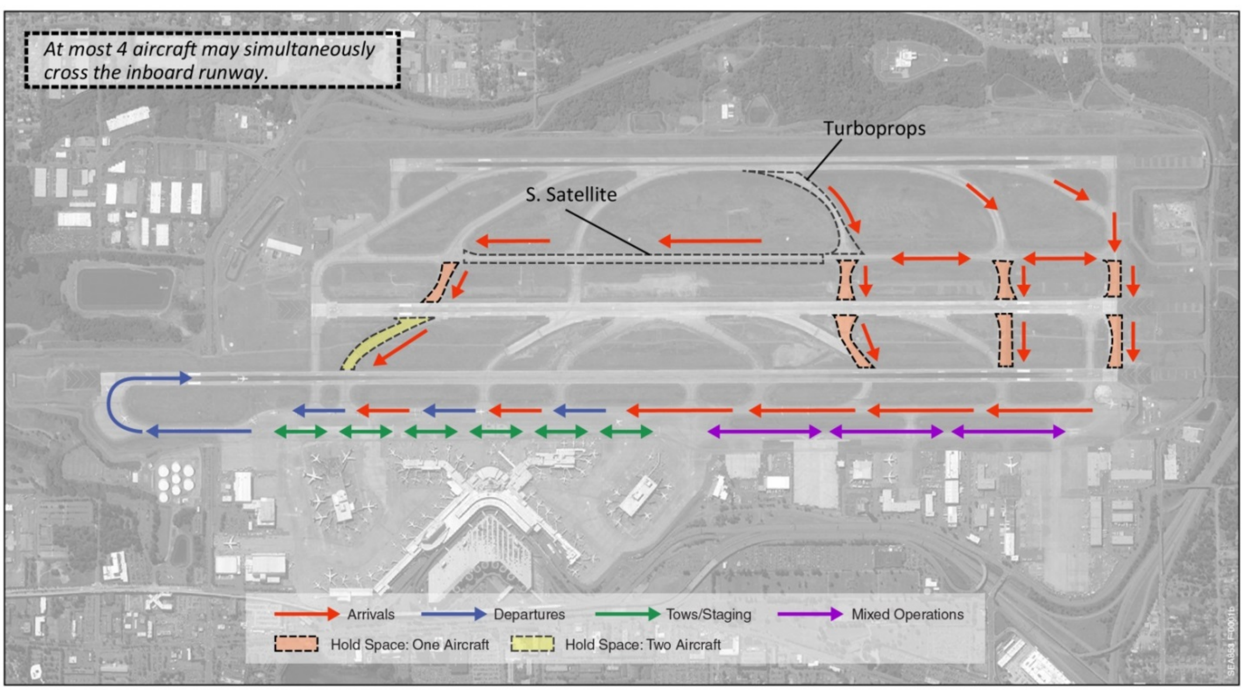
Existing Taxiway Flows – South and North Flow Operations

Seattle-Tacoma International Airport

South Flow Operations



North Flow Operations



Source: LeighFisher, 2017.

For these flows, the following restrictions are applied to taxiing operations at the Airport:

1. Use of the segment of Taxiway A south of Taxiway G is restricted to aircraft with wingspans of 225 feet or less.

2. During CAT II/III operations, use of Taxiway B is limited to aircraft with tail height of 48 feet or less due to the 400-foot spacing between Runway 16L-34R and Taxiway B.

3. Use of Taxilane W south of Taxiway N is restricted to aircraft with wingspans of 167 feet or less.

4. Use of Taxilane W north of Taxiway N is restricted to aircraft with wingspans of 135 feet or less.

For the future-year models, certain taxiway enhancements were assumed to be implemented, specifically:

1. A taxilane that wraps around the southern hold pads to provide additional departure queuing space in North flow.

2. An extension of Taxiway A/B that may be used to create a dual departure-runway entry stream in North flow.

3. An additional high-speed exit from Runway 34L.

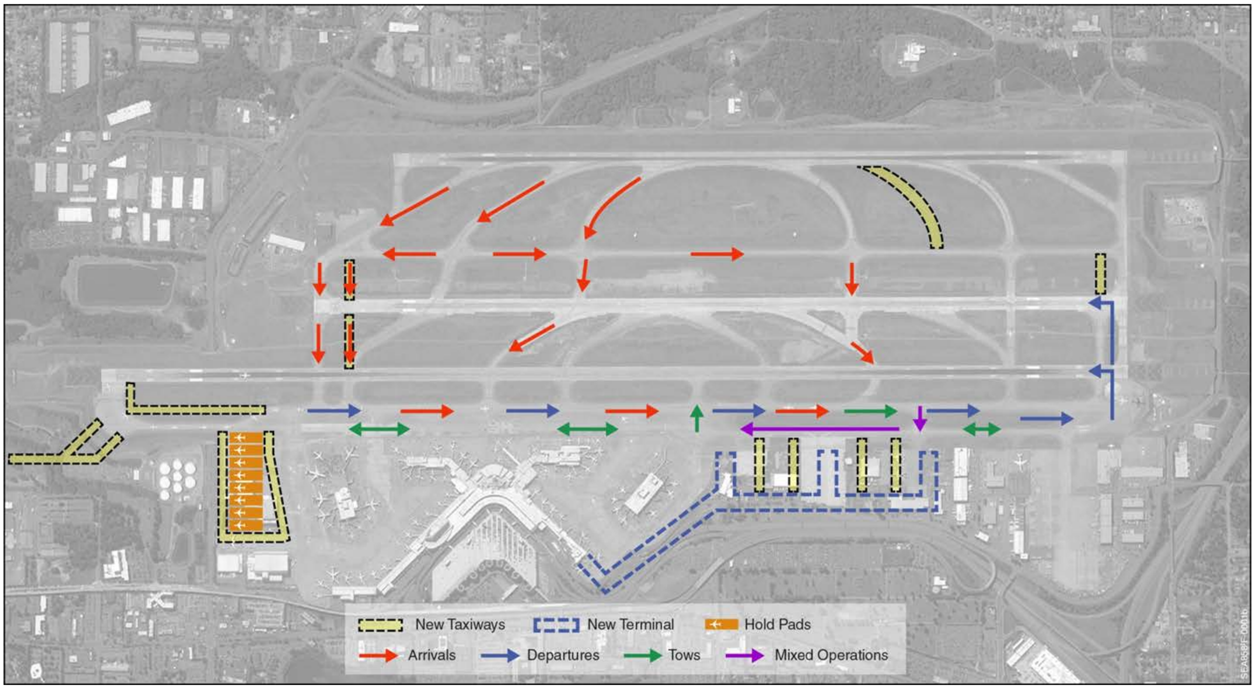
4. Additional runway crossing points at Taxiway D and between Taxiways P and Q.

5. A new three-pier terminal complex and an extension of Concourse D north of the North Satellite terminal, accompanied by surrounding taxilanes.

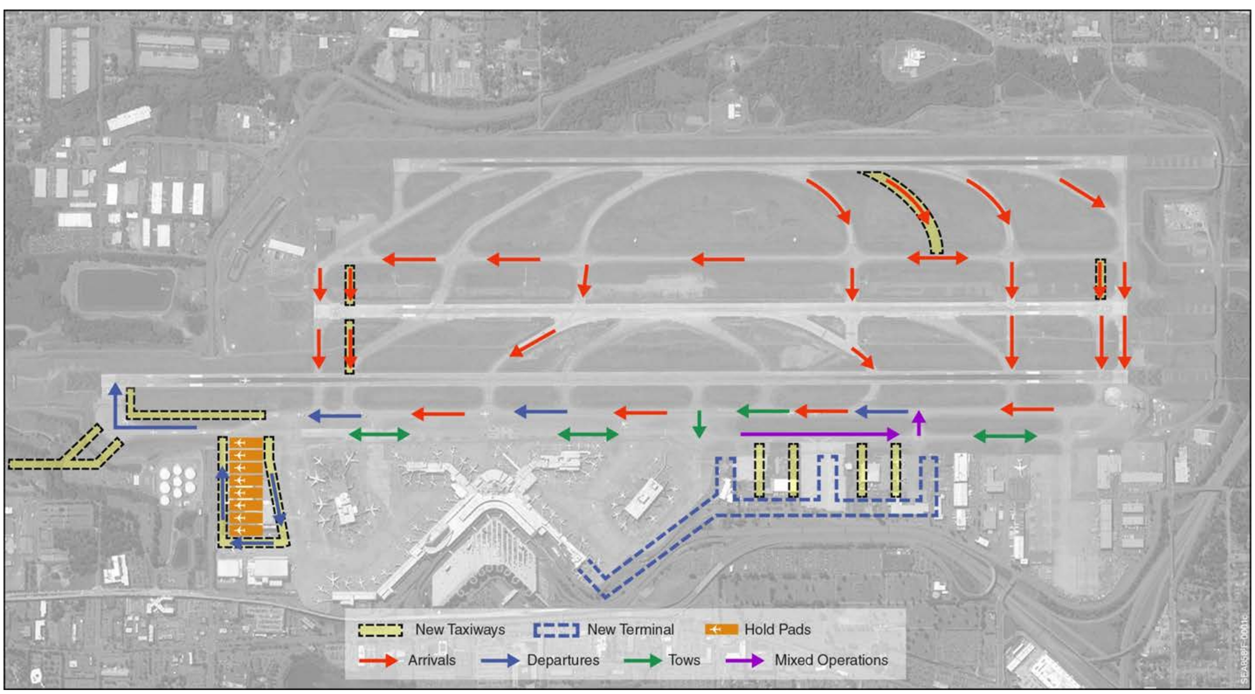
Taxiway flows for the future-year models are illustrated on Figure 2-29.

Figure 2-29
Taxiway Flows Assumed in Future Year Models – South and North Flow Operations
Seattle-Tacoma International Airport

South Flow Operations



North Flow Operations



Source: LeighFisher, 2017.

2.5.3.6 Operational Capacity Enhancements

Various NextGen technologies may become available at the Airport within the planning period, but no specific technology is certain to be implemented. Through consultation with the FAA, it was determined to be reasonable and consistent with typical capacity planning efforts to assume that implementation of one or more of these technologies will lead to changes in runway throughputs. Therefore, the simulation approach was to create future-year models that represent "Low," "Medium," and "High" operational efficiency improvements. More specifically, the "Low" improvement model uses the same runway configuration and calibrated separations as in the baseline models, and the target throughputs approach the maximum sustainable throughputs (MST) achievable under the calibrated operating regime. The "Medium" improvement model aims to achieve 3 to 4 additional operations per hour (approximately a 5% increase in throughputs) over the calibrated MST throughputs. The "High" improvement model aims to achieve 6 to 8 additional operations per hour (approximately a 10% increase in throughputs) over the calibrated MST throughputs. This approach to modeling theoretical operational improvements is similar in scale to the approach taken by the FAA's NextGen group to model the "aggregate" effects of one or more technologies.

The next section focuses on the results of the "Medium" improvement models. The FAA has confirmed that this is a credible assumption. Results for the "Low" and "High" improvement models are provided in Appendix G.

2.5.4 Results

2.5.4.1 Delay

"Delay" is defined generally as the difference between a flight's actual travel time on a given route and the time it would have taken a flight to travel that route without impediment. The specific components of TAAM arrival and departure delays are defined below.

Arrival Delay = Air Delay + Taxi-In Delay + Arrival Gate Delay

- Air Delay: Delay that an arriving aircraft incurs prior to runway touchdown. This includes delay due to holding, sequencing, or speed adjustment to maintain safe separations.

- Taxi-In Delay: Delay that an arriving aircraft incurs while taxiing in. This includes delay due to taxiing at reduced speeds, stopping and starting to allow other aircraft movements, and waiting to cross active runways.

- Arrival Gate Delay: Delay that an arriving aircraft incurs if a gate is not immediately available and it must wait at a remote position.

Departure Delay = Departure Gate Delay + Taxi-Out Delay + Departure Queue Delay

- Departure Gate Delay: Delay a departing aircraft incurs when it must be held at its gate because of queue length or departure sequencing procedures at the departure runway.

- Taxi-Out Delay: Delay that a departing aircraft incurs while taxiing out. This includes delay due to taxiing at reduced speeds, stopping and starting to allow other aircraft movements, and waiting to cross active runways.

- Departure Queue Delay: Delay that a departing aircraft incurs while waiting in the departure runway line-up queue.

In this simulation effort, aircraft delays were the primary consideration in evaluating airfield performance. Delays are an appropriate metric for an airfield demand-capacity analysis, as delays result from a demand-capacity imbalance.

2.5.4.2 Annualized Delay

To provide an estimate of average annual aircraft delay, the relative frequencies of each of the five operating conditions simulated (South flow VMC, South flow MMC, South flow IMC, North flow VMC, and North flow IMC) are multiplied by the simulated delay values to produce a weighted sum of delay. This weighted sum is then scaled by an adjustment factor to account for the fact that the DDFS represents an ADPM flight schedule, rather than a true "average day" flight schedule. The adjustment factor for these annualizations is approximately 0.917, the calculation of which is provided in Appendix G.

An additional factor to the ADPM adjustment factor is applied to the simulated delays for North IMC. Simulated delays in the North IMC model far exceed ASPM-reported delays during historical North IMC hours. There are at least two probable causes for this discrepancy. First, the North IMC model assumed these operating conditions occurred for an entire day. When run for a full day, queues that form early in the day compound, with delays propagating to all subsequent flights. Analysis of historical data revealed that North IMC has only been observed at the Airport for short periods of at most five consecutive hours. Periods of increased throughput capacity followed these observed North IMC delay periods, which allowed the Airport to recover.

Second, the North IMC model assumed that all scheduled operations flew to completion. In practice, airlines might cancel flights likely to experience high delays during these conditions. Cancellations would result in a reduced operating schedule and, consequently, lower delays for the operations that do occur.

For these reasons, annualized simulated delays may be artificially high. To compensate for the overrepresentation of North IMC simulated delays, a delay adjustment factor was added to the weight of the North IMC model. Additional discussion on this factor and its calculation are provided in Appendix G.

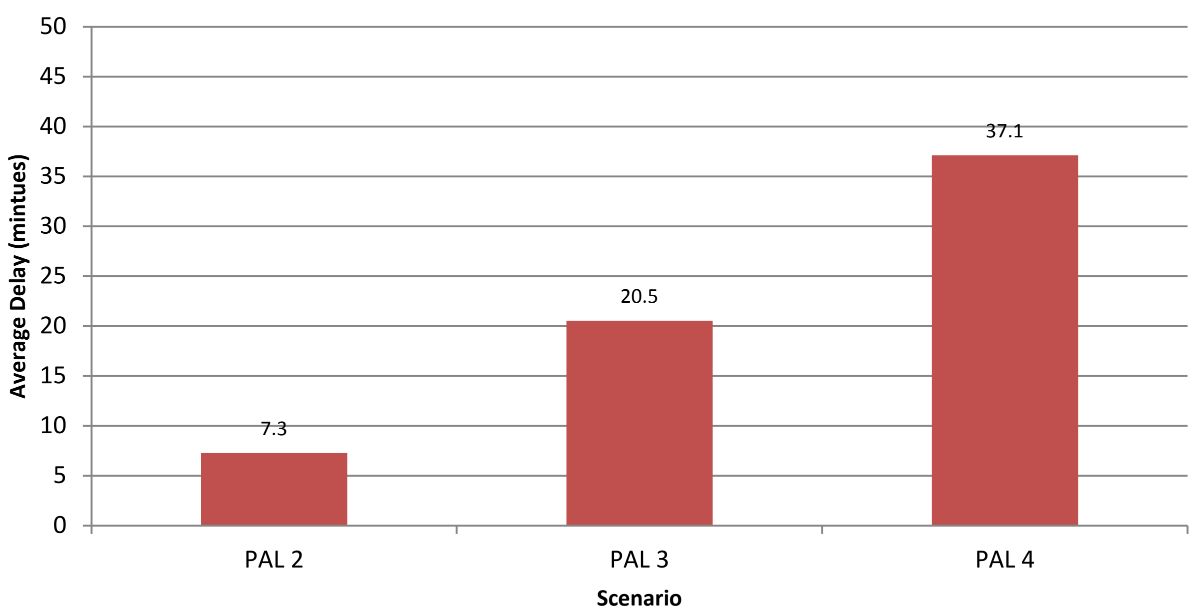
The delay results of the simulations are presented for each of the five major weather condition/flow direction combinations (South flow VMC, South flow MMC, South flow IMC, North flow VMC, and North flow IMC) in Table 2-3 for the PAL 2, PAL 3, and PAL 4 DDFS. An estimate of average annual delay, in minutes, for each of the demand levels is shown graphically on Figure 2-30. These average annual delays were computed using the weights shown in the rightmost columns beneath each of the PALs.

Table 2-3
Simulated Arrival and Departure Delay (minutes) by Weather Condition and PAL
Seattle-Tacoma International Airport

Model	PAL 2				PAL 3				PAL 4			
	Arrival	Departure	Total	Weight	Arrival	Departure	Total	Weight	Arrival	Departure	Total	Weight
South VMC	5.6	4.9	5.3	0.3345	13.2	7.0	10.1	0.3345	19.9	10.7	15.3	0.3345
South MMC	11.9	6.6	9.3	0.1099	23.1	17.8	20.4	0.1099	67.9	26.0	46.6	0.1099
South IMC	15.5	6.4	10.9	0.2028	50.2	8.5	29.1	0.2028	92.0	10.4	50.1	0.2028
North VMC	5.2	6.2	5.7	0.2496	8.1	12.4	10.2	0.2496	12.1	38.3	25.0	0.2496
North IMC	35.6	73.3	53.9	0.0141	123.5	86.1	105.0	0.0127	179.0	103.7	142.1	0.0118
Annualized				7.5				20.5				37.1

Source: LeighFisher, 2017.

Figure 2-30
Estimated Annualized Average Delay, by PAL
Seattle-Tacoma International Airport



Source: LeighFisher, September 2017.

2.5.4.3 Evaluation of Infrastructure Improvements

Analyses of the simulation results revealed that all the proposed infrastructure improvements to the Airport's airfield provided benefit in terms of aircraft delay savings. Some improvements, including the new passenger gates, additional movement area provided by the addition of hold pads on the south end of the airfield, and the extension of Taxiway A/B, provide noticeable and substantial direct benefit, while the other improvements, including the additional high-speed runway exits, additional runway crossings, and relocation of the cargo facility, provide more subtle and indirect benefit. It is important to note that many of the improvements work in conjunction with each other to provide a collective benefit. For example, the benefit of additional runway crossing points is amplified by the additional passenger gates necessary to accommodate higher arrival volume. Without these gates, the benefit of these runway crossing points may not fully manifest, as the reduced gate availability might not permit the higher arrival rate that the additional runway crossing points could provide.

2.5.4.4 Conclusions and Recommendations

Even with the proposed airfield improvements, simulated airfield delays at the Airport exceed 20 minutes in PAL 3 and 37 minutes in PAL 4. Future analyses of additional capacity-enhancing improvements should be pursued following the SAMP. Some potentially pertinent analyses include (but are not limited to): a comprehensive end-around taxiway study; a runway shortening or lengthening cost-benefit analysis; and a re-examination of the airspace structure. Until these future analyses are more properly defined, it is recommended that the airfield improvements proposed in this SAMP which have demonstrated noticeable and direct benefit through airfield simulation be implemented as soon as possible.

Passenger Terminal

The most urgent planning issues are the lack of gates and identifying how to deliver the needed gates as quickly and cost effectively as possible.

3.1 Introduction

This chapter identifies the alternative concepts considered for satisfying the Airport's passenger terminal requirements, documented in *Technical Memorandum No. 5 – Facility Requirements*, and is organized in four parts:

- A description of the alternative concepts considered and the process by which the alternatives were screened to identify those that were eliminated and the finalist One-Terminal and Two-Terminal concepts
- An explanation of how the finalist One-Terminal concept was refined
- An explanation of how the finalist Two-Terminal concept was refined
- A summary of the comparison of the refined One-Terminal and Two-Terminal concepts and the rationale for recommending the Two-Terminal concept as the preferred passenger terminal development concept

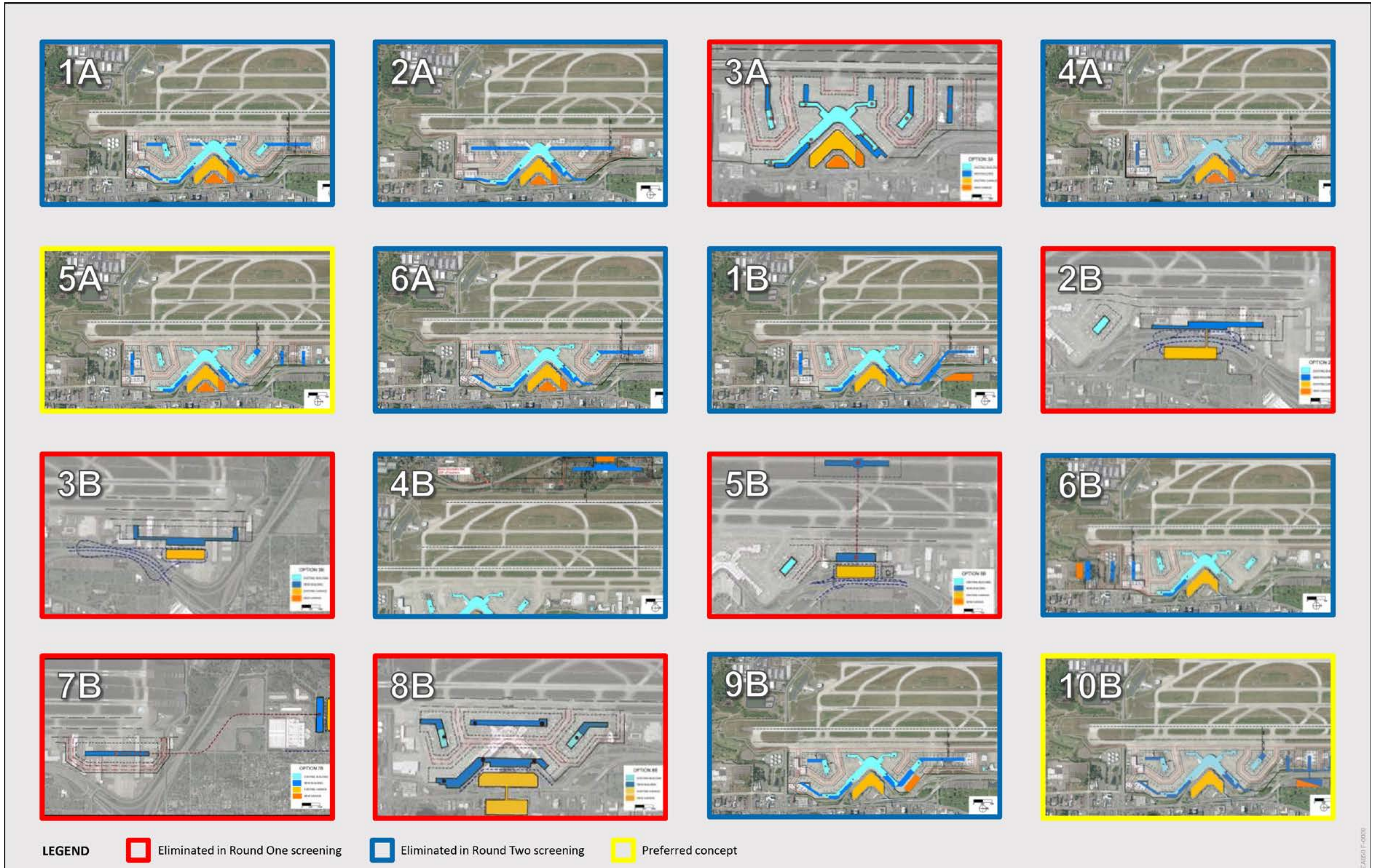
Our approach was based heavily on experience and judgment supported by appropriate analyses, tools, and stakeholder input. The alternative concepts were developed and assessed recognizing the Port's goal of having the Airport acknowledged within its peer group as one of the top five North American airports for customer service.

3.2 Alternative Development Concepts Considered

Sixteen alternatives for satisfying passenger terminal requirements were identified in a series of "Big Ideas" workshops involving both the planning team and senior Port staff. The alternative concepts, shown on Figure 3-1 (larger illustrations of the alternative concepts are shown in Appendix A), were driven by three beliefs:

- Considerable land with airside access is needed to accommodate the 35 additional gates required by PAL 4.
- The passenger processing functions associated with the gates could be at multiple locations and could be remote from the gates.
- The passenger terminal alternatives are inextricably linked with ground access and parking functions.

Figure 3-1
Alternative Passenger Terminal Concepts Considered
Seattle-Tacoma International Airport



Source: LeighFisher, Corgan Associates, and Port of Seattle Staff, 2016.

The alternatives were divided into two groups of concepts: One-Terminal and Two-Terminal (the designation "Two-Terminal" has been used for convenience; a more accurate designation would be "New-Terminal" inasmuch as one concept includes the total demolition and replacement of the existing passenger terminal). There are 6 One-Terminal concepts (1A through 6A) and 10 Two-Terminal concepts (1B through 10B):

One-Terminal Options

- **Option 1A**—North-south concourses concept retaining North and South Satellites and resolving "500-foot issue"*
- **Option 2A**—North-south concourses concept demolishing North and South Satellites and resolving "500-foot issue"*
- **Option 3A**—East-west concourses concept retaining existing facilities
- **Option 4A**—North Satellite dogleg with second south satellite
- **Option 5A**—East-west concourses to north with second south satellite
- **Option 6A**—North Satellite dogleg, South Satellite dogleg, and Concourse A extension

Two-Terminal Options

- **Option 1B**—Option 4A with second terminal on Doug Fox lot
- **Option 2B**—Second terminal on Doug Fox lot with adjacent airside concourse
- **Option 3B**—Second terminal with adjacent airside concourse in north cargo area
- **Option 4B**—Second terminal with adjacent airside concourse on west side of Airport
- **Option 5B**—Second terminal on Doug Fox lot with midfield airside concourse
- **Option 6B**—Second terminal with adjacent airside concourse in South Aviation Support Area
- **Option 7B**—Second terminal north of SR518 with airside concourse in north cargo area
- **Option 8B**—New terminal on existing garage site
- **Option 9B**—Second terminal to south of North Satellite
- **Option 10B**—Modified Option 5A with second terminal on Doug Fox lot

*The "500-foot issue" refers to the desired 500-foot separation between the centerline of Runway 16L-34R and the centerline of Taxiway B. Achieving this separation along the full length of Runway 16L-34R has significant impacts on existing facilities.

The alternatives were evaluated based on decision criteria in three rounds of screening, which concluded with the identification of two finalist alternatives—a One-Terminal concept and a Two-Terminal concept. The gate layout concept for the two finalist alternatives was then refined and finalized for use in subsequent analyses. The process of screening the alternatives and refining the gate layout concept is described in the following sections.

3.2.1 Round One Screening

Round one screening was designed to eliminate alternative concepts based on criteria that can primarily viewed as "threshold" or pass/fail:

- **Sufficiency of available area** – This criterion reflects the ability of an area of the Airport to accommodate a proposed concept and considers constraints such as topography, State highways, the Bonney-Watson Cemetery, and SeaTac City Center.
- **Capable of meeting gate requirements** – This criterion reflects the ability of a concept to be developed to provide the number of gates required.
- **Acceptable impact on existing facilities** – This criterion reflects whether or not a concept's impacts on existing facilities were judged to be acceptable.
- **Compatible with airfield** – This criterion reflects whether or not airfield operations would be significantly degraded by a concept.
- **Constructible** – This criterion reflects the relative ease or difficulty of construction.
- **Relative cost** – This criterion reflects the perceived relative cost to construct a concept based on professional judgement.

Table 3-1 summarizes how each alternative concept was scored against the criteria. Any alternative failing one or more criteria was considered to be fundamentally flawed and was eliminated from further consideration for the reasons illustrated in Table 3-1 and described below."

Table 3-1
Round One Passenger Terminal Concepts Screening Results
Seattle-Tacoma International Airport

Criteria	Concept															
	1A	2A	3A	4A	5A	6A	1B	2B	3B	4B	5B	6B	7B	8B	9B	10B
Sufficiency of available area			■								■			■		
Capable of meeting gate requirements								■	■				■			
Acceptatable impact on existing facilities									■							
Compatible with airfield									■							
Constructible														■		
Relative cost													■	■		

■ indicates a concept fatally flawed relative to the criteria

Source: LeighFisher, Corgan Associates, and Port Staff, 2016.

- Alternative 3A did not meet the needs for sufficiency of available area. There is not sufficient space to accommodate the pier lengths required to provide a sufficient number of gates without relocating the existing Runway 16L-34R or compromising airfield operations by removing a taxiway.

- Alternative 2B does not provide a sufficient number of gates.

- Alternative 3B – 1) Does not provide a sufficient number of gates, 2) displaces too many cargo facilities, and 3) the taxiway system could not accommodate so many gates adjacent to the Runway 16L threshold.

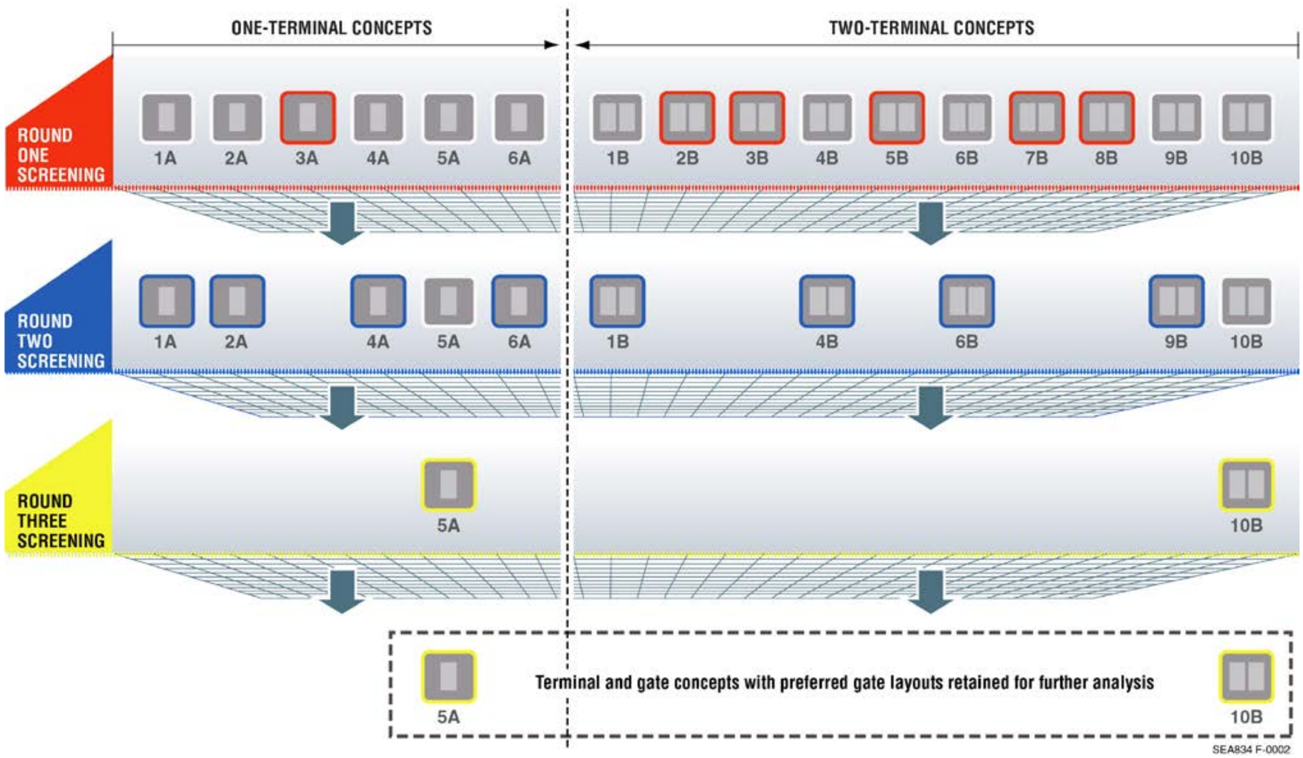
- Alternative 5B did not meet the needs for sufficiency of available area. There is insufficient space available to accommodate a mid-field concourse and its supporting taxiway system and it is not possible to move the adjacent runways to provide the necessary space.

- Alternative 7B does not yield enough gates and was judged to be too expensive.

- Alternative 8B was judged to be too expensive, too difficult to construct, and have too great an impact on the City of SeaTac City Center and adjacent residential uses because it would require taking city land.

Concepts shown on Figure 3-1 and Figure 3-2 with a red border (Concepts 3A, 2B, 3B, 5B, 7B, and 8B) failed at least one threshold criteria, were considered fundamentally flawed, and were eliminated from further consideration. Concepts shown on Figure 3-1 and Figure 3-2 with a blue border passed all the threshold criteria.

Figure 3-2
One-Terminal and Two-Terminal Concepts Screening Process
Seattle-Tacoma International Airport



Source: LeighFisher, Corgan Associates, and Port of Seattle Staff, 2016.

3.2.2 Round Two Screening

Round two screening was designed to identify the preferred One-Terminal and the preferred Two-Terminal concepts based on decision criteria that reflected economic and operational, environmental, and social issues.

3.2.2.1 Criteria Related to Economic and Operational Issues

- **Taxiway operations** (e.g., pushbacks onto taxiway) – This criterion reflects the potential impact of a terminal and gate concept on the ability of the taxiway system to effectively accommodate aircraft. For example, any terminal concept that would require aircraft to be pushed off a gate into an active taxiway is undesirable.

- **Passenger convenience** – This criterion reflects passenger convenience in terms of multiple factors, such as intuitive wayfinding or being able to walk from one gate to another without the need for one or more ride systems.

- **Incremental expansion** – This criterion reflects the ability to add relatively small numbers of gates without triggering relatively large or expensive enabling projects (e.g., demolishing existing concourses).

- **Constructability** – This criterion reflects the relative ease or difficulty of construction.

- **Flexibility to assign gates** – This criterion reflects the predominance of contiguous gates that provide greater flexibility in assigning airlines and flights to common use facilities.

- **Ease of adding international gates** – This criterion reflects the relative ease of adding international gates linked with the new International Arrivals Facility (IAF).

- **Ability to add gates quickly** – This criterion reflects the Port's immediate need for gates and the potential to implement early phases of the concept relatively soon.

3.2.2.2 Criteria Related to Environmental Issues

- **Reduced taxi delay** – This criterion reflects the potential for terminal and gate concepts to contribute to greenhouse gas (GHG) and criteria pollutant emissions as a result of the amount of time passenger aircraft engines are operating while aircraft maneuver to and from gates.

- **Impact on wetlands/creeks** – Considers the potential to affect sensitive natural resources.

- **Limits new impervious surface** – This criterion reflects the Port's desire to limit surface water runoff, which is exacerbated by the addition of impervious surfaces.

3.2.2.3 Criteria Related to Social Issues

- **Proximity to noise and light sensitive land uses** – Considers the potential effects on nearby residential uses.

- **Consistency with zoning** – Considers the potential effects on nearby residential uses.

Round two screening criteria began to align the alternative review process with the Port's sustainability goals and objectives. This round also used a scoring approach that permitted the alternatives to be discussed and debated for their merits relative to each criterion. Each alternative was evaluated and scored: (-1) if it was considered poor or undesirable relative to the intent of the criteria; (0) if it was neutral relative to the intent of the criteria; or (+1) if it was considered good relative to the intent of the criteria. Round two screening was intended to be conducted at a high level; therefore, no relative weights were assigned to the criteria. The scores for each alternative were totaled for comparison purposes.

Table 3-2 summarizes the scoring for the round two screening process. The rationale for the scoring is summarized below, by criterion.

Table 3-2
Round Two Passenger Terminal Concepts Screening Results
Seattle-Tacoma International Airport

Criteria	Concept									
	1A	2A	4A	5A	6A	1B	4B	6B	9B	10B
Taxiway operations	-1	-1	-1	1	-1	-1	1	0	-1	1
Passenger convenience	0	1	-1	-1	0	-1	0	-1	0	1
Incremental expansion	-1	-1	-1	0	-1	-1	-1	-1	-1	0
Constructability	-1	-1	0	1	0	1	1	1	0	1
Flexibility to assign gates	0	1	0	-1	0	1	0	0	0	-1
Ease of adding international gates	1	1	-1	-1	1	-1	1	-1	1	1
Ability to add gates quickly	1	-1	1	1	1	1	-1	-1	1	1
Reduced taxi/idle/delay	-1	-1	-1	1	-1	-1	1	-1	-1	0
Impact on wetlands/creeks	0	0	0	0	0	0	-1	-1	0	0
Limits addition of impervious surfaces	0	0	0	0	0	0	-1	-1	0	0
Proximity to noise and light sensitive land uses	0	0	0	0	0	0	-1	-1	0	0
Consistency With Zoning	0	0	0	0	0	0	-1	-1	0	0
Score summary	-2	-2	-4	1	-1	-2	-2	-8	-1	4

-1 poor/undesrable

1 good

0 neutral

Source: LeighFisher, Corgan Associates, and Port of Seattle Staff, 2016.

- **Taxiway operations (e.g., pushbacks onto taxiway) -** Concepts 1A, 2A, 4A, 6A, 1B, and 9B were scored "poor" relative to this criterion because aircraft would push back onto Taxiway A from many or all of the following locations: South Satellite "dogleg," North Satellite "dogleg," Concourse B, and Concourse C. Concepts 5A, 4B, and 10B were scored "good" relative to this criterion because fewer push backs onto Taxiway A would occur than with Concepts 1A, 2A, 4A, 6A, 1B, and 9B. Concept 6B was scored "neutral" relative to this criterion because of the increased concentration of gates at the south end of the Airport and the resulting concentration of taxiing aircraft adjacent to the threshold of Runway 34R (During north flow operations, the queue of aircraft taxiing southbound on Taxiway B to depart from Runway 34R sometimes extends to the South Satellite; thus any additional concentration of gates to the south could exacerbate the queuing and sequencing of aircraft).

- **Passenger convenience -** Concepts 4A, 5A, 1B, and 6B, were scored "poor" relative to this criterion because they all involve one or more additional satellites and an additional Satellite

Transit System (STS) extension or new automated people mover, thus increasing the wayfinding difficulty in an airport already consisting of two satellites and three STS segments. Concept 2A was scored "good" relative to this criterion because it would eliminate both the North and South Satellites, thus facilitating passenger wayfinding. Concept 10B was scored "good" relative to this criterion because while it maintains the existing North and South satellites, it provides a perceived increase in passenger convenience made possible by the second passenger terminal. Concepts 1A and 6A were scored "neutral" relative to this criterion because they are neither better nor worse than existing conditions. Concept 4B was scored "neutral" relative to this criterion, even though it involves a second passenger terminal, because of the significant separation between the terminals and the travel time between them for passengers driving to the wrong terminal. Concept 9B was scored "neutral" relative to this criterion because the potential benefits of connecting the North Satellite directly to Concourse D were considered to be offset by limitations of the site to accommodate the second terminal, roadways, and nearby parking.

- **Incremental expansion -** Concepts 1A, 2A, 4A, 6A, 1B, 4B, 6B, and 9B were scored "poor" relative to this criterion because they involve removing three airline maintenance hangars and an air cargo warehouse to add more gates to the south. Concepts 5A, and 10B were scored "neutral" relative to this criterion because the relative ease of adding gates to the north somewhat offsets the need to demolish hangars and a warehouse to the south.

- **Constructability -** Concepts 1A and 2A were scored "poor" relative to this criterion because of the difficulty of demolishing and reconstructing passenger concourses and/or satellites while maintaining an acceptable level of service. Concepts 5A, 1B, 4B, 6B, and 10B were scored "good" relative to this criterion because the construction areas can be cleared, yielding "greenfield" sites. For the purposes of screening, a greenfield site refers to an area in which construction can occur with limited impacts to ongoing passenger activity and aircraft operations. Concepts 4A, 6A, and 9B were scored "neutral" relative to this criterion because of the somewhat offsetting "greenfield" sites to the south and modifications to the North Satellite to the north. All the One-Terminal concepts would be challenged with respect to the criterion because of the complexity of the construction required inside an operating terminal.

- **Flexibility to assign gates -** Concepts 5A, and 10B were scored "poor" relative to this criterion because the north piers are short with relatively few contiguous gates—this situation increases the difficulty of assigning airline gates or making additional contiguous gates available. Concepts 2A, and 1B were scored "good" relative to this criterion because they have fewer and longer concourses. Concepts 1A, 4A, 6A, 4B, 6B, and 9B were scored "neutral" because they lack the distinguishing features of the other concepts.

- **Ease of adding international gates -** Concepts 4A, 5A, 1B, and 6B were scored "poor" relative to this criterion because each concept's south gate expansion is a satellite and would require the removal of three aircraft maintenance hangars and a cargo facility at the same time. Concepts 1A, 2A, 6A, 9B, and 10B were scored "good" relative to this criterion because each concept's south gate expansion is an extension of Concourse A and not all the aircraft maintenance hangars would have to be removed at the same time. Concept 4B was scored "good" relative to this criterion because all options for adding international gates are equally available.

- **Ability to add gates quickly -** Concepts 2A, 4B, and 6B were scored "poor" relative to this criterion because of the significant impact to existing facilities (2A), the environmental process required because of the potential to impact critical areas (4B and 6B), and/or the extent of demolition, site preparation, and construction required (6B). Concepts 1A, 4A, 5A, 6A, 1B, 9B, and 10B were scored "good" relative to this criterion because new gates could be constructed in areas that are not occupied by passenger facilities and would not affect passenger operations (such new gates need not necessarily be contiguous to existing gates; e.g., the "dogleg" to the North Satellite could be constructed beginning at the north end and joined to the North Satellite later).

- **Reduced taxi/idle/delay -** Concepts 1A, 2A, 4A, 6A, 1B, and 9B were scored "poor" relative to this criterion because aircraft would push back onto Taxiway A from many or all of the following locations: South Satellite "dogleg," North Satellite "dogleg," Concourse B, and Concourse C; thus, these aircraft would exacerbate taxiway congestion and further increase engine operating time and criteria pollutant emissions. Concept 6B scored "poor" relative to this criterion because of the increased number of gates at the south end of the Airport and the resulting concentration of taxiing aircraft and congestion adjacent to the threshold of Runway 34R. Concepts 5A and 4B were scored "good" relative to this criterion because they reduce or eliminate aircraft pushbacks onto Taxiway A. Concept 10B was scored "neutral" relative to this criterion—the elimination of pushbacks onto Taxiway A from the north gates offsets the pushbacks onto Taxiway A from the south gates.

- **Impact on wetlands/creeks -** Concepts 4B and 6B were scored "poor" relative to this criterion because they would generate new impacts on sensitive natural resources. All other options concepts were "neutral" relative to this criterion because they would not generate new direct impacts on sensitive natural resources.

- **Limits addition of impervious surface -** Concepts 4B and 6B were scored "poor" relative to this criterion because the amount of new impervious surface is substantially different from the other concepts and could exacerbate surface water runoff. All the other concepts were scored "neutral" relative to this criterion.

- **Proximity to noise and light sensitive land uses -** Concepts 4B and 6B were scored "poor" relative to this criterion because they are the only concepts that could generate new noise and light impacts on nearby residential areas. All other concepts were scored "neutral" relative to this criterion because they would not generate new noise and light impacts on nearby residential areas as a result of the location of new terminal and gate facilities.

- **Consistency with zoning -** Concepts 4B and 6B were scored "poor" relative to this criterion because they have not been contemplated in the current zoning/interlocal agreement and could have impacts on nearby residential areas. All other concepts were scored "neutral" relative to this criterion.

From round two screening, it was concluded that there are two preferred alternatives—Alternative 5A for the One-Terminal option and 10B for the Two-Terminal option. As shown in Table 3-3, these are also the only alternatives receiving a net positive evaluation score.

3.2.3 Round Three Screening

The objectives for the third round of screening were to 1) identify two gate layout concepts each for the new north and south gate areas of the preferred terminal alternatives, and 2) assess those gate layout concepts using a refined set of screening criteria.

Based on the results of the second round of screening, the two gate layout concepts identified for the new north gate area were the North Satellite dogleg (included in passenger terminal concepts 1A, 4A, 6A, 1B, and 9B) and the north piers (included in passenger terminal concepts 5A and 10B). These concepts are shown on Figure 3-3. The two gate layout concepts identified for the new south area were a second south satellite (included in passenger terminal concepts 4A, 5A, 1B, and 6B) and an extension of Concourse A to the south and west (south extensions only were included in passenger terminal concepts 1A, 6A, 9B, and 10B). These concepts are also shown on Figure 3-3.

Figure 3-3
Gate Layout Concepts Evaluated for North and South Areas
Seattle-Tacoma International Airport

Source: LeighFisher, 2016.

These gate layout concepts were screened and it was determined that, for the purpose of evaluating gate options for the new north and south areas, serving one vs. two terminals would not be a discriminating factor. The two passenger terminal alternatives identified would add an equivalent number of gates in the north and south areas; the gates would be operated the same regardless of where passenger processing occurs; therefore the preferred gate layout concept is the same for both the One-Terminal and Two-Terminal alternatives.

Round three screening was designed to identify the preferred gate layout concepts for the north and south gate areas of the preferred terminal alternatives (Concepts 5A and 10B) based on seven decision criteria, described below, that reflect economic, operational, and environmental issues.

3.2.3.1 Criteria Related to Economic and Operational Issues

- **Ramp operations** – (e.g., pushbacks onto taxilane) – This criterion reflects the potential impact of the gate layout option on the ability of the taxiway system to effectively accommodate aircraft. For example, any gate layout option that would require aircraft to be pushed off a gate into an active taxiway is undesirable.
- **Passenger convenience** – This criterion reflects passenger convenience in terms of multiple factors, such as intuitive wayfinding or being able to walk from one gate to another without the need for one or more ride systems.
- **Incremental expansion** – This criterion reflects the ability to add relatively small numbers of gates without triggering relatively large or expensive enabling projects (e.g., demolishing existing concourses).
- **Constructability** – This criterion reflects the relative ease or difficulty of construction.
- **Flexibility to assign gates** – This criterion reflects the predominance of contiguous gates that provide greater flexibility in assigning airlines and flights to common use facilities.
- **Ability to add gates quickly** – This criterion reflects the Port's immediate need for gates and the potential to implement early phases of the concept relatively soon.

3.2.3.2 Criteria Related to Environmental Issues

- **Natural resources impacts** – This criterion reflects the potential to affect sensitive natural resources. For the purposes of evaluating gate layout options, this criterion was not a differentiator because all the gate layout options considered are on sites that are already developed and would be repurposed.
- **Building energy use** – This criterion reflects the Port's commitment to using energy wisely. For the purposes of evaluating gate layout options, this criterion was not a differentiator because the developed areas and volume of new terminal space would be approximately the same and choices between existing vs. new energy infrastructure, to be made at a later date, would not be influenced by the gate layout.

- **Reduced taxi/idle/delay** – This criterion reflects the potential for terminal and gate concepts to contribute to greenhouse gas and criteria pollutant emissions as a result of their effect on the amount of time passenger aircraft engines are operating while aircraft maneuver to and from gates.

This third screening round used the same scoring approach as the second screening round. This approach continued to allow for alternatives to be discussed and debated for their merit with regard to each criterion. Each alternative was evaluated and scored: (-1) if it was considered poor or undesirable relative to the intent of the criteria; (0) if it was neutral relative to the intent of the criteria; or (+1) if it was considered good relative to the intent of the criteria. As previously stated in Section 3.2.2.3, the prior second round of screening and this third round of screening are intended to be conducted at a high level and so no relative weight was assigned to each criterion. The scores for each alternative were totaled for comparison purposes.

Table 3-3 summarizes the scoring for the round three screening process. The rationale for the scoring is summarized below, by criterion.

Table 3-3
Round Three Gate Layout Concepts Screening Results
Seattle-Tacoma International Airport

Criteria	Concept			
	South Airport		North Airport	
	South End Satellite	Concourse A Extension	North Satellite Dogleg	North End Piers
Ramp Operations	0	1	-1	1
Passenger Convenience	0	1	0	0
Incremental Expansion	-1	-1	0	0
Constructability	1	0	-1	1
Flexibility to assign gates	1	1	1	-1
Ability to add gates quickly	-1	-1	1	1
Natural resources Impacts	Not a differentiator			
Building energy use	Not a differentiator			
Reduced taxi/idle/delay	-1	1	-1	1
Social criteria	Not a differentiator			
Score summary	-1	2	-1	3

-1	poor/undesrable	
0	neutral	
1	good	

Source: LeighFisher, Corgan Associates, and Port of Seattle Staff, 2016.

- **Ramp operations**
  - **North Airport.** The North Satellite "dogleg" concept was scored "poor" relative to this criterion because all gates on the west side of the dogleg push back onto Taxiway A and gates on the east side of the dogleg can be accessed by only one taxilane. The north end pier concepts were scored "good" relative to this criterion because dual taxilane access is provided to all interior gates and pushbacks onto Taxiway A are limited to a single gate at the end of each pier.
  - **South Airport.** The south end satellite was scored "neutral" relative to this criterion because, although it eliminates pushbacks onto Taxiway A, access to gates on the south side of the south end satellite is provided by only a single taxilane. The Concourse A extension was scored "good" relative to this criterion because dual taxilane access is provided to every gate and pushbacks onto Taxiway A are eliminated from all but one gate.
- **Passenger convenience**
  - **North Airport**. Under the One-Terminal concept, the North Satellite dogleg and the north end piers were scored "neutral" relative to this criterion. This is because, similar to today, access between the North Satellite and the main terminal (and other concourses) would require the use of the satellite transit system. Wayfinding would not be as intuitive as it could be if the North Satellite physically connected to the Main Terminal, and walking would not be an option. Under the Two-Terminal concept, the scoring for the north end piers would be "good" because the north end pier gates would be connected to the second passenger terminal by a pedestrian walkway.
  - **South Airport**. The south end satellite was scored "neutral" relative to this criterion because access to the main terminal and other concourses would require the use of the satellite transit system, wayfinding would not be as intuitive as it could be between connected buildings, and walking would not be an option. Conversely, the Concourse A extension was scored "good" relative to the criterion. These scores apply equally to the One-Terminal and Two-Terminal concepts.
- **Incremental expansion**
  - **North Airport**. The North Satellite dogleg and north end piers were scored "neutral" relative to this criterion because of the relative ease of clearing the ARFF and cargo facilities to permit the construction of additional gates.
  - **South Airport**. The south end satellite and the Concourse A extension were scored "poor" relative to this criterion because they involve removing three airline maintenance hangars and an air cargo warehouse to add more gates to the south.

- **Constructability**
  - **North Airport:** The North Satellite dogleg was scored “poor” relative to this criterion because, although most construction would occur in a greenfield setting, some would occur at the northwest end of the North Satellite and somewhat affect its operation. The north end piers option was scored “good” relative to this criterion because construction would occur entirely in a location that would not affect aircraft operations.
  - **South Airport:** The south end satellite was scored “good” relative to this criterion because construction would occur entirely in a greenfield setting. The Concourse A extension was scored “neutral” relative to this criterion because, although most construction would occur in a greenfield setting, some would occur at the end of Concourse A and somewhat affect its operation.
- **Flexibility to assign gates**
  - **North Airport:** The north end pier option was scored “poor” relative to this criterion because of the relatively small number of contiguous gates that would be available on each pier. The North Satellite dogleg was scored “good” relative to this criterion because of the relatively large number of contiguous gates that would be available.
  - **South Airport:** The south end satellite and Concourse A extension were both scored “good” relative to this criterion because of the relatively large number of contiguous gates that would be available.
- **Ability to add gates quickly**
  - **North Airport:** The North Satellite dogleg and north end pier were scored “good” relative to this criterion because of the ability to clear some portion of the site required by the concepts (e.g., the Cargo 5 hardstand and adjacent area) and initiate early phase development of gates.
  - **South Airport:** The south end satellite and Concourse A extension were both scored “poor” relative to this criterion because of the need to relocate one or more aircraft maintenance hangars and a cargo warehouse before beginning construction and the difficulty and length of time required to accomplish those relocations.
- **Natural resources impacts** – not a differentiator
- **Building energy use** – not a differentiator

- **Reduced taxi/idle/delay**
  - **North Airport:** The North Satellite dogleg was scored “poor” relative to this criterion because the concept requires aircraft to pushback onto Taxiway A and provides only single taxilane access to gates on the east side of the dogleg. The north end piers were scored “good” relative to this criterion because the concept eliminates pushbacks onto Taxilane A with the exception of the end gate on each pier and provides dual taxilane access to gates.
  - **South Airport:** The south end satellite was scored “poor” relative to this criterion because of the single taxilane on the south side of the satellite. The single taxilane does not provide the desired capacity for gate ingress and egress; during north flow operations, when aircraft are queuing on Taxiway A for departure on Runway 34R, gate access and egress to/from the west end of the taxilane could be restricted. The Concourse A extension was scored “good” relative to this criterion because dual taxilanes are provided to all gates.
- **Social criteria**– not a differentiator

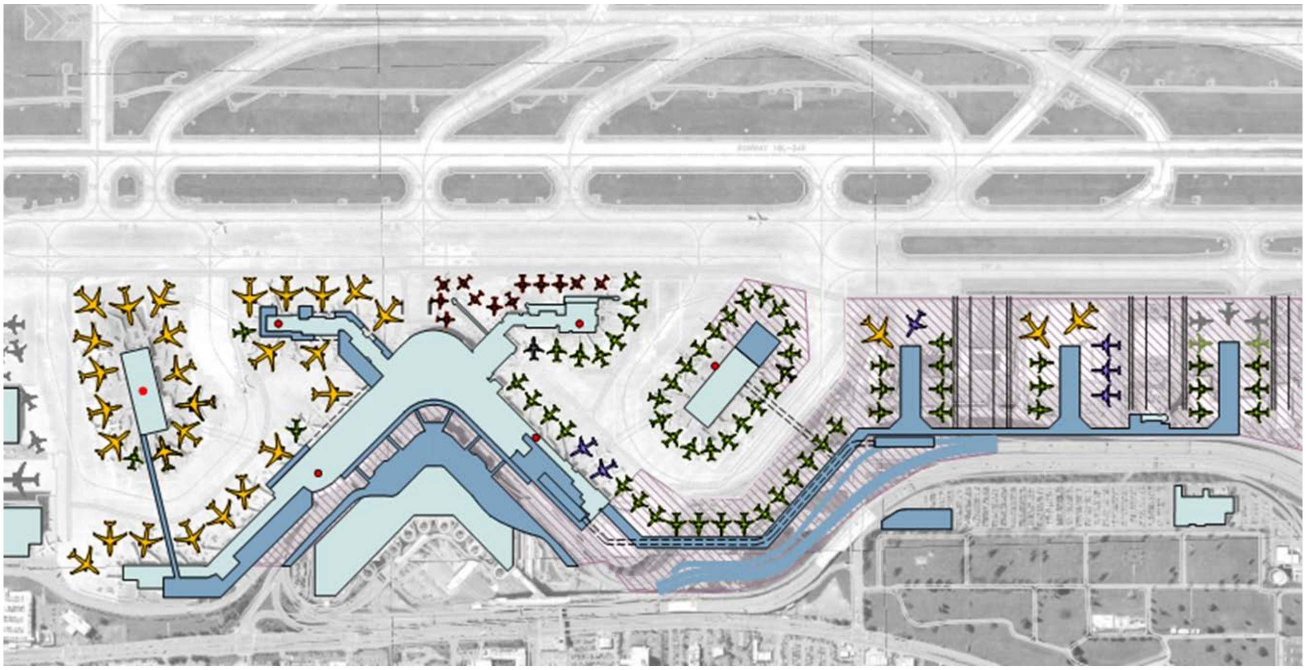
From the round three screening process, two key preliminary conclusions were reached: (1) for the South Passenger Terminal Area, extending Concourse A is preferable to constructing a second south satellite, and (2) for the North Passenger Terminal Area, the north piers concept is preferable to the North Satellite dogleg concept.

3.2.4 Refinement of Gate Layout Concept Subsequent to Round Three Screening

From airfield simulation analyses completed subsequent to round three screening, it was concluded that (1) off-gate parking positions adjacent to the South Satellite are essential for effective future airfield operations at PAL 3, and (2) the space currently occupied by Delta Air Lines’ and Alaska Airlines’ aircraft maintenance hangars and Delta Air Lines’ cargo warehouse should be reserved for off-gate aircraft parking rather than for extending Concourse A to provide the space necessary for off-gate parking positions. Thus, the preferred gate layout concept for either the One-Terminal or Two-Terminal concept was refined by (1) eliminating from consideration the southern extension of Concourse A and instead (2) adding a third pier to the northern gates and connecting the three north piers with an extension of Concourse D, as shown on Figure 3-4.

The gate layout for the three northern piers was refined further, resulting in the recommended U-shaped gate layout concept on Figure 3-5. The key dimensions related to the U-shaped north gate layout concept are shown on Figure 3-6. This recommended gate layout concept provides approximately the same number of gates and provides additional off-gate parking in an ideal location immediately west of the gates.

Figure 3-4
Refined Gate Layout Concept
Seattle-Tacoma International Airport

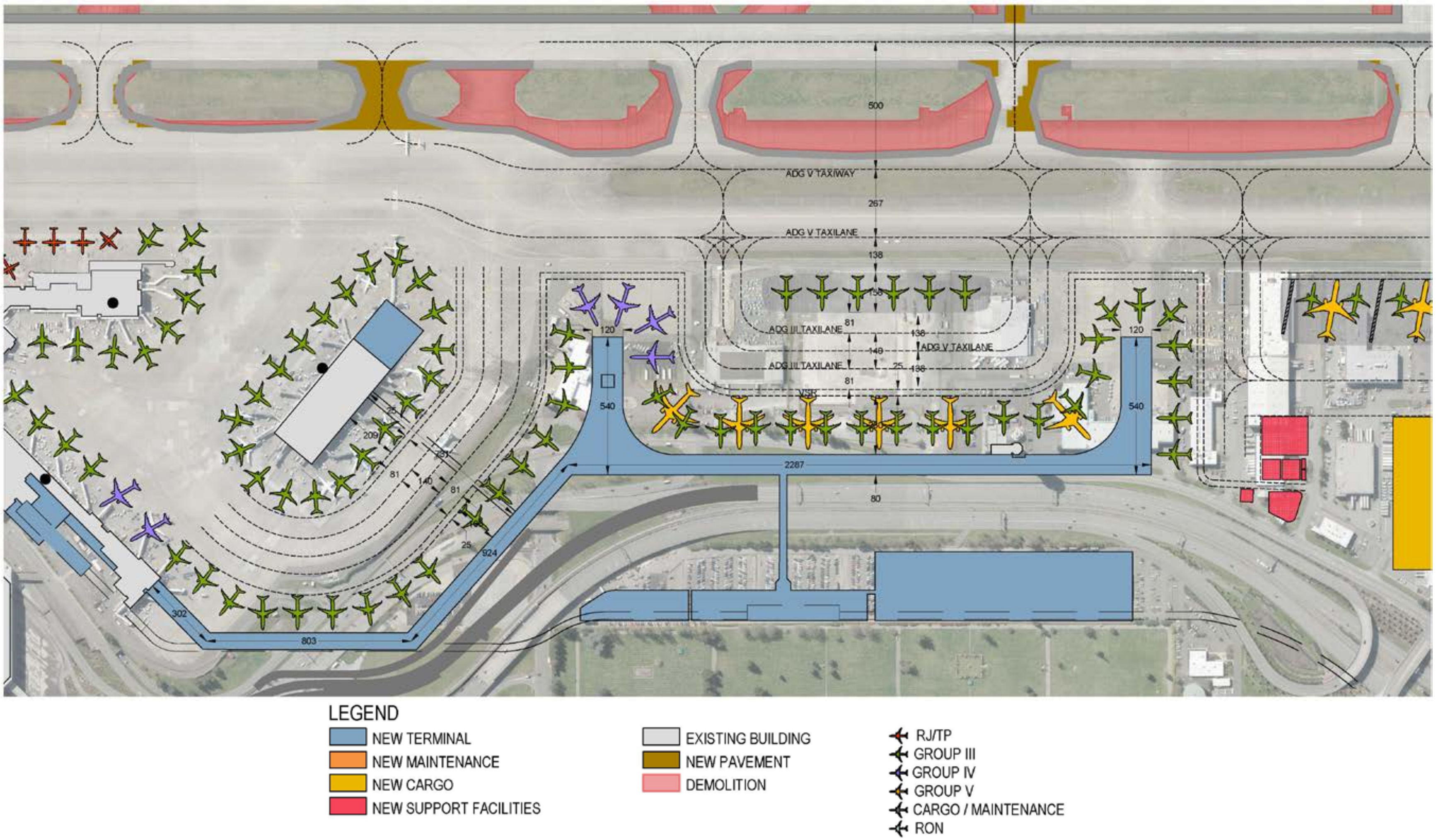


Source: LeighFisher and Port of Seattle staff, 2015.

Figure 3-5
Recommended Gate Layout Plan
Seattle-Tacoma International Airport

Source: LeighFisher and Port of Seattle staff, 2015.

Figure 3-6
Key Dimensions Related to North Gate Layout Concept
Seattle-Tacoma International Airport



Source: LeighFisher, Corgan Associates, and Port of Seattle staff, 2016.

3.3 Refined One-Terminal Concept

This section summarizes the refined One-Terminal concept (i.e., expanding the existing passenger terminal) to satisfy the passenger terminal requirements identified for PALs 1 through 4.

3.3.1 Functions Driving the Concept

Planning related to the One-Terminal concept considered all the functional areas discussed in Technical Memorandum No. 5 – Facility Requirements. However, the planning focused on functions in the non-secure portions of the passenger terminal, referred to as landside functions, which have the most significant impact on the One-Terminal concept:

- Ticketing and baggage drop
- Passenger circulation
- Passenger security screening check points
- Baggage claim
- Ground access and curbsides

3.3.1.1 Ticketing and Baggage Drop

Trends influenced by technology, changing passenger preferences, and airline business models indicate reduced future demand for fully staffed ticketing and baggage drop positions. These trends suggest the use of online ticketing, self-service kiosks, checked baggage fees, and self-bag tagging at home. Despite these trends and the Airport's currently empty ticketing positions, there is insufficient space in the existing passenger terminal to satisfy the requirement for ticketing and baggage drop through the planning period—additional terminal space will be required to provide the desired level of service.

3.3.1.2 Passenger Circulation

Passenger circulation on the ticketing and the baggage claim levels of the passenger terminal is severely restricted by elevators, escalators, and ramps to the curbside, resulting in an unacceptable level of service. This issue will be exacerbated as passenger activity increases and can only be resolved in the long term either by enlarging the existing landside terminal building and rearranging the layout of key functions or shifting demand to another passenger processor (i.e., a second terminal).

3.3.1.3 Security Screening Check Points

During peak periods, the security screening check point (SSCP) queues severely restrict passenger flow within the north-south corridor designed to provide access to the checkpoints, food, beverages, and concessions. In order to satisfy requirements through the planning period, additional security lanes are required. Level of service issues associated with the constrained security screening check points will be exacerbated as passenger activity increases and can only be resolved in the long term either by enlarging the existing landside terminal building and rearranging the layout of key functions or shifting demand to another passenger processor (i.e., a second terminal).

3.3.1.4 Baggage Claim

Both the number of baggage claim carousels and the presentation lengths provided (i.e., the lengths of the claim devices upon which baggage is placed) must be increased to meet requirements through the planning period. By PAL 4, it is estimated that approximately 24 claim devices providing 4,400 feet of claim device length will be required. Currently, 16 claim devices provide 2,700 feet of claim device length. Baggage claim requirements and level of service objectives cannot be satisfied without increasing the space available for baggage claim.

3.3.1.5 Ground Access and Curbsides

Under any One-Terminal concept, the existing roadway and curbside system cannot accommodate forecast demand without major expansion and modification.

By PAL 4, it is estimated that the enplaning and deplaning curbsides will require 1,460 and 1,480 linear feet, respectively, of public curb. Currently, these curbsides provide 1,200 and 1,050 linear feet, respectively, of public curb.

Passenger terminal functions are linked with ground access and parking functions. Therefore, the passenger terminal and access and parking alternatives were developed in parallel.

3.3.2 One-Terminal Concept—Landside

The proximities and functional relationships of the existing passenger terminal, curbsides, and the parking garage present both challenges and opportunities to modify the facilities to meet requirements and provide the desired level of service.

3.3.2.1 Alternative Concepts Considered

The passenger terminal needs to be expanded to the east, on both the enplaning and deplaning levels, to provide the additional space needed for new facilities and to better distribute the available space among competing functions. Due to low levels of service on both the enplaning level and deplaning level curbside roadways and the need for additional terminal capacity, options were considered to relocate the Upper Drive (enplaning) roadway functions to the existing garage and widen the Lower Drive (deplaning) roadway by a lane. By relocating Upper Drive roadway functions to the garage, the terminal could be expanded to the east, making it possible to provide the additional space needed for new facilities and to better distribute the available space among competing functions.

Four preliminary concepts were considered for modifying the existing passenger terminal and garage to accommodate forecast activity through PAL 4 (2034). The key characteristics of the concepts are summarized in Table 3-4. The concepts are illustrated by plan views of the ticketing level and baggage claim levels, shown on Figure 3-7, Figure 3-8, Figure 3-9, and Figure 3-10. Plans for the roof-level, enplaning-level, and deplaning-level of the concepts are located in Appendix B.

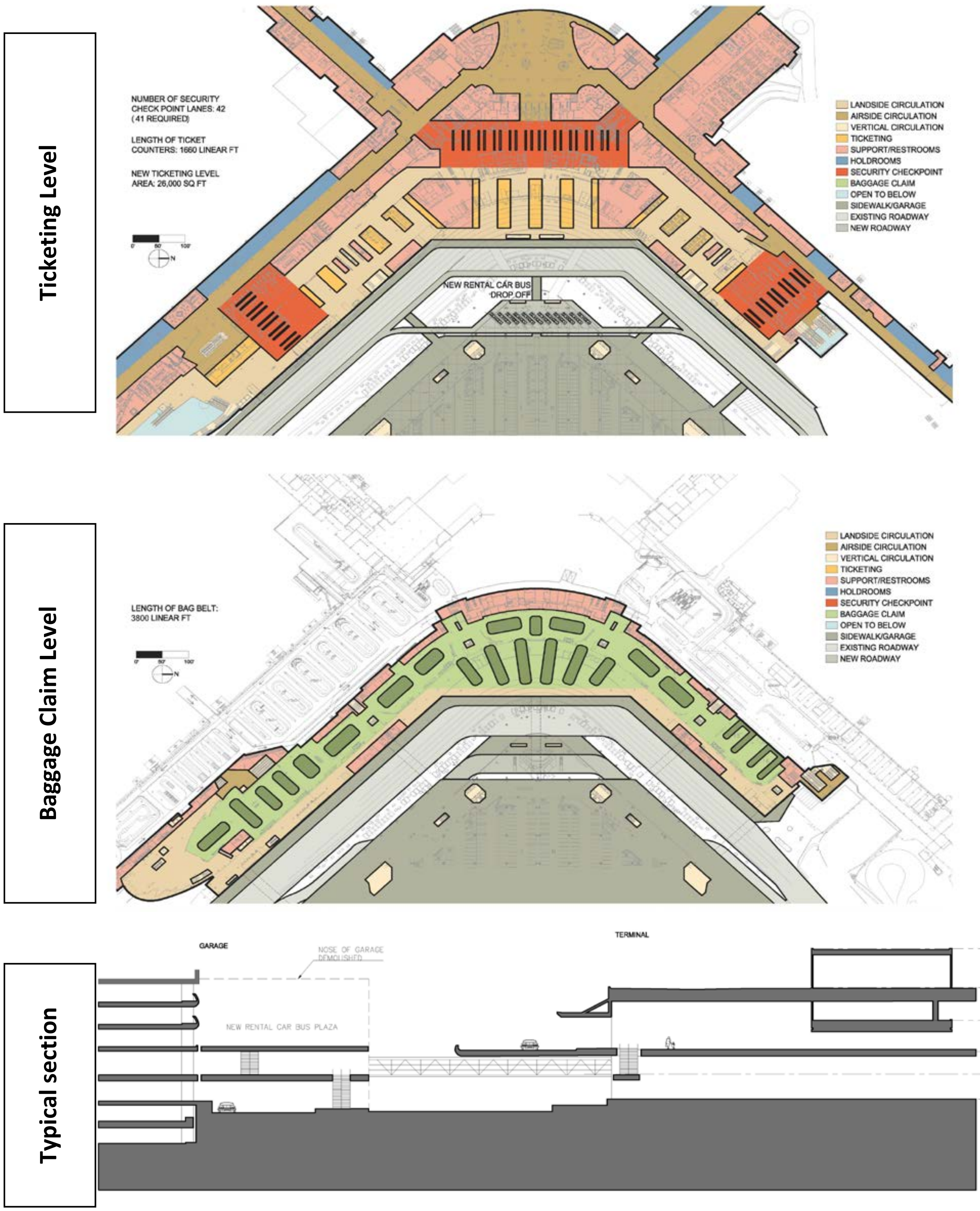
Table 3-4
Key Characteristics of One-Terminal Concepts Considered
Seattle-Tacoma International Airport

	CONCEPT 1 Expand terminal to north	CONCEPT 2 Expand terminal façade to the east Move Upper Drive functions into the Garage Remove Upper Drive Raise Lower Drive	CONCEPT 3 Expand center of terminal façade to the east Remove garage levels 6 - 8	CONCEPT 4 Expand center of terminal to east Provide secure and non-secure APM station in garage
SAMP designation *(a)*		Option 1 (preferred option)	Option 3	Option 5
Garage	No change to structure	Remove western portion of garage on levels 6-8 Move upper curb functions and rental car shuttle areas to garage level 5 (approaches considered for this action are provided in Chapter 4)	Remove garage "nose" on all levels; preserve a portion of level 1 – 5 to allow for a rental car shuttle area on garage level 5	Remove garage "nose" on all levels; if possible, preserve a portion of level 1 - 4 beneath APM station. Construct secure and non-secure APM station at level 5 of garage. Secure portion provides access to new northern gates. Non-secure portion provides access to remote rental car facility.
Upper drive	No change. Widen roadway to provide additional capacity (approaches considered for this action are provided in Section 4).	Demolish and relocate functions to garage level 5	Realign to match new terminal face alignment, widen to 5 lanes	Realign to match new terminal face alignment, widen to 5 lanes
Lower drive	No change	Raise drive to match baggage claim level floor elevation, move rental car shuttles to level 5 curb area within garage	Realign to match new terminal face alignment, move rental car shuttle areas to level 5 of garage	Realign to match new terminal face alignment
Terminal	Expand terminal to north Reconfigure check-in, SSCP, and bag claim	Relocate pedestrian bridge to garage from level 4 to level 5 Move ticketing-level façade to east Reconfigure check-in, SSCP, bag claim Replace "switch-back" escalators with additional escalators connecting baggage claim and ticketing levels	Realign center section of terminal to the east Reconfigure check-in, SSCP, bag claim	Realign center section of terminal to the east Reconfigure check-in, SSCP, bag claim Construct secure walkway (at level 7 of the garage) between secure portion of the APM station and the security checkpoint
Automated people mover	No station in garage	No station in garage	No station in garage	Station in garage

(a) For the purposes of this Technical Memorandum, the concept numbering scheme was changed.

Source: Corgan Associates, 2015.

Figure 3-7
Concept 1 – Expand Terminal to North
Seattle-Tacoma International Airport



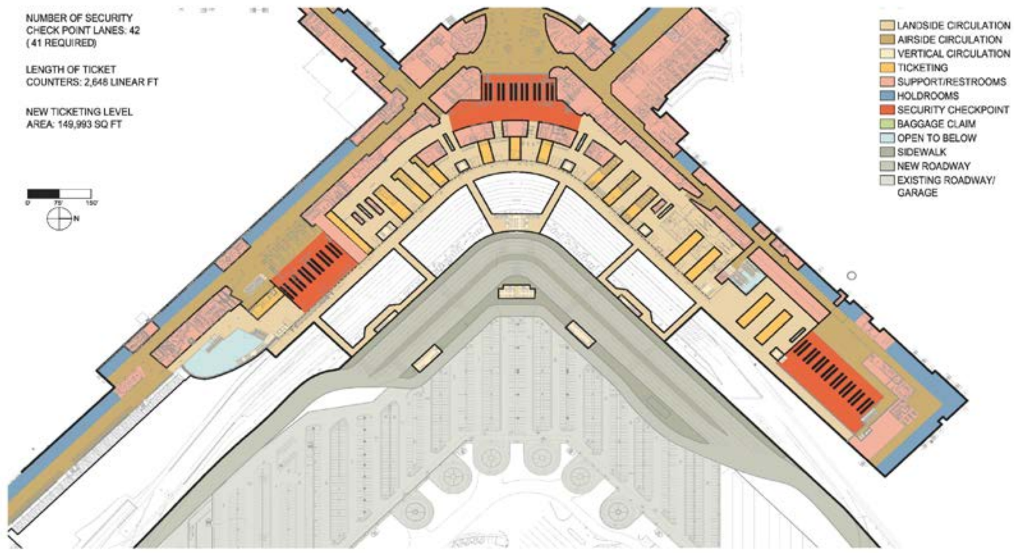
Source: Corgan Associates, 2015.

Figure 3-8

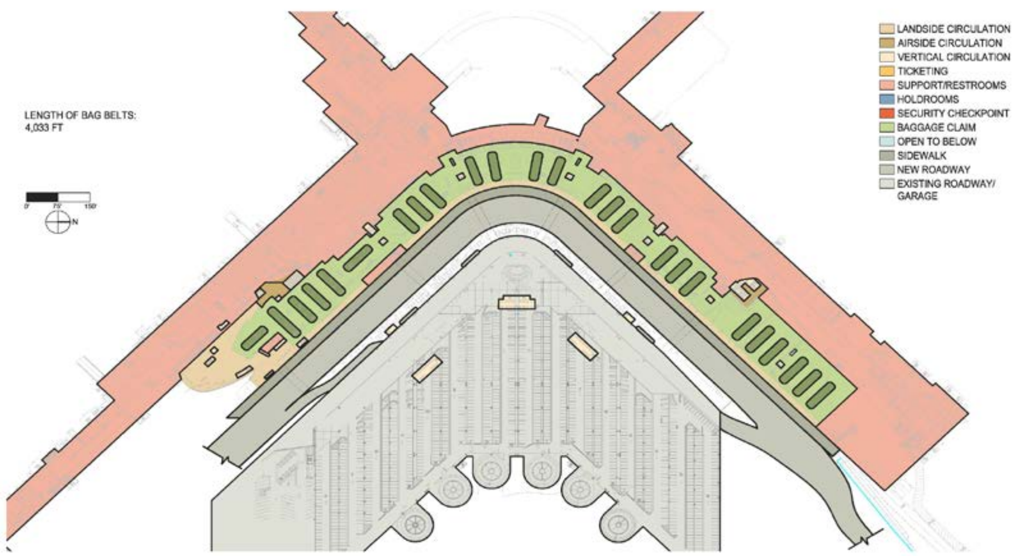
Concept 2 – Expand Terminal Façade to East and North

Seattle-Tacoma International Airport

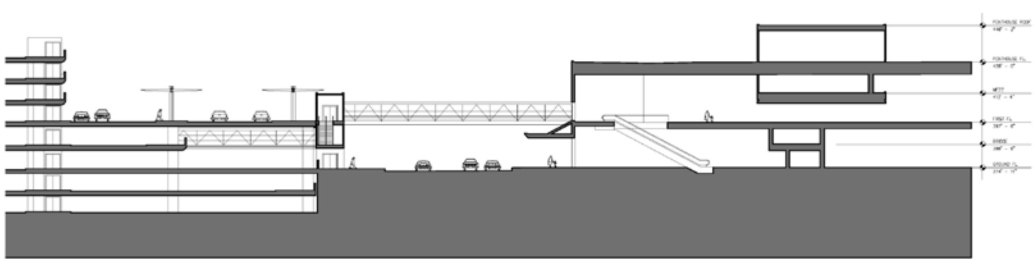
Ticketing Level



Baggage Claim Level



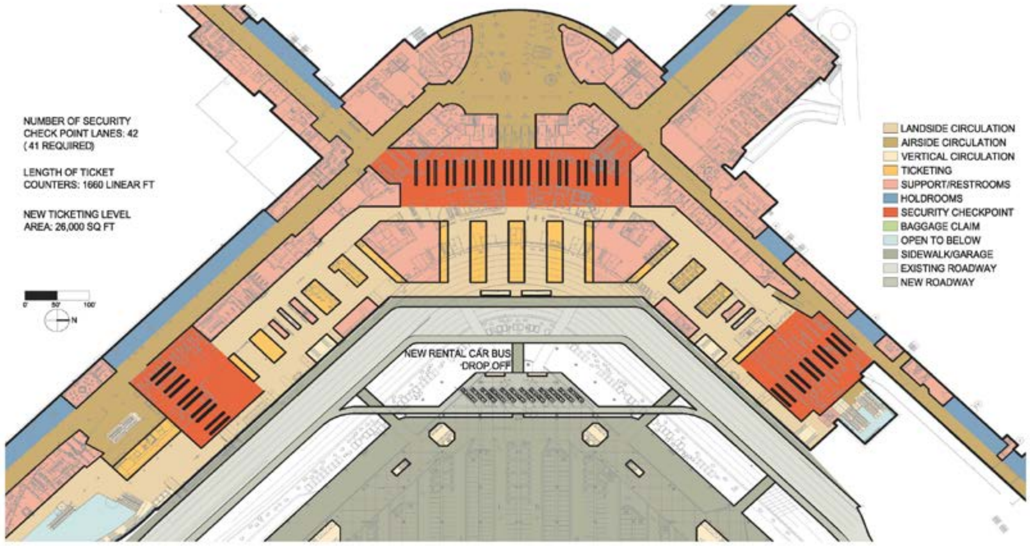
Typical section



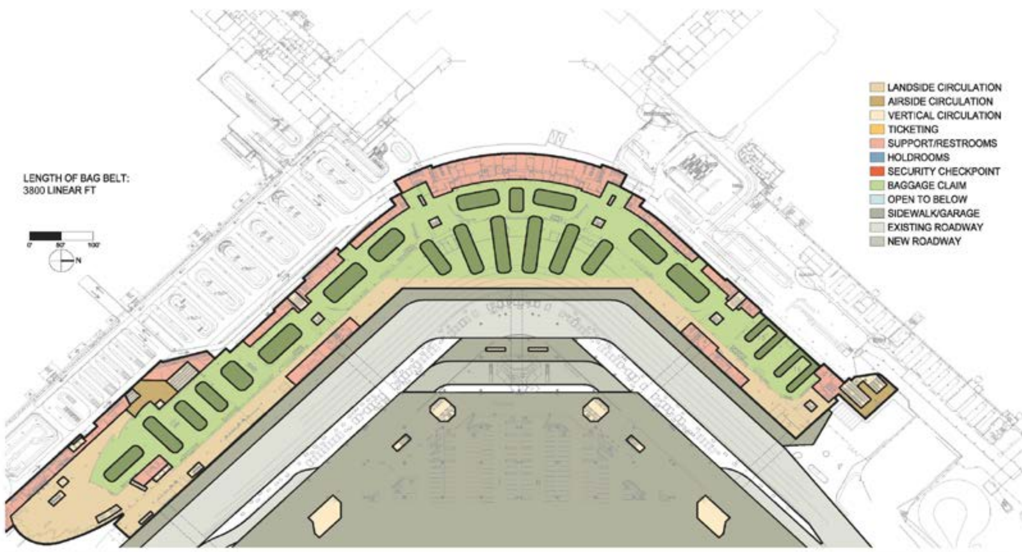
Source: Corgan Associates, 2015.

Figure 3-9
Concept 3 – Expand Center of Terminal to East
Seattle-Tacoma International Airport

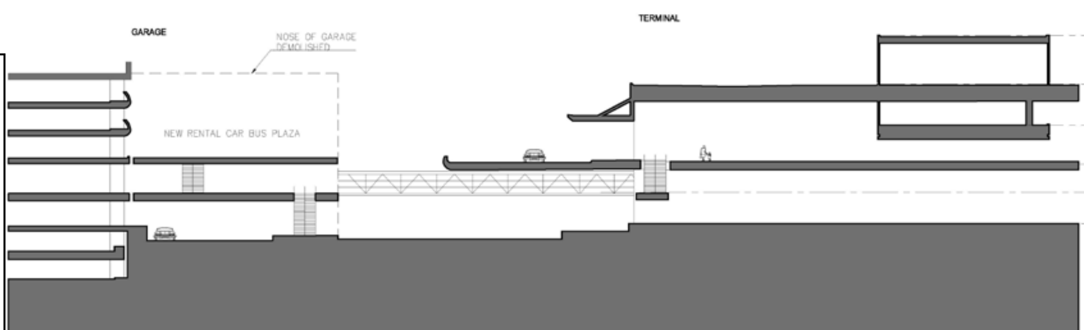
Ticketing Level



Baggage Claim Level



Typical section

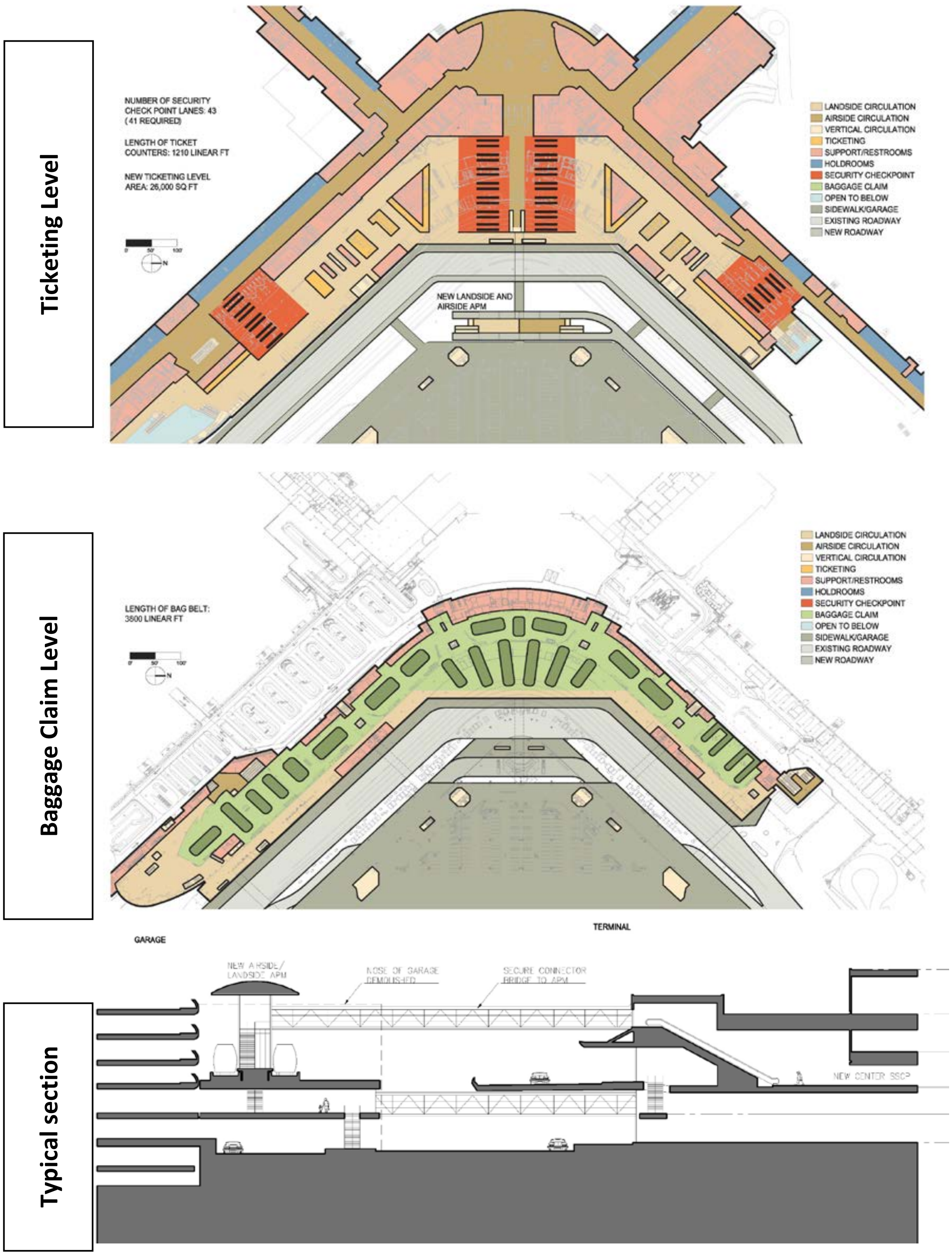


Source: Corgan Associates, 2015.

Figure 3-10

Concept 4 – Expand Center of Terminal to East, Provide Secure & Non-secure APM

Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

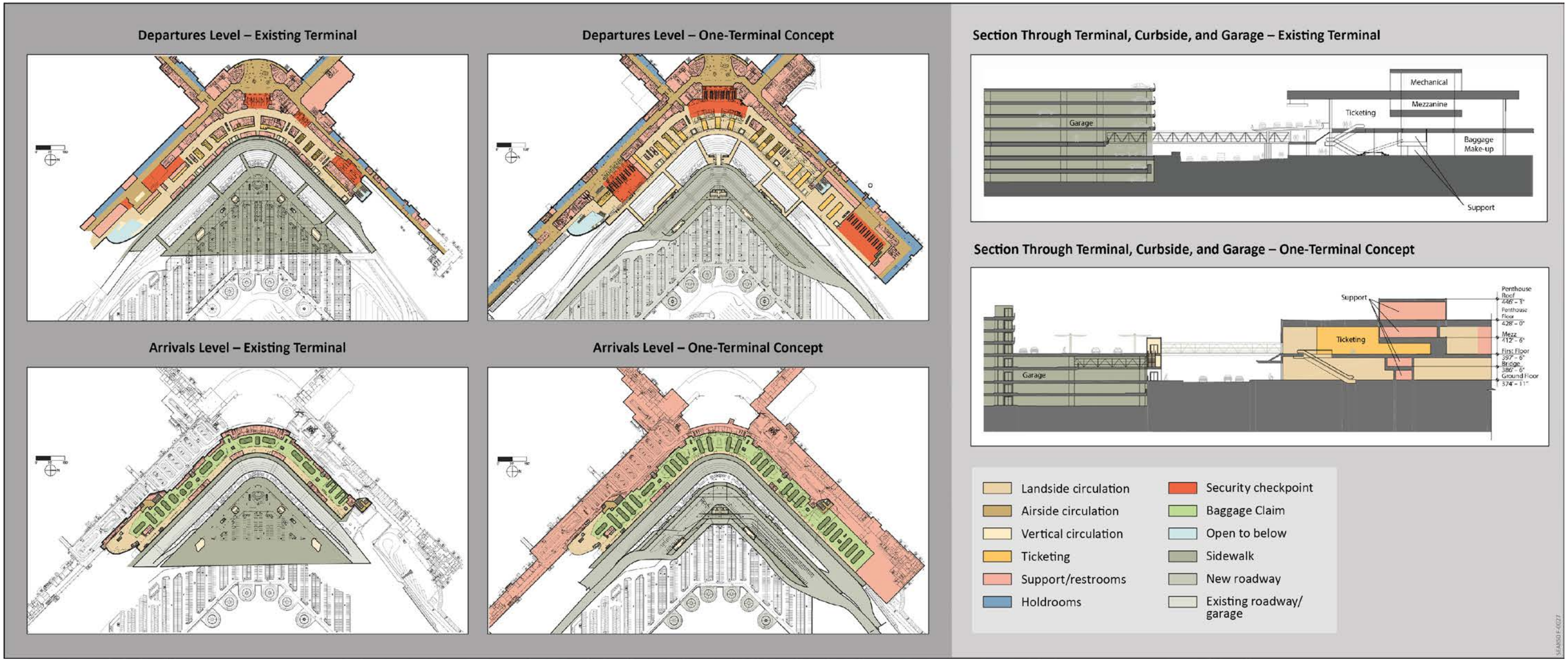
The preliminary concepts were evaluated based on experience and professional judgement, resulting in the following conclusions:

- Concept 1 was rejected because it does not enable the resolution of significant issues related to major functions (e.g., passenger security screening, passenger circulation, baggage claim, upper drive, lower drive, and curbsides).
- Concept 2 is the preferred One-Terminal concept. The preferred strategy for accommodating Upper Drive functions within the garage is described in Chapter 4.
- Concept 3 was rejected because it involves costs similar to those for Concept 2 without resolving as many issues.
- The purpose of preliminary Concept 4 was to explore the possibility of including an automated people mover system station within the garage. The purpose of a secure (i.e., post-security) APM is to transport passengers to the north gates. The purpose of a non-secure (i.e., pre-security) APM is to transport passengers to and from the rental car facility, thus reducing roadway congestion created by rental car buses. From this exploration, it was concluded that (1) it is possible, and (2) the minimum connect times possible with the location shown may exceed the goal of 90 minutes. Minimum connect time (MCT) refers to the minimum time necessary for an arriving international passenger to be processed and board a connecting flight departing from the farthest gate. Concept 4 was rejected because it costs nearly as much as Concept 2 and requires the development of both a secure APM to the north gates and a non-secure APM to the remote rental car facility.

The preferred One-Terminal passenger processor Concept 2, compared with the existing terminal in plan and in cross section on Figure 3-11, involves expanding the passenger terminal to the east and, consequently, the following primary elements of construction:

- Remove Upper Drive
- Remove three upper garage levels (limited to the western sections of the garage) to accommodate displaced upper level roadway functions on level 5 of the garage
- Construct new elevated roadway connecting level 5 of the garage to the roadways approaching and departing from the Upper Drive
- Relocate pedestrian bridges between garage and terminal up to garage level 5
- Build new larger elevator cores within the garage and at bridges, including elevators connecting the courtesy van islands to the pedestrian bridges
- Expand ticketing level exterior wall to roof drip line limits
- Realign all ticketing counters to "island" configuration
- Reconfigure escalators between bag claim and ticketing levels
- Expand ticketing and baggage claim functions to the north

Figure 3-11
One-Terminal Concept Compared to Existing Terminal
Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

Implementing the One-Terminal concept would involve resolving substantial issues during advanced planning and design phases. Those issues include the planning and design of the (1) the modified garage and roadway structure to support fire and rescue vehicles, (2) an automated people mover (APM) system potentially needed to support international to domestic connecting passengers, and (3) a new high speed baggage system between the existing terminal and the new gates to the north.

3.3.3 One-Terminal Concept—Airside

Planning related to functions in the secure portions of the passenger terminal, referred to as airside functions, focused on outbound baggage makeup, Concourses A through D, and the South and North satellites. The details of many of these concepts will be developed in advanced planning, subsequent to the selection of the preferred terminal concept.

3.3.3.1 Concourse A

Concourse A, the newest of the concourses, is in excellent condition and provides a high level of service. As the level of international activity increases at Concourse A, it is anticipated that relatively minor improvements (e.g., concessions) will be implemented.

3.3.3.2 Concourse B

Some holdrooms on Concourse B are undersized for the current fleet mix and are often crowded. Concessions are limited and, due to the narrow concourse width, fewer restrooms are provided than on other concourses and passenger movement is somewhat constrained. Accordingly, at an appropriate time in the future, Concourse B should be either enlarged and reconfigured or demolished and replaced.

By the time the forecast PAL 4 international activity is realized, additional international gates will be required. One alternative to meet this requirement is to modify Concourse B to provide additional international gates. The key elements of the concept include:

- Build new gates to accommodate both international and domestic activity (i.e., “swing” gates).
- Construct new international gates corridor that connects with the arrivals corridor designed for the IAF.
- Remedy existing deficiencies with circulation space, hold rooms, concessions, and toilets.

The concept for replacing Concourse B is the same for the One-Terminal or Two-Terminal concept. The key features of the replacement Concourse B are shown on Figure 3-12. Full-sized illustrations of the Concourse B redevelopment are shown in Appendix C. The concept shown on Figure 3-12 was developed in 2015. At the time this Technical Memorandum No. 6 was prepared, the FAA has directed that there be no further expansion, beyond what has already been approved by the FAA's Seattle Airports District Office, to impede Runway 16L-34R from meeting the permanent runway-to-taxiway separation standard of 500 feet. The redevelopment of Concourse B could be such an impediment. Please refer to Section 2.3.1 of this Technical Memorandum for a complete discussion of the agreement the Port and FAA have reached related to this runway-to-taxiway separation standard. Other alternatives for providing additional international gates exist, including hardstand operations or extending Concourse A.

3.3.3.3 Concourse C

Concourse C is adequate for the near term. The need for possible improvements to its facilities will be reviewed as its use evolves.

3.3.3.4 Concourse D

The width of Concourse D is narrow and limits passenger movements, an issue that will be exacerbated with the ultimate extension of Concourse D and connection to the southern pier of the north gates. Concourse D should be widened by approximately 40 feet over a length of nearly 500 feet, adding moving walkways and expanding concessions. Additional space would be provided on the departures level as well as on the ramp level below.

3.3.3.5 South Satellite

The South Satellite will be expanded and refurbished as part of the current International Arrivals Facility project.

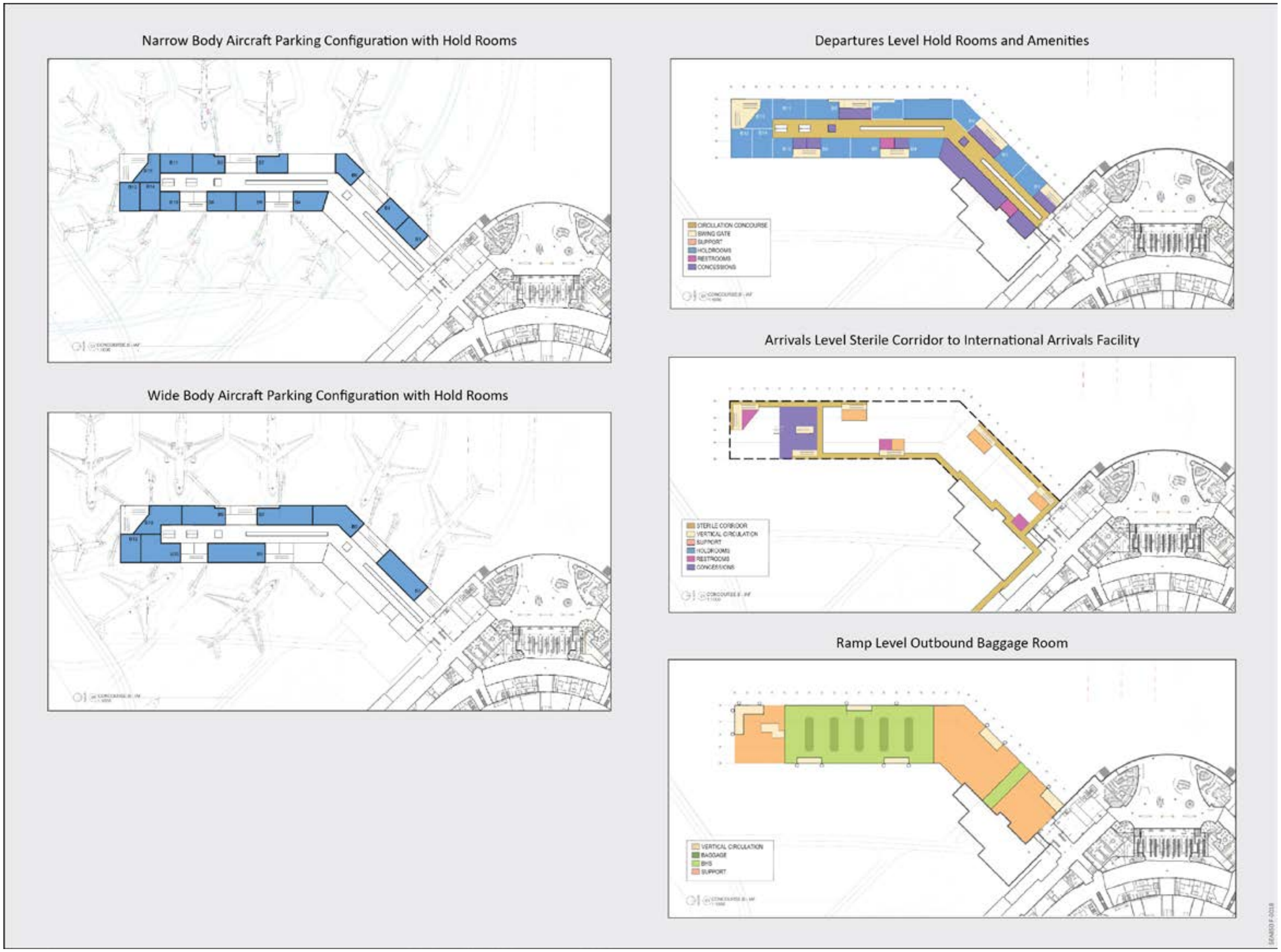
3.3.3.6 North Satellite

The North Satellite will be expanded and refurbished as part of the current NorthSTAR project.

Figure 3-12

Concept for Replacement Concourse B

Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

3.3.4 Post-security APM System

Four APM options were considered for transporting post-security passengers (i.e., passengers who have passed through the passenger security screening check points) between passenger terminal concourses and satellites and between the new International Arrivals Facility and gates. The factors considered in developing and assessing the options included minimum connect time, systems cost, passenger level of service, and the potential impact of construction.

Minimum Connect Time (MCT) refers to the minimum time necessary for an arriving international passenger to be processed and board a connecting flight departing from the farthest gate. MCT consists of the time necessary for a passenger to travel from the arriving gate to the International Arrivals Facility (IAF), the time to be processed through the IAF, the time to travel time from the IAF to the connecting flight's gate, and a 10 minute buffer. The SAMP goal for MCT is 90 minutes.

The preliminary systems cost estimates are anticipated costs for the APM system supplier contract only and exclude the costs for fixed facilities (i.e., the costs for elevated guideways, tunnels, stations, and maintenance facility) and the costs associated with oversight provided by Port personnel. The primary elements included in the APM system cost estimates are those associated with:

- Vehicles
- Train control
- Communications
- Power Distribution
- Maintenance equipment, including fit out and equipping of the maintenance facility
- Station equipment
- APM contractor design, coordination, installation, and testing
- Labor

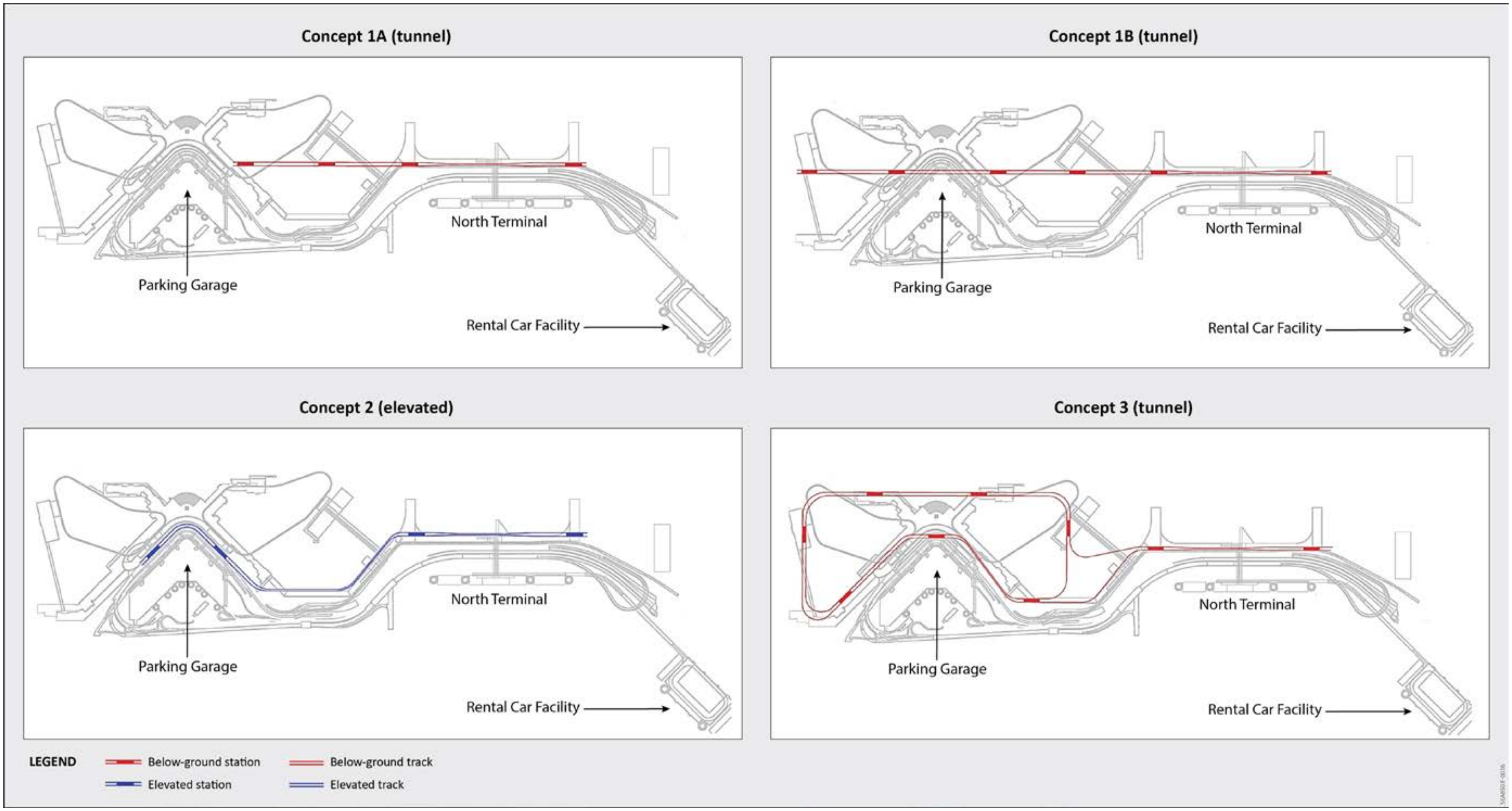
The secure APM concepts considered are illustrated on Figure 3-13 and the potential locations for elevated and below-ground tracks are shown on Figure 3-14. Post-security APM concepts are the same for the One-Terminal and Two-Terminal concepts.

The characteristics of the secure APM concepts are summarized in Table 3-5.

3.3.4.1 Post-security Concept 1A

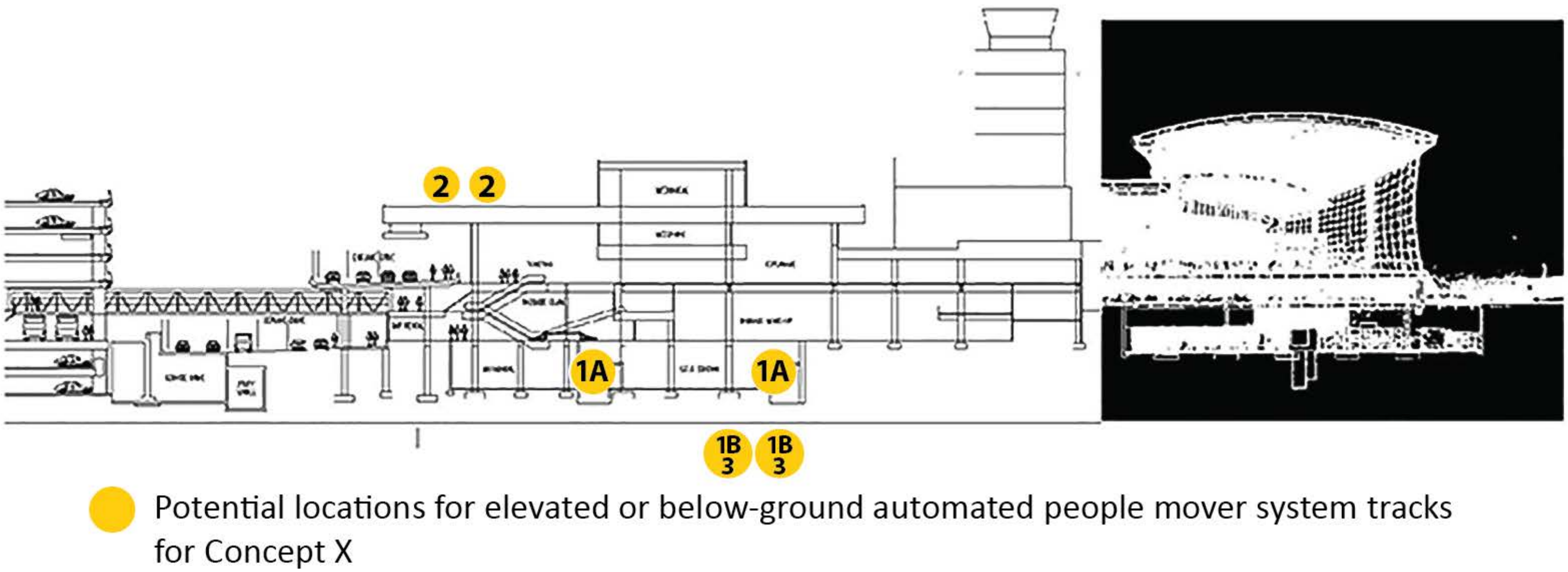
Post-security Concept 1A would operate as a pinched loop tunnel system and have four stations serving Concourse D, the North Satellite, and the north and south piers of the new north gates. This concept would require a portion of the existing STS to continue to serve the existing concourses. The north loop would be partially demolished to make room for the new station at Concourse D, adjacent and connecting to the existing Concourse D station. The south loop would remain intact to serve Concourse A, Concourse B, and the South Satellite, as would the existing shuttle connecting Concourses A and D.

Figure 3-13
Assessed Post-security APM Concepts
Seattle-Tacoma International Airport



Source: Lea+Elliott, November 2016.

Figure 3-14
Potential Track Locations for Post-security APM Concepts 1A, 1B, 2, and 3
Seattle-Tacoma International Airport



Source: Port of Seattle, 2016.

Table 3-5
Characteristics of Assessed Post-security APM Concepts
Seattle-Tacoma International Airport

Characteristic	Concept 1A	Concept 1B	Concept 2	Concept 3
elevated- or below-ground	below-ground	below-ground	elevated	below-ground
Number of stations:				
Main Terminal	2	4	2	7
North Terminal	2	2	2	2
Disposition of STS *(a)*				
South loop	no change	abandoned	no change	abandoned
North loop	partially demolished	abandoned	no change	abandoned
Shuttle between A and D	no change	abandoned	abandoned	abandoned
Number of cars in train	3	4	1	Inner loop: 4 Outer loop: 3
Headway (min)	3.2	3.1	2.6	Inner loop: 3.1 Outer loop: 3.1
Capacity (pphpd) *(b)*	3,400	3,525	1,050	Inner loop: 2,600 Outer loop: 3,520
Maximum one-way travel time (min)	4.7	7.7	6.4	Inner loop: 6.2 Outer loop: 9.3
MCT *(c)*	87 - 102	84 - 99	78 - 93	Inner loop: 90 - 105 Outer loop: 90 - 105
System cost	\$150 - \$200 million	\$210 - \$270 million	\$100 - \$125 million	\$360 - \$450 million
Annual O&M cost	\$5 - \$6 million	\$6.5 - \$7.5 million	\$3.5 - \$4.5 million	\$10 - \$11 million

Note: Post-security APM concepts are the same for the One-Terminal and Two-Terminal concepts.
(a) The existing STS will continue to operate, except as noted.
(b) pphpd = peak passengers per hour per direction
(c) MCT = minimum connect time

Source: Lea+Elliott, 2016.

The partial north loop could continue to serve Concourse C and Concourse D as a shuttle system. With Concept 1A, passengers transferring between distant concourses could be required to ride multiple systems to reach their final destinations.

Using four-car trains on this system, a 3.2-minute headway can provide a system capacity of 3,400 pphpd (passengers per hour per direction). The one way travel time for passengers on this system would be 4.7 minutes with an overall MCT (minimum connect time) between 87 and 102 minutes.

The systems capital cost for Concept 1A is approximately \$150 to \$200 million and it would cost approximately \$5 to \$6 million per year for operations and maintenance.

3.3.4.2 Post-security Concept 1B

Post-security Concept 1B is an extension of Post-security Concept 1A with six stations rather than four. The existing STS loop systems would both be demolished and there will be two additional stations serving Concourse A and the South Satellite. This would reduce the need for passengers to connect to multiple systems to reach their destinations. However, there will be no direct connection to Concourse B and C; passengers in these concourses would be required to walk to or from the nearest station at Concourse A and D or airport entrances/exits.

Using four-car trains on this system, a 3.1-minute headway could provide a system capacity of 3,525 pphpd. The one way travel time for passengers on this system would be 7.7 minutes with an overall MCT between 84 and 99 minutes.

The systems capital cost for Concept 1B would be approximately $210.0 to $270.0 million and it would cost approximately $6.5 to $7.5 million per year for operations and maintenance.

3.3.4.3 Post-security Concept 2

Post-security Concept 2 is a secure elevated system that would have four stations serving Concourse A, Concourse D, and the north and south piers of the new North Terminal. As this option does not serve the Satellite Concourses (North and South), the existing loops would remain intact and in operation. Passengers transferring to or from these satellites would be required to ride the existing loops and transfer at Concourse A or D to reach the North Terminal gates. This configuration will require passengers to make multiple level changes to move between elevated and underground systems.

Using one-car trains on this system, a 2.6-minute headway would provide a system capacity of 1,050 pphpd; longer trains could be used to increase capacity if warranted. The one way travel time for passengers on this system will be 6.4 minutes with an overall MCT between 78 and 93 minutes.

The systems capital cost for Concept 2 would be approximately $100.0 to $125.0 million and it would cost approximately $3.5 to $4.5 million per year for operations and maintenance.

3.3.4.4 Post-security Concept 3

Post-security Concept 3 is the “ideal” loop APM system. This option would require demolition of the existing north and south STS loops and would replace the existing STS with an underground system that connects to all concourses. By choosing the inner or outer loop, passengers would not be required to transfer between different APM systems to reach their destinations. The inner loop would operate clockwise serving existing gates while the outer loop and “tail” would operate counterclockwise, serving existing gates and planned new north gates.

The inner loop would operate four-car trains, and provide a system capacity of 2,600 pphpd with a maximum travel time of 6.2 minutes. The outer loop would operate three-car trains, and provide a system capacity of 3,520 pphpd with a maximum travel time of 9.3 minutes. Both loops have a 3.1-minute headway and a minimum connect time of 90 and 105 minutes. The systems capital cost for this Option 3 would be approximately $360 to $450 million and it would cost approximately $10 to $11 million per year for operations and maintenance.

3.3.4.5 Concept Screening and Conclusions

The post-security APM concepts were screened by Port staff to identify the preferred option. The screening was based on decision criteria that reflected passenger level of service, cost, construction, facilities, and other issues.

Criteria related to passenger level of service

- **Connect time** – This criterion reflects the time require for international passengers to transfer from a South Satellite gate, through the IAF, and to the farthest new north gate.
- **Wayfinding** – This criterion reflects the assessment of the complexity of wayfinding.
- **Level changes** – This criterion reflects the number of times a passenger might be required to descend from the concourse level to an underground STS; then up to the concourse level or up to an elevated APM system, then back down to terminal level. Increased level changes generally diminish passenger experience.
- **Transfers** – This criterion reflects the number of different trains a passenger must ride to transfer between gates.

Criteria related to cost

- **Capital cost (systems)** – This criterion reflects the estimated cost of APM systems (e.g., vehicles, power, communications, and train control) but does not include the cost of fixed facilities (e.g., guideway, stations, and tunnel).
- **Annual operating cost** – This criterion reflects the cost for operating and maintaining the APM system, including staffing costs.
- **Construction cost (qualitative)** – This criterion reflects a qualitative review of costs related to fixed facilities.
- **Replaces existing STS** – This criterion reflects the potential to save approximately $5 million annually if the STS does not have to be maintained and future renewal and replacement costs are avoided.

Criteria related to construction

- **Operational impacts during construction** – This criterion reflects the potential for construction to impact ongoing airport operations.
- **Construction risks** – This criterion reflects the degree to which unknowns (design or otherwise) might pose risks to the schedule, cost, or feasibility of the solution.

Criteria related to facilities

- **Gate impact (at completion)** – This criterion reflects the potential for the system to displace gates.
- **Impact to future facilities** – This criterion reflects the potential for the system to preclude future development.
- **Synergy with baggage and utilities** – This criterion reflects the potential for APM infrastructure to be used for baggage systems and utilities (e.g., a tunnel could be used by both, resulting in cost savings).

Criteria related to other factors (not scored)

- **Passenger volume** - This criterion reflects system capacity.

The post-security APM concepts were evaluated and scored against each criterion. The scores ranged from 1 to 5; a score of 1 indicated poor performance relative to the criterion and a score of 5 indicated good performance relative to the criterion. Weights were assigned to the criteria according to their relative importance and a weighted score was computed for each concept.

Table 3-6 summarizes the criterion weights, scoring, and results of the screening process. Concept 1B is the preferred post-security APM option.

3.4 Refined Two-Terminal Concept

This section summarizes the refined Two-Terminal concept to satisfy the passenger terminal requirements identified for PALs 1 through 4. The Two-Terminal concept includes a second passenger terminal, referred to as the North Terminal, which would supplement operations in the existing Main Terminal. This minimizes the need for modifications to existing passenger terminal, curbside, and garage facilities. The following sections describe the key features of the Two-Terminal concept according to its two principal components—the North Terminal and the Main Terminal.

Table 3-6
Post-security APM Concepts Screening Results
Seattle-Tacoma International Airport

Criteria	Criteria weight	Concept 1A Score *(a)*	Concept 1A Weighted score	Concept 1A Criteria value	Concept 1B Score *(a)*	Concept 1B Weighted score	Concept 1B Criteria value	Concept 2 Score *(a)*	Concept 2 Weighted score	Concept 2 Criteria value	Concept 3 Score *(a)*	Concept 3 Weighted score	Concept 3 Criteria value
Passenger Level of Service (LOS)													
Minimum connect time	5	3	15	87 - 102	4	20	84 - 99	5	25	78 - 93	2	10	90 - 105
Best wayfinding	5	2	10	--	4	20	--	3	15	--	5	25	--
Number of level changes (b)	3	4	12	--	4	12	--	3	9	--	5	15	--
Number of transfers	4	2	8	--	5	20	--	4	16	--	5	20	--
Costs													
Capital cost (systems)	2	4	8	$150 - 200 M	3	6	$210 - 270 M	5	10	$100 - 125 M	1	2	$360 - 450 M
Operating cost	1	4	4	$5.0 - 6.0 M	3	3	$6.5 - 7.5 M	5	5	$3.5 - 4.5 M	1	1	$10 - 11 M
Construction costs (qualitative)	5	5	25	Possible shallow tunnel or cut &cover	2	10	deep tunnel	3	15	--	1	5	lengthy deep tunnel
Replaces existing STS resulting in about $5M annual savings and avoiding need for eventual STS rebuild	2	0	0	--	5	10	--	0	0	--	5	10	--
Construction													
Operational impacts during construction	3	1	3	--	4	12	--	1	3	--	3	9	--
Construction risks (e.g., schedule, unknowns)	2	3	6	--	2	4	--	1	2	--	1	2	--
Facilities													
Gate impact (at completion)	-5	0	0	--	0	0	--	0	0	--	0	0	--
Impact to future facilities	1		0	--	4	4	--	1	1	--	4	4	--
Synergy with baggage and utilities	3	5	15	--	5	15	--	0	0	--	3	9	--
Other (not scored)													
Passenger volume (pphpd) (c)	n/a	--	--	3,400	--	--	3,525	--		1,050	--	--	2,600; 3,520
Passenger group(s) served / connectivity	n/a	--	--	Secure traffic from D and N to new north gates	--	--	All secure traffic (no direct connections to B and C)	--		Secure traffic between A, D, and new North Gates	--	--	All secure traffic
Other comments	n/a	--	--	System partially replaces current loops with new technology; reduced O&M cost; cut & cover	--	--	System replaces current loops with new technology; reduced O&M cost; deep bored tunnel	--		--	--	--	System replaces current loops with new technology; reduced O&M cost
Weighted total score			106	--	--	136	--	--	101	--	--	112	--
Percent of best option		0%	78%	--	--	100%	--	--	74%	--	--	82%	--

(a) Scores ranged from 1 - 5; 5 is good, 1 is bad.
(b) Level change counts are based on longest route.
(c) pphpd = peak-period passengers per hour per direction.

Source: Port of Seattle, 2016.

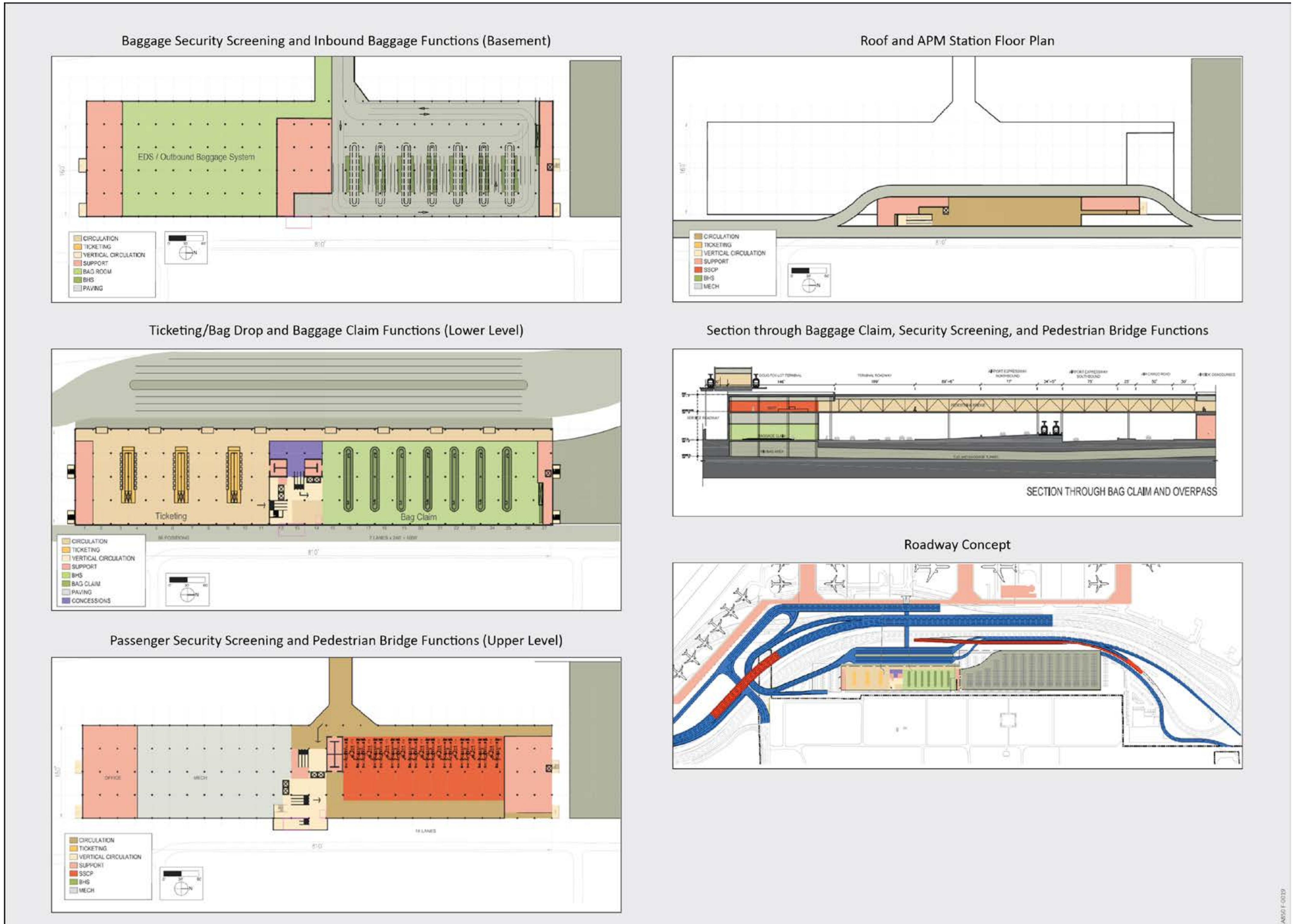
3.4.1 Two-Terminal Concept—North Terminal

The key features of the North Terminal include the following:

- The North Terminal will operate effectively for either a single airline or a combination of airlines, and should ultimately accommodate approximately 30% of passenger activity forecast for PAL 4 (66 MAP).
- The building footprint, approximately 130,000 square feet, was sized to fully utilize the Doug Fox site.
- Curbsides will be provided on a single level to reduce roadway complexity and cost.
- Both ticketing/bag drop and baggage claim functions will be on the same level as the roadway.
- The adjacent Bonney-Watson cemetery will not be affected.
- Adequate parking will be provided adjacent to the terminal.
- Passengers will be able to walk between the North Terminal and north gates through an enclosed pedestrian bridge that spans the North Airport Expressway and light rail right-of-way.
- Outbound baggage makeup functions will be located on the airside, beneath the piers. Outbound baggage will be screened at the North Terminal and transferred via conveyors to the outbound baggage makeup areas.
- The North Terminal outbound baggage system will be connected with the Main Terminal's outbound baggage system, making it possible to drop a bag in the Main Terminal for a flight departing from the North Terminal. Similarly, it will be possible to drop a bag in the North Terminal for a flight departing from a gate in the Main Terminal.
- Inbound baggage will be transferred via tugs and dollies through a tunnel to inbound belts at the North Terminal.
- The North Terminal concept will allow for the effective inter-terminal transfer of passengers with an APM, if desired.

Key features of the North Terminal concept are illustrated on Figure 3-15. Full-sized illustrations of the North Terminal concept are shown in Appendix D. The ticketing and baggage drop-off functions are placed in the south half of the building, and baggage claim functions are in the north half. The parking garage (providing both public parking and commercial vehicle loading areas) is immediately north of, and adjacent to, the baggage claim functions. After arriving at the North Terminal, a departing passenger would check-in (if necessary) on the Lower Level and proceed directly, by escalator or elevator, to the security screening check point located on the Upper Level. Once processed through security, the passenger would continue across a bridge to the new north gates or other connected gates.

Figure 3-15
Key Features of the North Terminal
Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

3.4.2 Two-Terminal Concept—Main Terminal

Key assumptions in assessing the potential modifications to the Main Terminal were:

- The North Terminal would be constructed by about 2027 (based on preliminary phasing estimates at the time this technical memorandum was prepared).
- When the North Terminal opens, the Main Terminal may accommodate as many as 54 million annual passengers, albeit at less than desirable levels of service.
- Accordingly, modifications to the Main Terminal will be limited to those needed to accommodate 54 million annual passengers.
- Following the opening of the North Terminal, the Main Terminal would accommodate approximately 70% (46 MAP) of the forecast PAL 4 passenger activity.

3.4.2.1 Main Terminal—Landside

The objective of the Two-Terminal concept is to minimize the overall facilities cost by investing in the main terminal only as necessary to satisfy demand until the North Terminal is opened, or to renew aging infrastructure. Accordingly, improvements planned as part of pre-SAMP projects such as the International Arrivals Facility (IAF), NorthSTAR, and Baggage Optimization would be entrusted to provide significant customer service enhancements.

In addition to a completely redeveloped North Satellite, NorthSTAR includes Main Terminal improvements to the curbside, ticketing lobby, and passenger security screening facilities. Ground access services and access would be enhanced through operational improvements (described in Chapter 4) and a widened approach to the Lower Drive.

3.4.2.2 Main Terminal—Airside

Planning related to functions in the secure portions of the passenger terminal, referred to as airside functions, focused on outbound baggage makeup, Concourses A through D, the South and North satellites, and an APM.

The modifications required to Concourses A through D, the South Satellite, and the North Satellite, and the alternatives for an APM are the same for the Two-Terminal concept as for the One-Terminal concept. Please refer to Section 3.3.3 for a summary of the recommended airside functions and facilities.

3.5 Comparison of the Refined One-Terminal and Two-Terminal Concepts

The refined One-Terminal and Two-Terminal concepts were compared based on five criteria—cost, risk, phasing, operational flexibility, and level of service. This section defines the criteria, compares the concepts relative to the criteria, and presents the resulting conclusions.

3.5.1 Cost

The criterion "cost" represents the total cost of ownership (TCO; i.e., total capital, operations, renewal, and utilities costs).

- Capital cost estimates were prepared only for major elements that differ between the One-Terminal and Two-Terminal concepts. The capital cost estimates included "soft" costs (e.g., contingencies, fees, management, testing, and administration). Capital cost estimates were prepared for the SAMP planning period (i.e., 2015 – 2034).
- Operating, renewal, and utilities costs were prepared for the period 2015 – 2050, to reflect at least one renewal cycle for all assets.

The key projects related to the One-Terminal vs Two-Terminal cost comparison are shown in Table 3-7. The results of the TCO comparison of the One-Terminal and Two-Terminal concepts are summarized in Table 3-8. The conclusion from the TCO comparison is that the net present value of TCO for the Two-Terminal option is approximately $450 million less than the net present value of TCO for the One-Terminal option.

3.5.2 Risk

The criterion "risk" was introduced to capture the ways the One-Terminal and Two-Terminal concepts might avert risks related to design and construction or passenger activity. Design-related risks refer to building codes and the inability to fully understand the code requirements that must be satisfied for an existing facility without significant design effort. Construction-related risks refer to the unknowns associated with modifying existing structures. The Two-Terminal concept has considerably less design-related risk than the One-Terminal concept as it requires fewer improvements to an existing building.

Passenger activity-related risks refer to the possibility that actual passenger demand might (1) be higher or lower than forecast for a particular PAL, or (2) materialize more quickly or more slowly than forecast. The responses of the One-Terminal and Two-Terminal concepts to activity-related risks are summarized in Table 3-9. The Two-Terminal concept has less passenger activity-related risk than the One-Terminal concept.

3.5.3 Phasing

The criterion "phasing" represents the relative difficulty or ease of sequencing demolition and construction in a complex operating environment. Significant phasing challenges related to the One-Terminal concept, all involving the main terminal, are illustrated on Figure 3-16. The Two-Terminal concept would also require renovations to the Main Terminal, but on a much smaller scale. Most of the major construction for the Two-Terminal concept would be related to the North Terminal and would occur on a greenfield site. The Two-Terminal concept is considerably easier to phase than the One-Terminal concept.

Table 3-7

Key Projects Included in the One-Terminal vs. Two-Terminal Cost Comparison

Seattle-Tacoma International Airport

One-Terminal Concept

- Remove interior ramps connecting the lower level roadway and the Arrivals floor level in Level 1
- Remove upper level departure road
- Raise lower level roadway to align with Arrivals floor level
- Remove pedestrian bridges from level 4 and relocate to level 5
- New garage level 5 entrance and exit lanes and roadway
- Remove western edge section of parking garage levels 6 to 8
- Expand departure level façade by 25' to west and remove interior ramps connecting upper level roadway with Departures floor level.
- Reconfigure interior of existing Terminal Level 1
- Reconfigure interior of existing Terminal Level 2
- System transfer OB/IB baggage between Main Terminal and North Gates
- Relocate/replace/install elevator cores, escalators, vent stacks as required to move upper drive functions and rental car shuttles onto level 5 of garage
- Expand ticketing and baggage claim levels at north end of existing terminal building
- New garage on Doug Fox Lot to provide spaces removed from Main Garage
- New automated people mover between main terminal and north gates

Two-Terminal Concept

- Baggage system & tunnel between north Terminal & Airside Corridor
- New north terminal garage for 320 cars
- New north terminal roadway
- Pedestrian bridge between north terminal and airside concourse
- New utility plant for North Terminal
- New north terminal garage for 5,000 cars (the requirement is for about 3,600 cars; additional capacity allows for commercial vehicles and contingencies)
- New north terminal
- Ticket & baggage expansion at north end of existing terminal building

Source: Corgan Associates and LeighFisher, 2015.

Table 3-8
One-Terminal vs. Two-Terminal Total Cost of Ownership Comparison
Seattle-Tacoma International Airport

	One-Terminal Concept	Two-Terminal Concept	Difference
Capital Cost Differences			
Current dollars	$1,191,431,947	$ 646,342,323	$545,089,624
Future dollars	1,764,664,048	1,110,603,090	654,060,959
Net Present Value	889,947,766	424,872,946	475,074,820
Operations, renewal, and energy costs			
Current dollars	$489,911,000	$562,876,000	($72,965,000)
Future dollars	829,042,000	957,952,000	(128,910,000)
Net Present Value	160,831,000	181,270,000	(20,439,000)
Capital cost differences + operations, renewal, and energy costs			
Current dollars	$1,681,342,947	$1,209,218,323	$472,124,624
Future dollars	2,593,706,048	2,068,555,090	525,150,959
Net Present Value	1,060,778,766	606,142,946	454,635,820

Notes:
1. Current dollars reflect fourth quarter 2015 values.
2. Future dollars reflect appropriate inflation to the year of expenditures.
3. Net present value reflects the sum of all expenditures in future dollars, discounted at 6.5%.

Source: CH2M Hill Engineers, C&N Consultants, Lea+ Elliott, and LeighFisher, 2015.

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Table 3-9

Activity-Related Risk Characteristics of One-Terminal and Two-Terminal Concepts

Seattle-Tacoma International Airport

Risk Characteristics if Activity Is Higher or Lower than Forecast

	ONE-TERMINAL CONCEPT	TWO-TERMINAL CONCEPT
Higher		
	Challenges of accommodating demand in existing terminal become more pronounced	Second terminal is already positioned to accommodate more demand
	May lead to development of a second terminal anyway	All elements of a single terminal solution are still available
Lower		
	More time is available to modify facilities before breaking points are reached	Better overall level of service, but not overbuilt

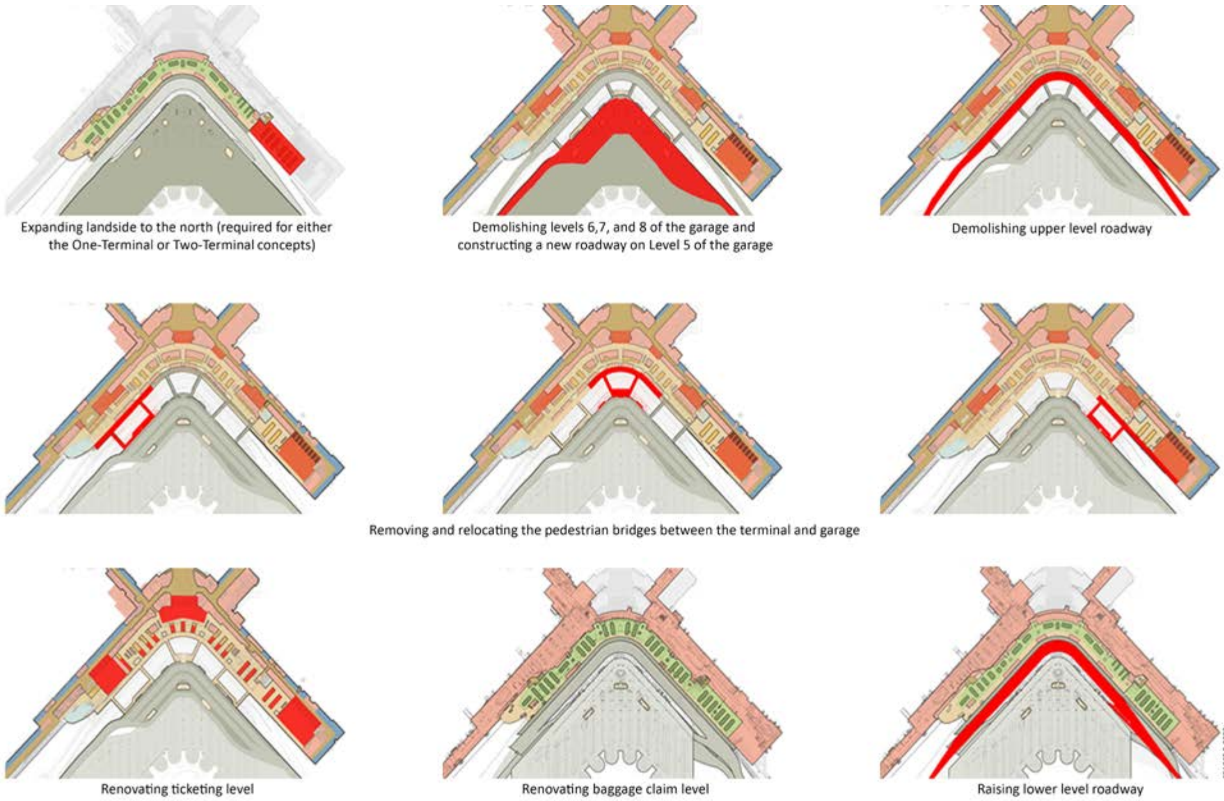
Risk Characteristics if Activity Grows Faster or Slower than Anticipated

	ONE-TERMINAL CONCEPT	TWO-TERMINAL CONCEPT
Faster		
	Existing facility reaches breaking points more quickly	Second terminal is brought on line more quickly
	First step does not "solve" the level-of-service and capacity issues	First step is the solution for many level-of-service and capacity issues
Slower		
	More time to re-evaluate growth and long-term plan	More time to re-evaluate growth and long-term plan

SEA862F-0006

Source: Corgan Associates and LeighFisher, 2015.

Figure 3-16
Phasing Challenges for the One-Terminal Concept
Seattle-Tacoma International Airport



Source: Corgan Associates and LeighFisher, 2016.

3.5.4 Operational Flexibility

The criterion "operational flexibility" reflects (1) the ability of the One-Terminal and Two-Terminal concepts to adapt to changing circumstances, and (2) options available to Port staff or the relative ease or difficulty Port staff would encounter in managing passenger terminal operations, for example, options for:

- Assigning airlines to new gates and offering conveniently located ticketing, bag check, and baggage claim facilities associated with those gates
- Optimally distributing demand along curbs
- Accommodating surge loads generated by groups checking-in
- Relieving stressed baggage handling systems
- Transporting passengers between check in and the north gates

The Two-Terminal concept has greater operational flexibility than the One-Terminal concept for all considerations.

3.5.5 Level-of-Service

The criterion "level-of-service" was employed to permit the planning team to qualitatively compare the One-Terminal and Two-Terminal concepts with respect to factors that would contribute to achieving the desired optimum level of service, for example:

- Sizing and locating all processors to result in a balanced flow of passengers and an overall positive customer experience
- Providing convenient places for passengers to wait when congestion in one area results in crowding
- Mitigating the effects of prolonged construction periods in areas adjacent to ongoing operations

The Two-Terminal concept provides a higher level-of-service than the One-Terminal concept for all these factors.

3.5.6 Summary and Conclusions

The conclusions from this final screening analysis are:

- TCO is less for the Two-Terminal concept than for the One-Terminal concept. This is largely attributable to the high cost of the post-security APM, and terminal, roadway, and garage modifications required for the One-Terminal concept and relatively lesser cost of new construction on a greenfield site for the North Terminal.
- There are lower risks associated with the Two-Terminal concept than with the One-Terminal concept. With the One-Terminal concept, (1) it is much more difficult to accommodate faster than expected passenger growth than with the Two-Terminal concept, and (2) the modifications envisioned to the garage are complex and subject to the interpretation of construction codes that cannot occur until the project is designed.
- Phasing is easier with the Two-Terminal concept than with the One-Terminal concept. The complexity of phasing necessary to maintain passenger operations and the duration of inconvenience of major construction to passengers are significantly greater with the One-Terminal concept than with the Two-Terminal concept.
- The Two-Terminal concept has greater operational flexibility than the One-Terminal concept. The Two-Terminal concept enables (1) easier airline assignments to new gates, (2) group check-in and surge loading to be distributed between two terminals, and (3) more options for relief to stressed baggage handling systems.

- A higher level of customer service would be achieved with the Two-Terminal concept than with the One-Terminal concept. Wayfinding and walking distances between security screening and gates in the North Terminal are considerably improved over the Main Terminal.
- The overall conclusion from this final comparison was that the Two-Terminal Concept is superior to the One-Terminal concept.

3.6 Passenger Terminal Requirements for the Two-Terminal Concept

Passenger terminal requirements for the Main Terminal and North Terminal are summarized in Table 3-10. The requirements assume all passenger-processing occurs in the Main Terminal until the North Terminal is constructed. Following completion of the North Terminal construction, expected between PAL 2 (2024) and PAL 3 (2029), passenger processing would occur in both terminals.

Table 3-10
Terminal Requirements for the Two-Terminal Concept
Seattle-Tacoma International Airport

Facility	Existing (2014)	PAL 1 (2019) Main Terminal	PAL 2 (2024) Main Terminal	PAL 3 (2029) Main Terminal	PAL 3 (2029) North Terminal	PAL 3 (2029) Total	PAL 4 (2034) Main Terminal	PAL 4 (2034) North Terminal	PAL 4 (2034) Total	Sources
BASIS FOR FACILITY REQUIREMENTS (AVIATION ACTIVITY FORECASTS)										LeighFisher, 2015
Total annual passengers (millions)	37.4	44.8	51.8	41.2	17.7	58.9	45.9	19.7	65.6	
Aircraft operations	340,478	398,910	448,860	--	--	--	--	--		
PASSENGER TERMINAL										
Aircraft gates										LeighFisher, 2015
Domestic gates *(d)*										
RJ/TP	20	19	21	Gate requirements are independent of passenger terminals		21	Gate requirements are independent of passenger terminals		12	
Jet III	32	47	50			51			63	
Jet IV	12	10	10			8			6	
Jet V	6	1	1			2			3	
Jet VI	--	--	--			--			--	
Total	70	77	82			82			84	
International gates *(d)*										LeighFisher, 2015
RJ/TP	1	0	0	Gate requirements are independent of passenger terminals		0	Gate requirements are independent of passenger terminals		0	
Jet III	0	0	1			0			2	
Jet IV	2	2	2			2			0	
Jet V	8	16	19			22			27	
Jet VI	2	--	--			--			--	
Total	13	18	22			24			29	
Total gates *(d)*										LeighFisher, 2015
RJ/TP	21	19	21	Gate requirements are independent of passenger terminals		21	Gate requirements are independent of passenger terminals		12	
Jet III	32	47	51			51			65	
Jet IV	14	12	12			10			6	
Jet V	14	17	20			24			30	
Jet VI	--	--	--			--			--	
Total	81	95	104			106			113	
Off-gate parking positions *(e)*										LeighFisher, 2015
RJ/TP	--	1	2	Gate requirements are independent of passenger terminals		3	Gate requirements are independent of passenger terminals		4	
Jet III	--	20	22			27			30	
Jet IV	--	3	4			3			3	
Jet V	--	4	3			4			7	
Jet VI	--	--	--			--			--	
Total	--	28	31			37			44	

Table 3-10 *(continued)*
Terminal Requirements for the Two-Terminal Concept
Seattle-Tacoma International Airport

Facility	Existing (2014)	PAL 1 (2019) Main Terminal	PAL 2 (2024) Main Terminal	PAL 3 (2029) Main Terminal	PAL 3 (2029) North Terminal	PAL 3 (2029) Total	PAL 4 (2034) Main Terminal	PAL 4 (2034) North Terminal	PAL 4 (2034) Total	Sources
Off-gate parking positions *(e)*										LeighFisher, 2015
RJ/TP	--	1	2	Gate requirements are independent of passenger terminals		3	Gate requirements are independent of passenger terminals		4	
Jet III	--	20	22			27			30	
Jet IV	--	3	4			3			3	
Jet V	--	4	3			4			7	
Jet VI	--	--	--			--			--	
Total	--	28	31			37			44	
Passenger check-in facilities										LeighFisher, 2015
Check-in lobby										
Kiosk no bag check	40	77	80	68	29	--	72	31	--	
Agent with no bag check	214	211	219	189	81	--	201	86	--	
Garage	15	11	11	9	4	--	10	4	--	
Curb	15	14	15	13	6	--	14	6	--	
Inbound domestic baggage										Logplan, 2016
Peak hour bags										
Total claim frontage (feet)	2,700	2,982	3,441	2,730	1,406	--	3,047	1,406	--	
Number of claim devices	16	18	20	16	6	--	18	6	--	
Outbound domestic and international baggage										Logplan, 2016
Peak hour bags	3,564	4,748	5,911	5,051	2,393	--	5,742	2,393	--	
Security screening machines	12	9	11	10	5	--	11	5	--	
Make-up positions *(f)*	--	490	386	293	129	--	334	130	--	
Early bag storage positions	0	--	393	374	181	--	435	181	--	
International Arrivals Facility										Port of Seattle, 2014
Processing capacity (pax per hour)	1,200	1,900	1,900	2,600	--		2,600	--	--	

(a) Aircraft approach category D includes aircraft with an approach speed of 141 nautical miles per hour but less than 166 nautical miles per hour
(b) Airplane design group V includes aircraft with a wingspan of 171 feet but less than 214 feet or tail height of 60 feet but less than 66 feet
(c) Taxiway design groups are based on main gear width and cockpit to main gear distance and are defined in FAA Advisory Circular 150/5300-13A, Airport Design
(d) Aircraft gates were classified according to wingspans included in airplane design groups (ADG) defined in FAA Advisory Circular 150/5300-13A, Airport design:
RJ/TP refers to regional jets or turboprops in either ADG I or ADG II and with wingspans no greater than 79 feet.
Jet III refers to aircraft in ADG III which have wingspans greater than or equal to 79 feet but less than 118 feet.
Jet IV refers to aircraft in ADG IV which have wingspans greater than or equal to 118 feet but less than 171 feet.
Jet V refers to aircraft in ADG V which have wingspans greater than or equal to 171 feet but less than 214 feet.
Jet VI refers to aircraft in ADG VI which have wingspans greater than or equal to 214 feet but less than 262 feet.
(e) Bag make up requirements for PAL 1 and PAL 2 assume the installation of an early bag store system as recommended in the baggage optimization study.
(f) 22 spaces are shared among courtesy vehicles, airline crew vans, and the downtown shuttle.

Ground Access and Parking

Without improvements, the on-Airport roadway system may be gridlocked within 10 years.

4.1 Introduction

The alternatives to accommodate future access and parking requirements focused on two overall concepts: (1) continuing to process all passengers through the existing Main Terminal or (2) developing a North Terminal located on the current Doug Fox Lot parking facility. Ground access and parking alternatives presented in this chapter are associated with one or the other of these overall concepts.

4.2 One-Terminal Concept

The One-Terminal concept assumes all passenger-processing continues to occur at the Main Terminal building. Accordingly, all curbside, close-in parking, and commercial vehicle pickup/drop-off facilities are also assumed to be located at the Main Terminal. Therefore, facilities requirements for ground access and parking facilities are identical to those provided in Technical Memorandum No. 5, Chapter 4. As described in Technical Memorandum No. 5, these facilities requirements predominately assume no major change in mode share between private vehicles and public transit options. While on an annual basis there may be changes, those changes may not be as significant during the peak hours that influence facilities requirements. For example, public transit use may increase during much of the day, but may not increase during the early morning peak period (4 a.m. to 6 a.m.) on the Upper Drive (transit services may not operate early enough to serve these customers and regional congestion may not be sufficiently severe to encourage use of public transit).

4.2.1 Off-Airport Access Roadways

As discussed in Technical Memorandum No. 5, Section 4.2.1, off-Airport roads of particular importance include the surrounding state and regional highway network (i.e., I-5, I-405, SR 518, and SR 509) as well as local roadways (i.e., SR 99 / International Boulevard, S. 188th St, S. 170th St, and S. 160th St) that provide access to and from the Airport. Although the Port does not control these off-Airport access roadways, and their future requirements are outside the scope of the SAMP, the roads were evaluated by Port staff using the Sea-Tac airport travel demand forecasting model (the model). This model incorporates the Puget Sound Regional Council (PSRC) land use, employment, trip generation, and travel patterns from areas outside the Airport and is integrated with data related to air passenger travel for the Airport.

The Washington State Department of Transportation (WSDOT) is currently working with stakeholders (including the Port of Seattle. the Port of Tacoma, and local jurisdictions) to refine the scope of improvements for The Puget Sound Gateway project (Gateway project). The Gateway project received funding from the State Legislature in 2016 and includes improvements to SR 167 and SR 509. Of particular importance to Airport access are the phased improvements currently envisioned for planning purposes as part of the SR 509 portion of the Gateway project. By 2026, Gateway project improvements are assumed to connect I-5 to 24/26th Ave S. and Port-constructed improvements are assumed to relocate the at-grade entrance at S 182nd ST. to S. 188th ST (Interim South Access). By 2031, Gateway project improvements are assumed to extend SR 509 from 24/26th Ave S. to the current terminus at S 188th St. and Port-constructed improvements are assumed to connect the Port's roadways system to the SR 509 extension via an aerial crossing of S 188th at the intersection of S 188th and 28th AVE S (South Airport Expressway, or SAE).

For the purpose of assessing off-Airport roadways at PAL 4 (2034) and establishing a baseline for planning on-Airport roadways associated with the One- and Two-Terminal concepts, the Port's model assumes improvements consistent with the Gateway project and no changes to other on-Airport roadways. The baseline assessment of off-Airport roadways concluded that by PAL 4, the improvements assumed as part of the Gateway project will result in a 10% reduction in the number of Airport trips using SR 518 (it is estimated that 77% of future Airport trips will use SR 518 and 23% will use the new SAE) and reduced congestion on the City of Sea-Tac roadway system. The model also assessed congestion of off-Airport roadways associated with increased trips as a consequence of growth in employment, population, and travel in the region. As discussed in Technical Memorandum No. 5, Section 4.2.1, the model assesses roadway performance in terms of a volume/capacity (V/C) ratio for roadway segments in the regional network. The model indicates that in addition to further degradation of conditions on the regional facilities experiencing congestion in 2010 (such as the I-5/I-405 interchange and southbound I-5), SR 509 and SR 518 will experience V/Cs exceeding 0.8 (representing LOS E). However, conditions on I-405 are expected to improve.

4.2.2 On-Airport Access Roadways

As described in Technical Memorandum No. 5, Section 4.4.2 (Table 4-8 and Table 4-9), under a One-Terminal scenario, the model indicates that additional capacity is required as follows to achieve LOS C or better during the design hour:

- *North Airport Expressway (NAE).* On the southbound NAE (between SR 518 and South 170th Street), one additional lane (for a total of 4 lanes) is required by PAL 2, and a second additional lane (for a total of 5 lanes) is required by PAL 4. On the northbound NAE (north of the return-to-terminal exit), one additional lane (for a total of 4 lanes) is required by PAL 3. In all cases, it appears there is sufficient right-of-way to accommodate the additional lanes, though it may require that the exit to and entrance from the return-to-terminal ramp be reduced to one lane (volumes on the return-to-terminal ramp are sufficiently low that a single lane can accommodate volumes through PAL 4). South of South 170th Street, the southbound NAE will be realigned to follow the alignment of the northbound lanes and Sound Transit light-rail to enable future airfield expansion and roadway capacity/efficiency improvements. When realigned, the roadway should have sufficient width to allow for six lanes (the capacity required by PAL 4).

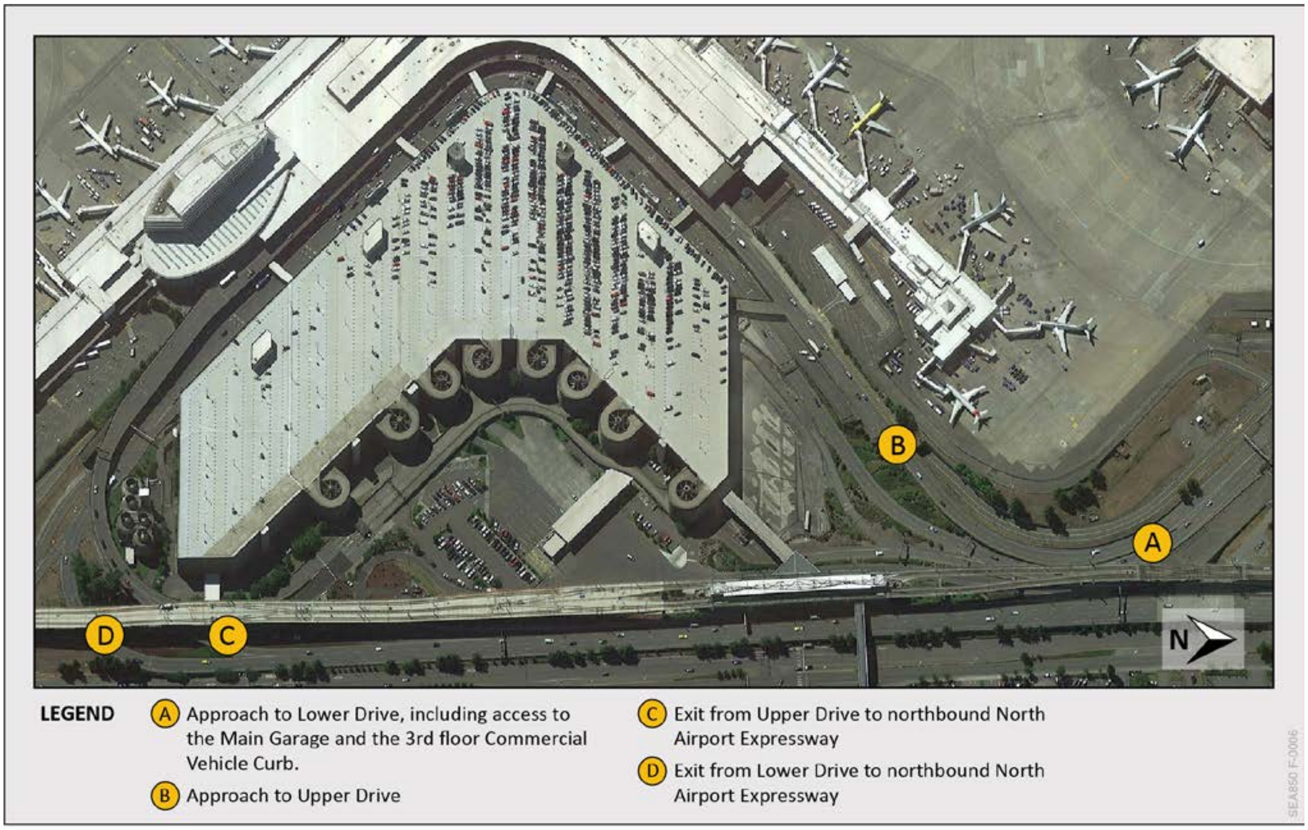
- *SR 518 ramps.* The Airport entrance roadway from westbound SR 518 requires one additional lane (for a total of 3 lanes) by PAL 2 and it appears there may be sufficient area to convert existing shoulder area to provide for a third lane, though the location of columns and bridge abutments supporting SR 518 may limit this opportunity. The Airport entrance roadway from eastbound SR 518 requires one additional lane (for a total of 2 lanes) by PAL 3, and there appears to be sufficient shoulder and adjacent area. The Airport exit roadway to eastbound SR 518 requires one additional lane (for a total of 3 lanes) by PAL 2 and there appears to be sufficient shoulder and adjacent area. The Airport exit roadway to westbound SR 518 requires no additional capacity by PAL 4. Each of these ramps, however, is predominately outside Airport property, is under control of the WSDOT, and widening would require coordination with the alignment and merge/diverge locations on SR 518. Therefore, any improvements to these ramps would require close coordination with the WSDOT.

- *South Access.* Current plans for the interim South Access roadway indicate one lane in each direction. Traffic volumes indicate two southbound lanes are required by PAL 2. For the South Airport Expressway (expected to open between PAL 3 and PAL 4), current plans indicate one lane in each direction. Traffic volumes indicate two lanes are required in each direction by PAL 4.

4.2.3 Terminal-area Circulation Roadways

As described in Technical Memorandum No. 5, Section 4.4.3, under a One-Terminal alternative, four terminal-area circulation roadways, identified on Figure 4-1, require additional capacity to accommodate PAL 4 activity. By PAL 4, it is estimated the roadways approaching the Upper Drive and Lower Drive will require 3 lanes and 5 lanes, respectively. Currently, these roadways provide 2 lanes each. The roadways exiting the Upper Drive and Lower Drive (for traffic bound for the North Airport Expressway) will require 2 lanes and 3 lanes, respectively. Currently, the Upper Drive exit provides 1 lane and the Lower Drive exit to the North Airport Expressway provides 2 lanes.

Figure 4-1
Terminal Area Circulation Roadways Requiring Greater Capacity
Seattle-Tacoma International Airport



Source: Inter*VISTAS* Inc., 2016.

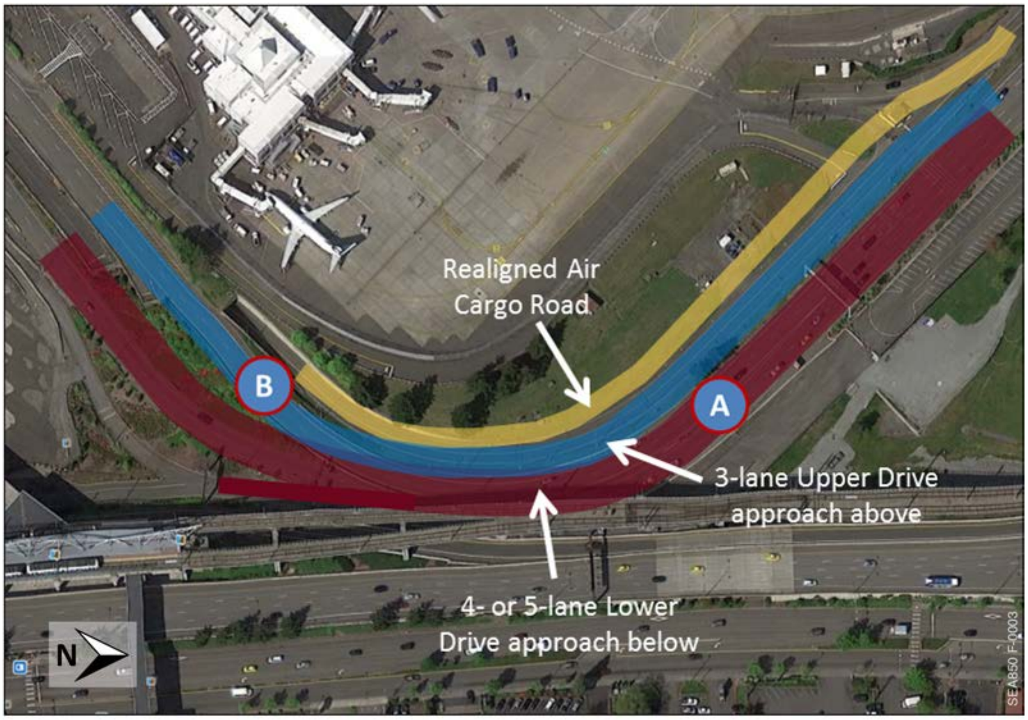
4.2.3.1 Approaches to Lower Drive and Upper Drive (Segments A and B)

Due to the narrow corridor occupied by the existing approaches to the Upper and Lower drives, alternatives must address both roadways (the corridor, which includes Air Cargo Road, is bounded on the west by the airfield and the east by the Sound Transit light-rail).

Figure 4-2 depicts the preferred alignment that provides 3 lanes for the approach to the Upper Drive and 5 lanes to the approach to the Lower Drive. As shown, the approach to the Upper Drive diverges from the approach to the Lower Drive and ramps up to achieve sufficient grade separation to partially cross above the approach to the Lower Drive. In addition, the impact area of the realignment would likely extend further north to allow the North Airport Expressway to transition from a narrower cross-section (4 lanes today, 6 lanes are needed by PAL 4) to 8 lanes.

Alternatively, if the Port were to consider accepting LOS D at the end of the planning period (PAL 4), the approach to the Lower Drive could be reduced to 4 lanes.

Figure 4-2
One-Terminal Concept – Preferred Roadway Alignment and Number of Lanes for Approach to Lower and Upper Drives
Seattle-Tacoma International Airport



Source: Inter*VISTAS* Inc., 2016.

4.2.3.2 Exit from Upper Drive to North Airport Expressway (Segment C)

Two lanes are required to provide LOS C or better on this roadway today and through PAL 4. Given the expected magnitude of the deficiency, adding a second lane is the preferred alternative to address the poor level-of-service. The existing structure appears to be approximately 22 feet wide, which would allow for two 10-foot lanes but with minimal allowance for shoulders and side rails.

4.2.3.3 Exit from Lower Drive to North Airport Expressway (Segment D)

Three lanes are required by PAL 3 to provide LOS C or better on this roadway. Though the deficiency could be addressed by shifting curbside demand to other facilities, this approach would deteriorate the level of service in the other facilities. Thus, adding a third lane can sufficiently address the poor level of service. The existing structure appears to be approximately 34 feet wide, which would allow for three 10-foot lanes but with minimal allowance for shoulders and side rails. Alternatively, if the approach is determined to be infeasible, road widening would help address level of service issues. However, if determined that LOS D in PAL 3 and PAL 4 is acceptable, this roadway could remain with two lanes.

Using VISSIM, a roadway microsimulation model, Port staff modeled the on-Airport access roadway system to determine the potential benefits of improvements described above. From this modeling, Port staff concluded

- Without improvements, the on-Airport roadway system will be gridlocked by PAL 2 (2024).
- The addition of one lane for approach to the lower drive and two separate lanes for the rental car buses would avoid the gridlock envisioned by PAL 2 (2024) without the additions.
- Unless more lanes are added to the approaches to the upper and lower drives and to the curbs, by PAL 4 (2034), approximately 30% of the projected demand by private vehicles cannot be accommodated. The Port did not use the simulation model to test the impact of the configuration depicted on Figure 4-2, but believes it would likely address the PAL 4 conditions as it would increase the number of lanes approaching the terminal from 5 (3 feeding the Lower Drive and 2 feeding the Upper Drive) to 8 (5 feeding the Lower Drive and 3 feeding the Upper Drive).

4.2.4 Curbside Roadways

Under a One-Terminal concept, alternatives are tightly linked to the terminal configurations developed to address terminal deficiencies. As discussed in Chapter 3, there are four general terminal concepts:

- **Concept 1:** Extend the Main Terminal to the north (Figure 3-7)
- **Concept 2 (Preferred):** Extend the Main Terminal ticketing level façade to the east along the entire terminal face (Figure 3-8)
- **Concept 3:** Extend the middle section of the Main Terminal to the east (cutting across the nose of the garage) (Figure 3-9)
- **Concept 4:** Extend the middle section of the Main Terminal to the east and provide a secure/non-secure automated people mover station in the garage (Figure 3-10)

The following sections describe the curbside roadway alternatives associated with the preferred terminal configuration (as described in Chapter 3, extending the Main Terminal ticketing level façade to the east along the entire face of the building is the preferred One-Terminal option [Concept 2]).

4.2.4.1 Operational Strategies

Four low-cost, operational strategies were identified to improve the curbside facilities and balance curbside demand with available capacity. All strategies are summarized in Table 4-1.

Table 4-1

Curbside Alternatives Applicable to All Terminal Concepts; Option 1—Operational Strategies

Seattle-Tacoma International Airport

Strategies	Reduce average dwell times to 90 seconds to 2 minutes (other airports of similar size have achieved average dwell times of 90 seconds for unscheduled vehicles picking up or dropping off passengers). Encourage use of parking (e.g., provide advanced warning of curbside congestion, reduce parking price for short durations). This strategy can be supported with options that provide direct entry to the Main Garage from the Lower Drive approach road, which would increase the attractiveness of the Main Garage for drivers picking up and dropping off airline passengers. Encourage use of alternate curbside (i.e., direct drivers to drop customers off on Lower Drive during Upper Drive busy periods and vice versa). Relocate airline sign locations to improve balance of demand along curb.
Purpose	Reduce demand for curbside facilities and/or improve the balance of demand with available capacity.
Compatibility with Terminal Configuration Options	Compatible with all three terminal configuration options.
Advantages	Low-cost strategies that improve curbside LOS.
Disadvantages	Operational strategies cannot, by themselves, achieve LOS goals.
Analysis	Upper Drive: Can achieve LOS D through reduced average dwell times (90 seconds) and optimized distribution of demand along the curbside. Lower Drive: Would operate at LOS F due to insufficient area for rental car shuttles and corresponding impact on the overall roadway. If rental car shuttles are relocated, the Lower Drive can achieve LOS D through reduced average dwell times (90 seconds) and optimized distribution of demand along the curbside.
Other Information	Can be combined with all other curbside alternatives. The Upper Drive can operate at LOS C or better through 54 MAP if: (1) the average dwell time reduces to 90 seconds *and* (2) 12% of drivers divert to other facilities (e.g., Lower Drive, Main Garage, other access modes). The Lower Drive can operate at LOS C or better through 54 MAP if (1) the average dwell time reduces to 90 seconds *and* (2) 22% of drivers divert to other facilities (e.g., Upper Drive and Main Garage, other access modes).

Source: Inter*VISTAS*, 2016.

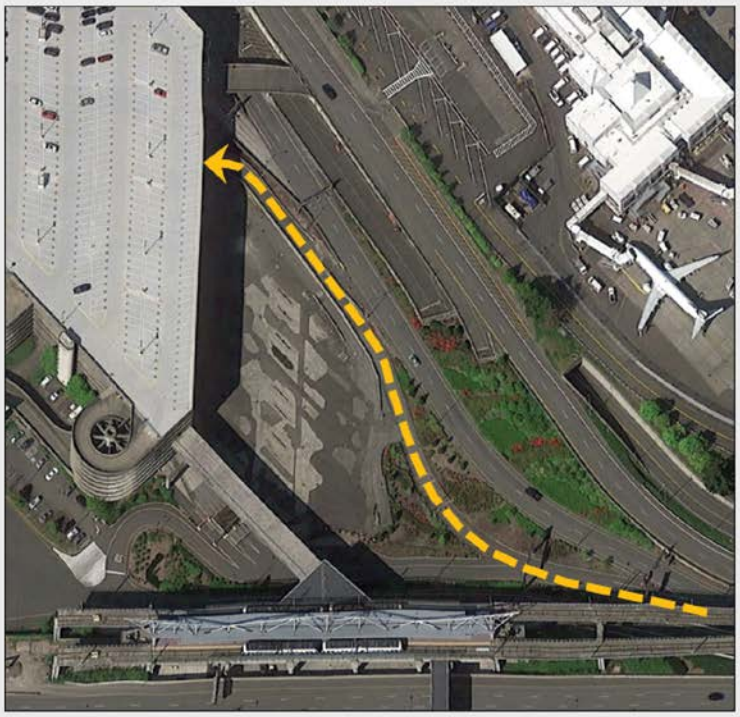
Provide direct access to and from Level 2 of the Main Garage

Additionally, by providing direct access from the roadway to the Main Garage, curbside demand can be reduced. The elements of this strategy are summarized in Figure 4-3.

Figure 4-3

Curbside Alternatives Applicable to All Terminal Concepts; Option 2—Provide Direct Access to and from Level 2 of Main Garage

Seattle-Tacoma International Airport



Strategies	Provide direct access from entry roadway to Level 2 of the Main Garage using ramp formerly used by rental cars. Use former rental car exit roadway from Level 2 to reach North Airport Expressway. Allocate portion (or all) of Level 2 for short-duration parking (i.e., 4 hours and less). *Note: this alternative could be implemented under either a One- or a Two-Terminal scenario.*
Purpose	Improve attractiveness of parking in the Main Garage for drivers picking up and dropping off airline passengers.
Advantages	Limited reconfiguration required, drivers avoid helices, and increases quantity of reliably-available close-in parking spaces for short-duration parking customers.
Disadvantages	Eastern spaces on Level 2 are much less desirable (but could be incorporated into the General Parking area). Does not provide curbside-like facility.
Analysis	Would decrease traffic volumes using Upper and Lower drives, but magnitude of impact is unknown.

Source: Inter*VISTAS* Inc., 2016.

4.2.4.2 Curbside Options, Terminal Concept 2 (Preferred)

As described in Chapter 3, and depicted on Figure 3-9, the preferred One-Terminal development plan consists of the following elements:

- Remove portions of the upper levels of the west section of the Main Garage.
- Relocate the Upper Drive to Level 5 of the Main Garage
- Relocate the existing pedestrian bridges to Level 5 of the Main Garage
- Move the ticketing level façade to the east to align with the façade of the baggage claim level
- Raise the Lower Drive to match the floor height of baggage claim

Three curbside configurations were developed to match with this terminal concept:

1. Develop multiple curb lanes on level 5 of the garage (removing sections of level 6 – 8 located above the curb lanes), and raise the Lower Drive.
2. Same as above, but develop additional pedestrian bridges spanning above the new curbside lanes (to allow garage customers a grade-separated crossing to reach the pedestrian bridges connecting to the terminal).
3. Develop rental car shuttle roadway on level 6 of the garage (removing sections of levels 7 – 8 located above the new roadway), relocate the Upper Drive into level 5 of the garage (overheight vehicles would be directed to use the Lower Drive), and raise the Lower Drive.

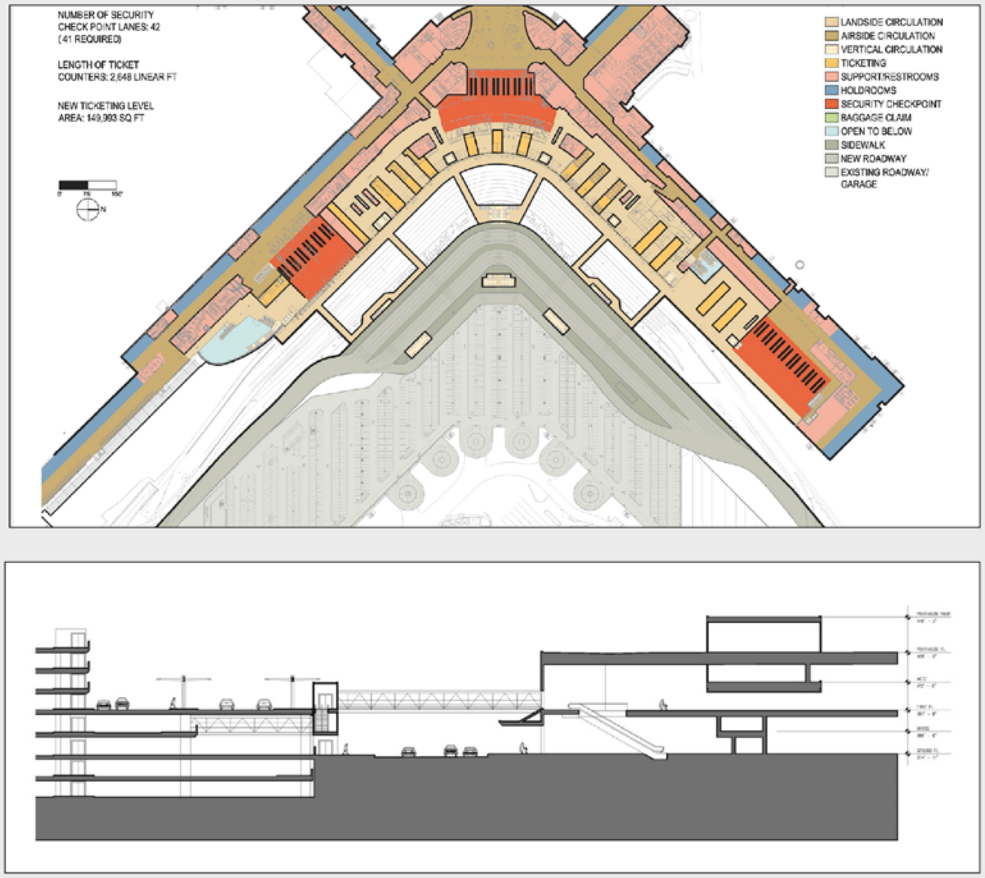
Figure 4-4 depicts the first of the three options described above. Figure 4-5 depicts the second option. The only difference between the second option and that depicted on Figure 4-4 is the additional pedestrian bridge connecting the garage elevator cores to new cores located on the west side of the garage. Figure 4-6 depicts the third curbside option.

As noted on Figure 4-4, there is uncertainty regarding the use of portions of the Main Garage for curbside and which building code would then apply to the facility. If the Main Garage continues to be considered a “garage,” it would be subject to the Universal Building Code. If it becomes a “roadway,” it would be subject to AASTHO requirements. Another consideration is whether the curbside section of the Main Garage would be considered an “essential” facility for emergency response in the event of an earthquake. Structurally, the Main Garage may not be able to accommodate the loads required to satisfy that requirement.

Figure 4-4

Curbside Alternatives Applicable to Terminal Concept 2 (Preferred); Option 1—Develop Multiple Curb Lanes on Level 5 of Garage; Remove Garage Levels 6 – 8 above Curb Lanes; Raise Lower Drive

Seattle-Tacoma International Airport



Strategies	Remove portions of Levels 6 through 8 on the west side of the Main Garage. Develop curbside facilities on Level 5 of the Main Garage. Develop new elevator cores on the east side of the garage connecting Levels 3 through 5.
Purpose	Provide increased drop-off curbside capacity. Replace curbside capacity lost if terminal configuration displaces Upper Drive; meet curbside length and roadway capacity requirements; provide capacity for Rental Car Facility buses. Remove pedestrian crossings from commercial vehicle lanes.
Advantages	Can achieve Upper Drive LOS goals; provides capacity to relocate Rental Car Facility buses, which improves Lower Drive LOS; allows relocation of terminal window wall.
Disadvantages	Garage may not structurally support concept [currently in review], loss of parking capacity (approximately 3,000 spaces). Structural analysis contingent on determination of (a) whether garage would be subject to Universal Building Code (as a garage) versus AASHTO requirements (as a roadway) and (b) whether the garage would qualify as an 'essential' facility for purposes of emergency response following an earthquake.
Analysis	Enplaning curb: can achieve LOS C Lower Drive: can achieve LOS D if Rental Car Facility buses are relocated to new curbside area Provides same or better conditions for same or lower cost than other options. *Preferred option.*

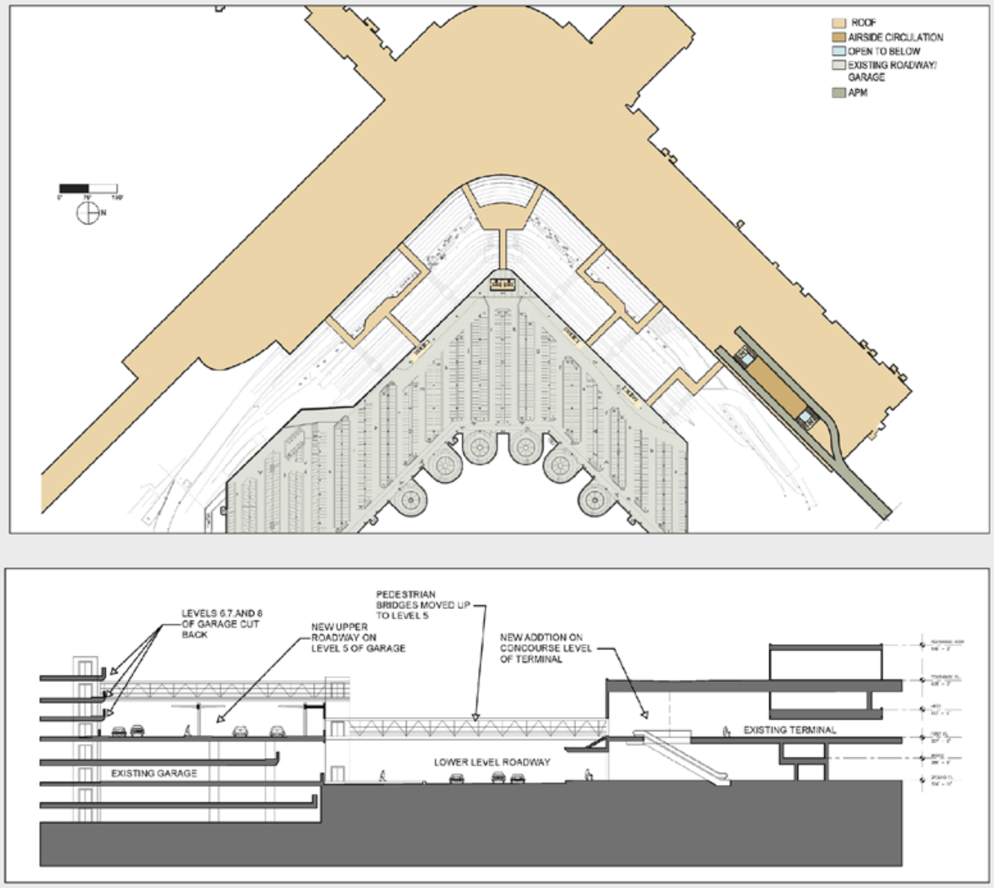
SEA862 F-0001

Source: Corgan Associates, 2015.

Figure 4-5

Curbside Alternatives Applicable to Terminal Concept 2 (Preferred); Option 2—Option 1 Plus Additional Pedestrian Bridges Across New Curb Lanes

Seattle-Tacoma International Airport



Strategies	Remove portions of Levels 6 through 8 on the west side of the Main Garage. Develop curbside facilities on Level 5 of the Main Garage. Develop new elevator cores on the east side of the garage connecting Levels 3 through 8. Provide new pedestrian bridges connecting interior garage elevators to new elevators on east side of garage.
Purpose	Provide increased drop-off curbside capacity. Replace curbside capacity lost if terminal configuration displaces Upper Drive; meet curbside length and roadway capacity requirements; provide capacity for Rental Car Facility buses. Remove pedestrian crossings from commercial vehicle lanes. Reduce pedestrian crossings of new curbside roadways.
Advantages	Can achieve Upper Drive LOS goals; provides capacity to relocate Rental Car Facility buses, which improves Lower Drive LOS; allows relocation of terminal window wall.
Disadvantages	Garage may not structurally support concept [currently in review], loss of parking capacity (approximately 3,000 spaces). Structural analysis contingent on determination of (1) whether garage would be subject to Universal Building Code (as a garage) versus AASHTO requirements (as a roadway) and (2) whether the garage would qualify as an “essential” facility for purposes of emergency response following an earthquake.
Analysis	Provides same traffic pros and cons as option depicted on Figure 4-4. Pedestrian path provided by additional (Level 7) bridges is already provided on Level 4, so desired pedestrian grade separation can be achieved in a different manner. *Not preferred option.*

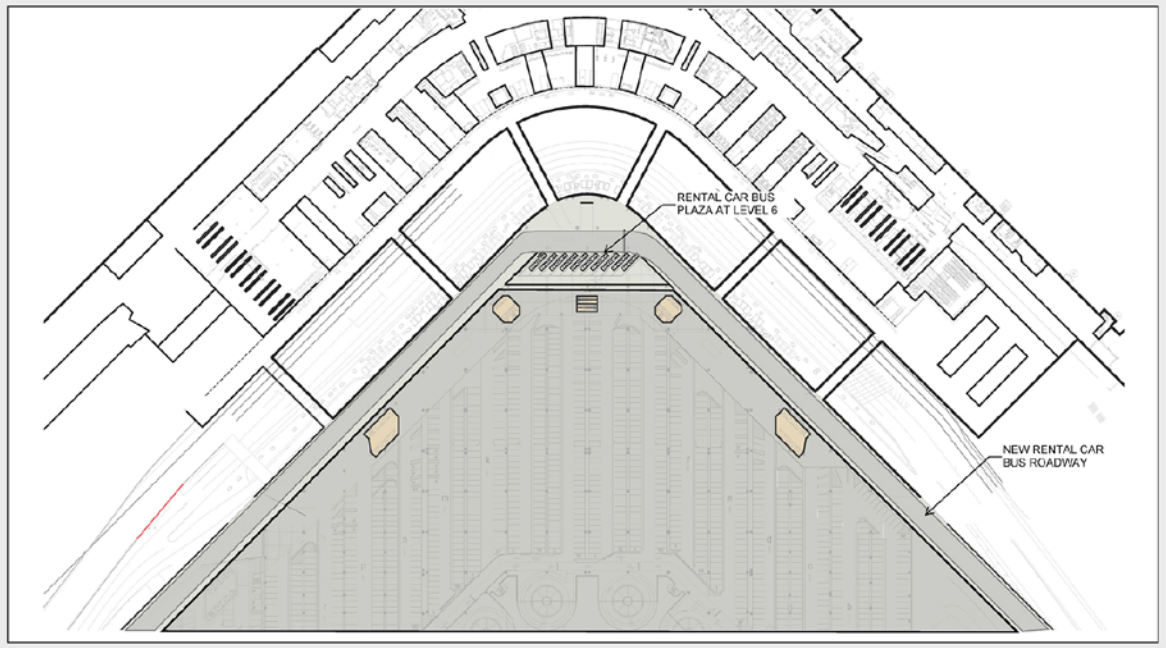
SEA862 F-0003

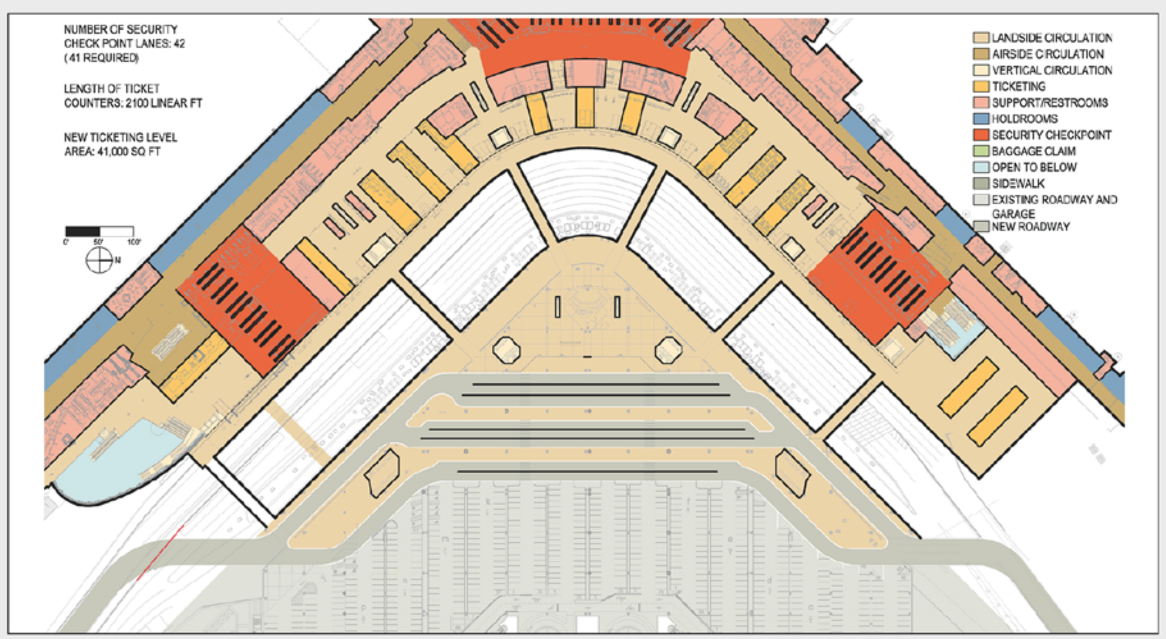
Source: Corgan Associates, 2015.

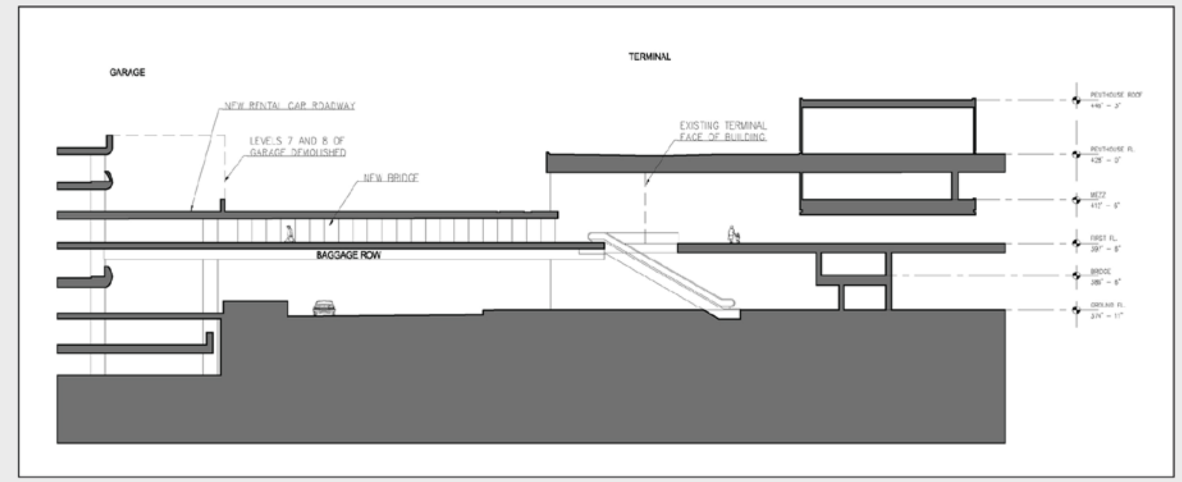
Figure 4-6

Curbside Alternatives Applicable to Preferred Terminal Concept 2 (Preferred); Option 3—Develop Rental Car Shuttle Roadway on Level 6 of Garage; Remove Garage Levels 7 and 8 above New Roadway; Raise Lower Drive

Seattle-Tacoma International Airport







Strategies	Remove portions of Levels 7 through 8 on the west side of the Main Garage. Develop rental car shuttle bus parking area on level 6 and public curbside facilities on Level 5 of the Main Garage. Develop new elevator cores on the east side of the garage connecting Levels 3 through 8.
Purpose	Provide increased drop-off curbside capacity. Replace curbside capacity lost if terminal configuration displaces Upper Drive; meet curbside length and roadway capacity requirements; provide capacity for Rental Car Facility buses.
Advantages	Can improve conditions on drop-off curbs, but may not achieve LOS goals; provides capacity to relocate Rental Car Facility buses, which improves Lower Drive LOS; allows relocation of terminal window wall.
Disadvantages	Level 5 curbside does not allow overheight private vehicles. Curb configuration within garage will need to accommodate numerous structural columns and 3-lane curb roadway configuration may not provide desired capacity. Garage may not structurally support concept, loss of parking capacity (several thousand spaces). Structural analysis contingent on determination of (1) whether garage would be subject to Universal Building Code (as a garage) versus AASHTO requirements (as a roadway) and (2) whether the garage would qualify as an "essential" facility for purposes of emergency response following an earthquake.
Analysis	May be as disruptive and costly as first option (Figure 4-4), but does not provide same capacity benefits. *Not preferred option.*

SEA802 F-0004

Source: Corgan Associates, 2015.

As described in the above figures, the curbside configuration depicted on Figure 4-4 is the preferred option for this terminal development scenario.

4.2.5 Commercial Vehicles

Under the One-Terminal concept, additional capacity is needed for courtesy vehicles (by PAL 4), charter buses (By PAL 2), and the taxicab feeder queue (by PAL 3).

Through PAL 3, courtesy vehicles can be accommodated within the existing capacity by relocating the pickup location for airline crew vans (which need three spaces by PAL 4) and the Downtown shuttle (which needs one space through PAL 4) into extra loading stalls currently allocated to the shared-ride vans (which have eight spaces and are expected to need four through PAL 4).

By PAL 4, courtesy vehicles would require two additional spaces. This additional capacity would be obtained through the implementation of the curbside expansion concept described above on Figure 4-4, which would create new vertical circulation cores on the west side of the courtesy vehicles to allow pedestrians to transfer to and from the pedestrian bridges without crossing the courtesy vehicle roadway. This would allow the removal of the existing pedestrian crosswalks from the courtesy vehicle roadway, which would provide the extra curb length needed for the two additional spaces.

As a result of the IAF, the charter bus spaces in the South Ground Transportation (GT) Lot were removed. As of mid-2017, charter buses are accommodated in the North GT Lot and the area north of the garage formerly occupied by rental car services facilities (NE GT Lot). With the planned construction of a facility to accommodate departing passenger holding and busing for hardstand operations in 2018 (Concourse D Hardstand Holdroom) at the North GT Lot site, charter bus activity will be relocated to the NE GT Lot.

4.2.6 Public Transit Facilities

Public Transit Bus Loading/Unloading Areas

These vehicles currently pick up and drop off passengers on the south end of the Lower Drive. Service levels could be improved by dropping passengers off on the Upper Drive and/or providing a stop at the north end of the terminal. Stopping on both curbside levels would increase each route's length and passenger travel time as buses exiting the Upper (or Lower) Drive would need to travel back to South 170^{th} Street (adding 2 miles to the route) or South 160^{th} Street (adding 3 miles to the route) to reach the other curbside. Introducing an additional stop at the north end of the terminal could increase congestion and bus travel time. Currently, buses on the Lower Drive can stay in the far left lane for much of the curb length before transitioning over to the curb lane near the south end of the terminal. A north end stop would require buses to either travel the length of the drive using the busier curbside lanes or maneuver to the far left lane across all private vehicles entering the curbside.

Additional space dedicated to public transit buses would reduce the space available for the Rental Car Facility (RCF) shuttle and/or private vehicles, which in turn would increase roadway congestion and create additional delays for buses. Lastly, the existing Main Terminal bus stop is close to the building, adjacent to the southern-most baggage claim devices. Thus, the One-Terminal concept retains the existing Main Terminal public transit stop comprised of two loading spaces (120 linear feet). While hourly volumes are limited and may not justify the existing two spaces, the One-Terminal concept retains the existing public transit stop length to account for the occasional instance of two buses arriving simultaneously.

Light Rail Loading/Unloading Areas

The location of the existing light rail Airport station requires 1,100- to 1,800-foot unassisted walks to and from the Main Terminal. To mitigate this walking distance, the One-Terminal concept includes providing moving walkways in the corridor connecting the station to the Main Terminal. If subsequent refined planning efforts determine the moving walkways are not feasible within the garage, the Port could continue operating the existing electric shuttle service between the station and the northernmost pedestrian bridge entering the Main Terminal.

Strategies to Increase Use of Public Transit

This section presents six options intended to encourage use of public transportation modes by airline passengers. For purposes of this section, "public transportation" includes shared-ride vans, scheduled airporters, and public transit services. These are access modes that (1) carry multiple passengers or groups of passengers that otherwise would not be traveling together (unlike charter buses) and (2) provide transportation that is not provided as part of another service (such as an Airport-area hotel/motel or off-Airport parking facility). Of these options, only one (Option 5) is within the exclusive control of the Port. All other options rely on actions of the transportation provider.

Strategies to Increase Use of Public Transit; Option 1–Reduce Fares

Strategies	Reduce fare paid by passengers to travel to and from the Airport.
Purpose	Reduce airline passenger use of single-occupant and single-party access modes by reducing the cost of alternatives.
Advantages	Reduces an airline passenger's cost of transportation to and from the Airport, the number of vehicle trips on Airport roadways, and regional vehicle-miles-travelled.
Disadvantages	All modes: may require that the Port provide funds to subsidize the reduced fares. Shared-ride vans and scheduled airporters: requires modifications to existing business arrangements; policy would need to be consistent with State rules and regulations governing such transportation services. Public transit: limited opportunity to change behavior because fares are relatively low.
Analysis	All modes: passengers that switch to one of these modes due to changes in fare may already be using one of the other modes, which would reduce the potential impact of the action. Public transit: fare reductions alone are expected to have minimal impact on airline passenger mode choice. Passengers also consider other service aspects (such as service area, service hours, frequency, and travel time), which may have a greater influence on their mode choice decision.

Strategies to Increase Use of Public Transit; Option 2—Increase Service Area

Strategies	Encourage, or sponsor, transportation operators to expand the geographic areas they serve.
Purpose	Reduce airline passenger use of single-occupant and single-party access modes by increasing the proportion of airline passengers in the region that have public transportation as an option for Airport access.
Advantages	Increases the number of airline passengers who could consider using public transportation for Airport access. For switches to public transportation from single-party modes, reduces the number of vehicle trips on Airport roadways, and reduces regional vehicle-miles-travelled.
Disadvantages	All modes: may require that the Port provide funds to subsidize the increased operating costs potentially associated with larger service areas. Shared-ride vans and scheduled airporters: may require modifications to existing business arrangements; policy would need to be consistent with State rules and regulations governing such transportation services.
Analysis	All modes: passengers that switch to one of these modes due to increased service area may already be using one of the other modes, reducing the potential impact of the action. Public transit: increases in service area would likely need to be combined with reduced travel times to be most effective.

Strategies to Increase Use of Public Transit; Option 3—Increase Service Frequency and Hours

Strategies	Encourage, or sponsor, transportation operators to provide additional service hours and/or increased number of daily trips.
Purpose	Reduce airline passenger use of single-occupant and single-party access modes by (1) ensuring that passengers are offered public transportation services capable of delivering them for early morning departures and picking them up at the Airport after late night arrivals and (2) reducing wait times between subsequent scheduled trips.
Advantages	Increases the number of airline passengers who could consider using public transportation for Airport access in the event such services are not already capable of providing early morning and late night access. Increases the attractiveness of such services by providing additional departure times throughout the day. For those that choose to switch to public transportation from single-party modes, reduces the number of vehicle trips on Airport roadways, and reduces regional vehicle-miles-travelled.
Disadvantages	All modes: may require that the Port provide funds to subsidize the increased operating costs potentially associated with increased service hours and trip frequencies. Shared-ride vans and scheduled airporters: may require modifications to existing business arrangements; policy would need to be consistent with State rules and regulations governing such transportation services.
Analysis	All modes: passengers who switch to one of these modes due to increased service hours and frequencies may already be using one of the other modes, which would reduce the potential impact of the action. Public transit: increases in service hours and frequencies would likely need to be combined with reduced travel times to be most effective.

Strategies to Increase Use of Public Transit; Option 4—Reduce Travel Times

Strategies	Encourage, or sponsor, transportation operators to reduce the travel time for Airport-related trips. For shared-ride vans, this could mean reducing the number enroute stops. For public transit, this could mean providing express routes between the Airport and key regional population centers. This would likely not apply to scheduled airporters as most serving the Airport already operate on an express basis.
Purpose	Reduce airline passenger use of single-occupant and single-party access modes by providing comparable travel times using public transportation modes.
Advantages	Increases the attractiveness of public transportation services by providing travel times comparable with single-party vehicles. For those that choose to switch to public transportation from single-party modes, reduces the number of vehicle trips on Airport roadways, and reduces regional vehicle-miles-travelled.
Disadvantages	All modes: may require that the Port provide funds to subsidize the increased operating costs potentially associated with express routes. Shared-ride vans and scheduled airporters: may require modifications to existing business arrangements; policy would need to be consistent with State rules and regulations governing such transportation services.
Analysis	Has the highest potential impact of encouraging use of public transportation modes. Such services, when combined with parking, high frequencies, and service hours that meet the schedule needs of airline passengers, can be successful in attracting passengers from single-party modes. However, as evidenced by the experiences of similar services at Los Angeles International Airport and Boston-Logan International Airport, services may require subsidies to provide an attractive product at a price acceptable to airline passengers.

Strategies to Increase Use of Public Transit; Option 5—Provide Attractive Loading and Unloading

Strategies	Provide pickup and drop-off locations at the Airport that are as (or more) convenient and attractive for airline passengers as those provided single-party modes.
Purpose	Reduce airline passenger use of single-occupant and single-party access modes increasing the attractiveness of public transportation modes.
Advantages	Increases the attractiveness of public transportation services by providing reduced walking distances and comfortable and attractive waiting areas for passengers.
Disadvantages	If attractive loading/unloading areas require reductions in the curbside area available for single-party modes, this alternative would further degrade already-poor curbside levels-of-service, which would in turn impact access to and from the loading/unloading areas.
Analysis	Shared-ride vans and scheduled airporters: these vehicles currently drop off passengers on the Upper Drive, so the experience is equivalent to that of a single-party vehicle passenger. These vehicles pick up passengers on the third floor of the Main Garage or in the South GT Lot, which means passengers have a longer walk than to the Lower Drive curbside, but those vehicles are less likely to be impacted by Lower Drive congestion. Furthermore, passengers waiting for vehicles using the South GT Lot have an attractive, comfortable waiting area in the GML Arrivals Hall. Public transit: these vehicles currently pick up and drop off passengers on the south end of the Lower Drive. While service levels could be improved by dropping passengers off on the Upper Drive, such operation would increase each route's length and passenger travel time. Geometric requirements of the public transit vehicles and competing demands for the Lower Drive (e.g., RCF shuttles) limit the alternative locations that could be considered for these services.

Strategies to Increase Use of Public Transit; Option 6—Increase Public Parking Prices

Strategies	Increase Main Garage prices.
Purpose	Reduce airline passenger use of single-occupant and single-party access modes by decreasing the attractiveness of the Main Garage.
Advantages	Increases the relative attractiveness of public transportation services by increasing the cost of another access option. Potential slight increase in public parking revenues.
Disadvantages	Main Garage customers are not likely to consider shared-ride vans, schedule airports, or public transit as immediate alternatives if Main Garage prices increase. Rather, these customers, who are predominately time-sensitive, would be more likely to switch to taxicabs, limousines, TNCs, or off-Airport parking.
Analysis	All modes: while increasing parking prices would discourage use of the Main Garage, those customers would likely be unwilling to switch to public transit modes as they would likely be willing to pay for modes providing shorter travel-times and not reliant on schedules.

Given the operational focus of these strategies and limited magnitude of likely impact on passenger mode choice, no evaluation is provided. However, as the terminal planning components of the Master Plan are refined during advanced planning, public transportation pickup and drop-off facilities will be incorporated with a goal of (1) providing a level-of-service comparable with single-party modes while (2) recognizing the geometric, operational, and business requirements and goals of the transportation providers.

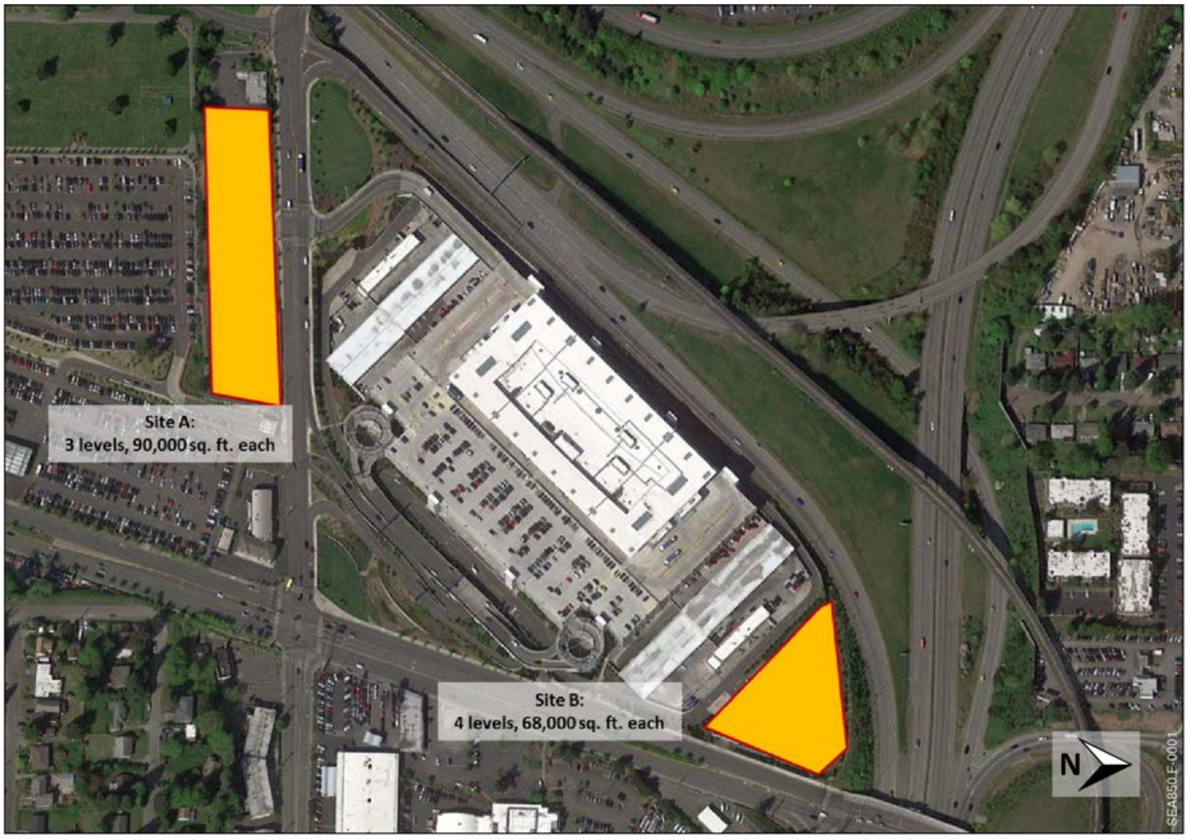
4.2.7 Public Parking

While existing on-Airport public parking facilities, the Main Garage and Doug Fox Lot, have sufficient capacity to meet requirements through the planning period, the preferred One-Terminal concept terminal and curbside plan will displace approximately 3,000 Main Garage spaces. To provide this capacity, a parking structure would be developed at the Doug Fox Lot providing at least 4,600 spaces (the existing Doug Fox Lot capacity plus the displaced 3,000 Main Garage spaces).

4.2.8 Rental Car Facility

Figure 4-7 depicts two sites near the existing rental car facility that could be developed to provide the additional 270,000 square feet needed by 66 MAP. It is assumed that these areas would be used predominately for vehicle storage and as such, would not be accessible to the public.

Figure 4-7
Alternative Sites to Accommodate Supplemental Rental Car Facilities
Seattle-Tacoma International Airport



Source: Inter*VISTAS* Inc., 2016.

Of these sites, Site A is on existing Port property and is currently used as a commercial vehicle hold lot (this use could be incorporated a structure shared with rental cars). Site A is also on a hill, so a structure would likely not consist of 3 flat levels. Site B is not currently owned by the Port but is used for rental car vehicle storage associated with the Rental Car Facility.

4.2.9 Rental Car Shuttle/Pre-security APM

Rental car shuttles are expected to require up to 15 parking positions by PAL 4. The preferred alternative is to develop an APM connecting the Main Terminal to the Rental Car Facility, but, as described in Section 4.2.4, the preferred One-Terminal curbside alternative provides sufficient capacity for the rental car shuttle bus to operate from new curbside located on Level 5 of the Main Garage.

Section 4.3.5 describes the alternatives and recommendation for a non-secure APM under a Two-Terminal scenario, with the APM connecting the Main Terminal, the new North Terminal and the remote rental car facility. Under a One-Terminal scenario, the APM alignment options would be the same as described on Figure 4-16 but the system would either omit the North Terminal station or have a station serving the parking customers using the Doug Fox Lot. It is assumed that either of those variants would impact each APM alternative equally, and therefore not change the evaluation and recommendation.

4.2.10 Non-motorized Access

Options for pedestrians and bicyclists to access the Airport terminal are limited. The objective is to ensure that, during advanced planning and design, alternatives related to future landside facilities consider maintaining and improving non-motorized access.

4.3 Two-Terminal Concept

The Two-Terminal concept assumes that by PAL 3 (2029) passenger-processing will occur at both the Main Terminal and a North Terminal located on the site of the existing Doug Fox Lot. Accordingly, all curbside, close-in parking, and commercial vehicle pickup/drop-off facilities are also assumed to be located at both the Main Terminal and North Terminal. This section is organized by topic as follows:

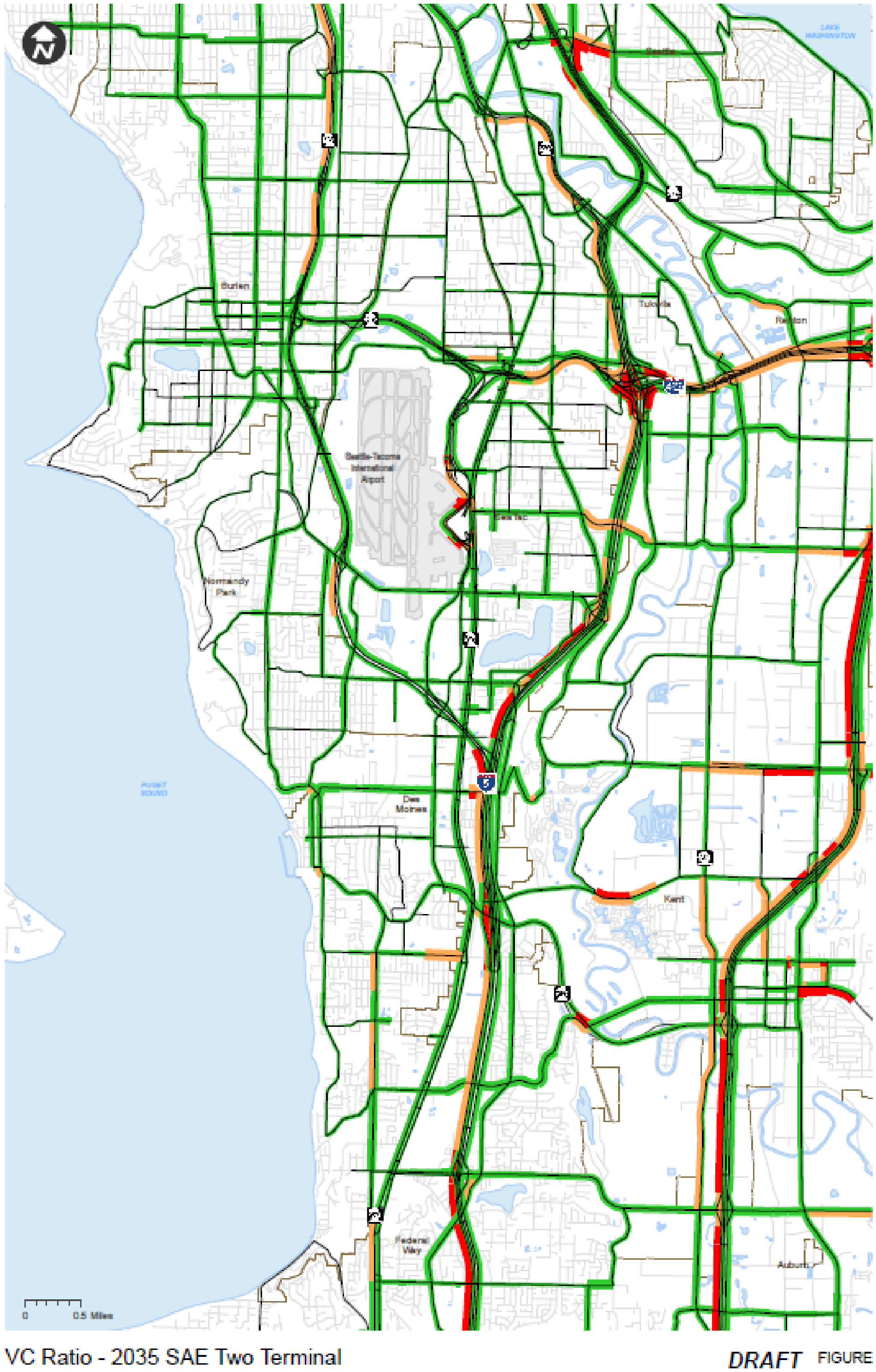
- Off-Airport Access Roadways
- On-Airport Access Roadways
- Elements specific to the North Terminal
- Elements specific to the Main Terminal
- The APM connecting both terminals to the ConRAC
- Remote facilities providing employee parking, commercial ground transportation hold capacity, and the cell phone lot

4.3.1 Two-Terminal Concept – Off-Airport Access Roadways

Under a Two-Terminal scenario, use of the regional roadways is slightly different from a One-Terminal scenario in that 82% of vehicles are expected to enter and exit the Airport from the north (compared with 77% under a One-Terminal scenario). This is because the proximity of the North Terminal to SR 518 is expected to attract some drivers who, were they using the Main Terminal, would use the future South Access facilities.

Figure 4-8 depicts the regional model V/C ratios for key roadways in the Airport vicinity under a Two-Terminal scenario. As under the One-Terminal scenario, in addition to further degradation of conditions on the regional facilities experiencing congestion in 2010 (such as the I-5/I-405 interchange and southbound I-5), SR 509 and SR 518 are expected to experience V/Cs exceeding 0.8 (representing LOS E). However, conditions on I-405 are expected to improve.

Figure 4-8
2035 Regional Traffic Conditions, Two-Terminal Scenario
Seattle-Tacoma International Airport



Source: Port of Seattle, 2017.

Comments related to addressing future off-airport access roadway conditions are identical as those for a One-Terminal scenario and are provided in Section 4.2.1.

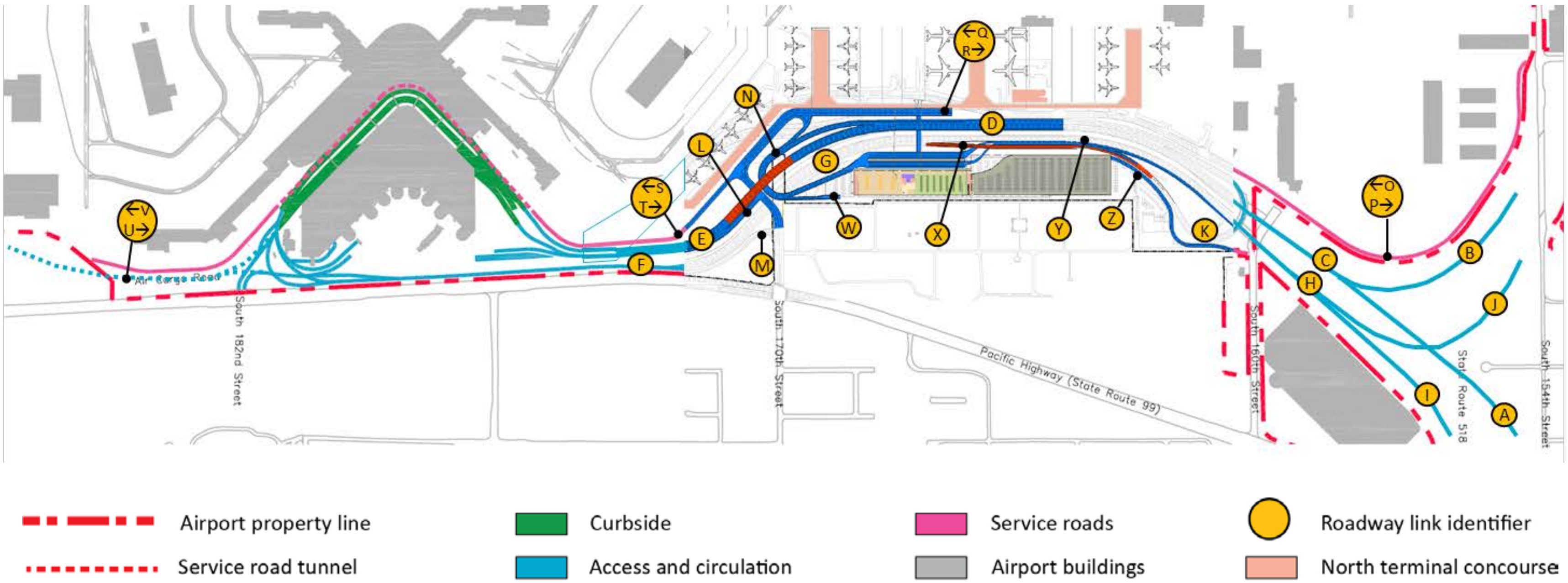
4.3.2 Two-Terminal Concept – On-Airport Access Roadways

Figure 4-9 depicts key on-Airport access roadways under a Two-Terminal scenario. Table 4-2 presents anticipated peak hour volumes on key network links, as provided by Port staff (using the regional traffic model) for PAL 4. PAL 3 volumes are not shown because the regional model was only used to evaluate a Two-Terminal scenario under PAL 4 conditions. PAL 4 conditions cannot be used to estimate PAL 3 volumes because between PAL 3 and PAL 4, the interim South Access roadway is replaced by the South Airport Expressway. As shown in Table 4-2, additional capacity is required by PAL 4 on the southbound North Airport Expressway, the northbound direction of the interim South Access roadway, and on both ramps connecting to/from SR 518 to the east. However, deficiencies are typically less severe than under the One-Terminal scenario due to the amount of traffic shifted from the Main Terminal to the North Terminal.

Figure 4-9

On-Airport Access Roadways, Two-Terminal Scenario

Seattle-Tacoma International Airport



Note: Roadway link identifiers are keyed to data presented in Table 4-1.

Source: Inter*VISTAS*, from background map provided by Shen Consulting.

Table 4-2

PAL 4 On-Airport Access Roadway Volumes and Lanes Required to Achieve Los C or Better (PALS 3 and 4)

Seattle-Tacoma International Airport

Link identifier	Facility	Assumed speed (mph)	Lanes	Capacity *(a)*	Volume *(b)*	Volume/ capacity ratio	Level of service *(c)*	Lanes to achieve LOS C or better
A	Ramp from SR 518, westbound	50	2	3,240	2,354	0.73	D	3
B	Ramp from SR 518, eastbound	40	1	1,410	680	0.48	C	1
C	North Airport Expressway, southbound, prior to return-to-terminal ramp	40	3	4,230	3,035	0.72	D	4
D	North Airport Expressway, southbound, after return-to-terminal ramp	40	3	4,230	3,616	0.85	E	5
E	Terminal area entrance	30	4	4,680	2,889	0.62	D *(e)*	4
F	Terminal area exit to north	40	4	5,640	3,017	0.53	C	4
G	North Airport Expressway, northbound, prior to North Terminal exit	40	5	7,050	2,275	0.32	B	5
H	North Airport Expressway, northbound, after return-to-terminal ramp	40	3	4,230	3,070	0.73	D	4
I	Ramp to SR 518, eastbound	50	2	3,240	2,607	0.80	E	3
J	Ramp to SR 518, westbound	45	2	3,060	750	0.25	A	2
K	Return-to-terminal ramp	25	2	2,020	343	0.17	A	2
L	On-ramp from South 170th Street	25	1	1,000	520	0.52	C	2
M	Northbound exit to South 170th Street	25	1	1,000	742	0.74	D	2
N	North Terminal entrance	25	2	2,260	1,247	0.55	C	2
O	Air Cargo Road, southbound, north of South 160th Street	35	2	2,400	423	0.18	A *(d)*	2
P	Air Cargo Road, northbound, north of South 160th Street	35	2	2,400	276	0.11	A *(d)*	2
Q	Air Cargo Road, southbound, north of South 170th Street	35	1	1,200	147	0.12	A *(d)*	1
R	Air Cargo Road, northbound, north of South 170th Street	35	1	1,200	173	0.14	A *(d)*	1
S	Air Cargo Road, southbound, south of South 170th Street	35	1	1,200	-	0.00	A *(d)*	1
T	Air Cargo Road, northbound, south of South 170th Street	35	1	1,200	-	0.00	A *(d)*	1
U	South Airport Expressway, northbound	40	1	1,410	963	0.68	D *(d)*	2
V	South Airport Expressway, southbound	40	1	1,410	864	0.61	D *(d, e)*	1
W	North Terminal garage entrance	25	1	1,010	126	0.13	A	1
X	Main Terminal traffic bypass to return-to-terminal ramp	40	1	1,410	196	0.14	A	1
Y	North Airport Expressway, northbound, prior to return-to-terminal ramp	40	4	5,640	3,413	0.61	D	4
Z	North Terminal garage exit to South 160th Street	25	1	1,010	126	0.13	A	1

(a) See Technical Memorandum No. 5, Table 4-8.
(b) Based on volumes provided by the Port of Seattle.
(c) Based on Airport Cooperative Research Program (ACRP) Report 40, Table 4-1.
(d) Traffic conditions also impacted by intersections and/or truck turning movements.

Source: Inter*VISTAS*, from traffic volume data provided by the Port of Seattle, 2017.

Under a Two-Terminal scenario, additional capacity is required as follows to achieve LOS C or better during the design hour by PAL 4. All improvements recommended for a Two Terminal scenario through PAL 3 are based on results of the One-Terminal scenario:

- *North Airport Expressway (NAE).* On the southbound NAE (between SR 518 and South 170th Street), one additional lane (for a total of 4 lanes) is required by PAL 2 (the 5th lane required by PAL 4 under One-Terminal scenario would not be needed under a Two-Terminal scenario). On the northbound NAE (north of the return-to-terminal exit), one additional lane (for a total of 4 lanes) is required by PAL 3. In all cases, it appears there is sufficient right-of-way to accommodate the additional lanes, though it may require that the exit to and entrance from the return-to-terminal ramp be reduced to one lane (volumes on the return-to-terminal ramp are sufficiently low that a single lane can accommodate volumes through PAL 4). South of South 170th Street, the southbound NAE will be realigned to follow the alignment of the northbound lanes and SoundTransit light-rail to enable future airfield expansion and roadway capacity/efficiency improvements. When realigned, the roadway should have sufficient width to allow for four lanes (the capacity required by PAL 4).

- *SR 518 ramps.* The Airport entrance roadway from westbound SR 518 requires one additional lane (for a total of 3 lanes) by PAL 2 and it appears there may be sufficient area to convert existing shoulder area to provide for a third lane, though the location of columns and bridge abutments supporting SR 518 may limit this opportunity. The Airport entrance roadway from eastbound SR 518 requires one additional lane (for a total of 2 lanes) by PAL 3, and there appears to be sufficient shoulder and adjacent area. The Airport exit roadway to eastbound SR 518 requires one additional lane (for a total of 3 lanes) by PAL 2 and there appears to be sufficient shoulder and adjacent area. The Airport exit roadway to westbound SR 518 requires no additional capacity by PAL 4. Each of these ramps, however, is predominately outside Airport property, is under control of the WSDOT, and widening would require coordination with the alignment and merge/diverge locations on SR 518. Therefore, any improvements to these ramps would require close coordination with the WSDOT.

- *South Access.* Current plans for the interim South Access roadway indicate one lane in each direction. Traffic volumes indicate two southbound lanes are required by PAL 2. For the South Airport Expressway (expected to open between PAL 3 and PAL 4), current plans indicate one lane in each direction. Traffic volumes indicate two lanes in the northbound direction are required by PAL 4.

4.3.3 Two-Terminal Concept – North Terminal

This concept assumes that by PAL 3, a second passenger processor is constructed on the site of the existing Doug Fox Lot. As such, curbside, close-in parking, and commercial vehicle pickup/drop-off facilities would be provided at both the Main Terminal and North Terminal based on peak period activity levels expected to occur at each. In general, in PAL 3 and 4, approximately 30% of the design day passenger traffic would be processed through the new North Terminal.

4.3.3.1 Terminal-area Circulation Roadways

As described in Section 4.3.3.2, the North Terminal would be served by a curbside roadway consisting of a four-lane terminal-front curb and a parallel four-lane island curbside running the length of the building. The following three alternatives were developed to provide access from the North Airport Expressway (NAE) to and from the new terminal. As shown, to allow for increased airfield apron in the vicinity of the North Satellite, all three alternatives assume that the southbound NAE will be realigned to the east to run parallel to the northbound NAE.

As shown on Figure 4-10, Alternative 1 provides access to and from the new terminal from the NAE. Traffic exiting the southbound NAE would climb to cross over the NAE and light rail alignment then descend to match the elevation of the new terminal's curbside roadway. Traffic bound for the new terminal from South 170th Street would turn onto a realigned Air Cargo road before turning south to merge with ramp crossing over the NAE and light-rail alignment. Traffic departing the new terminal would cross over above the northbound NAE then divide into traffic bound for SR-518 or the return-to-terminal ramp.

Figure 4-10
New Terminal Access Roadways, Alternative 1
(Cross-Over Expressway and Rail Alignment)
Seattle-Tacoma International Airport

Source: Inter*VISTAS* Inc., 2016.

This configuration does not allow for traffic to use the southbound NAE to reach South 170th Street nor does it allow traffic to reach the northbound NAE from South 170th Street. These movements predominately serve vehicles that are (1) travelling between SR-518 and destinations within the City of SeaTac, (2) not related to Airport activities, and (3) using Airport roadways to avoid traffic signals and traffic congestion on SR-99 (International Boulevard). Thus, the Port does not need to continue to provide those movements and may have an interest in intentionally removing the ability for such traffic to use on-Airport roadways.

Alternative 2, shown on Figure 4-11, is similar to Alternative 1 except traffic exiting the southbound NAE would descend to cross under the NAE and light rail alignment then climb to match the elevation of the new terminal's curbside roadway.

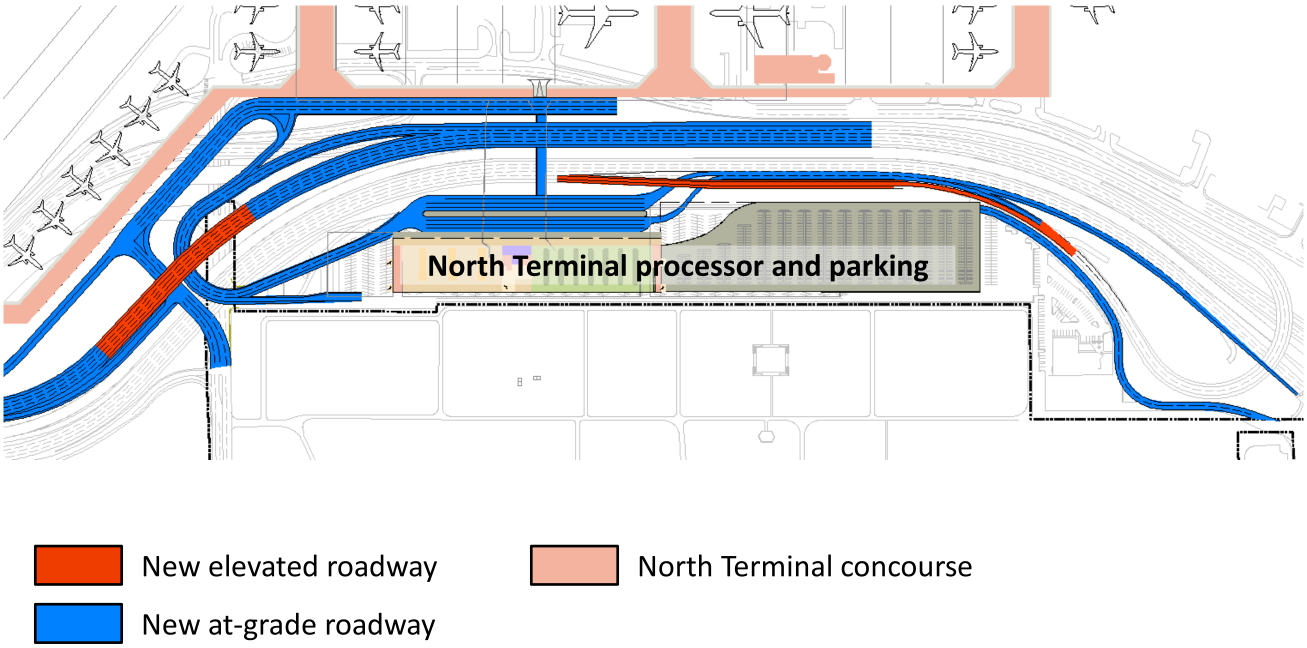
Figure 4-11
New Terminal Access Roadways, Alternative 2
(Cross Under Expressway and Rail Alignment)
Seattle-Tacoma International Airport

Source: Inter*VISTAS* Inc., 2016.

Alternative 3, depicted on Figure 4-12, attempts to provide access to and from the new terminal using roadways located in alignments similar to existing roadways. The intent of this alternative is to avoid the creation of roadway geometry that is inconsistent with geometries previously determined to be consistent with Washington State Department of Transportation (WSDOT) code and design standards. As shown, the approach to the new terminal is similar to that in Alternative 2, but the exit to the north is different in that Main Terminal traffic on the northbound North Airport Expressway bound for the return-to-terminal ramp climbs to allow roadways from the new terminal to merge with the North Airport Expressway at-grade. Vehicles exiting the new terminal parking facility would travel north to South 160th Street to either (1) cross directly to the on-ramp for eastbound SR-518 or (2) turn right onto South 160th Street towards International Boulevard, which in turn provides access to westbound SR-518 (this path is similar to that used by rental cars bound for westbound SR-518).

Table 4-3 summarizes a comparative assessment of the three new terminal roadway alternatives. As shown, Alternative 3 requires less elevated roadway and would require less construction above active SoundTransit and freeway facilities.

Figure 4-12
New Terminal Roadways, Alternative 3
(Maximize Use of Existing Roadway Network)
Seattle-Tacoma International Airport



Source: Inter*VISTAS* Inc., 2016.

Table 4-3
Comparative Assessment, New Terminal Roadway Alternatives
Seattle-Tacoma International Airport

	Alternative 1	Alternative 2	Alternative 3
Key features	• Three-lane approach road crosses ***over*** North Airport Expressway and SoundTransit • Three-lane exit road crosses over North Airport Expressway to provide access to SR-518 and return-to-terminal road	• Approach road crosses ***under*** North Airport Expressway and SoundTransit at-grade • Three-lane exit road crosses over North Airport Expressway to provide access to SR-518 and return-to-terminal road	• Approach road crosses ***under*** North Airport Expressway and SoundTransit • Lane bound from Main Terminal to return-to-terminal road crosses over new terminal exit, which merges with North Airport Expressway at-grade
Length of elevated roadway	**Highest amount.** Elevated roadways include both the approach to the new terminal as well as the exit from the new terminal.	**Less than Alternative 1, but more than Alternative 3.** Elevated roadways include the exit from the new terminal	**Least amount.** Elevated roadways include a new (single-lane) ramp providing access from the Main Terminal to the return-to-terminal roadway.
Constructability	**More challenging** than other alternatives due to construction in the vicinity of SoundTransit catenary wires and construction above two sections of the NAE.	**More challenging than Alternative 3** due to construction above one section of the NAE.	**Least challenging** in that construction is adjacent to, or below existing structures of the NAE and SoundTransit.

Source: LeighFisher, 2015.

4.3.3.2 Curbside Roadways

As described in Chapter 3, the preferred site for a new terminal building (under a Two-Terminal scenario) is located on the site of the existing Doug Fox Lot. This terminal would be a two-level building with both ticketing and bag claim functions located on the ground floor. The building would be approximately 700 feet long.

North Terminal curbside volumes and requirements are provided in Table 4-4 and Table 4-5.

Table 4-4

North Terminal Curbside Volumes

Seattle-Tacoma International Airport

	PAL 3		PAL 4	
	Enplaning peak hour drop-off volumes	Deplaning peak hour pickup volumes	Enplaning peak hour drop-off volumes	Deplaning peak hour pickup volumes
Private vehicles	406	423	435	456
Taxicabs	60	n/a	64	n/a
Limousines	41	n/a	44	n/a
Shared ride vans *(a)*	19	n/a	21	n/a
Scheduled vans/buses (Airporters) *(b)*	13	n/a	13	n/a
Charter buses	2	n/a	2	n/a
Rental car shuttle *(c)*	n/a	67	n/a	72
Public transit *(b, c)*	n/a	8	n/a	8
Other vehicles	5	n/a	6	n/a
Total	546	498	585	536

(a) Assumes that 50% of Main Terminal vehicles also stop at the North Terminals and 50% of North Terminal vehicles also stop at the Main Terminal.

(b) Assumes each vehicle stops at each terminal.

(c) Assumes these vehicles pick up and drop off passengers at the same location.

Source: LeighFisher, March 2015.

Table 4-5

North Terminal Curbside Requirements, Two-Terminal Scenario

Seattle-Tacoma International Airport

	PAL 3		PAL 4	
	Required length (linear feet) *(a)*	Required number of total roadway lanes (assuming required curb length is available)	Required length (linear feet) *(a)*	Required number of total roadway lanes (assuming required curb length is available)
Enplaning curb	540	4 *(b)*	560	4 *(b)*
Deplaning curb				
Unallocated curb	385		420	
Rental car shuttles	240		300	
Public transit	120		120	
Total	745	4 *(b)*	840	4 *(b)*

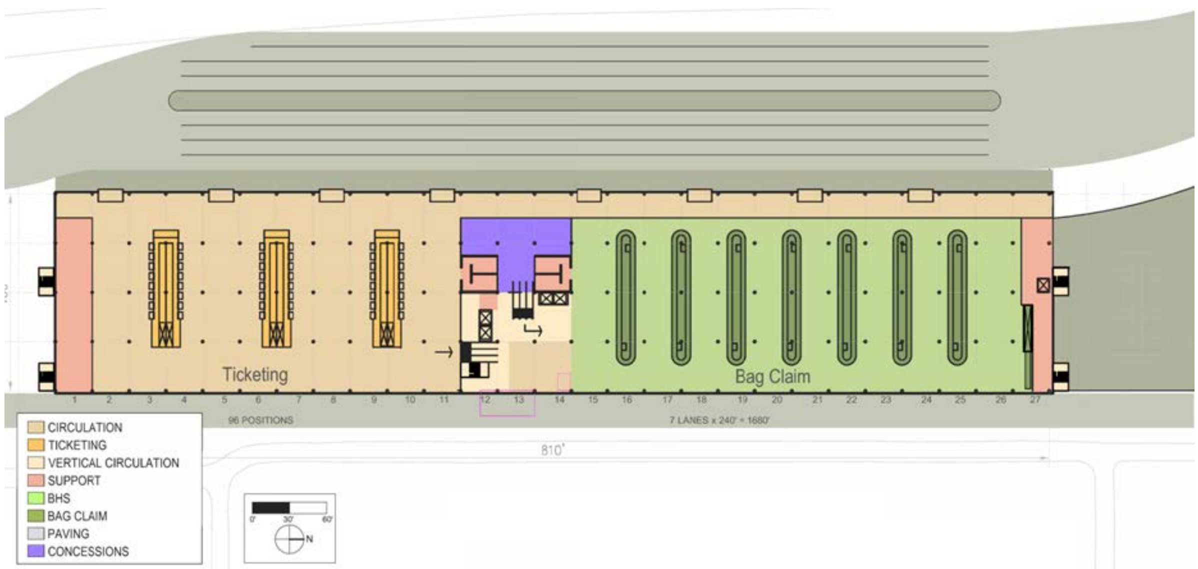
Source: Inter*VISTAS* Inc., 2016.

(a) Assumes double parking is acceptable for the Enplaning curb and unallocated curb on the Deplaning curb.

(b) Four lanes is the recommended minimum curbside cross-section even if not warranted by traffic volumes. For curbside roadways allowing double-parking, vehicles maneuvering in and out of the second lane may obstruct the third lane; the fourth lane ensures traffic can flow in such situations.

As described in Table 4-4, the new terminal at PAL 4 requires approximately 560 feet of enplaning curb, 420 feet of deplaning curb, 300 feet of curb for the RCF bus, and 120 feet of curb for public transit buses, for a total curbside requirement of 1,400 feet. Given the building length of 700 feet, the recommended curbside configuration, as shown on Figure 4-13, consists of two parallel curbside roadways of four lanes each, providing a total of 1,400 feet of curbside. (As described in Section 4.3.3.3, additional commercial vehicle pickup facilities are located in the garage constructed adjacent to the terminal.)

Figure 4-13
New Terminal Curbside Configuration
Seattle-Tacoma International Airport



Source: Corgan Associates, 2016.

4.3.3.3 Commercial Vehicles

Commercial vehicle loading areas at the North Terminal are to be located on the ground (overheight) floor of the parking garage, which has been sized to accommodate the projected PAL 4 demands on a single floor plate. Table 4-6 summarizes the volumes and corresponding space requirements projected for the North Terminal.

Table 4-6
North Terminal Commercial Vehicle Pickup Volumes and Requirements, Two-Terminal Scenario
Seattle-Tacoma International Airport

	Hourly Volumes		Pickup stalls	
	PAL 3	PAL 4	PAL 3	PAL 4
Taxicabs	157	166	5	6
Taxicab feeder queue			26	28
On-call limousines	6	6	1	1
Shared-ride vans	10	10	2	2
Pre-arranged limousines	2	3	5	5
Transportation Network Companies *(a)*	n/a	n/a	n/a	32
Courtesy vehicles *(b)*	197	215		
Crew vans	18	21	22 *(f)*	24 *(f)*
Downtown shuttle *(c)*	2	2		
South Ground Transportation Lot				
Scheduled airporters *(d)*	8	8	3	3
Charter buses – drop-off *(e)*	12	12	4	4
Charter buses – pickup *(e)*	12	12	3	3

(a) Expected PAL 4 requirements provided by Port staff (volumes not provided).
(b) Includes courtesy vehicles operated by hotels, motels, and off-Airport parking operators. Volume growth reflects estimated increase in the number of operators, not increase in passenger activity.
(c) Scheduled service (two trips per hour).
(d) Scheduled services. Peak hour volumes would increase based on introduction of new operators or increased frequencies. To increase capacity, most existing operators could choose to operate larger vehicles rather than increase the number of trips.
(e) Charter bus peak volumes reflect cruise ship charter bus activity during summer months. Volumes are based predominately on number of cruise ships (and boat capacity) using downtown Seattle piers. Absent cruise ship forecasts, demand is assumed to increase at similar rate as midday arriving passengers.
(f) These spaces serve courtesy vehicle, the Downtown shuttle, and airline crew vans.

Source: Inter*VISTAS*, October 2016.

4.3.3.4 Public Transit Facilities

Public Transit Bus Loading/Unloading Areas

It is assumed that transit routes serving Airport will serve both terminals. As described in Section 4.2.6, the One-Terminal concept provides two loading positions to account for the occasional instance with two buses arrive simultaneously. Because the routes will serve both terminals, the North Terminal provides 120 linear feet of public transit curb.

Light Rail Loading/Unloading Areas

As with the One-Terminal concept, the Main Terminal under the Two-Terminal concept includes providing moving walkways in the corridor connecting the station to the Main Terminal. Light rail customers bound for the North Terminal would use these same walkways to reach the automated people mover connecting the Main Terminal with the North Terminal. If subsequent refined planning efforts determine the moving walkways are not feasible within the garage, the Port could continue operating the existing electric shuttle service between the station and the northernmost pedestrian bridge entering the Main Terminal.

Strategies to Increase Use of Public Transit

Under a Two-Terminal concept, strategies to increase public transit use at the North Terminal are identical as those described in Section 4.2.6.

4.3.3.5 Public Parking

Approximately 87% of long-duration parking spaces currently provided on Port property (the Main Garage and Doug Fox Lot) are located "close-in" in the Main Garage. Given that the Two-Terminal concept will displace the Doug Fox Lot and there is limited property available for remote parking, public parking requirements for a Two-Terminal concept assume 100% of long-duration parking spaces would be provided close-in. Table 4-7 summarizes the public parking facility requirements under a Two-Terminal concept for the North Terminal.

Table 4-7
Public Parking Facility Requirements, North Terminal, Two-Terminal Concept
Seattle-Tacoma International Airport

	North Terminal	
	PAL 3	PAL 4
On-Airport parking		
Short-duration (less than 24 hours)	700	700
Long-duration (greater than 24 hours)	3,300	3,500
Total	4,000	4,200
Off-airport facilities	25,400	28,000

Source: Inter*VISTAS Inc.*, 2016, from data provided by the Port of Seattle and LeighFisher.

Public parking requirements will be accommodated in a parking garage constructed immediately north of the North Terminal. While the program may evolve during refined planning, the initial concept is to provide enough capacity to meet the 4,200-space requirement, as well as the commercial vehicle loading requirements (which would occur on an overheight first floor of the garage).

4.3.3.6 Rental Cars

Alternatives for meeting rental car demand under a Two-Terminal scenario are identical to those for the One-Terminal scenario (see Section 4.2.8).

4.3.3.7 Non-motorized Access

Options for pedestrians and bicyclists to access the Airport terminal are limited. The objective is to ensure that, during advanced planning and design, alternatives related to future landside facilities consider maintaining and improving non-motorized access.

4.3.4 Two-Terminal Concept – Main Terminal

4.3.4.1 Terminal-area Circulation Roadways

At the Main Terminal, PAL 3 and PAL 4 traffic is expected to be approximately 30% less than under the One-Terminal concept. For the four key roadways entering and exiting the Main Terminal Area (see Figure 4-1), Table 4-8 summarizes the PAL 3 and PAL 4 volumes, the calculated volume/capacity ratio, and the corresponding level-of-service.

Table 4-8
Future Peak Hour Volumes, Selected Main Terminal-Area Roadways, Two-Terminal Concept
Seattle-Tacoma International Airport

			PAL 3			PAL 4		
	Number of lanes	Assumed capacity (vehicles per hour) *(a)*	Design hour volumes	Volume/ capacity	LOS *(a)*	Design hour volumes	Volume/ capacity	LOS *(a)*
A. Approach to Lower Drive	2	2,500	2,520	1.01	F	2,710	1.08	F
B. Approach to Upper Drive	2	2,500	1,060	0.42	C	1,200	0.48	C
C. Exit from Upper Drive to North Airport Expressway	1	1,450	1,060	0.73	D	1,200	0.83	E
D. Exit from Lower Drive to North Airport Expressway	2	2,900	1,490	0.51	C	1,605	0.55	C

(a) Based on Airport Cooperative Research Program Report 40, Table 4-1.

Source: LeighFisher, 2015, from data provided by the Port of Seattle.

Table 4-9 summarizes the number of lanes required to achieve LOS C or better for each of the key Main Terminal area roadway links for PAL 1 through PAL 4. For PAL 1 and PAL 2, results are identical to the One-Terminal scenario.

Table 4-9
Lanes Required to Address Terminal-Area Roadway Deficiencies, Two-Terminal Concept
Seattle-Tacoma International Airport

		2014		PAL 1		PAL 2		PAL 3		PAL 4	
	Existing lanes	Baseline LOS *(a)*	Total lanes required for LOS C	Baseline LOS *(a)*	Total lanes required for LOS C	Baseline LOS *(a)*	Total lanes required for LOS C	Baseline LOS *(a)*	Total lanes required for LOS C	Baseline LOS *(a)*	Total lanes required for LOS C
A. Approach to Lower Drive	2	E	***3***	F	4 *(b)*	F	4 *(b)*	F	4 *(b)*	F	4 *(b)*
B. Approach to Upper Drive	2	C	2	C	2	C	2	C	2	C	2
C. Exit from Upper Drive to North Airport Expressway	1	E	***2***	E	***2***	F	***2***	D	***2***	E	***2***
D. Exit from Lower Drive to North Airport Expressway	2	C	2	C	2	C	2	C	2	C	2

(a) See Table 4-7.
(b) LOS D can be achieved with 3 total lanes.
LOS = level of service

Source: LeighFisher, 2015.

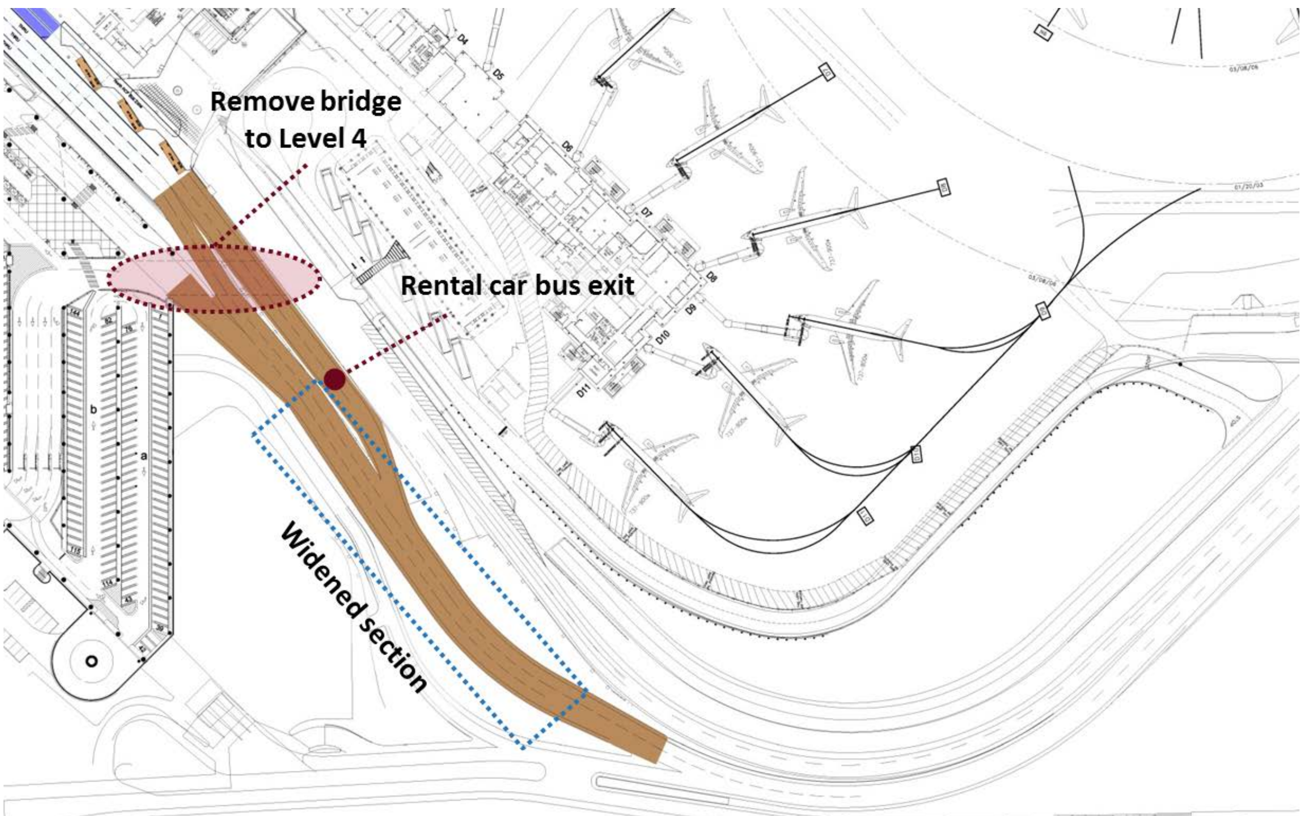
Approach to Lower Drive (Segment A)

As shown in Table 4-9, by PAL 1 the approach to the Lower Drive would require four total lanes to operate at LOS C, but could operate at LOS D with three lanes. Figure 4-14 and Figure 4-15 depict a two-phase approach for providing three lanes on the approach to the Lower Drive. Phase 1, shown on Figure 4-14 includes the following actions:

- Remove the bridge connecting the Upper Drive to Level 4 of the Main Garage and the supporting column. This creates a wider envelope for the roadway as it approaches the curbside and allows continuous flow in both traffic lanes (when rental car shuttle buses travel through this section, they often obstruct both traffic lanes as they avoid the column and turn right to enter the bus loading zones).

- If feasible, lower the remaining section of the return-to-terminal ramp that used to connect to the Lower Drive to create an exit and roadway reserved for rental car shuttle buses. This removes the shuttle buses from the main traffic lanes and provides direct access to their curbside loading areas.
- Widen the approach to the Lower Drive to three lanes starting in the vicinity of the exit to the Main Garage.

Figure 4-14
Lower Drive Approach Widening Concept – Phase 1
Seattle-Tacoma International Airport



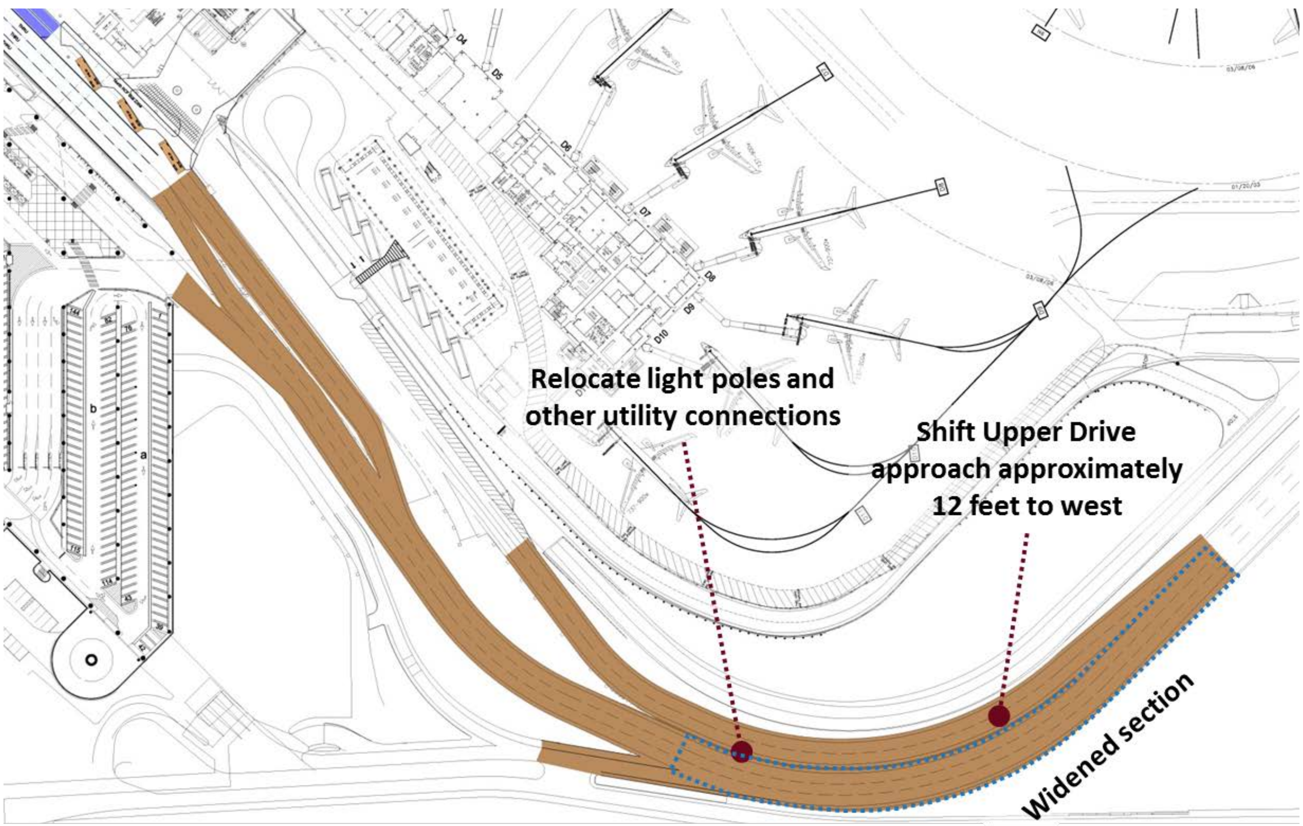
Source: Inter*VISTAS* Inc., 2016.

Based on microsimulation analysis conducted by Port of Seattle staff, this is expected to substantially improve traffic flow as it allows two full lanes to approach the Lower Drive and provides a separate lane for vehicles bound for the 3rd floor commercial vehicle areas.

Phase 2, shown on Figure 4-15, includes the following actions:

- Remove light poles and other utility connections currently located between the approaches to the Upper and Lower drives.
- Regrade the current approach to the Upper Drive as well as the grass median separating the Upper Drive approach from Air Cargo Road.
- Shift the Upper Drive approach approximately 12 feet to the west.
- Widen the Lower Drive approach back to the gore point separating the approaches to the Upper and Lower drives.

Figure 4-15
Lower Drive Approach Widening Concept – Phase 2
Seattle-Tacoma International Airport



Source: Inter*VISTAS* Inc., 2016.

To provide LOS C, which would require four lanes by PAL 1, the Upper Drive approach could be relocated another 12 feet to the west to allow a fourth lane on the Lower Drive approach. This would, however, require realignment of Air Cargo Road.

Approach to Upper Drive and Exit from Lower Drive (Segments B and D)

As shown in Table 4-9, under a Two-Terminal scenario these two roadways are expected to operate at LOS C or better through PAL 4.

Exit from Upper Drive (Segment C)

The deficiency on the exit from the Upper Drive can be addressed in the same manner described in Section 4.2.3.2 for the One-Terminal scenario.

4.3.4.2 Curbside Roadways

For PAL 3 and PAL 4, Main Terminal curbside volumes and requirements are provided in Table 4-10 and Table 4-11.

Table 4-10
Main Terminal Curbside Volumes, Two-Terminal Concept
Seattle-Tacoma International Airport

	PAL 3		PAL 4	
	Enplaning peak hour drop-off volumes	Deplaning peak hour pickup volumes	Enplaning peak hour drop-off volumes	Deplaning peak hour pickup volumes
Private vehicles	815	1,284	921	1,374
Taxicabs	120	n/a	136	n/a
Limousines	82	n/a	41	n/a
Shared ride vans *(a)*	24	n/a	27	n/a
Scheduled vans/buses (Airporters) *(b)*	13	n/a	13	n/a
Charter buses	2	n/a	2	n/a
Rental car shuttle *(c)*	n/a	152	n/a	172
Public transit *(b) (c)*	n/a	8)	n/a	8
Other vehicles	12	n/a	13	n/a
Total	1,068	1,444	1,153	1,524

(a) Assumes that 50% of Main Terminal vehicles also stop at the North Terminals and 50% of North Terminal vehicles also stop at the Main Terminal.
(b) Assumes each vehicle stops at each terminal.
(c) Assumes these vehicles pick up and drop off passengers at the same location.

Source: LeighFisher, March 2015.

Table 4-11
Main Terminal Curbside Requirements, Two-Terminal Concept
Seattle-Tacoma International Airport

		PAL 3		PAL 4	
	Existing capacity (linear feet)	Required length (linear feet) *(a)*	Required number of total roadway lanes (assuming required curb length is available)	Required length (linear feet) *(a)*	Required number of total roadway lanes (assuming required curb length is available)
Upper Drive	1,200	930	4	1,050	4
Lower Drive					
Unallocated curb	1,050	1,040		1,100	
Rental car shuttles	360	540		600	
Public transit	120	120	—	120	—
Total	1,530	1,700	4	1,820	4

(a) Assumes double parking is acceptable for the Upper Drive and unallocated curb on the Lower Drive.

Source: Inter*VISTAS* Inc., 2016.

Under the Two-Terminal concept, the existing curbsides at the Main Terminal appear to be able to accommodate the Main Terminal's share of 66 MAP activity at the desired LOS assuming (1) implementation of operational strategies (i.e., reducing average dwell times) and (2) the RCF buses can be relocated away from the Lower Drive. Under a Two-Terminal scenario, it is assumed that an APM connecting the Main Terminal, North Terminal, and rental car facility would remove the rental car shuttles from the Lower Drive and allow the existing Main Terminal curbsides to meet requirements through PAL 4.

4.3.4.3 Commercial Vehicles

The volumes and corresponding space requirements projected for the Main Terminal are summarized in Table 4-12.

Table 4-12
Main Terminal Commercial Vehicle Pickup Volumes and Requirements, Two-Terminal Concept
Seattle-Tacoma International Airport

	Existing capacity	Hourly Volumes		Pickup stalls	
		PAL 3	PAL 4	PAL 3	PAL 4
3rd Floor of Main Garage					
Taxicabs	13	287	333	9	10
Taxicab feeder queue	70			48	56
On-call limousines	2	11	12	1	2
Shared-ride vans	8	18	20	3	3
Pre-arranged limousines	48	4	5	8	9
Transportation Network Companies (a)	57	n/a	n/a	n/a	56
Courtesy vehicles (b)		197	215		
Crew vans	22 (f)	18	21	22 (g)	24 (g)
Downtown shuttle (c)		2	2		
South Ground Transportation Lot (d)					
Scheduled airporters (e)	2	8	8	3	3
Charter buses – drop-off (f)	20	35	37	10	10
Charter buses – pickup (f)		35	37	7	8

(a) Expected PAL 4 requirements provided by Port staff (volumes not provided).
(b) Includes courtesy vehicles operated by hotels, motels, and off-Airport parking operators. Volume growth reflects estimated increase in the number of operators, not increase in passenger activity.
(c) Scheduled service (two trips per hour).
(d) South Ground Transportation Lot may be fully displaced by construction of the International Arrivals Facility. Charter bus spaces serve both pickup and drop-off activity.
(e) Scheduled services. Peak hour volumes would increase based on introduction of new operators or increased frequencies. To increase capacity, most existing operators could choose to operate larger vehicles rather than increase the number of trips.
(f) Charter bus peak volumes reflect cruise ship charter bus activity during summer months. Volumes are based predominately on number of cruise ships (and boat capacity) using downtown Seattle piers. Absent cruise ship forecasts, demand is assumed to increase at similar rate as midday arriving passengers.
(g) These spaces serve courtesy vehicle, the Downtown shuttle, and airline crew vans.

Source: Inter*VISTAS*, October 2016.

As shown, under the Two-Terminal scenario, Main Terminal commercial vehicles can be accommodated within the existing facilities. As noted in Section 4.2.5, as a result of the IAF, the charter bus spaces in the South Ground Transportation (GT) Lot may be removed. It is suggested that charter bus alternatives be refined through subsequent planning efforts to better reflect the evolving use of the current charter bus sites.

4.3.4.4 Public Transit Facilities

Public Transit Bus Loading/Unloading Areas

As described in Section 4.2.6 for the One-Terminal concept, the Two-Terminal concept provides two loading positions at the Main Terminal to account for the occasional instance with two buses arrive simultaneously. Because the routes will serve both terminals, the Main Terminal will continue to provide 120 linear feet of public transit curb.

Light Rail Loading/Unloading Areas

As with the One-Terminal concept, the Main Terminal under the Two-Terminal concept includes providing moving walkways in the corridor connecting the station to the Main Terminal. If subsequent refined planning efforts determine the moving walkways are not feasible within the garage, the Port could continue operating the existing electric shuttle service between the station and the northernmost pedestrian bridge entering the Main Terminal.

Strategies to Increase Use of Public Transit

Under a Two-Terminal concept, strategies to increase public transit use at the Main Terminal are identical as those described in Section 4.2.6.

4.3.4.5 Public Parking

Approximately 87% of long-duration parking spaces provided on Port property (the Main Garage and Doug Fox Lot) are provided “close-in” in the Main Garage. Given that the Two-Terminal concept will displace the Doug Fox Lot and there is limited property available for remote parking, public parking requirements for a Two-Terminal concept assume 100% of long-duration parking spaces are provided close-in. Table 4-13 summarizes the public parking facility requirements under a Two-Terminal concept for the Main Terminal. Prior to PAL 3, requirements are identical to those for the One-Terminal concept.

Table 4-13
Public Parking Facility Requirements, Main Terminal, Two-Terminal Concept
Seattle-Tacoma International Airport

	Main Terminal	
	PAL 3	PAL 4
On-Airport parking		
Short-duration (less than 24 hours)	1,500	1,700
Long-duration (greater than 24 hours)	7,400	8,300
Total	8,900	10,000
Off-airport facilities	25,400	28,000

Source: Inter*VISTAS Inc.*, 2016, from data provided by the Port of Seattle and LeighFisher.

Through PAL 4, the existing capacity of the Main Garage is expected to be able to accommodate the forecast requirements.

4.3.4.6 Rental Car Facility

Alternatives for meeting rental car demand under a Two-Terminal scenario are identical to those for the One-Terminal scenario (see Section 4.2.9).

4.3.4.7 Non-motorized Access

Options for pedestrians and bicyclists to access the Airport terminal are limited. The objective is to ensure that, during advanced planning and design, alternatives related to future landside facilities consider maintaining and improving non-motorized access.

4.3.5 Automated People Mover Connecting Terminals and Remote Rental Car Facility

The APM connecting to the rental car facility is referred to as a pre-security APM because it would transport non-secure passengers (i.e., passengers who have not passed through the passenger security screening check points). The preferred alignment and timing for implementation will be identified through subsequent facilities planning efforts.

Five pre-security APM options were considered for transporting non-secure passengers between terminal, rental car, and light rail facilities. The factors considered in developing and assessing the options included minimum connect time, systems cost, passenger level of service, and the difficulty of construction.

As described previously, minimum connect time (MCT) refers to the minimum time necessary for an arriving international passenger to be processed and board a connecting flight departing from the farthest gate. MCT consists of the time necessary for a passenger to travel from the arriving gate to the

International Arrivals Facility (IAF), the time to be processed through the IAF, the time to travel time from the IAF to the connecting flight's gate, and a 10-minute buffer. The SAMP goal for MCT is 90 minutes. For non-secure APM options, analysis of alternatives incorporates a calculation of each option's MCT in the event the APM would be used for passenger connecting between terminals via the landside (i.e., exit the secure side of one terminal, use the APM to travel to the other terminal, and then re-screened).

The preliminary systems cost estimates are anticipated costs for the APM system supplier contract only and exclude the costs for fixed facilities (i.e., the costs for elevated guideways, tunnels, stations, and maintenance facility) and the costs associated with oversight provided by Port personnel. The primary elements included in the APM system cost estimates are those associated with:

- Vehicles
- Train control
- Communications
- Power Distribution
- Maintenance equipment, including fit out and equipping of the maintenance facility
- Station equipment
- APM contractor design, coordination, installation, and testing
- Labor

The pre-security APM concepts considered are illustrated on Figure 4-16; the characteristics of the pre-security APM concepts are summarized in Table 4-14. For purposes of this section, option numbers are those used during APM-related workshops with Port staff.

4.3.5.1 Pre-security Concept 4B

Pre-security Concept 4B would operate as a non-secure, elevated system and have four stations with stops at Concourse A and Concourse D of the Main Terminal, the new North Terminal, and the RCF.

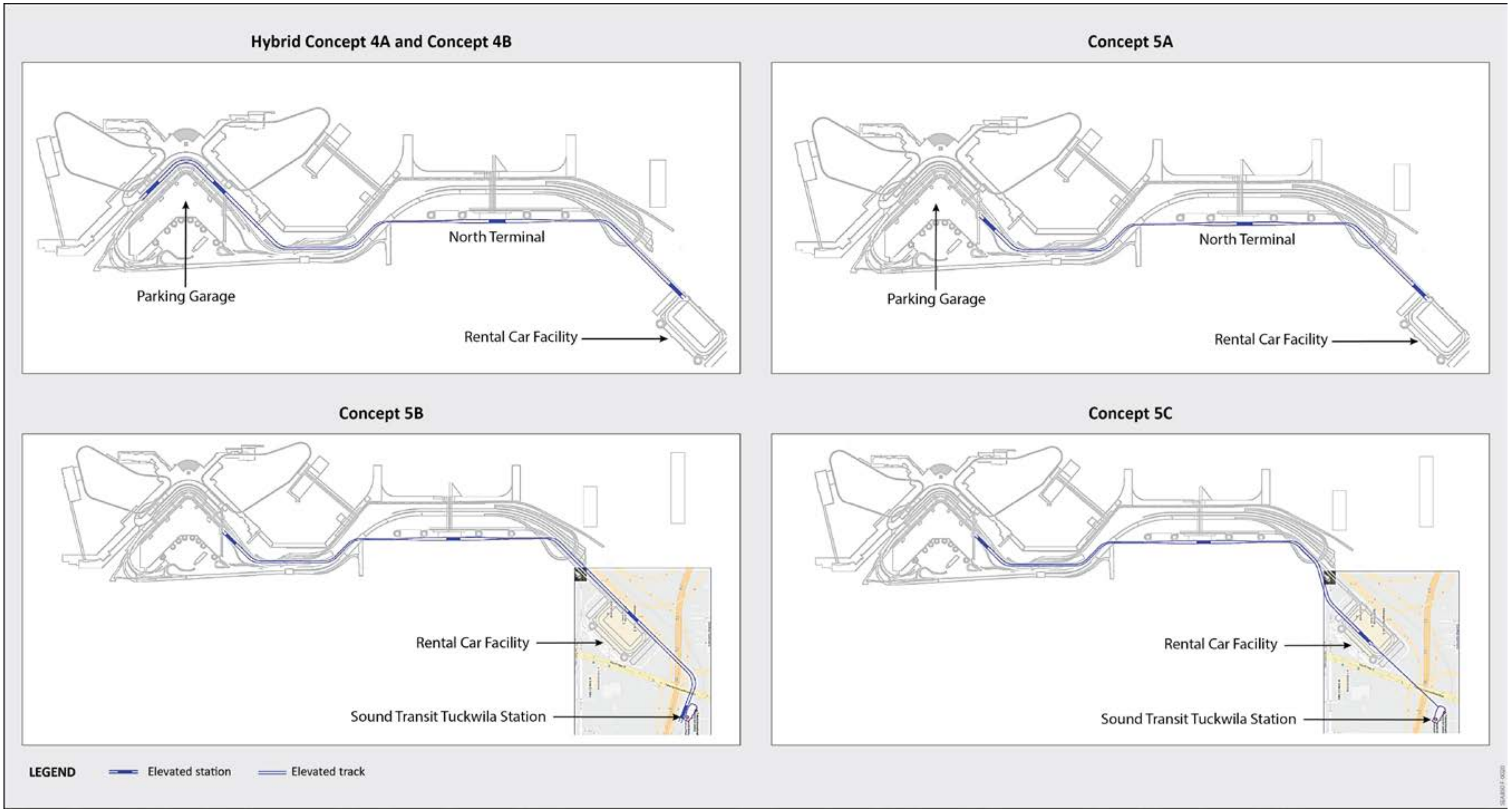
Using three car trains on this system, a 3-minute headway can provide a system capacity of 2,690 pphpd (passengers per hour per direction).] The one way travel time for passengers on this system will be 7.5 minutes with an overall MCT between 85 and 100 minutes.

The system's capital cost for this option is approximately $175.0 to $220.0 million and it would cost approximately $5.5 to $6.5 million per year for operations and maintenance

4.3.5.2 Pre- and Post-security Concept 4A

Pre- and post-security Concept 4A could accommodate both secure and non-secure passengers and is based on the alignment of Concept 4B with four total stations serving Concourse A and Concourse D of the Main Terminal as well as the North Terminal and RCF station.

Figure 4-16
Pre-security APM Concepts
Seattle-Tacoma International Airport



Source: Lea+Elliott, 2016.

Table 4-14

Characteristics of Pre-security APM Concepts Assessed

Seattle-Tacoma International Airport

Characteristic	Concept 4A (secure and non-secure)	Concept 4B (non-secure)	Concept 5A (non-secure)	Concept 5B (non-secure)	Concept 5C (non-secure)
Elevated or below-ground	elevated	elevated	elevated	elevated	elevated
Number of stations:					
Main Terminal	2	2	1	1	1
North Terminal	1	1	1	1	1
Rental car facility	1	1	1	1	1
Tukwila LRT station	none	none	none	1	none
Disposition of STS *(a)*	no change	no change	no change	no change	no change
Number of cars in train	6	3	3	4	4
Headway (min)	3.0	3.0	2.4	3.4	3.4
Capacity (pphpd) *(b)*	5,380	2,690	3,375	3,190	3,150
Maximum one-way travel time (min)	7.5	7.5	4.8	6.7 (to Tukwila LRT station)	5.1 (to rental car facility)
MCT *(c)*	85 - 100	85 - 100	93 - 108	TBD	TBD
System cost	$275 - $345 million	$175 - $220 million	$150 - $190 million	$200 - $250 million	$180 - $225 million
Annual O&M cost	$9 - $10 million	$5.5 - $6.5 million	$5.5 - $6.5 million	$6.5 - $7.5 million	$5.8 - $6.8 million

(a) The existing STS will continue to operate, except as noted.

(b) pphpd = passengers per hour per direction

(c) MCT = minimum connect time

Source: Lea+Elliott, 2016.

Concept 4A would require the segregation of cars and stations to maintain the secure and non-secure split. The stations would require physical separation of areas for secure and non-secure passengers including separate vertical circulation. Segregation would be maintained on the train by only allowing secure and non-secure passengers into designated cars.

Concept 4A would also require a secure walkway from the new North Terminal station to the secure side, increasing facilities costs and potentially walking distances. The existing STS loops and shuttle will continue operation to transfer secure passengers within the existing concourses.

Concept 4A would have the same headway and travel time as Pre-security Concept 4B. However, because the train would be transporting two passenger groups, more cars would be needed to provide for the increased demand. Using six-car trains (three secure cars/three non-secure cars) can provide a total system capacity of 5,380 pphpd. As with the Pre-security Concept 4B, the MCT of this system is between 85 and 100 minutes.

The system's capital cost for this option is approximately $275 to $345 million and it would cost approximately $9 to $10 million per year for operations and maintenance.

4.3.5.3 Pre-security Concept 5A

Pre-security Concept 5A would operate as a non-secure, elevated system and have three stations connecting the Airport's Main Terminal, the new North Terminal, and the RCF.

Using three car trains on this system, a 2.4-minute headway can provide a system capacity of 3,375 pphpd. The one way travel time for passengers on this system would be 4.8 minutes with an overall MCT between 93 and 108 minutes.

The system's capital cost for this option is approximately $150.0 to $190.0 million and it would cost approximately $5.5 to $6.5 million per year for operations and maintenance

4.3.5.4 Pre-security Concept 5B and Concept 5C

Pre-security Concept 5A has two variants to potentially connect the Tukwila LRT station for easy transfer from public transportation to the Airport terminals. Pre-security Concept 5B proposes to extend the APM system and add an APM stop serving the Tukwila LRT station. Pre-security Concept 5C would connect the APM CONRAC station to the LRT station with a pedestrian bridge and moving walkways. The location of the APM RCF station in this scenario is repositioned from the location of the station in Concept 5A but provides similar travel times and capacity.

Using four-car trains for Concept 5B, a 3.4-minute headway can provide a system capacity of 3,190 pphpd. The one way travel time for passengers on this system would be 6.7 minutes to or from the LRT station.

The system's capital cost for Concept 5B is approximately $200.0 to $250.0 million and it would cost approximately $6.5 to $7.5 million per year for operations and maintenance.

Using four-car trains for Concept 5C, a 3.4-minute headway can provide a system capacity of 3,150 pphpd. The one way APM travel time for passengers on this system would be 5.1 minutes to or from the RCF.

The system's capital cost for Concept 5C is approximately $180.0 to $225.0 million and it will cost approximately $5.8 to $6.8 million per year for operations and maintenance.

4.3.5.5 Option Screening and Conclusions

The pre-security APM options were screened by Port staff to identify the preferred option. The screening was based on decision criteria that reflected passenger level of service, cost, construction, facilities, and other issues.

Criteria related to passenger level of service

- **Connect time:** This criterion reflects the time require for international passengers to transfer from a South Satellite gate, through the IAF, and to the farthest new north gate.
- **Wayfinding:** This criterion reflects the assessment of the complexity of wayfinding.
- **Level changes:** This criterion reflects the number of times a passenger might be required to descend from the concourse level to an underground STS; then up to the concourse level or up to an elevated APM system, then back down to terminal level. Increased level changes generally diminish passenger experience.
- **Transfers:** This criterion reflects the number of different trains a passenger must ride when transferring between gates.

Criteria related to cost

- **Capital cost (systems)**: This criterion reflects the estimated cost of APM systems costs (e.g., vehicles, power, communications, and train control) but does not include the cost of fixed facilities (e.g., guideway, stations, and tunnel).
- **Annual operating cost**: This criterion reflects the cost for operating and maintaining the APM system, including staffing costs.
- **Construction cost (qualitative)**: This criterion reflects a qualitative review of costs related to fixed facilities.
- **Replaces existing STS**: This criterion reflects the potential to save approximately $5 million annually if the STS does not have to be maintained and future renewal and replacement costs are avoided.

Criteria related to construction

- **Operational Impacts during construction**: This criterion reflects the potential for construction to impact ongoing airport operations.

- **Construction risks**: This criterion reflects the degree to which unknowns (design or otherwise) might pose risks to the schedule, cost, or feasibility of the solution.

Criteria related to facilities

- **Gate impact (at completion)**: This criterion reflects the potential for the system to displace gates.

- **Impact to future facilities**: This criterion reflects the potential for the system to preclude future development.

- **Synergy with baggage and utilities**: This criterion reflects the potential for APM infrastructure to be used for baggage systems and utilities (e.g., a tunnel could be used by both resulting in cost savings).

Criterial related to other factors (not scored)

- **Passenger volume**: This criterion reflects system capacity.

The pre-security APM concepts were evaluated and scored against each criterion. The scores ranged from 1 to 5; a score of 1 indicated poor performance relative to the criterion and a score of 5 indicated good performance relative to the criterion. Weights were assigned to the criterion according to their relative importance and a weighted score was computed for each concept.

The criterion weights, scoring, and results of the screening process are summarized in Table 4-15. The conclusion was that Concept 4B is the preferred pre-security APM option.

Table 4-15
Pre-security APM Concepts Screening Results
Seattle-Tacoma International Airport

Criteria	Criteria weight	Option 4A *(d)*			Option 4B			Option 5A			Option 5B			Option 5C		
		Score	Weighted score	Elevated APM	Score	Weighted score	Criteria value	Score	Weighted score	Criteria value	Score	Weighted score	Criteria value	Score	Weighted score	Criteria value
Passenger LOS																
Minimum connect time	5	4	20	85 - 100	4	20	85 - 100	1	5	93 - 108	1	5	--	1	5	--
Best wayfinding	5	2	10	--	3	15	--	2	10	--	1	5	--	1	5	--
Number of level changes *(b)*	3	3	9	--	3	9	--	2	6	--	2	6	--	2	6	--
Number of transfers	4	4	16	--	4	16	--	3	12	--	3	12	--	2	8	--
Costs																
Capital cost (systems)	2	2	4	$ 275 - 345 M	4	8	$ 175 - 220 M	4	8	$ 150 - 190 M	3	6	$ 200 - 250 M	4	8	$ 180 - 225 M
Operating cost	1	2	2	$ 9.0 - 10.0 M	4	4	$ 5.5 - 6.5 M	4	4	$ 5.5 - 6.5 M	3	3	$ 6.5 - 7.5 M	4	4	$ 5.8 - 6.8 M
Construction costs (qualitative)	5	3	15	--	3	15	--	5	25	--	3	15	--	3	15	--
Replaces existing STS resulting in about $5M annual savings and avoiding need for eventual STS rebuild	2	0	0	--	0	0	--		0	--	0	0	--	0	0	--
Construction																
Operational impacts during construction	3	1	3	--	3	9	--	3	9	--	2	6	--	2	6	--
Construction risks (e.g., schedule, unknowns)	2	1	2	--	1	2	--	3	6	--	2	4	--	3	6	--
Facilities																
Gate impact (at completion)	-5	0	0	none	0	0	none	0	0	none	0	0	none	0	0	none
Impact to future facilities	1	1	1	--	1	1	--	4	4	--	4	4		4	4	
Synergy with baggage and utilities	3	0	0	--	0	0	--	0	0	--	0	0	N/A	0	0	N/A
Other (not scored)																
Passenger volume (pphpd) *(c)*	n/a	--	--	5,380	--	--	2,690	--	--	3,375	--	--	3,190	--	--	3,150
Passenger group(s) served / connectivity	n/a	--	--	All connections between A, D, new North Gates and RAC	--	--	Landside traffic between A, D, new North Gates and RAC	--	--	Landside traffic between D, new North Gates and RAC	--	--	Landside traffic between D, new North Gates, RAC and Tukwila LRT	--	--	Landside traffic between D, new North Gates, RAC and Tukwila LRT
Other comments	n/a	--	--	Reduced post-security connections as compared to Post-Security Option 2	--	--	Challenging for international to domestic transfers	--	--	More challenging for international to domestic transfers	--	--	Highway crossing adds complexity	--	--	Highway crossing adds complexity
Weighted total score		--	82			99			89			66			67	
Percent of best option		--	60%			100%			90%			67%			68%	

(a) Scores ranged from 1 - 5; 5 is good, 1 is bad
(b) Level change counts are based on longest route.
(c) pphpd = peak-period passengers per hour per direction
(d) Pre- and Post-security option

4.3.6 Remote Facilities

Recommendations in this section reflect the results of Port staff assessments of future space needs for these uses and the corresponding preferred locations.

Given the limited property available on-Airport, Port staff determined that the preferred location for the following facilities is north of the Airport in the vicinity of SR 518, and the preferred locations are identical under either a One- or a Two-Terminal scenario:

- Employee parking
- Ground transportation hold facilities
- Cell phone lot

Figure 4-17 depicts a preferred land use plan for Port property north of SR 518. The preferred locations for these uses are noted by the numbers 6 and 7 for employee parking, the number 5 for ground transportation facilities, and the number 4 for the cell phone lot.

4.3.6.1 Employee Parking

There are two options for the development of employee parking facilities to the north of the Airport. These include:

- **North Employee Parking Lot (NEPL) Structured Parking concept:** The portion of the NEPL outside the runway protection zone could be redeveloped into parking structures. Given airspace limitations that define the maximum height of the structure and general parking facility considerations, NEPL could be redeveloped to provide a total of approximately 6,000 parking stalls (900 stalls surface parking, and 5,100 stalls structured parking). A general massing diagram of this concept is provided on Figure 4-17.

- **Surface & Structured Parking concept (separate from NEPL):** The NEPL would remain as a surface parking lot and would be reduced from its existing capacity of 4,122 parking stalls to approximately 2,500 parking stalls with the development of the cargo warehouses. Additional employee parking would be provided in a new 1,500 stall surface lot (location 6 in Figure 4-17) and a 2,000 stall parking structure located directly west of the existing NEPL surface lot (location 7 in Figure 4-17).

The preferred option is the Surface & Structured Parking concept. This concept utilizes available land not currently being used for an airport purpose to develop less expansive surface parking as opposed to the NEPL Structured Parking concept that takes surface parking capacity out of service to develop more expensive structured parking. Based upon activity forecasts, the first phase (surface lot) would need to be completed by 2024 (PAL 2) and prior to the development of the cargo warehouses that displaced the existing employee parking at NEPL. The second phase (structured parking) would need to be complete by PAL 3.

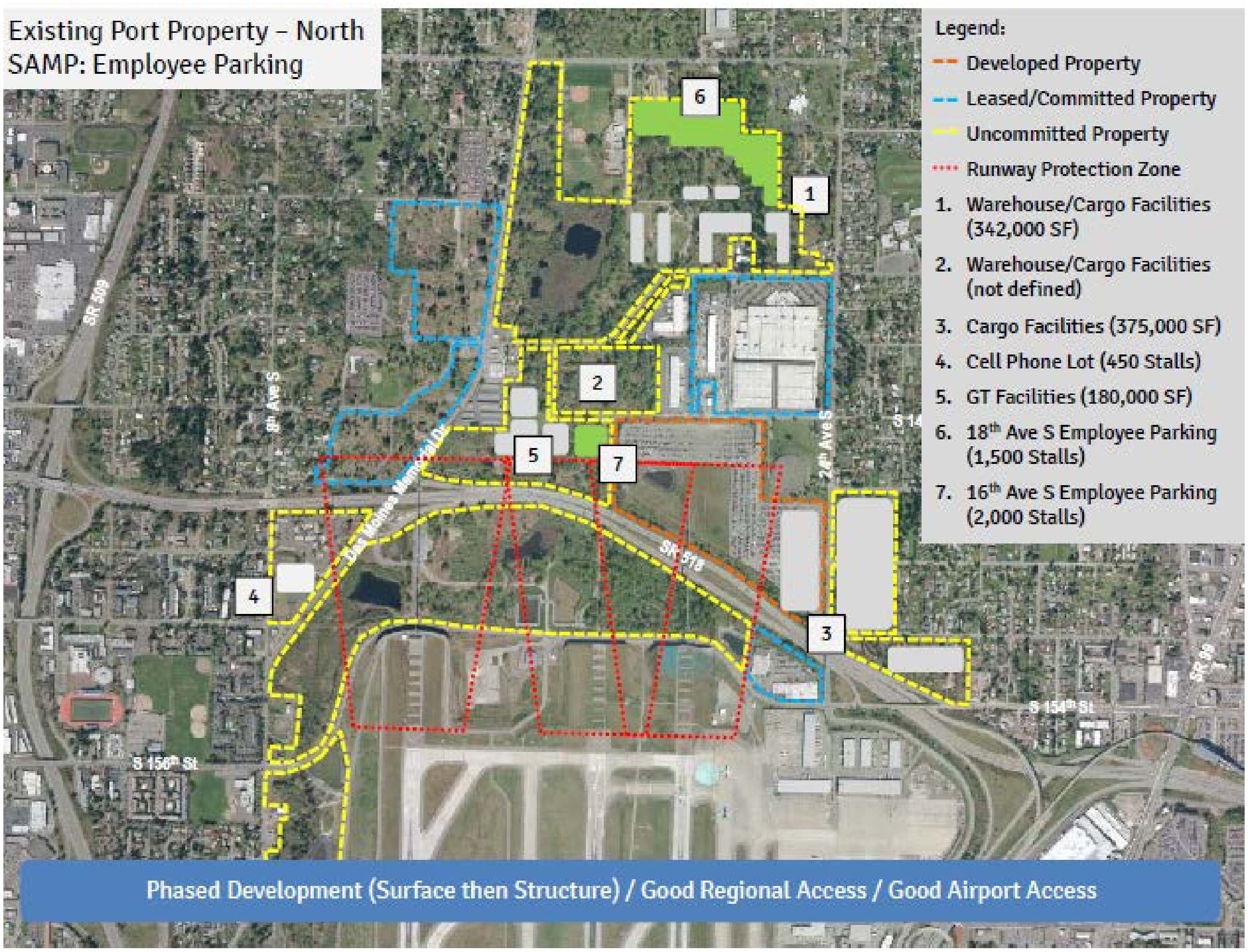
4.3.6.2 Ground Transportation Hold Facilities

A remote holding lot (or lots) with efficient access to both terminals needs to be provided to support ground transportation operations. The lot is located as depicted in Figure 4-17 with access to both terminals via the 24th Ave S. corridor and local access at S 160th St. The lot is generally sized at 180,000 SF and can accommodate all holding requirements for various modes under the One- or Two-Terminal options.

4.3.6.3 Cell Phone Lot

A cell phone lot with convenient access to both terminals and the primary Airport access (SR 518) needs to be provided to improve customer service and relieve congestion on the terminal drives. The lot is located as depicted in Figure 4-17 with access to both terminals via SR 518 The lot is generally sized to accommodate 450 stalls.

Figure 4-17
Location for Employee Parking, Ground Transportation Hold Lot, and Cell Phone Lot
Seattle-Tacoma International Airport

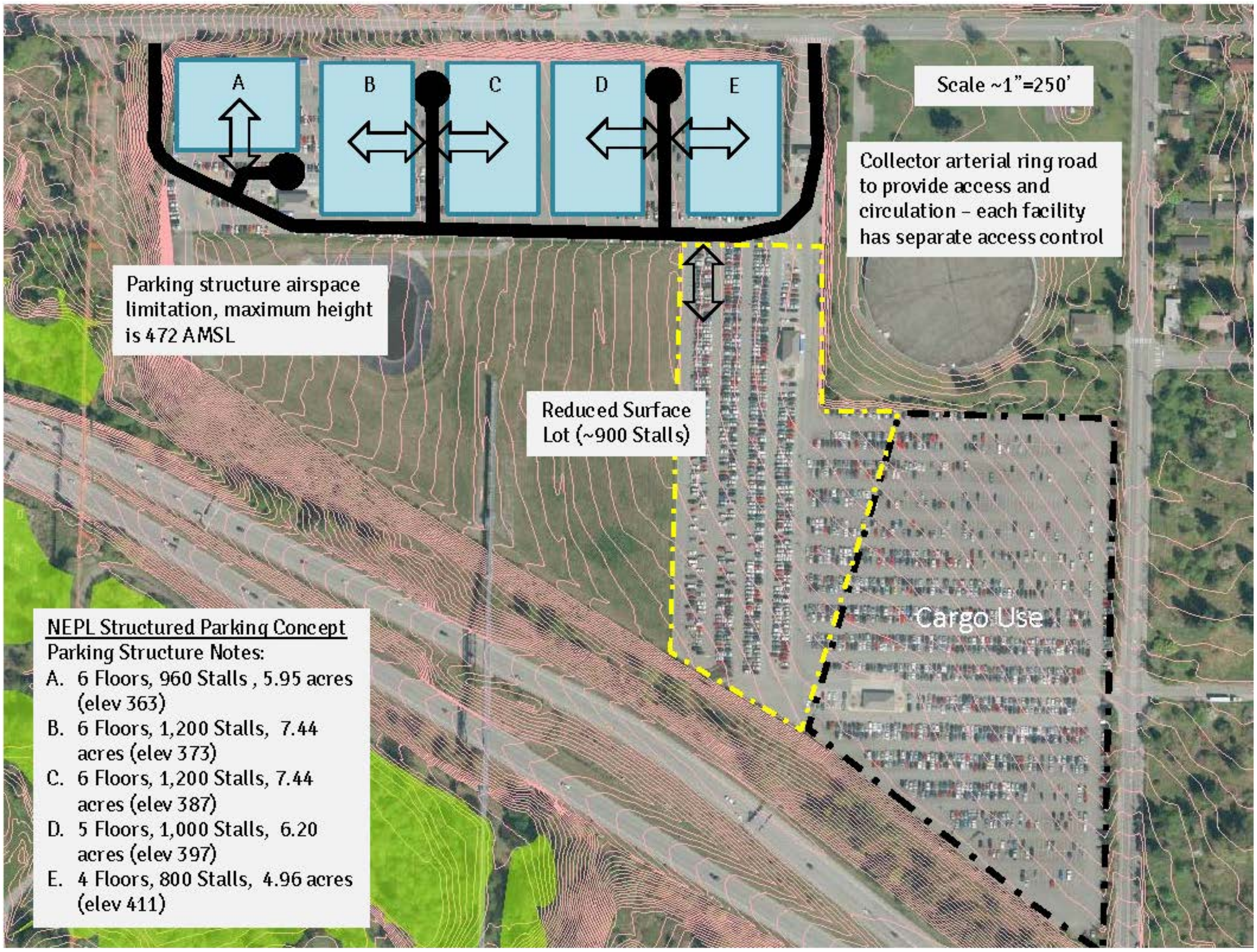


Source: Port of Seattle, 2016.

Figure 4-18

NEPL Structured Parking Concept for Employee Parking

Seattle-Tacoma International Airport



Source: Port of Seattle, 2016.

Air Cargo

During the planning period, a significant number of air cargo facilities will be displaced by higher priority passenger facility development. The Port's stated cargo requirements cannot be satisfied without the development of SASA.

5.1 Introduction

This chapter presents the key concepts that influenced the formulation and evaluation of air cargo alternatives, describes the alternatives considered and how they were evaluated, and summarizes the conclusions and recommendations from the evaluations.

5.2 Key Concepts Influencing the Alternatives

The key concepts influencing the formulation of air cargo facility alternatives were land use priorities and the impact of future passenger facilities development on existing and future air cargo facilities.

5.2.1 Land Use Priorities

For the purposes of allocating scarce land, the priorities among the Airport's key functions are:

1. Passenger
2. Airfield
3. Landside
4. Cargo
5. Airline support
6. Airport support
7. General aviation

5.2.2 Impact of Passenger Facilities Expansion on Existing Cargo Facilities

The major conclusions from Chapter 3 *Passenger Terminal,* and the assessment of overall Airport land uses that relate to cargo facilities were:

1. The PAL 4 (2034) requirements are for:
   - A total of 113 contact gates (35 additional contact gates; a contact gate is an aircraft parking position served by a passenger loading bridge)
   - A total of approximately 44 off-gate aircraft parking positions to accommodate the needs of passenger aircraft remain overnight (RON) operations

2. The facilities (i.e., passenger terminal, concourses, satellites, aircraft parking apron, and taxilanes) necessary to accommodate 35 additional contact gates alone will occupy much of the Airport's available land in a rectangle bounded to the south by South 188th Street, to the east by International Boulevard and the Airport Expressway, to the west by Taxiway A, and to the north by the FAA air traffic control tower (approximately). The approximate area required to accommodate 35 additional contact gates needed by PAL 4 is illustrated on Figure 5-1.

Figure 5-1
Approximate Area Needed for 35 Additional Contact Gates by PAL 4 (2034)
Seattle-Tacoma International Airport

Source: LeighFisher, 2016.

3. Existing Airport facilities to the north of the ultimate extent of passenger aircraft gates and to the south of the existing FedEx facility (refer to Figure 5-2) must ultimately be demolished and made available for higher priority uses such as aircraft RON parking. The area encompassing these facilities that must be demolished is shown on Figure 5-3.

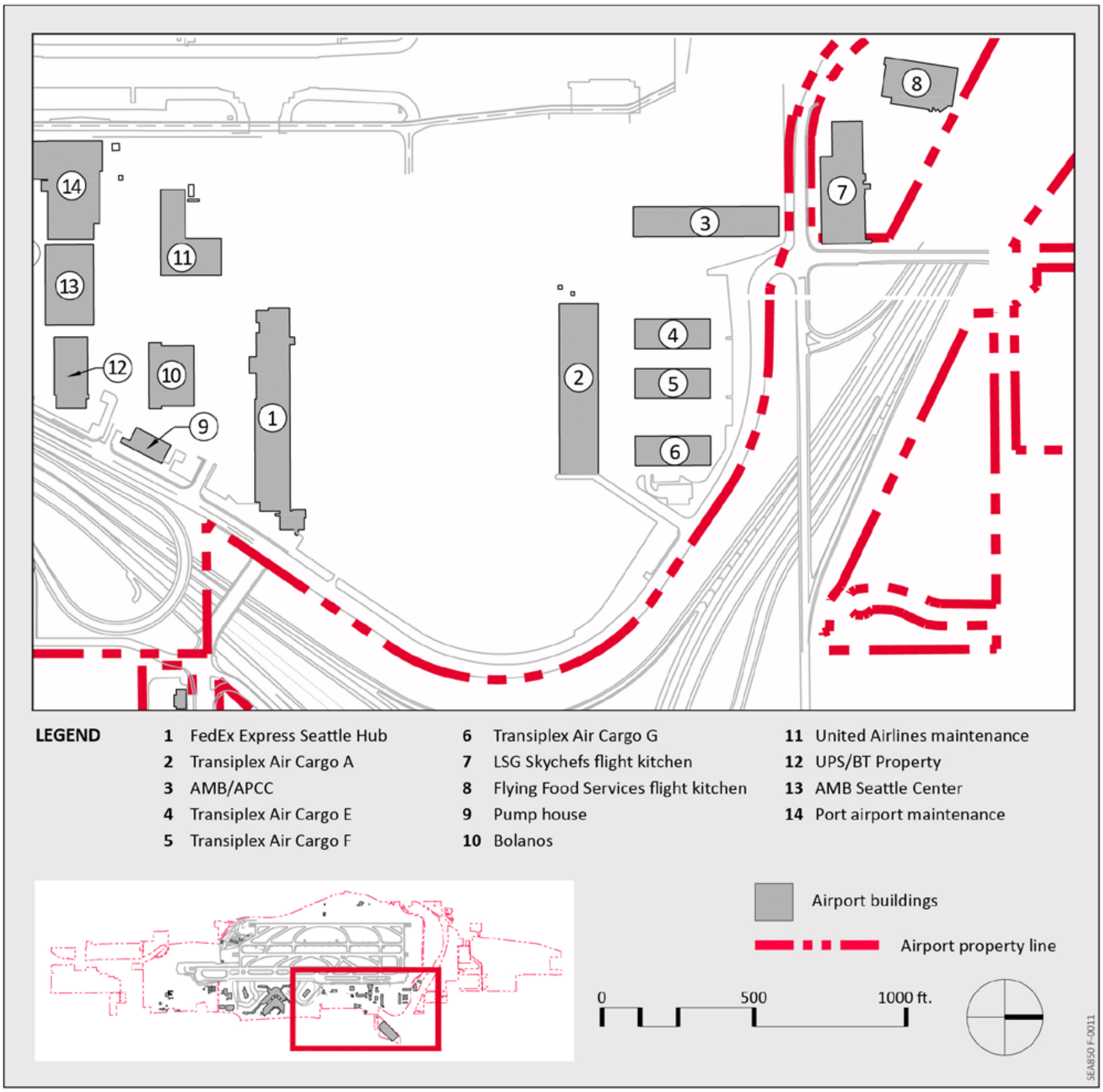
4. The best use of developable Airport land bounded to the south by the existing FedEx facility, to the north by State Route (SR) 518, to the west by Taxiway A, and to the east by Air Cargo Road is for air cargo. This area, referred to as the north cargo area, is identified on Figure 5-4.

5. A significant number of air cargo and other facilities, displaced to permit construction of the necessary PAL 4 passenger facilities or needed to satisfy other requirements, may be competing for the same scarce Airport land, for example:

    - Aircraft RON positions
    - Ground run-up enclosure
    - Aircraft maintenance hangars (Alaska Airlines has two existing hangars and Delta Air Lines has one existing hangar that could be displaced by passenger aircraft gates)

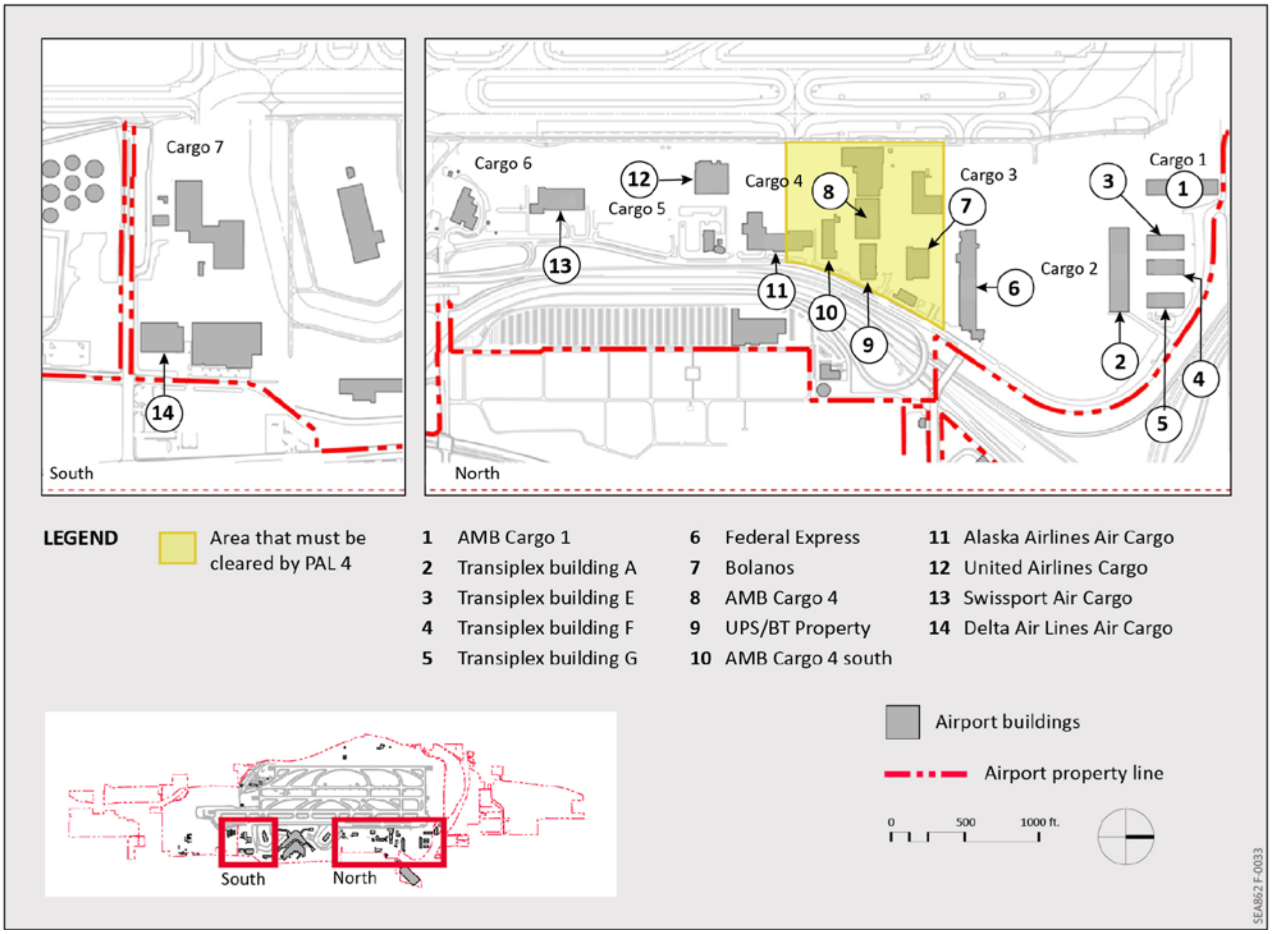
- Cargo warehouses
- Cargo hardstands
- An aircraft deicing pad

Figure 5-2
Facilities in the North Cargo Area and Its Vicinity
Seattle-Tacoma International Airport



Source: LeighFisher, 2016.

Figure 5-3
Areas that Must be Cleared by PAL 4 for Functions Such as Passenger Aircraft RON Parking
Seattle-Tacoma International Airport

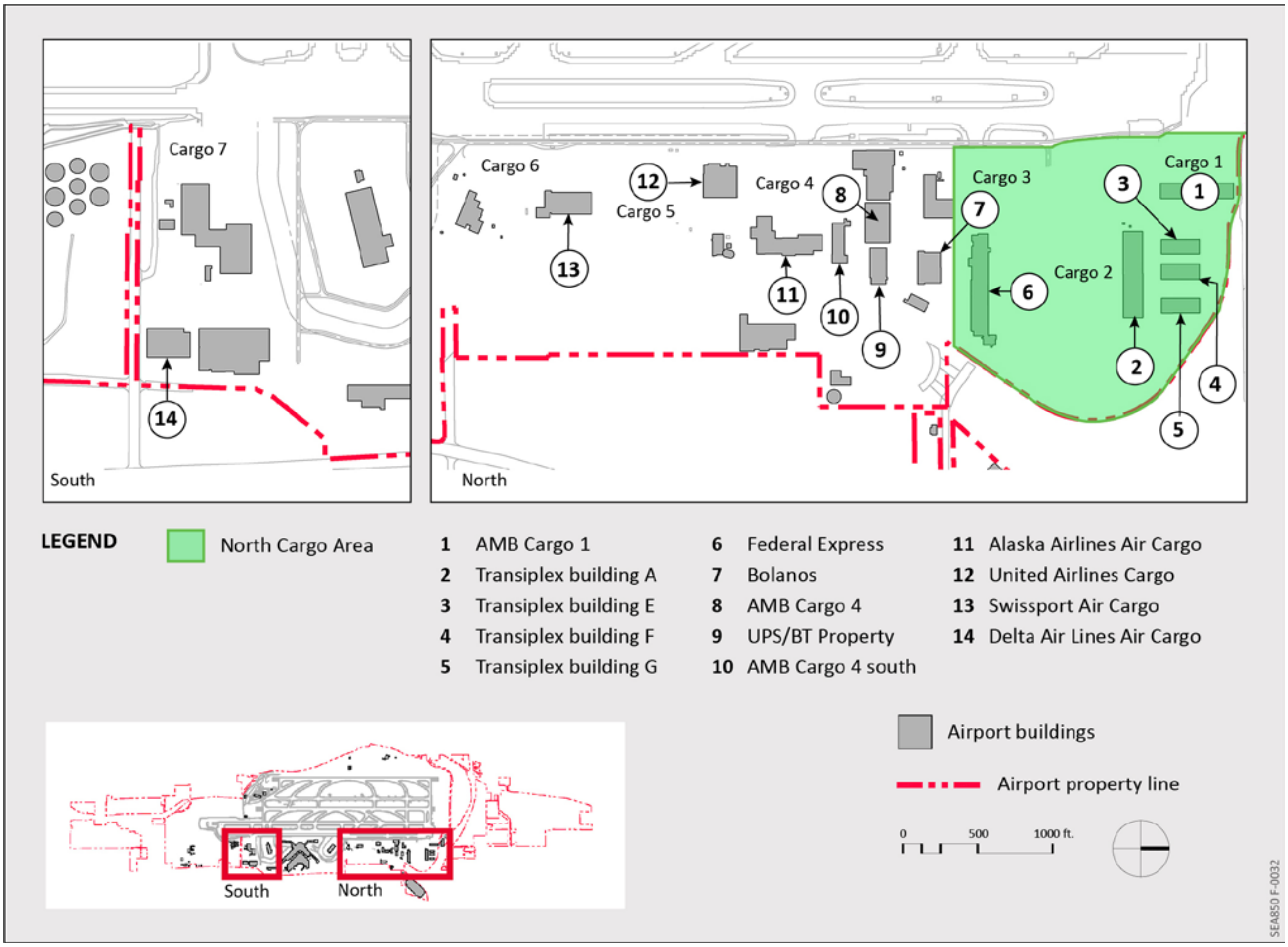


Source: LeighFisher, 2016.

5.2.3 *Desired Cargo Site Size and Gap Analysis*

A total site area of approximately 92.5 acres is needed to accommodate the forecast PAL 4 cargo requirements related to taxilane access, freighter hardstands, airside, warehouse, and landside. The area available in the north cargo area is approximately 68 acres, leaving a gap between the area required and the area available of 24.5 acres. This gap must ultimately be satisfied by (1) expanding the existing north cargo area to the south of the FedEx facilities, (2) supplementing the facilities in the north cargo area with another, non-contiguous area, or (3) relocating all cargo functions to a new location.

Figure 5-4
North Cargo Area
Seattle-Tacoma International Airport



Source: LeighFisher, 2016.

5.3 Identification and Assessment of Alternative Cargo Sites

This section describes (1) five potential cargo sites, (2) an assessment of the potential for each site to satisfy all, or some portion, of the cargo requirements identified in *Technical Memorandum No. 5 – Facility Requirements*, (3) the criteria used to screen the alternative cargo sites, (4) the screening matrix and rationale for scoring the alternatives relative to the criteria, and (5) the conclusions reached based on the assessment and screening.

5.3.1 *Potential Cargo Sites*

Five potential sites for cargo development were identified:

- North Cargo Area
- North of North Cargo Area
- L-shaped parcel
- South Aviation Support Area (SASA)
- Westside parcel

The locations of the cargo sites are shown on Figure 5-5.

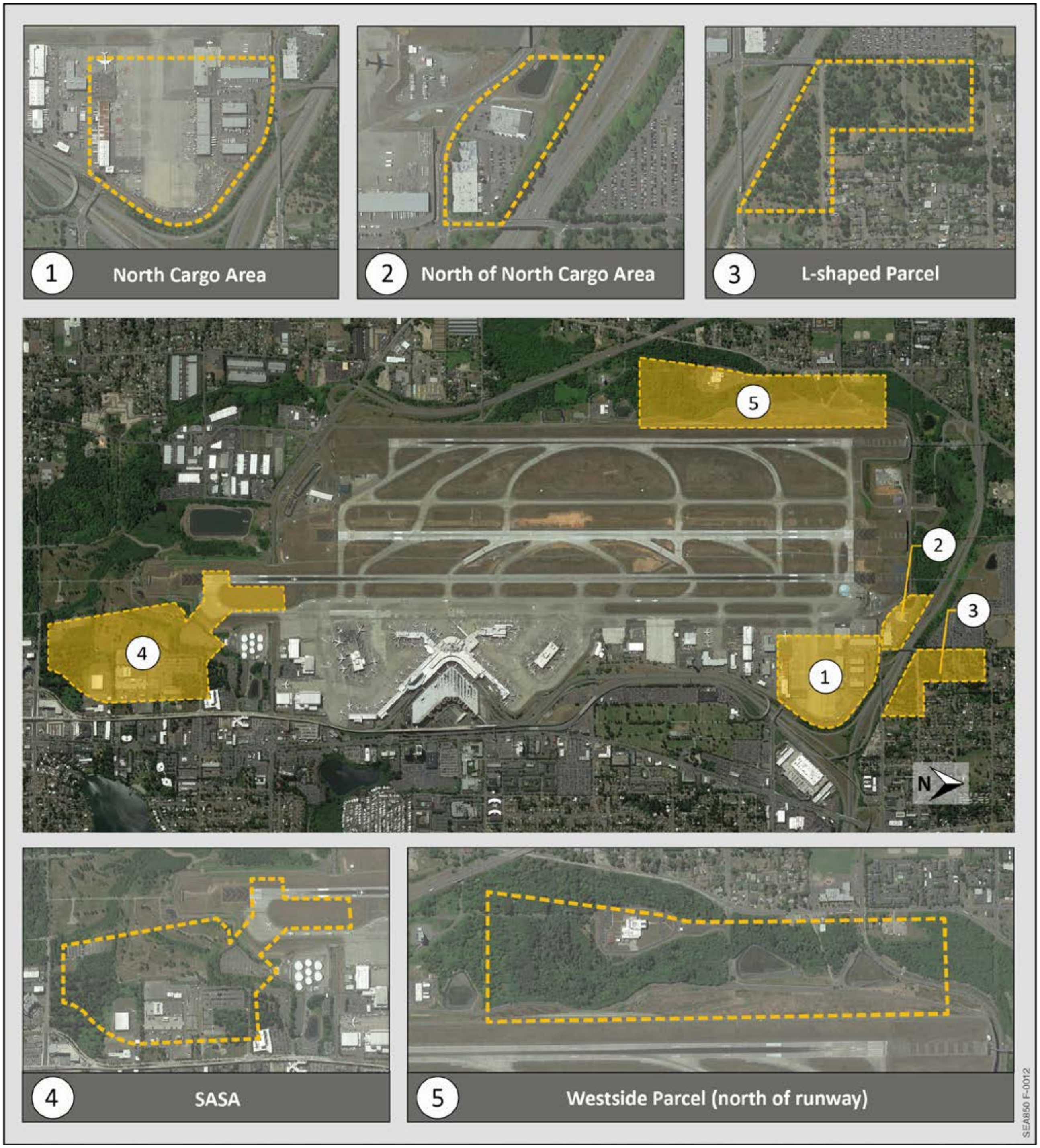
5.3.2 *Site Assessment*

Site #1 – North Cargo Area

The following summarize the assessment of Site #1, identified on Figure 5-5.

- The area of Site #1, approximately 68 acres, is sufficient to satisfy a significant portion, although not all, of cargo requirements through PAL 4 (2034).
- Site #1 is currently utilized for cargo operations, therefore future development costs would be reasonable.
- Site #1 provides direct access to the airfield. The taxilane bisecting Site #1 provides direct airside access for freighter hardstands on both the north and south sides of the taxilane and adequate airside ramp space for aircraft load and unload operations, including B747-8F nose loading.
- Site #1 provides direct access to the landside cargo road and the local roadway system. The site offers the potential to (1) improve access and reduce congestion related to warehouse activities and (2) improve facilities utilization.
- Site #1 is available now; it is believed that the phasing of necessary improvements could be accomplished effectively, assuming the necessary business arrangements are completed expeditiously.
- Site #1 is relatively close to the passenger terminal gates, is convenient for tug and cart/dolly deliveries of belly cargo to passenger aircraft, and offers opportunities to increase the efficiency of ground vehicle operations within the site. Therefore, the potential exists to reduce carbon emissions.
- Site #1 is currently used for cargo operations; therefore its selection for continued use would have no environmental impact.
- The redevelopment of cargo facilities on Site #1 is consistent with public expectations.

Figure 5-5
Potential Cargo Sites
Seattle-Tacoma International Airport



Source: LeighFisher, 2016.

Site #2 – North of Site #1, Currently Occupied by Flight Kitchens

The following summarize the assessment of Site #2, identified on Figure 5-5.

- The area of Site #2, approximately 6 acres, is suitable for supplementing cargo capability provided by another site, such as Site #1. It cannot satisfy all cargo requirements.

- Site #2 is currently occupied by two flight kitchens. Future development costs could entail the demolition and replacement of those facilities and earthwork (i.e., fill). The elevation of the site is approximately 30 feet lower than the elevation the north cargo area. Therefore, unless the site was raised, it would not permit direct access to the adjacent north cargo area (e.g., if the site was used for an air freight warehouse, it would not permit direct access to freighter hardstands unless it was raised). Raising the site elevation could entail rerouting 154th Street or placing it in a tunnel.

- Site #2 could provide direct access to both the airfield if the site elevation was raised.

- Site #2 provides direct access to 154th Street but offers limited potential to (1) improve access and reduce congestion related to warehouse activities and (2) improve facilities utilization.

- Site #2 would be available only upon relocating the existing tenants. Upon relocation of the tenants, phasing of the desired improvements would be relatively easy.

- Site #2 is relatively close to the passenger terminal gates and Site #1, the north cargo area. Depending on the desired use of Site #1, it could offer opportunities to increase the efficiency of cargo-related ground vehicle operations. Therefore, the potential exists to reduce carbon emissions.

- Site #2 is currently developed for flight kitchen operations; its selection for cargo use would have no environmental impact.

- The redevelopment Site #2 for cargo facilities would be consistent with public expectations.

Site #3 – L-Shaped Parcel

Site #3, the L-Shaped Parcel, is located to the north of both the north cargo area and SR 518 and is shown on Figure 5-5. The following summarizes the assessment of Site #3.

- The area of Site #3, approximately 30.5 acres, is sufficient to satisfy a significant portion, although not all, of cargo requirements through PAL 4 (2034). With the purchase of adjacent properties, it could be possible to meet all the requirements at the L-shaped parcel. However, consideration of the L-shaped parcel for all Airport cargo operations (i.e., warehouses and freighter hardstands) would require bridges for aircraft and ground equipment, connecting the site with the existing airfield and spanning SR518.

- Site #3 provides considerable potential for providing support facilities related to air cargo operations; however as a remote site without direct access to freighter hardstands and, considering the distance from the site to the passenger aircraft gates, it is not well suited for air freight warehouses or integrator facilities. Instead, the site is better suited for support functions such as freight forwarder warehouses, remote truck parking, or flight kitchens.

- Assuming Site #3 is utilized for support functions, its development costs could be reasonable.

- Site #3 does not provide direct access to the airfield; although such access could be provided, the cost to do so is not believed to be reasonable.

- Depending on how Site #3 is used, access to the local roadway system could be inefficient. Site access is via South 154th Street and 24th Avenue South.

- Site #3 is available now.

- Site #3 is relatively far from the passenger terminal gates and site access is deficient in comparison to Site #1. Therefore, Site #3 offers little opportunity to increase the efficiency of ground vehicle operations and reduce carbon emissions.

- Site #3 consists of former residential property and is undeveloped; therefore, any development has the potential to increase the amount of impervious surface on the Airport.

- Public expectations related to cargo or support facilities on Site #3 are unknown.

Site #4 – South Aviation Support Area (SASA)

The following summarize the assessment of Site #4, identified on Figure 5-5.

- The area of Site #4, approximately 70 acres, is sufficient to satisfy all or a portion of cargo requirements through PAL 4 (2034). SASA is currently occupied by a facilities maintenance warehouse, bus maintenance facility, and employee parking lot and is also being considered for aircraft maintenance hangars, a ground run-up enclosure, and aircraft RON positons.

- The cost to develop Site #4 would involve considerable earthwork (i.e., cut and fill) and the construction of bridges for both aircraft and ground equipment, connecting the site with the existing airfield, and rerouting Des Moines Creek. The overall cost could be relatively high but would be shared among multiple other projects (e.g., aircraft RON parking positions, aircraft maintenance facilities, and a ground run-up unit).

- Site #4 would provide direct access to the airfield.

- Site #4 provides direct access to the local roadway system. The site offers the potential to (1) improve access and reduce congestion related to warehouse activities and (2) improve facilities utilization.

- Site #4 is available now. However, a considerable number of steps would need to be completed before the development of air cargo functions could begin. These steps include the completion of a National Environment Protection Act process, relocation of existing functions, site work, and bridge construction.

- Site #4 will be approximately the same distance from the ultimate centroid of passenger gates as is Site #1. Similar to Site #1, it offers opportunities to increase the efficiency of ground vehicle operations compared with current operations. Therefore, the potential exists to reduce carbon emissions.

- The development of Site #4 would involve the relocation of Des Moines Creek and could result in an increase in the Airport's impervious surface. Any environmental impact would have to be mitigated.

- Public expectations related to cargo or support facilities on Site #4 are unknown.

Site #5 – West Side

The following summarize the assessment of Site #5, identified on Figure 5-5.

- Currently, development on the west side of the Airport consists of a radar installation and a limited number of trailers that accommodate Airport staff. The area available is potentially adequate to satisfy the entire PAL 4 (2034) cargo requirement. However, developing Site #5 would require (1) considerable earthwork (i.e., fill) to provide a platform for air cargo warehouses and associated freighter hardstands at the appropriate elevation, (2) improved roadways connecting the site with Des Moines Memorial Drive, (3) a taxiway parallel to and west of Runway 16R-34L and spanning SR 509, and (4) potentially, the construction of a service vehicle tunnel connecting the site with the terminal area (Unless mitigated by an east-west vehicle tunnel beneath the runways, and connecting the site with the passenger terminal area, the distance and vehicle travel time between the site and passenger gates would be excessive. This distance would contribute to higher than desired operating costs and vehicle emissions.). The overall site development cost would be the highest of all sites considered.

- Site #5 would provide direct access to the airfield.

- Site #5 would provide direct access to the local roadway system. The site offers the potential to (1) improve access and reduce congestion related to warehouse activities and (2) improve facilities utilization.

- Site #5 is available now. However, a considerable number of steps would need to be completed before the development of air cargo functions could begin. These steps include a National Environment Protection Act process, site work, and construction related to a taxiway, taxiway bridge, and, potentially, a vehicle tunnel.

- Assuming construction of a service vehicle tunnel, the travel distance between Site #5 and the terminal area would be approximately 40% greater than the travel distance from either Site #1 or Site #4. Therefore, Site #5 does not offer the potential to reduce carbon emissions related to ground service vehicles traveling between the site and the passenger terminal.

- The development of Site #5 would result in an increase in the Airport's impervious surface and could potentially disturb environmentally sensitive areas.

- Development of Site #5 may not be consistent with public expectations related to development on the west side of the Airport.

A policy decision was made by Port management to eliminate Site #5 from further consideration as a potential cargo site.

5.3.3 Site Screening

The following criteria were used to screen the alternative cargo sites.

Economic/operational

- **Potential to meet PAL 4 requirements**: This criterion reflects the ability of the site to accommodate the required warehouse area (area for airfreight, integrator freight, and mail warehouses) and freighter aircraft hardstand positions.

- **Site development cost**: This criterion reflects the relative capital cost to develop the sites. The criterion was subjective and considered factors such as roadway and utility infrastructure, the relocation and demolition of existing facilities, earthwork, and access roadways.

- **Potential direct airfield access**: This criterion reflects the importance of direct airfield access so freighter aircraft may park in front of an air freight warehouse and tugs with airfreight dollies have direct access between freight warehouses and both passenger and freighter aircraft.

- **Potential to improve access and congestion**: This criterion reflects the potential to reduce the difficulty cargo vehicle drivers generally experience in accessing the existing warehouses.

- **Potential to promote optimum utilization**: This criterion reflects the extent to which the location and geometry of a site would allow it to be optimally utilized.

- **Site availability**: This criterion reflects the ease or difficulty of making the site available.

- **Phasing**: This criterion reflects the ease or difficulty of phasing the necessary work.

Environmental

- **Reduced engine run time (ground vehicles):** This criterion reflects the potential for cargo sites to contribute to greenhouse gas (GHG) and criteria pollutant emissions as a result of their effects on the amount of time ground vehicles must spend traveling between cargo warehouses and freighter and passenger aircraft.

- **Impact on wetlands/creeks**: This criterion reflects the potential for cargo sites to affect sensitive natural resources.

- **Limits addition of impervious surfaces**: This criterion reflects the Port's desire to limit storm runoff, which is exacerbated by the addition of impervious surfaces.

Social

- **Proximity to noise and light sensitive land uses**: This criterion reflects the potential effects on nearby residential uses.

- **Consistency with zoning:** This criterion reflects the potential effects on nearby residential uses.

- **Consistency with public expectations:** This criterion enables the identification of sites that may not meet public expectations and reflect commitments, implied or otherwise, related to development in certain parts of the Airport.

The completed screening matrix, which shows how each site alternative was scored relative to each criterion, is shown on Figure 5-6. The rationale for scoring against the criteria is summarized below.

Economic/operational

- **Potential to meet PAL 4 area requirements**: Sites #1, #2, and #3 are not large enough to meet all PAL 4 cargo requirements and, accordingly, were scored "poor" relative to this criterion. Site #4 is the only site large enough to meet all PAL 4 cargo requirements and was scored "good" relative to this criterion.

- **Site development cost:** Site #4 was scored "poor" relative to this criterion because of the infrastructure (which includes an aircraft bridge connecting the site with Taxiway A) and earthwork costs. Site #1 and Site #2 were scored "good" relative to this criterion because the sites are already developed. Site #3 was scored as "neutral" relative to the criterion because the site development cost is not expected to be extraordinary.

- **Potential direct airfield access:** Site #3 was scored "poor "relative to this criterion because it does not have the potential for airfield access without a very expensive aircraft bridge and extensive earthwork. Sites #1, #2, and #4 were scored as "good" relative to this criterion because they offer direct airfield access.

Figure 5-6
Cargo Sites Round 1 Screening Matrix
Seattle-Tacoma International Airport

Criteria	Site			
	Site #1 North Cargo Area	Site #2 North of Cargo 1	Site #3 L-Shaped Parcel	Site #4 SASA
Potential to meet PAL 4 area requirements	-1	-1	-1	1
Site development cost	1	1	0	-1
Potential direct airfield access	1	1	-1	1
Potential to improve access and congestion	1	-1	-1	1
Potential to promote optimum utilization	1	1	0	1
Site availability	1	0	1	-1
Phasing	0	1	1	0
Reduced engine run time (ground vehicles)	0	0	-1	0
Impact on wetlands/creeks	1	1	-1	-1
Limits addition of impervious surfaces	0	0	-1	-1
Proximity to noise and light sensitive land uses	0	0	-1	0
Consistency with zoning	1	1	1	1
Consistency with public expectations	1	0	1	1
Score summary	7	4	-3	2

-1	poor/undesirable	1	good
0	neutral		

Source: Logplan and LeighFisher, 2016.

- **Potential to improve access and congestion:** Site #2 was scored "poor" relative to this criterion because it has limited access and offers no opportunities to ease congestion at adjacent Site #1. Site #3 was scored "poor" relative to this criterion because of the difficulty of providing access that would be better than existing access. Sites #1 and #4 were scored as "good" relative to this criterion because they provide opportunities for facilities modifications that have the potential to improve access and congestion.

- **Potential to promote optimum utilization:** This criterion reflects the extent to which the location and geometry of a site would allow it to be optimally utilized. Site #3 was scored "neutral" relative to this criterion because access is perceived as a detriment to its optimum utilization. Sites #1 and #2 were scored as "good" relative to this criterion because many opportunities exist for facilities modifications that would promote optimum utilization. Site #4 was scored as "good" relative to this criterion because it could be optimally utilized for a function such as an air mail warehouse.

- **Site availability:** Site #4 was scored "poor "relative to this criterion because of the environmental process and extensive earthwork and infrastructure (e.g., an aircraft bridge) required to make the site available. Sites #1 and #3 were scored as "good" relative to this criterion because they are available immediately. Site #2 was scored as “neutral” because it is occupied by two flight kitchens which would have to be relocated to make the site available.

- **Phasing:** This criterion reflects the ease or difficulty of phasing the necessary work. Site #1 was scored “neutral “relative to this criterion because of the existing business arrangements that must be renegotiated to allow the series of moves necessary to implement a plan to optimize the facilities. Site #4 was scored as “neutral” relative to this criterion because of the existing facilities that must be relocated to allow its development. Sites #2 and #3 were scored as “good” relative to this criterion because the phasing is considered uncomplicated.

Environmental

- **Reduced engine run time (ground vehicles):** Sites #1 and #4 were scored as “neutral” relative to this criterion because it is perceived that the travel distances and, therefore, engine run times would be the same and approximately the same, respectively, as exist today. Site #2 was scored as “neutral” relative to this criterion because the travel times for functions for which the site is appropriate (e.g., mail) would be approximately the same as exist today. Site #3 was scored as “poor” relative to this criterion because of the increased travel distance to the site.

- **Impact on wetlands/creeks:** Sites #3 and #4 would likely affect sensitive natural resources and were scored as “poor” relative to this criterion. Sites #1 and #2 are currently developed and contain no sensitive natural resources; therefore, they were scored as “good” relative to this criterion.

- **Limits addition of impervious surfaces**: Sites #3 and #4 would likely increase impervious surfaces at the Airport and were scored as “poor” relative to this criterion. Sites #1 and #2 are presently developed and would not increase impervious surfaces at the Airport; therefore, they were scored as “good” relative to this criterion.

Social

- **Proximity to noise and light sensitive land uses:** Site #3 was scored as “poor” relative to this criterion because it would place cargo facilities closer to noise sensitive residential areas. Sites #1, #2, and #4 were scored as “neutral” relative to this criterion because the sites are furthest from residential areas.

- **Consistency with zoning:** All the sites were scored as “good” relative to this criterion because they are consistent with past plans.

- **Consistency with public expectations:** Sites #1, #3, and #4 were scored as “good” relative to this criterion because they are consistent with past plans that have been communicated to the public. Site #2 was scored as “neutral” relative to this criterion given its present use for flight kitchens.

5.3.4 *Site Screening Conclusions*

From the assessment and round 1 screening of the four potential cargo sites, the following conclusions were reached.

- Although not large enough to meet all cargo requirements, Site #1 is a desirable cargo site.
  - The location is good for cargo and not usable for passenger facilities.
  - The infrastructure is well developed—the aircraft hardstands are well located and the integrator (FedEx) warehouse is adequate and can be expanded when necessary.
- Site #2, currently occupied by flight kitchens, could effectively supplement Site #1.
- Site #3 is not suitable for primary cargo development.
- Site # 4 is the only site large enough to meet all cargo requirements.
- The preferred sites for cargo development are Site #1 – the north cargo area, and Site #4 – SASA.
- The opportunity to develop both Site #1 and Site #4 for cargo functions should be explored.

5.4 Identification and Assessment of Cargo Site Development Concepts

This section describes (1) alternative concepts for cargo development at Site #1 (existing north cargo area) and Site #4 (SASA), (2) concept assessments, (3) criteria used to screen the concepts, (4) the screening matrix and rationale for scoring the alternatives relative to the criteria, and (5) the conclusions reached based on the assessment and screening.

5.4.1 *Development Concepts Assessment*

The approach was to first prepare alternative concepts for cargo development at Site #1 (existing north cargo area) and then to develop alternative concepts for supplemental cargo development at Site #2 (SASA). In preparing these concepts, opportunities for Site #2 and Site #3 to accommodate supporting functions were considered.

Site #1 – North Cargo Area

Three alternative concepts for developing Site #1 were assessed. The concepts and their objectives, descriptions, and assessments are summarized on Figure 5-7.

Site #4 – SASA

Two alternative concepts for developing Site #4 were assessed. The concepts and their objectives, descriptions, and assessments are summarized on Figure 5-8.

5.4.2 *Development Concepts Screening*

The following criteria were used to screen the alternatives.

Economic/operational

- **Meets PAL 4 warehouse area requirements:** This criterion reflects the ability of a concept to meet the requirements for warehouse space.
- **Meets PAL 4 air freight hardstand requirements:** This criterion reflects the ability of a concept to meet the requirements for air freight aircraft hardstands (i.e., the required number and the appropriate proximity to the air freight warehouse).
- **Meets PAL 4 integrator hardstand requirements:** This criterion reflects the ability of a concept to meet the requirements for integrator aircraft hardstands (i.e., the required number and the appropriate proximity to the integrator warehouse).
- **Wayfinding to air freight warehouse:** This criterion reflects the relative ease or difficulty for cargo vehicle drivers to locate the air freight warehouses.
- **Wayfinding to integrator warehouse:** This criterion reflects the relative ease or difficulty for cargo vehicle drivers to locate the integrator freight warehouses.
- **Distance between air freight warehouses:** This criterion reflects judgment related to transshipment travel time (time to transport cargo between warehouses).

Environmental

- **Reduced engine run-time (ground vehicles):** This criterion reflects judgment related to emissions related to travel time between warehouses and the terminal gates by non-electric service vehicles (distance was used as a proxy for time).
- **Impact on wetlands/creeks:** This criterion reflects the potential for air cargo development to affect sensitive environmental areas.
- **Limits addition of impervious surfaces**: This criterion reflects the Port's desire to limit storm runoff, which is exacerbated by the addition of impervious surfaces.

Social

- **Proximity to noise and light sensitive land uses:** This criterion reflects the potential effects on nearby residential uses.
- **Consistency with zoning:** This criterion reflects the potential effects on nearby residential uses.
- **Consistency with public expectations:** This criterion enables the identification of sites that may not meet public expectations, and reflect commitments related to development in certain parts of the Airport.

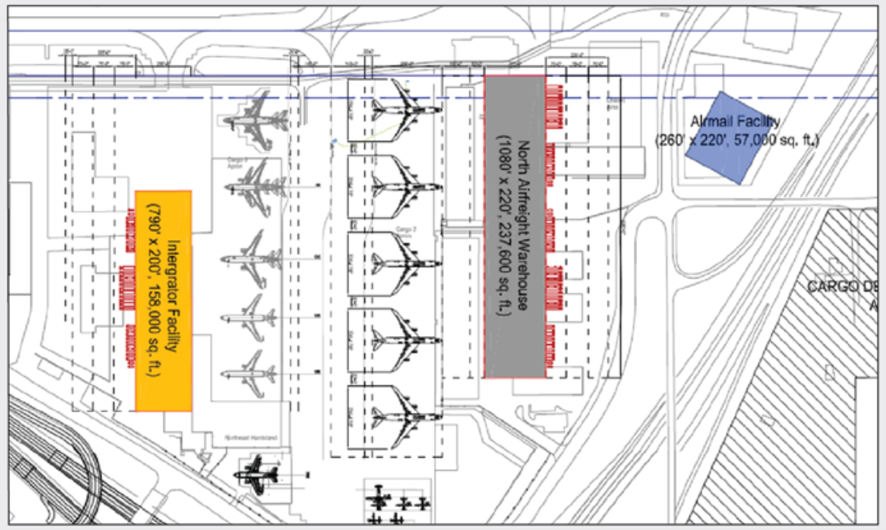
The completed screening matrix, shown on Figure 5-9, depicts how each site alternative was scored relative to each criterion

Figure 5-7

Cargo Site #1: Concept #1, Concept #2, and Concept #3

Seattle-Tacoma International Airport

Concept 1

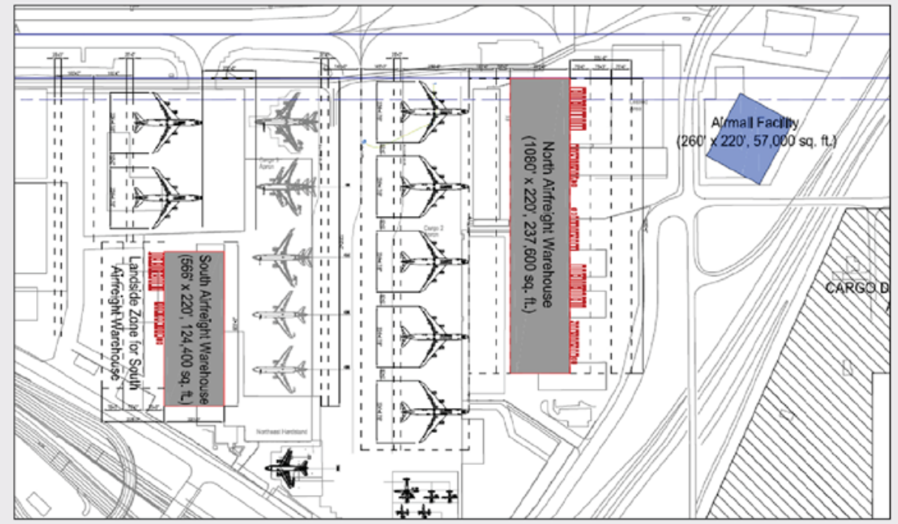


Objective: Determine how much of the forecast PAL 4 (2034) cargo requirements could be accommodated if the integrator (i.e., FedEx) warehouse remains in its existing location.

Description: Buildings 2, 3, 4, 5, and 6, identified in Figure 5-4, and collectively known as Transiplex, would be demolished and a new 237,600 square feet multi-user air freight warehouse constructed. Building #7 would be redeveloped only as required and if necessary. One of the flight kitchens, identified on Figure 5-4, would be relocated to Site #3. An airmail facility would be developed in the location currently occupied by the relocated flight kitchen.

Assessment: The air freight warehouse area and hardstands provided at Transiplex would be deficient by 124,400 square feet and three hardstands (two of which are domestic), respectively at PAL 4 (2034). Compared with the Century Agenda requirements, the air freight warehouse area provided at the site would be deficient by 296,400 square feet.

Concept 2



Objective: Determine how the site might be developed if all air freight requirements are satisfied in the north cargo area and integrator requirements are satisfied in SASA.

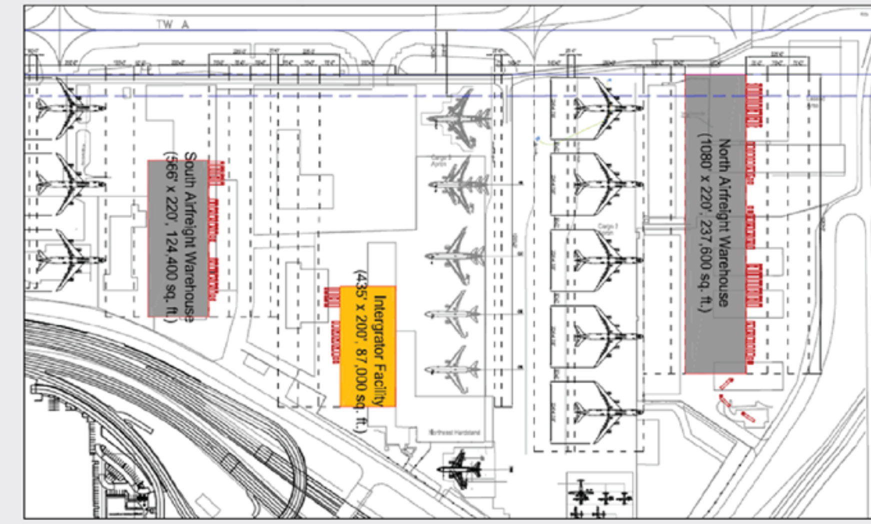
Description: Buildings 2, 3, 4, 5, and 6, identified in Figure 5-4 and collectively known as Transiplex, would be demolished and a new 237,600 square feet multi-user air freight warehouse constructed. Building #7 would be redeveloped to accommodate a 124,400 square feet air freight warehouse and additional freighter hardstands. A single airmail facility could be developed in the location currently occupied by one of the flight kitchens. Alternatively, airmail could be relocated to SASA.

Assessment: A new 237,600 square feet multi-user air freight warehouse and five air freight hardstands would be located on the Transiplex site. The warehouse area provided would be deficient by 124,400 square feet at PAL 4 (2034). Compared with the Century Agenda requirements, the warehouse area provided at the site would be deficient by 296,400 square feet.

A new 124,400 square feet air freight warehouse, located on the current integrator (FedEx) site, would satisfy the balance of the forecast air freight warehouse requirement for forecast PAL 4 (2034) activity. Seven freighter hardstands would be located adjacent to the warehouse. The north cargo area is not large enough to satisfy the Century Agenda PAL 4 (2034) air freight requirement.

The total number of freighter hardstands provided by Concept #2 would satisfy the forecast PAL 4 (2034) requirement.

Concept 3



Objective: Determine the extent to which the north cargo area would have to increase to accommodate all the forecast PAL 4 (2034) cargo requirements and assess the concept.

Description: Buildings 2, 3, 4, 5, and 6, identified in Figure 5-4 and collectively known as Transiplex, would be demolished and a new 237,600 square feet multi-user air freight warehouse constructed. Building #7 would be redeveloped only if necessary and the area to the south would be developed for air freight and freighter hardstands. One of the flight kitchens, identified on Figure 5-4, would be relocated to Site #3 if necessary and an air mail facility developed.

Assessment: A new 237,600 square feet multi-user air freight warehouse and five air freight hardstands would be located on the Transiplex site. The warehouse would be deficient by 124,400 square feet at PAL 4 (2034). An 87,000 square foot integrator warehouse would be located on the FedEx site. A 124,400 square feet warehouse and three air freight hardstands would be located to the south of FedEx. The hardstands deficient by three positions (two of which are domestic).

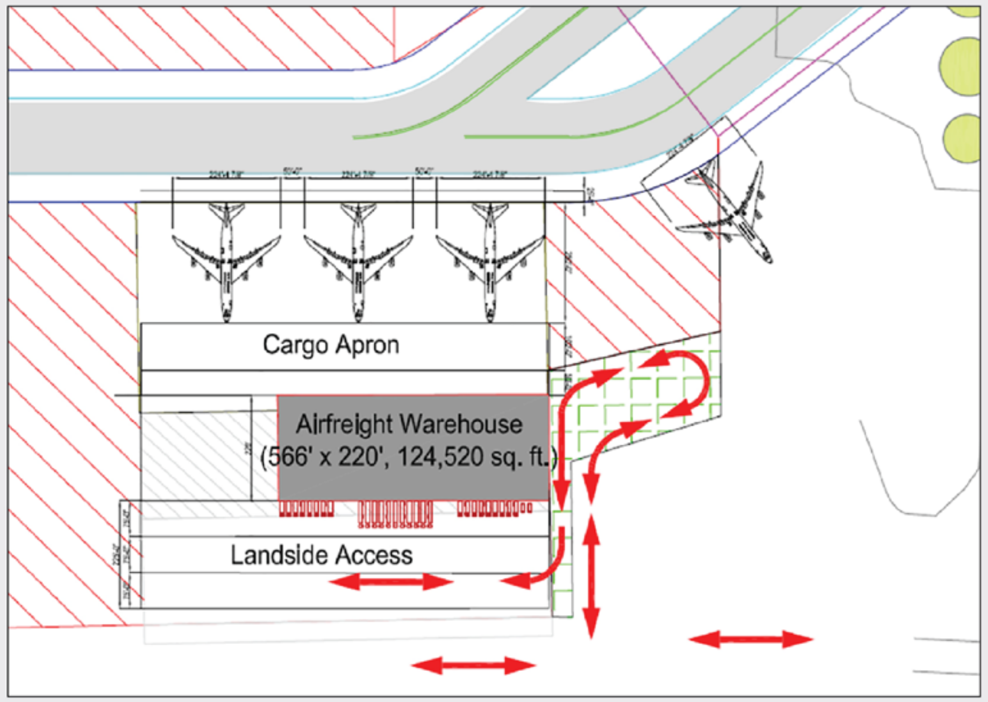
Concept #3 severely limits the utility of the area to the south of the existing FedEx facility. The area envisioned for Concept #3 is not large enough to satisfy the Century Agenda air freight requirement.

SEA850 F-0025

Source: Logplan, 2016.

Figure 5-8
Cargo Site #4: Concept #1 and Concept #2
Seattle-Tacoma International Airport

Concept 1



Objective: Provide airfreight warehouse capacity and freighter parking positions to supplement the facilities provided in the north cargo area.

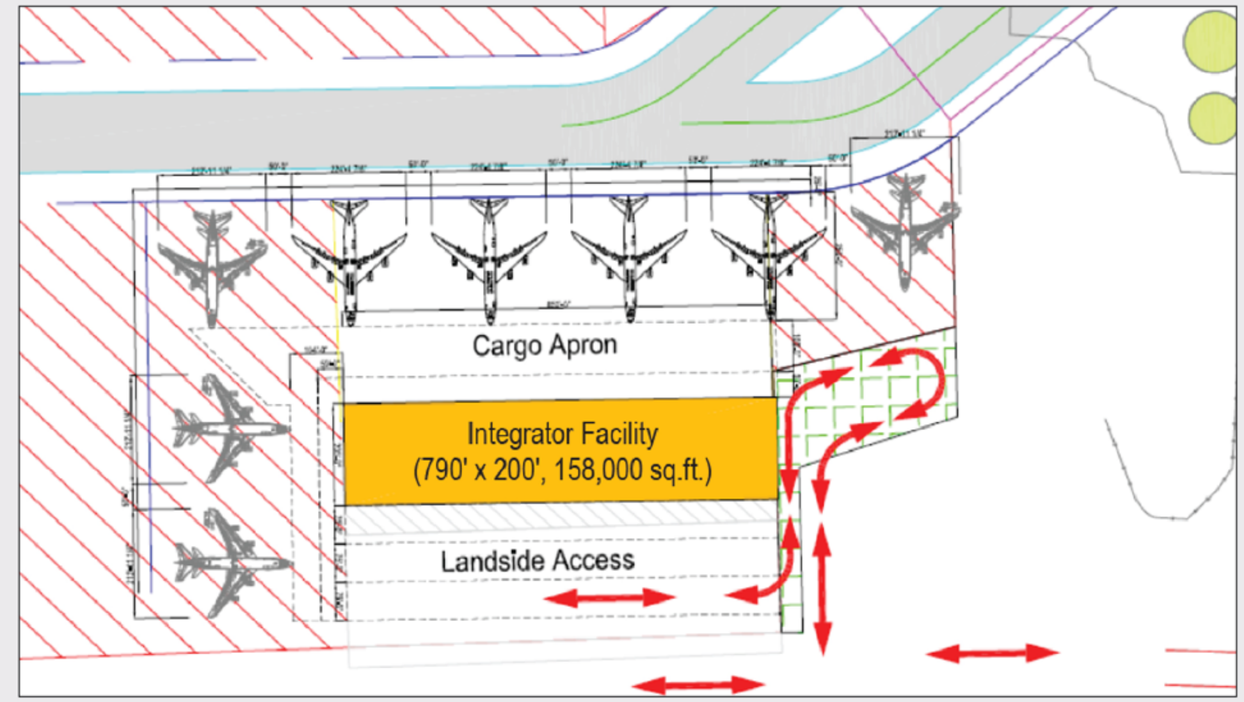
Description: Concept 1 would provide (1) an air freight warehouse to supplement the capacity provided by the North Cargo Area Option 1, in order to satisfy PAL 4 (2034) requirements, (2) space for three freighter hardstands, and (3) landside access to the site from south 199th Street.

Assessment: Concept #1 for Site #4, which complements Concept #1 for Site #1, would allow the forecast air freight requirements for PAL 4 (2034) to be satisfied.

Concept #1 provides the flexibility to increase air freight warehouse capacity to achieve the Century Agenda goal of 750,000 metric tons of cargo annually.

Concept #1 involves split air freight warehouse operations and a relatively long travel distance between the Site #4 and the Site #1 warehouses. This would increase the travel time for containers arriving on a freighter handled at the north cargo area and departing on a freighter handled at SASA.

Concept 2



Objective: Demonstrate how SASA might be developed to satisfy all integrator freight requirements.

Description: An integrator warehouse up to 790 feet in length and 200 feet in depth could be developed, using the same airside dimensional characteristics applicable to the Site #1 Concept #1 options, described on Figure 5-7.

Assessment: Concept #2 for Site #4, which complements Concept #2 for Site #1, would allow the integrator requirements for PAL 4 (2034) to be satisfied.

Concept #2 provides the flexibility to increase integrator warehouse capacity if necessary (e.g., should an airmail facility adjacent to the integrator warehouse be needed), or to achieve the Century Agenda cargo objective.

Source: Logplan, 2016.

Figure 5-9
Cargo Site Development Assessment Summary
Seattle-Tacoma International Airport

Criteria	Concept #1 Site #1 - Air freight & integrator freight Site #4 - Overflow air freight	Concept #2 Site #1 - Air freight Site #4 - Integrator freight
Meets PAL 4 warehouse area requirements	1	1
Meets PAL 4 air freight hardstand requirements	-1	1
Meets PAL 4 integrator hardstand requirements	-1	1
Wayfinding to air freight warehouse	0	1
Wayfinding to integrator warehouse	1	1
Distance between air freight warehouses (transshipment time)	-1	1
Reduced engine run time (ground vehicles)	0	0
Impact on wetlands/creeks	0	-1
Limits addition of impervious surfaces	0	-1
Proximity to noise and light sensitive land uses	Not a differentiator	
Consistency with zoning	Not a differentiator	
Consistency with public expectations	Not a differentiator	

-1	poor/undesirable
0	neutral
1	good

Source: LeighFisher, Corgan Associates, and Port of Seattle Staff, 2016.

The rationale for scoring against the screening criteria is summarized below.

Economic/operational

- **Meets PAL 4 warehouse area requirements:** Concept #1 and Concept #2 were scored "good" relative to this criterion because both can meet the warehouse area requirements.

- **Meets PAL 4 air freight hardstand requirements:** Concept #1 was scored "poor" relative to this criterion because the required number of hardstands cannot be sited adjacent to the warehouses. Concept #2 was scored "good" relative to this criterion because the required number of hardstands can be sited adjacent to the warehouses.

- **Meets PAL 4 integrator hardstand requirements:** Concept #1 was scored "poor" relative to this criterion because the required number of hardstands cannot be sited adjacent to the warehouses. Concept #2 was scored "good" relative to this criterion because the required number of hardstands can be sited adjacent to the warehouses.

- **Wayfinding to air freight warehouse:** Wayfinding to the air freight warehouses would more difficult for Concept #1 than for Concept #2 because the warehouses would not all be in the same location (i.e., Concept #1 incorporates "split" facilities and Concept #2 does not); therefore, Concept #1 was scored "poor" and Concept #2 was scored "good" relative to this criterion.

- **Wayfinding to integrator warehouse:** It is believed that wayfinding would be about the same for either Concept #1 or Concept #2; each was scored "good" relative to this criterion.

- **Distance between air freight warehouses:** Concept #1 was scored "poor" relative to this criterion because the air freight warehouses are in two locations and transshipment time between the warehouses would increase. Concept #2 was scored as "good" relative to this criterion because transshipment times would remain relatively unchanged from today.

Environmental

- **Reduced engine run-time (ground vehicles):** Both Concept #1 and Concept #2 were scored "neutral" relative to this criterion because each concept would require aircraft engine run times greater than existing times. At this level of definition, there is no clear differentiator for this criterion.

- **Impact on wetlands/creeks:** Both Concept #1 and Concept #2 require the development of Site #4 (SASA). Concept #2 would require the bigger area and, therefore, was judged to have the bigger potential impact on wetlands/creeks. Concept #1 and Concept #2 were scored as "neutral" and "poor," respectively, relative to this criterion.

- **Limits addition of impervious surfaces:** Concept #2 requires greater additional new impervious surface and was scored "poor," whereas Concept #1 requires less additional impervious surface and thus was scored "neutral" to differentiate it from Concept #2.

Social

- **Proximity to noise and light sensitive land uses:** Both Concept #1 and Concept #2 require the development of Site #4 (SASA) and, therefore, were judged to be approximately equal in terms of this criterion and scored "neutral." Both concepts could have been scored "poor," but such scoring would not alter the conclusion as to the better performing concept.

- **Consistency with zoning:** Both Concept #1 and Concept #2 require the development of Site #4 (SASA) and, therefore, were judged to be approximately equal in terms of this criterion and scored "neutral." The criterion was not a differentiator as the Port has identified SASA development for 20 years as well as the improved North cargo area.

- **Consistency with public expectations**: Both Concept #1 and Concept #2 require the development of SASA and, therefore, were judged to be approximately equal in terms of this criterion and scored "neutral." The criterion was not a clear differentiator.

5.4.3 Development Concepts Screening Conclusions

The concepts for developing Site #1 and Site #4 assume (1) cargo-related development must occur on both sites and (2) that two concepts for coordinated overall Airport cargo development exist. Therefore, from the perspective of overall Airport development, Concept #1 refers to the implementation of both Concept #1 at Site #1 and Concept #1 and Site #4. Concept #2 refers to the implementation of both Concept #2 at Site #1 and Concept #2 at Site #4.

From the assessment and screening, described in the previous sections, the following conclusions were reached:

- Either Concept #1 or Concept #2 can meet the PAL 4 requirements and provide the potential to implement different facilities and a different business model should it be appropriate to pursue the Commission Century agenda goal of 750,000 metric tons per year of cargo.

- Concept #2 meets the PAL 4 (2034) cargo hardstand requirements; Concept #1 does not.

- Wayfinding to air freight warehouses may be easier with Concept #2 than with Concept #1 because the air freight warehouses will be at one location rather than two locations.

- Cargo transshipments will be easier with Concept #2 than with Concept #1 because the air freight warehouses are at a single location.

- The preferred long-term cargo development concept is Concept #2, which is to develop Site #1, the North Cargo Area, for air freight and to develop Site #4, SASA, for integrator freight.

High-level concepts related to the relocations of existing tenants and the phased construction necessary to redevelop the Transiplex facilities are essential to the near-term success of Concept #2. These concepts should be developed during subsequent SAMP tasks. Similarly, projects that will enable the longer-term success of Concept #2 (e.g., SASA site development) and their approximate timing should be determined.

Port staff should consider developing a detailed cargo phasing plan and strategy immediately. The recommended cargo development concept will involve renegotiating leases, relocating existing tenants and functions (e.g., airmail), the completion of enabling projects, the completion of environmental and permitting processes, the and the interim use of facilities that must be demolished as quickly as possible to permit the construction of passenger facilities.

Airline Support

The most pressing issue related to Airport support facilities is the need to relocate existing airline maintenance hangars to provide additional off-gate parking positions.

6.1 Introduction

Airline support facilities include aircraft maintenance hangars, flight kitchens, ground handling service facilities, fuel storage and distribution facilities, and office space. This chapter summarizes objectives, approach, scope, assumptions, and recommendations related to the alternatives for airline support facilities considered in the SAMP.

6.2 Aircraft Maintenance Hangars

From the airfield simulation analyses, it was concluded that Alaska Airlines' two aircraft maintenance hangars and Delta Air Lines' single aircraft maintenance hangar must be relocated to provide the space necessary for higher-priority off-gate aircraft parking (to accommodate arriving aircraft awaiting gates, departing aircraft awaiting their departure sequence, and aircraft with long dwell times that must be towed from contact gates). From analyses related to on-Airport land development, it was concluded that two areas exist for potentially locating replacement aircraft maintenance hangars—the north cargo area and SASA. Three alternatives for developing aircraft maintenance hangars were considered for these areas:

- **Alternative 1:** Construct all replacement aircraft maintenance hangars on or in the vicinity of the north cargo area.
- **Alternative 2**: Construct some replacement aircraft maintenance hangars in the north cargo area and some replacement aircraft maintenance hangars in SASA.
- **Alternative 3**: Construct all replacement aircraft maintenance hangars in SASA.

Alternative 1 was rejected because there is insufficient space to accommodate the hangars and some air cargo activity without encroaching on space needed for higher priority off-gate aircraft parking.

Alternative 2 was rejected because (1) there is insufficient space in the north cargo area to accommodate one or more hangars and some air cargo activity without encroaching on space needed for higher priority off-gate aircraft parking, and (2) locating aircraft maintenance hangars in both the north cargo area and SASA would require two engine run-up facilities rather than one.

Alternative 3 was selected as the concept of focus because it allows the most effective use of the space available and permits the Port to achieve its objective of reducing noise generated by aircraft engine testing with a single engine run-up facility.

The most significant assumption related to the alternatives for aircraft maintenance functions was that those functions cannot be accommodated at another airport. Both Alaska Airlines and Delta Air Lines representatives stated that the hangars are essential to their passenger operations at the Airport.

6.3 Flight Kitchens

There are currently three providers of aircraft food and beverage services to the airlines (i.e., flight kitchens) operating at the Airport—Gate Gourmet, Flying Foods, and SkyChef. For the purposes of SAMP, it is assumed:

- The airlines are responsible for meeting their needs related to flight kitchens.
- The Gate Gourmet flight kitchen (located adjacent to the Doug Fox lot) will be demolished to make available space for the north terminal and associated parking. If other Port-owned property is available, it will be offered as a replacement site.
- The Flying Foods and SkyChef flight kitchens (located to the north of the North Cargo Area) will be permitted to remain as long as the properties are not needed for higher-priority functions (e.g., cargo). If the properties are needed and no other alternative properties are available, the facilities will be demolished to make the space available.

6.4 Ground Handling Services Facilities

Airline ground handling services include aircraft cargo and baggage loading and unloading, fueling, de-icing; baggage sorting, ground power service, aircraft push-back and towing, aircraft cleaning, aircraft security, and ground service equipment repair and maintenance. Ground handling services are currently provided at the Airport by airline personnel and third party providers, Aircraft Service International Group and Swissport, operating from leased facilities.

Because the Airport is land poor, most facilities from which ground handling services are currently provided will be demolished to allow the development of additional gates. The specific requirements and alternatives for replacement facilities will be determined during advanced planning, which will occur after the SAMP is completed. To ensure that alternatives exist for replacing ground handling services facilities, the SAMP identified areas that, as the Airport is redeveloped, could accommodate new ground handling services facilities. Such areas include the redeveloped north cargo area and SASA.

6.5 Fuel Storage and Distribution Facilities

Fuel storage requirements range from a low of 6.1 million gallons to over 35 million gallons over the planning period, depending on the desired amount of reserve fuel and the level of activity at the Airport. Planning for the most demanding scenario in 2034 with 10 days fuel reserves would require setting aside an additional 5 to 6 acres for storage capacity to supplement the existing 9.48 acre site. Property to the east and south of the existing tank farm provides an ample supply of land for future expansion of the tank farm as the need arises and should be reserved for expansion of the fuel farm. The key conclusions related to fuel storage are (1) sufficient land is available adjacent to the existing fuel farm and (2) decisions related to the volume and timing of incremental fuel storage facilities will be driven by airlines.

In addition to providing more storage capacity, the other strategy for maintaining fuel reserves would be to increase the frequency of deliveries or the quantity of fuel in each delivery to the fuel farm. Jet fuel is delivered to the Airport from multiple refineries in Northern Washington via the Olympic Pipeline. An additional pipeline between the Airport fuel farm and the Olympic Pipeline's Renton Terminal should be considered to provide redundancy in the case of a failure or maintenance issues related to the existing pipeline. Following completion of the SAMP, it is recommended that discussions be undertaken with SeaTac Fuel Facilities Inc. to determine its interest in this project.

The existing underground fuel hydrant system (i.e., the fuel distribution system) is well maintained and should be expanded to meet future fueling needs as the Airport's gate facilities are expanded. Decisions related to the fuel distribution system should be made during advanced planning and design.

6.6 Office Space

It is assumed that (1) the amount of space available for airline offices will increase in the future as additional passenger terminal and gate facilities are provided, (2) the specific needs for office space will be programmed as part of advanced planning that will occur following completion of the SAMP, and (3) the Port will continue to reallocate existing office space to meet changing future needs.

Airport Support

The most pressing issue related to airline support facilities is the displacement of aviation maintenance and airport rescue and firefighting facilities to permit the development of new gates.

7.1 Introduction

Airport support facilities include aviation maintenance facilities, aircraft rescue and firefighting facilities, and an aircraft ground run-up enclosure. This chapter summarizes the objectives, approach, scope, assumptions, and recommendations related to the alternatives for airport support facilities.

7.2 Aviation Maintenance Facilities

Seven sites were reviewed to determine their suitability to satisfy the requirements for aviation maintenance facilities, described in Section 7.2 of *Technical Memorandum No. 5 - Facility Requirements*. Figure 7-1 illustrates the locations of the potential sites. The criteria for assessing the suitability of the potential sites were (1) access to public streets and the airfield, (2) availability within 5 years, and (3) the potential for expansion.

After assessing the sites relative to the criteria, Sites A, B, D, E, and F were found to be unsuitable for the following reasons:

- Site A (South Aviation Support Area) is not available within the next 5 years and is also programmed for other uses
- Site B (snow shed area) may be impacted by an end-around taxiway in the future and is too small to accommodate the functions currently located at Cargo 4.
- Site D (north side batch plant site) may be impacted by an end-around taxiway in the future.
- Site E (transiplex cargo area) is too small and is needed for higher priority cargo functions.
- Site F (L-shaped) does not have direct airfield access and the cost to provide access is considered excessive (a new bridge over SR518 would be required).

Site C, the west side construction trailer site, is the only viable site to accommodate the relocated Cargo 4 and snow shed maintenance facility function which, in total, would require approximately 13 acres. Site C is built-up almost level with the airfield. Including the two drainage ponds, the potentially developable area is approximately 17 acres.

Site C was used for construction access during the construction of Runway 16R-34L and has access to public streets via S. 168th Street and access to the airfield perimeter road via a gate in the perimeter fence. Development of the site would require earthwork (fill) to level the site and relocation of the drainage ponds to maximize the area available. Buildings will have to be sited with careful review of potential impacts to the Airport's protected airspace (i.e., TERPS surfaces), the function of the ASR-9 radar located immediately to the west and other electronic navigation aids located near the adjacent Runway 16R-34L, and sensitive environmental areas. Additional study will be needed to during advanced planning to determine the potential impacts on those facilities and environmentally sensitive areas, as well as methods to mitigate those impacts.

Figure 7-1
Potential Sites for Relocated Maintenance Facilities and Shops
Seattle-Tacoma International Airport

Source: Corich Group, 2016.

7.3 Aircraft Rescue and Firefighting Facilities

As described previously, the demand for developable land on the east side of the Airport near the existing fire station exceeds the supply. Nevertheless, to meet requirements related to fuel spill, medical, and structural responses, a fire station must be located on the east side of the airfield near the passenger terminal. The existing station location meets the requirements very well. Therefore, a replacement site close to the existing station would continue to meet the requirements best. Moving away from the existing location will result in slower response times for fuel spill, medical, and structural responses at the passenger terminal.

The existing station occupies an area of approximately 3.5 acres. As requirements for the Fire Department and the Airport have grown over the years, the station has been added to and modified in ways that have created an inefficient footprint. There are also new vehicles that need to be stored and maintained that cannot be accommodated in the existing station. To meet current demands, a new station at a single location (i.e., a single-station concept) would require between 3.5 and 4 acres. This is a significant amount of land on the east side of the Airport; however, from an operational standpoint, a single station would be the best alternative for the Fire Department. A single station would promote better use of staff and equipment and would facilitate training by having all staff located in one station.

In recognition of the scarcity of land on the east side and also to maintain critical emergency response to the airfield and terminal building, it would be possible to locate the Fire Department's functions in two stations (i.e., a dual-station concept)—one on the east side of the Airport and the other on the west side of the Airport. In a dual-station configuration, a footprint of two acres per station was considered for planning purposes.

Seven potential fire station locations were identified and evaluated. The potential station locations are identified as 1 through 7 on Figure 7-2, and the results of the evaluations are summarized below.

- Station Site 1 provides the best station site on the east side of the airfield. Located close to the existing station, it is centrally located to both the airfield and the terminal, allowing emergency responders to meet all the emergency response requirements outlined above. Development at this site will impact terminal development. A single-station site would require a site of up to 4 acres. If combined with a west-side station at Site 5, the footprint could be halved.

- Station Sites 2 and 4 were eliminated for operational reasons related to airfield response time. Located at the far south and north ends of the Airport respectively, both sites are negatively impacted by airfield operations. During busy aircraft departure periods, it would be difficult for ARFF to meet FAA emergency response-time targets because of aircraft queues at the departure ends of the runways.

- Station Site 3 could also function as a site for either the single-station or dual-station concept. Response times to the terminal for medical, fire, or fuel spills will be longer than for the existing station location (Site 1). Site 3 is approximately 3,300 feet further north from the passenger terminal than Site 1 and thus would require an additional 1 minute 19 seconds of travel time to respond to medical emergencies in the passenger terminal. This will be most critical for the high percentage of medical calls where the current response times average less than 2 minutes. As a single station, it would require a site of up to 4 acres. If combined with a west side station at Site 5, the footprint could be halved to 2 acres.

Figure 7-2
Potential Locations for Future Fire Stations
Seattle-Tacoma International Airport

Source: Corich Group, 2016.

- Station Site 5 would only be a viable station site if paired with another station on the east side of the airfield. Emergency vehicles traveling to the passenger terminal could experience unacceptable delays waiting for aircraft traffic to clear prior to obtaining clearance to cross the airfield by the FAA air traffic controllers. This delay could be life threatening and is unacceptable. The location of station Site 5 for ARFF response to the airfield is ideal. It is in the approximate center of the west runway and the site is currently one of the only areas on the west side that is built up to be close to the elevation of the airfield. Therefore, in a dual-station configuration, the east side station would remain the main station housing one ARFF crash truck, the structures fire truck, and the care car along with vehicles for supervisory staff. The Department administration staff would also be housed in the east station. The west station would include two active duty ARFF vehicles, the mass casualty response vehicle, the hazardous materials response vehicle, the associated emergency response staff, a variety of backup vehicles, and the fire prevention staff.

- Site 6, which assumes a fire station integrated with extended Concourse D, is the second best location on the east side of the airfield. Any development at Site 6 would affect the development and operation of gates.
- Site 7 is not large enough to be a candidate for a single-station solution. However, it would permit airfield response times to be met and, similar to Site 5, would be a viable station location if paired with another station on the east side of the airfield. The utilization of Site 7 for an ARFF station assumes the Weyerhaeuser Corporation lease is terminated.

The conclusions from the site assessment were that (1) a dual-station concept is preferred, and (2) Site 6 and Site 7 sufficiently meet the Airport's long-range ARFF requirements and are the preferred locations for east-side and west-side fire stations, respectively, and (3) the program and concepts for developing new fire-fighting facilities on these sites will be developed during advanced planning.

7.4 Aircraft Ground Run-up Enclosure

The ground run-up enclosure must be located nearby the aircraft maintenance hangars. Therefore, the preferred alternative location for the ground run-up enclosure is SASA. The program and concept for this facility will be developed during advanced planning. Previously developed concepts for a ground run-up enclosure are shown in Appendix F.

7.5 Centralized Receiving Warehouse

Goods utilized by the Airport's concessionaires currently arrive via multiple daily semi-truck deliveries. The trucks enter the Airport through security gates and travel across the apron to reach multiple receiving docks where goods are unloaded.

A centralized receiving warehouse is required to (1) eliminate unneeded vehicle traffic from the apron, (2) provide a single location for all Airport deliveries, and (3) enhance security by providing a centralized location at which all Airport deliveries are inspected, prior to delivery to concessionaires. The program and plan for a centralized receiving warehouse should be developed in advanced planning.

7.6 Trash, Recycling, and Compost

Trash collecting, recycling, and composting functions are currently accomplished using dumpsters and compactors at several locations in the terminals and on the airfield. The current facilities are at or nearing capacity and have no room to accommodate growth. The operational "work arounds" currently employed to manage the solid waste streams are increasingly difficult, costly, and are generating significant additional waste hauler truck traffic within the Airport Operations Area.

The requirement is for a centralized waste processing facility at which compactors and dumpsters may be dropped off and picked up and waste may be sorted and pre-processed. Such a facility is expected to facilitate the Port's ability to manage the movement of waste, minimize long-term costs, free airfield space for higher and better uses, contribute to more sustainable operations, and keep third-party waste hauling trucks off the airfield. The program and plan for a centralize waste processing facility should be developed in advanced planning.

7.7 Utilities

As discussed in Section 7.7 of *Technical Memorandum No. 5 – Facilities Requirements*, the Airport's existing utility infrastructure and the supply of supporting regional infrastructure (e.g., power, water, and sewerage) are generally adequate to meet current and future needs. The recommended approach to satisfying project-specific requirements is to conduct the appropriate analyses during detailed planning and design efforts that will follow the SAMP.

General Aviation

The itinerant general aviation area will remain unchanged.

Consistent with the Port's philosophy of compliance with FAA grant assurances, it is recommended that the site utilized to accommodate itinerant GA aircraft (i.e., the site accommodating both the FBO building and itinerant GA aircraft apron) be retained. It is adequate to accommodate demand through PAL 4 (2034); no increase in size is recommended.

However, there is no requirement to continue leasing the land adjacent to the itinerant GA apron to the Weyerhaeuser Corporation for its corporate hangar. It is recommended that the Weyerhaeuser Corporation's lease be terminated and the area be made available for a second ARFF station.

Comprehensive Airport Development

The preferred long-range plan for developing the Airport has been identified. Further planning related to the airfield and its operation is needed.

Following the process in which alternatives for the individual functional areas of the airport were identified and evaluated, the preferred alternatives for the individual areas were combined. This resulted in (1) identifying the vision for comprehensive long-range Airport development and (2) the conclusion that, in terms of its breadth and cost, comprehensive Airport development will be determined by five elements. These elements are summarized below and their locations are shown on Figure 9-1.

- **Gates**: There is only one reasonable location for new gates—to the north of existing Concourse D and the North Satellite. Providing gates in this location forces the relocation of numerous existing facilities including the fire station, cargo warehouses, and the Airport's primary maintenance complex.

- **Off-gate aircraft parking**: Additional off-gate aircraft parking positions are required to support the forecast volume of aircraft activity. Additional positions will be needed both to the north and south of the gates, the need will occur as early as PAL 2, and there are only two feasible locations as shown on Figure 9-1. The positions to the north will limit the area that can be developed for cargo. The positions to the south will result in the need to relocate three aircraft maintenance hangars and one cargo warehouse.

- **Cargo**: The existing north cargo area is suitably located, but its facilities must be redeveloped to ensure greater productivity. Even with the greater productivity envisioned, the north cargo area cannot satisfy the requirements for forecast cargo activity or the even greater requirements of the Century Agenda. Therefore, another cargo area with access to both the airfield and the public roadway system must be developed.

- **Airline aircraft maintenance**: Representatives from Alaska Airlines and Delta Air Lines, whose hangars would be displaced by the preferred long-range development plan, have stated that their operations require maintenance hangars located at the Airport. The new location or locations for the hangars must be on the east side of the airfield (to avoid delay-causing runway crossings) and must provide access to both the airfield and the public roadway system.

- **SASA**: SASA is the only Airport property that can be developed to satisfy long-term cargo and aircraft maintenance needs resulting from the accommodation of passenger activity on a severely constrained Airport site.

The conclusions from the initial identification of a comprehensive alternative for developing the entire Airport were (1) there appears to be only one area of the Airport in which multiple functions are competing for the same land (i.e., a "contested" area) and (2) decisions for developing other areas of the Airport (i.e., "uncontested" areas) appear to be relatively uncomplicated.

The contested area is the north cargo area. The functions competing for the space are cargo, aircraft maintenance hangars, and an aircraft ground run-up enclosure, which needs to be located near the hangars. Given (1) the effectiveness of the north cargo area geometry and (2) that aircraft maintenance hangars could function in either the north cargo area or SASA, it was concluded that the north cargo area should remain relatively intact and, in the long-term, airline maintenance functions belong in SASA. The preferred long-range plan for developing the entire Airport is illustrated on Figure 9-2.

The key conclusions related to elements of comprehensive Airport development in uncontested areas of the Airport are summarized below.

- **Airfield:** The major airfield development envisioned includes dual Taxiways A and B at the south end of the Airport, end-around-taxiways, taxiway changes to ensure compliance with FAA design criteria, and the creation of deice pads adjacent to the thresholds of Runway 16L and Runway 34R. The effects on airfield operations of changes to individual airfield components are related to both the overall configuration of the airfield as well as the way it is operated. Therefore, a comprehensive study of potential changes to the airfield is planned following completion of the SAMP. The study will involving appropriate local , regional, and national FAA staff as well as stakeholders.

- **Passenger terminal:** The significant terminal development envisioned includes 35 new gates; a new north terminal (located on the existing Doug Fox lot); modifications to the existing terminal as necessary to meet demand until the second terminal is opened or to renew aging infrastructure; and off-gate aircraft parking positions at the north and south ends of the terminal envelope. Requirements for gates and off-gate aircraft parking positions cannot be met unless SASA is developed to accommodate displaced aircraft maintenance hangars and cargo facilities.

- **Landside and parking:** The significant landside and parking development envisioned includes roadway realignments to facilitate the extension of Concourse D and construction of the north gates, a widened approach to the lower drive, roadways providing ingress/egress to the north terminal, a north terminal parking garage, relocated and expanded employee parking, relocated and expanded ground transportation holding lots, a new cell phone lot, and a pre-security (i.e., non-secure) APM to transport passengers between the passenger terminals and the rental car facility, thus eliminating bus traffic from the congested roadways.

- **Air cargo:** Significant air cargo facilities development will be required to enable redevelopment of existing facilities on the far north of the north cargo area and to accommodate growth in cargo tonnage and corresponding freighter operations. Cargo requirements cannot be satisfied unless the SASA is developed.

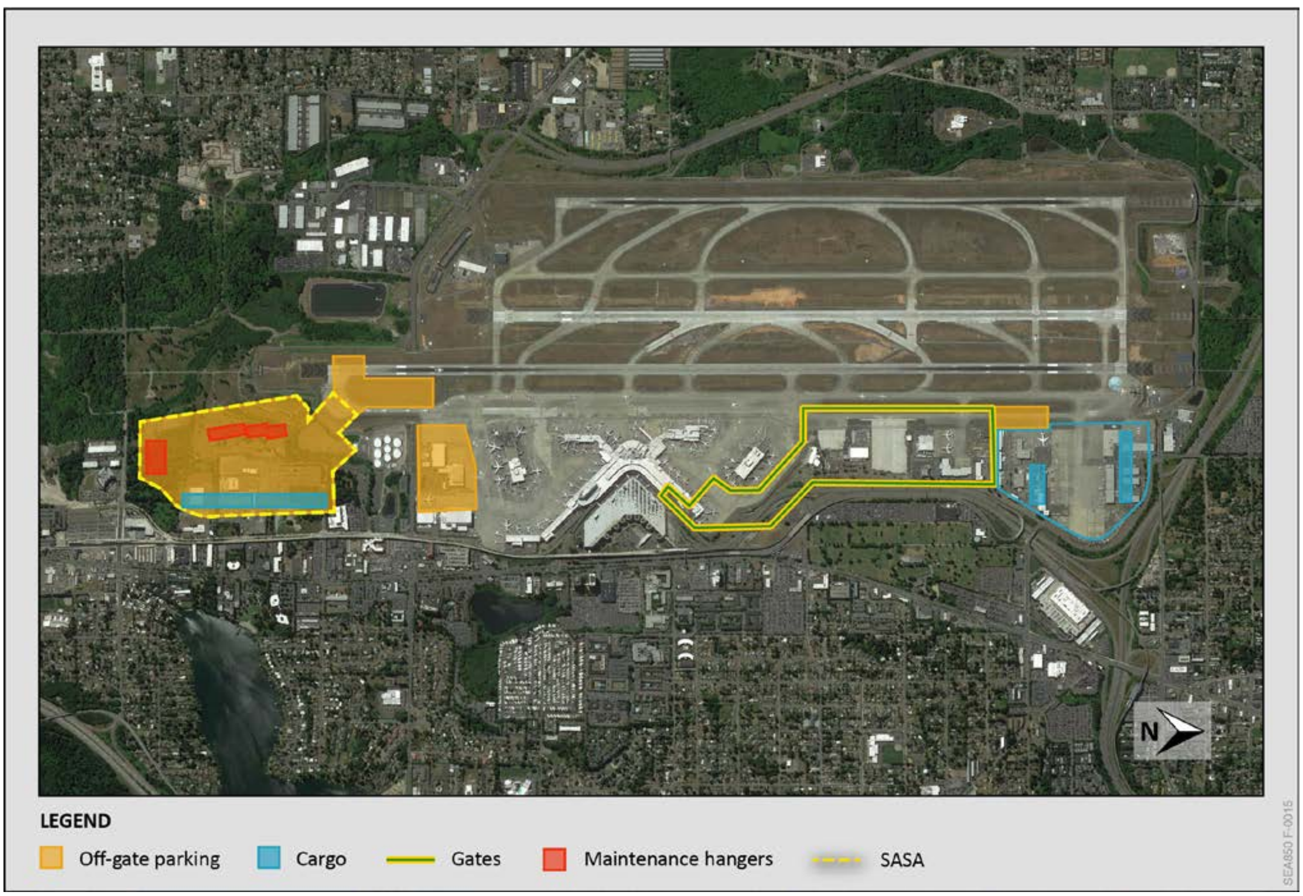
- **Airline support:** The significant airline support development envisioned includes additional jet fuel storage tanks, fuel rack and fuel truck parking, deicing and deice truck parking, and airline aircraft maintenance hangars to replace those displaced to provide off-gate aircraft parking positions.

- **Airport support (west-side maintenance):** The significant airport support development envisioned includes a new west-side maintenance campus, a centralized warehouse and centralized trash/recycling/composting facility located on Port property to the north of SR 518, and two new fire stations.

- **General aviation:** The itinerant general aviation area will remain relatively unchanged and a new Airport fire station will be developed on the site of the existing Weyerhaeuser hangar.

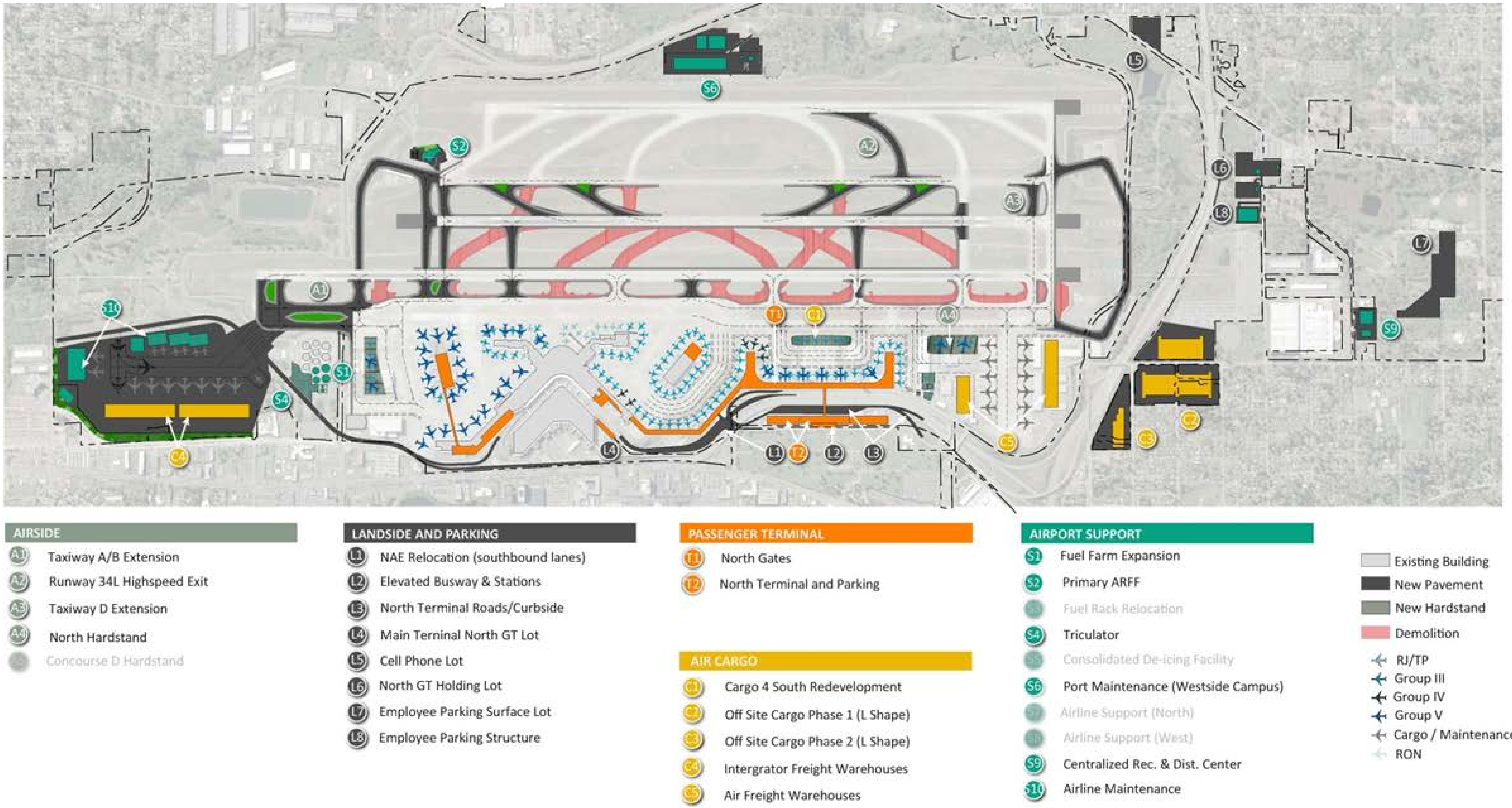
Elements of the preferred long-range plan recommended for implementation will be determined by issues such as financial feasibility and phasing; such issues will be resolved during subsequent tasks (i.e., financial feasibility and long-range strategy).

Figure 9-1
Elements Driving Long-Term Airport Development
Seattle-Tacoma International Airport



Source: LeighFisher, 2016.

Figure 9-2
Vision for Comprehensive Long-range Airport Development
Seattle-Tacoma International Airport



Source: Port of Seattle and LeighFisher, 2016.

Appendix A

Alternative Passenger Terminal Development Concepts

Figure A-1
ALTERNATIVE 1A – "ONE TERMINAL" OPTION (PASSED ALL THRESHOLD CRITERIA)
Seattle-Tacoma International Airport

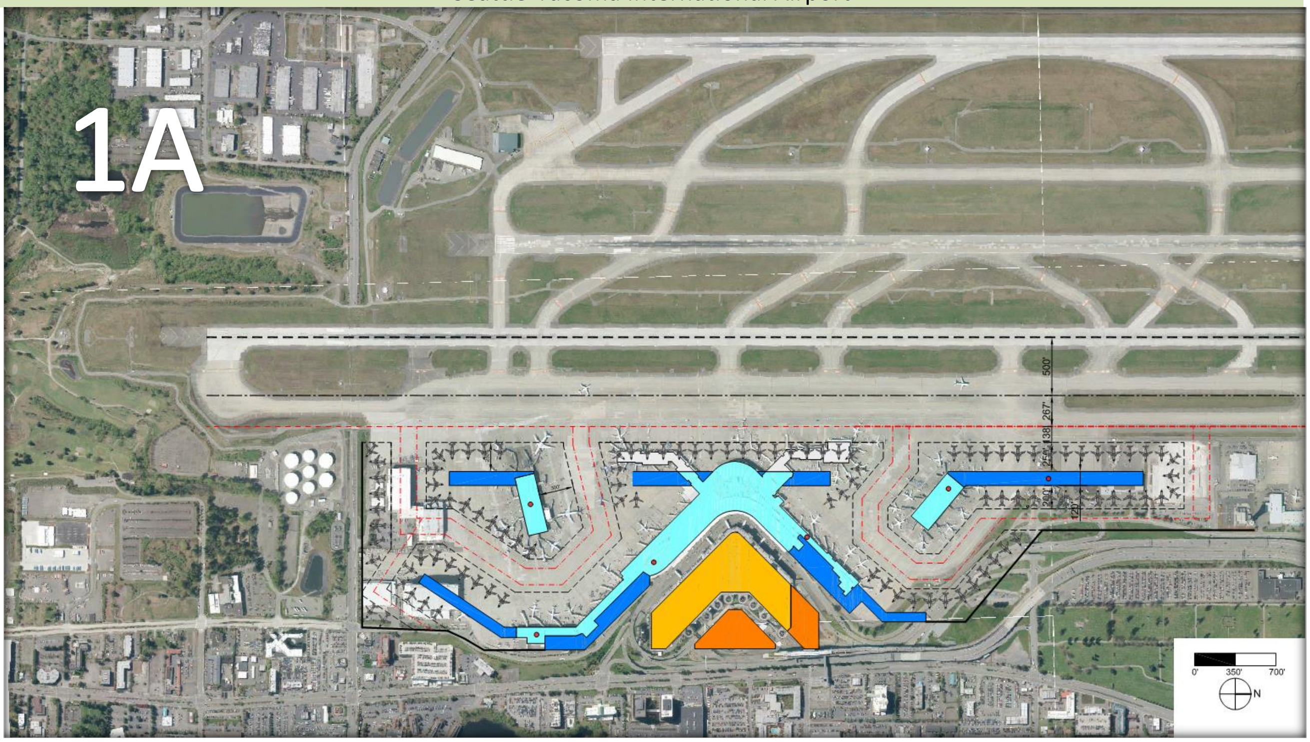
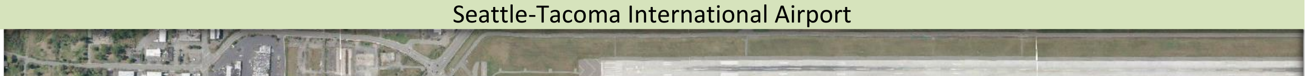
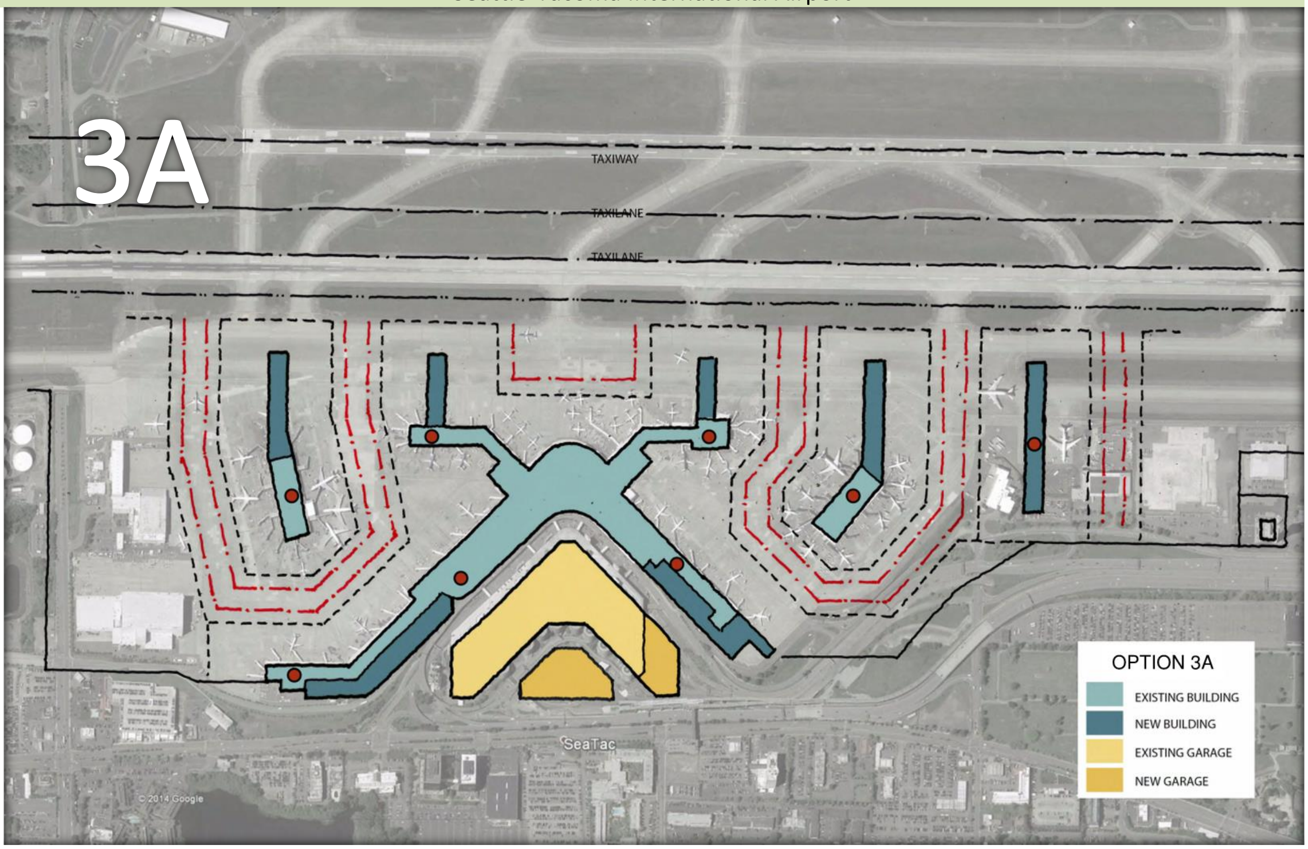


Figure A-2
ALTERNATIVE 2A – "ONE TERMINAL" OPTION (PASSED ALL THRESHOLD CRITERIA)
Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

Figure A-3
ALTERNATIVE 3A – "ONE TERMINAL" OPTION (FATALLY FLAWED – ELIMINATED)
Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

Figure A-5
ALTERNATIVE 4A – "ONE TERMINAL" OPTION (PASSED ALL THRESHOLD CRITERIA)
Seattle-Tacoma International Airport

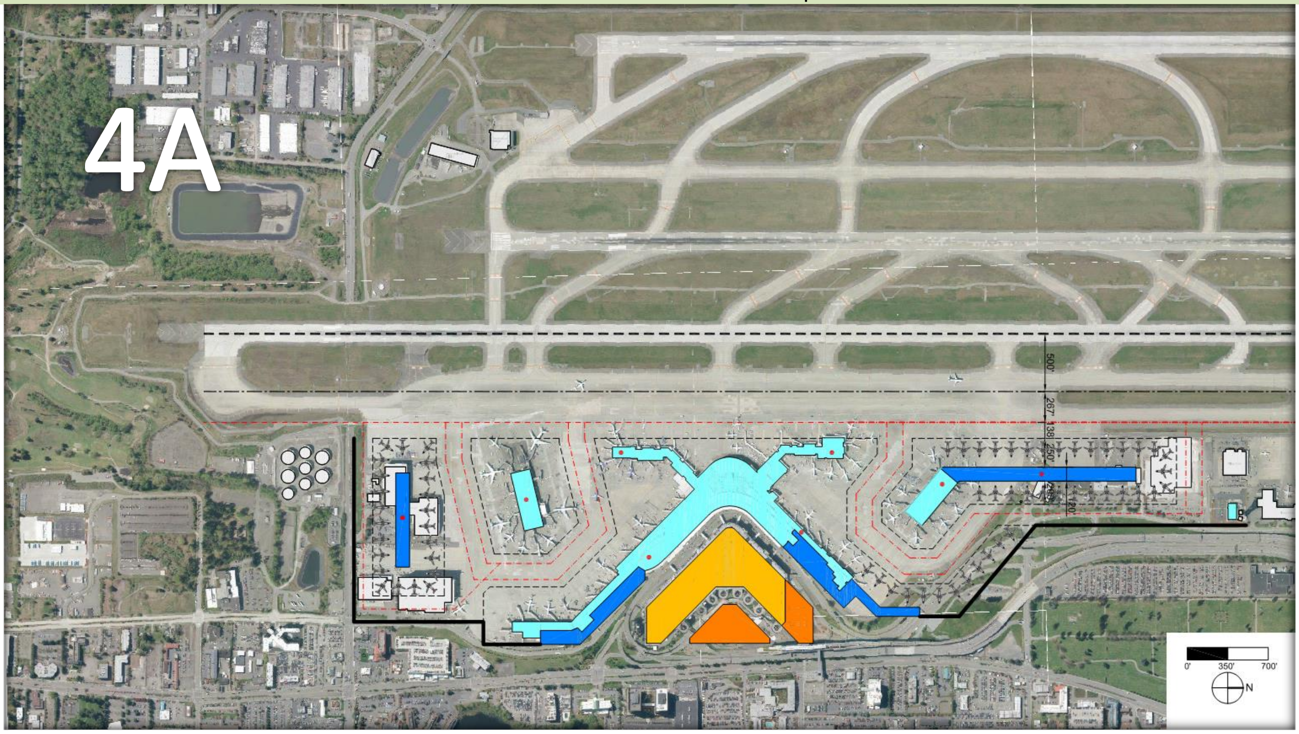


Figure A-6
ALTERNATIVE 5A – "ONE TERMINAL" OPTION (PREFERRED ONE TERMINAL OPTION)
Seattle-Tacoma International Airport

Figure A-7

ALTERNATIVE 6A – "ONE TERMINAL" OPTION (PASSED ALL THRESHOLD CRITERIA)

Seattle-Tacoma International Airport

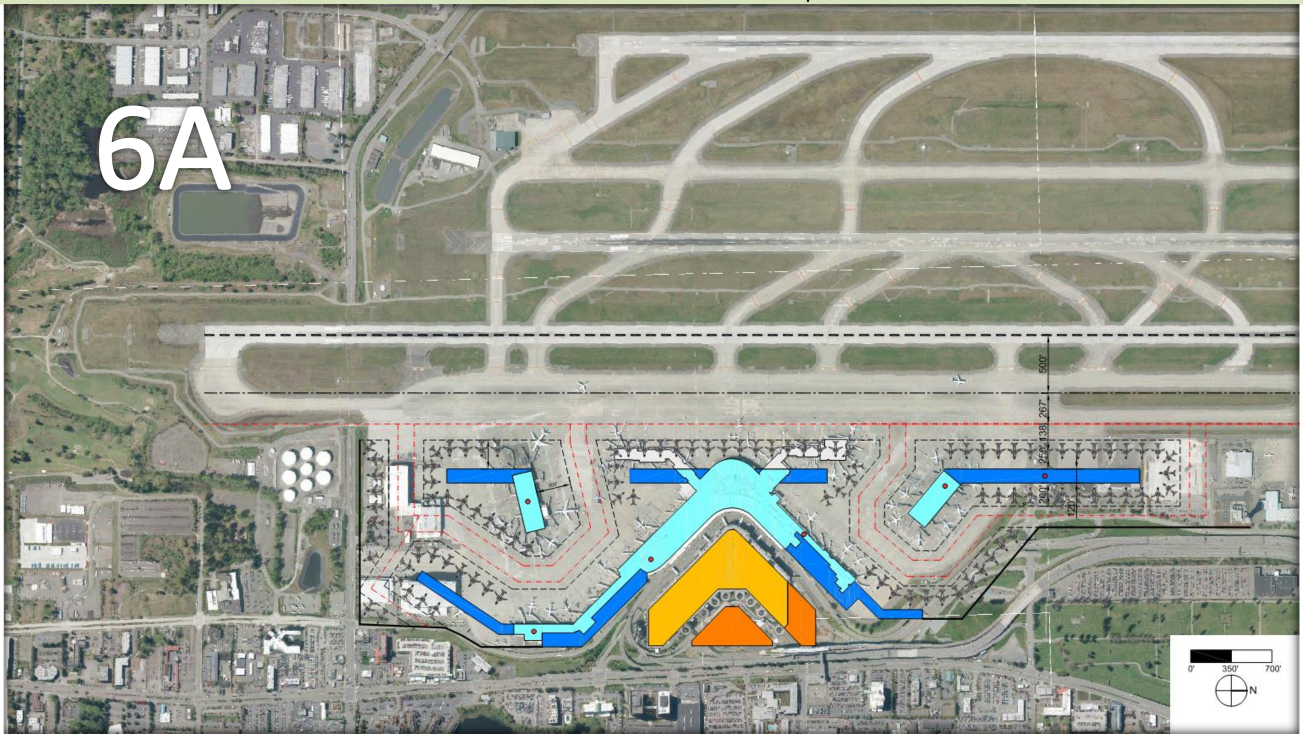
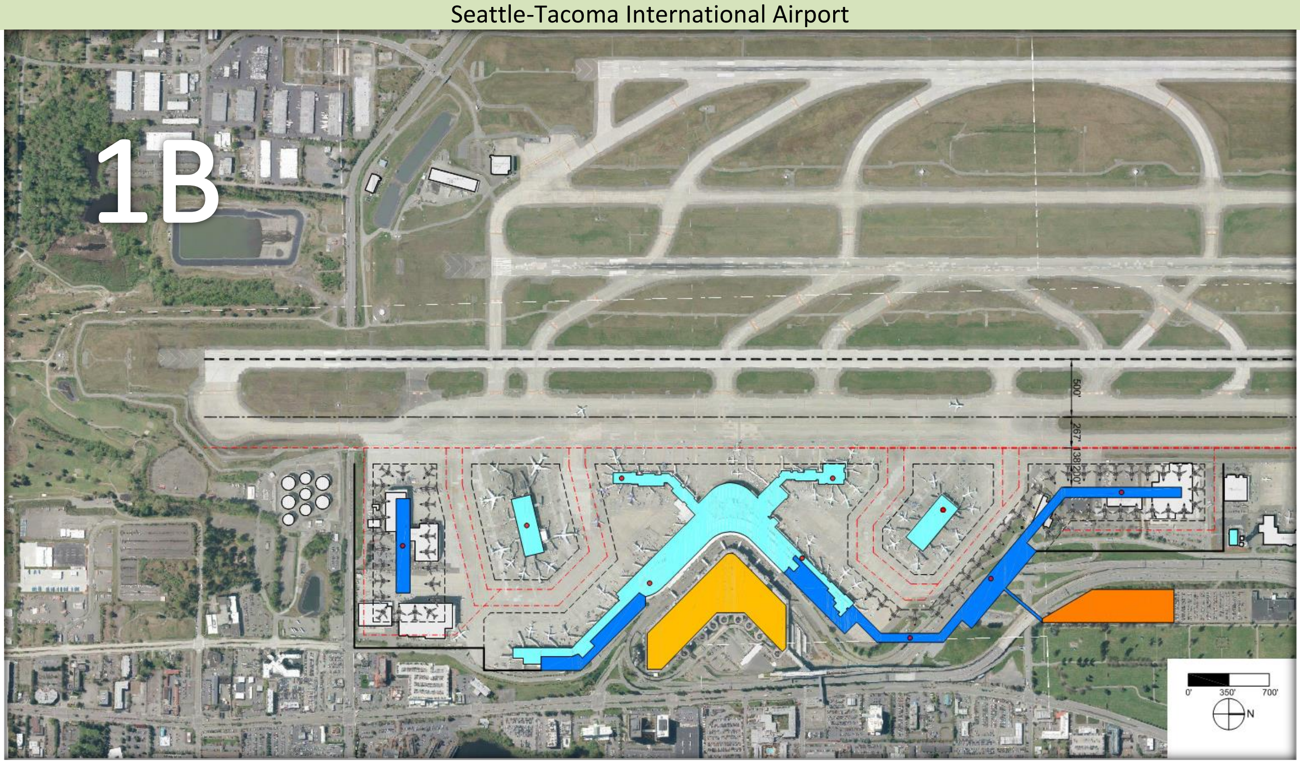


Figure A-8

ALTERNATIVE 1B – "TWO TERMINAL" OPTION (PASSED ALL THRESHOLD CRITERIA)

Seattle-Tacoma International Airport

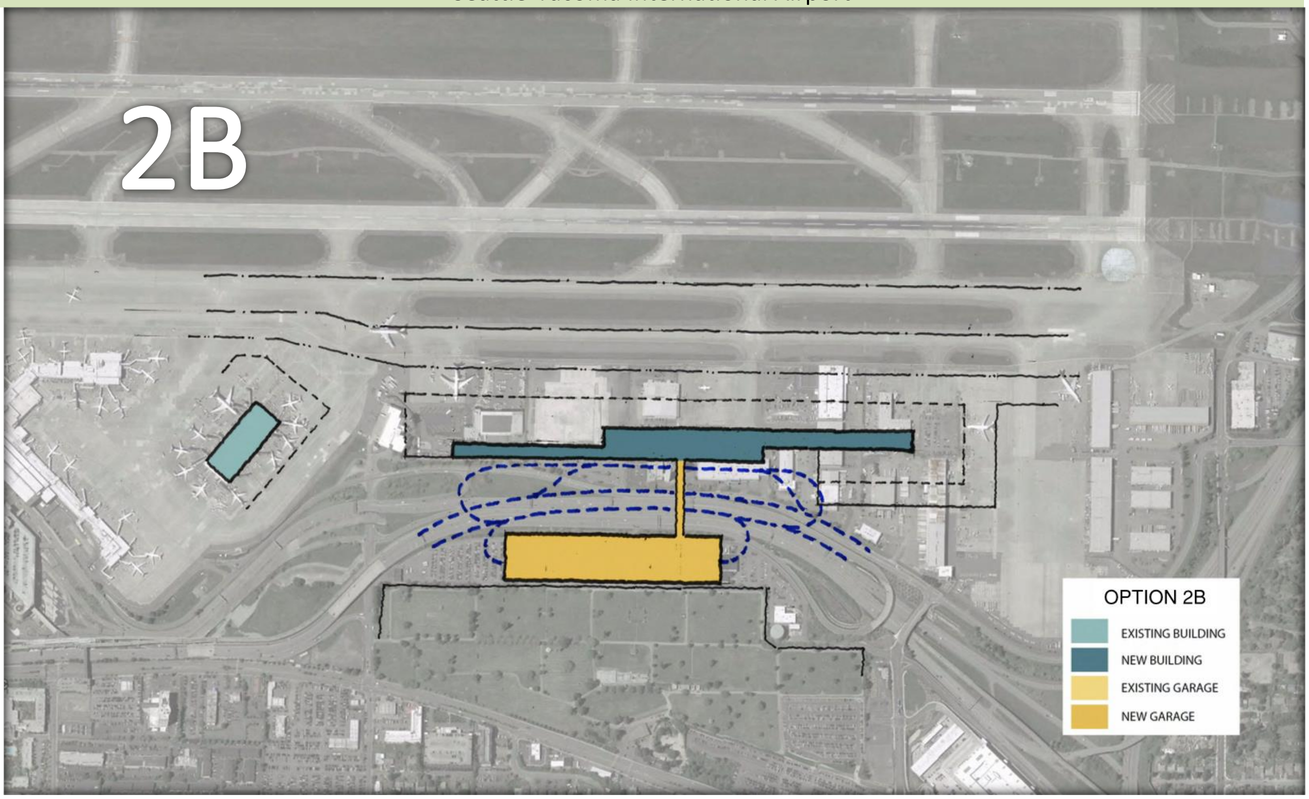


Source: Corgan Associates, 2015.

Figure A-9

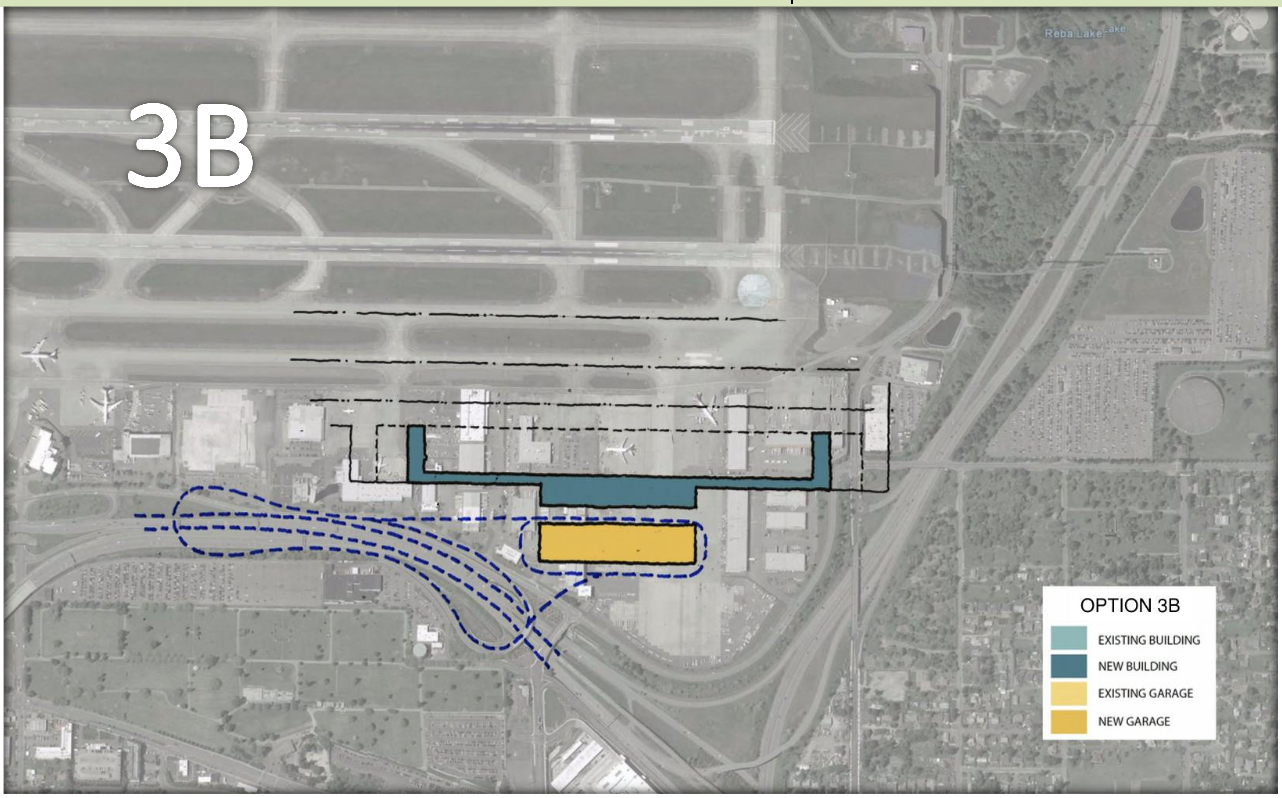
ALTERNATIVE 2B – "TWO TERMINAL" OPTION (FATALLY FLAWED – ELIMINATED)

Seattle-Tacoma International Airport



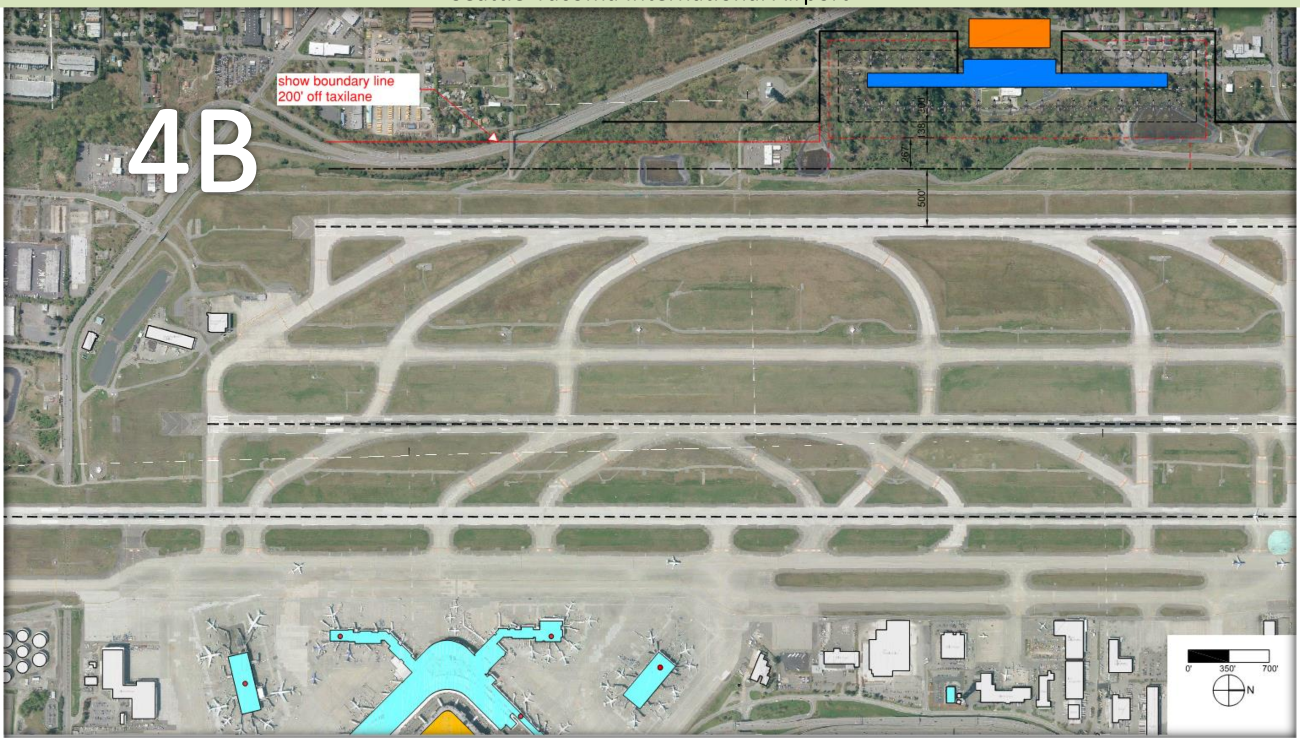
Source: Corgan Associates, 2015.

Figure A-10
ALTERNATIVE 3B – "TWO TERMINAL" OPTION (FATALLY FLAWED – ELIMINATED)
Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

Figure A-11
ALTERNATIVE 4B – "TWO TERMINAL" OPTION (PASSED ALL THRESHOLD CRITERIA)
Seattle-Tacoma International Airport

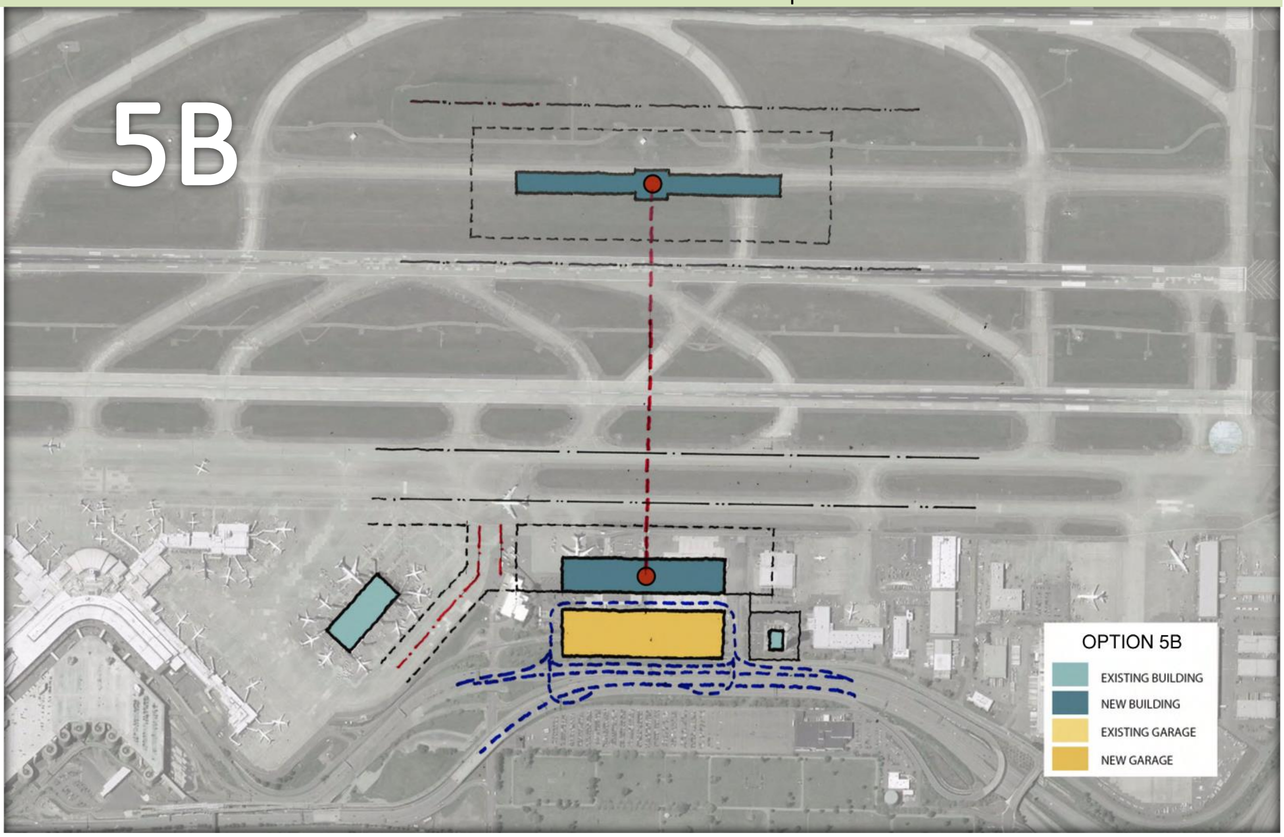


Source: Corgan Associates, 2015.

Figure A-12

ALTERNATIVE 1B – "TWO TERMINAL" OPTION (FATALLY FLAWED – ELIMINATED)

Seattle-Tacoma International Airport

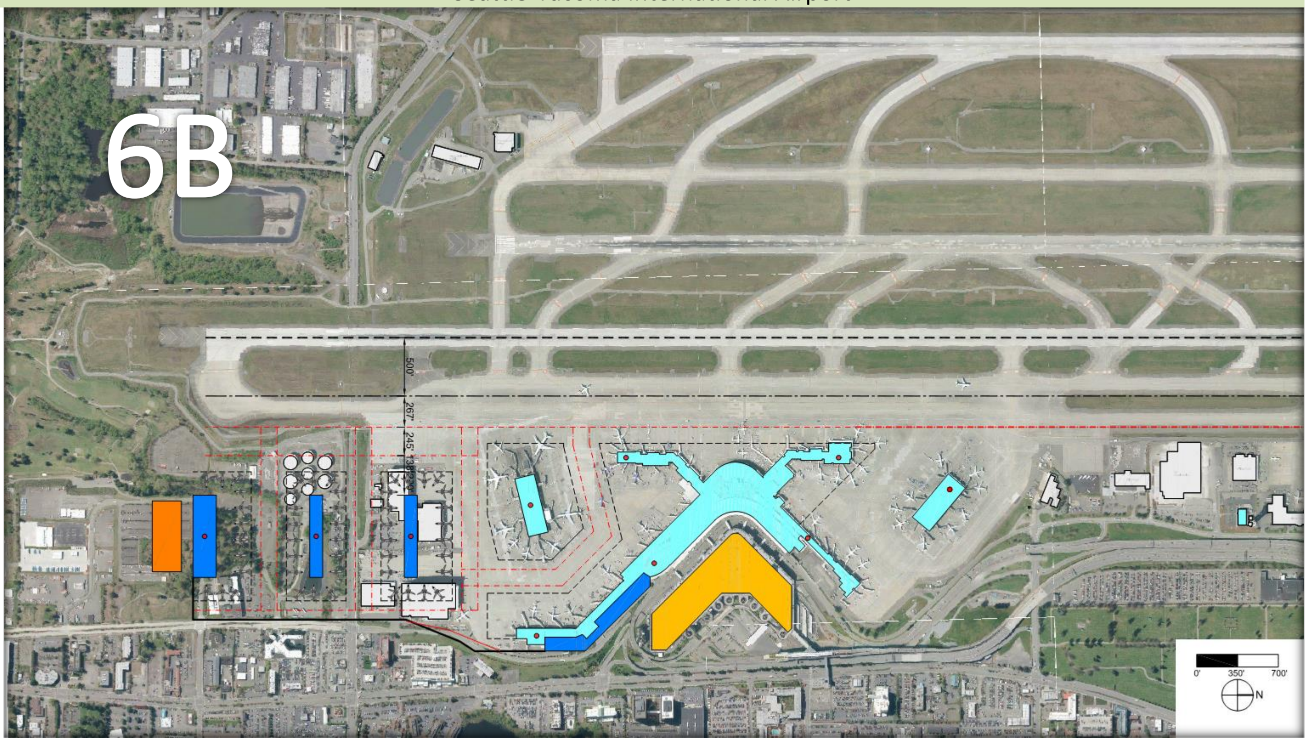


Source: Corgan Associates, 2015.

Figure A-13

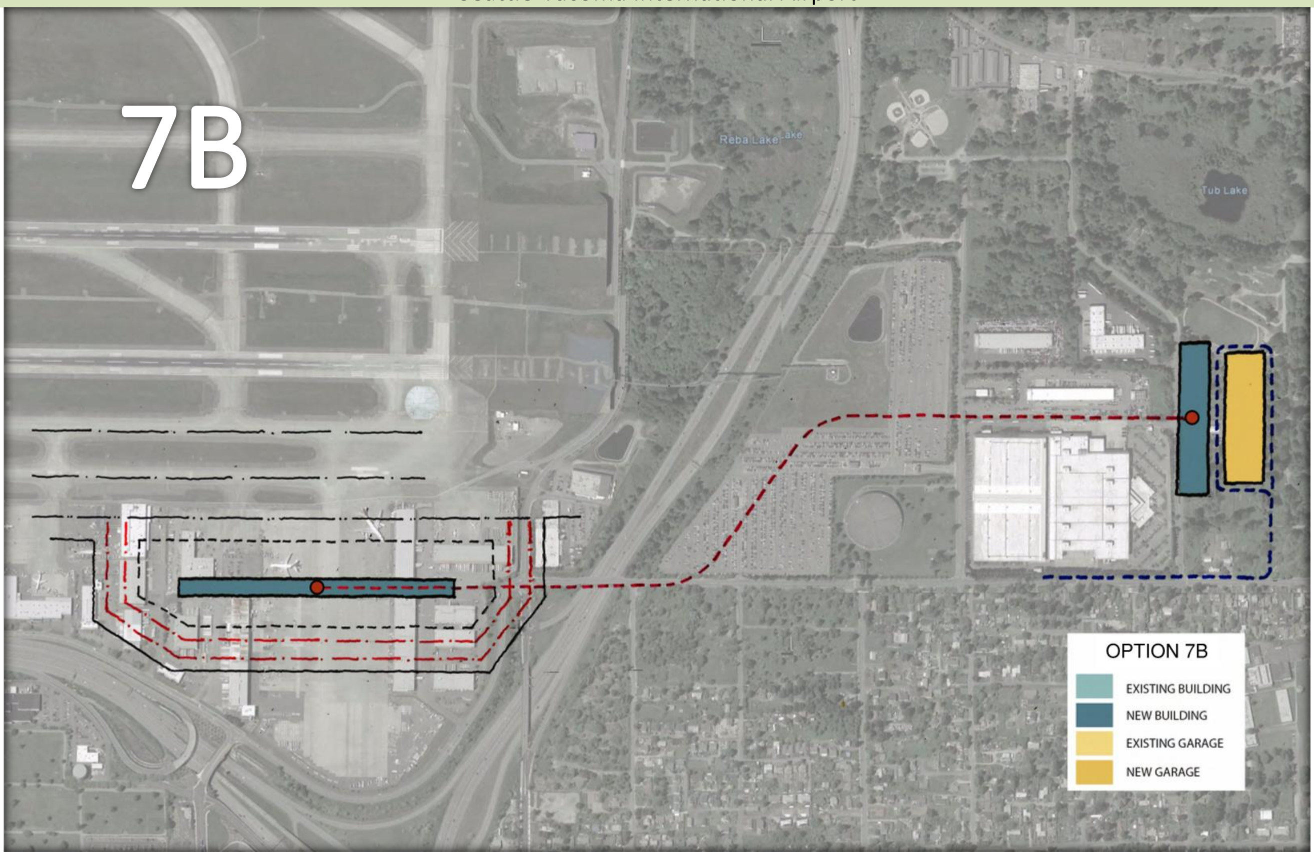
ALTERNATIVE 6B – "TWO TERMINAL" OPTION (PASSED ALL THRESHOLD CRITERIA)

Seattle-Tacoma International Airport



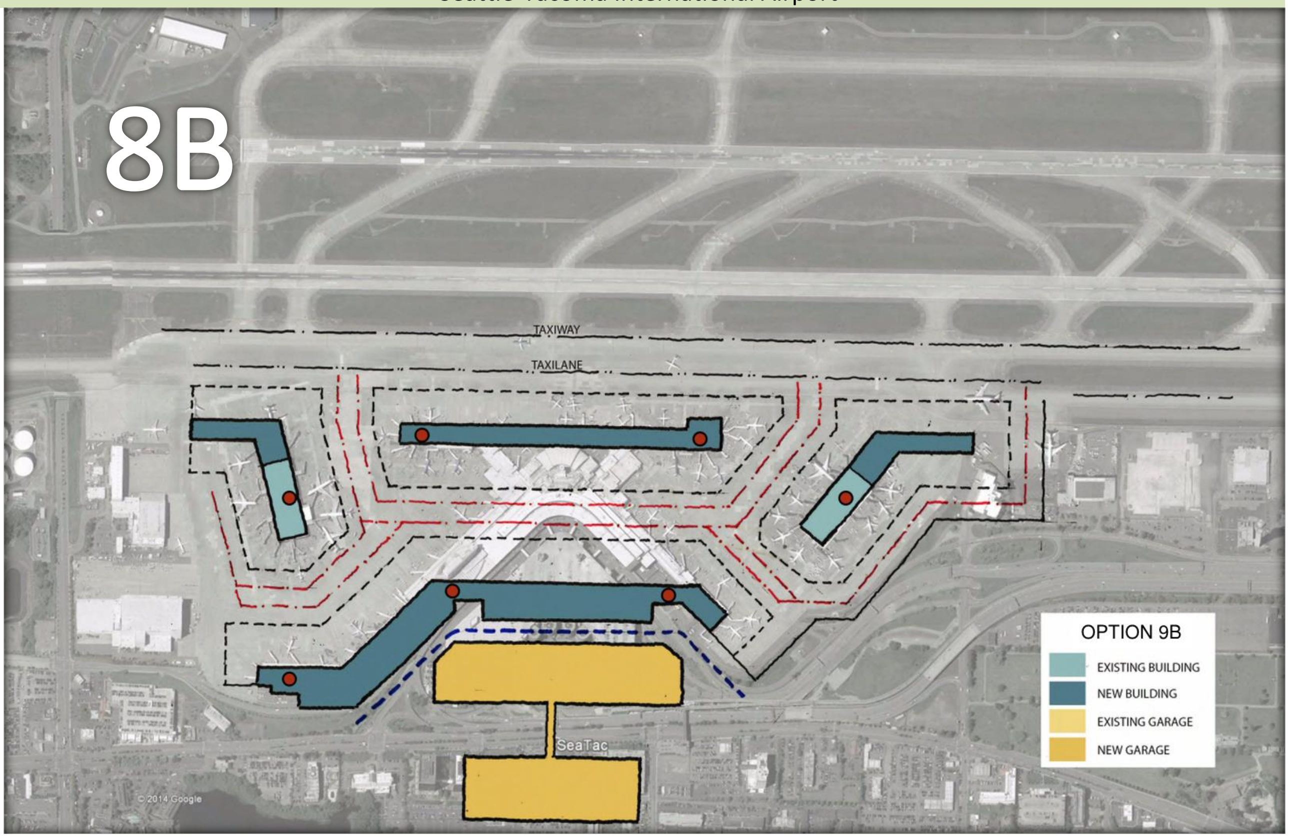
Source: Corgan Associates, 2015.

Figure A-14
ALTERNATIVE 7B – "TWO TERMINAL" OPTION (FATALLY FLAWED – ELIMINATED)
Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

Figure A-15
ALTERNATIVE 8B – "TWO TERMINAL" OPTION (FATALLY FLAWED – ELIMINATED)
Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

Figure A-16

ALTERNATIVE 9B – "TWO TERMINAL" OPTION (PASSED ALL THRESHOLD CRITERIA)

Seattle-Tacoma International Airport

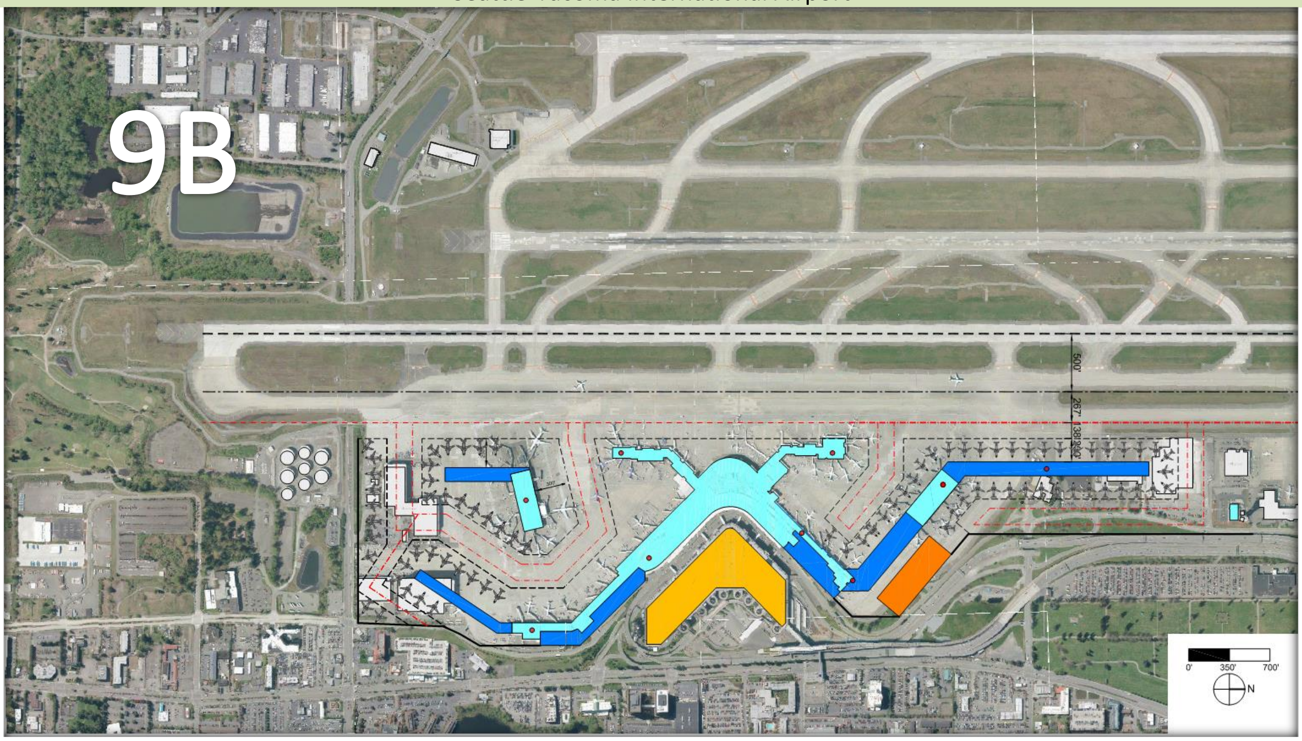
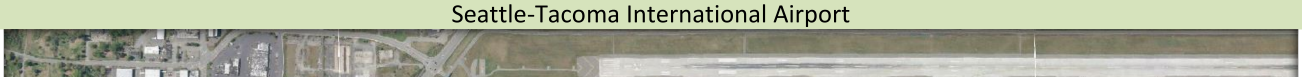


Figure A-17

ALTERNATIVE 10B – "TWO TERMINAL" OPTION (PREFERRED TWO TERMINAL OPTION)

Seattle-Tacoma International Airport



Source: Corgan Associates, 2015.

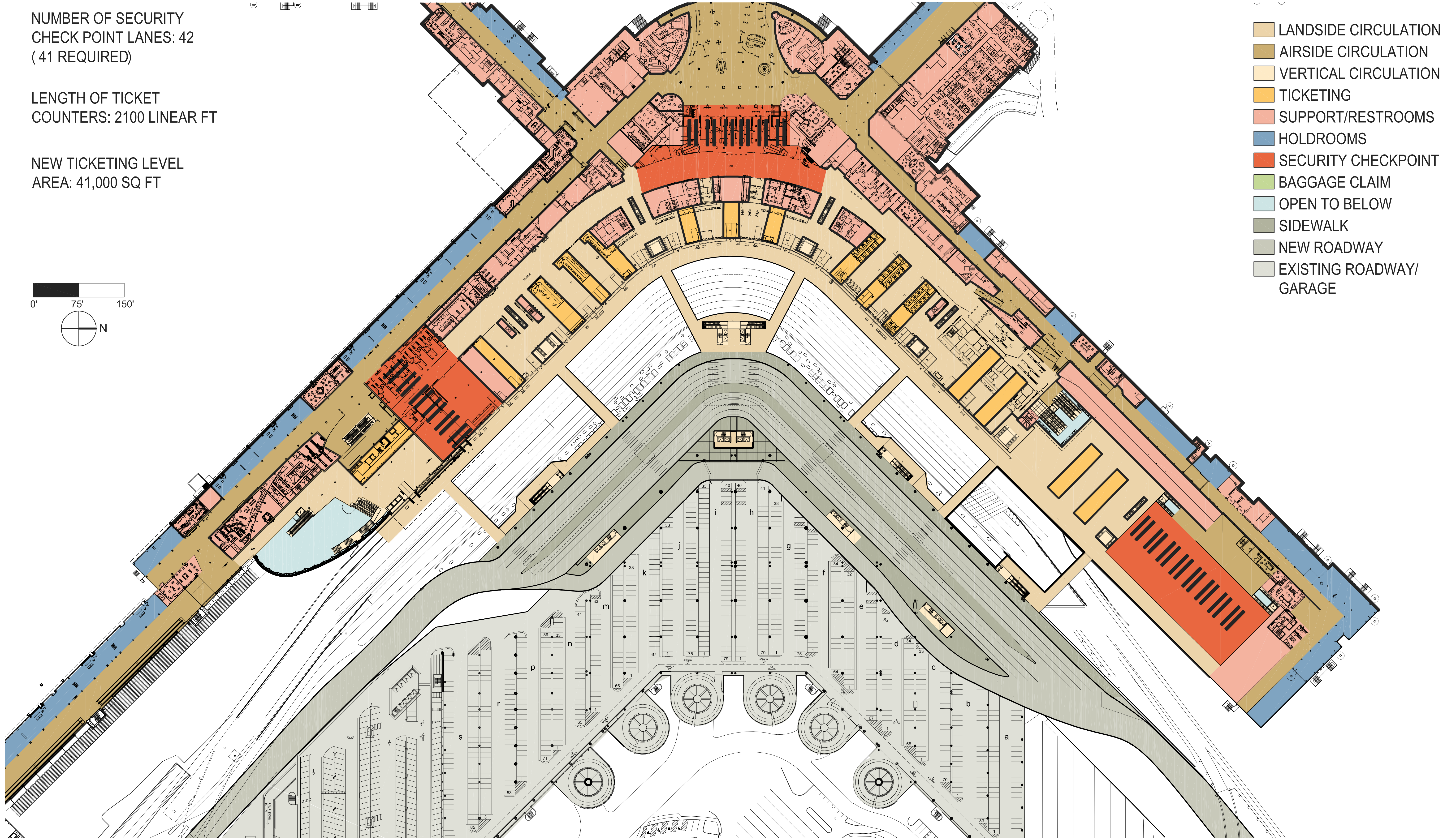
Appendix B

One-Terminal Development Concepts

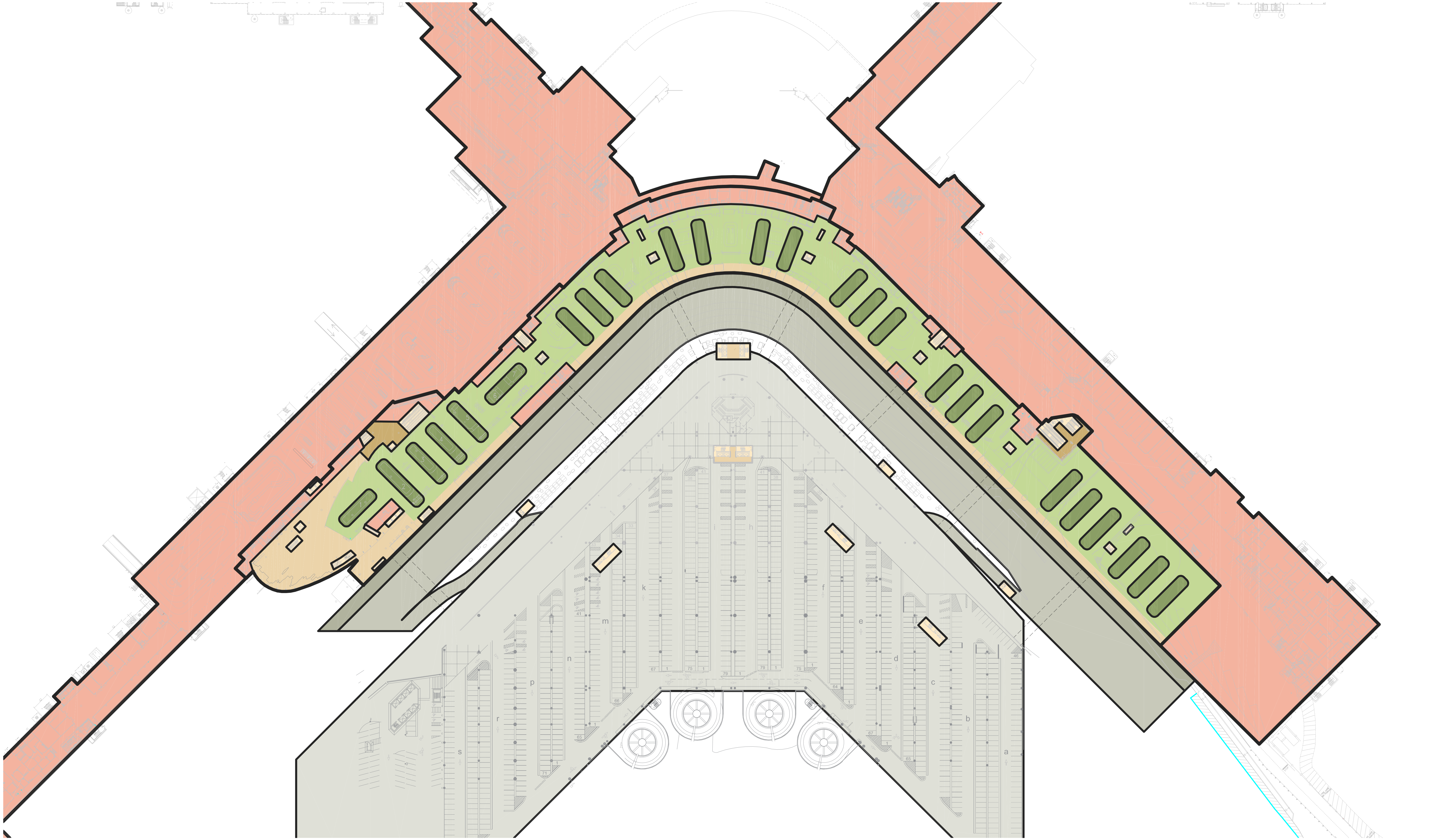
NUMBER OF SECURITY CHECK POINT LANES: 42 (41 REQUIRED)

LENGTH OF TICKET COUNTERS: 2100 LINEAR FT

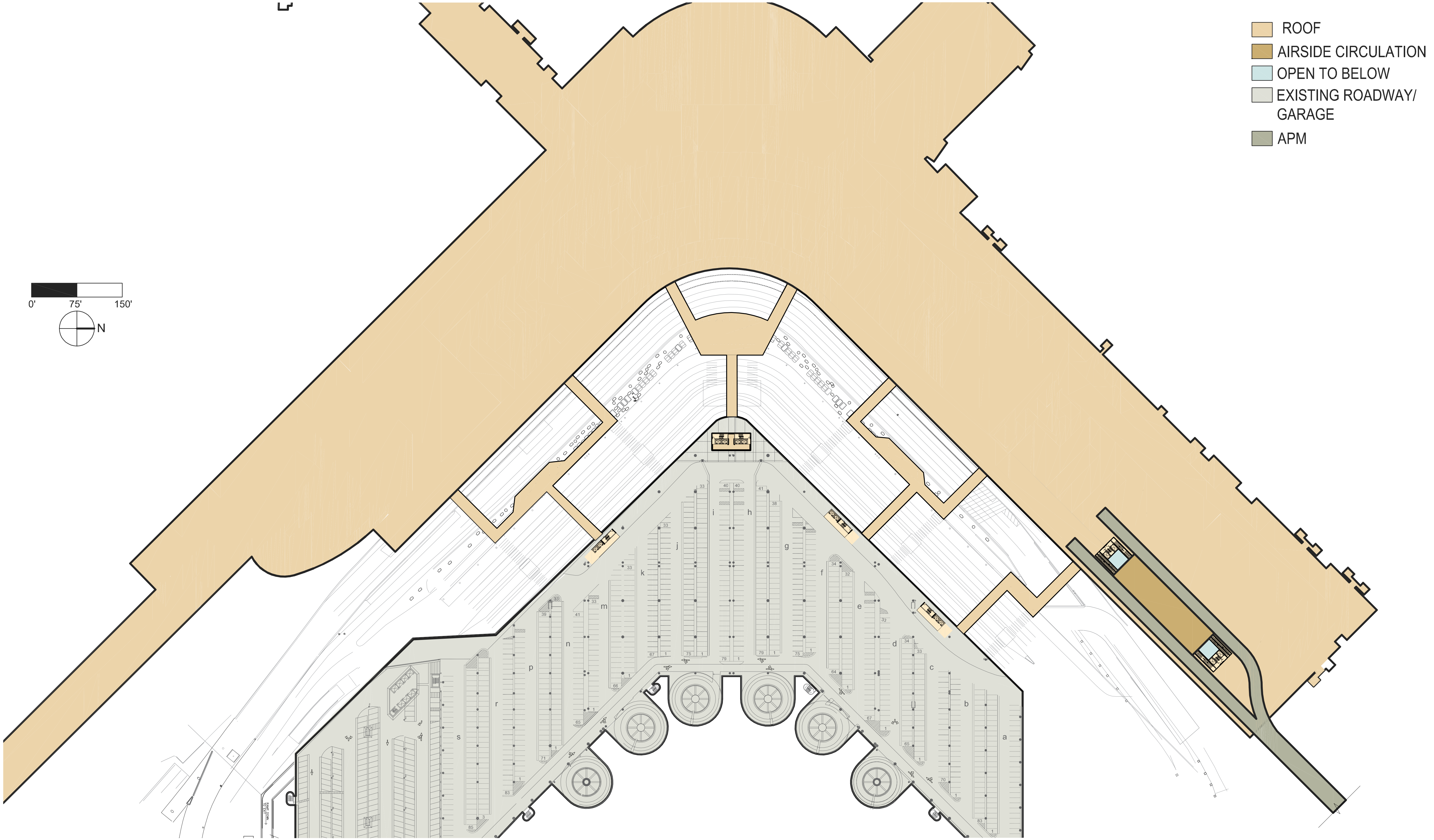
NEW TICKETING LEVEL AREA: 41,000 SQ FT



SEA MASTERPLAN - OPTION 1 - CONCOURSE LEVEL - EXPANDED FRONT FACADE / EXPANDED UPPER LEVEL ROADWAY



SEA MASTERPLAN - OPTION 1 - RAMP LEVEL



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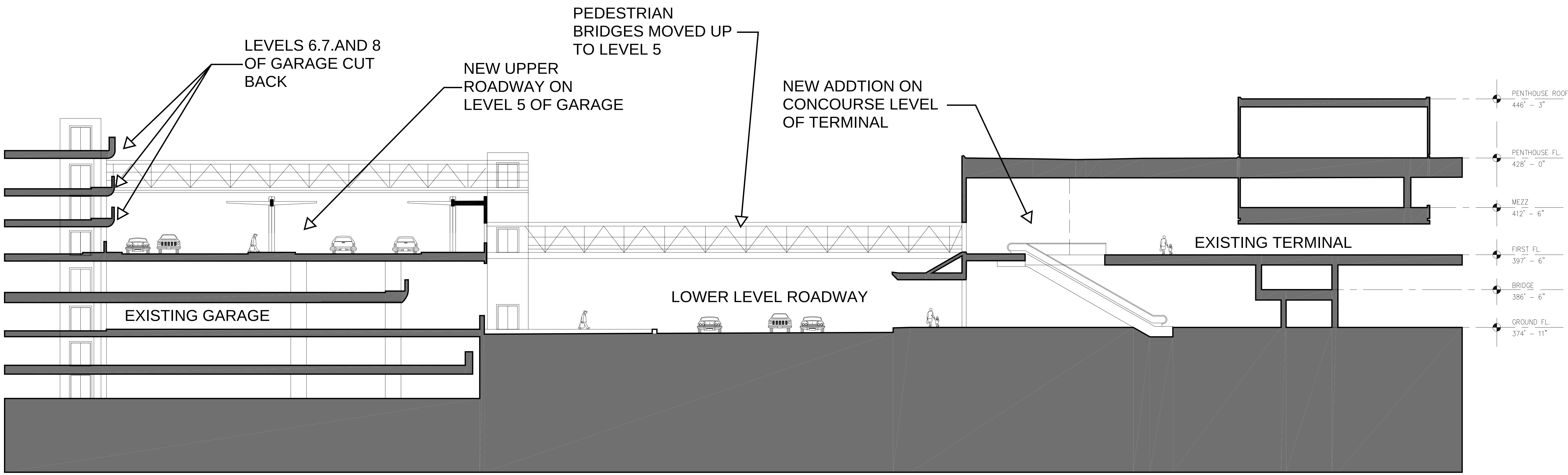
SEA MASTERPLAN - OPTION 1 - ROOF LEVEL - EXPANDED FRONT FACADE / EXPANDED UPPER LEVEL ROADWAY

Leigh|Fisher CORGAN

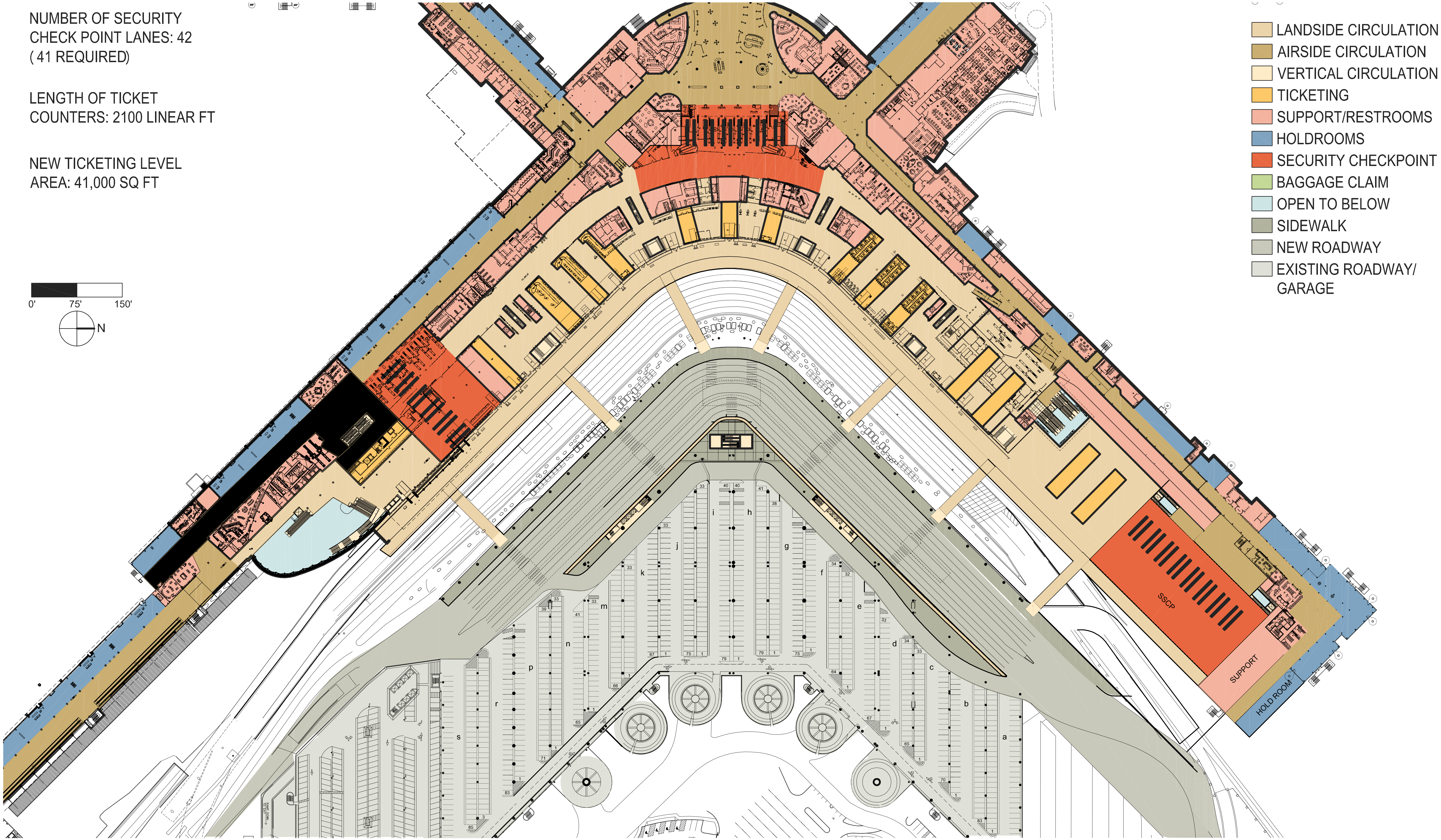


LEVELS 6.7.AND 8
OF GARAGE CUT
BACK
NEW UPPER
ROADWAY ON
LEVEL 5 OF GARAGE
PEDESTRIAN
BRIDGES MOVED UP
TO LEVEL 5
NEW ADDTION ON
CONCOURSE LEVEL
OF TERMINAL
EXISTING TERMINAL
LOWER LEVEL ROADWAY
EXISTING GARAGE
PENTHOUSE ROOF
446' – 3"
PENTHOUSE FL.
428' – 0"
MEZZ
412' – 6"
FIRST FL.
397' – 6"
BRIDGE
386' – 6"
GROUND FL.
374' – 11"

NUMBER OF SECURITY CHECK POINT LANES: 42 (41 REQUIRED)

LENGTH OF TICKET COUNTERS: 2100 LINEAR FT

NEW TICKETING LEVEL AREA: 41,000 SQ FT



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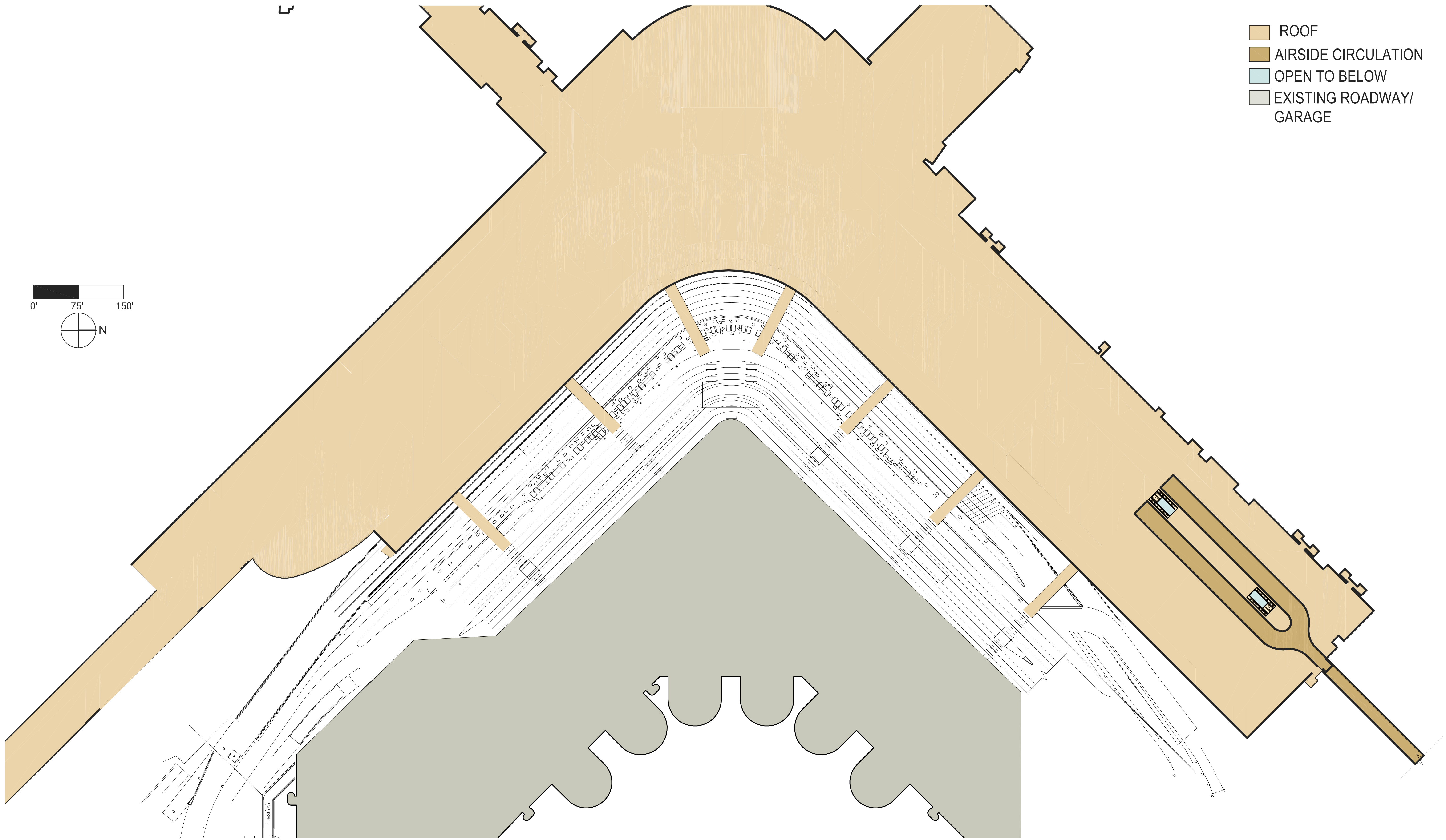
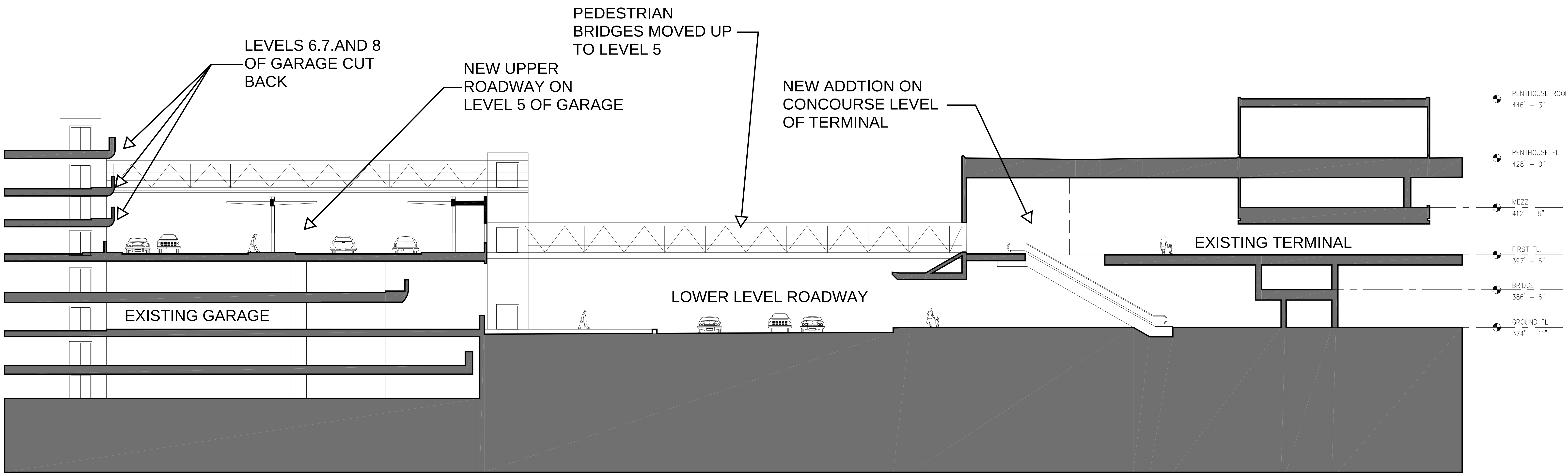
SEA MASTERPLAN - OPTION 1 - CONCOURSE LEVEL - EXPANDED FRONT FACADE / EXPANDED UPPER LEVEL ROADWAY

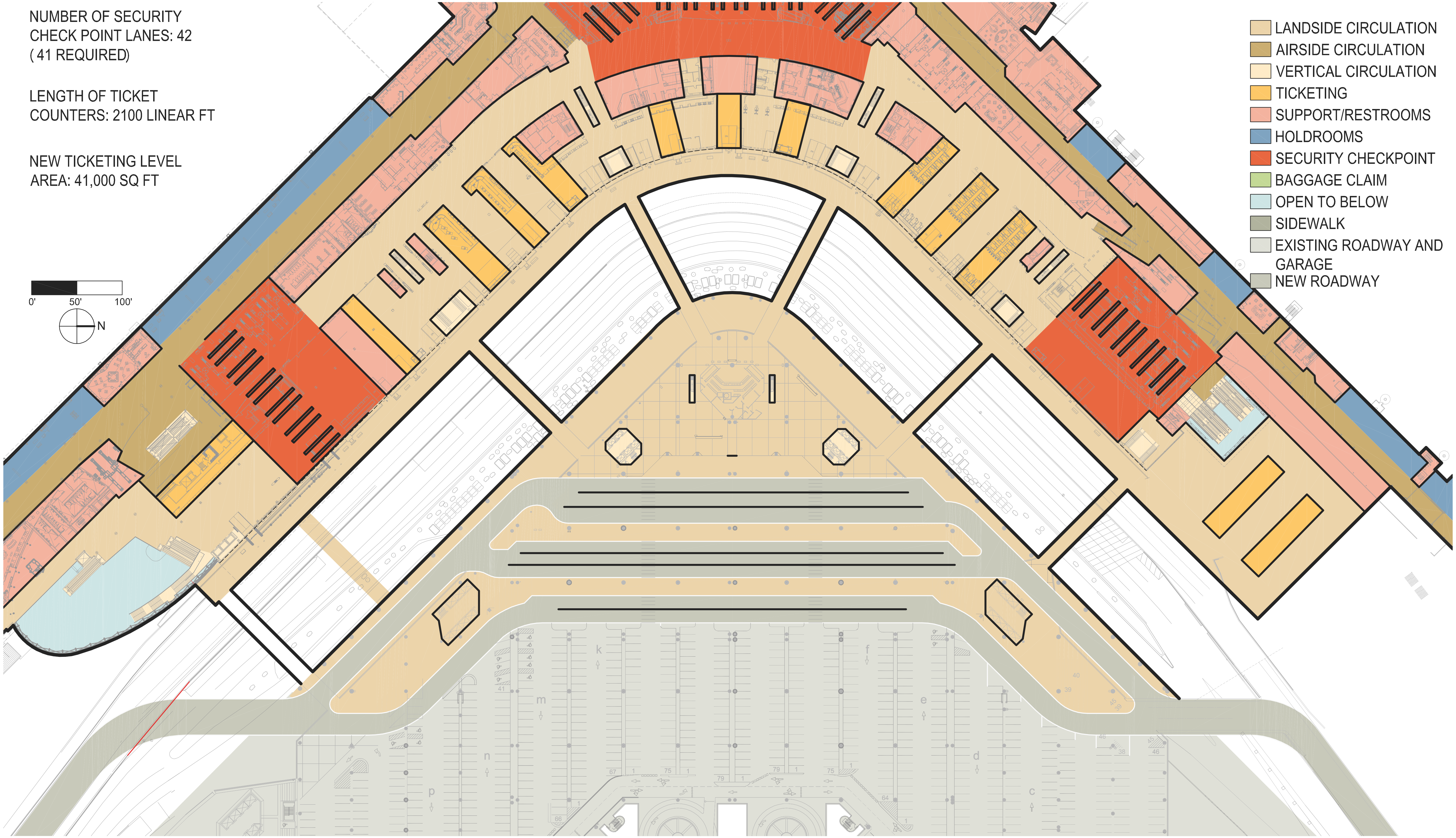
LeighFisher CORGAN



SEA MASTERPLAN - OPTION 1 - ROOF LEVEL - EXPANDED FRONT FACADE / EXPANDED UPPER LEVEL ROADWAY



LEVELS 6.7.AND 8 OF GARAGE CUT BACK
NEW UPPER ROADWAY ON LEVEL 5 OF GARAGE
PEDESTRIAN BRIDGES MOVED UP TO LEVEL 5
NEW ADDTION ON CONCOURSE LEVEL OF TERMINAL
EXISTING TERMINAL
LOWER LEVEL ROADWAY
EXISTING GARAGE
PENTHOUSE ROOF 446' - 3"
PENTHOUSE FL. 428' - 0"
MEZZ 412' - 6"
FIRST FL. 397' - 6"
BRIDGE 386' - 6"
GROUND FL. 374' - 11"



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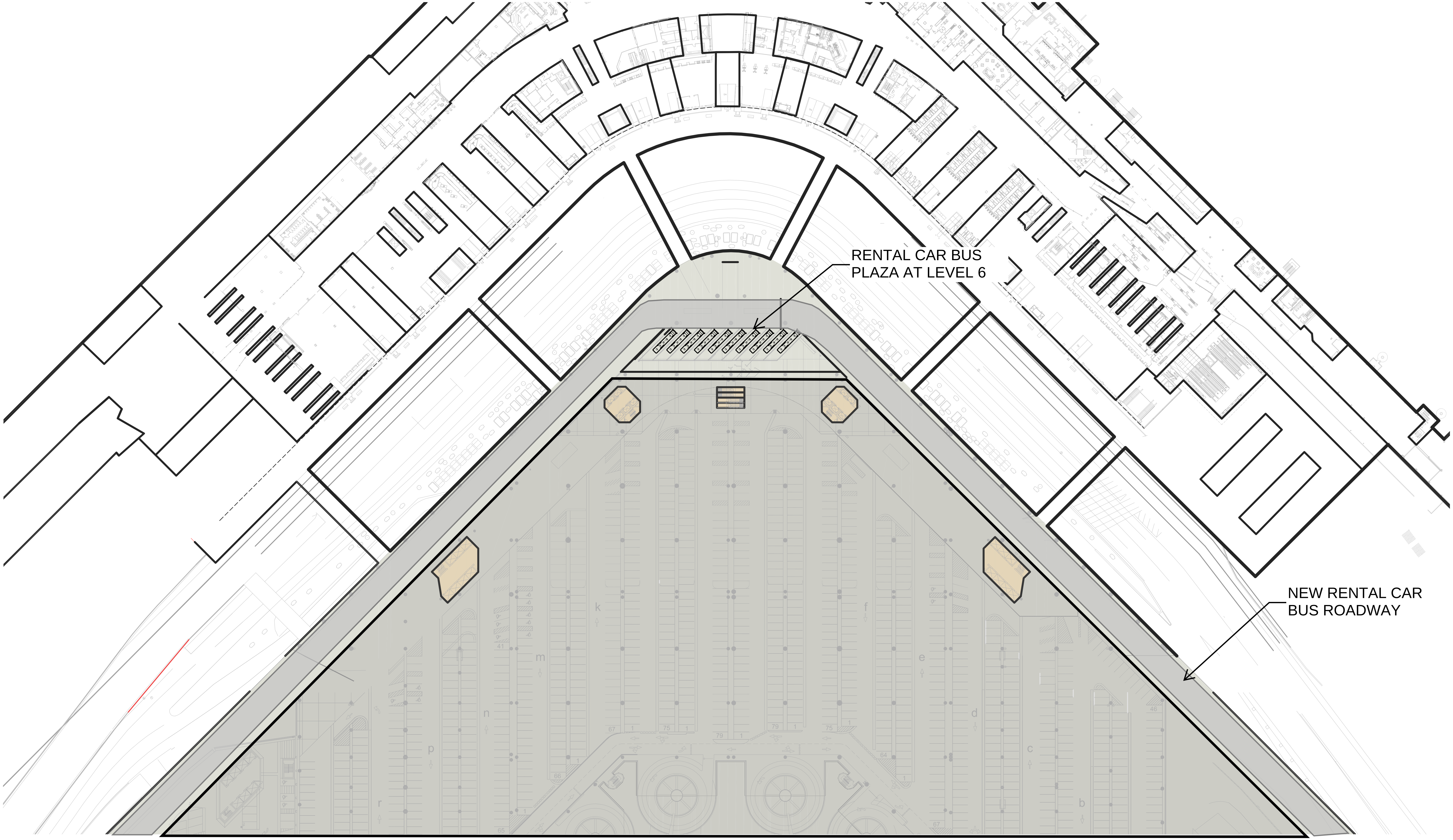
SEA MASTERPLAN - OPTION 1A - CONCOURSE LEVEL - EXPAND FRONT FACADE / UPPER CURBSIDE IN GARAGE

LeighFisher CORGAN



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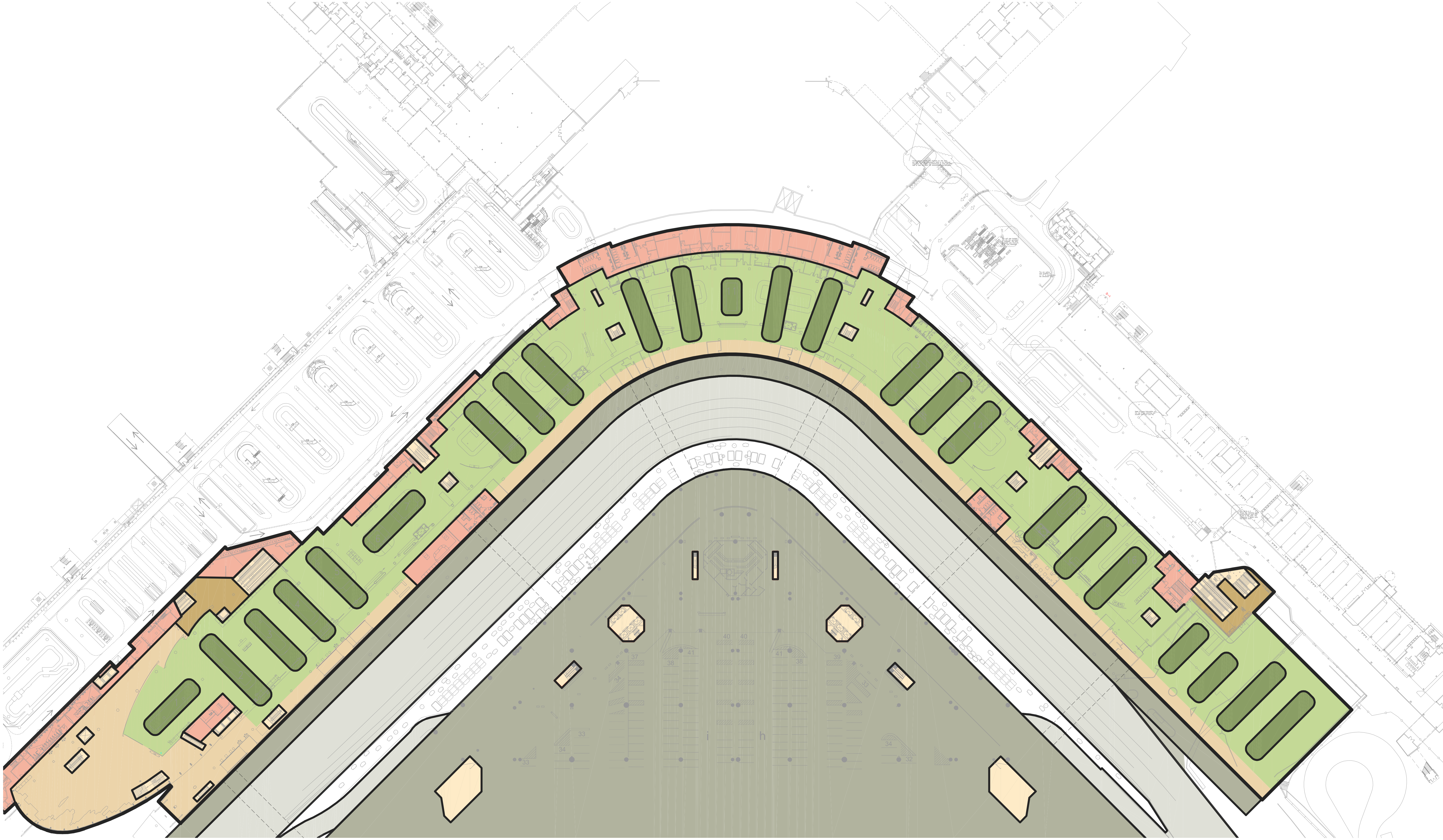
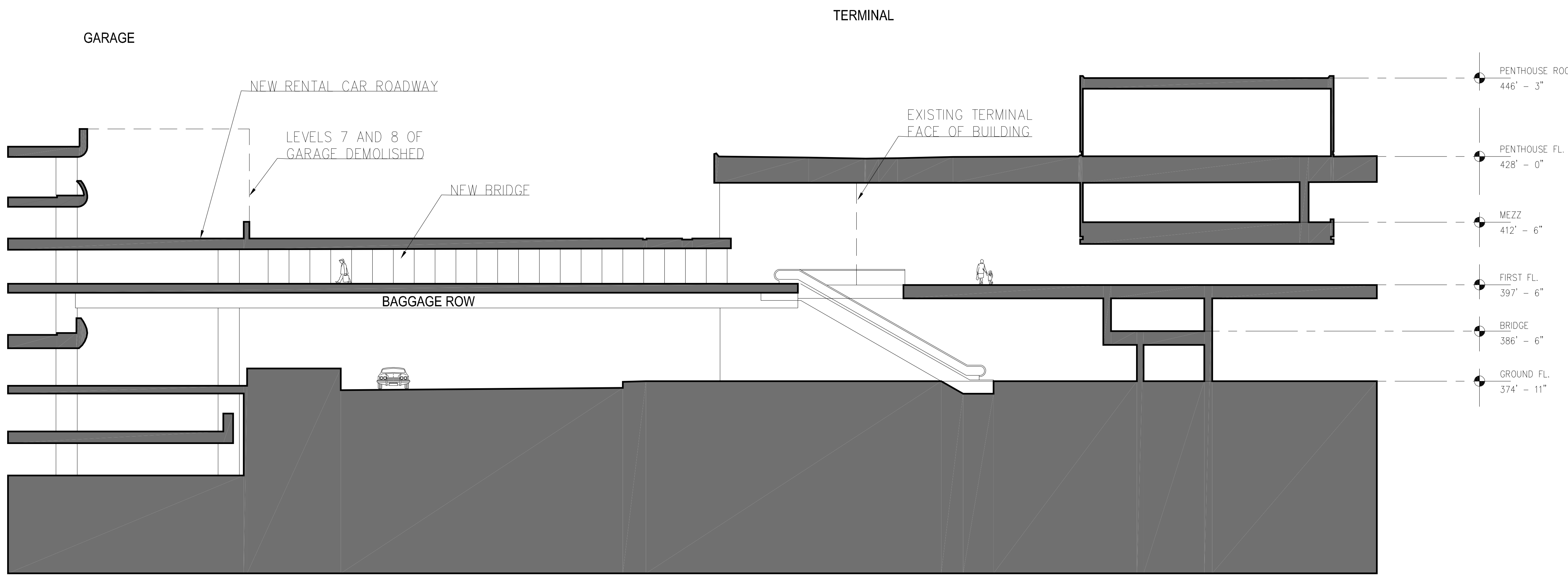
SEA MASTERPLAN - OPTION 1A - UPPER LEVEL - EXPAND FRONT FACADE / UPPER CURBSIDE IN GARAGE

Leigh|Fisher CORGAN



SEA MASTERPLAN - OPTION 1A - RAMP LEVEL - EXPAND FRONT FACADE / UPPER CURBSIDE IN GARAGE

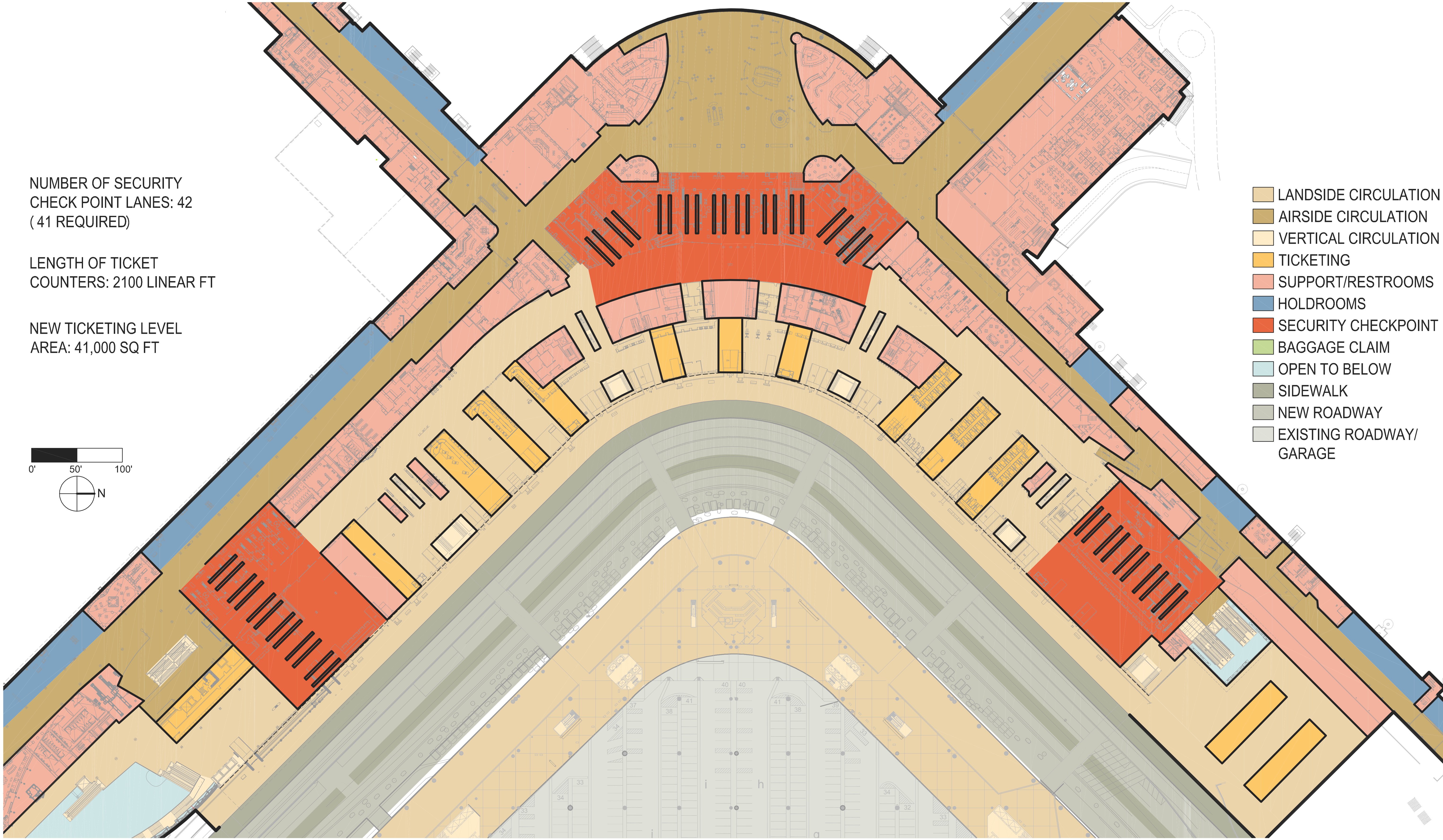


SEA MASTERPLAN - OPTION 1B - SECTION - EXPANDED FRONT FACADE / EXPANDED UPPER LEVEL ROADWAY

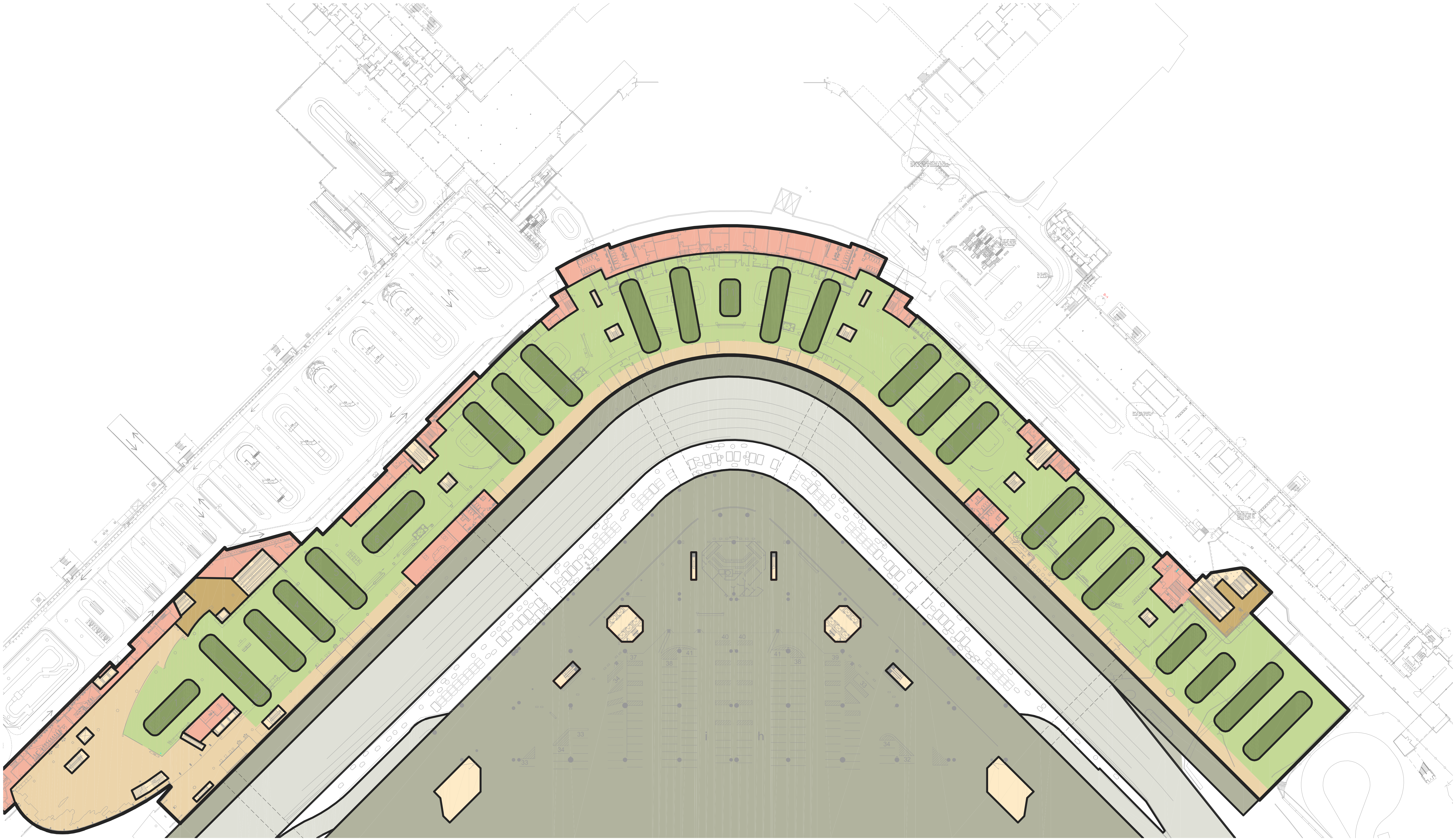
NUMBER OF SECURITY
CHECK POINT LANES: 42
(41 REQUIRED)

LENGTH OF TICKET
COUNTERS: 2100 LINEAR FT

NEW TICKETING LEVEL
AREA: 41,000 SQ FT



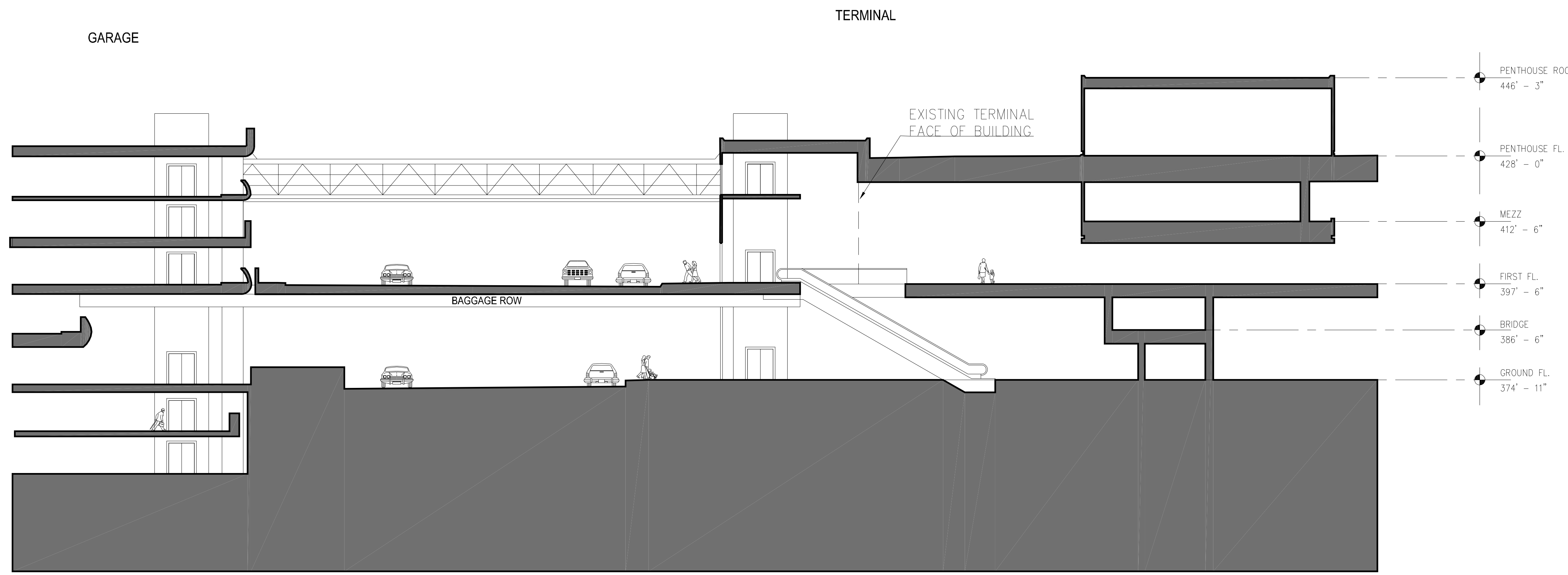
SEA MASTERPLAN - OPTION 1B - CONCOURSE LEVEL - EXPANDED FRONT FACADE / EXPANDED UPPER LEVEL ROADWAY



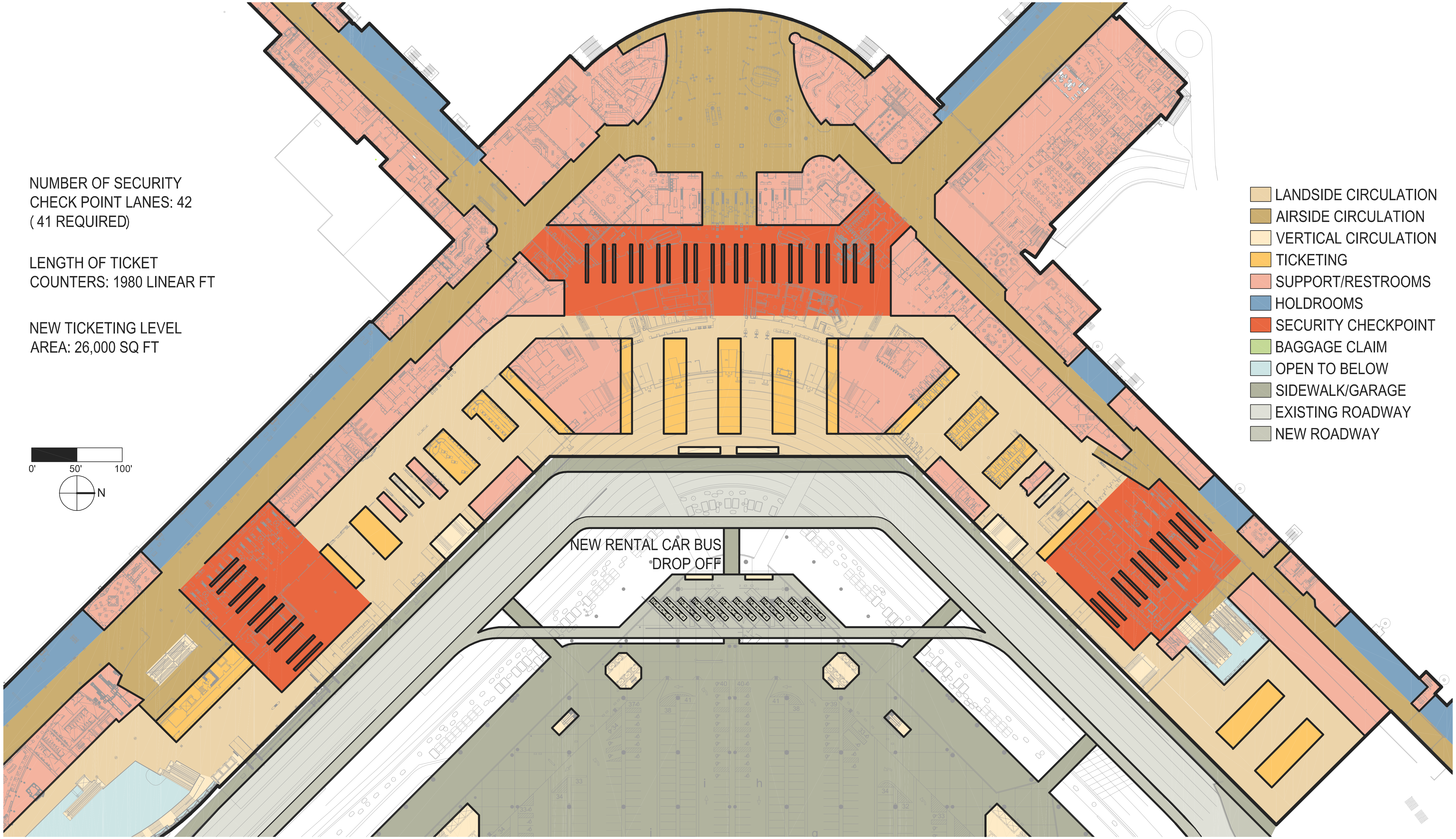
Sustainable
Airport Master Plan
Seattle-Tacoma International Airport

SEA MASTERPLAN - OPTION 1B - RAMP LEVEL - EXPANDED FRONT FACADE / EXPANDED UPPER LEVEL ROADWAY

LeighFisher CORGAN



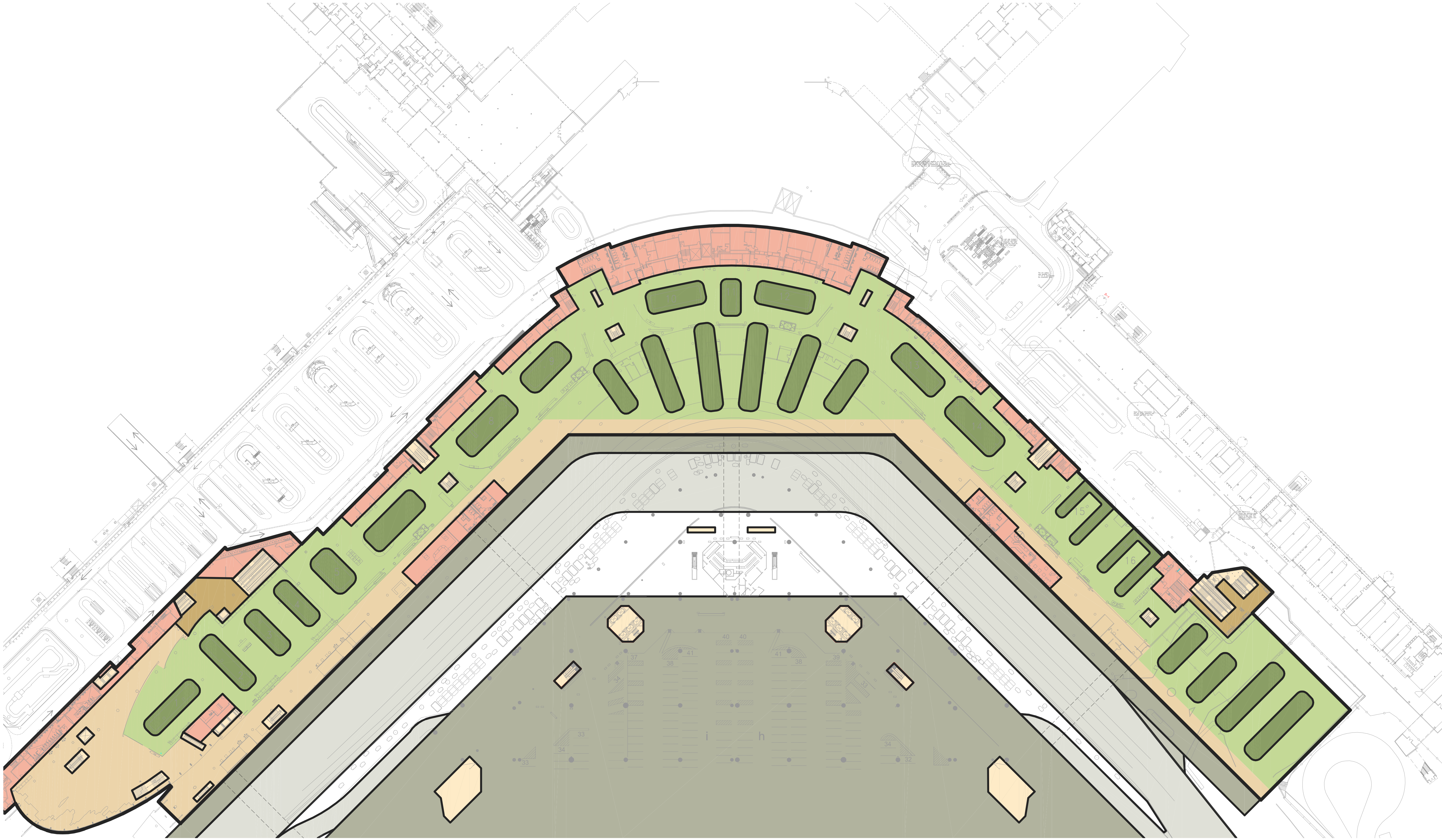
SEA MASTERPLAN - OPTION 1B - SECTION - EXPANDED FRONT FACADE / EXPANDED UPPER LEVEL ROADWAY



Sustainable Airport Master Plan
Seattle-Tacoma International Airport

SEA MASTERPLAN - OPTION 2A - CONCOURSE LEVEL - DEMO GARAGE NOSE

LeighFisher CORGAN



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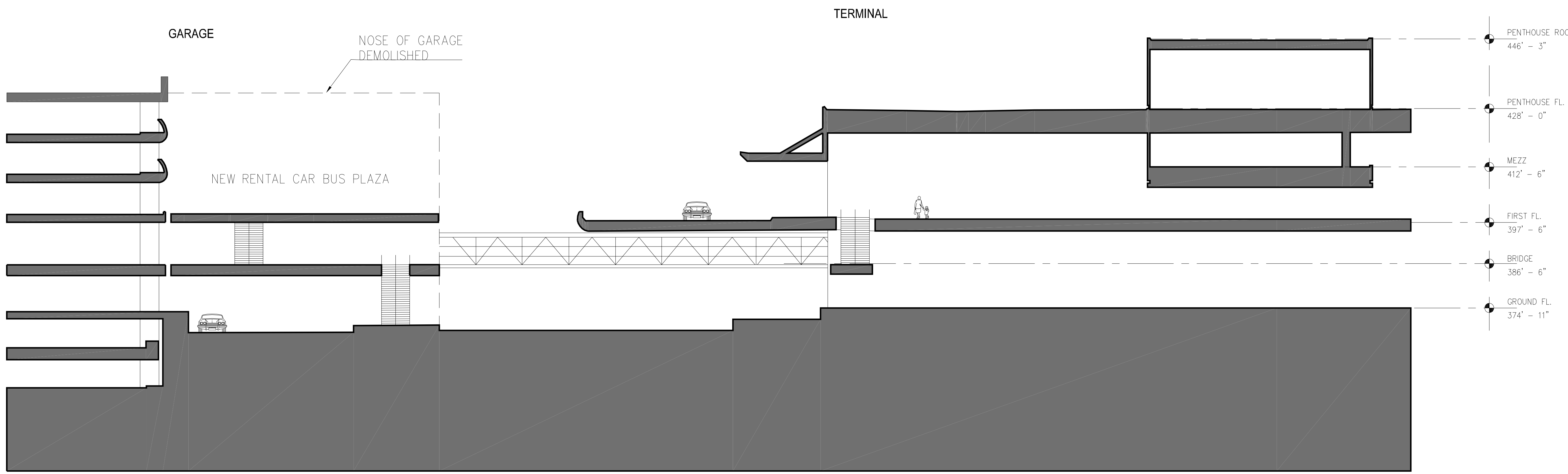
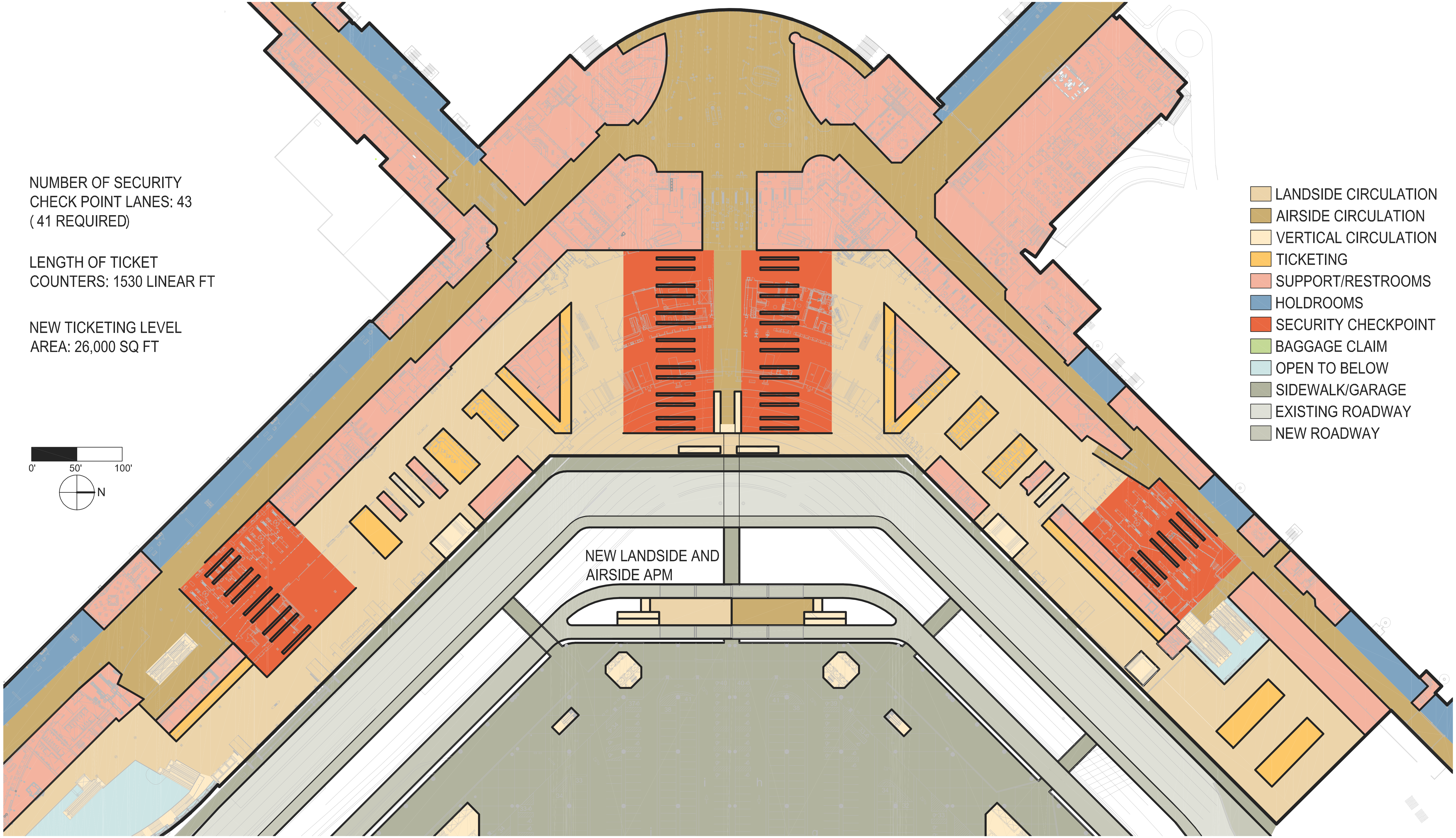
SEA MASTERPLAN - OPTION 2A - RAMP LEVEL - DEMO GARAGE NOSE / RENTAL CAR BUS PLAZA

LeighFisher CORGAN



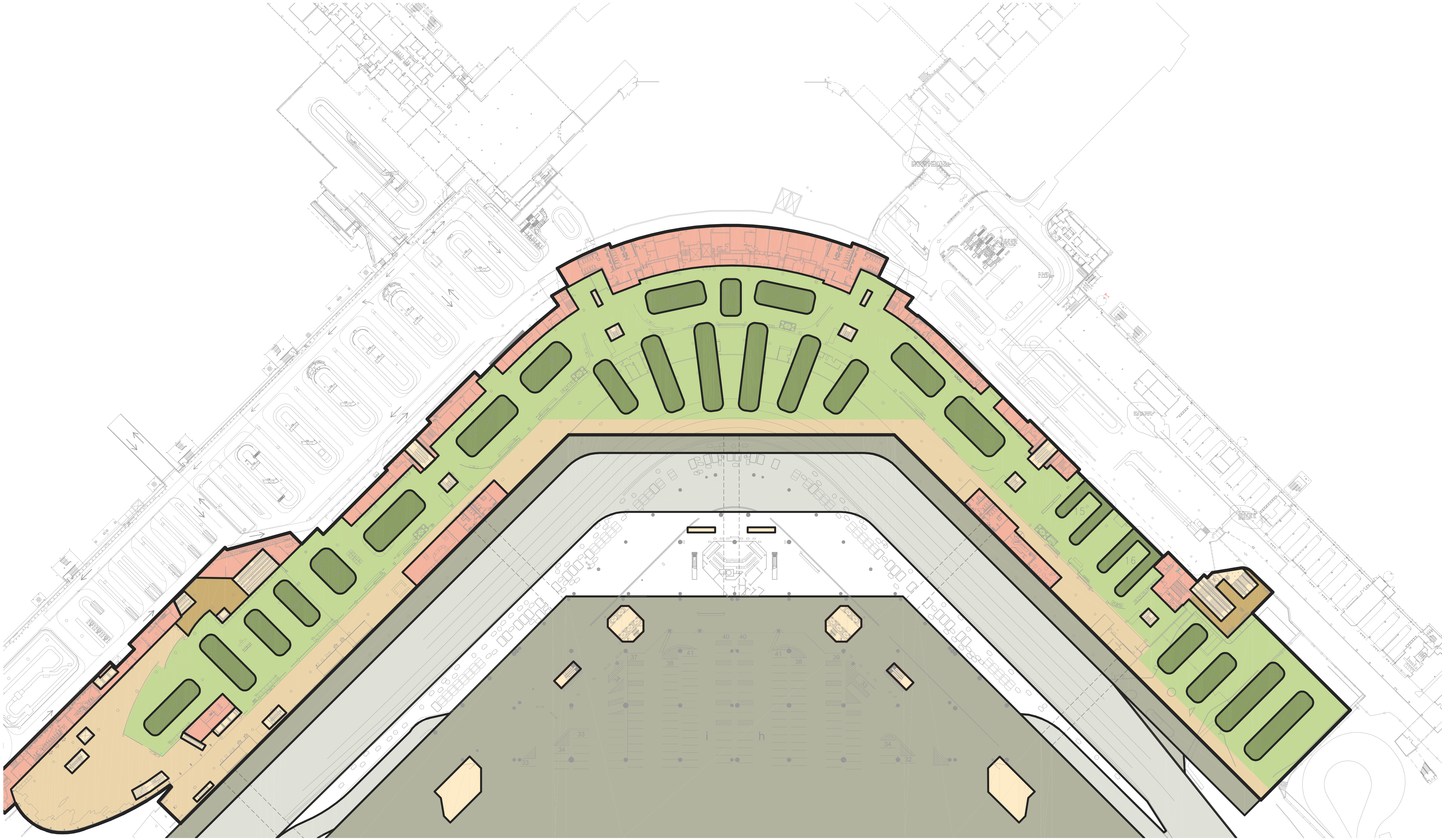
TERMINAL
GARAGE
NOSE OF GARAGE DEMOLISHED
NEW RENTAL CAR BUS PLAZA
PENTHOUSE ROOF
446' – 3"
PENTHOUSE FL.
428' – 0"
MEZZ
412' – 6"
FIRST FL.
397' – 6"
BRIDGE
386' – 6"
GROUND FL.
374' – 11"



Sustainable Airport Master Plan
Seattle-Tacoma International Airport

SEA MASTERPLAN - OPTION 2B - CONCOURSE LEVEL - DEMO GARAGE NOSE / NEW APM

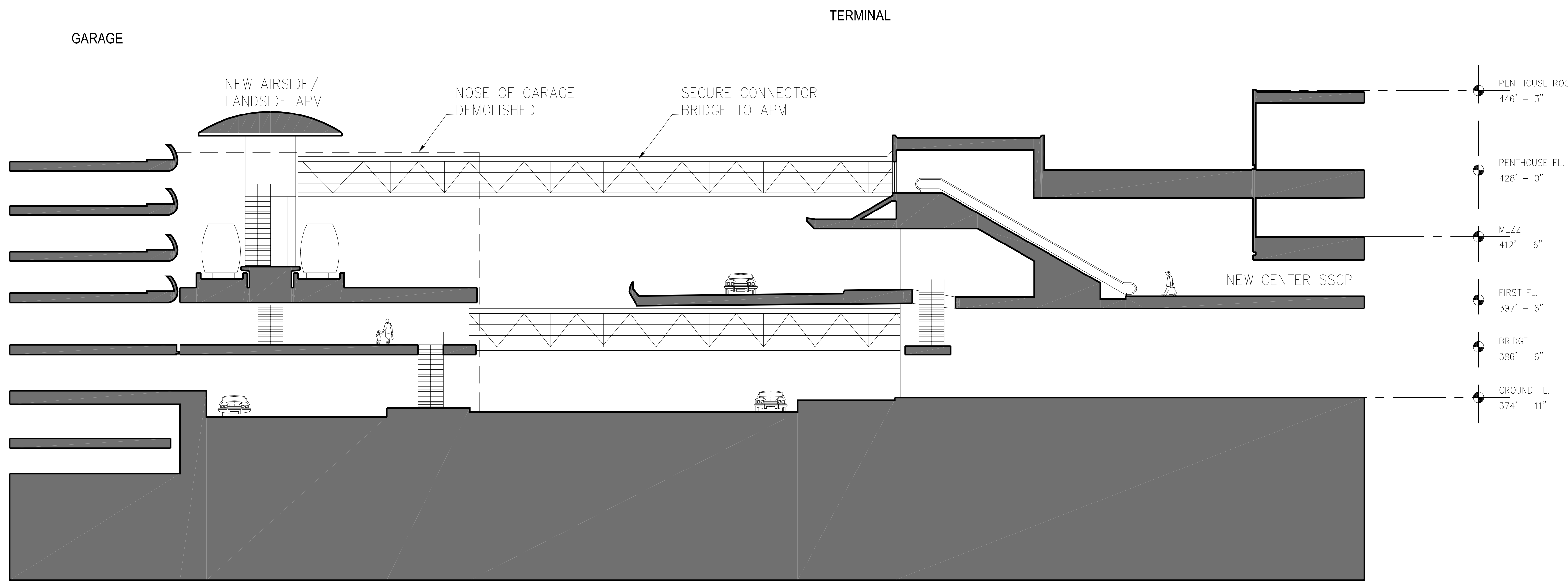
Leigh|Fisher CORGAN



Sustainable Airport Master Plan
Seattle-Tacoma International Airport

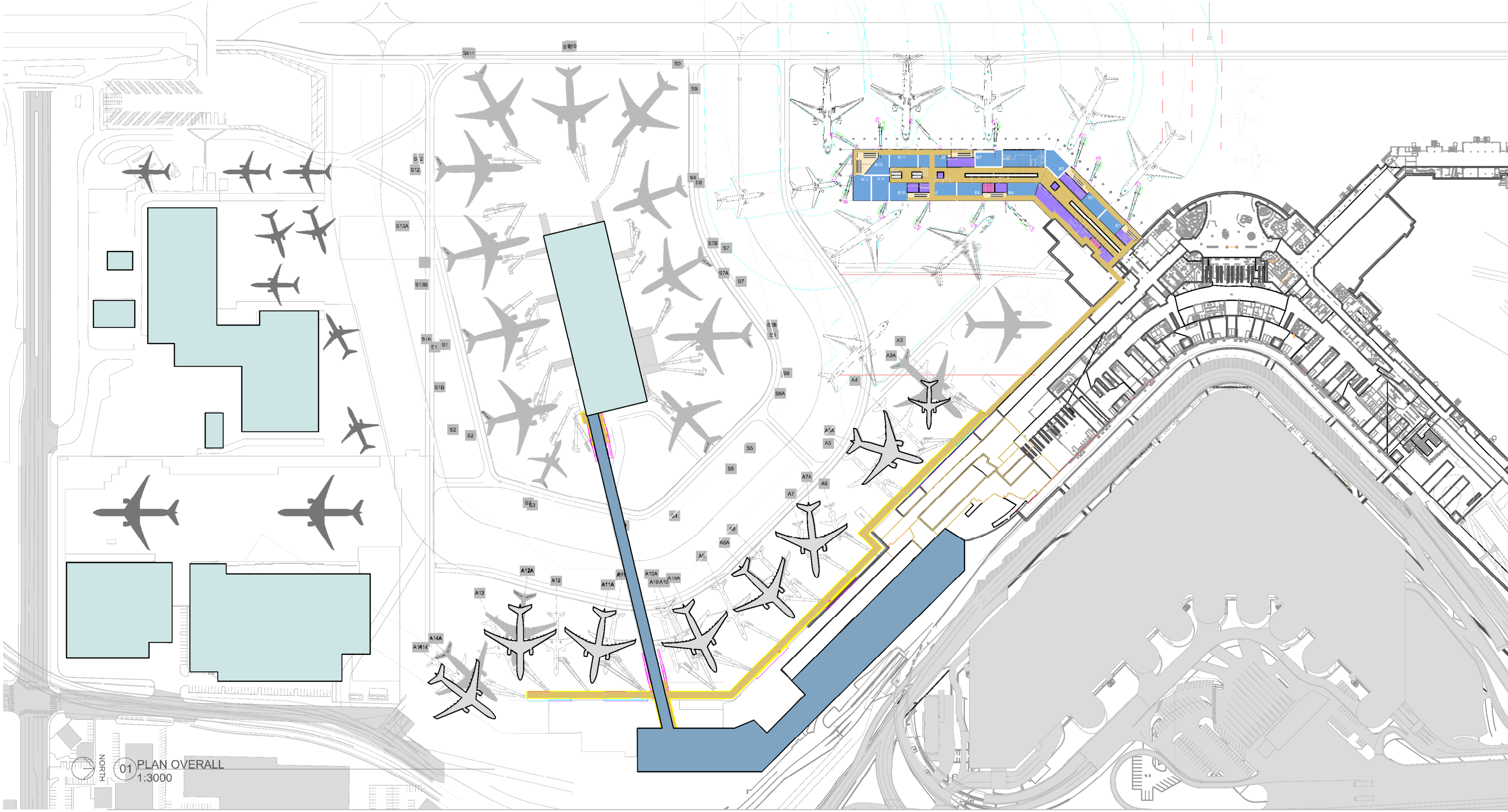
SEA MASTERPLAN - OPTION 2B - RAMP LEVEL - DEMO GARAGE NOSE / NEW APM

LeighFisher CORGAN


GARAGE
TERMINAL
NEW AIRSIDE/
LANDSIDE APM
NOSE OF GARAGE
DEMOLISHED
SECURE CONNECTOR
BRIDGE TO APM
NEW CENTER SSCP
PENTHOUSE ROOF
446' – 3"
PENTHOUSE FL.
428' – 0"
MEZZ
412' – 6"
FIRST FL.
397' – 6"
BRIDGE
386' – 6"
GROUND FL.
374' – 11"

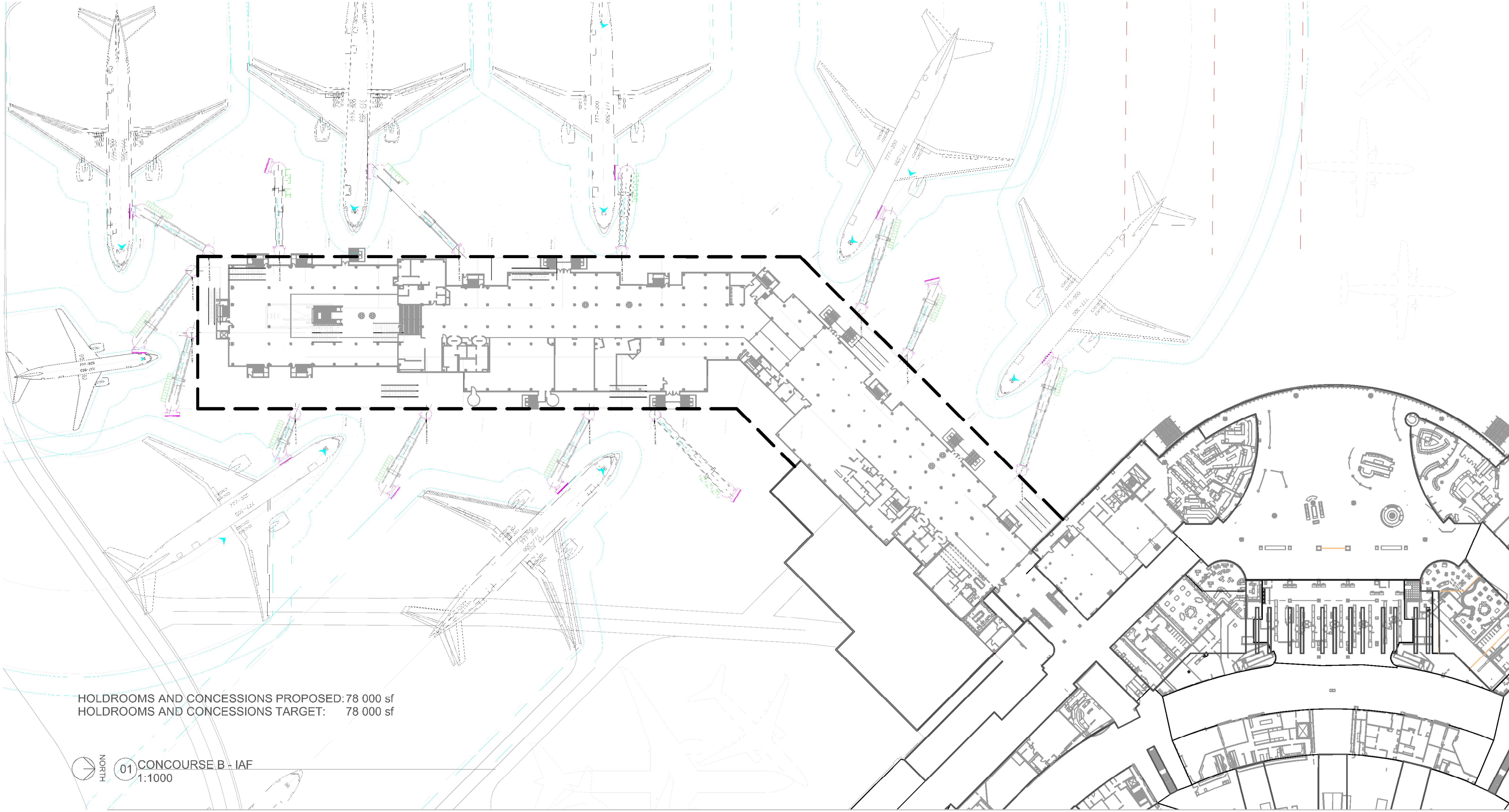
Appendix C

Concept for Concourse B Redevelopment



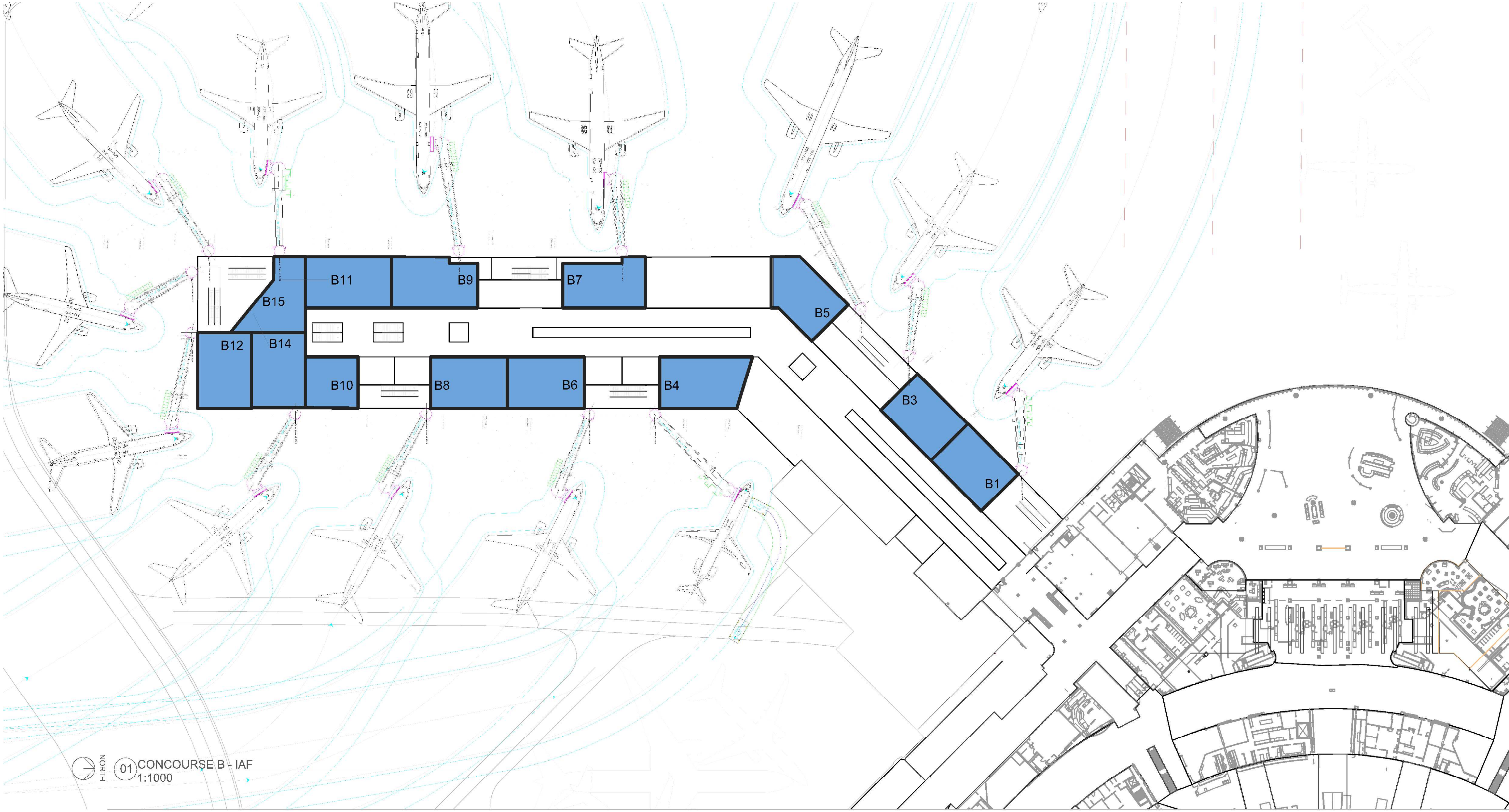
STIA-IAF | A1.01 | TERMINAL B - OVERALL | 2015.11.24

CORGAN



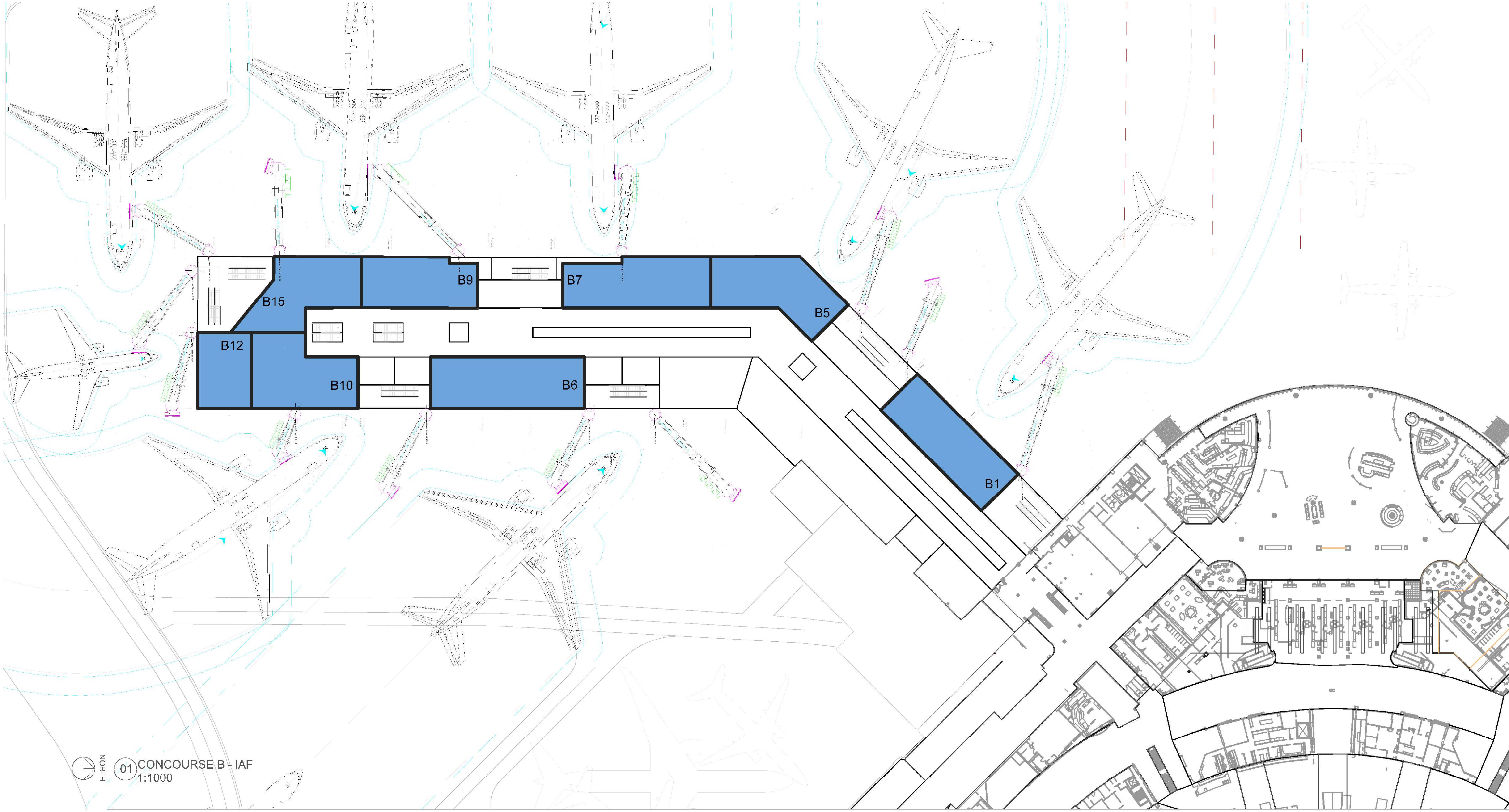
STIA-IAF | A1.02| TERMINAL B - PLAN - OVERLAY EXISTING | 2015.11.24

CORGAN



STIA-IAF | A1.03 | TERMINAL B - NARROW BODY | 2015.11.24

CORGAN



STIA-IAF | A1.04 | TERMINAL B - WIDE BODY | 2015.11.24

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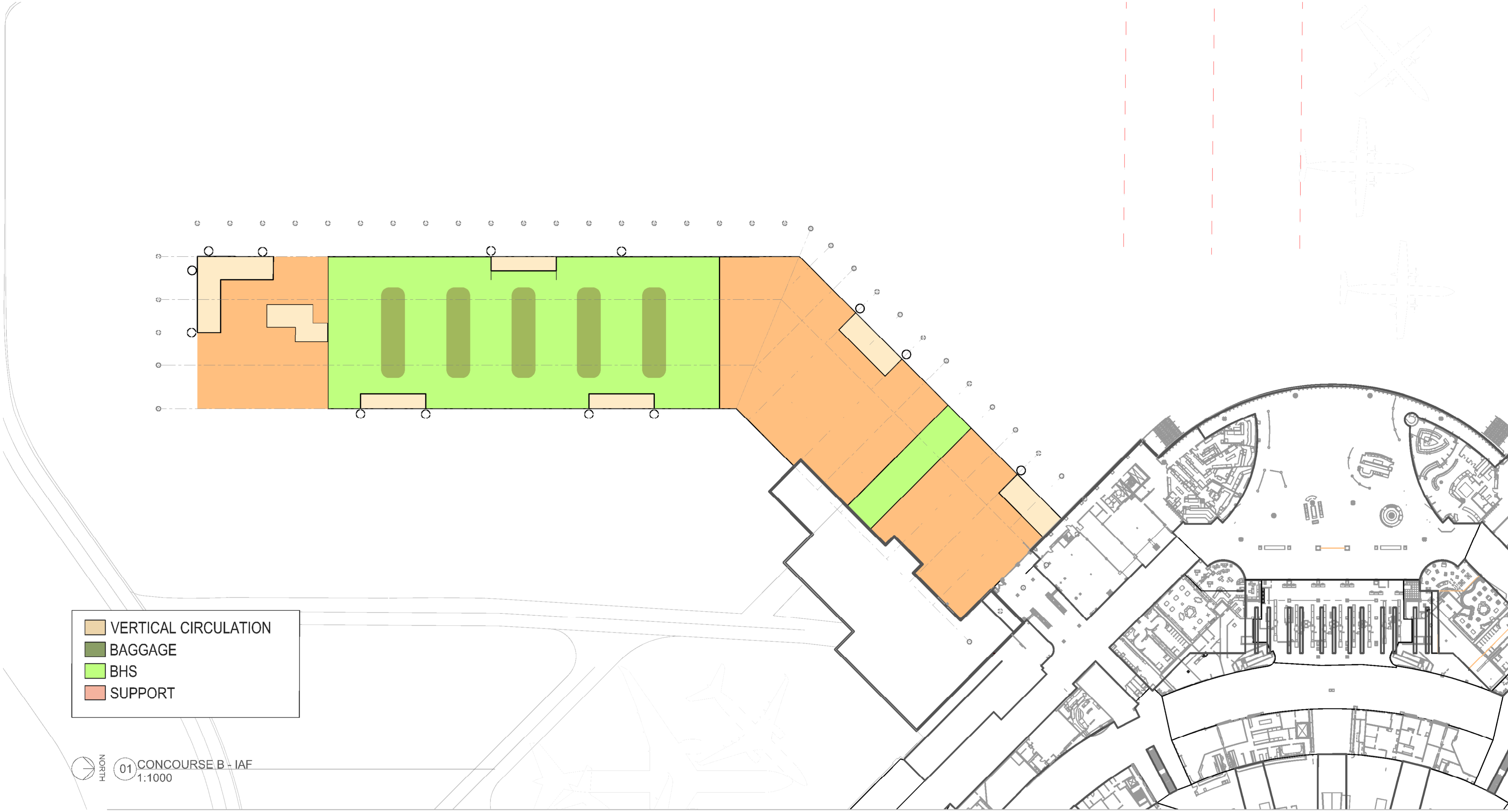

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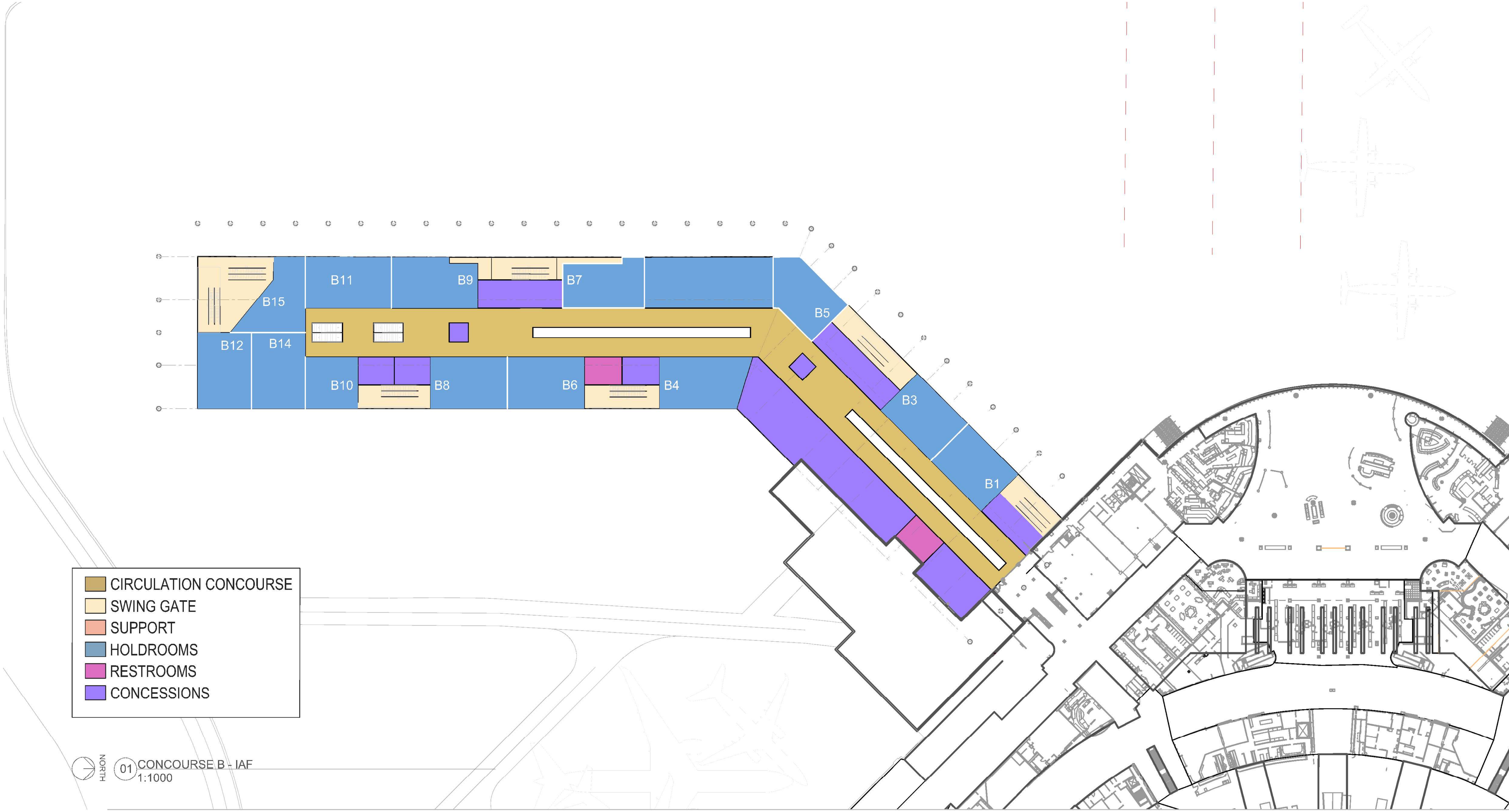

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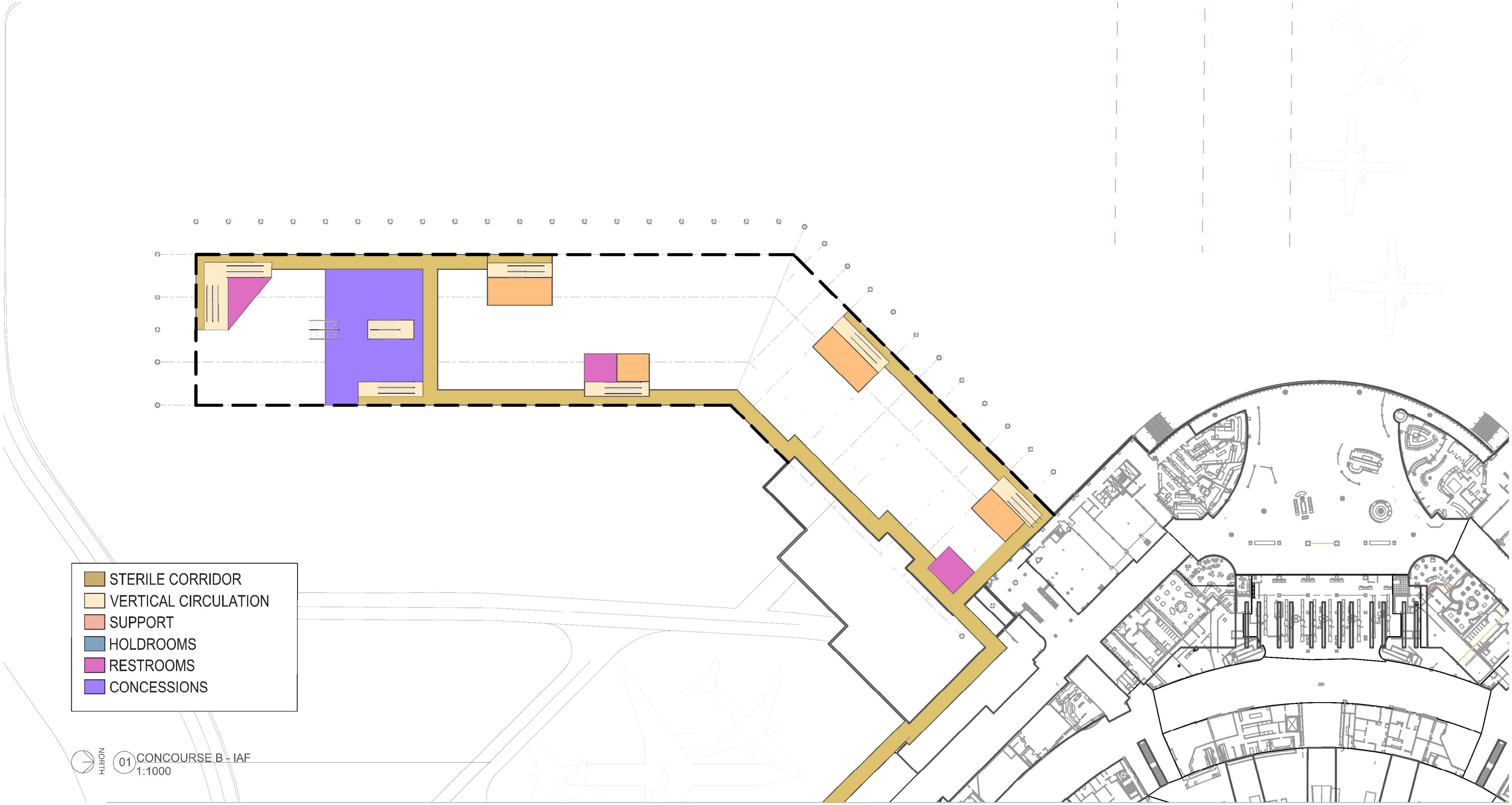

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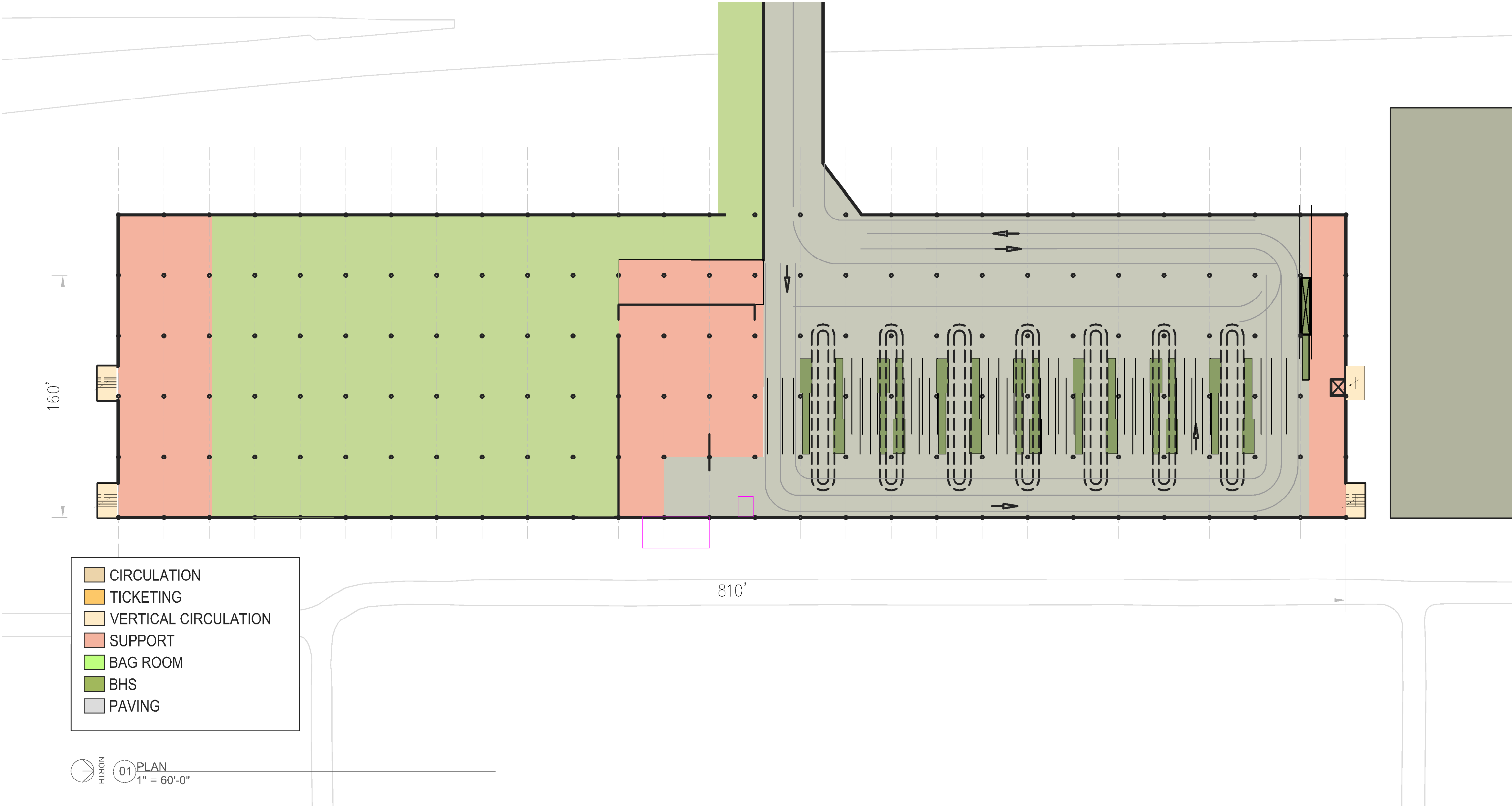
Appendix D

Two-Terminal Development Concepts for the North Terminal



13141.400 | A1.00 | PLAN - LEVEL 00 | 2015.12.01

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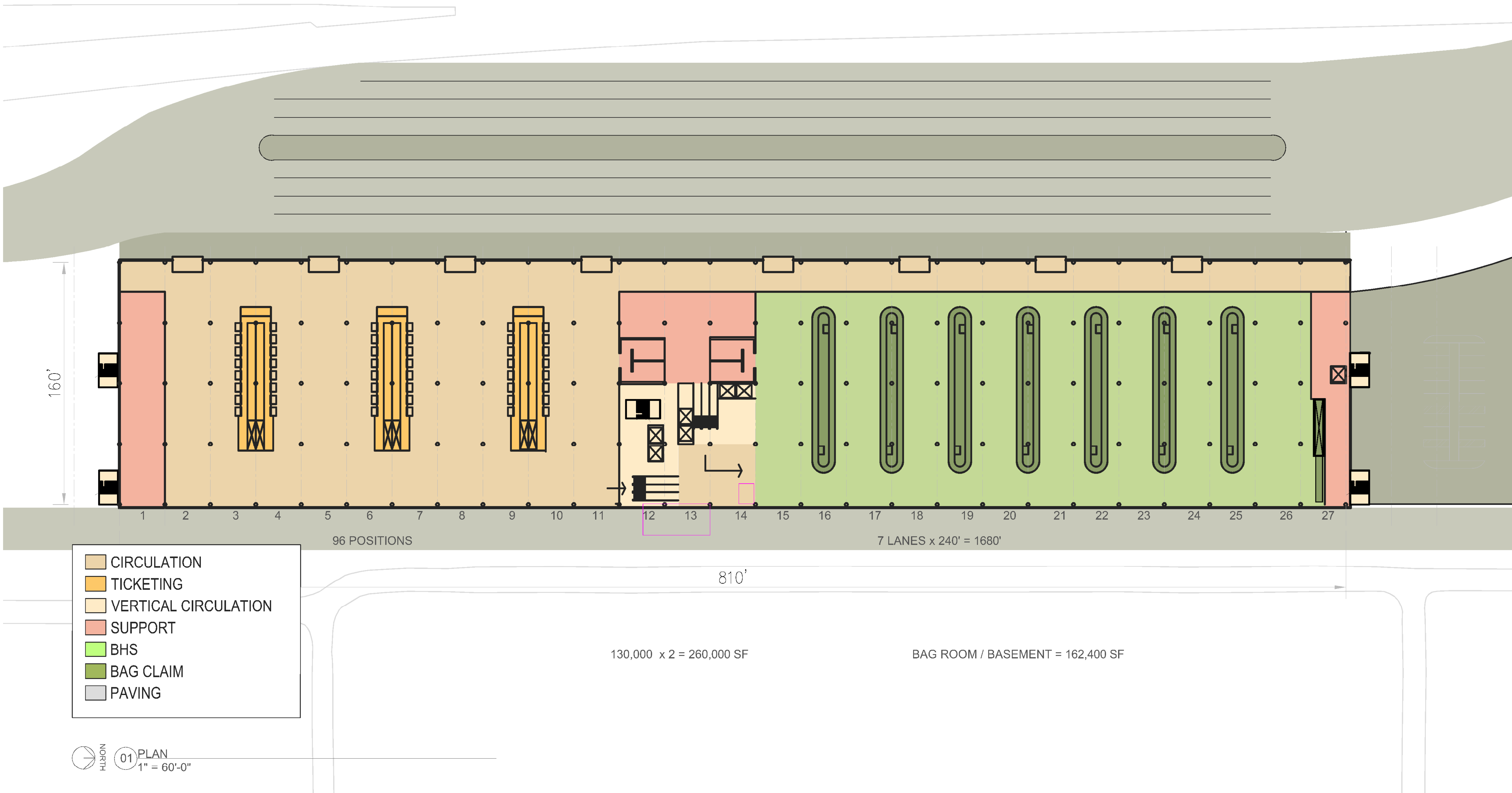

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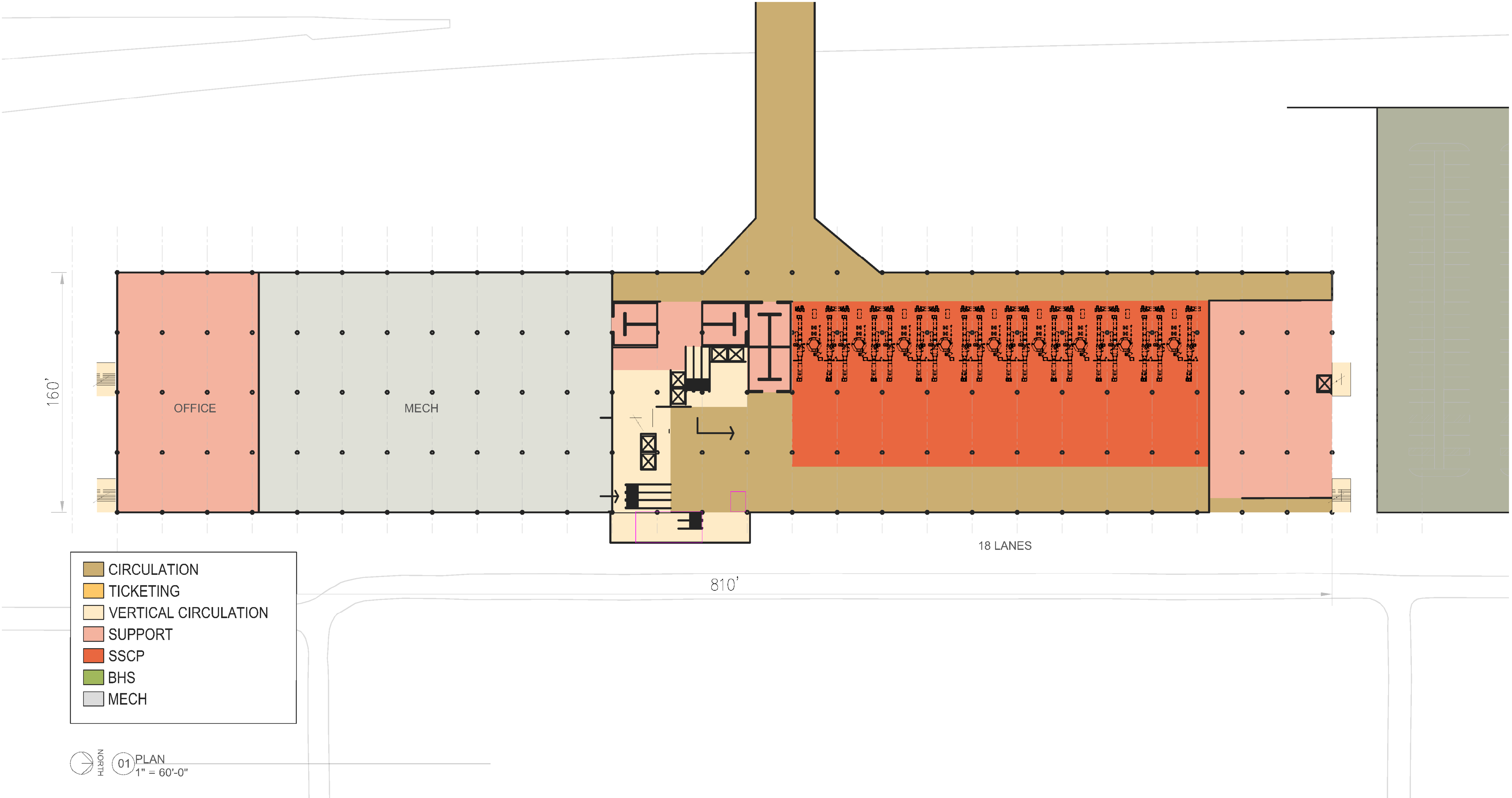

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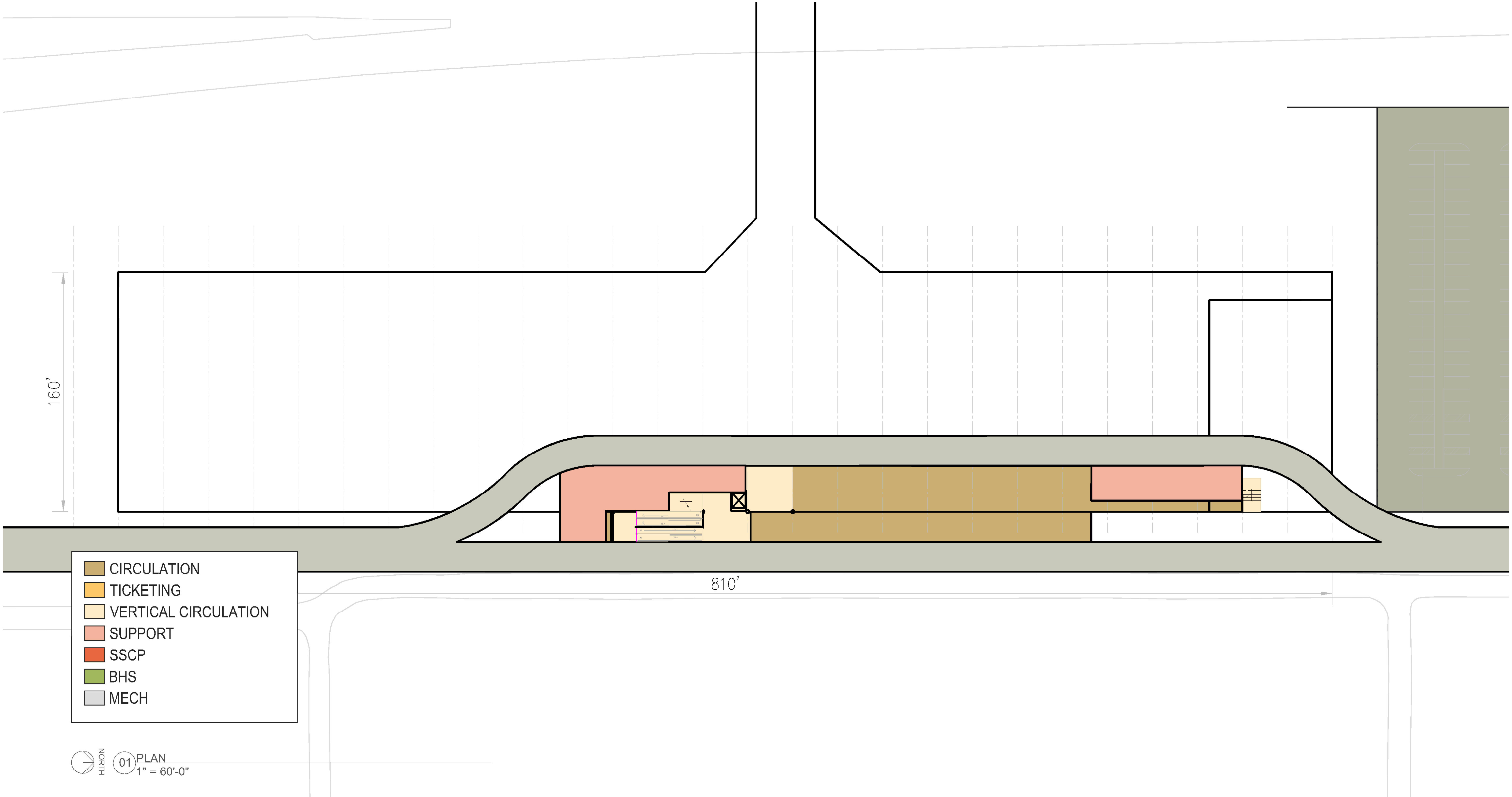

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Appendix E

Baggage Handling Systems Requirements and Alternatives

WORKING PAPER – BAGGAGE HANDLING SYSTEMS REQUIREMENTS AND ALTERNATIVES

Sustainable Airport Master Plan

Seattle-Tacoma International Airport

Prepared for:
Port of Seattle
Seattle, Washington

Prepared by:
Logplan
December, 2016

1 Baggage Handling Systems Requirements

1.1 Introduction

a. Logplan has, in the Requirements subtask of the master plan, prepared an analysis of BHS/EDS Requirements using an Excel flight schedule driven analysis method for the design year flight schedules provided by LeighFisher (for 2014, 2019, 2024, 2029 and 2034). The analysis also included consideration of interim years taking into account the anticipated date for commencement of operations at the proposed new North Terminal.

b. The Alternatives subtask of the master plan considered options for BHS/EBS development of systems at the proposed new North Terminal and for key elements of BHS (make up and domestic claim) at the existing terminal.

c. The objective of these subtasks is to determine baggage handling system facility requirements to meet future needs at the Airport over the planning horizon, and to develop facility layout alternatives based on block diagrams and schematic layouts.

d. Consideration has been given to expansion of BHS facilities based on a two terminal approach to development at SEA, including expansion of the existing main terminal to meet future processing requirements until the new North Terminal facility has been designed & constructed and has commenced operations

1.2 Planning Years

a. Logplan has prepared analysis of BHS requirements for the 2014 base year and four Planning Activity Levels (PAL) i.e.2019, 2024, 2029, and 2034, respectively, based on flight schedules provided by LeighFisher.

b. It is anticipated that the North Terminal is unlikely to be available for operational use until the 2025/6 period, requiring all operations to remain at the main terminal until that time.

c. The tabulation below illustrates the PAL's and the need for BHS facilities in the two terminals to support anticipated traffic growth.

PAL	Year	MAP	Main Term	North Term
Base Year	2014	37.434	X	
1	2019	44.816	X	
2	2024	51.828	X	
	2025	53.247	X	
	2026	54.666	X	X
	2027	56.084	X	X
	2028	57.503	X	X
3	2029	58.922	X	X
4	2034	65.648	X	X

Values in blue represent pro rata values (linear growth assumed)

Table 1 Passenger growth, 2014 to 2034 period
(source LeighFisher SEA SAMP Forecasts Draft 09 17 2015)

d. It has been assumed, therefore, that the main terminal BHS will have to accommodate increasing baggage volume through end of 2026, with the new North Terminal being introduced in 2026 i.e. at approximately 54 MAP total for both terminals.
e. The 2026 BHS requirements have been determined, based on a pro rata assessment related to the PAL 2 and PAL 3 (2024 and 2029) BHS requirements analyses
f. Logplan's analysis also assessed if the BHS facilities for the main terminal in subsequent years (after North Terminal is operational in 2026, up to PAL 4, 2034) will require any further expansion beyond what is required for 2026.
g. It has been further assumed that the North Terminal BHS requirements will be based on the 2034 (PAL 4) requirements, i.e. providing a facility that could accommodate almost 10 years of growth at the North Terminal, to avoid the need for BHS expansion there in the early years of operations.

1.3 Analysis Approach and Assumptions

e. Logplan has analyzed BHS requirements using a schedule driven method based on flight schedules provided by LeighFisher.
a. Logplan has used in house Logplan analysis tools (Excel spreadsheet based) using planning parameters and assumptions derived from Seattle information, where provided, and supplemented by Logplan in house data where necessary.
b. Analysis focused on the BHS elements covered in Logplan's scope of work. In the case of the main terminal this involved primarily outbound bag delivery, sortation and make up and inbound (domestic) claim, with other elements such as centralized screening, backbone delivery and early bag storage in the main terminal being the responsibility of others (BNP). IAF claim & re-check has not been addressed as this operation was previously analyzed and concepts developed in an earlier phase of the Master Plan project, and has now proceeded to a detail design phase (by others).
c. In the case of the North Terminal Logplan has analyzed all aspects of the BHS operation, including outbound bag delivery, security screening, early bag storage (EBS), sortation, make up and inbound (domestic) claim. It has previously been decided by Port staff that there will be no International arrival operations processed at an FIS facility at the North Terminal.
d. Logplan's scope of work does not include consideration of ticketing requirements (including remote or self-service bag drop provisions).
e. The analysis took into account the previously discussed objective of minimizing BHS expenditure on main terminal facility expansion to minimize the over-provision of BHS systems likely to result upon transfer of around 30% of passenger traffic from the main terminal to the proposed North Terminal around 2026. Analysis was based on previous information that a new EBS would be provided at the main terminal (under the central screening/EBS/conveyor backbone "Optimization Project, by others) and that the availability of this EBS would permit reduced make up device allocation times (I.e. compressed build operation) to minimize the need to add new make up areas in the main terminal to meet demand prior to the 2026 North Terminal opening. It has subsequently been discovered that the plans to implement the proposed EBS have been put on hold, implying that there may be a need to re-visit the analysis based on current make up device allocation times (without benefit of EBS for compressed build purposes).

f. The analysis is documented in Appendix A, BHS Requirements Analysis Report, which documents the main parameters and assumptions used by the analysis.

1.4 Analysis Results

a. Inbound domestic baggage

i. Claim frontage

- For the main terminal the analysis indicated that claim frontage requirements would be 2,982ft in 2019 and 3,441ft in 2024. For 2029 and 2034 design years, following service entry of claim facilities in the new North Terminal, the main terminal requirements would reduce to 2,730ft in 2029 and 3,047ft in 2034.

- For the North Terminal, anticipated to commence operations in 2026, the claim frontage requirements would be 1,406ft in both 2029 and 2034 design years.

ii. Claim devices

- For the main terminal the number of required claim devices has been based on the average length of existing claim devices in the main terminal, which is 168.75 ft (i.e. 16 claim units providing a total frontage of 2,700 ft), as based on layout drawings provided by SEA. On this basis the required number of claim devices for the future design years would be as shown in Table 2 Claim Device requirements, Main Terminal as follows:

Year	Overall claim length (ft)	Number of claim devices required
2019	**2,982**	**18 (17.67)**
2024	**3,441**	**20 (20.39)**
2029	**2,730**	**16 (16.18)**
2034	**3,047**	**18 (18.06)**

Table 2 Claim Device requirements, Main Terminal

It can be seen that the worst case condition for main terminal claim requirements is in the period immediately prior to opening of the new North Terminal (i.e. an additional 4 units are required for 2024 design year). In order to avoid over providing claim capacity in the years prior to opening of the new North Terminal it is suggested that reduced service standards be accepted during this period, and that the 2034 design year capacity (18 units at average size of 168.75 ft) would be a more realistic target for implementation prior to the 2019 design year.

- For the North Terminal, anticipated to commence operations in 2026, the proposed terminal layout provides for a domestic bag claim area with six (6) claim devices of equal size. Based on the overall peak period claim length requirement, i.e. 1,406 ft, each device would require a perimeter length of 234 ft. This peak requirement is, however, an isolated very narrow peak, and as detailed elsewhere in this report (refer para 1A e) a reduced requirement has been suggested, based on a 99th percentile value of 1,266 linear feet of claim device frontage. This would reduce the claim length from 234 ft. to 211 ft. As shown in Figure 1 Proposed domestic claim layout, North Terminal, the current layout provides for 6 equal sized claim devices of 165 ft., providing an overall presentation length of 990 linear feet. It will therefore be necessary for consideration to be given to increasing the size of the claim area to meet the 2034 requirement of 1,266 ft. If site constraints do not permit such expansion it may be necessary to accept somewhat reduced customer service standards in the North Terminal claim hall, or alternatively consider relocation of flights to the main terminal for the purposes of bag reclaim.

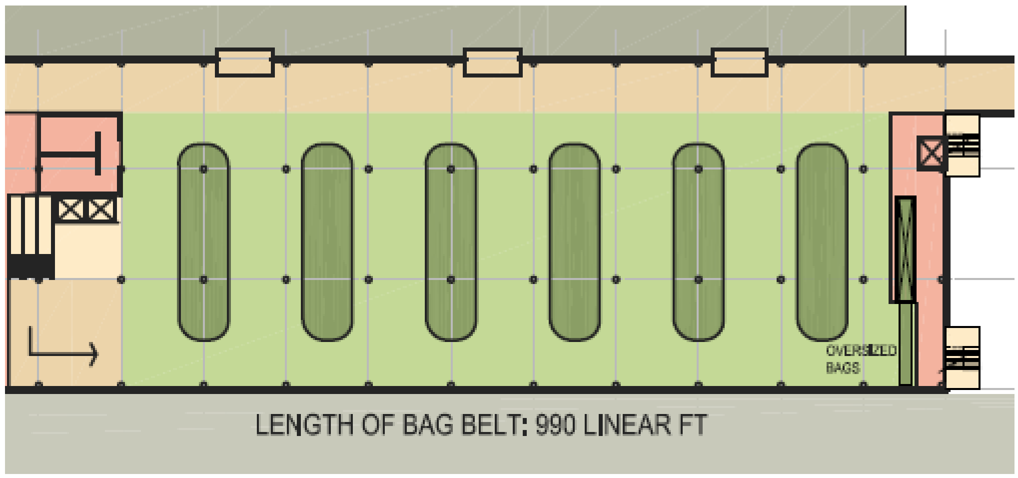


Figure 1 Proposed domestic claim layout, North Terminal

b. Outbound domestic and international baggage make up

i. Number of makeup positions (carts staged)

- For the main terminal the analysis indicated that bag make up requirements would be 490 in 2019 reducing (*) to 386 in 2024. For 2029 and 2034 design years, following service entry of bag make up facilities in the new North Terminal, the main terminal requirements would reduce to 293 in 2029 and 334 in 2034.
  * It should be noted that the reduction of make up requirement from 2019 to 2024 results from the parameters assumed for the analysis with regard to availability of a new Early Bag Store planned for the main terminal as part of the Baggage Optimization Study (under separate contract), which also involved provision of a centralized bag screening facility and a conveyor backbone system for bag delivery between the screening facility and the various make up areas as well as the proposed centralized EBS. The main terminal central EBS was planned to be available for use by 2019, at which stage the analysis assumed that a limited form of "compressed build" would be adopted, in order to minimize make up expansion prior to opening of the new North Terminal. The parameters on which the analysis has been based are shown below:

Domestic makeup open no EBS	-180	minutes	prior to scheduled time of departure (STD)
Domestic makeup open yes EBS	-120	minutes	prior to scheduled time of departure (STD)
Domestic makeup close	-20	minutes	prior to scheduled time of departure (STD)
International makeup open no EBS	-240	minutes	prior to scheduled time of departure (STD)
International makeup open yes EBS	-180	minutes	prior to scheduled time of departure (STD)
International makeup close	-30	minutes	prior to scheduled time of departure (STD)

By reducing the length of time that each make up device is open for bag delivery (with bags received prior to the open time being stored in the EBS it is possible to achieve a significant reduction in the number of make up units required.

It is now understood, however, that the EBS portion of the Baggage Optimization project may not be implemented, in which case increased bag make up positions would be required.

It can be seen that the worst case condition for main terminal make up requirements (assuming an EBS is available from 2019) is in the period immediately prior to opening of the new EBS and that adoption of compressed build operations for the main terminal would limit 2034 design year requirements to 334 make up positions (for main terminal). In order to avoid over providing make up capacity in the years prior to opening of the new North Terminal it is suggested that reduced operational service standards, if required, be accepted during this period. This could be achieved by reducing the number of carts/containers presented for each flight, at least during peak and shoulder periods, requiring some additional manpower and equipment for cycling carts/containers in the bag room(s). It is therefore suggested that the 2034 design year requirement for 334 make up positions would be a realistic target for implementation prior to the 2019 design year.

- For the North Terminal, anticipated to commence operations in 2026, the bag make up requirements would be 129 and 130 in 2029 and 2034 design years. The 2034 requirement for 130 make up positions should be used therefore for North Terminal initial implementation purposes

c. Peak hour bag flow rate and EDS screening machine requirements Inbound domestic baggage

i. Peak hour bag flow rate

- For the main terminal the analysis indicated that peak hour bag flow rate requirements would be 4,748 bags/hr in 2019 and 5,911 bags/hr in 2024. For 2029 and 2034 design years, following service entry of screening systems in the new North Terminal, the main terminal requirements would reduce to 5,051 bags/hr in 2029 and 5,742 bags/hr in 2034.

- For the North Terminal, anticipated to commence operations in 2026, the peak hour bag flow rate requirements would be 2393 bags/hr in both 2029 and 2034 design years.

ii. Bag screening machines

- Analysis of bag screening machine numbers required was based on the following assumptions:-

a. All originating bags departing SEA and all transfer bags from International arrival flights would be subject to bag screening.
b. A surge factor was applied to flow rates derived from schedule driven analysis to account for short duration peaking conditions, e.g. when transfer bags are introduced for screening in significant batch volumes and when local conditions such as a conveyor jam downstream of check in zone result in higher than normal bag flows
c. Medium throughput screening machines, similar to CTX 9800, have been assumed in analysis, with a machine throughput flow rate of 674 bags/hr (as per PGDS_v5 indications).
d. Additional machines to provide for redundancy have been assumed, in accordance with TSA guidelines. It was assumed that for each terminal screening system one additional machine would be provided in all cases where analysis indicates a need for fewer than 7 machines (without redundant machine). A second redundant machine is assumed where analysis indicates a need for 7 machines or more (without redundant machine).

- For the main terminal the number of required screening machines was assessed for reference purposes, however this requirement and the layout alternatives resulting therefrom are being addressed under the separate BHS Optimization Project, by others, which it is assumed will take into account re-use of existing screening machines with different throughput rates than assumed for the SAMP analysis. The analysis indicated that the required number of screening machines (at 674 bag/hr throughput and including redundant machines) would be nine (9) machines in 2019 and eleven (11) machines in 2024. For 2029 and 2034 design years, following service entry of screening systems in the new North Terminal, the main terminal requirements would reduce to ten (10) machines in 2029 and eleven (11) machines in 2034.

- For the North Terminal, anticipated to commence operations in 2026, the screening machine requirement is quoted based on medium throughput machines with 674 bag/hr capacity on the assumption that bags would be screened in a non ICS conveyor environment, i.e. raw bag delivery to screening machines, with subsequent induction to ICS carriers after screening has been completed. In the event that screening of bags "in carrier" is preferred the screening rate would be significantly affected by the ICS carrier length. In this case an argument could be made for using a higher speed machine, for example L-3 eXaminer XLB with an idealized throughput of 1145 bags/hr, assuming 28" bag length and 12" bag to bag spacing. Refer also to Paragraph 2 below Baggage Handling Systems Alternatives Development and Evaluation. The analysis indicated that the required number of screening machines (at 674 bag/hr throughput and including redundant machines) would be five (5) machines in both 2029 and 2034 design years.

d. Early Bag Storage Positions

i. For the main terminal the number of required early bag storage positions was assessed for reference purposes, however this requirement and the layout alternatives resulting therefrom are being addressed under the separate BHS Optimization Project, by others. The analysis indicated that the required number of EBS storage positions would be 393 in 2024, 471 in 2029 and 534 in 2034. No assessment was made for 2019, as this was the earliest date that an EBS could be implemented and it would not be reasonable to provide only the storage capacity needed in the opening year of the facility. Following service entry of an EBS system in the new North Terminal, the main terminal EBS bag storage requirements would reduce to 374 in 2029 and 435 in 2034.

ii. For the new North terminal the analysis indicated that the required number of EBS storage positions would be 181 in both 2029 and in 2034.

e. Consideration of peaking characteristics implied by analysis

i. The analysis results discussed above relate in each case to the peak values for each requirement resulting from the schedule based analysis. On reviewing the graphed results it became clear that in some cases the peaks were very narrow isolated peaks, which would not normally be expected to occur in practice, due to normal operational factors, such as resource allocation, flight delays and similar. In these cases consideration was given to adjusting the isolated narrow peak values based on use of a percentile distribution (98%'ile or 99%'ile typically), resulting in somewhat lower requirements values, considered to be more representative and realistic requirement values to be used as a basis of design.

f. Summary of analysis results

i. The requirements analysis results, adjusted for percentile distribution as discussed in para e.i above, for the key design years are provided below in Table 3 Summary of Requirements Analysis Results. It has been noted above that the worst case design requirement for the main terminal occurs in most cases immediately prior to commencement of operations of the new North terminal, since upon opening of the new terminal demand at the main terminal will decrease, so that year 2026 (under current planning assumptions regarding project schedule) is the key design year for the main terminal, whereas year 2034 is the key design year for the new North terminal.

Requirement	Location	Peak type	Year	Quantity	UOM
Domestic Claim Length	Main Terminal	98th percentile	2026	2,480	linear feet of carousel
Early Bag Storage Locations		Maximum	2026	433	bag storage locations
Checked Baggage Screening		Maximum	2026	6,116	bags/hour
EDS Count		Maximum	2026	12	EDS machines
Makeup Sortation Cart Positions		98th percentile	2018	448	Cart/container positions
Domestic Claim Length	North Terminal	99th percentile	2034	1,266	linear feet of carousel
Early Bag Storage Locations		Maximum	2034	181	bag storage locations
Checked Baggage Screening		Maximum	2034	2,393	bags/hour
EDS Count		Maximum	2034	5	EDS machines

Makeup Sortation Cart Positions		Maximum	2034	130	Cart/container positions

Table 3 Summary of Requirements Analysis Results

2 Baggage Handling Systems Alternatives Development and Evaluation

2.1 Introduction

2.1.1 Background and Scope

2.1.2 Approach and Assumptions

The primary assumptions used in the master plan study have been identified in the System Requirements Analysis, see Appendix 1 below. An additional key assumption was that the expansion of facilities in the main terminal would be minimized leading up to opening of the North Terminal, making use of compressed build for main terminal outbound bag make up operations, to minimize the need to expand bag make up facilities in the main terminal and avoid to the extent possible capital & operational expenditure (including manpower to staff additional bag rooms) which would result in provision of excess main terminal make up capacity in the years subsequent to the North terminal commencing operations.

The approach to development of BHS alternates taken was to use a schematic layout approach using block diagrams and material flow diagrams to define and evaluate appropriate BHS layout alternatives, and to define building area requirements on dimensional studies based on normal conveyor equipment sizing and Logplan in-house standards regarding mobile equipment drive aisle and passenger access & queuing dimensions, as applicable.

Appendices E, F & G, below pictorially illustrate the preferred BHS material flow for the North terminal, and illustrate a planning solution that is intended to meet the performance and system redundancy requirements considered appropriate for the new terminal. The diagram also illustrates the key BHS elements and operational functions to be provided by the future BHS design, and the connectivity existing and expanded BHS systems in the main terminal. In the event that the North terminal project is implemented on a design build (or design build operate and maintain) basis it is believed that material flow diagrams (amended as required during more detailed planning of the North terminal) may be used during the procurement process. In this case the BHS suppliers' proposals would be required to include a concept design submittal including both a material flow diagram and a concept level BHS proposed design (providing equivalent functionality to the MFD's issued for tender) for tender evaluation purposes and subsequent contract award. Since ICS suppliers use proprietary design solutions which differ from supplier to supplier it is suggested that procurement should be based on performance level specifications, rather than detailed equipment layout drawings as often used for conventional BHS projects, with procurement taking place ideally prior to finalizing terminal layout to allow the BHS supplier to participate as a member of the design team to assure a good fit between the BHS and its enclosing building infrastructure. With this in mind the competing BHS suppliers should, during procurement be encouraged to propose alternative design solutions based on their in house proprietary products and design approach, with the objective of achieving a "best value" solution for the Owner, taking into account the total costs of acquiring, operating and maintaining the BHS over an extended period of operation.

2.1.3 Alternate Concepts Considered

a. It was decided in liaison with SEA to restrict alternatives to be considered to the Two Terminal concept involving an expanded main terminal and a new North Terminal. Alternatives for BHS facility development at the existing main terminal and the new North Terminal were therefore based on the Alternate 2B gating allocation discussed at the workshop in Seattle (October 26 to 28, 2015). At the workshop a guideline had been suggested that the main terminal should accommodate between 60% and 70% of total annual passenger traffic, and a gate allocation with Hub Carrier 2 allocated to North Terminal and all other carriers (i.e. International, Hub Carrier 1 and Other Airlines) allocated to the main terminal. The suggested guideline regarding traffic distribution between terminals was estimated to be generally in line with this distribution. The gating allocation and distribution of gates is illustrated in Appendix B
b. At the same workshop a general approach to BHS facility development was agreed, illustrated at Appendix C. This illustration was based on a preliminary & approximate assessment of BHS requirements, which has been subsequently superseded following development of Logplan requirements analysis, referred to above in para 0 above, which has been based to determine the design requirements for both terminals.
c. The alternatives considered in this report have been developed based on expansion of existing make up and domestic claim areas in the main terminal using conventional BHS equipment, similar to existing, in the areas generally illustrated in Appendix C. This requires development of additional make up zones and expansion of claim areas.
d. For the North Terminal consideration has been given to an outbound system based on Individual Carrier System (ICS) technology, to include an automated storage and retrieval EBS and de-centralized make up areas for each of 2 concourses at apron level. (It should be noted that at the time of the October workshop it was anticipated that a 3 concourse configuration would be adopted, however in subsequent Months SEA decided to revise the layout to two concourses. During discussions on this subject consideration was also given to routing of ICS delivery conveyors between main and North terminals, resulting in an updated version of the terminal area layout as illustrated in Appendix E Revised Terminal layout with ICS routing options
e. It has been recommended that inbound baggage delivery to the claim hall at the North Terminal should be based on conventional tug and cart delivery and bag loading to local delivery belts at basement level of the terminal, rather than by use of an ICS delivery system, as the ICS based inbound system would involve higher baggage throughput, incurring additional expenditure on conveyor systems and requiring increase of building area to house these systems.
f. Consideration has also be given to an ICS delivery system linking the North Terminal with the existing main terminal and with the North Satellite building, primarily for transfer bag connectivity, but also to allow for operational flexibility (e.g. to allow passenger to check in at any location and have his/her bags delivered to any bag room for make up. As discussed above alternate routings for this ICS delivery system have been considered, refer also to Appendix E Revised Terminal layout with ICS routing options. The most direct routing is illustrated in Appendix D, Long term terminal layout,

developed at October 2015 BHS coordination workshop, however this involves tunnel infrastructure below active taxiways and hardstands. The alternate routing illustrated in Appendix E Revised Terminal layout with ICS routing options is probably more reasonable in terms of construction cost and apron disruption. (see extract below, Figure 2)

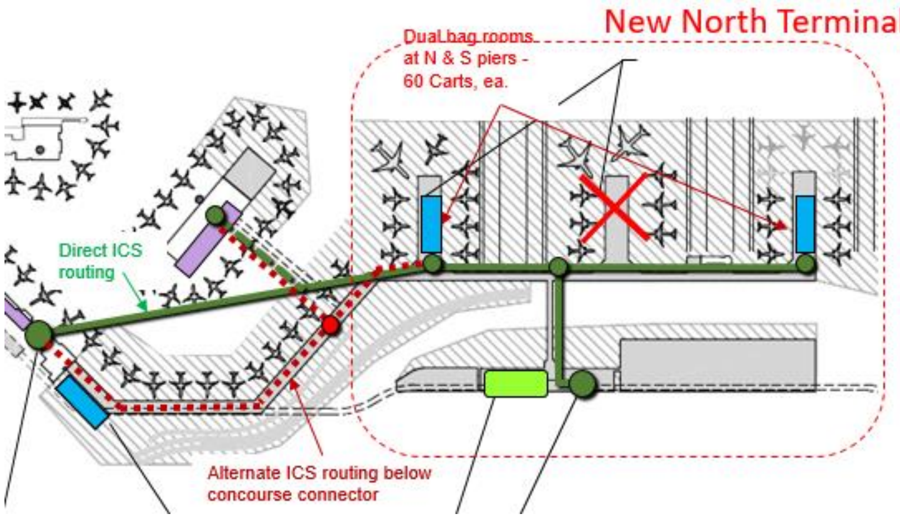


Figure 2 Alternate ICS routing to connect terminal areas

In this case ICS delivery conveyors could be installed totally in tunnel/basement areas, or if preferred parts of the system could be installed at apron level below the concourse connection between the terminals. The alternative ICS routing at the North Terminal is illustrated below, see Figure 3:-

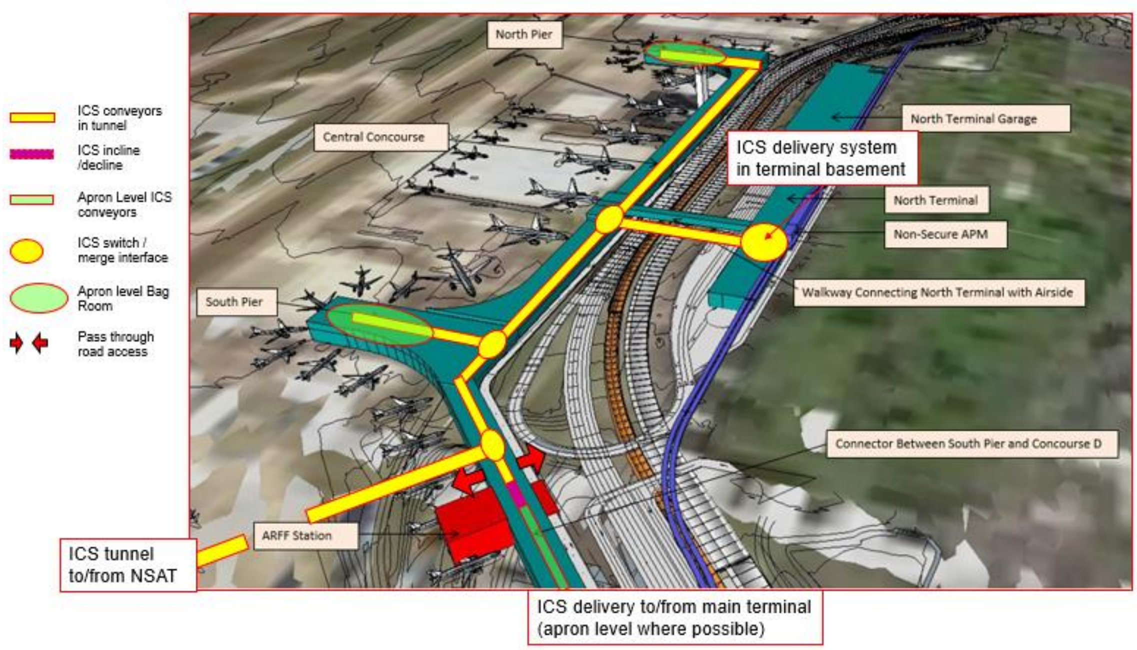


Figure 3 View illustrating ICS connectivity at North Terminal

g. In the case of the main terminal, BHS layouts (in block diagram/schematic form) have been developed for the critical or key design year, i.e. 2026 (Intermediate year at approx. 54 MAP), considered to be maximum extent that existing terminal can be reasonably expected to handle all operations, prior to introduction of North Terminal
h. In the case of the North Terminal, BHS design features have been based on the 2034 (PAL 4) design year, with the objective of providing a facility that could accommodate almost 10 years of growth, to avoid the need for BHS expansion there in the early years of operations.
i. Alternatives with regard to the IAF and the North Satellite expansion have not been developed as these are ongoing detail design project, by others.
j. For subsequent design years analysis confirmed that the main terminal requirements for the 2029 and 2034 design years (PAL 3 & 4 respectively) will not be greater than the 2026 (54 MAP) requirements (i.e. requirements just prior to capacity being transferred to the new North Terminal).

2.2 Two-Terminal Concept

2.2.1 North Terminal

2.2.1.1 Key BHS functionality features

The North terminal BHS concept as illustrated in the material flow diagrams developed during the study is based on the following key features :-

a. Standard size bags (ST) and conveyable oversize (OS) bags to be handled within the ICS based outbound system
b. Inbound (terminating) BHS system to be based on conventional tug and cart/container delivery system.
b. Automatic Tag readers (ATR's) to be used on each outbound system input line (for both originating and transfer bags) for bag identification.
c. ICS loading positions for loading of bags into ICS carriers for delivery to EDS screening, EBS and bag make-up facilities in North terminal make up facility.
d. A bag measurement array immediately downstream of each ICS loading station to be provided to check if bag has been correctly loaded on ICS carrier (e.g. no bag overhang outside perimeter of ICS carrier).
e. A No-read and mis-loading position to be provided on each system input line to provide for manual coding (MC) of bags whose tags cannot be successfully read by the ATR. The manual coding station should in addition provide ability for MC operator to correct a mis-loaded bag, to minimize risk of bag mishandling during conveying on the ICS system.
f. Empty carrier delivery and buffer queue system to be provided for delivery of carriers to ICS load positions.
g. ST and OS bags to be handled with new ICS for manual code and automatic EBS storage. Non conveyable oversize (NC) originating bags (bags exceeding OOG dimensions or not suitable for handling on a conveying/sorting system, e.g. fragile, livestock, etc.) are to be manually handled e.g. by porter, for delivery to TSA CBIS area and subsequently manually delivered to the North terminal make up areas or other facilities (e.g. main terminal, NSAT etc.), as appropriate. Transfer NC bags will also be handled and delivered manually.

h. Early Bag Store – automatic random access storage and retrieval system based on ICS design approach (i.e. with bags stored in ICS carriers (both ST and OOG bags)
i. Conveyor connections to/from existing BHS systems in main terminal for both ST and OS bags by ICS delivery, e.g. for transfer bags.
j. ICS delivery system to provide for final sorting to make-up devices at North terminal make up facilities and for inter-terminal transfer bag connections.

2.2.1.2 Inbound Domestic Baggage

A conventional delivery conveyor and claim hall system has been proposed for the North Terminal. Tugs and Carts would be used to deliver baggage from arriving flights to the basement level of the North Terminal, accessed via apron roadways and tunnel connection.

A claim hall layout with 6 medium sized incline plate claim devices has been proposed, each of a preferred perimeter claim frontage length of 211 ft., to meet 2034 requirements. This device claim frontage is somewhat greater than provided for in Architect layout as illustrated in Figure 1 Proposed domestic claim layout, North Terminal, above, which was based on a claim frontage length of 165 ft. per carousel (6 carousels).

In addition to the 6 make up devices claim provisions for oversize baggage will be required in the claim hall, for both:-

- conveyable oversize bags, delivered by incline belt conveyor via basement level to an oversize run out belt for passenger collection, and
- non-conveyable oversize bags, such as surf boards, fragile goods, etc. These bags should be delivered by porter, using an oversize bag elevator located adjacent to the passenger collection area for the incline belt.

A dimensional study is provided, see Figure 4 BHS Facility Space Requirements – Possible layout approach for claim hall - illustrating a preferred claim hall layout for BHS claim elements. The layout provides for major circulation aisles (15ft wide) around the perimeter of the area and minor circulation aisles (10ft wide) between devices. A 15ft wide zone for passenger queuing is also provided around each device. Space is also allowed for oversize bag claim, requiring a 15ft zone, preferably located close to the exit from the claim hall, to minimize walking distances, e.g. for passengers claiming both standard bags and oversize bags.

In the case of the North terminal, a total overall area of 60,000 sq. ft. would result from applying these design standards.

If this cannot be accomplished in the Architectural design of the North terminal it is feasible to reduce claim size, however this would result in an increased level of passenger congestion and a reduction of customer service standards.

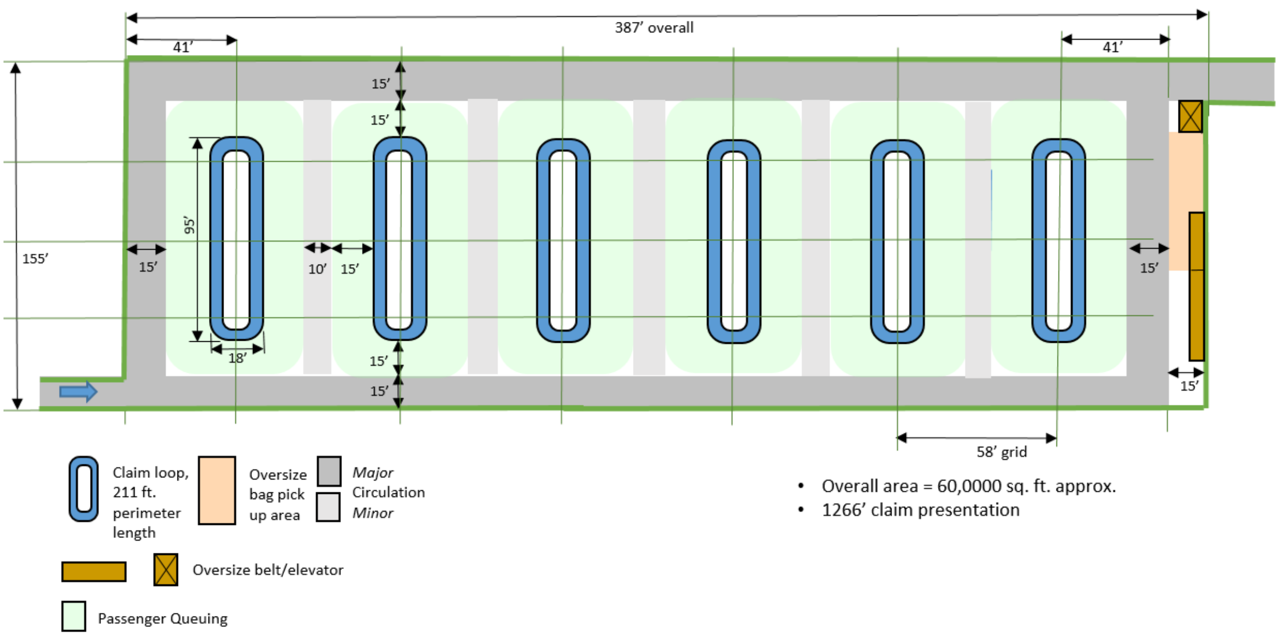


Figure 4 BHS Facility Space Requirements – Possible layout approach for claim hall

Baggage delivery to the carousels would be provided by load belt and transport conveyors located at basement level, with one delivery line to each carousel. Incline belts would deliver bags to the interior of the carousel, with discharge to the incline plate device via 90 degree power turn conveyor and transition slide. Figure 5 Architect suggested layout, basement level BHS at North Terminal, below, illustrates a concept, considered during preliminary planning of terminal overall layout.

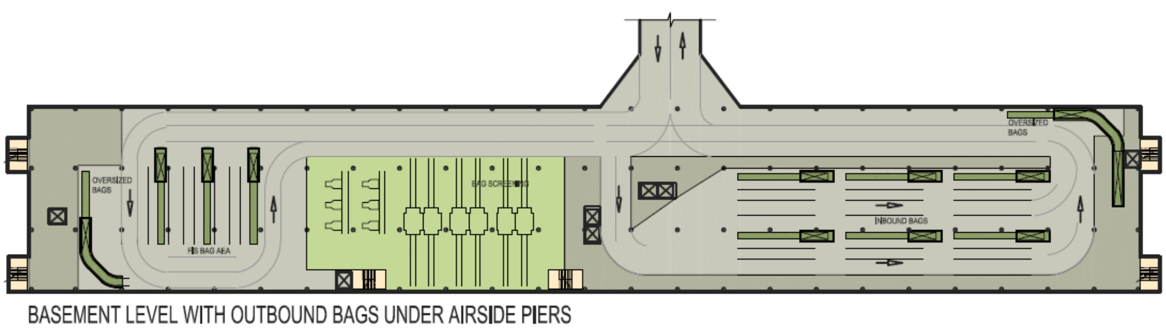


Figure 5 Architect suggested layout, basement level BHS at North Terminal

In this layout option it was assumed that baggage make up would be located in the airside concourse area, at apron level, served by tunnel mounted delivery conveyors from the landside processor basement (not shown in layout). The layout also indicated claim unload belts for an FIS facility at North Terminal, since discontinued, as well as EDS screening at the Checked Bag Inspection Area (CBRA) and the Checked Bag Resolution Area (CBRA).

An alternate layout study option is provided below, see Figure 7 North Terminal Inbound Baggage Unload Area, suggesting a possible BHS layout as a basis for facility area and cost estimation purposes.

The space required for the tug and cart/container unload zone is shown below in

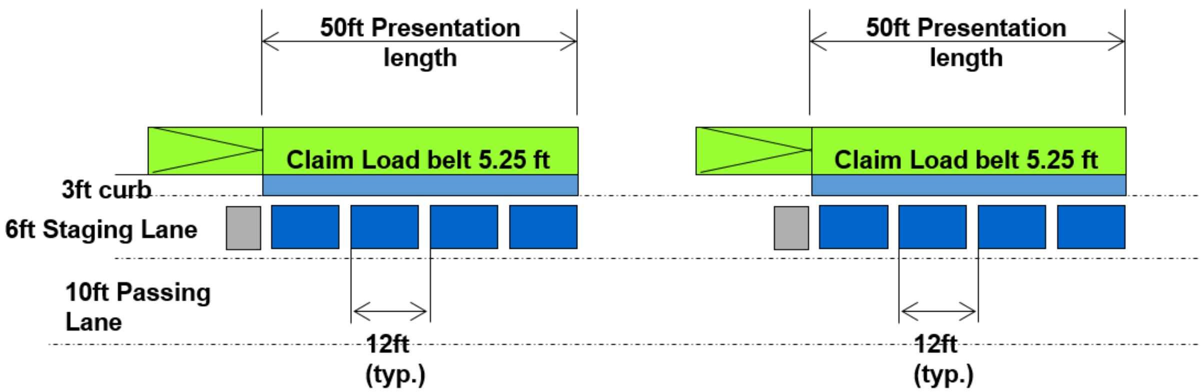


Figure 6 Possible layout approach for claim load belts. The spacing between adjacent claim load belts will vary depending on routing of delivery belts downstream of the incline section, but in any event it will need to provide clear headroom for load personnel below the incline and subsequent conveyors working at the adjacent claim load belt.

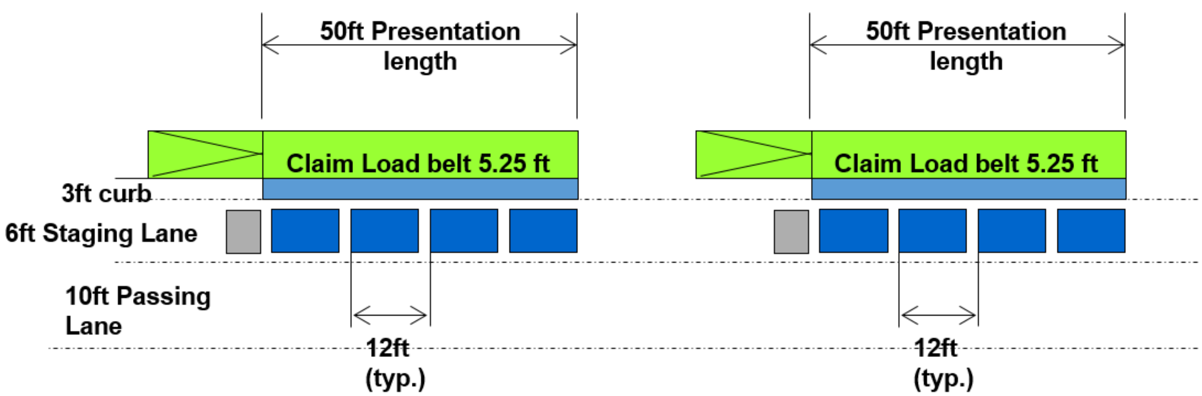


Figure 6 Possible layout approach for claim load belts

In the alternate layout (Figure 7) one unload conveyor lateral is provided for each carousel in the claim hall. Each unload lateral is capable of being accessed by a tug and 4 carts. A one way flow system around a central island bag load area is proposed, so that a consistent cart/container orientation is used for each lateral, to avoid need to rotate containers and to adapt to carts with load/unload access from only one side. It is considered that this layout will reduce facility area and cost, due to the reduced tug and cart driveways required, compared with the layout illustrated above in Figure 5 Architect suggested layout, basement level BHS at North Terminal.

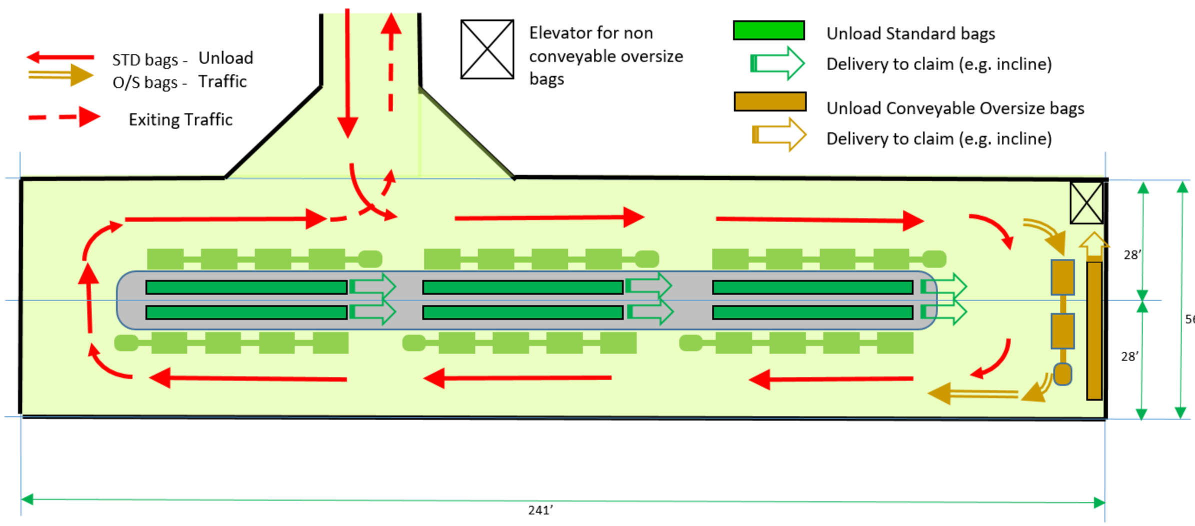


Figure 7 North Terminal Inbound Baggage Unload Area

The overall area required for the above layout (Figure 7) is estimated to be approximately 13,500sq. ft., allowing for 24 cart presentation positions servicing 6 claim devices each with a single feed line. This equates to an average metric value of 562 sq. ft. per cart staged (2,250 sq. ft./claim loop) which is believed to be a suitable value to be used for assessment of area required and facility cost.

2.2.1.3 Bag delivery from ticketing/bag drop counters and baggage security screening

Baggage security screening for the North Terminal is based on the assumption that all originating baggage will be screened in the basement area of the North terminal landside processor building, along the lines generally illustrated in Figure 5, above, and that transfer bags from International flights will have been rechecked and screened at the main terminal (at IAF). Bags from domestic flights transferring to departures are, under current TSA operational procedures, not required to be screened, with reliance placed on screening performed at origin airport.

For an ICS delivery system as proposed for implementation in the North terminal, and for transfer connectivity to NSAT and main terminal, two alternative approaches to screening can be considered:-

- Screening of bag after bag has been loaded to the ICS carrier, preferably as soon as possible after bag check in.
- Screening of bag prior to loading to the ICS carrier.

In the former approach the risk of loss of bag tracking during transport is significantly reduced, whereas in the latter approach the risk of loss of bag tracking will be increased, also increasing the throughput at Automatic Tag Read (ATR) systems immediately upstream of the ICS carrier bag induction stations and associated manual encode and bag alignment stations (downstream of bag induction), thus increasing complexity, bag delivery times, and capital and operational expenditure.

The former (& preferred) approach is often difficult to achieve when implementation in an existing terminal is required, but is more realistic and beneficial in a green field site, such as the North Terminal, where a basement located below the check in area may be provided to provide the necessary Empty Carrier Buffer (ECB) queues and carrier induction stations in close proximity to the delivery line (preferably a tracked conveyor to minimize manual encoding system requirements) from check in counters (e.g. immediately downstream of decline belt from check in zone).

The main disadvantage of the former approach is that the average bag length "seen" by the EDS screening machines is the ICS carrier length, which is always longer than actual bag length. This would require either a greater number of EDS machines or alternatively a similar number of higher throughput machines. The requirements analysis (Appendix 1, below) assumed a screening capacity of 674 bags/hr per machine, based on medium throughput machines handling average 28" long bags at a spacing of 12" between bags (i.e. not in ICS carriers). An alternative approach would be to assume a high capacity machine such as L3 examiner XLB, rated at 1260 bags/hr (per TSA PGDS) at average 28" long bags at a spacing of 12". For an ICS carrier based system, using the former approach, with 48" long carriers at 12" spacing the throughput would reduce to 840 bags/hr. Since non conveyable bags would ideally also be handled via the screening system, as per Figure 8 - Preferred EDS schematic diagram, below, using longer carriers, the overall rate will reduce, and therefore it is suggested to assume the same overall rate as for a medium throughput, i.e. 746 bags/hr, used for analysis purposes.

In the extract from Appendix A North Terminal Landside Processor - Material Flow Diagram, the preferred approach is illustrated in Figure 8 - Preferred EDS schematic diagram.

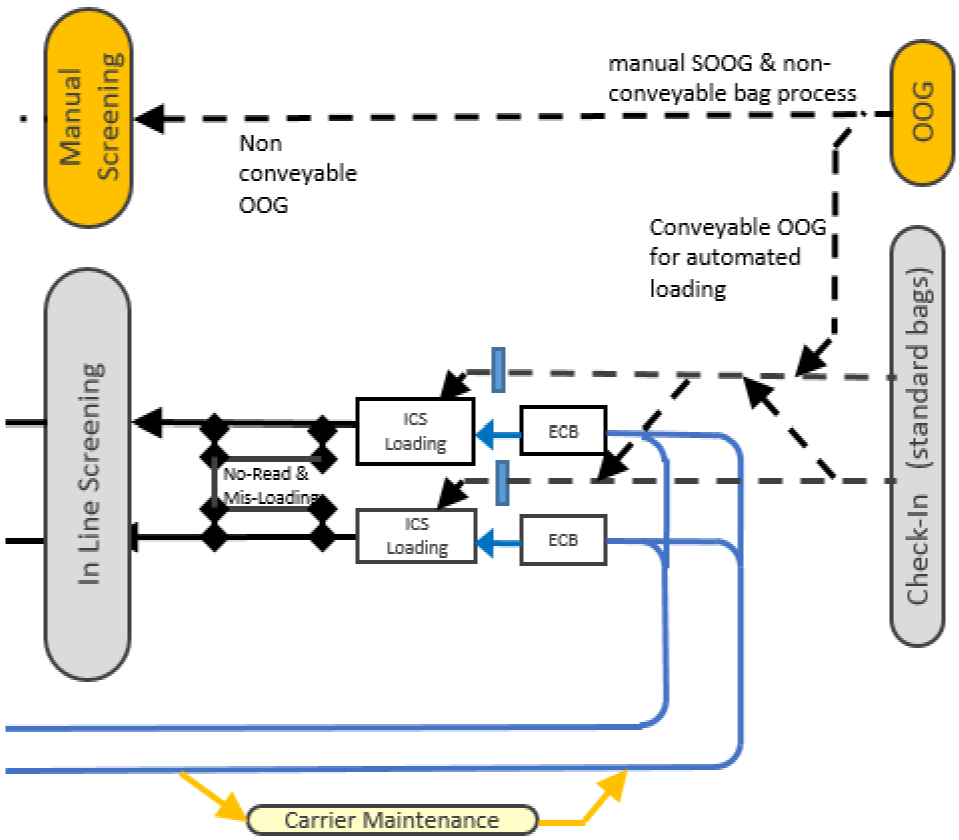


Figure 8 - Preferred EDS schematic diagram

Bags checked in at standard bag capable counters are delivered by delivery belt to the basement level and proceed (via crossover links to provide redundancy) to the ICS carrier induction station.

Bags checked in at the conveyable oversize capable counter(s) are delivered by oversize conveyor to the basement level via a bag measurement array, which determines if bags are correctly sized to fit within an oversize ICS carrier. If not the bags are diverted to a manual output spur to allow for manual delivery to the TSA screening area. For bags in compliance with OS carrier limits delivery to the ICS carrier induction station takes place.

The bags then proceed to an automatic tag reader (ATR) array for encoding. Each loading station is equipped with its own ATR. After passing the ATR, the bag will proceed (under conveyor tracking controls) to the ICS carrier load position (top loader) and queue, awaiting loading to the ICS carrier. An empty ICS carrier delivery line will release an empty carrier of the correct size to the top loader station, and the vacated space will be filled with a new empty carrier supplied from an empty carrier buffer queue upstream. The carrier and bag release at the top loader station are controlled to ensure the bag loads successfully onto the carrier.

After each top loader is a sensor array and manual intervention station to allow no-read bags and bags that are 'mis-loaded' to be detected and manually dealt with. Figure 9 below (source: Vanderlande) illustrates this functionality.

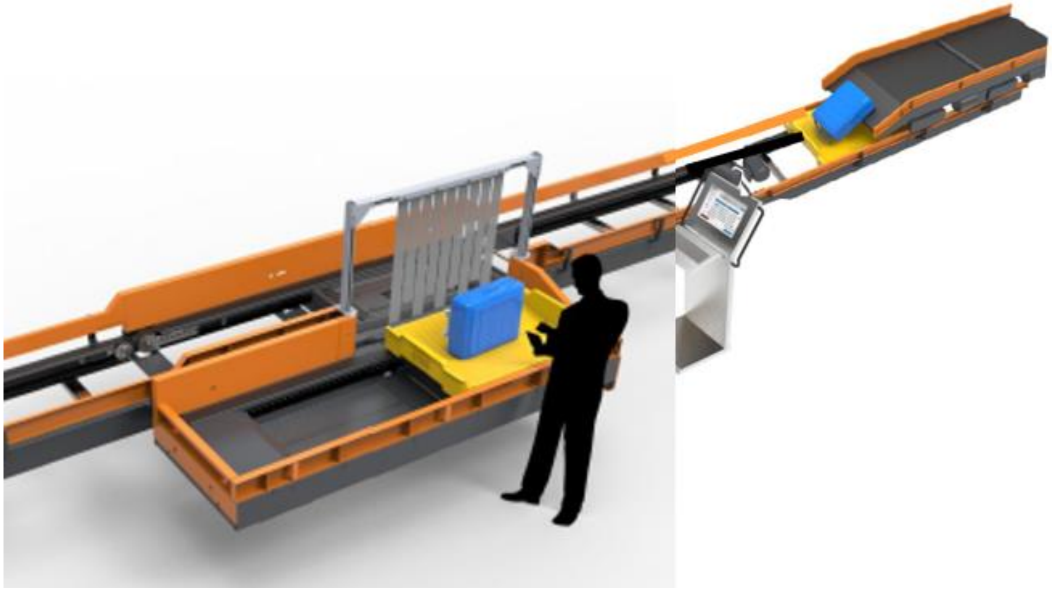


Figure 9 Bag induction and manual encode/mis-load station

Misloaded bags should be automatically detected as 'mis-loaded' and immediately diverted off line to a holding position so as not to hold up the flow on the main line. No read bags will also be diverted to the no read and mis-loading station. A CCTV camera positioned over the holding position, such that operators can view the bag remotely and decide if the bag needs manual intervention or not. If the remote operator is able to read the bag tag ID and is sure that the bag does not require intervention he will encode the bag, initiate re-entry to the delivery line via remote coding and release control. If a bag requires manual intervention, the operator will proceed to the no-read and mis-loading station to re-code the bag and/or rectify the mis-loading condition and initiate re-entry of the carrier and bag to the delivery line using local controls.

Baggage security screening will be provided in accordance with TSA PGDS requirements in the Checked Bag Inspection System (CBIS), with ST and OS bags being screened by certified in line screening machines with bags in ICS carrier during screening. NC bags will be delivered manually and screened by certified equipment such as Electronic Trace Detection (ETD) or manual search.

Following screening cleared bags (ST and OS) will be delivered via tunnel mounted ICS conveyors to the airside for sortation to the appropriate North terminal bag room (at N or S concourse bag room, as required) or to other terminal areas (e.g. NSAT bag room or main terminal ICS to conveyor backbone interface system).

Area required for EDS screening has been assessed based on conventional EDS systems at other airports, on the assumption that higher throughput EDS in line machines would be used in the ICS approach, thus requiring the same number of machines, albeit with higher throughput.

Using data from previous Logplan projects, a metric for CBIS area of 2,000 sq. ft. per screening machine is suggested (see Figure 10, below) for standard conveyor system design.

Airport	Location	EDS machines	CBIS space [sq.ft.]
Denver	M1E	4	8930
Detroit	North Terminal	4 (3)	5599
Wichita	Mid-Continent	3 (2)	3900

Figure 10 CBIS area values from other airport projects

An alternate metric value, derived from an example provided in the TSA PGDS-v5 document (see Figure 11, below) indicates a somewhat higher value of around 3,150 sq. ft. per screening machine. A value of 3,000 sq. ft. is therefore suggested for space planning purposes for the North terminal project.

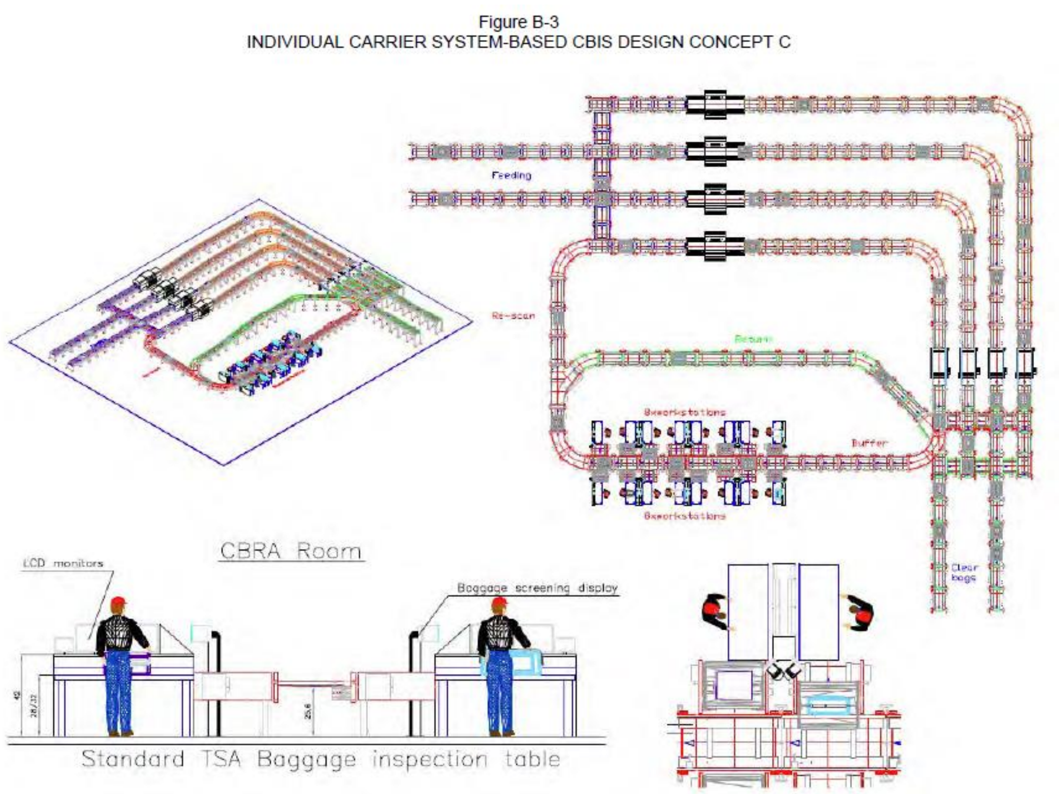


Figure 11 ICS based CBIS/CBRA concept example from PGDS-v5

The system requirements analysis indicates that for the 2034 design year five (5) EDS screening machines would be required, indicating an area requirement of approximately 15,000 sq. ft. of basement area for the CBIS area.

The facility height required for the CBIS area should be sufficient to accommodate floor mounted screening machines (including their overhead maintenance clearance space) and an overhead conveyor right of way (ROW), i.e. approximately 14ft in total (88” machine height + 20” clearance + 60” ICS ROW).

The space required for the North terminal EDS CBIS area is therefore assessed at approximately 15,000 sq. ft. of area, with a height of 14 ft., to be provided in a basement in close proximity to the ticketing/bag drop area at the level above.

The area required for the CBRA area, based on the TSA PGDS-v5 document, see Figure 11, above, has been assessed to be approximately 450 sq. ft. per ETD/search workstation, with a ratio of 4 ETD stations per inline machine. For the North terminal CBRA this would indicate a need for 9,000 sq. ft. of area (i.e. 5 machines x 4 stations per machine x 450 sq. ft. per station).

The height for the CBRA area would be less than needed for the CBIS area, and a clear height of not less than 9 ft. is suggested.

2.2.1.4 Early Baggage Store (EBS)

Each supplier of ICS equipment uses a proprietary approach for early bag storage systems, however for a random access automated EBS using a multi-level racking system it is believed that each suppliers system will require a similar space.

A modular EBS approach developed by the Beumer Group, an experienced supplier of ICS technology equipment, is illustrated below in Figure 12.

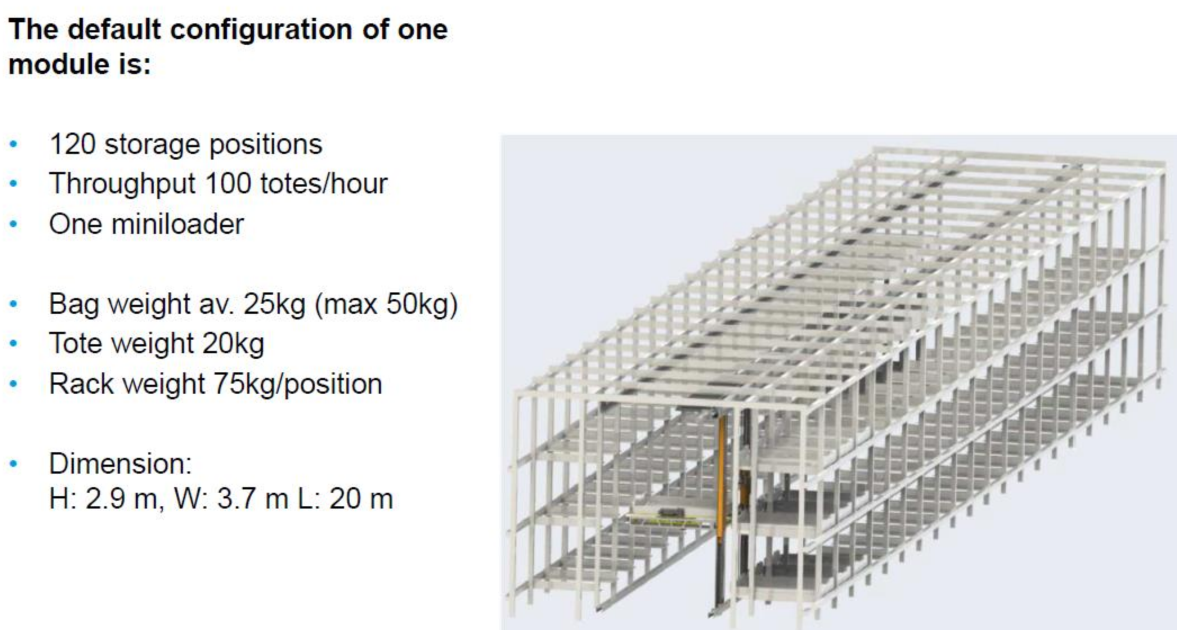


Figure 12 Example of modular EBS storage system (source Beumer Group)

The system requirements analysis (Appendix 1) indicated a need for a North terminal EBS capacity of 181 positions to meet 2034 design year. This would require 2 modules as shown above. Assuming a single level layout (side by side or end to end, not stacked) this would involve a racking size of 800 sq. ft. Allowing 25% space for input/output systems yields a required area of 1,200 sq. ft., with a clear height of around 9.5 ft. which it is suggested be rounded up to 12 ft., to allow for lighting, sprinklers and to provide flexibility to adapt to other supplier's requirements. It should be noted that a conservative estimate is suggested in this case, in order to retain flexibility with regard to potential adaptation of design solution to other suppliers' technology and to allow a provision for oversize ICS carrier storage for OS bags.

2.2.1.5 Other North terminal landside processor area requirements at basement level.

A tunnel right of way for both tug and cart/container traffic and ICS delivery conveyors will be required. In addition ECB queue positons will be required to ensure that adequate quantities of carriers (both ST and OS types) are available to meet peak period throughput rate of originating bag flow and input flow from the EBS. The amount of ECB storage required is dependent on average round trip carrier travel time.

In the extract from Appendix B North Terminal Landside Processor - Material Flow Diagram, shown below at Figure 13 the delivery scheme at the North Terminal landside processor facility is illustrated, for the system downstream of the ICS induction stations. This indicates that the tunnel to the airside concourse area needs to provide space for both outbound and return ICS lines and also T&C drive aisles for terminating baggage and for outbound NC bag delivery.

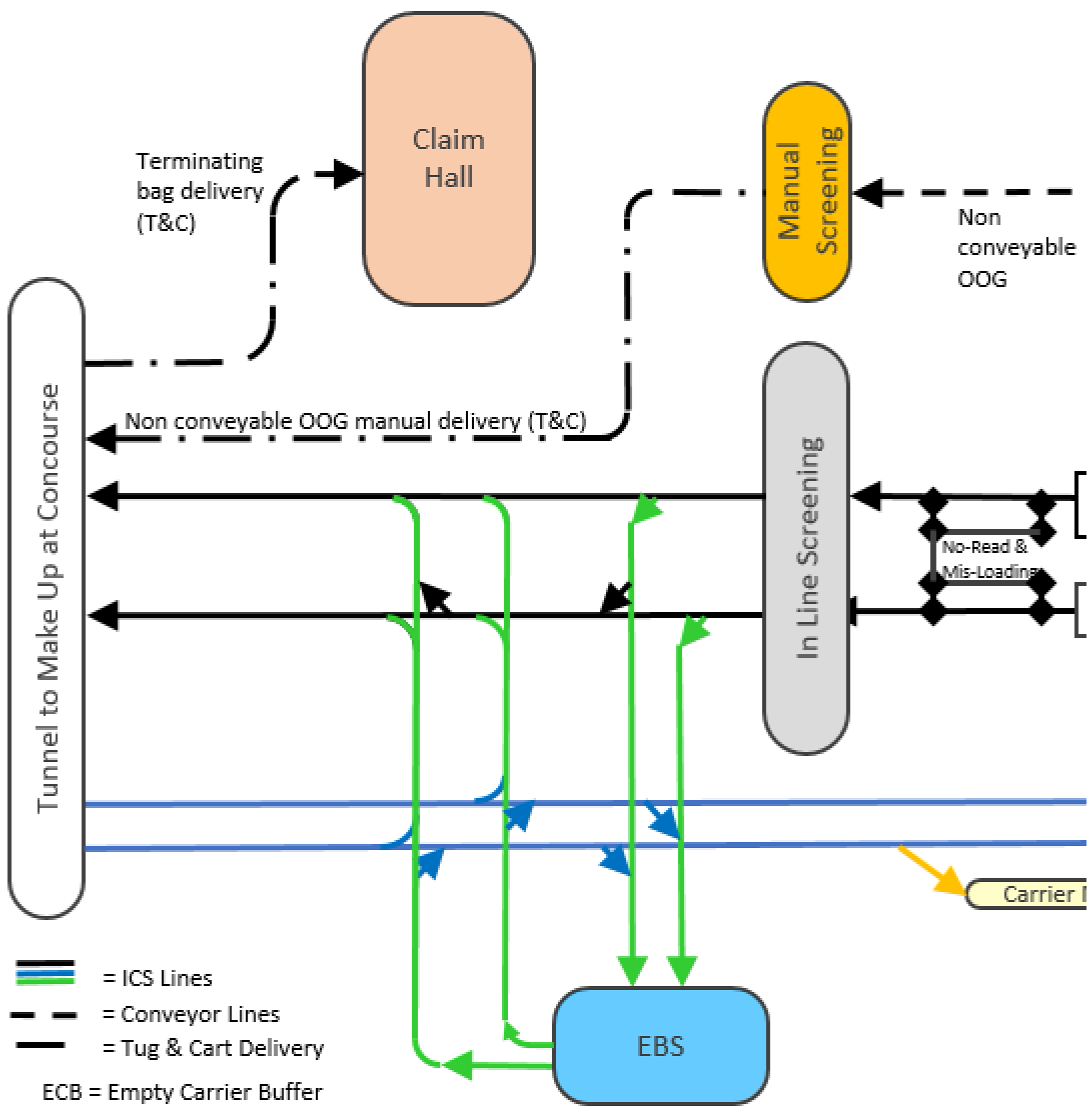


Figure 13 ICS and T&C delivery between N terminal processor and concourses

The peak originating bag flow rate required for EDS screening system has been estimated at close to 2400 bags/hr (2034 design year), which is approximately equal to the anticipated realistic capacity of one ICS delivery line (carrying a mix of ST and OS carriers). Release of bags from the EBS and occasional release of empty carriers to supply the bag room transfer input ECB's will increase this somewhat. Assuming a 20% increase for these additional flows the required peak flow would be 2,880 bags/hr. On this basis it can be seen that 2 delivery lines would be required, to provide a total capacity of 4800 bags/hr. In a fall back condition, with one line out of service for repair or maintenance, the system would be able to handle 83.3% of peak demand (i.e. 2400/2880), in excess of a suggested guideline that not less than 75% of peak period demand should be able to be accommodated during fallback conditions.

A total of 4 ICS lines are therefore required, i.e. 2 outbound and 2 inbound. A dimensional study is shown below at Figure 14, showing a possible layout configuration for the tunnel infrastructure between different terminal facilities (i.e. North terminal landside process, airside concourse area, NSAT and main terminal).

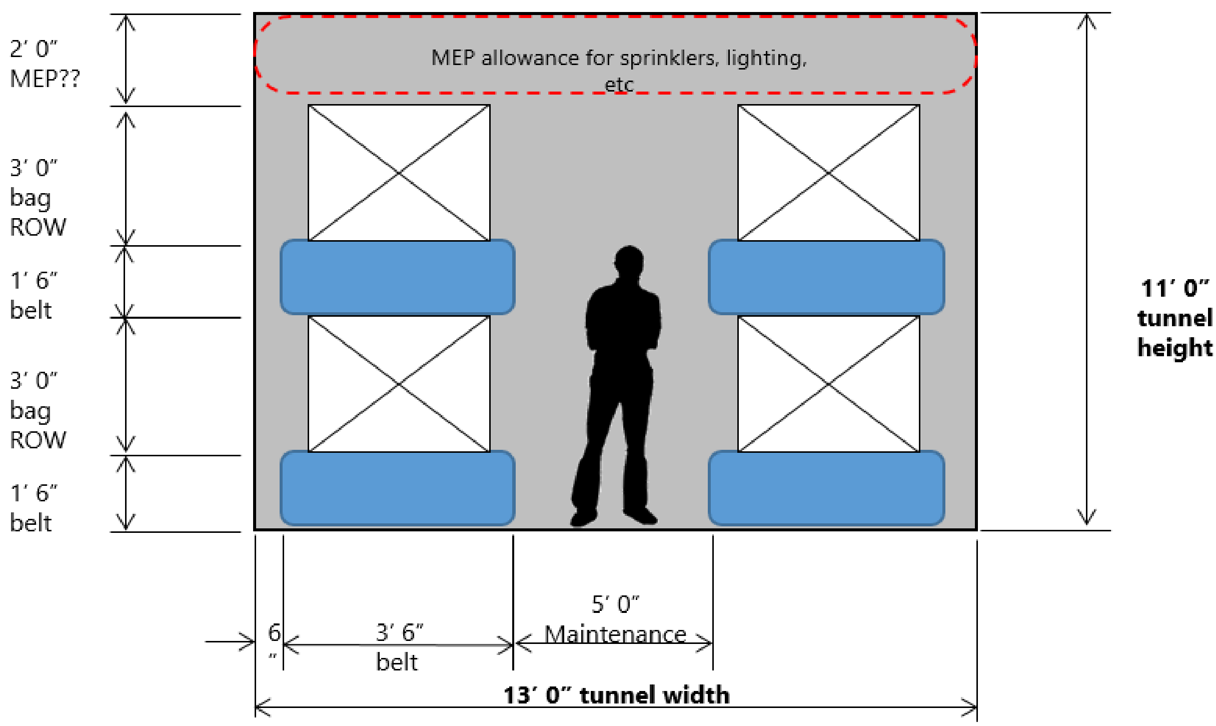


Figure 14 Possible Tunnel Configuration (4 lines)

A double stacked ICS line configuration is suggested, with outbound and return lines (for the same ICS loop) stacked together, so that if a line fails or is out of service any maintenance or jam clearance on one of the lines will not affect the other ICS loop (since for safety reasons it is not feasible to work on one line of a stacked pair with the other line remaining in service).

A 5ft wide maintenance zone between the 2 conveyor stacks would be sufficient for maintenance personnel either on foot or if one way traffic using a very small maintenance service vehicle is used. A wider maintenance zone could be provided if preferred by maintenance department and could for example allow for 2 maintenance service vehicles to pass in the aisle.

In the case of the tunnel between the landside processor and the airside concourse facility it may be worth considering, from an architectural/space planning viewpoint, locating the ECB's for the landside processor bag induction from check in operation in the tunnel rather than in the basement below the landside processor itself. In this case an In-line empty carrier storage system would be appropriate, as shown below in Figure 15. The system illustrated would be configured as a spur line running parallel to the return line, it requires the same dimensions as for an ICS conveyor line, and incorporates empty carrier stacker and de-stacker units in a configuration to provide the required throughput to match required induction rate.

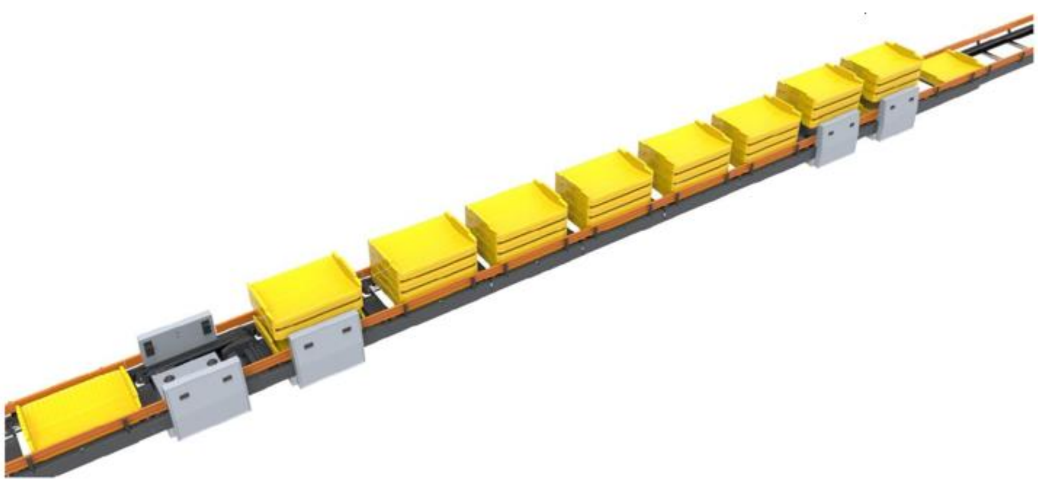


Figure 15 In-line empty carrier storage ECB (source Vanderlande)

This approach is illustrated below in Figure 16, below, showing schematically how in-line empty carrier storage ECB's could be provided in a widened tunnel, rather than in the basement of the landside processor facility. It is assumed that the tunnel length between the landside processor and the airside concourse would provide sufficient ECB storage capacity, including future expansion if needed.

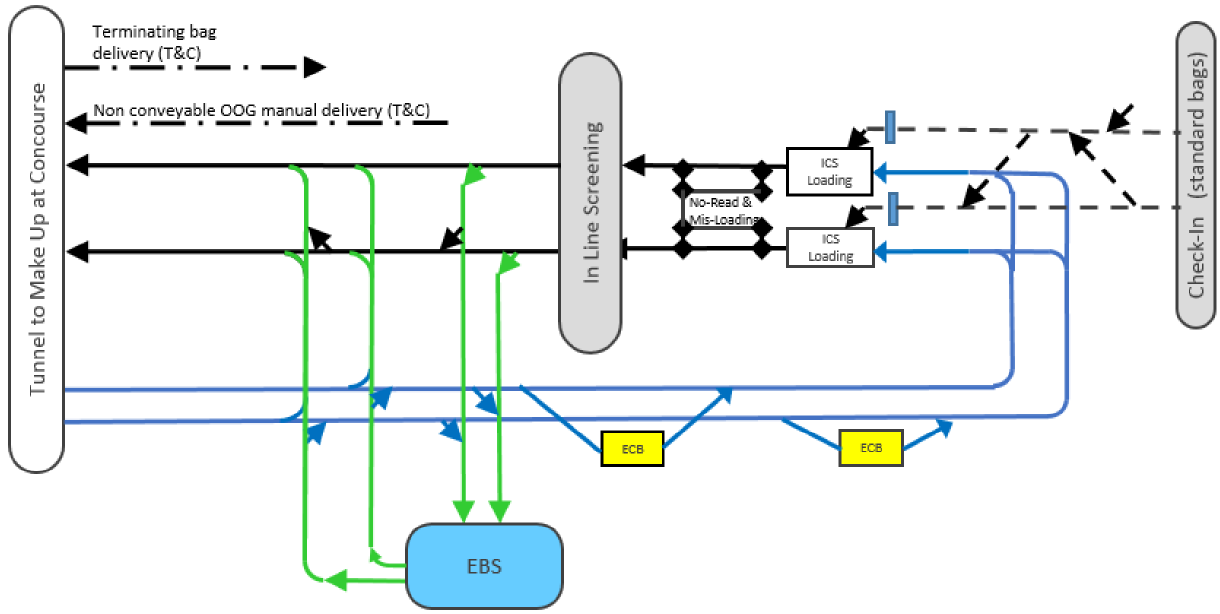


Figure 16 Modified MFD providing ECB storage in tunnel

This would, however, require other changes, either by providing a locally deeper tunnel to allow crossover from both return lines to one side of the outbound & return stacked lines or other system changes, to be determined. The revised tunnel section is illustrated below in Figure 17 with representative dimensions shown.

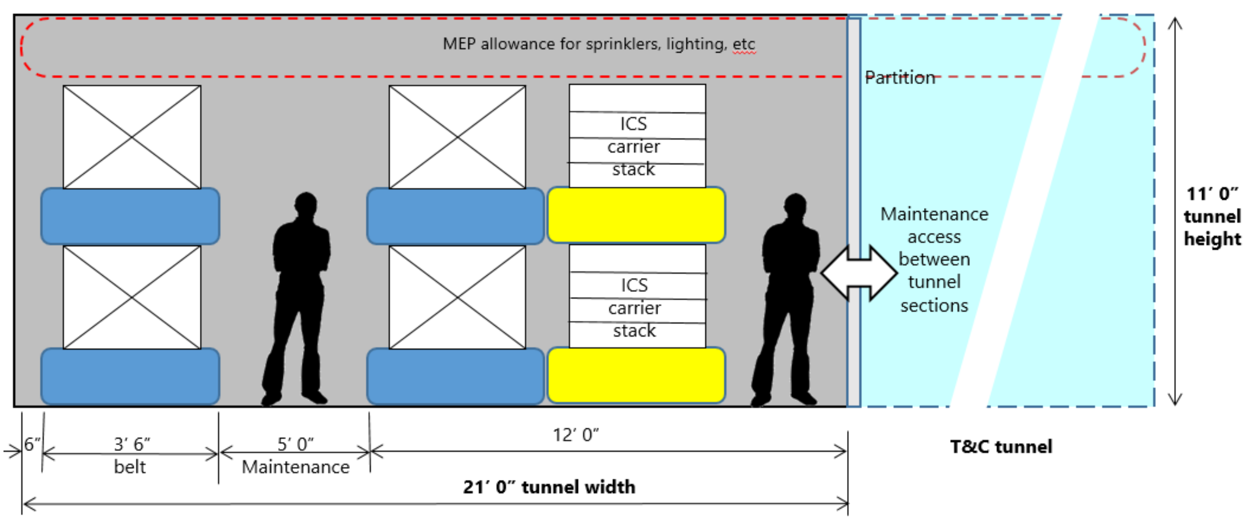


Figure 17 Modified tunnel configuration with ECB storage in tunnel

2.2.1.6 Outbound/Transfer baggage delivery system

Material flow diagrams (MFD's) are provided in Appendices E, F & G, below illustrating the functionality suggested for ICS delivery and sortation systems for North Terminal facilities for both the North

Terminal and for the infrastructure to connect the North Terminal landside processor and airside make up areas via an ICS delivery system to the:-

- the main terminal, via an interface area for interchange between ICS delivery system and main terminal tracked belt backbone systems (by others)
- The North Satellite make up area (including transfer input).

The MFD shown below in Figure 18 MFD for N Terminal concourse bag rooms illustrates the functionality of the ICS delivery system from the tunnel connection to/from the North terminal landside processor and also to/from other terminal areas, i.e. main terminal interface and NSAT facility.

The proposed approach is that two out and return ICS loops from the landside processor connect to dual ICS loops connecting (at basement level, below the North terminal concourse connector) the two make up areas (bag rooms) at apron level below the North and South concourse piers. Each bag room would be equipped with make up carousels for cart/container loading and additionally with a transfer bag input, 1 Problem Bag/ OOG handling area, in addition to operational space for temporary storage of early non conveyable oversize (NC) bags, manually delivered to area.

In order to provide redundancy to allow operations to continue during failure or maintenance/repair periods it is proposed to configure the delivery & sortation system so that each make up carousel can be accessed from both ICS delivery loops. Crossover connections between loops are also proposed, as shown, to allow bags in ICS carriers to be diverted to the other delivery line, for example if a discharge spur is temporarily blocked.

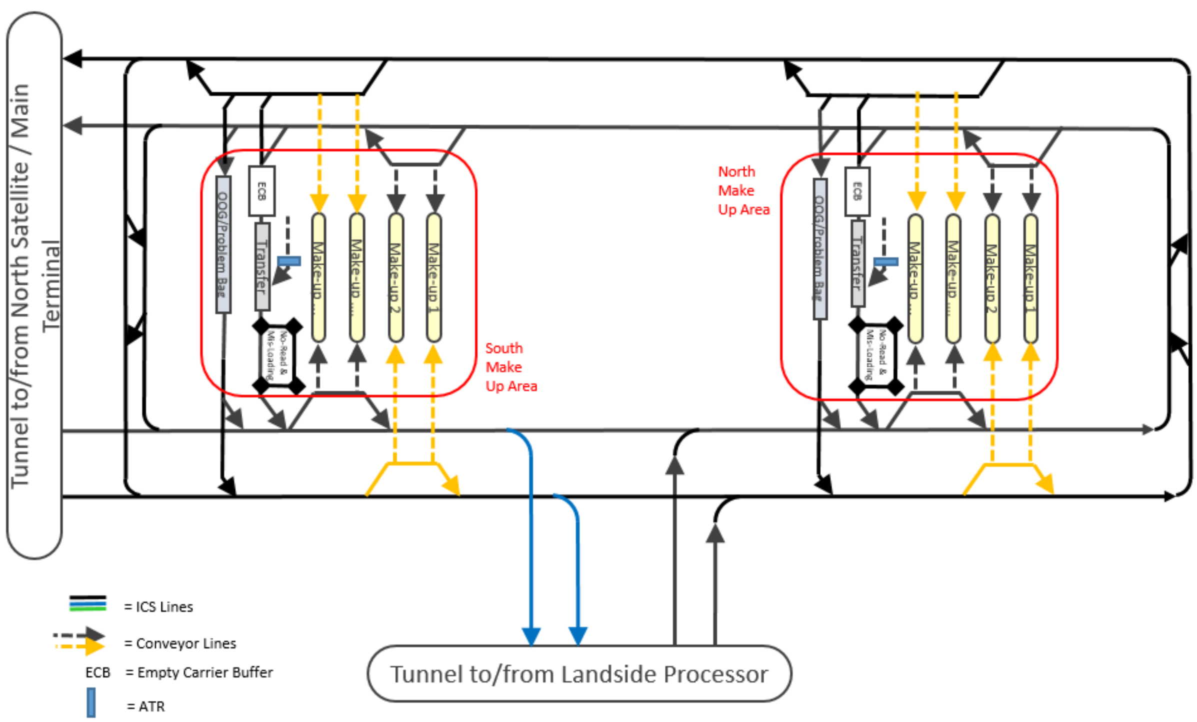


Figure 18 MFD for N Terminal concourse bag rooms

An example of a possible bag room layout at the apron level of the concourse pier is shown below in Figure 19 Possible layout approach for apron level bag room below concourse.

This layout is based on the use of incline plate make up devices, each capable of accommodating six (6) carts or containers on each side of the carousel, i.e. 12 per carousel. Devices of this size are advantageous for an ICS delivery system as they reduce the number of ICS discharge outputs required, reducing basement level system complexity and cost. This size also is convenient where a 4 cart/container presentation is used for medium sized aircraft, so that 3 (or smaller) flights can be accommodated on each device.

The layout example in Figure 19 with 6 make up carousels could provide for presentation of 72 carts/containers.

In addition to the make up carousels the bag room would typically require a transfer input line for delivery of arriving transfer bags for sortation and delivery to make up devices within the same bag room or the bag room at the other concourse pier, or in other terminal areas including:-

- EBS in North terminal landside processor building
- NSAT bag room make up device
- Main terminal interface area, for subsequent delivery to appropriate main terminal bag room make up device, main terminal EBS and SSAT bag room make up device.

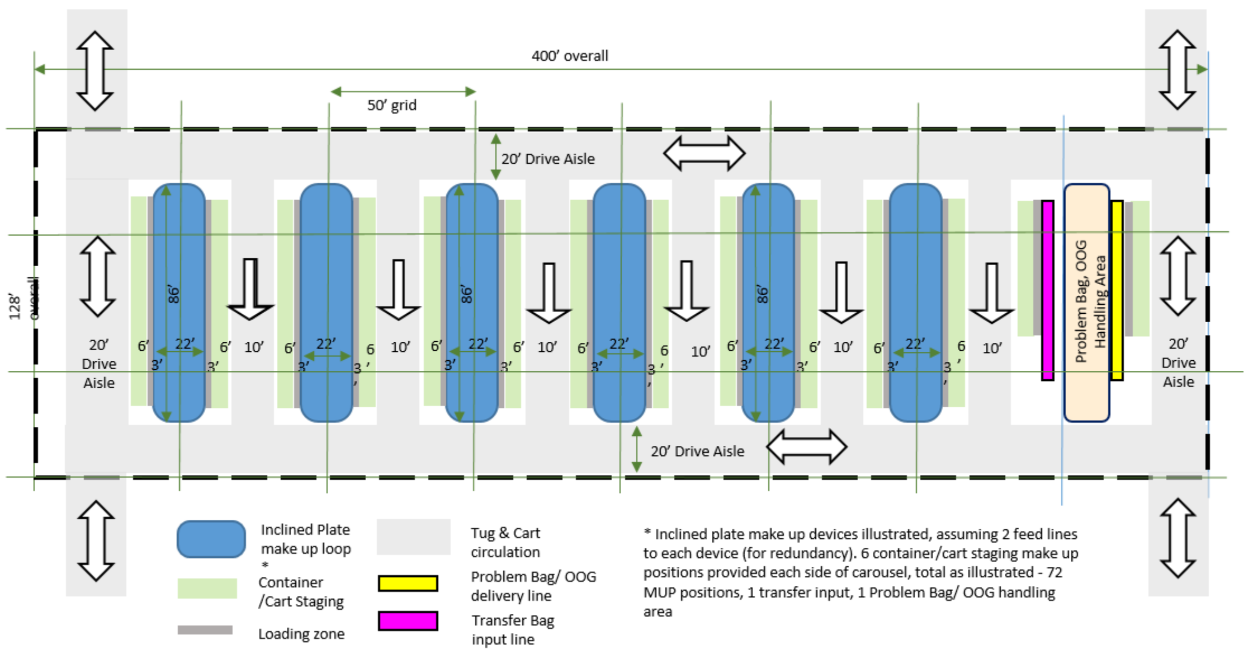


Figure 19 Possible layout approach for apron level bag room below concourse

An additional area is also required, for processing of problem bags (e.g. bags delivered after flight close out requiring re-flighting, etc.) and for handling oversize bag deliveries (e.g. oversize carriers delivered to apron level for unloading and manual delivery to make up carousel, and also non conveyable oversize bags delivered manually for redistribution by bag room staff or, in the case of early NC bags for temporary storage prior to flight open time at the carousel).

Figure 20, below, illustrates these ancillary bag room functions. At the apron level a transfer unload belt provides for a train to carts with transfer bags to be unloaded and delivered via a bar code reader (ATRA) and a decline belt to a to the basement level below, where it is inducted onto an ICS carrier, released from a local ECB storage zone. After bag induction to the ICS carrier the bag proceeds to the ICS delivery and sortation system, unless the bar code was not successfully read at the ATR or if measurement controls indicate a mis-loading condition. In such cases the bag in the carrier are diverted off line for manual encode or correction of the mis-loading condition.

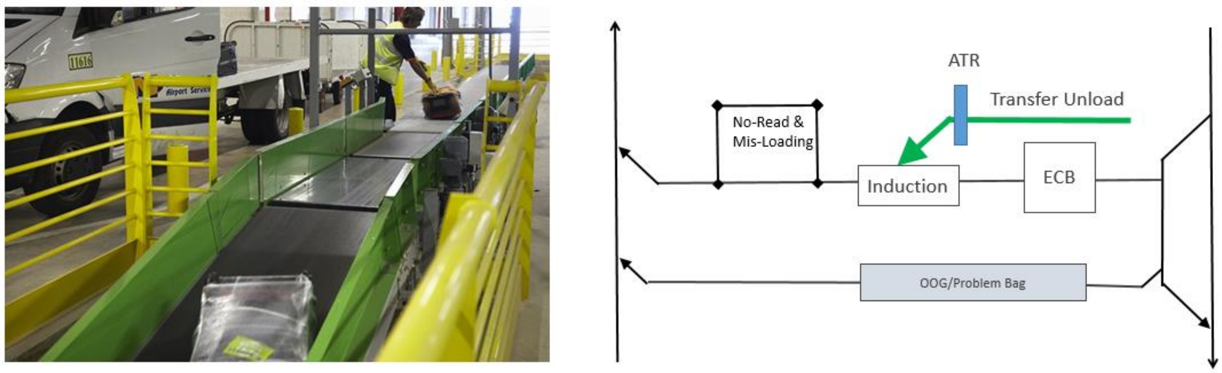


Figure 20 Transfer input and OOG problem bag area

The analysis of requirements indicates a peak requirement (2034 design year) of 130 cart/container staging positions to service North terminal make up needs. Since 2 bag rooms are proposed, one for each concourse pier, and since some operational imbalance is likely to occur between the 2 concourse piers it is believed that if each bag room is configured with 6 carousels, each of 12 cart/container capacity, adequate make up staging will be provided. The layout illustrated in Figure 19 above is therefore proposed as suitable for each of the two bag rooms.

Each apron level bag room therefore should be configured with the dimensions shown, representing a floor area including drive aisles and staging positions of 51,200sq ft., for each of 2 bag rooms.

The extent of the basement level below the bag room will need to be determined in a future project phase, but will probably require at least 2 levels of ICS conveyor and discharge spur systems. Basement depth will probably need to be approximately 12 ft. in order to provide sufficient space for conveyors and maintenance platforms and catwalks.

An ICS delivery conveyor tunnel will be required running below the concourse connector between the North and South concourse piers, with connecting tunnels to the basement areas located below the bag rooms. In addition an interchange area will be required, where the tunnel from the landside processor connects to the tunnel between the concourse piers, to be defined in more detail in a subsequent project phase, but probably requiring both greater depth and width than the tunnel section as illustrated in Figure 14 Possible Tunnel Configuration (4 lines).

2.2.1.7 ICS connection between North terminal and other terminal areas

The probable routing for the ICS delivery and sortation system connecting the main terminal areas (i.e. North terminal landside processor & concourse piers, main terminal interface and NSAT interface) is illustrated below in Figure 21 below.

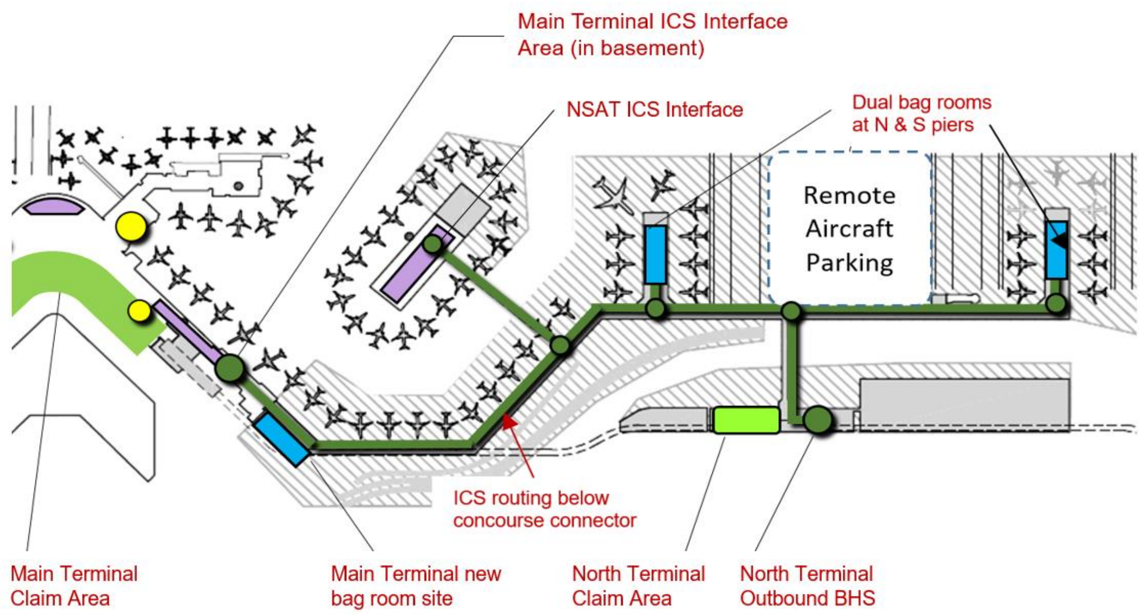


Figure 21 Possible Inter-Terminal connectivity of BHS facilities by ICS delivery/sortation system

The routing shown in Figure 21 illustrates the most probable ICS delivery routing as it will minimize disruption of apron operations in the area around NSAT during tunnel and other basement area construction. The functionality of the North terminal outbound, both in the landside processor and the two concourse pier bagrooms has been described above.

A tunnel network will run from the North terminal landside processor to connect to the two concourse piers and connect to a tunnel below the apron to the NSAT building. The ICS delivery system connection between the Main terminal interface Area and the North terminal & NSAT complex can be either a continuation of the tunnel network, or alternatively could be an apron level surface connection below the concourse connector linking Main and North terminals, depending on construction cost, complexity and overall site disruption during construction.

The functionality of the Inter-Terminal ICS delivery & sortation system is further described below referencing proposed ICS material flow diagrams included in Appendices E, F & G, below.

Figure 22 below provides an MFS overview of the ICS delivery & sortation system from the tunnel below the concourse connector linking the North and South piers of the North terminal with the Main terminal interface and the NSAT interface, and shows three areas, i.e.

- Tunnel interchange, where ICS carriers can be diverted as required between main and north terminals and NSAT

- Main terminal BHS interface area, for interconnection of the proposed ICS delivery and sortation system with the backbone delivery system being implemented in the main terminal and satellite buildings under separate contract.
- North Satellite BHS interface area, connecting the North Satellite BHS to the proposed ICS delivery and sortation system.

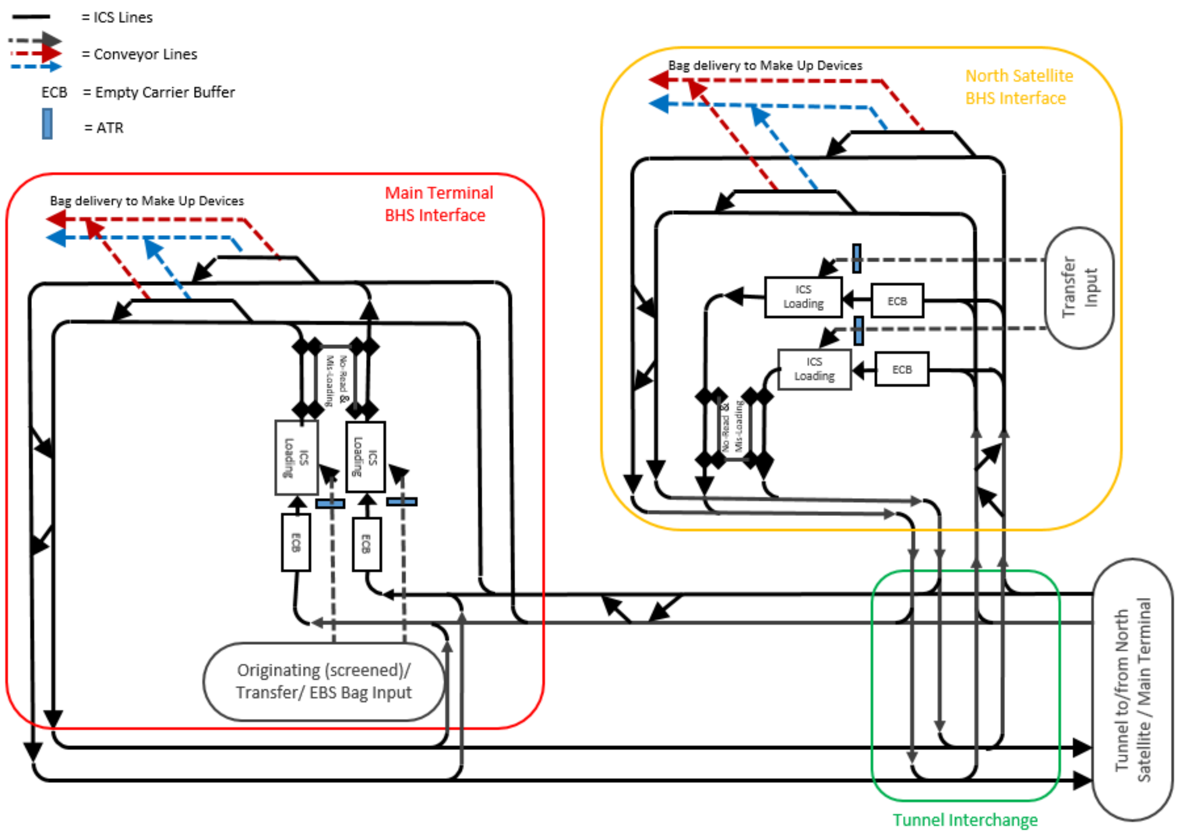


Figure 22 Overview of ICS delivery/sortation connectivity, North Terminal to other terminal areas

Figure 23 below focuses on the tunnel interchange, which provides the following ICS conveyor connectivity:-

- Transfer bags from North Terminal input lines in the North and South concourse bag rooms diverted at tunnel interchange to either NSAT or main terminal interfaces
- Transfer bags from NSAT input lines diverted at tunnel interchange to either North terminal bag rooms or to main terminal interface.
- Transfer bags from main terminal interface (delivered by backbone system) diverted at tunnel interchange to either North terminal bag rooms or to NSAT bag room
- Originating bags from North Terminal check in /bag drop diverted at tunnel interchange to either NSAT or main terminal interfaces.
- Originating bags from main terminal interface (delivered by backbone system) diverted at tunnel interchange to either North terminal bag rooms or to NSAT bag room.

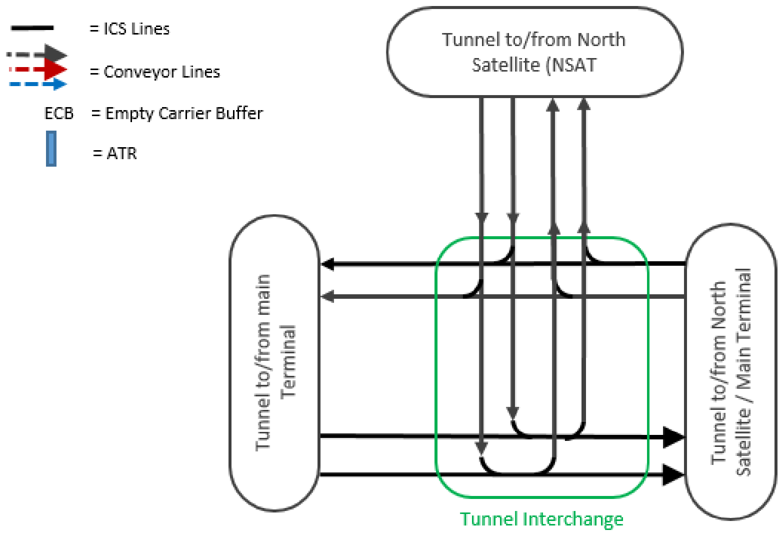


Figure 23 Tunnel interchange

Due to the large number of divert points and merge points in the tunnel interchange area it is likely that the tunnel width at the interchange will need to be local widened (relative to base tunnel section shown at Figure 14 above, and will need to be deeper, to allow for conveyors to cross the normal double stacked tunnel conveyors shown in the section. An increase in basement height of at least 5ft i.e. from 11ft to 16ft is likely to be required for the tunnel interchange. Additional features to provide additional redundancy and cross-over connectivity may also be required in this area.

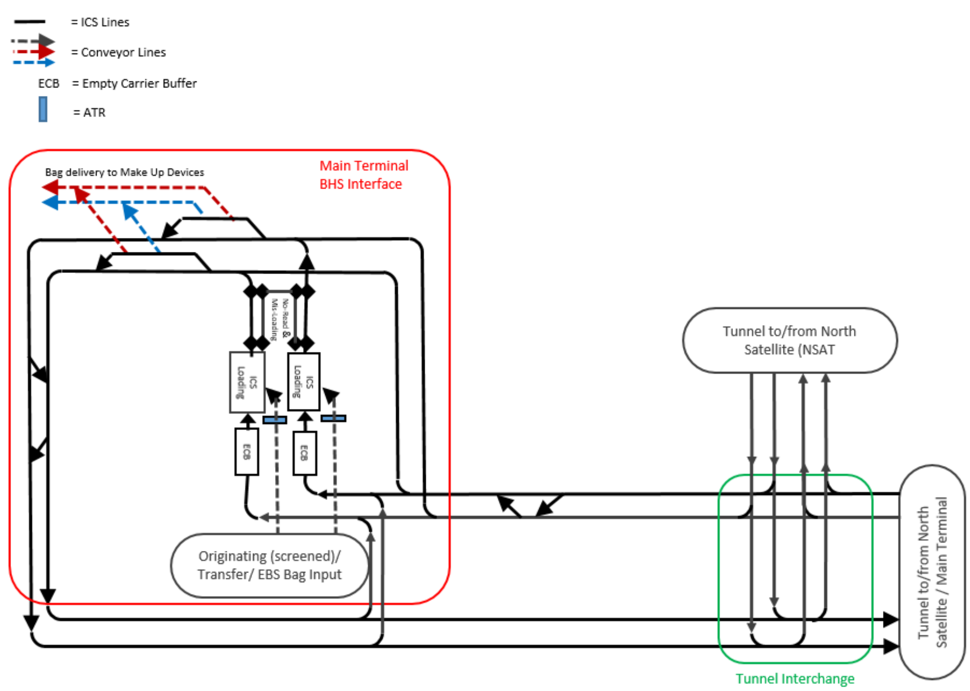


Figure 24 ICS connectivity North terminal to main terminal interface area

Figure 24 above, illustrates the main terminal interchange functionality and tunnel connectivity provided by the ICS delivery and sortation system.

Transfer bags from either the North Terminal or NSAT bag rooms will be delivered via ICS double stacked conveyors from the Tunnel Interchange facility to the main terminal BHS interface where they will be diverted to discharge spurs and then, after discharge, continue via the main terminal backbone system to the appropriate make up area (or to the main terminal EBS if applicable/provided). Empty ICS carriers, following bag discharge, will continue to adjacent diversion points either for delivery back to the tunnel interchange or direct to ECB's serving the main terminal BHS interface system where empty carriers can be stored for subsequent induction of screened originating or transfer bags (or bags from EBS) via the main terminal backbone conveyor system.

Bags from the main terminal backbone system (originating, transfer and from EBS) will be routed, under tracking controls, via ATR bag tag readers to ICS induction stations for loading to ICS carriers (with no-read/mis-load station provided downstream) for delivery via the ICS delivery/sortation system to the Tunnel Interchange for sortation to either North terminal or NSAT bag rooms or to the North terminal EBS.

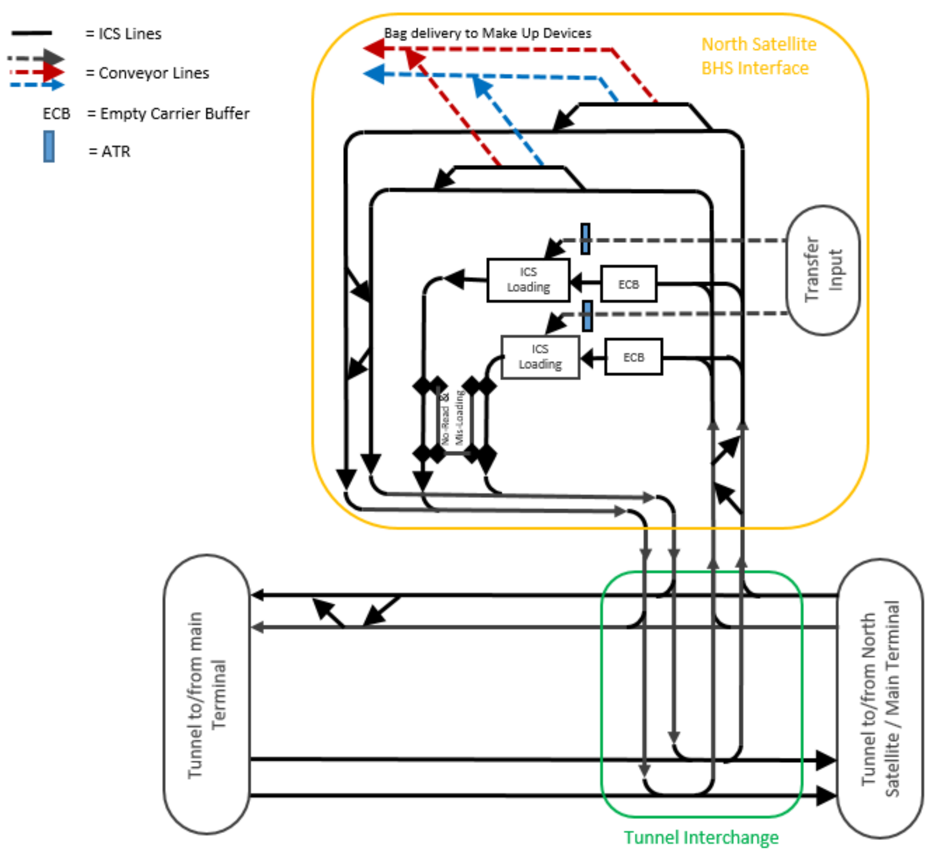


Figure 25 ICS connectivity North Terminal to North Satellite bag room

Figure 25 above illustrates the North Satellite interchange functionality and tunnel connectivity provided by the ICS delivery and sortation system.

Transfer bags from inputs at either the North Terminal or main terminal bag rooms will be delivered via ICS double stacked conveyors from the Tunnel Interchange facility to the NSAT BHS interface where they will be diverted to discharge spurs and then, after discharge, continue and merge with the NSAT outbound system for delivery to the NSAT sortation system for discharge to make up laterals. Empty ICS carriers, following bag discharge, will continue to the tunnel interchange for subsequent delivery to ECB storage areas in any part of the ICS delivery/sortation system.

Transfer bags input locally at the NSAT bag room will be routed, under tracking controls, via ATR bag tag readers to ICS induction stations for loading to ICS carriers (with no-read/mis-load station provided downstream) for delivery via the ICS delivery/sortation system to the Tunnel Interchange for sortation to either North terminal or main terminal bag rooms or to either the North terminal EBS or the main terminal EBS, as applicable.

It should be noted that the proposed system functionality will allow for bags checked in at either the main terminal or at the North terminal to be delivered to the NSAT bag room make up laterals, providing for improved outbound system operational flexibility.

Appendix A
SEA Sustainable Airport Master Plan: BHS Requirements Analysis Report

3 Introduction

This document outlines the analysis parameters, approach and results produced by Logplan to determine BHS requirements for the Seattle-Tacoma International Airport (SEA) sustainable airport master plan (SAMP).

4 Model Inputs

4.1 Flight Schedules

Analysis was performed on flight schedules for 8-10 July in the years 2014, 2018, 2023, 2028 and 2034, which were provided to Logplan in the file "SAMP Future Schedules.xlsx". These flight schedules contain airline, seat count, arrival/destination, date and time, load factor, O/D percentage, bags per passenger as well as sector FIS (D = domestic, I = international or P = pre-clear) for each flight.

4.2 Parameters

4.2.1 Arrival

Description	Value	UOM
Domestic baggage carts per passenger	0.1	cart/pax
International baggage carts per passenger	0.75	cart/pax
Area per baggage cart	10.8	ft^2/cart
Area per arrival passenger at claim	18.3	ft^2/pax
Domestic rows of passengers around claim unit	2	rows
International rows of passengers around claim unit	4	rows
Depth of passenger row	3.28	ft.
Domestic claim use	70%	
International claim use	90%	
Concurrent passengers at claim unit	50%	
Narrow body claim unit occupation	20	minutes
Wide body claim unit occupation	45	minutes
Arrival transport time	15	minutes

4.2.2 Transfer

Description	Value	UOM
Transfer transport time	10	minutes
Time to/from EBS	20	minutes

4.2.3 Early Bag Store (EBS) Availability

Description	Main	North
2014	No	No
2018	No	No
2023	Yes	No
2026	Yes	Yes
2028	Yes	Yes
2034	Yes	Yes

4.2.4 Departure

Description	Value	UOM
EDS screening capacity	674	bax/hour
Cut-off for single redundant EDS	7	machines
RJ/TP make up presentation	1.5	carts
Jet III make up presentation	4	carts
Jet IV make up presentation	5	carts
Jet V make up presentation	7	carts
Domestic makeup open no EBS	-180	minutes
Domestic makeup open yes EBS	-120	minutes
Domestic makeup close	-20	minutes
International makeup open no EBS	-240	minutes
International makeup open yes EBS	-180	minutes
International makeup close	-30	minutes

4.3 Distributions

Several distributions were used to spread baggage activity of each flight out over time in a way that simulates actual flights.

4.3.1 Earliness of Originating Baggage

Type	Name	-230	-220	-210	-200	-190	-180	-170	-160	-150	-140	-130	-120	-110	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0
Earliness (Outbound)	STD Before 9AM	0%	0%	2%	3%	4%	1%	5%	1%	5%	4%	13%	6%	8%	11%	12%	7%	10%	4%	3%	1%	1%	0%	0%	0%
Earliness (Outbound)	STD After 9AM	2%	3%	1%	1%	1%	1%	2%	3%	5%	7%	9%	8%	8%	9%	9%	10%	11%	5%	2%	1%	1%	0%	0%	0%

4.3.2 Transfer Layovers

Type	Name	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
Transfer Layover	Hub Carrier Domestic Arrival	0%	0%	1%	6%	10%	12%	12%	11%	9%	8%	6%	5%	4%	3%	3%	2%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Transfer Layover	Hub Carrier International Arrival	0%	0%	0%	0%	0%	0%	0%	1%	2%	4%	6%	7%	8%	8%	8%	7%	6%	6%	5%	5%	4%	4%	3%	3%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%
Transfer Layover	Other Carrier Domestic Arrival	0%	0%	0%	0%	4%	6%	8%	9%	9%	9%	9%	9%	8%	6%	5%	4%	3%	3%	2%	2%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Transfer Layover	Other Carrier International Arrival	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	2%	3%	5%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	5%	4%	2%	2%	1%	1%	1%	1%

4.3.3 Lateness of International Recheck Bags

Type	Name	0	10	20	30	40	50	60	70	80	90	100	110	120
Recheck Lateness	All bags				5%	10%	15%	15%	15%	15%	15%	10%		

4.4 Assumptions

- International (I, not D or P) arrivals from all groups go to IAF.
- International Arrival Facility (IAF) bags transferring to domestic flights are rechecked after customs clearance, screened at main terminal central screening facility and if determined to be early go to main or north terminal EBS.
- For international arrival flights, all bags and passengers go to claim. Transfer passengers re-check bags after clearing customs inspection, for delivery to central screening facility in main terminal, prior to delivery to outbound make up or EBS.
- Airline group assignments:
    - Delta Air Lines = Hub Carrier 1
    - Alaska Airlines Group & Virgin America = Hub Carrier 2
    - All other carriers = Other Airlines
- Baggage screening demand is increased by a surge factor per TSA PGDS requirements to determine the required EDS quantity.

5 Analysis

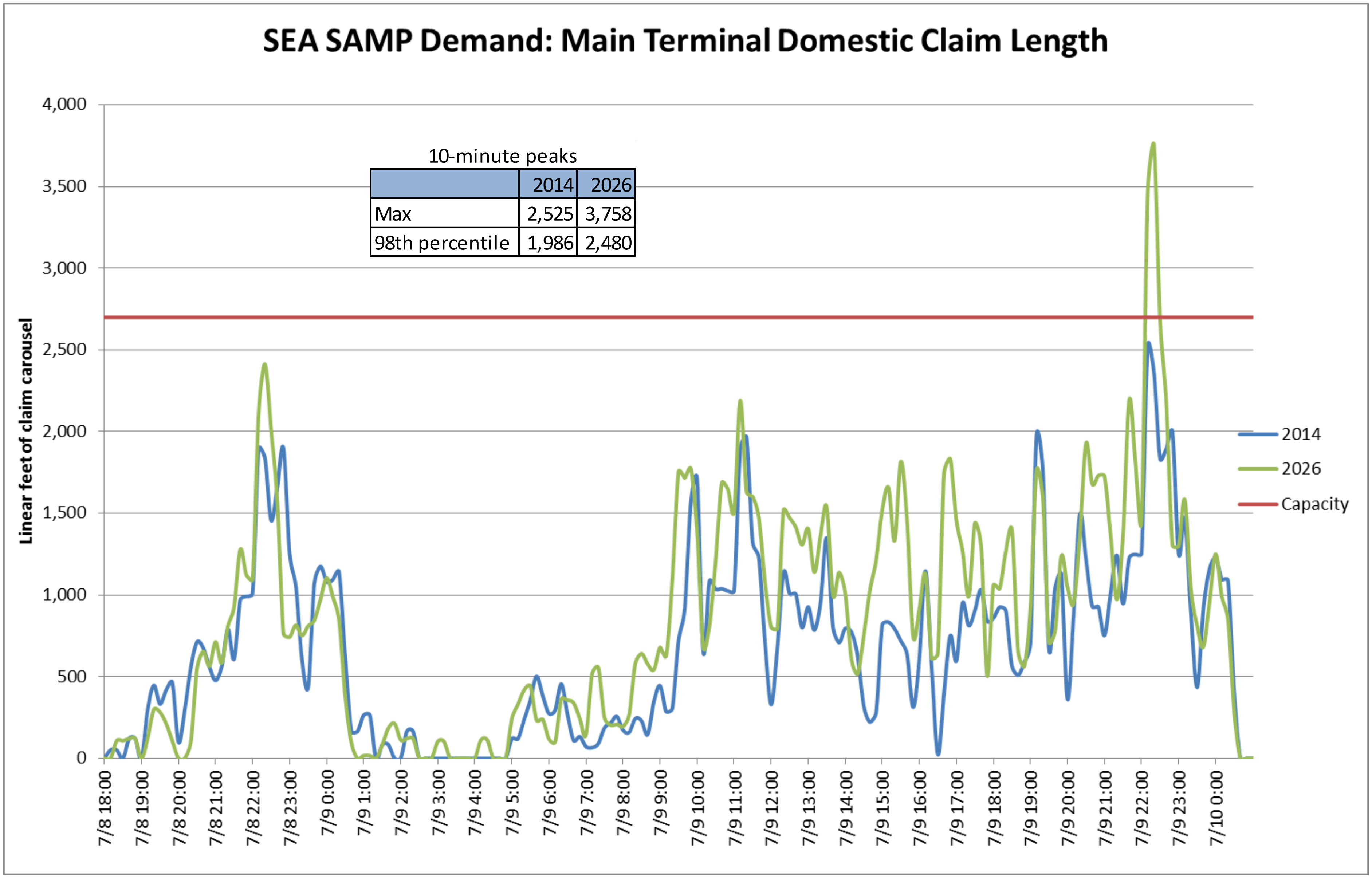
The model inputs are used to find baggage demand for each flight and the flight demands are aggregated to find total demand for makeup sortation positions and domestic claim requirements in the main terminal, as well as baggage screening and EBS storage locations in the north terminal.

6 Results

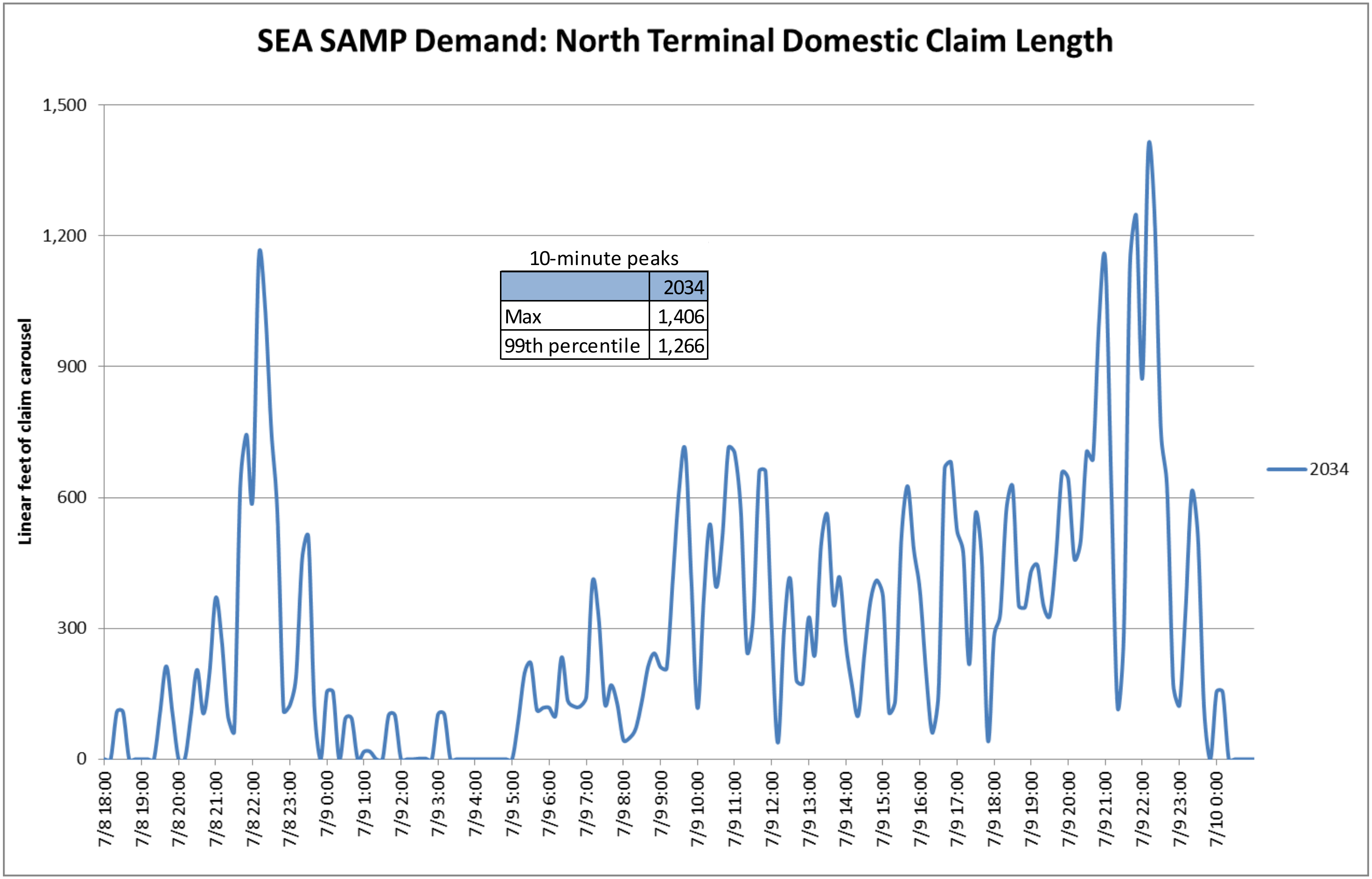
The following pages graphically display the analysis results, as well as quantifying the peaks

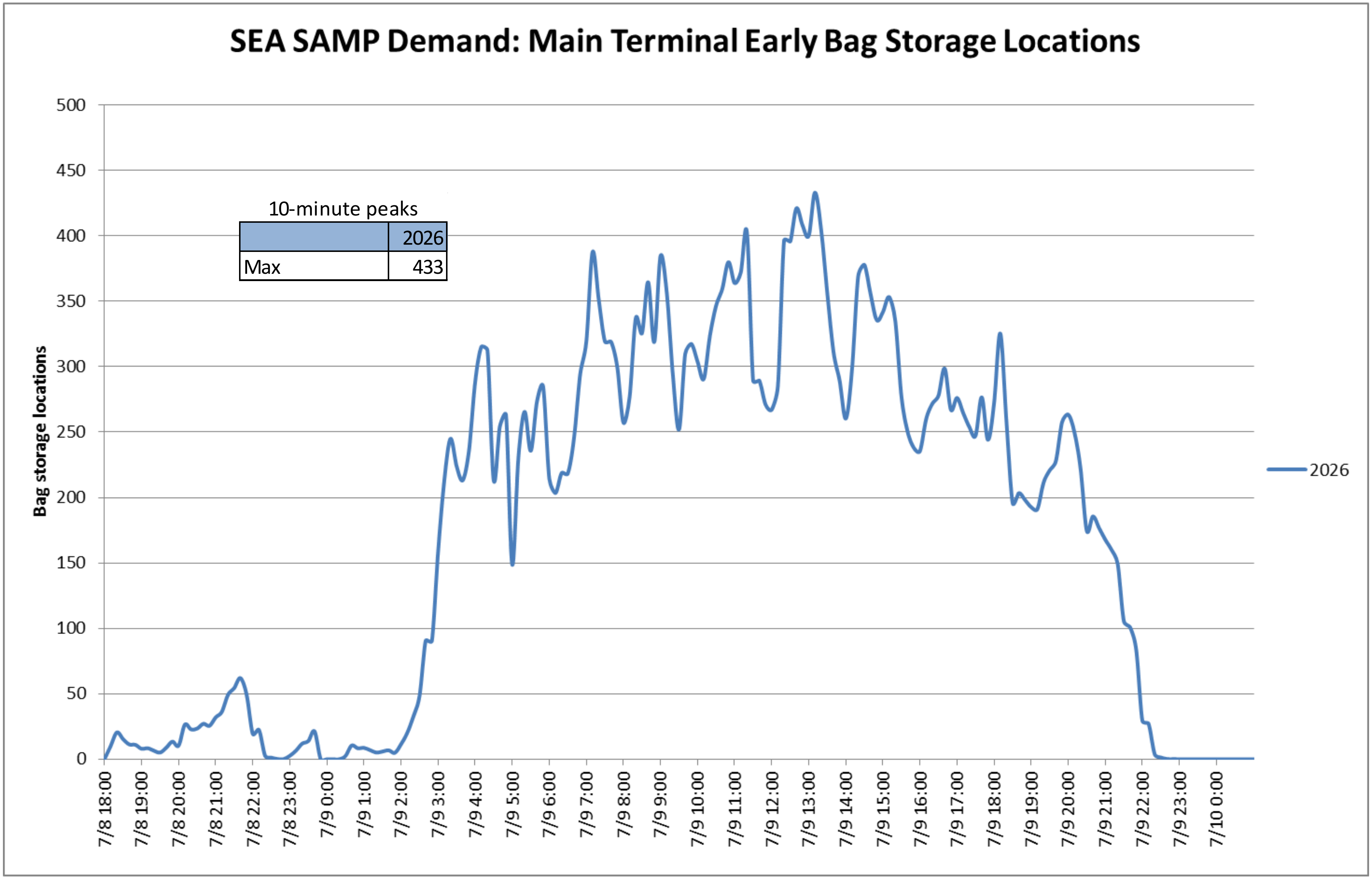
6.1 Requirements Summary

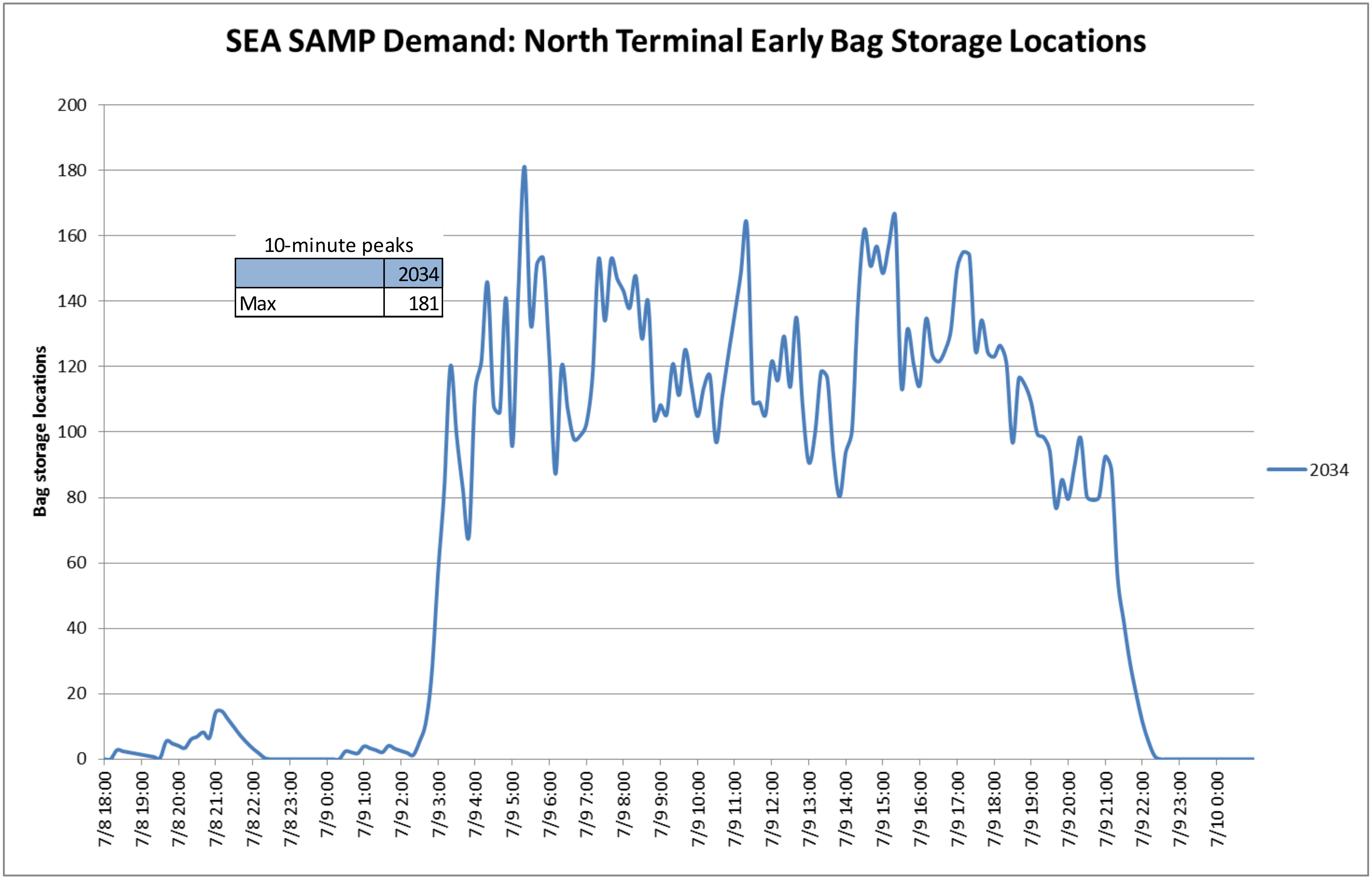
Dimension	Location	Peak type	Year	Quantity	UOM
Domestic Claim Length	Main Terminal	98th percentile	2026	2,480	linear feet of carousel
Domestic Claim Length	North Terminal	99th percentile	2034	1,266	linear feet of carousel
Early Bag Storage Locations	Main Terminal	Maximum	2026	433	bag storage locations
Early Bag Storage Locations	North Terminal	Maximum	2034	181	bag storage locations
Checked Baggage Screening	Main Terminal	Maximum	2026	6,116	bags/hour
Checked Baggage Screening	North Terminal	Maximum	2034	2,393	bags/hour
EDS Count	Main Terminal	Maximum	2026	12	EDS machines
EDS Count	North Terminal	Maximum	2034	5	EDS machines
Makeup Sortation Cart Positions	Main Terminal	98th percentile	2018	448	sortation positions
Makeup Sortation Cart Positions	North Terminal	Maximum	2034	130	sortation positions

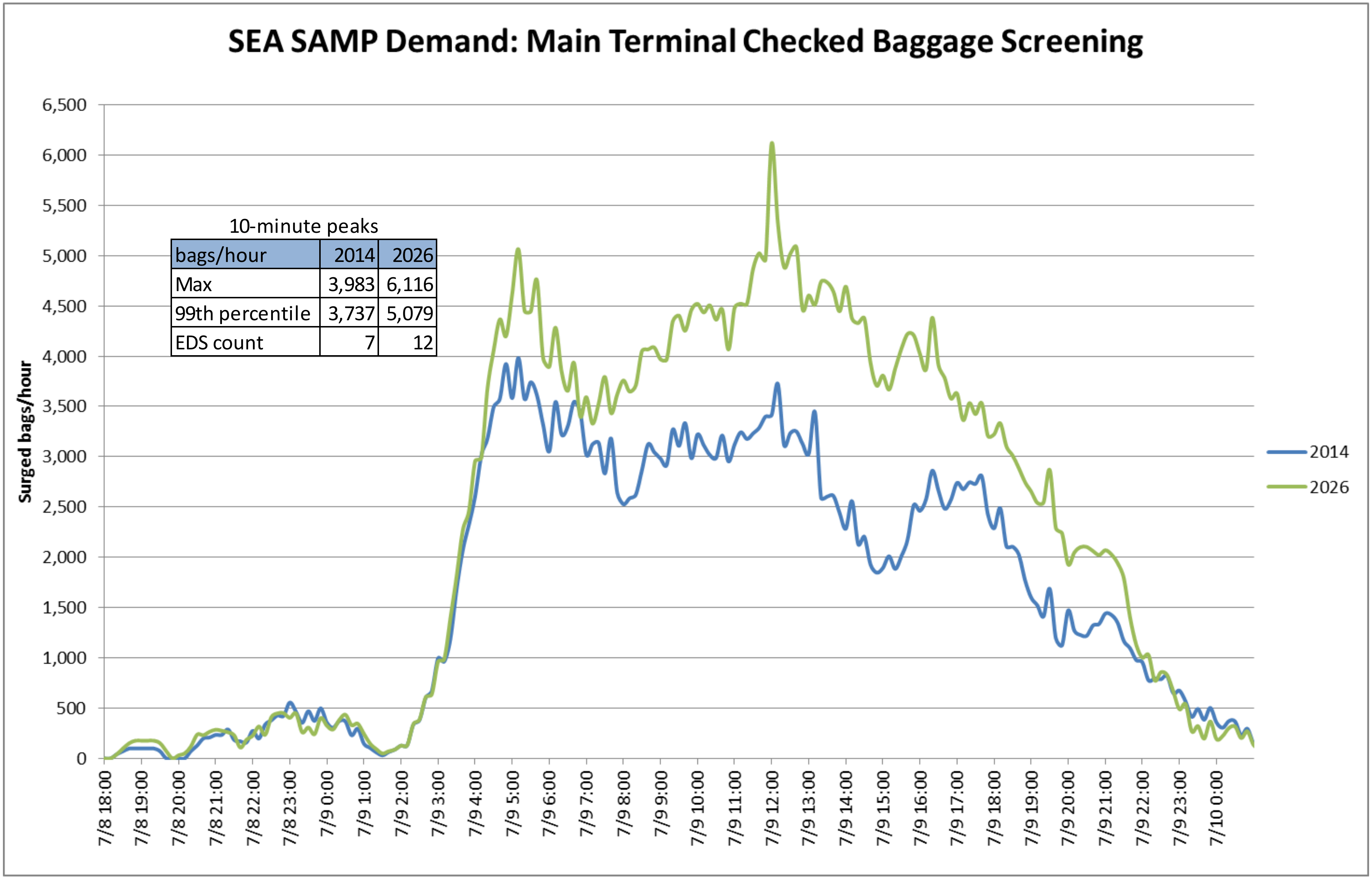


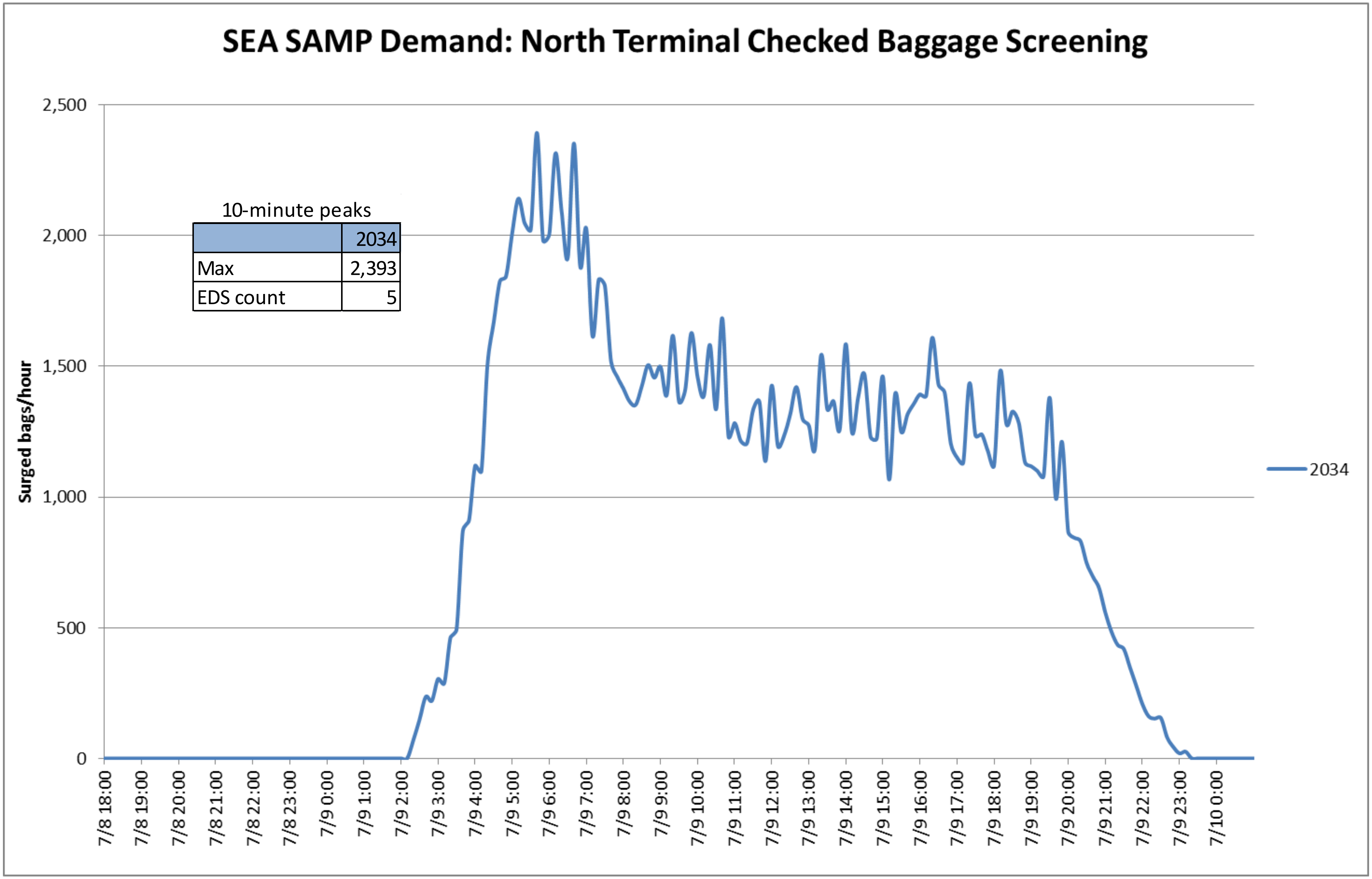
	2014	2026
Max	2,525	3,758
98th percentile	1,986	2,480

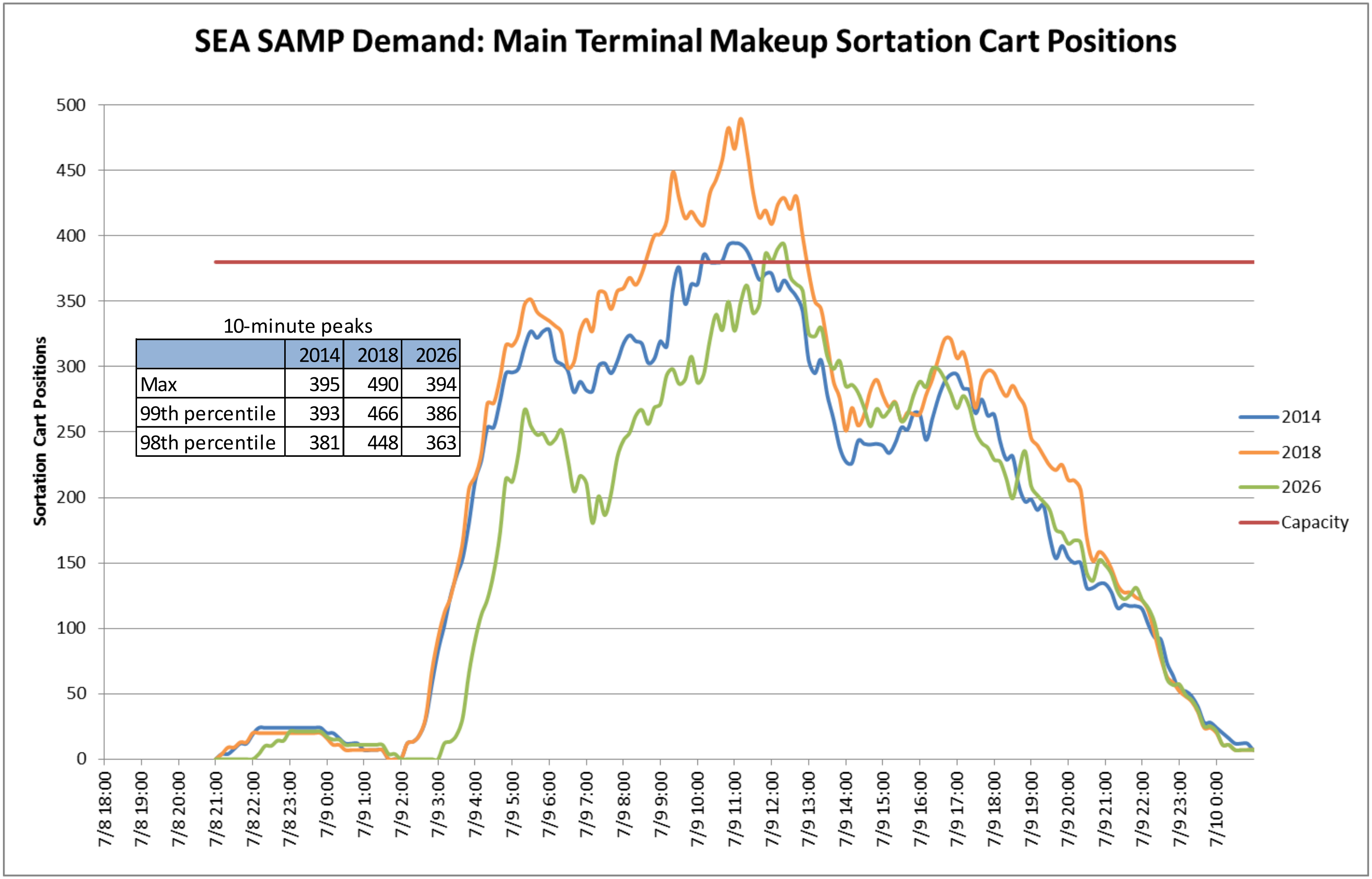

SEA SAMP Demand: North Terminal Domestic Claim Length
10-minute peaks
2034
Max 1,406
99th percentile 1,266
Linear feet of claim carousel
1,500
1,200
900
600
300
0
7/8 18:00
7/8 19:00
7/8 20:00
7/8 21:00
7/8 22:00
7/8 23:00
7/9 0:00
7/9 1:00
7/9 2:00
7/9 3:00
7/9 4:00
7/9 5:00
7/9 6:00
7/9 7:00
7/9 8:00
7/9 9:00
7/9 10:00
7/9 11:00
7/9 12:00
7/9 13:00
7/9 14:00
7/9 15:00
7/9 16:00
7/9 17:00
7/9 18:00
7/9 19:00
7/9 20:00
7/9 21:00
7/9 22:00
7/9 23:00
7/10 0:00
2034


SEA SAMP Demand: Main Terminal Early Bag Storage Locations
10-minute peaks
2026
Max
433
Bag storage locations
500
450
400
350
300
250
200
150
100
50
0
7/8 18:00
7/8 19:00
7/8 20:00
7/8 21:00
7/8 22:00
7/8 23:00
7/9 0:00
7/9 1:00
7/9 2:00
7/9 3:00
7/9 4:00
7/9 5:00
7/9 6:00
7/9 7:00
7/9 8:00
7/9 9:00
7/9 10:00
7/9 11:00
7/9 12:00
7/9 13:00
7/9 14:00
7/9 15:00
7/9 16:00
7/9 17:00
7/9 18:00
7/9 19:00
7/9 20:00
7/9 21:00
7/9 22:00
7/9 23:00
7/10 0:00
2026


SEA SAMP Demand: North Terminal Early Bag Storage Locations
10-minute peaks
2034
Max
181
Bag storage locations
200
180
160
140
120
100
80
60
40
20
0
7/8 18:00
7/8 19:00
7/8 20:00
7/8 21:00
7/8 22:00
7/8 23:00
7/9 0:00
7/9 1:00
7/9 2:00
7/9 3:00
7/9 4:00
7/9 5:00
7/9 6:00
7/9 7:00
7/9 8:00
7/9 9:00
7/9 10:00
7/9 11:00
7/9 12:00
7/9 13:00
7/9 14:00
7/9 15:00
7/9 16:00
7/9 17:00
7/9 18:00
7/9 19:00
7/9 20:00
7/9 21:00
7/9 22:00
7/9 23:00
7/10 0:00
2034

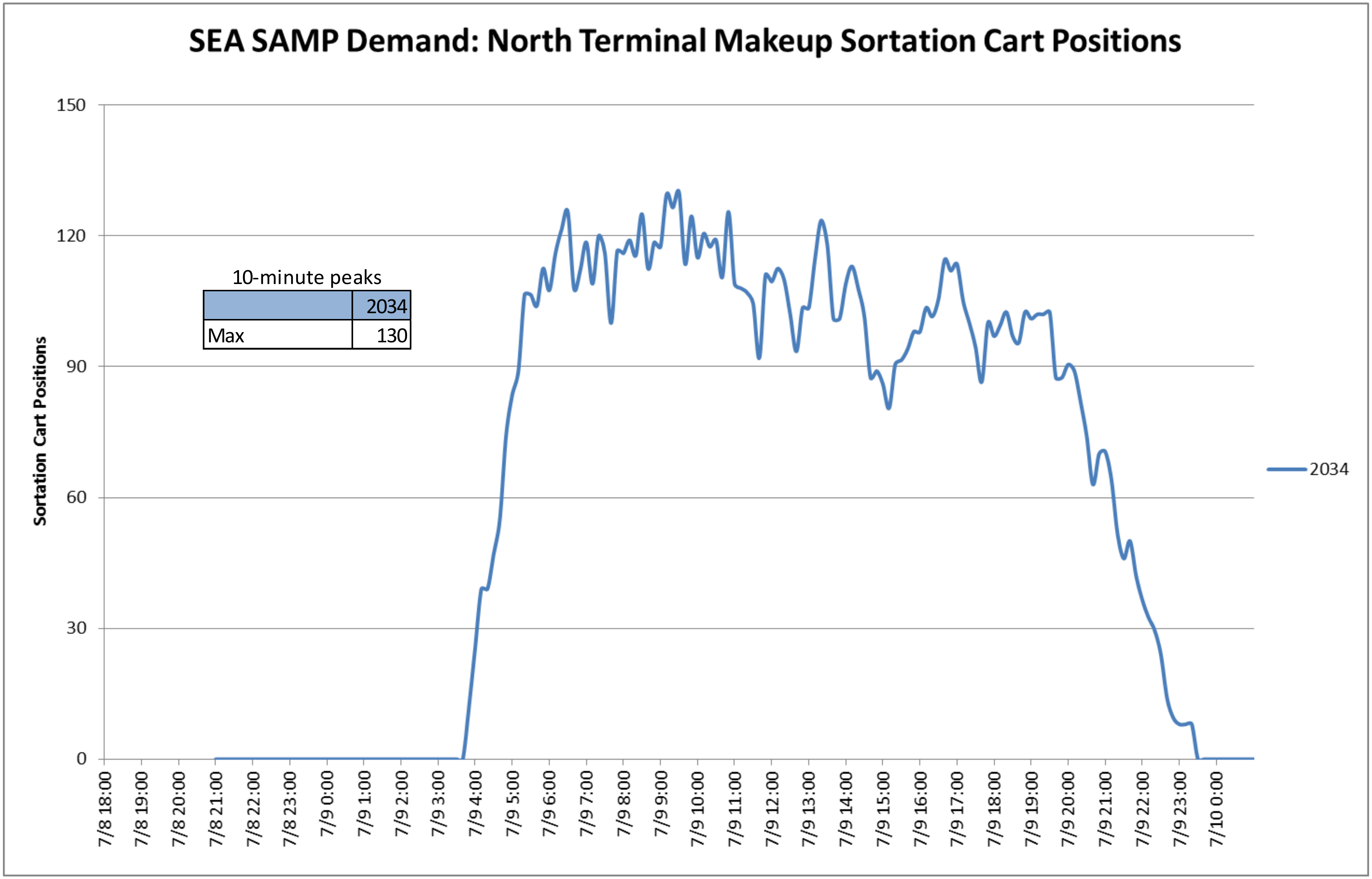

SEA SAMP Demand: Main Terminal Checked Baggage Screening
10-minute peaks
bags/hour | 2014 | 2026
Max | 3,983 | 6,116
99th percentile | 3,737 | 5,079
EDS count | 7 | 12
Surged bags/hour
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
7/8 18:00
7/8 19:00
7/8 20:00
7/8 21:00
7/8 22:00
7/8 23:00
7/9 0:00
7/9 1:00
7/9 2:00
7/9 3:00
7/9 4:00
7/9 5:00
7/9 6:00
7/9 7:00
7/9 8:00
7/9 9:00
7/9 10:00
7/9 11:00
7/9 12:00
7/9 13:00
7/9 14:00
7/9 15:00
7/9 16:00
7/9 17:00
7/9 18:00
7/9 19:00
7/9 20:00
7/9 21:00
7/9 22:00
7/9 23:00
7/10 0:00
2014
2026


SEA SAMP Demand: North Terminal Checked Baggage Screening
2,500
2,000
1,500
1,000
500
0
Surged bags/hour
10-minute peaks
2034
Max
2,393
EDS count
5
7/8 18:00
7/8 19:00
7/8 20:00
7/8 21:00
7/8 22:00
7/8 23:00
7/9 0:00
7/9 1:00
7/9 2:00
7/9 3:00
7/9 4:00
7/9 5:00
7/9 6:00
7/9 7:00
7/9 8:00
7/9 9:00
7/9 10:00
7/9 11:00
7/9 12:00
7/9 13:00
7/9 14:00
7/9 15:00
7/9 16:00
7/9 17:00
7/9 18:00
7/9 19:00
7/9 20:00
7/9 21:00
7/9 22:00
7/9 23:00
7/10 0:00
2034

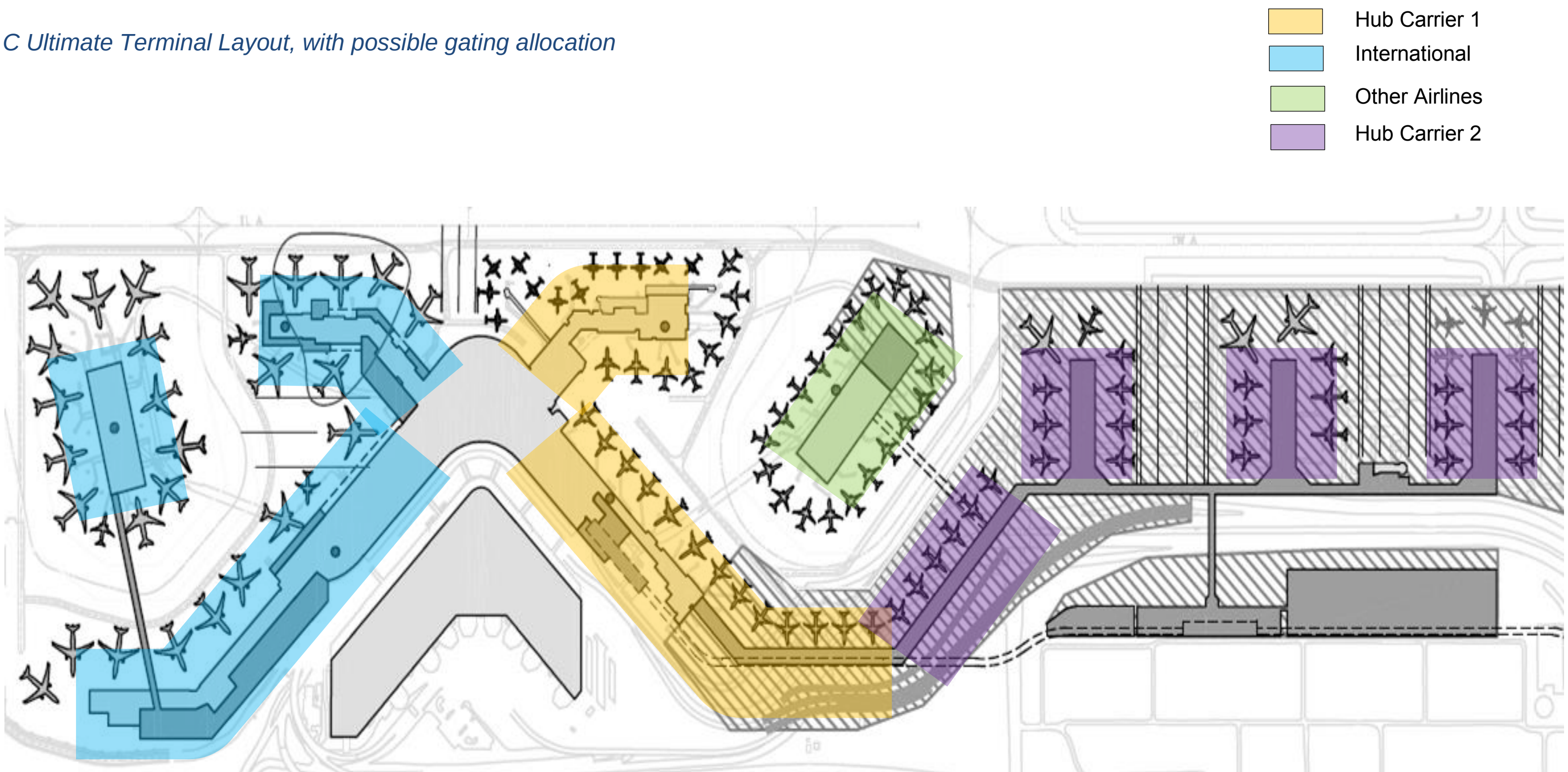


10-minute peaks

	2014	2018	2026
Max	395	490	394
99th percentile	393	466	386
98th percentile	381	448	363


SEA SAMP Demand: North Terminal Makeup Sortation Cart Positions
10-minute peaks
2034
Max 130
Sortation Cart Positions
150
120
90
60
30
0
7/8 18:00
7/8 19:00
7/8 20:00
7/8 21:00
7/8 22:00
7/8 23:00
7/9 0:00
7/9 1:00
7/9 2:00
7/9 3:00
7/9 4:00
7/9 5:00
7/9 6:00
7/9 7:00
7/9 8:00
7/9 9:00
7/9 10:00
7/9 11:00
7/9 12:00
7/9 13:00
7/9 14:00
7/9 15:00
7/9 16:00
7/9 17:00
7/9 18:00
7/9 19:00
7/9 20:00
7/9 21:00
7/9 22:00
7/9 23:00
7/10 0:00
2034

Appendix C Ultimate Terminal Layout, with possible gating allocation

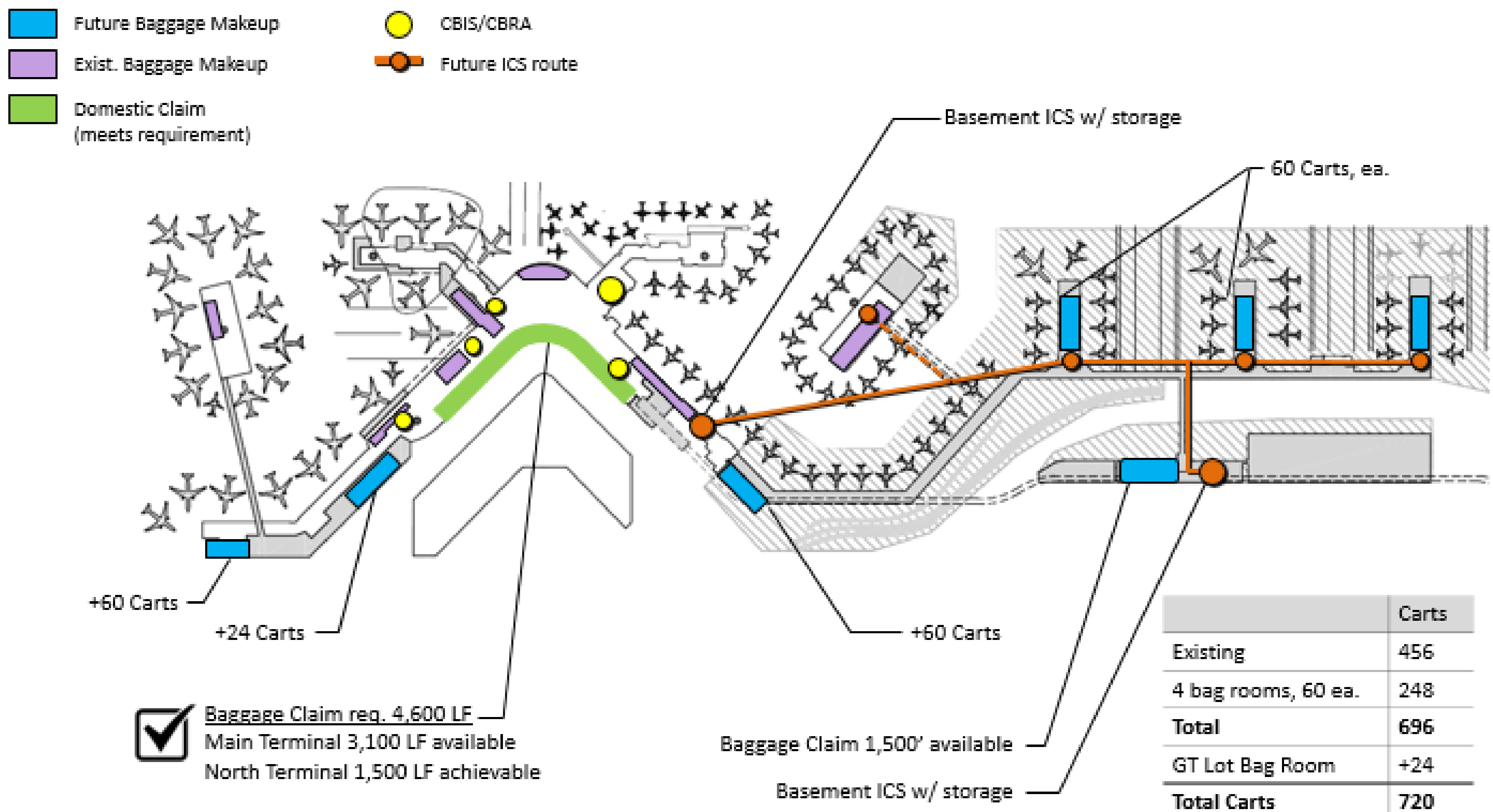


Aircraft Group	Main Terminal			North Terminal			Total		
	Int	Dom	Total	Int	Dom	Total	Int	Dom	Total
RJ/TP					12	12	0	12	12
Jet III	2	21	23		42	42	2	63	65
Jet IV		3	3		3	3	0	6	6
Jet V	27	2	29		1	1	27	3	30
Total	29	26	55	0	58	58	29	84	113
Gate Distribution	49%			51%			100%		

Appendix D, Long term terminal layout, developed at October 2015 BHS coordination workshop

Alternative 2B | Two Terminals, S concourse not extended, 3 piers on N concourse

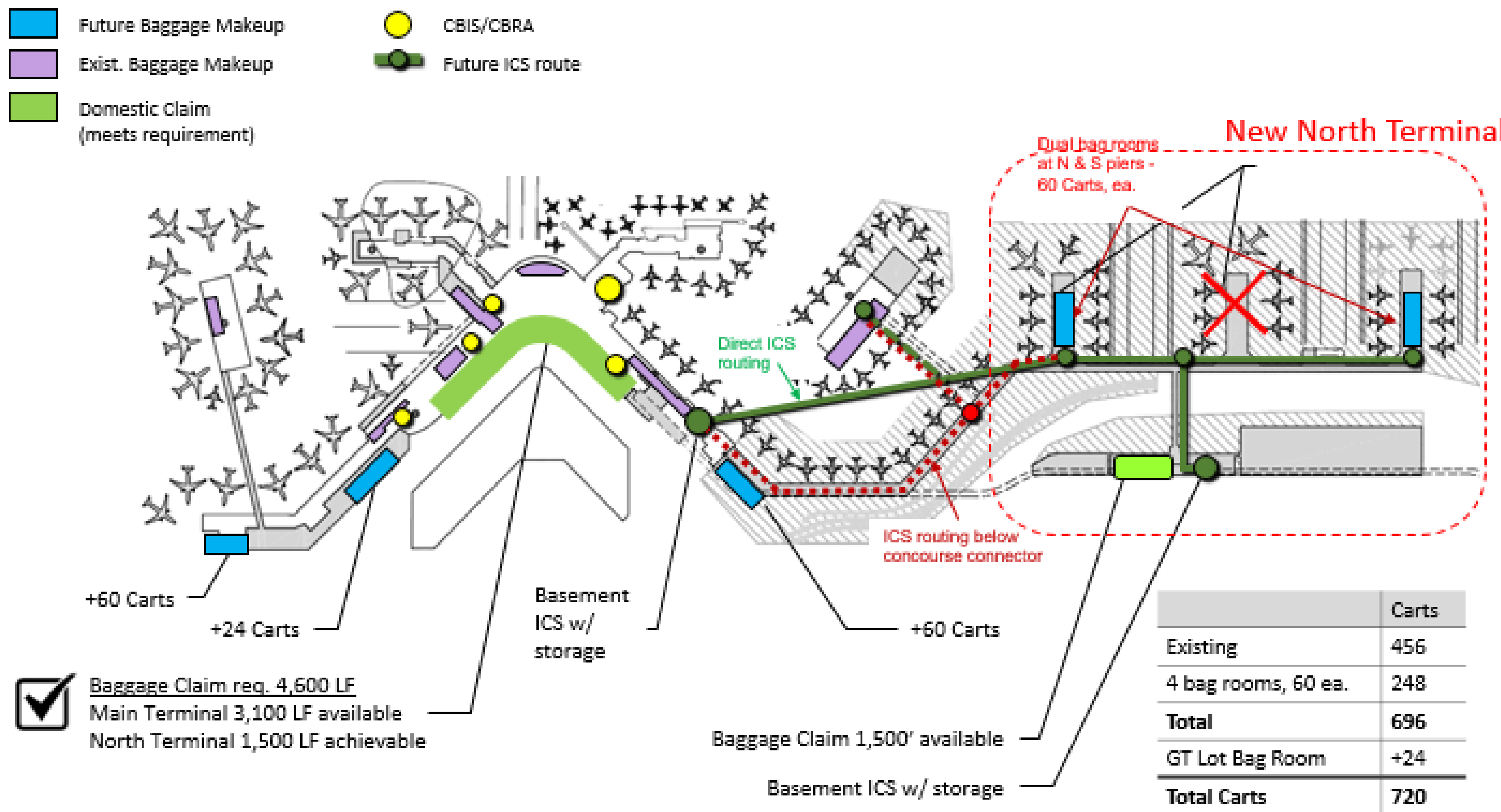
SEA SAMP | BHS Coordination Workshop



	Carts
Existing	456
4 bag rooms, 60 ea.	248
Total	**696**
GT Lot Bag Room	+24
Total Carts	**720**

**If confirmed*

Alternative 2B | Two Terminals, S concourse not extended, 2 piers on N concourse

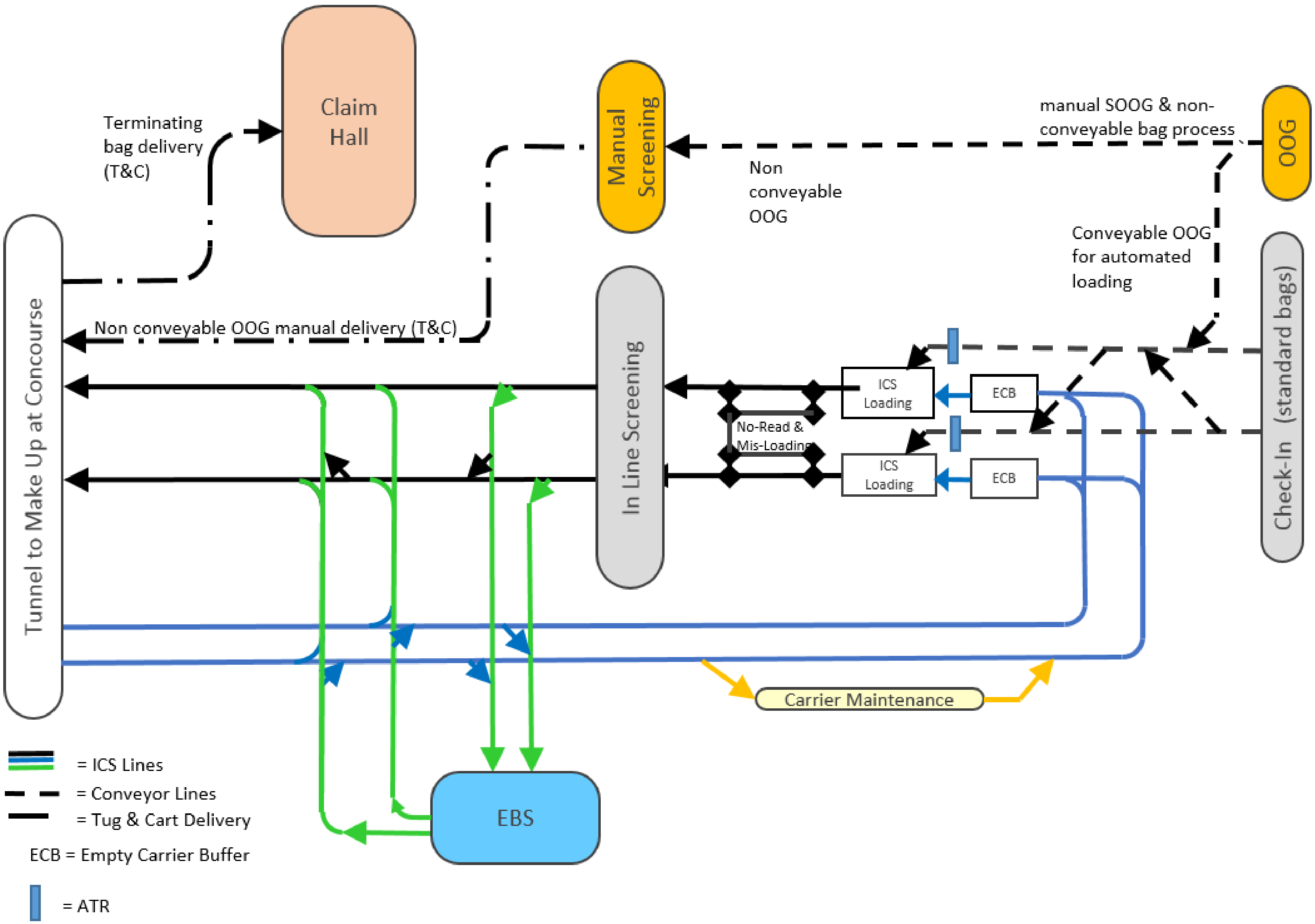


	Carts
Existing	456
4 bag rooms, 60 ea.	248
Total	**696**
GT Lot Bag Room	+24
Total Carts	**720**

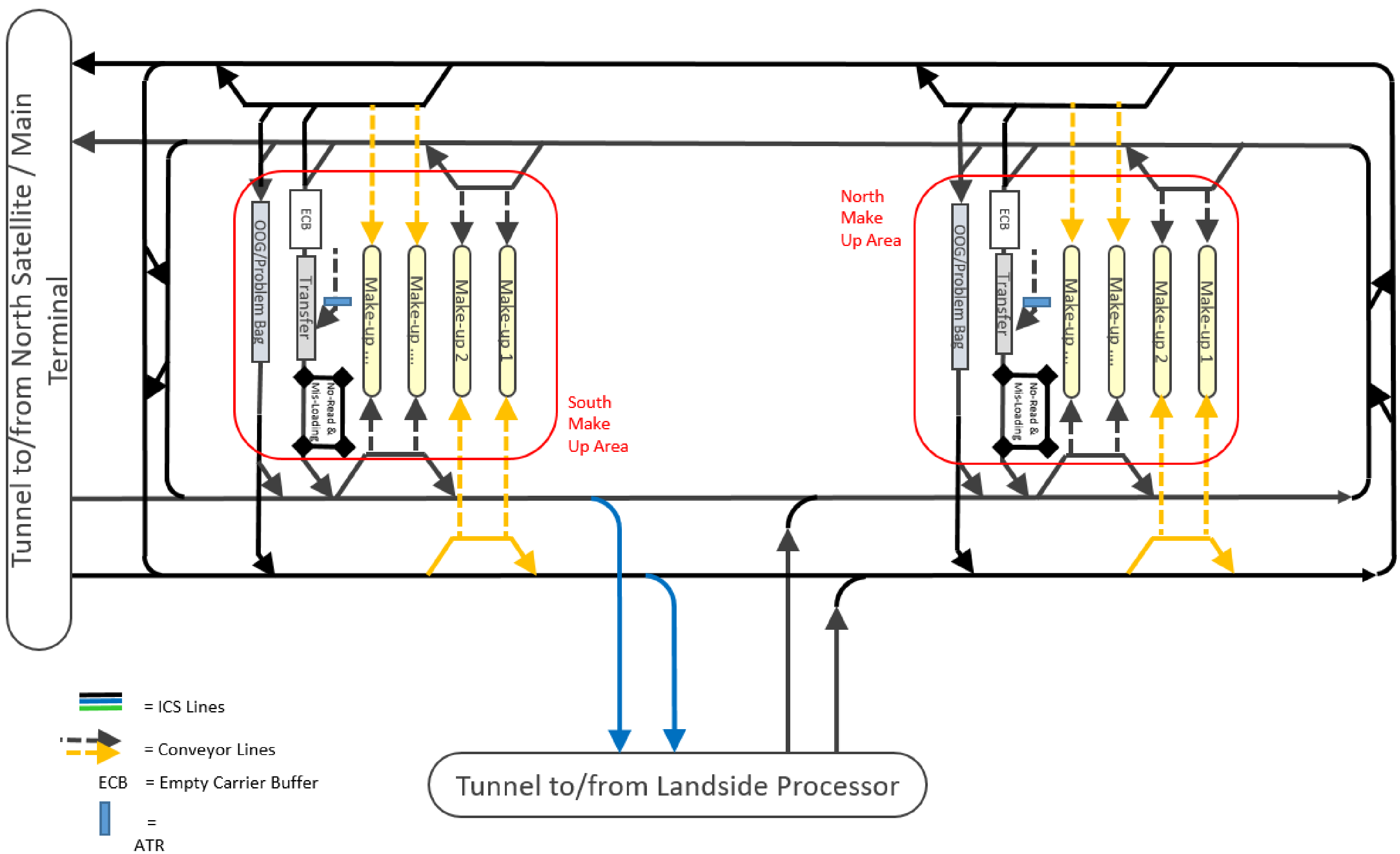
**If confirmed*

BHS Seattle –Baggage Handling Overall Concept

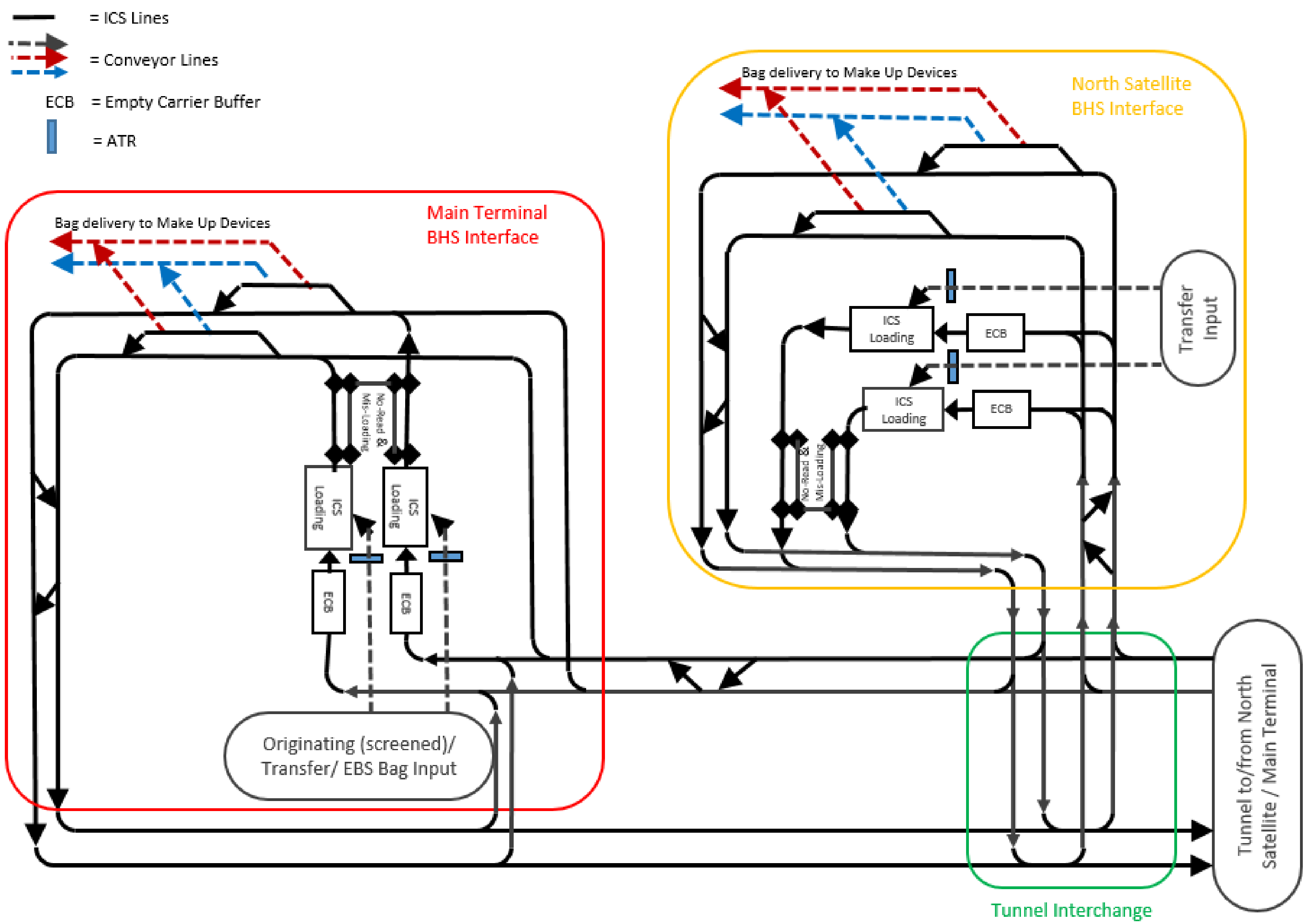
Appendix F North Terminal Landside Processor - Material Flow Diagram



Appendix G - North Terminal Airside Concourse - Material Flow Diagram, with 2 bag rooms

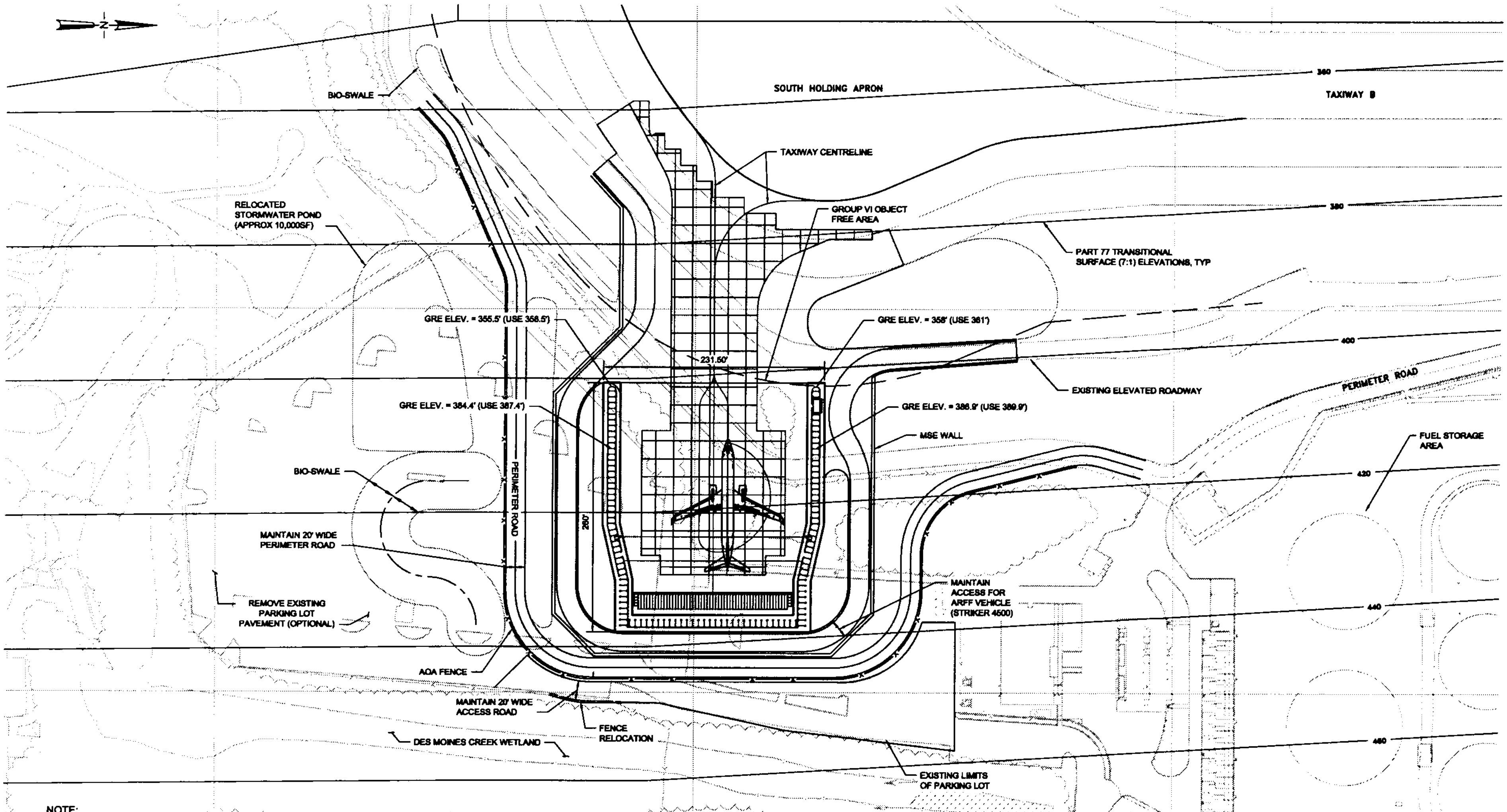


Appendix H - Main Terminal & North Satellite Interfaces - Material Flow Diagram



Appendix F

Ground Run-Up Enclosure Concepts



NOTE:
GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC. DIMENSIONS ARE TO OUTSIDE EDGE OF FOOTINGS.

LEGEND:

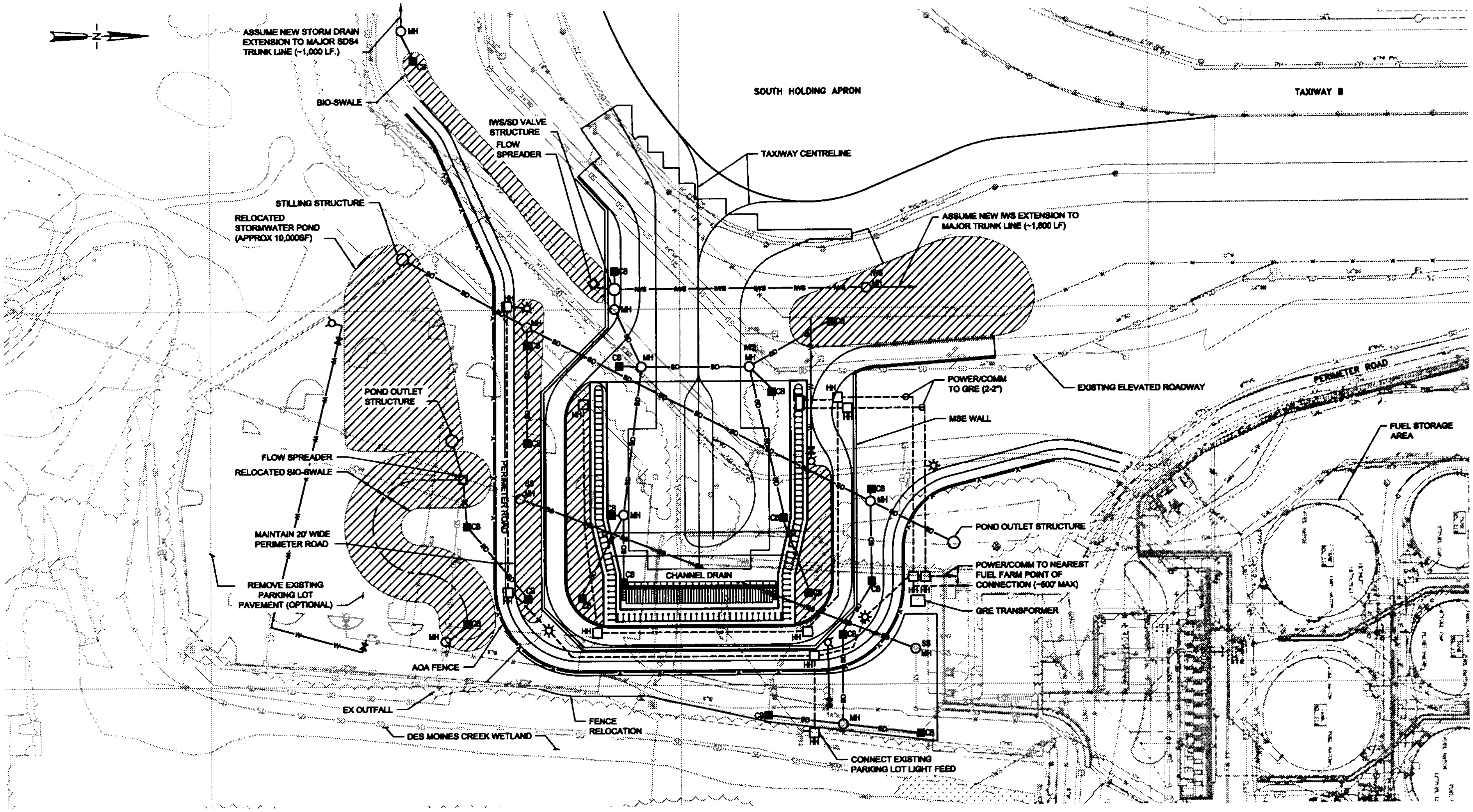
NEW AIRCRAFT RATED STRUCTURAL PAVEMENT (PORTLAND CEMENT CONCRETE OR ASPHALT CONCRETE)

NEW TRAFFIC RATED ASPHALT CONCRETE PAVEMENT

HNTB
2/25/13

50 0 50 100
scale feet

SOUTH HOLDING APRON
GROUND RUN-UP ENCLOSURE SITE A
POWER IN/POWER OUT LAYOUT
DRAFT



NOTE:
GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC.

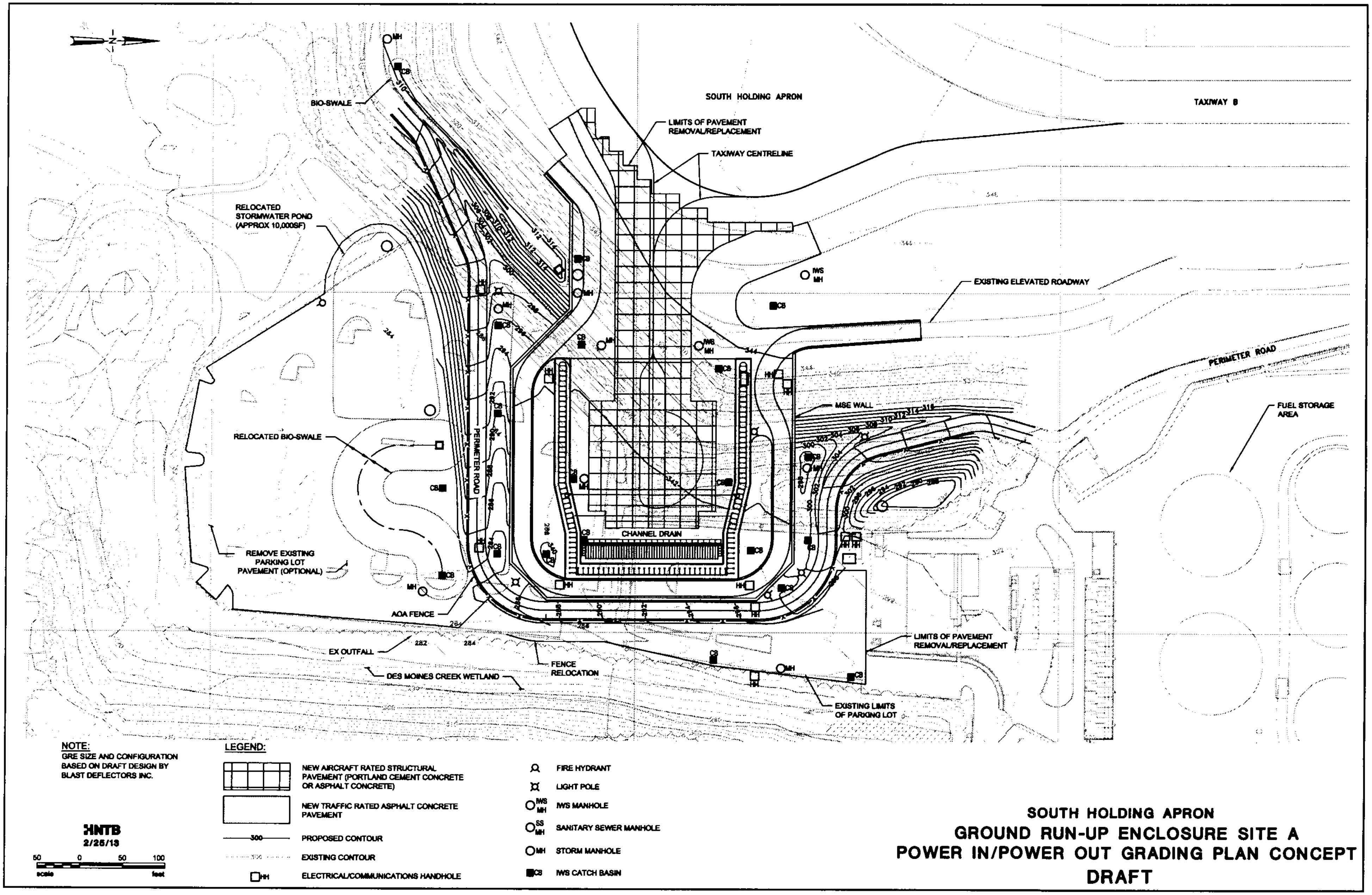
LEGEND:

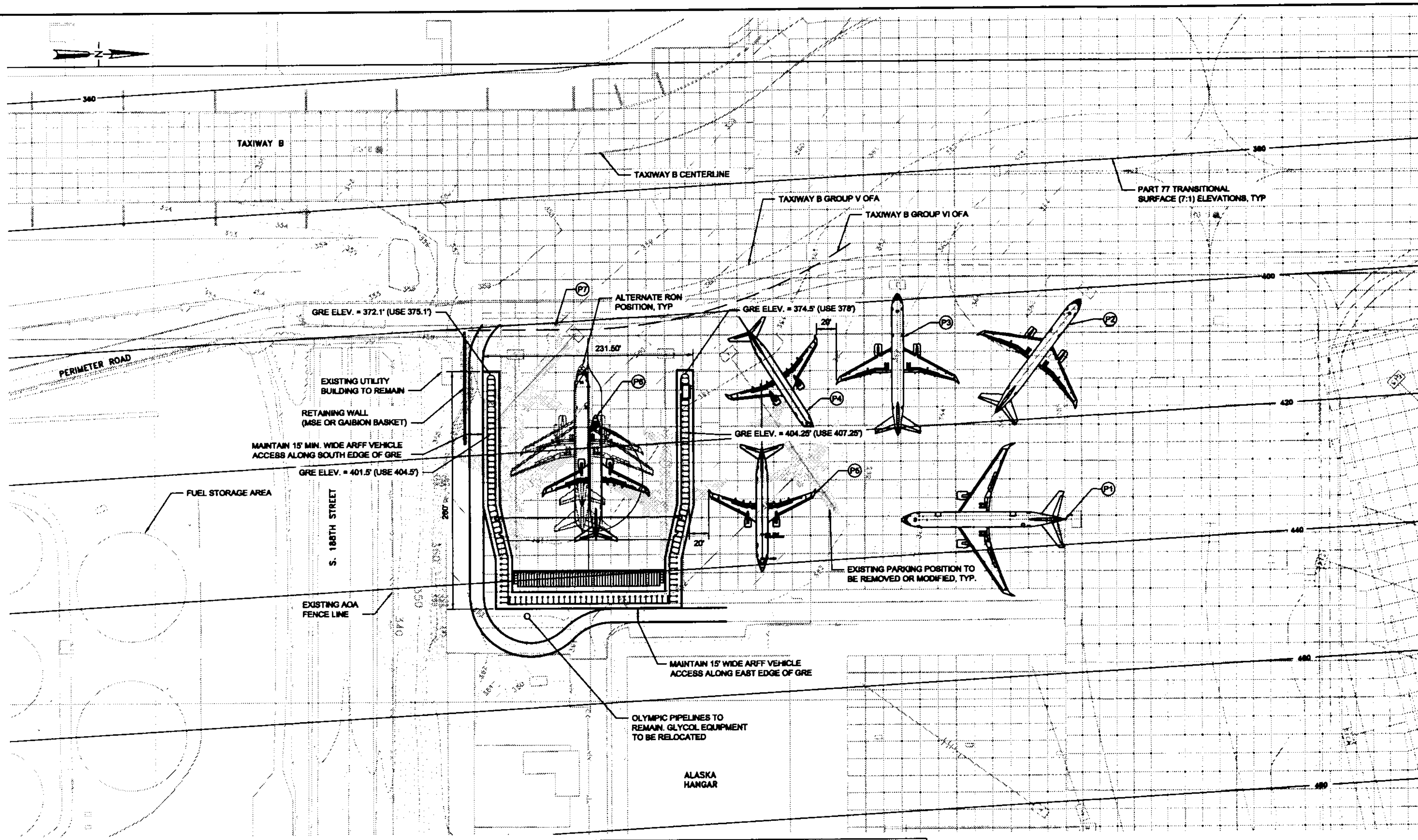
(hatched)	STORM WATER QUALITY PRE-TREATMENT AREAS
—SS—	SANITARY SEWER LINE
—IWS—	IWS LINE
	IWS CHANNEL DRAIN
—W—	WATERLINE
—SD—	STORM DRAIN
- - - -	ELECTRICAL DUCT BANK
— —	COMMUNICATIONS DUCT BANK
HH	ELECTRICAL/COMMUNICATIONS HANDHOLE
	FIRE HYDRANT
	LIGHT POLE
IWS MH	IWS MANHOLE
SS MH	SANITARY SEWER MANHOLE
MH	STORM MANHOLE
CS	IWS CATCH BASIN

HNTB
2/25/13

50 0 50 100
scale feet

SOUTH HOLDING APRON
GROUND RUN-UP ENCLOSURE SITE A
POWER IN/POWER OUT UTILITY PLAN CONCEPT
DRAFT


N
SOUTH HOLDING APRON
TAXIWAY B
LIMITS OF PAVEMENT REMOVAL/REPLACEMENT
TAXIWAY CENTRELINE
BIO-SWALE
RELOCATED STORMWATER POND (APPROX 10,000SF)
EXISTING ELEVATED ROADWAY
PERIMETER ROAD
MSE WALL
FUEL STORAGE AREA
RELOCATED BIO-SWALE
CHANNEL DRAIN
REMOVE EXISTING PARKING LOT PAVEMENT (OPTIONAL)
AOA FENCE
EX OUTFALL
FENCE RELOCATION
DES MOINES CREEK WETLAND
LIMITS OF PAVEMENT REMOVAL/REPLACEMENT
EXISTING LIMITS OF PARKING LOT
NOTE:
GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC.
HNTB
2/25/13
50 0 50 100
scale feet
LEGEND:
NEW AIRCRAFT RATED STRUCTURAL PAVEMENT (PORTLAND CEMENT CONCRETE OR ASPHALT CONCRETE)
NEW TRAFFIC RATED ASPHALT CONCRETE PAVEMENT
PROPOSED CONTOUR
EXISTING CONTOUR
ELECTRICAL/COMMUNICATIONS HANDHOLE
FIRE HYDRANT
LIGHT POLE
IWS MANHOLE
SANITARY SEWER MANHOLE
STORM MANHOLE
IWS CATCH BASIN
SOUTH HOLDING APRON
GROUND RUN-UP ENCLOSURE SITE A
POWER IN/POWER OUT GRADING PLAN CONCEPT
DRAFT



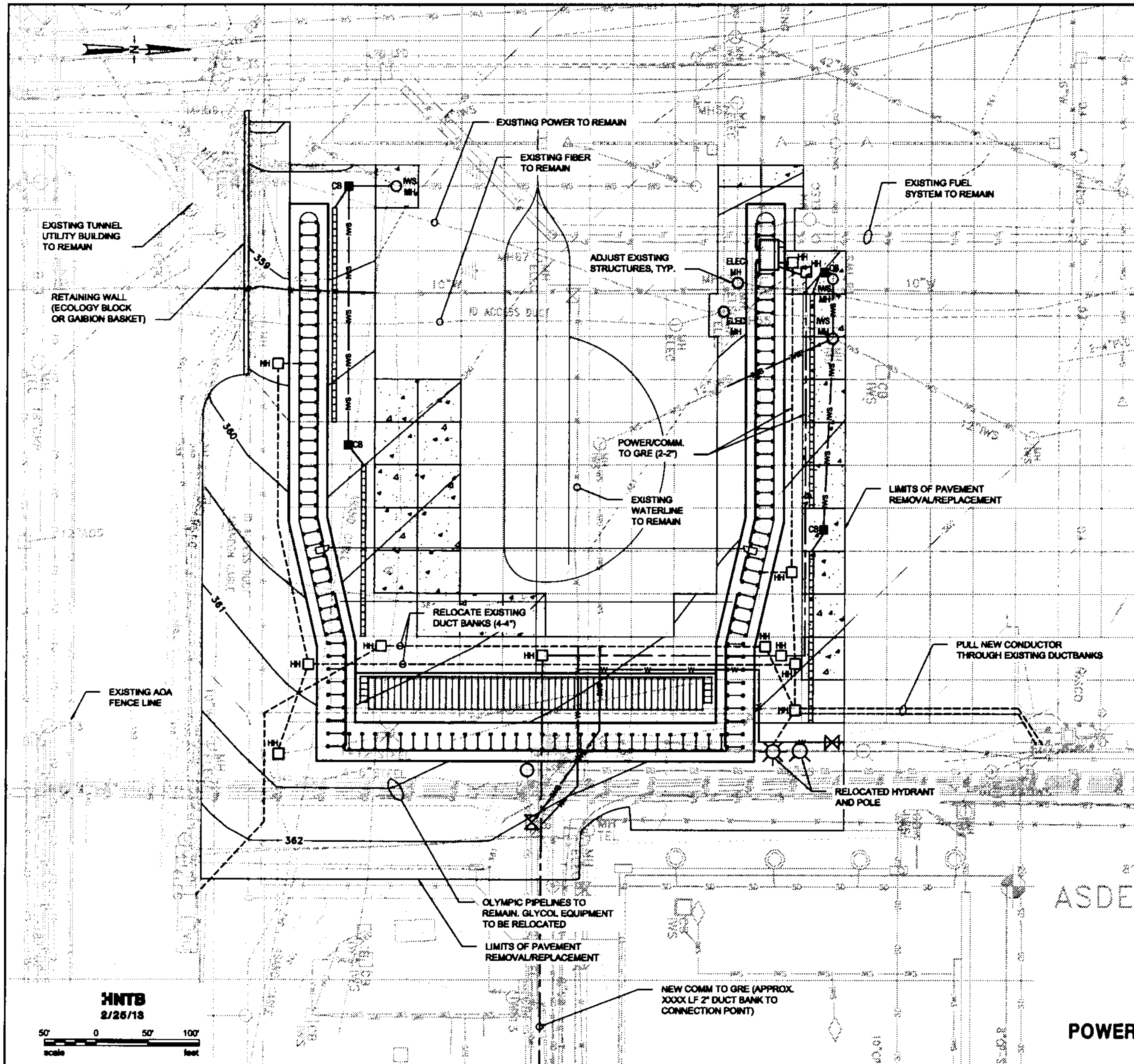
HNTB
2/25/13

50 0 50 100
scale feet

NOTE:
GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC. DIMENSIONS ARE TO OUTSIDE EDGE OF FOOTINGS.

POSITION	EXISTING RON CAPABILITY	RON CAPABILITY WITH GRE
1	A321, 737-900W, 757-300W, MD-80/90, 767-300W	NO CHANGE
2	A321, 737-900W, 757-200W, MD-80/90	NO CHANGE
3	A321, 737-900W, 757-200W, MD-80/90	NO CHANGE
4	A321, 737-900W, MD-80/90	FIRST-IN/FIRST-OUT 737-900W BEHIND POSITION 5 737-900W
5	A321, 737-900W, MD-80/90, 757-200W	A321, 737-900W, MD-80/90
6	A321, 737-900W, MD-80/90, 757-200W, 767-300	RON AT GRE: A321, 737-900W, 757-300W, 767-300
7	FIRST-IN/FIRST-OUT 737-900W BEHIND POSITION 6 737-900W	POSITION REMOVED

CARGO 7 HARDSTAND
GROUND RUN-UP ENCLOSURE SITE B1
POWER IN/POWER OUT LAYOUT
DRAFT



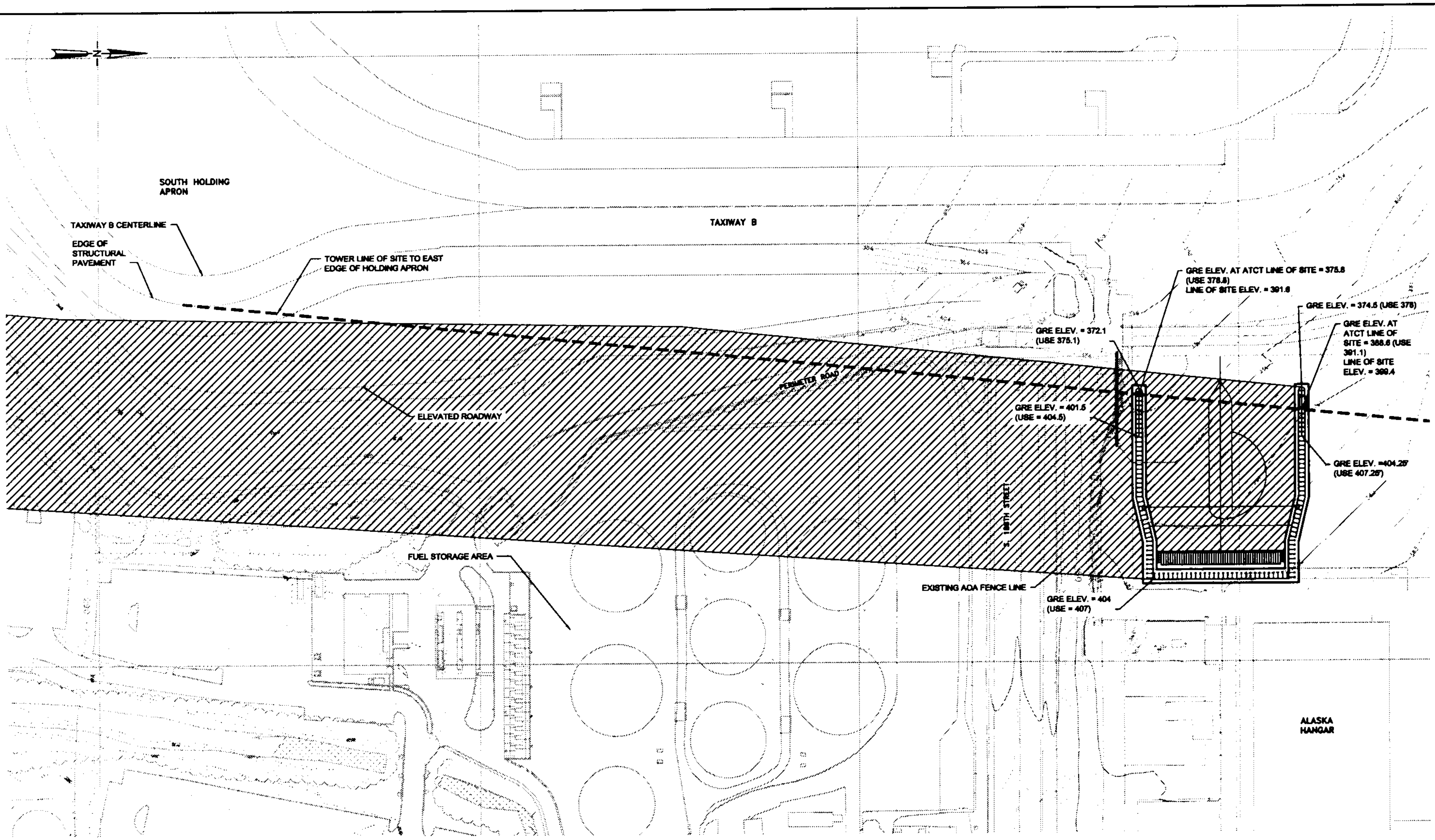
NOTES:

1. GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC.
2. GRE FOUNDATION MAY SLOPE UP TO 1% IN ONE DIRECTION.

LEGEND:

- NEW PCCP PANEL. ALL OTHER NEW OR REPLACEMENT PAVEMENT IS ACP
- PROPOSED CONTOUR
- EXISTING CONTOUR
- IWS MANHOLE
- ELECTRICAL MANHOLE
- IWS CATCH BASIN
- IWS LINE
- IWS CHANNEL DRAIN
- WATERLINE
- ELECTRICAL/COMMUNICATIONS HANDHOLE
- ELECTRICAL DUCT BANK
- COMMUNICATIONS DUCT BANK
- FIRE HYDRANT
- LIGHT POLE

CARGO 7 HARDSTAND
GROUND RUN-UP ENCLOSURE SITE B1
POWER IN/POWER OUT UTILITY & GRADING PLAN CONCEPT
DRAFT



NOTES:

1. GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC.
2. SHADOW DIAGRAM IS BASED ON AN ASSUMED ELEVATION OF 665.5 FOR THE ATCT CAB EYE LEVEL, A SOUTH HOLDING APRON AVERAGE ELEVATION OF 346, AND A MAX GRE HEIGHT OF 45'.

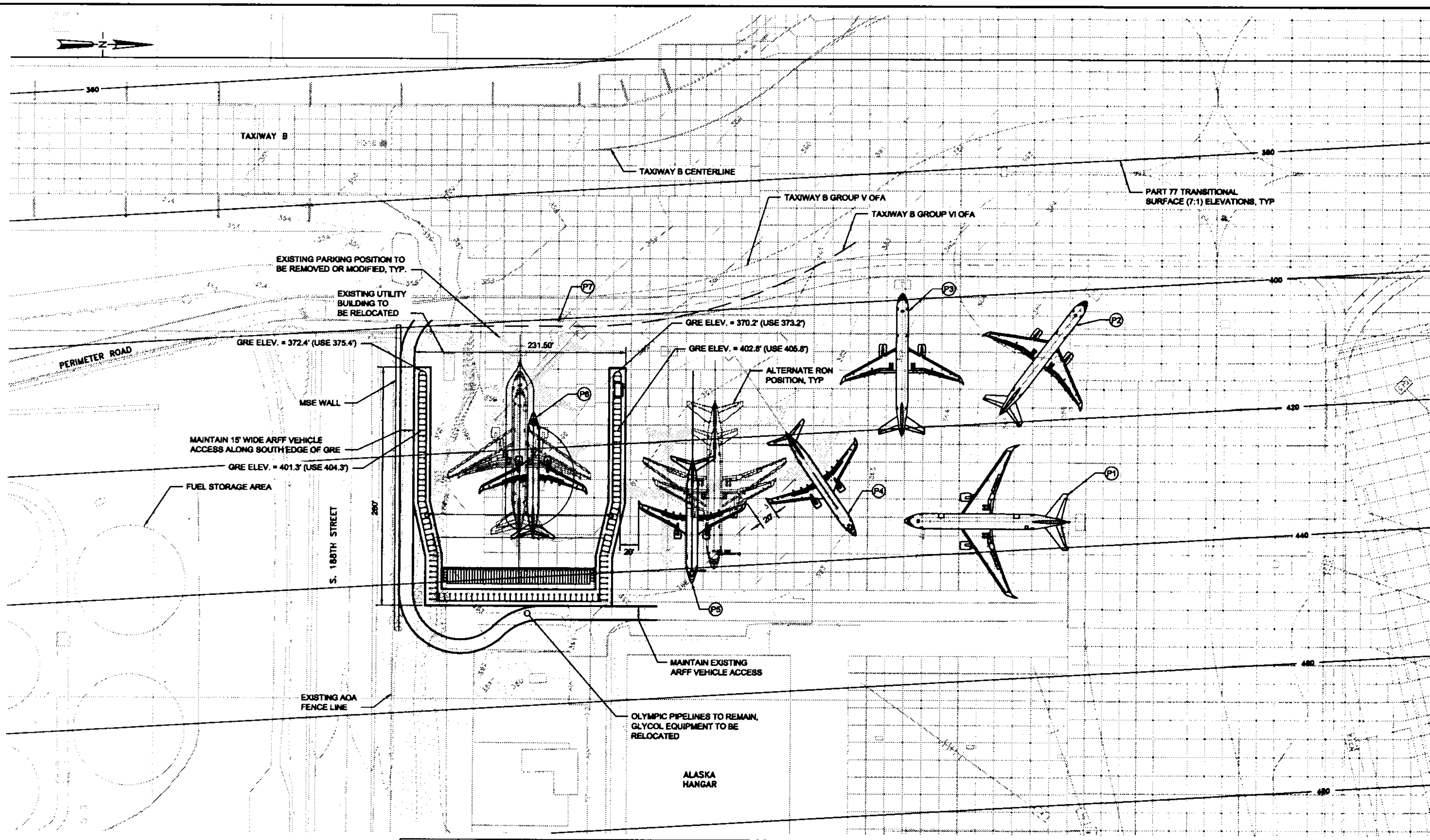
LEGEND:

(hatched) AREA NOT VISIBLE TO AIR TRAFFIC CONTROL TOWER DUE TO GRE PLACEMENT

HNTB
2/25/13

60 0 60 120
scale feet

CARGO 7 HARDSTAND
GROUND RUN-UP ENCLOSURE SITE B1
POWER IN/POWER OUT AIR TRAFFIC CONTROL TOWER
SHADOW DIAGRAM
DRAFT



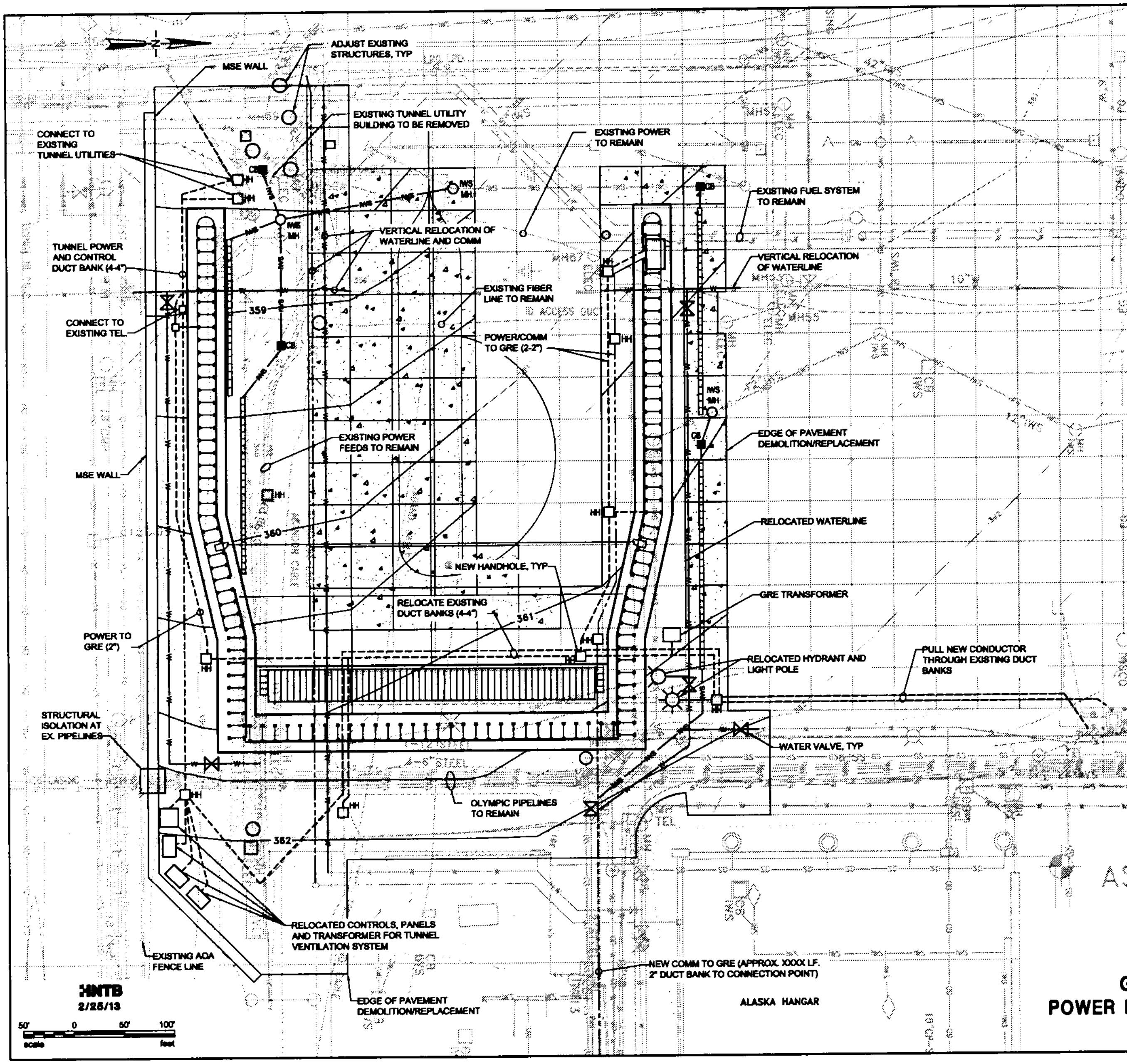
HNTB
2/25/13

50 0 50 100
scale feet

NOTE:
GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC.
DIMENSIONS ARE TO OUTSIDE EDGE OF FOOTINGS.

POSITION	EXISTING RON CAPABILITY	RON CAPABILITY WITH GRE	
1	A321, 737-900W, 757-300W, MD-80/90, 767-300W	NO CHANGE	
2	A321, 737-900W, 757-200W, MD-80/90	NO CHANGE	
3	A321, 737-900W, 757-200W, MD-80/90	NO CHANGE	
4	A321, 737-900W, MD-80/90	737-900W	OR 757-300W, 767-300
5	A321, 737-900W, MD-80/90, 757-200W	737-900W	
6	A321, 737-900W, MD-80/90, 757-200W, 767-300	RON AT GRE: 737-900, A321, 757-300W, 767-300	
7	FIRST-IN/FIRST-OUT 737-900W BEHIND POSITION 6 737-900W	POSITION REMOVED	

CARGO 7 HARDSTAND
GROUND RUN-UP ENCLOSURE SITE B2
POWER IN/POWER OUT LAYOUT
DRAFT



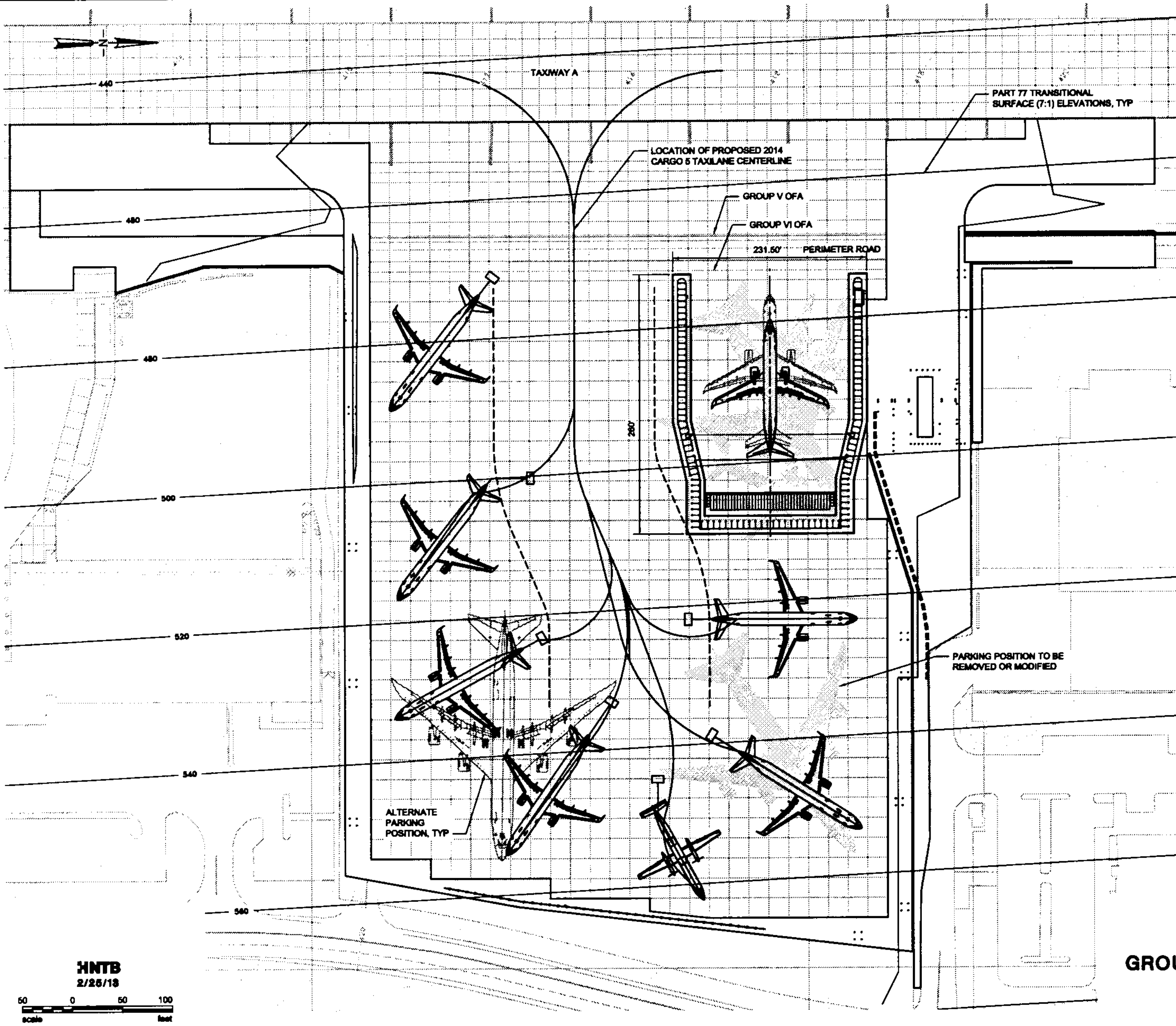
NOTES:

1. GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC.
2. GRE FOUNDATION MAY SLOPE UP TO 1% IN ONE DIRECTION.

LEGEND:

- NEW PCCP PANEL. ALL OTHER NEW OR REPLACEMENT PAVEMENT IS ACP
- 300 PROPOSED CONTOUR
- 300 EXISTING CONTOUR
- IWS MH IWS MANHOLE
- CB IWS CATCH BASIN
- IWS IWS LINE
- IWS CHANNEL DRAIN
- W WATERLINE
- HH ELECTRICAL/COMMUNICATIONS HANDHOLE
- ELECTRICAL DUCT BANK
- COMMUNICATIONS DUCT BANK
- FIRE HYDRANT
- LIGHT POLE

CARGO 7 HARDSTAND
GROUND RUN-UP ENCLOSURE SITE B2
POWER IN/POWER OUT UTILITY & GRADING PLAN CONCEPT
DRAFT

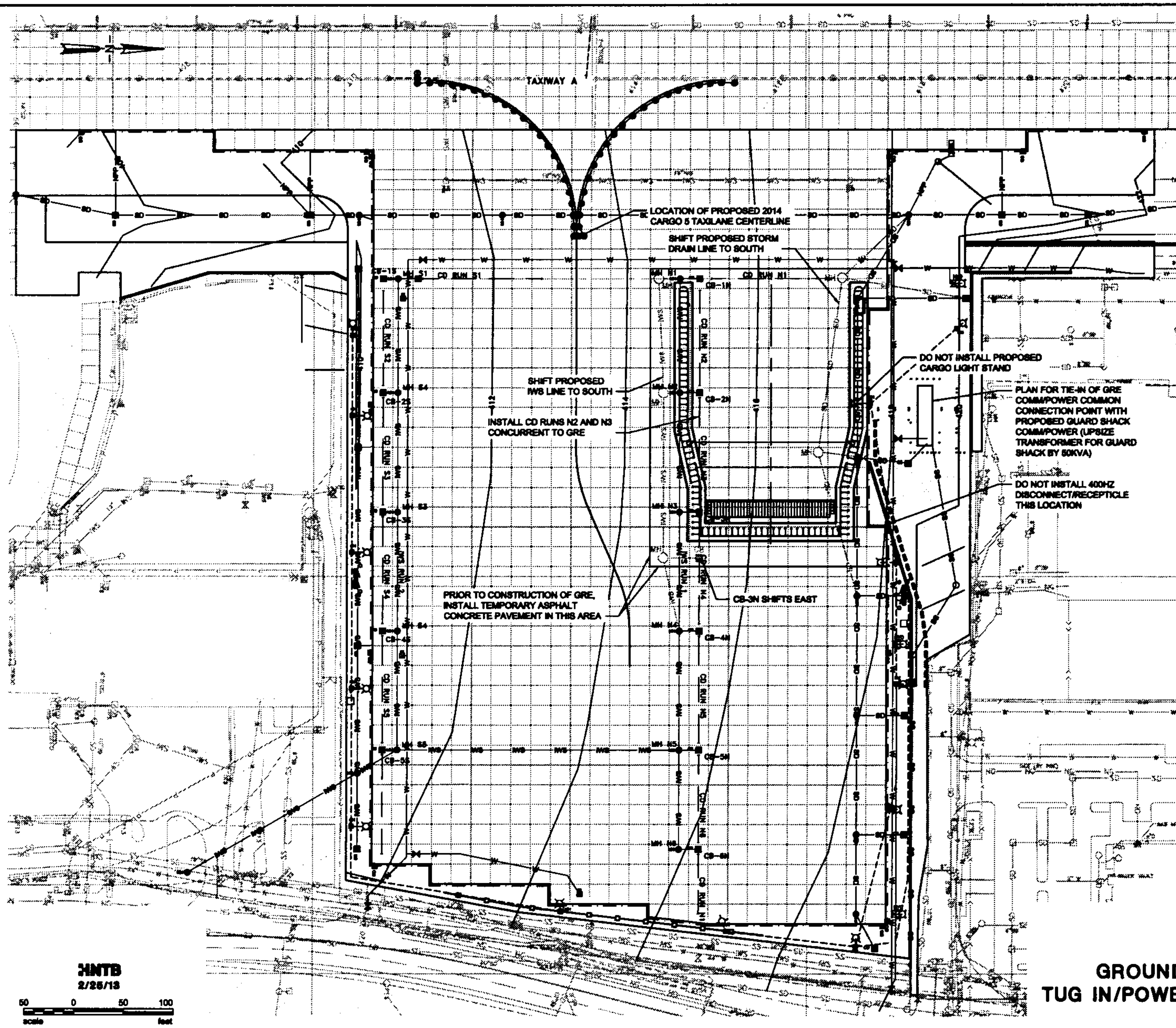


PROPOSED CARGO 5 POSITIONS (2014)	AS MODIFIED BY GRE
NARROW BODY LAYOUT: • EIGHT GROUP III POSITIONS • ONE Q400/CRJ-700	NARROW BODY LAYOUTS: • SEVEN GROUP III POSITIONS (INCLUDING ONE AT GRE) • ONE Q400/CRJ-700 OR: • SIX GROUP III POSITIONS • ONE Q400/CRJ-700 • ONE 757-300W (AT GRE)
WIDE BODY LAYOUTS: • TWO 747-8 • ONE 747-400 OR: • TWO 747-8 • TWO GROUP III POSITIONS OR (NOT SHOWN): • ONE 767-400 • SIX GROUP III POSITIONS • ONE Q400/CRJ-700 OR (NOT SHOWN): • TWO 767-400 • FOUR GROUP III POSITIONS	WIDE BODY LAYOUTS: • ONE 747-8 OR SMALLER • TWO GROUP III POSITIONS (INCLUDING ONE AT GRE) • ONE Q400/CRJ-700 OR: • ONE 747-8 OR SMALLER • ONE 757-300W (AT GRE) • ONE GROUP III POSITION • ONE Q400/CRJ-700

NOTE:
GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC.

CARGO 5 HARDSTAND
GROUND RUN-UP ENCLOSURE SITE D3
TUG IN/POWER OUT LAYOUT
DRAFT

NOTE:
GRE SIZE AND CONFIGURATION BASED ON DRAFT DESIGN BY BLAST DEFLECTORS INC.



CARGO 5 HARDSTAND
GROUND RUN-UP ENCLOSURE SITE D3
TUG IN/POWER OUT UTILITY & GRADING CONCEPT
DRAFT

Appendix G

Airfield Simulation Modeling Assumptions

AIRFIELD SIMULATION MODELING ASSUMPTIONS — SUSTAINABLE AIRPORT MASTER PLAN

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SUSTAINABLE AIRPORT MASTER PLAN

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1 BACKGROUND

In December 2015, LeighFisher concluded an initial round of Total Airport and Airspace Modeller (TAAM) simulation for the Airfield portion of the Sustainable Airport Master Plan (SAMP) at Seattle-Tacoma International Airport (SEA). The effort completed development of calibrated baseline models based on 2014 operations data as well as future-year models with and without airfield improvements such as taxiway reconfiguration, terminal expansion, and additional hold positions. Following this task, LeighFisher began a second round of simulation that explored additional airfield improvements, such as end-around taxiways, in future years.

Following the collection of initial calibration data, significant operational changes occurred at the Airport. Runway 16C/34C, the center runway, was closed from May 2015 through December 2015 for maintenance, and additional runway closures occurred during the first half of 2016. Runway use procedures changed significantly following these runway closures and reopenings. As a result, in October 2016, the FAA requested a refresh and update of the baseline TAAM model calibration, with additional simulation to estimate the maximum sustainable throughput for the baseline (existing) airport layout. LeighFisher recalibrated the baseline models in January and February 2017, and these models were approved by FAA stakeholders in April 2017.

Next, LeighFisher began the process of examining airfield performance at future-year demand levels. The demand levels simulated were Planned Activity Level (PAL) 2, which represents the year 2024; PAL 3, which represents the year 2029; and PAL 4, which represents the year 2034.

This memorandum describes the modeling calibration, procedure, and results.

2 BASELINE CALIBRATION

2.1 Data Sources

Data from various sources were analyzed in order to update the model input parameters and establish baseline calibration metrics for the simulations. Brief summaries of the data provided by each source are given below.

1. Flight operation records from the Port of Seattle Airport Noise Office: time of operation, operation type, runway used, aircraft type, call sign. Data prior to April 1, 2016 came from the Airport Noise Monitoring and Management System (ANOMS) at SEA. These data can be used to determine individual runway and total throughputs, airport flow direction, and runway use.

2. Flight Information System (FIS) records provided by the Port of Seattle: scheduled time of operation, estimated time of operation, and block on/off time. These data, in conjunction with Aerobahn data, can be used to estimate taxi times.

3. Aerobahn flight records provided by the Port of Seattle: gate assignment, operation type, scheduled wheels up/down time, actual wheels up/down time, call sign, international/domestic indicator, tail number, airline, origin, destination, runway, aircraft type, and seat configuration. The runway direction is frequently incorrectly recorded in these data, so they can be used to validate total throughputs given by the noise data. These data can be used to determine aircraft gate usage. In conjunction with the FIS records, these data can be used to estimate taxi times.

4. FAA Aviation System Performance Metrics (ASPM) operating summaries: hourly weather records, hourly throughputs, quarter-hourly called rates, average hourly taxi times. These data can be used to validate total throughputs given by the noise data, average taxi times yielded by Aerobahn and FIS data, and weather data. These data can also be used to compare FAA airport called rates with actual throughputs.

5. NOAA National Climate Data Center (NCDC) Weather data: hourly wind speed, hourly wind direction, hourly ceiling height, hourly visibility distance, and Hourly temperature records. These data can be used to estimate hourly weather conditions at the airport.

2.2 Benchmarking Historical Data Analysis

The objective of simulation calibration is to develop TAAM models that mimic current airfield operations at SEA. Using these calibrated models, airfield infrastructure and operational procedures can be adjusted as simulated demand increases in order to estimate the potential benefits of proposed changes to airfield infrastructure and operational procedures. The initial data analysis portion of this procedure establishes how the airport operates, and these analyses inform the TAAM model input assumptions.

2.2.1 Flow Direction

SEA's three runways lie parallel to each other in the North-South direction. The Airport operates in North flow or South flow, primarily depending on the prevailing wind direction. Historical noise data for the period January 1, 2012 through November 30, 2016 were broken into hourly operation profiles to estimate the actual frequency of North and South flow at SEA.

For analysis purposes, the airport was assumed to be operating in North flow during a particular hour if at least 10 operations occur in that hour, and if at least 90% of these operations use runways 34L, 34C, or 34R. Similarly, the airport was assumed to be operating in South flow during a particular hour if at least 10 operations occur in that hour, and if at least 90% of those operations use runways 16R, 16C, or 16L. The airport was assumed to be operating in a bi-directional flow during a particular hour if at least 10 operations occur in that hour, and if fewer than 90% of these operations use the same runway orientation. The airport was assumed to be in a period of low demand if fewer than 10 operations occur in a given hour.

Under these assumptions, the fraction of time that the airport was observed to operate in each of the above flow directions is shown in Table 1**.** South flow was observed to be the predominant configuration. It is believed that South flow was the predominant flow direction for a number of reasons, including prevailing winds, fewer interactions with nearby airports (i.e. Boeing Field - BFI), and a more favorable taxiway pattern to feed the primary departure runway.

Table 1
Observed Flow Direction by Hour

Flow direction	Percentage of time
North	23.13%
South	56.23%
Both	1.34%
Low Demand	16.94%
N/A	2.36%

Source: LeighFisher analysis of Airport Noise Office data, 2012-2016.

Table 2 summarizes the split between North flow and South flow at the Airport normalized to exclude the hours with bi-directional flow, low demand, and missing data.

Table 2
North Flow and South Flow Relative Frequency

Flow direction	Percentage of time
North	29.14%
South	70.86%

Source: LeighFisher analysis of Airport Noise Office data, 2012-2016.

2.2.2 Weather Conditions

Weather conditions — specifically cloud ceiling, visibility, and wind conditions — have a direct impact on dependencies between the runways and consequently on the FAA Air Traffic Control (ATC) procedures in use. The ATC procedures employed ultimately affect runway capacity and aircraft delay. Therefore, understanding the frequency of Visual Meteorological Conditions (VMC), Marginal Meteorological Conditions (MMC), and Instrument Meteorological Conditions (IMC) at the airport is necessary to estimate expected annual delay. The FAA ADO, Port of Seattle, FAA Airport Traffic Control Tower, and LeighFisher agreed upon the follow breakpoints to approximate the relative frequency of Visual, Marginal, and Instrument Conditions:

- South flow
  - VMC: cloud ceiling of at least 5,000 feet and visibility of at least 5 miles.
  - MMC: cloud ceiling lower than 5,000 feet but at least 3,000 feet, or visibility less than 5 miles, but at least 3 miles.
  - IMC: cloud ceiling lower than 3,000 feet or visibility less than 3 miles.
- North flow
  - VMC: cloud ceiling of at least 5,000 feet and visibility of at least 5 miles.
  - IMC: cloud ceiling lower than 5,000 feet or visibility less than 5 miles.

These five flow-weather configurations were assumed to represent the most common airfield use patterns at SEA. Therefore, five TAAM models were developed to model these five operating regimes.

Due to the difference in the missed approach thresholds and the runway stagger in North flow, the boundaries between weather conditions differ in North flow and South flow at SEA. The following charts provide a graphical illustration of the weather boundaries for North flow and South flow at SEA.

Figure 1
South Flow Weather Minima

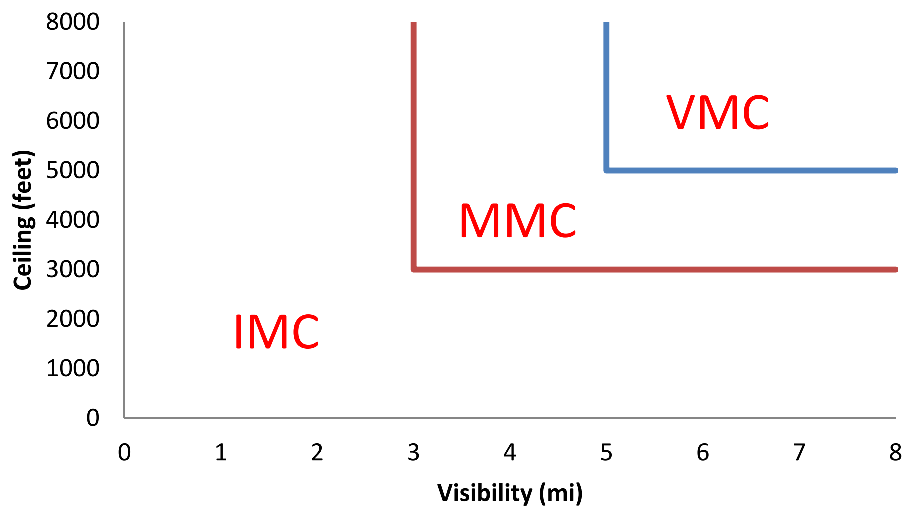
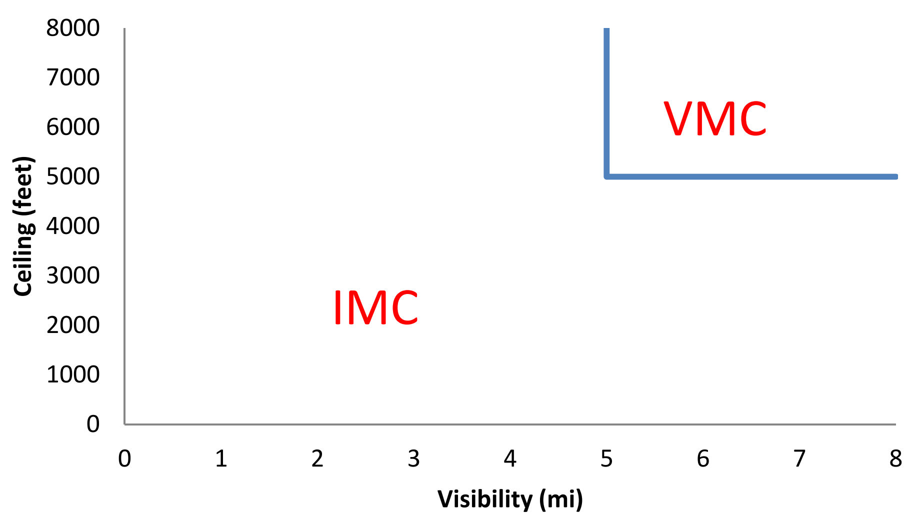


Figure 2
North Flow Weather Minima



2.2.3 Relative Frequency of Flow-Weather Configurations

Each of the five TAAM models was developed to simulate a combination of a flow direction and a weather condition. The design day flight schedule was applied to TAAM models representing South flow VMC, South flow MMC, South flow IMC, North flow VMC, and North flow IMC models. Performance metrics resulting from these five models were weighted by the relative frequency of each state to produce "annualized" performance metrics (See Sections 2.4.6, 4.3.2, and 4.3.4). Hours with missing noise data or missing NCDC data were excluded, as were hours with a "Low Demand" flow or a "Both" flow direction. The annualization percentages that resulted from these assumptions are shown in Table 3.

Table 3
Relative Frequency of Observed Flow-Weather Configuration

Flow-weather configuration	Frequency
South flow VMC	36.50%
South flow MMC	11.99
South flow IMC	22.12
North flow VMC	27.23
North flow IMC	2.16
Total	100.00%

Sources: Noise Office data provided by the Port of Seattle, 1/1/2012-11/29/2016. National Oceanic and Atmospheric Administration – National Climatic Data Center hourly observation data, 2012-2016; (24-hour Analysis - results exclude 1.4% hours with unknown conditions).

2.2.4 Runway Use

Over the last few years, temporary runway closures and changes in ATC procedures have changed how runways are used at the airport. Below is a summary of the recent runway closures:

- Runway 16C/34C (center) was closed from 5/5/2015 to 12/17/2015
- Runway 16L/34R (inboard) was closed from 4/1/2016 to 4/25/2016
- Runway 16C/34C (center) was closed from 5/15/2016 to 6/28/2016

In order to investigate the effect of runway closures and reopenings on runway use, LeighFisher analyzed runway use data provided by the Airport Noise Office. For purposes of this analysis, the data were categorized into six time periods:

- 1/1/2012 to 5/4/2015 (1,219 days): *"Before Closure"*
  - 5/4/2014 to 5/4/2015 (365 days): *"One Year Before Closure"*
- 5/5/2015 to 12/17/2015 (226 days): *"During Closure"*
- 12/18/2015 to 3/31/2016 (104 days): *"Reopened I"*

- 4/1/2016 to 6/28/2016 (88 days): *"Intermittent Closures"*
- 6/29/2016 to 11/29/2016 (154 days): *"Reopened II"*

The data were analyzed to identify the predominant runway use patterns at SEA during each time period. The two most notable changes observed were:

1. Center runway arrivals have been rerouted to the outboard runway.
2. The number of center runway departures has increased, especially in South flow.

Table 4 summarizes the overall historical runway use percentages for each of the five time periods.

Table 4
SEA Observed Runway Use 2014 – 2016

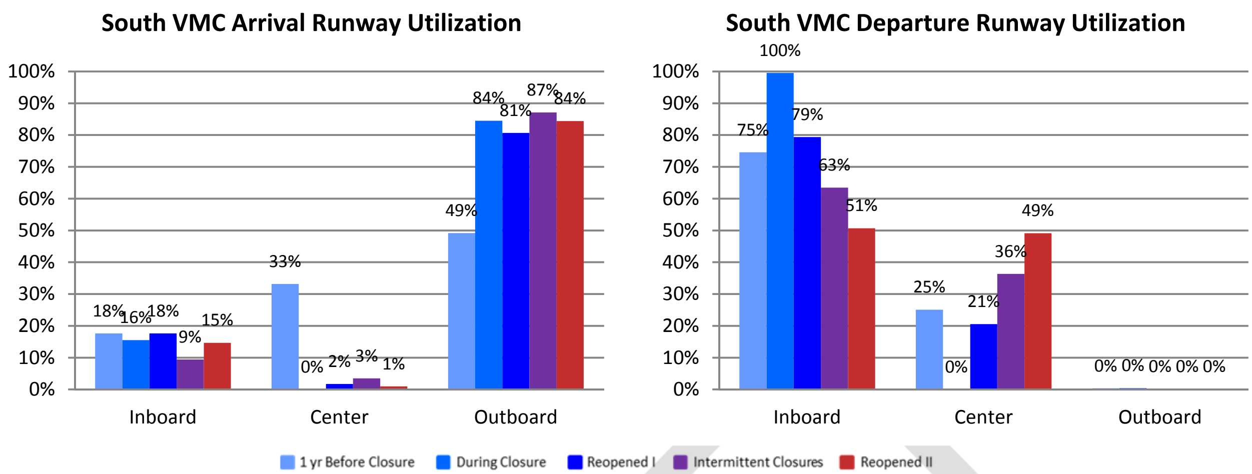
	One Year Before Closure	During Closure	Reopened I	Intermittent Closures	Reopened II
Inboard Arrivals	18.02%	17.25%	16.23%	10.10%	15.41%
Center Arrivals	33.97	0.00	3.95	4.94	1.36
Outboard Arrivals	48.00	82.75	79.82	84.96	83.23
Total Arrivals	100.00%	100.00%	100.00%	100.00%	100.00%
Inboard Departures	80.55%	99.46%	85.58%	70.51%	70.35%
Center Departures	19.07	0.01	14.28	29.21	29.46
Outboard Departures	0.38	0.54	0.14	0.27	0.19
Total Departures	100.00%	100.00%	100.00%	100.00%	100.00%

Source: Noise Office data provided by the Port of Seattle, 5/4/2014--11/29/2016.

The noise data were subsequently used to compute the percentage of operations on each runway for each of the five weather-flow configurations of interest. The objective was to find the predominant runway-use configuration to be simulated for each of the models. In particular, for purposes of the calibration update process, LeighFisher simulated the predominant runway-use configurations observed during the *Reopened II* period, as described in the following paragraphs.

The predominant observed configuration for South flow VMC is arrivals on 16R and 16L, and departures on 16L and 16C. A comparison between *One Year Before Closure* and *Reopened II* was developed to characterize the changes in runway use for different aircraft classes during high-departure-demand hours. A high-departure-demand hour is defined as an hour with 30 or more departures. Table 5 summarizes the changes in runway use percentages between *One Year Before Closure* and *Reopened II* for heavy, large, and small aircraft. The most notable change is that a great amount of center-runway arrival traffic has shifted to the outboard runway. It was also observed that approximately the same volume of departure traffic uses the outboard and center runways after *Reopened II*. Heavy-jet aircraft are more likely to use the inboard runway for both arrival and departure due to their longer take-off and landing distance requirements.

Figure 3
Arrival and Departure Observed Runway Use—South Flow VMC



Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

Table 5
Observed Runway Use Percentage by Aircraft Class—South Flow VMC High Departure Demand Hours

1 year Before Closure 5/4/2014 to 5/4/2015		Percentage by Aircraft Class: Arrival 16L	Arrival 16C	Arrival 16R	Departure 16L	Departure 16C	Departure 16R
SF VMC Dep ≥ 30	Heavy (7% of fleet)	60%	30%	10%	93%	7%	
	Large (91% of fleet)	9%	40%	51%	76%	24%	
	Small (2% of fleet)	6%	16%	78%	60%	24%	16%

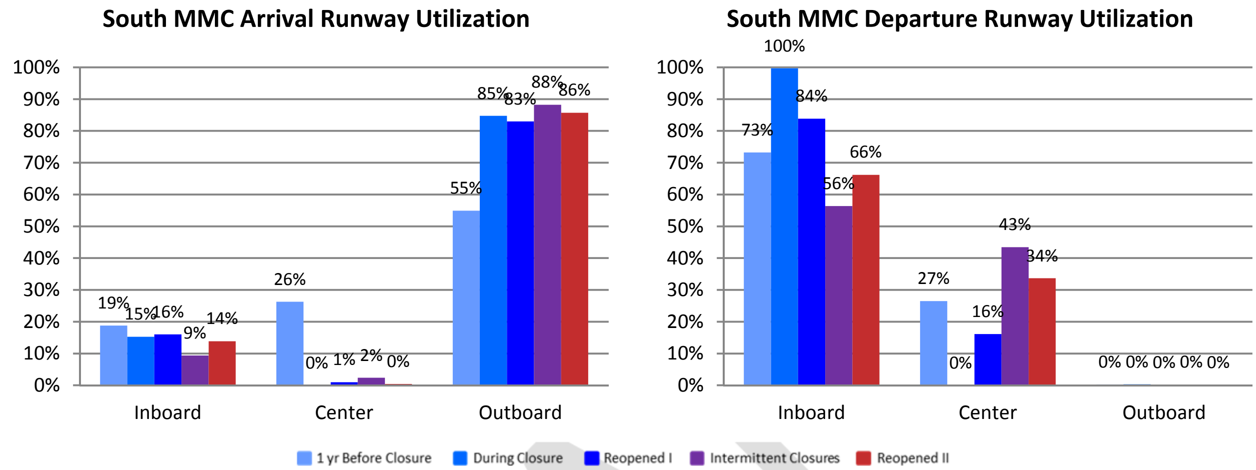
Reopened II 6/29/2016 to 11/29/2016		Percentage by Aircraft Class: Arrival 16L	Arrival 16C	Arrival 16R	Departure 16L	Departure 16C	Departure 16R
SF VMC Dep ≥ 30	Heavy (6% of fleet)	79%		21%	85%	15%	
	Large (93% of fleet)	7%	1%	92%	44%	56%	
	Small (1% of fleet)	29%	1%	70%	41%	55%	4%

Note: “Heavy” aircraft have a maximum takeoff weight (MTOW) capability of at least 300,000 lbs. “Large” aircraft have a MTOW capability between 41,000 and 300,000 lbs. “Small” aircraft have a MTOW capability of at most 41,000 lbs.

Source: Noise Office data provided by the Port of Seattle, 5/4/2014-5/4/2015 and 6/29/2016-11/29/2016.

Similar to South flow VMC, the predominant observed configuration for South flow MMC is arrivals on 16R and 16L, and departures on 16L and 16C. Table **6** summarizes the changes in runway use percentages between *One Year Before Closure* and *Reopened II* for heavy, large, and small aircraft. During the *Reopened II* period, few arrivals were observed on the center runway under any conditions, and the majority of arrivals landed on the outboard runway.

Figure 4
Arrival and Departure Observed Runway Use—South Flow MMC



Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

Table 6
Observed Runway Use Percentage by Aircraft Class—South Flow MMC High Departure Demand Hours

1 year Before Closure 5/4/2014 to 5/4/2015		Percentage by Aircraft Class					
		Arrival			Departure		
		16L	**16C**	**16R**	**16L**	**16C**	**16R**
SF MMC Dep ≥ 30	Heavy (7% of fleet)	66%	25%	10%	91%	9%	
	Large (92% of fleet)	9%	33%	58%	75%	25%	
	Small (2% of fleet)	8%	6%	86%	64%	28%	9%

Reopened II 6/29/2016 to 11/29/2016		Percentage by Aircraft Class					
		Arrival			Departure		
		16L	**16C**	**16R**	**16L**	**16C**	**16R**
SF MMC Dep ≥ 30	Heavy (6% of fleet)	80%		20%	88%	12%	
	Large (93% of fleet)	6%		94%	57%	42%	
	Small (1% of fleet)	24%		76%	56%	42%	2%

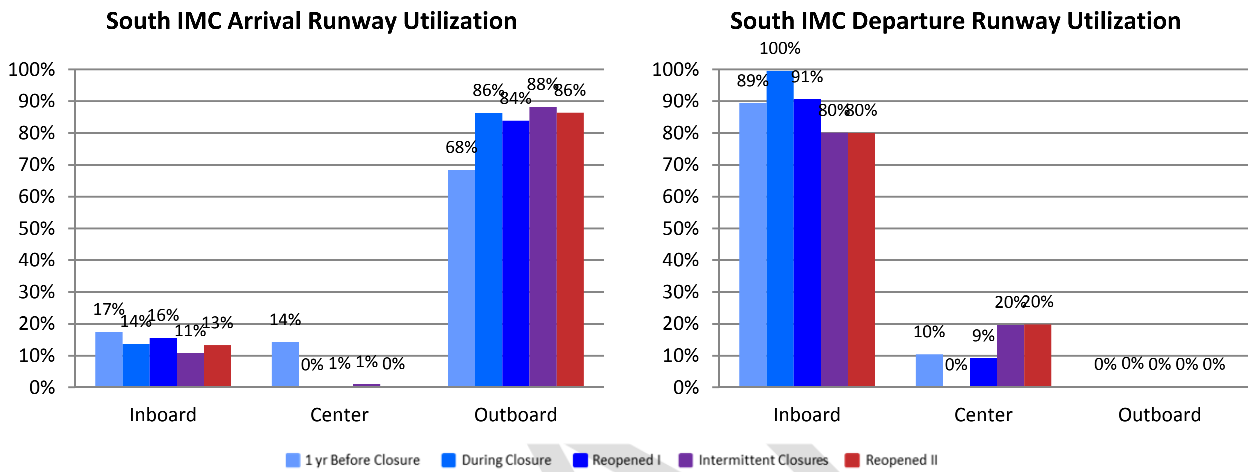
Note: "Heavy" aircraft have a MTOW capability of at least 300,000 lbs. "Large" aircraft have a MTOW capability between 41,000 and 300,000 lbs. "Small" aircraft have a MTOW capability of at most 41,000 lbs.

Source: Noise Office data provided by the Port of Seattle, 5/4/2014-5/4/2015 and 6/29/2016-11/29/2016.

The predominant observed configuration for South flow IMC is arrivals on 16R and 16L and departures on 16L. More than 90% of large and small aircraft use the outboard runway for arrival, while heavy aircraft tend to arrive on the inboard runway. Approximately 75% of non-heavy aircraft and 94% of heavy aircraft take off on the inboard runway during South flow IMC high departure demand hours.

Figure 5

Arrival and Departure Observed Runway Use—South Flow IMC



Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

Table 7

Observed Runway Use Percentage by Aircraft Class—South Flow IMC High Departure Demand Hours

1 year Before Closure 5/4/2014 to 5/4/2015		Percentage by Aircraft Class: Arrival 16L	Arrival 16C	Arrival 16R	Departure 16L	Departure 16C	Departure 16R
SF IMC Dep ≥ 30	Heavy (6% of fleet)	64%	15%	21%	96%	4%	
	Large (92% of fleet)	8%	16%	76%	89%	11%	
	Small (2% of fleet)	4%	6%	90%	79%	15%	6%

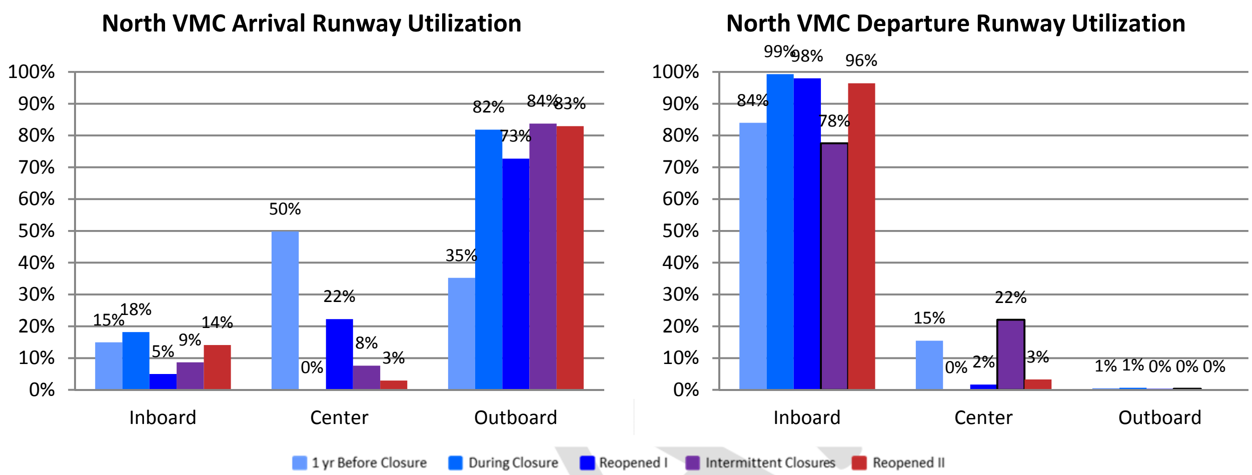
Reopened II 6/29/2016 to 11/29/2016		Percentage by Aircraft Class: Arrival 16L	Arrival 16C	Arrival 16R	Departure 16L	Departure 16C	Departure 16R
SF IMC Dep ≥ 30	Heavy (6% of fleet)	78%		22%	94%	6%	
	Large (93% of fleet)	5%		95%	77%	23%	
	Small (1% of fleet)	9%	1%	90%	74%	22%	3%

Note: “Heavy” aircraft have a MTOW capability of at least 300,000 lbs. “Large” aircraft have a MTOW capability between 41,000 and 300,000 lbs. “Small” aircraft have a MTOW capability of at most 41,000 lbs.

Source: Noise Office data provided by the Port of Seattle, 5/4/2014-5/4/2015 and 6/29/2016-11/29/2016.

The predominant observed configuration for both North flow VMC and North flow IMC is arrivals on 34L and 34R and departures on 34R. Most non-heavy aircraft land on the outboard runway and take off from the inboard runway. Small aircraft departures are nearly evenly split between the center and inboard runway. This may be attributable to the center runway's proximity to the general aviation (GA) terminal, whose tenants are primarily small aircraft. As in South flow, heavy aircraft generally prefer to land on the inboard runway in North flow.

Figure 6
Arrival and Departure Observed Runway Use—North Flow VMC



Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

Table 8
Observed Runway Use Percentage by Aircraft Class—North Flow VMC High Departure Demand Hours

1 year Before Closure 5/4/2014 to 5/4/2015		Arrival 34R	Arrival 34C	Arrival 34L	Departure 34R	Departure 34C	Departure 34L
NF VMC Dep ≥ 30	Heavy (7% of fleet)	37%	56%	7%	96%	4%	
	Large (91% of fleet)	7%	59%	34%	87%	13%	
	Small (2% of fleet)	2%	19%	79%	65%	13%	22%

Reopened II 6/29/2016 to 11/29/2016		Arrival 34R	Arrival 34C	Arrival 34L	Departure 34R	Departure 34C	Departure 34L
NF VMC Dep ≥ 30	Heavy (5% of fleet)	73%	1%	26%	100%		
	Large (93% of fleet)	7%	3%	89%	97%	3%	
	Small (2% of fleet)	6%	3%	91%	51%	41%	8%

Note: "Heavy" aircraft have a MTOW capability of at least 300,000 lbs. "Large" aircraft have a MTOW capability between 41,000 and 300,000 lbs. "Small" aircraft have a MTOW capability of at most 41,000 lbs.

Source: Noise Office data provided by the Port of Seattle, 5/4/2014-5/4/2015 and 6/29/2016-11/29/2016.

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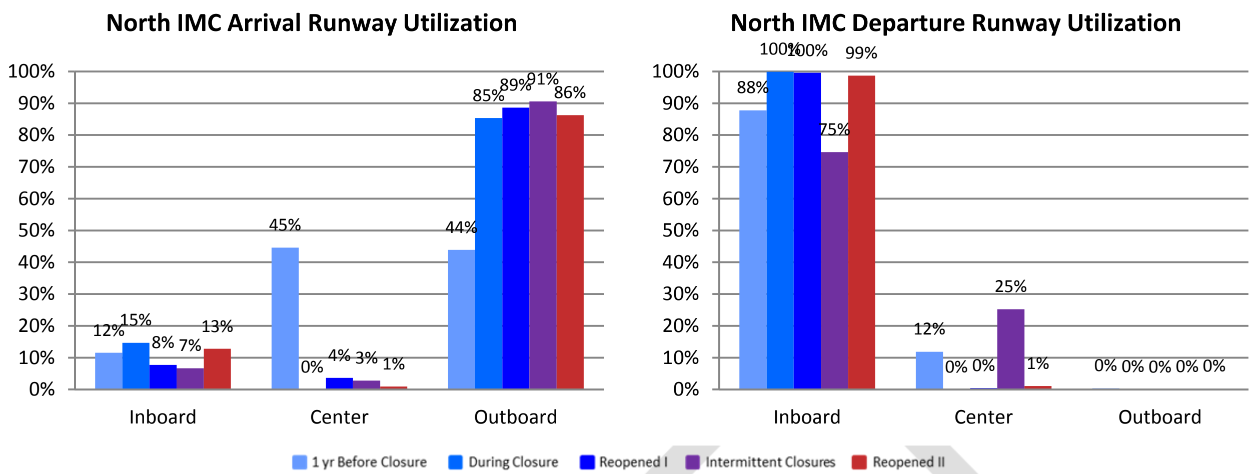
Figure 7
Arrival and Departure Observed Runway Use—North Flow IMC



Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

Table 9
Observed Runway Use Percentage by Aircraft Class—North Flow IMC High Departure Demand Hours

1 year Before Closure 5/4/2014 to 5/4/2015		Percentage by Aircraft Class: Arrival 34R	Arrival 34C	Arrival 34L	Departure 34R	Departure 34C	Departure 34L
NF IMC Dep ≥ 30	Heavy (6% of fleet)	29%	48%	24%	97%	3%	
	Large (93% of fleet)	3%	45%	51%	90%	9%	
	Small (1% of fleet)		29%	71%	65%	6%	29%

Reopened II 6/29/2016 to 11/29/2016		Percentage by Aircraft Class: Arrival 34R	Arrival 34C	Arrival 34L	Departure 34R	Departure 34C	Departure 34L
NF IMC Dep ≥ 30	Heavy (7% of fleet)	55%		45%	100%		
	Large (89% of fleet)	4%	1%	95%	99%	1%	
	Small (3% of fleet)			100%	62%	31%	8%

Note: "Heavy" aircraft have a MTOW capability of at least 300,000 lbs. "Large" aircraft have a MTOW capability between 41,000 and 300,000 lbs. "Small" aircraft have a MTOW capability of at most 41,000 lbs.

Source: Noise Office data provided by the Port of Seattle, 5/4/2014-5/4/2015 and 6/29/2016-11/29/2016.

In summary, the center runway had been used for less than 3% of all arrivals between June 29, 2016 and November 30, 2016, which contrasts with arrival runway assignments prior to the first runway closure. The percentage of arrivals using the inboard runway remained near 15% in both the *One Year Before Closure* and *Reopened II* periods (with a slight drop in inboard arrivals in South flow); therefore, these center-runway arrivals are assumed to have been shifted to the outboard runway. A majority of heavy arrivals occur on the inboard runway; non-heavy arrivals are almost always on the outboard runway. Center runway departures have increased, especially for non-heavy aircraft in South flow VMC. Arrival runway use is generally consistent in each flow direction regardless of weather condition, with the exception of North flow IMC. North flow IMC may have a different arrival runway use because the sample size of North IMC hours is small, and because fewer heavy arrivals may be granted the request to land on the inboard runway due to capacity constraints.

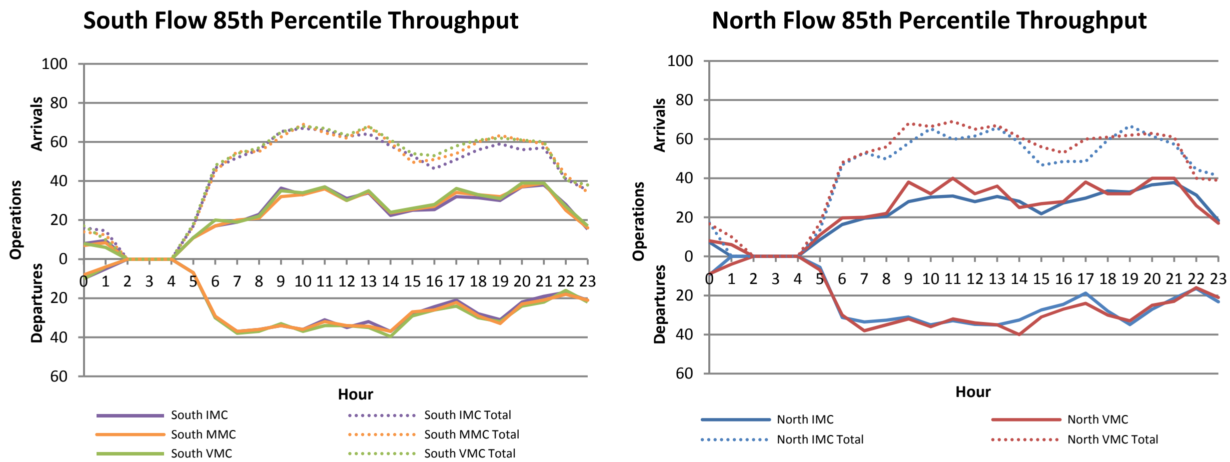
2.2.5 Runway Throughputs

Three data sources were reviewed as part of the throughput benchmarking process (Noise Office data, Aerobahn data, and ASPM data). These three sources report very similar total throughputs that are highly correlated with R-squared values ranging from 0.92 to 0.98. Of these three sources, the noise data set was selected for a more granular analysis, as it had the greatest integrity and level of detail.

Hourly throughput distributions were developed for all five weather-flow configurations during each runway closure time period. Figure 8 and Figure 9 present the 85th percentiles of the observed hourly throughput distributions for all five weather-flow configurations during the *One Year Before Closure* and *Reopened II* periods, respectively. Since North flow IMC occurs so infrequently, many hours are missing data, which is signified by the use of dotted lines in Figure 9.

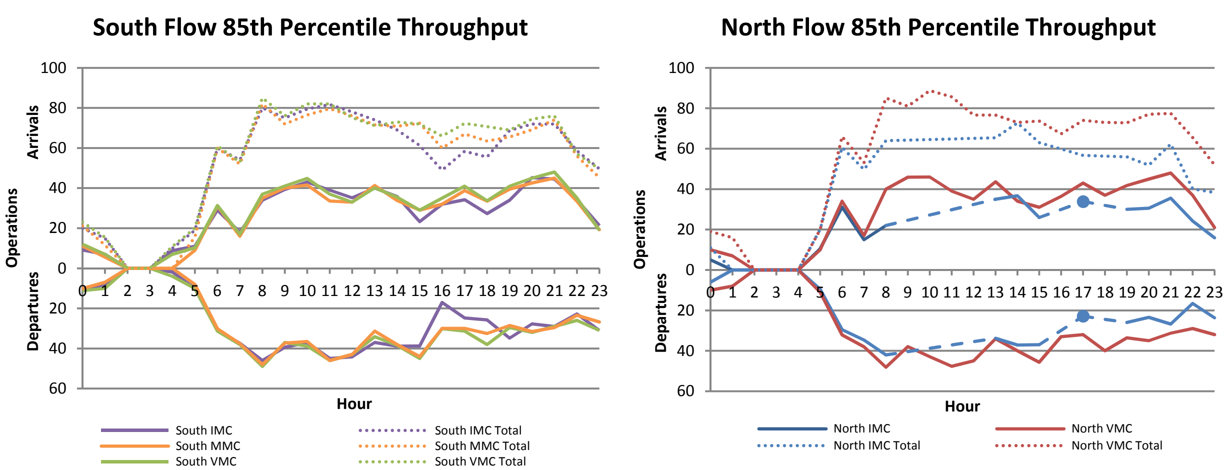
The throughput comparisons reveal that throughputs have grown substantially since the first runway closure. VMC hours generate higher throughputs than MMC and IMC hours due to the shorter separations between flights and fewer runway dependencies. The difference in throughput between VMC and IMC is more pronounced in North flow due to the adverse stagger between the outboard runway (primary arrival runway) and the inboard runway (primary departure runway).

Figure 8
North and South Flow 85th Percentile Observed Throughputs—One Year Before Closure



Source: Noise Office data provided by the Port of Seattle, 5/4/2014-5/4/2015.

Figure 9
North and South Flow 85th Percentile Observed Throughputs—Reopened II



Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

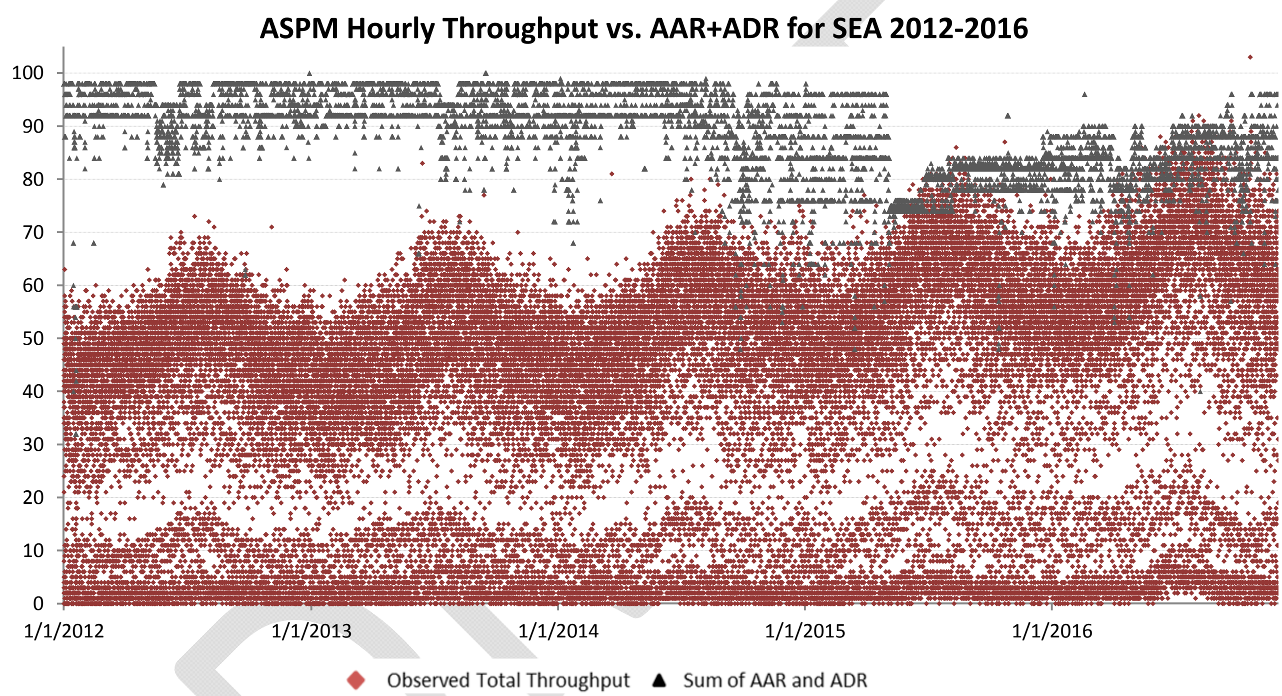
2.2.6 FAA Airport Called Rates

FAA airport called rates represent the planned capacities that are used for tactical air traffic management between the Air Traffic Control Tower (ATCT) and the Terminal Radar Approach Control (TRACON). The ASPM Airport Efficiency Report (AER) reports these capacities in terms of Airport Arrival Rates (AARs) and

Airport Departure Rates (ADRs), as well as actual arrival and departure throughputs. Typically these values are given in 15-minute intervals; however, the publicly-accessible AER only contains hourly measurements.

Hourly throughputs and called rates for January 2012 to November 2016 are shown in Figure 10. Overall, maximum hourly throughputs have increased from year to year. Maximum hourly throughputs during the first center runway closure were higher than those before primarily due to demand increases and seasonality. Two subsequent runway closures are visible in the called rates followed by "adjustment periods". Reported called rates appear to have stabilized as of July 2016.

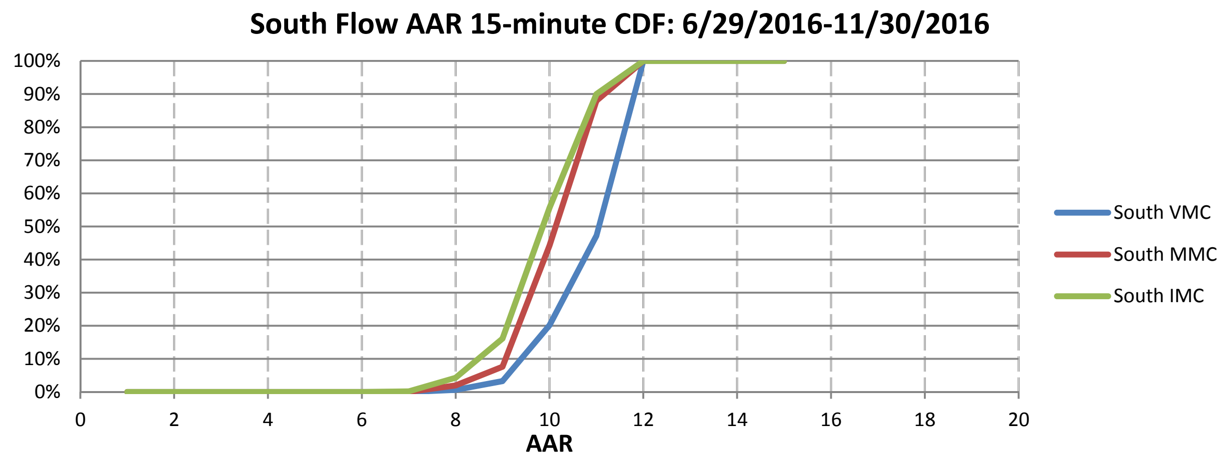
Figure 10
Hourly Called Rates versus Actual Throughputs: 2012-2016



Source: ASPM Airport Efficiency Report 1/1/2012-10/31/2016.

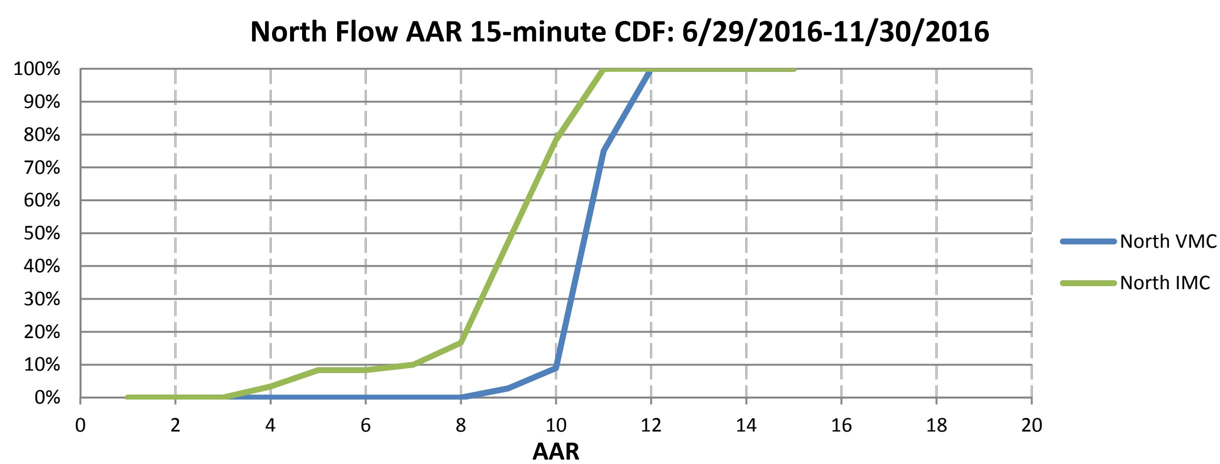
Furthermore, FAA provided LeighFisher with called rates for AAR and ADR in 15-minute intervals. Figure 11 and Figure 12 compare the distributions of AARs for South flow and North flow for 15-minute intervals since the reopening of all runways, respectively.

Figure 11
South Flow AARs by 15-minute Interval



Source: FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

Figure 12
North Flow AARs by 15-minute Interval



Source: FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

There is a greater difference in AARs between VMC and IMC in North flow than in South flow due to the adverse stagger in North flow IMC. In both flow directions, the benefits of the ability to conduct visual approaches are reflected in the planned arrival capacity of the airfield. However, each weather-flow configuration does not have a unique AAR associated with it; each configuration has a distribution of AARs. Based on this analysis, the usefulness of called rates to determine annualization percentages is unclear.

2.2.7 Inboard Runway Operations

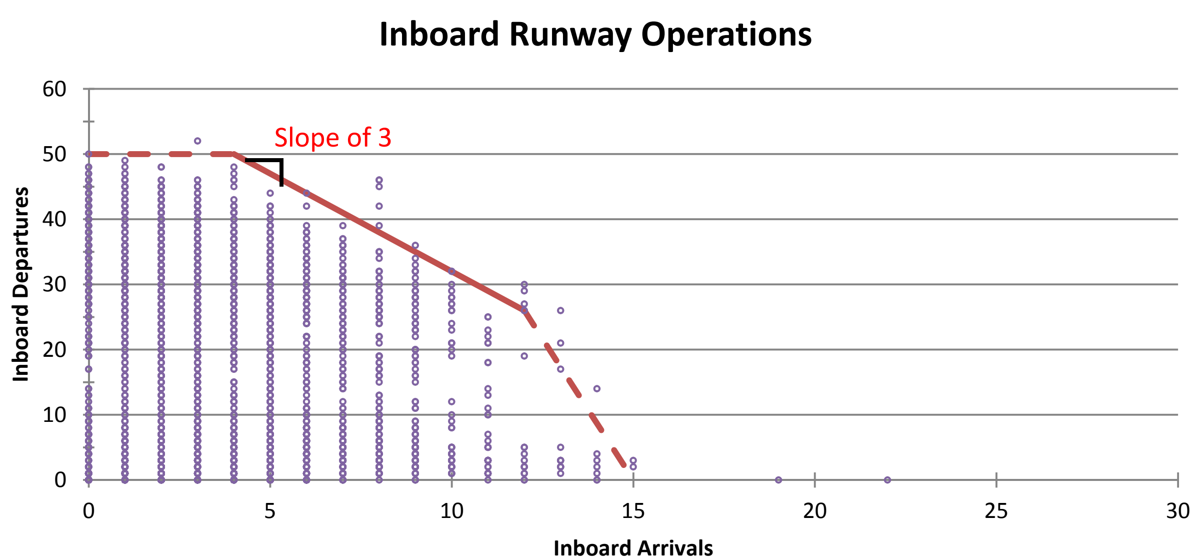
At SEA, pilots of heavy arriving aircraft often request to arrive on Runway 16L/34R, the inboard runway, which is the primary departure runway in all configurations. According to the Air Traffic Control Tower (ATCT) at SEA, pilots typically make this request so that aircraft can use the available length of the runway

(11,901 feet) to decelerate rather than the shorter center or outboard runways. Additionally, the inboard runway is adjacent to the terminal area, so the pilot can avoid having to cross active runways. However, ATCT controllers estimate that every heavy inboard arrival results in the loss of 3-4 inboard runway departure slots. This loss of departure throughput occurs because of the increased runway occupancy time that inboard arrivals experience, which may happen for the following reasons:

- The inboard runway has no high-speed exits, so arrivals must come to nearly a complete stop on the runway before making a 90-degree turn to exit the runway.
- An inboard departure may not begin its roll if an arrival to that runway is within the capture distance of 2 nautical miles.
- In South flow, inboard arrivals typically decelerate to taxiing speed around Taxiway M or N; however, because traffic on Taxiway B flows in the opposite direction, the arrival must taxi on the runway to exit further southward at Taxiway Q or S.
- When arrivals exit the inboard runway, they would ideally turn onto Taxiway B and then contact ground control. However, some international carrier pilots do not turn off before contacting ground control due to ICAO rules specifying that ground control must be contacted before entering a taxiway. (ATCT has indicated that they are in process of "training" international pilots to disregard this ICAO rule in order to decrease their runway occupancy time.)

Indeed, the noise data from June 29, 2016 to November 29, 2016 show that there is a direct tradeoff between inboard arrivals and departures, and it nearly follows a one-to-three tradeoff, as indicated by the sloping line shown on Figure 13.

Figure 13
Inboard Runway Arrivals versus Departures



Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016. Red line of slope 3 added for illustrative purposes only.

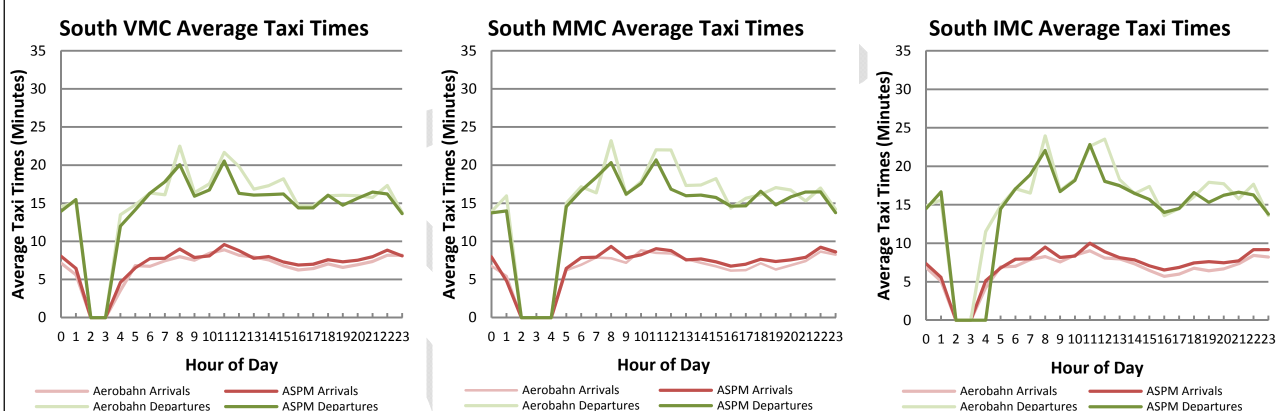
2.2.8 Taxi Times

In order to estimate taxi times, the Port of Seattle matched the Aerobahn flight records with the Flight Information System (FIS) records and provided these records to LeighFisher. Aerobahn data give the wheels up/down time to the nearest minute, while FIS data give the block on/off time to the nearest second.

If the operation is a departure, the taxi out time was approximated by subtracting the FIS block off time from the Aerobahn wheels up time, which is similar in definition to the ASPM "out-to-off" time. If the operation is an arrival, the taxi in time was approximated by subtracting the Aerobahn wheels down time from the FIS block on time, which is similar in definition to the ASPM "on-to-in" time. The result is that a full distribution of taxi times can be estimated.

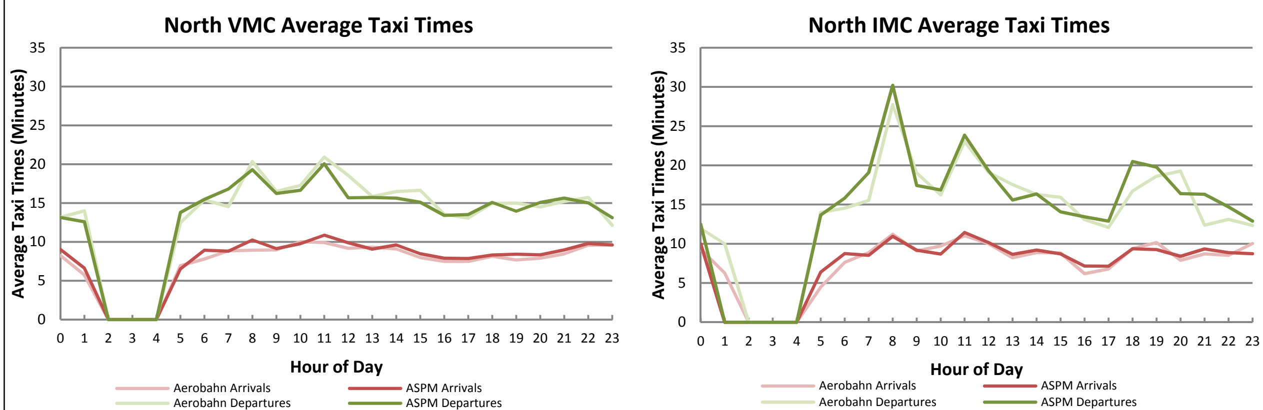
ASPM does not provide this level of detail for taxi times; only hourly average taxi times are available. However, these average taxi times may be compared with Aerobahn/FIS average taxi times to validate the use of Aerobahn/FIS data. Figure 14 and Figure 15 illustrate the difference in the hourly distribution of average taxi-in times and average time-out times for South flow and North flow between the two sources, respectively.

Figure 14
South Flow Average Taxi Times



Source: Aerobahn and FIS data provided by the Port of Seattle; ASPM Taxi Times report; 5/12/2016-11/1/2016.

Figure 15
North Flow Average Taxi Times



Source: Aerobahn and FIS data provided by the Port of Seattle; ASPM Taxi Times report; 5/12/2016-11/1/2016.

The results show that ASPM and Aerobahn/FIS taxi times tend to agree, which suggests that Aerobahn/FIS data may be used to estimate taxi times.

Taxi-out times are greater and exhibit more variability than taxi-in times, likely because taxi-out times include departure queuing. Average reported taxi-in times vary between 6 and 10 minutes, while average reported taxi-out times vary between 14 and 23 minutes. North flow IMC accounts for the most variable taxi-out times due to the infrequency of historical North flow IMC data. North flow taxi-in times are higher than South flow taxi-in times; similarly, North flow taxi-out times are lower than South flow taxi-out times. These differences arise as a result of the location of the main passenger terminals with respect to the runway entrances and exits.

2.2.9 Gate Use

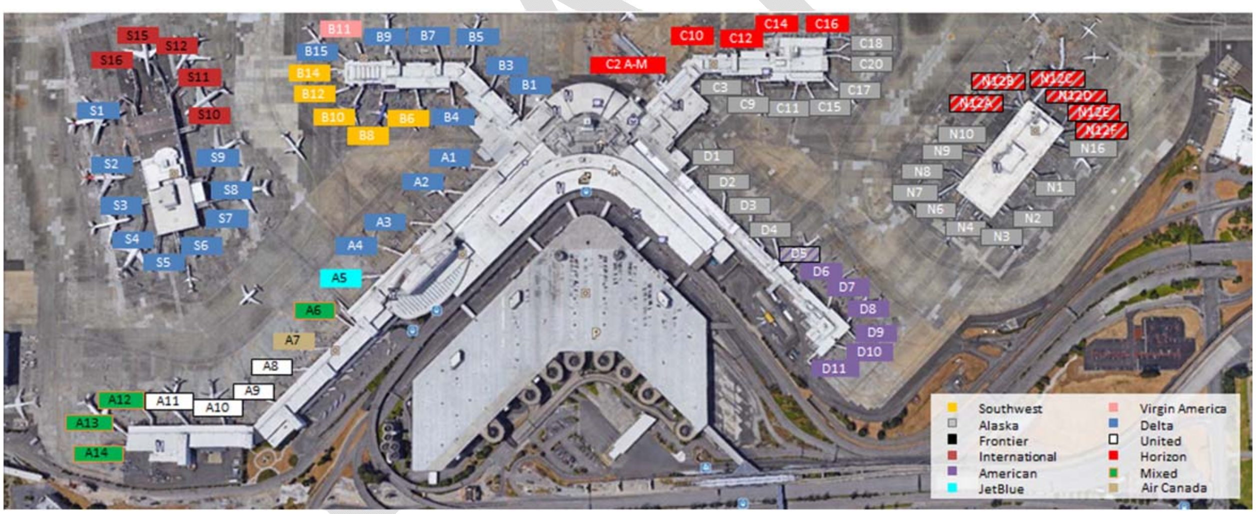
Aerobahn data were used to study the airline gate use at SEA. Table 10 summarizes the airline allocations observed from Aerobahn data, and Figure 16 illustrates gate use by airline in 2016. A gate is considered to be an airline-dedicated gate if that airline conducts more than 50% of the operations at that gate. The airline-dedicated gates are labeled with airline-specific colors in Figure 16, while “shared-use” gates are labeled by striped boxes with multiple colors.

Table 10
Observed Gate Allocations by Airline at SEA

Concourse	Primary Tenants
Concourse A	United, Air Canada, Delta, JetBlue, SkyWest, Compass, Frontier
Concourse B	Delta, Southwest, Virgin America, SkyWest
Concourse C West	Horizon
Concourse C	Alaska
Concourse D	Alaska, American
North Satellite	Alaska, Horizon
South Satellite	Delta, SkyWest, Compass, International

Source: Aerobahn Flight Details Report, 2016.

Figure 16
Observed Airline Gate Allocations at SEA



Source: Aerobahn Flight Details Report, 2016.

2.3 Assumptions: Input Parameters

The following section lists the assumed input parameters for the five baseline models.

2.3.1 Design Day Flight Schedule

The flight schedule used in the simulation effort represents an Average Day Peak Month (ADPM), which was identified by dividing the total number of operations in the peak month by the number of days in that month. An ADPM schedule is used rather than an "average day" schedule so that terminal and airfield worst-case needs can be assessed. Based on historical data from the Official Airline Guide (OAG), the peak demand month during 2016 at SEA was August. The base August 2016 OAG schedule does not include cargo and GA operations; therefore, flight records from the FAA ASPM database were used to add these operations to the schedule. Commercial passenger and cargo arrivals in the schedule were linked to subsequent departing flights to create a matched flight schedule. This allows the modeling in TAAM of not only arrival and departure operations, but also of gate occupancy and pushback operations.

Table 11 presents a summary of the baseline year demand level, along with the rolling peak hour operations for each operation type.

Table 11
Summary of Design Day Flight Schedule Operations

	Arrival	Departure	Total
Number of Annual Operations (2016)	N/A	N/A	412,170
Number of ADPM Operations	612	620	1,232
ADPM Annualization Adjustment Factor		0.9166	
Peak Hour Operations	61	57	94
Rolling Peak Hour Start Time	8:44 PM	7:16 AM	9:32 AM

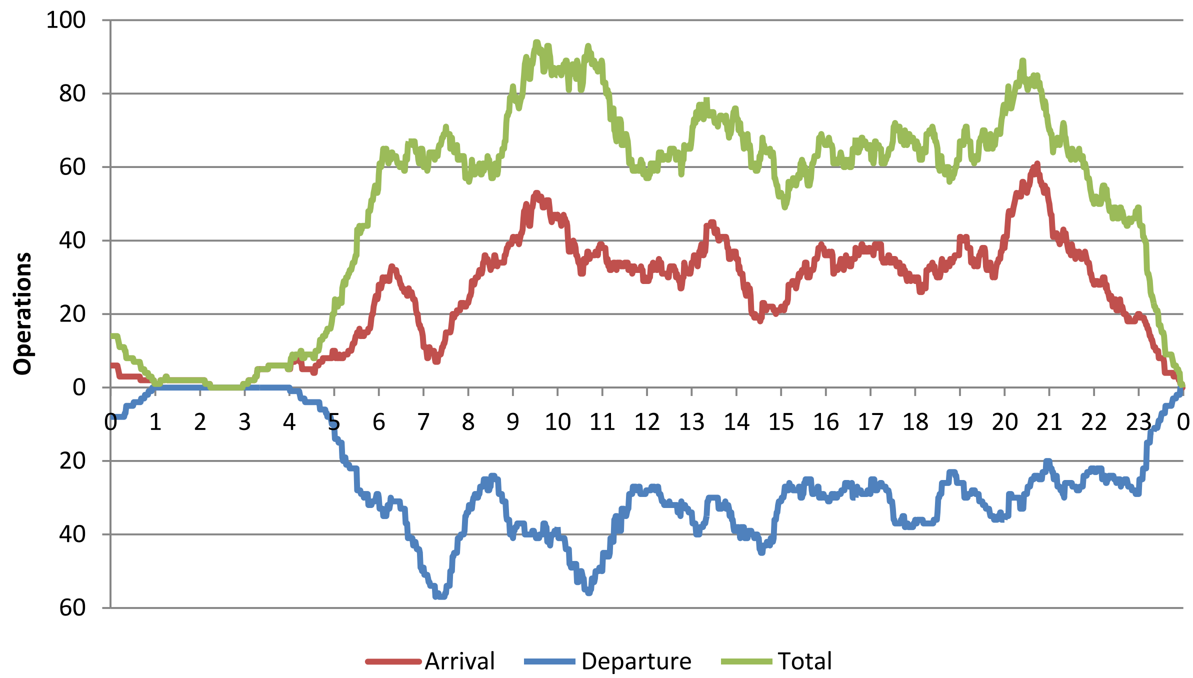
Table 12 summarizes the fleet mix in the design day flight schedule by operation type and aircraft type.

Table 12
Fleet Mix by Operation Type and Aircraft Type

	Arrivals	**Departures**	**Total**
By Operation Type			
Passenger Flights	594	602	1196
Cargo Flights	16	15	31
General Aviation	2	3	5
Total	612	620	1232
By Aircraft Type			
Wide Body	24	23	47
Narrow Body	372	379	751
Regional Jet	96	97	193
Turboprop	120	121	241
Total	612	620	1232

Figure 17 illustrates the design day activity profile based on the DDFS. This figure shows a rolling hourly count of the number of scheduled operations within the next hour. Arrivals and total operations are plotted upward on the positive y-axis, and departures are plotted downward on the negative y-axis.

Figure 17
Design Day Activity Profile



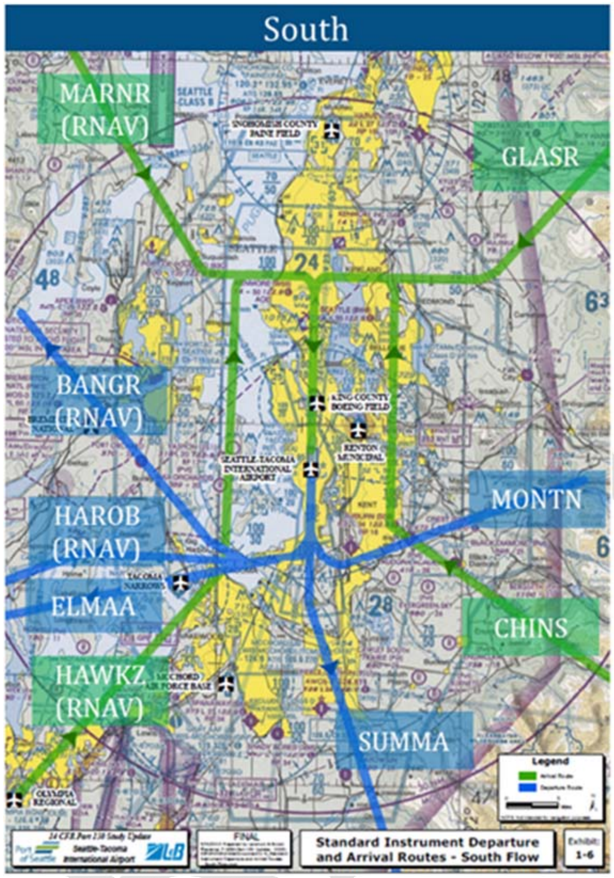
2.3.2 Airspace Structure

The airspace structure and flight procedures assumed in TAAM were developed from currently published Standard Terminal Arrival Routes (STARs) and Standard Instrument Departure Procedures (SIDs). In both flow directions, arriving flights were assigned to arrive from one of the four “corner posts”: in the northeast, southeast, southwest, and northwest directions.

Aircraft are assigned to the arrival and departure fixes on the basis of their origin or destination airports to minimize the number of airborne crossovers. The runway assignment of arrivals is based on current airfield practices: most arrivals land on the outboard runway (Runway 16R/34L), but most heavy (wide-body) jets request to land on the inboard runway (Runway 16L/34R) to make use of its additional length.

All departures in either flow direction, except turboprops, are directed by ATCT to pass over a single initial waypoint before they can turn on course. Therefore, only a single departure stream was simulated in TAAM. Figure 18 and Figure 19 illustrate the general arrival and departure fix airspace structure assumed for South flow and North flow, respectively.

Figure 18
Assumed Arrival and Departure Fix Airspace Structure—South Flow



Sources: Part 150 Noise Compatibility Study, Seattle-Tacoma International Airport (October 2013); LeighFisher analysis of published SIDs/STARs (May 2015).

Figure 19

Assumed Arrival and Departure Fix Airspace Structure—North Flow

Sources: Part 150 Noise Compatibility Study, Seattle-Tacoma International Airport (October 2013); LeighFisher analysis of published SIDs/STARs (May 2015).

In TAAM, departures were assumed to follow published Conventional and RNAV SIDS, which call for all jet departures to converge on a single airspace fix or waypoint. Similarly, the models considered jet noise-abatement procedures, which confine departures to narrow corridors in both directions. Turboprop departures are exempted and can make an immediate, divergent turn. Figure 20 shows both the Conventional and RNAV SIDS departure routes at the airport. Figure 21 and Figure 22 illustrate a sample flight track map at SEA for South flow and North flow respectively.

Figure 20
Conventional and RNAV SIDS

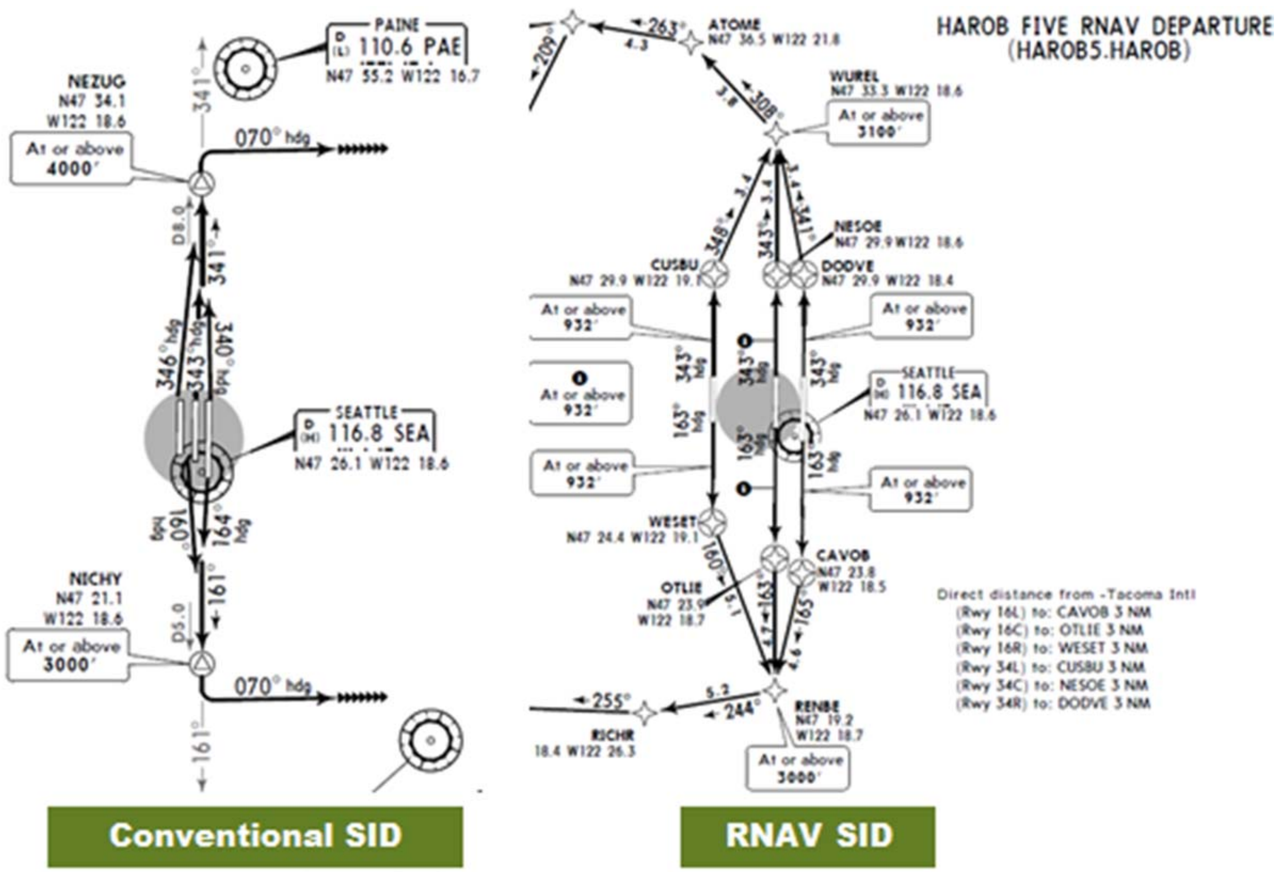
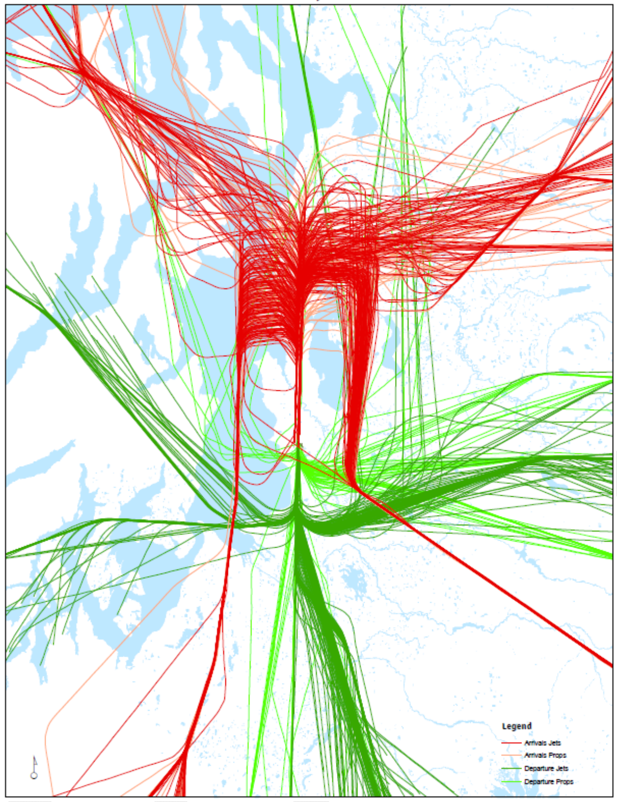


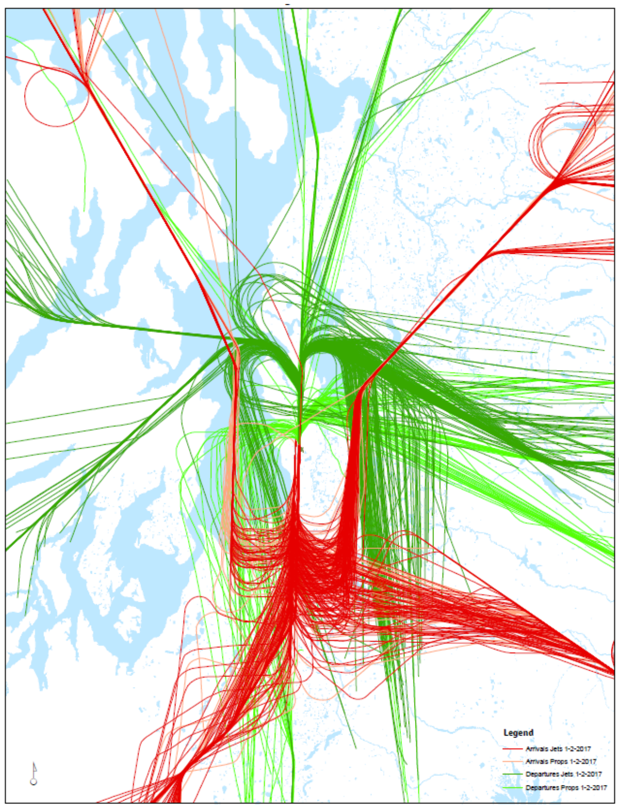
Figure 21

Observed South Flow Flight Tracks



Source: Port of Seattle. Flight tracks for 12/09/2016.

Figure 22
Observed North Flow Flight Tracks



Source: Port of Seattle. Flight tracks for 01/02/2017.

2.3.3 Runway Use

The following runway use percentages were assumed as inputs to the models. These splits were confirmed in the Calibration Input Review Meeting on January 6, 2017.

- South flow VMC
  - Heavy arrivals: 75% on 16L, 25% on 16R
  - Non-heavy arrivals: all on 16R
  - Heavy departures: all on 16L
  - Non-heavy departures: 60% on 16C, 40% on 16L
- South flow MMC
  - Heavy arrivals: 75% on 16L, 25% on 16R
  - Non-heavy arrivals: all on 16R
  - Heavy departures: all on 16L
  - Non-heavy departures: 25% on 16C, 75% on 16L
- South flow IMC
  - Heavy arrivals: 75% on 16L, 25% on 16R
  - Non-heavy arrivals: all on 16R
  - All departures on 16L
- North flow VMC
  - Heavy arrivals: 75% on 34R, 25% on 34L
  - Non-heavy arrivals: all on 34L
  - All departures on 34R
- North flow IMC
  - Heavy arrivals: 25% on 34R, 75% on 34L
  - Non-heavy arrivals: all on 34L
  - All departures on 34R

2.3.4 Runway Dependencies

The following dependencies between runways were assumed in the simulations.

- South flow VMC
  - Visual approaches are independent of each other
  - Departures on 16C are independent of arrivals on 16R and 16L
  - Jet departures from different runways are fully dependent on each other
  - Mixed operations runway
    - Departure on 16L cannot roll if next 16L arrival is within capture distance of 2 nmi
    - Departure on 16L cannot roll until previous arrival has cleared that runway
- South flow MMC
  - ILS approaches and instrument departures; no “2-increasing-to-3” rule
  - Arrivals to 16L and 16R are dependent and must maintain a minimum 1.0 nmi diagonal separation

- Departures on 16L are independent of arrivals on 16R
- Departures on 16C are independent of arrivals on 16R and 16L
- Jet departures from different runways are fully dependent on each other
- Mixed operations runway
  - Departure on 16L cannot roll if next 16L arrival is within capture distance of 2 nmi
  - Departure on 16L cannot roll until previous arrival has cleared that runway

- South flow IMC
  - Arrivals to 16L and 16R are dependent and must maintain a minimum 1.0 nmi diagonal separation
  - Departures on 16L are independent of arrivals on 16R
  - Mixed operations runway:
    - Departure on 16L cannot roll if next 16L arrival is within capture distance of 2 nmi
    - Departure on 16L cannot roll until previous arrival has cleared that runway

- North flow VMC
  - Visual approaches are independent of each other
  - Departures on 34R are independent of arrivals on 34L
  - Mixed operations runway
    - Departure on 34R cannot roll if next 34R arrival is within capture distance of 2 nmi
    - Departure on 34R cannot roll until previous arrival has cleared that runway

- North flow IMC
  - Arrivals to 34R and 34L are dependent and must maintain a minimum 1.0 nmi diagonal separation
  - Departures on 34R are dependent on arrivals to 34L
    - Must begin departure roll before the next 34L arrival reaches the capture distance of 2 nmi + 3,401 ft stagger
  - Mixed operations runway
    - Departure on 34R cannot roll if next 34R arrival is within capture distance of 2 nmi
    - Departure on 34R cannot roll until previous arrival has cleared that runway

2.3.5 Inboard Runway Operations

In the simulations, all inboard arrivals were required to stop and wait on the runway for 100 seconds to represent the increased runway occupancy time. Departures are held for 120 seconds during this time. The 20-second buffer is introduced in case the arrival cannot immediately turn off due to congestion on Taxiway B. If consecutive arrivals are assigned the inboard runway as their arrival runway, they must maintain at least a 10 nmi separation in the air to accommodate for the delay in clearing the runway.

2.3.6 Wake Turbulence Separations and Buffers

With respect to air traffic control rules, minimum separation requirements – including wake turbulence and in-trail separation requirements – specified in FAA Order JO 7110.65W, *Air Traffic Control*, are applied. Wake turbulence governs the required separation between successive departures on same or dependent runways, whereas in-trail requirements govern separation between successive arrivals on same or dependent runways. These separation requirements vary depending on the difference in weight class between the leading aircraft and the trailing aircraft, with larger separations required behind heavier aircraft to protect for wake turbulence. The minimum separations specified in the FAA Order 7110.65W, *Air Traffic Control*, are applied to the three aircraft classes. During visual conditions, the FAA TRACON can issue a visual clearance to pilots, which delegates the responsibility of maintaining safe separations to pilots. Therefore, under VMC, controllers can allow the separations between successive visual approaches on the final approach to "compress" below minimum radar separations required between instrument approaches. Table 13 below shows the IMC and VMC arrival-arrival minimum separation requirements, and Table 14 shows the departure-departure minimum separation requirements.

Table 13
FAA Minimum Arrival-Arrival Separation Requirements

FAA Minimum Aircraft Approach Separations (IMC)				
Units in nautical miles.		Follower		
		Heavy	Large	Small
Leader	Heavy	4	5	6
	Large	2.5	2.5	4
	Small	2.5	2.5	2.5

FAA Minimum Aircraft Approach Separations (VMC)				
Units in nautical miles.		Follower		
		Heavy	Large	Small
Leader	Heavy	2.7	3.6	4.5
	Large	1.9	1.9	2.7
	Small	1.9	1.9	1.9

Table 14
FAA Minimum Departure-Departure Separation Requirements

FAA Minimum Aircraft take-off Separations (secs)				
Units in seconds.		Follower		
		Heavy	Large	Small
Leader	Heavy	90	120	120
	Large	60	60	90
	Small	60	60	60

Controllers are rarely able to achieve minimum separations between successive arrivals because if the minimum arrival-arrival separation standard is violated, the controller can be charged with an operational error. Therefore, controllers tend to add buffers to the separations between successive arrivals. This practice was included in the models by adding a buffer roughly on the order of 1 nmi. Because throughputs are highly sensitive to separations, the assumed buffers were the final input parameters to be changed in order to calibrate the model to actual throughput data.

A sensitivity analysis on arrival throughputs was conducted with the arrival buffer ranging from 0.0 nmi to 1.5 nmi with an increment of 0.1 nmi. The arrival buffers that generated simulated arrival throughputs that agreed most closely with actual peak arrival throughputs were selected. Next, a similar sensitivity analysis on departure throughputs was conducted with the departure buffer ranging from 0.0 min to 0.5 min with an increment of 0.1 min, while the arrival buffer was held constant. The departure buffers that produced simulated departure throughputs that agreed most closely with actual peak departure throughputs were selected.

The separation buffers assumed in TAAM were adjusted to achieve reasonable agreement between the actual maximum throughputs and the simulated maximum throughputs from TAAM. Table 15 summarizes the calibrated arrival and departure separation buffers for all five models.

Table 15
Simulated Arrival and Departure Buffers

Model	Arrival Buffer	Departure Buffer
South flow VMC	1.0 nmi *(a)*	0.0 min
South flow MMC	0.5 nmi *(b)*	0.1 min
South flow IMC	0.5 nmi *(b)*	0.2 min
North flow VMC	0.5 nmi *(a)*	0.0 min
North flow IMC	1.2 nmi *(b)*	0.0 min

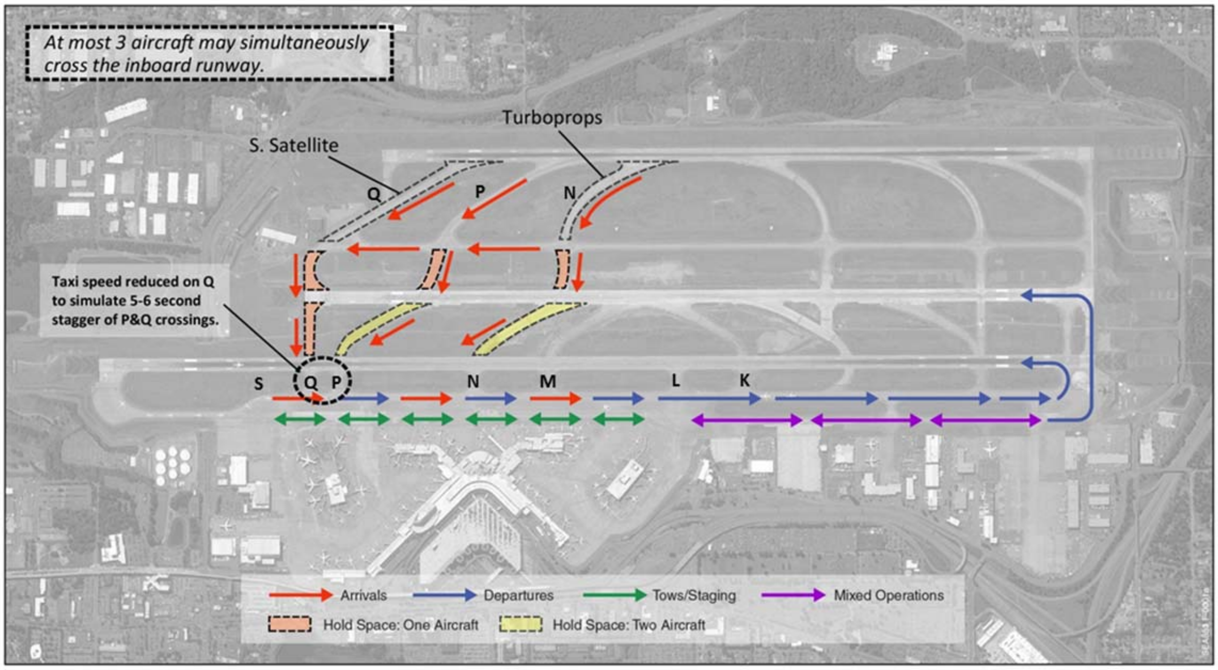
(a) VMC arrival buffers are added to the FAA minimum VMC separations.
(b) MMC and IMC arrival buffers are added to the FAA minimum IMC separations.

2.3.7 Taxi Paths, Runway Exit Usage, and Runway Crossings

In South flow, aircraft were assumed to move about the airfield in a predominantly counterclockwise direction. No arrivals were permitted to back-taxi on Taxiway T because of the terminal area's location. Taxiways P and Q were assumed to be unable to support simultaneous independent runway crossings because of the uncertainty in which direction each aircraft will turn after crossing the inboard runway. Therefore, a delay of approximately six seconds was introduced for the aircraft crossing on Taxiway Q.

In South flow, outboard arrivals heading to gates in the South Satellite area were assumed to use Taxiway Q to exit the runway. Turboprops arriving on the outboard runway were assumed to use Taxiway N to exit in order to decrease runway occupancy time. All other outboard arrivals were assumed to exit using Taxiway P. Inboard arrivals were permitted to use any of Taxiways L, K, M, or S to exit the runway; however, non-cargo inboard arrivals were preferred to exit using Taxiway S, as flows from further north exit points would create gridlock on Taxiway B. ATCT has indicated that this is how controllers strive to manage inboard arrivals in South flow. Figure 23 depicts the simulated taxi routes in South Flow.

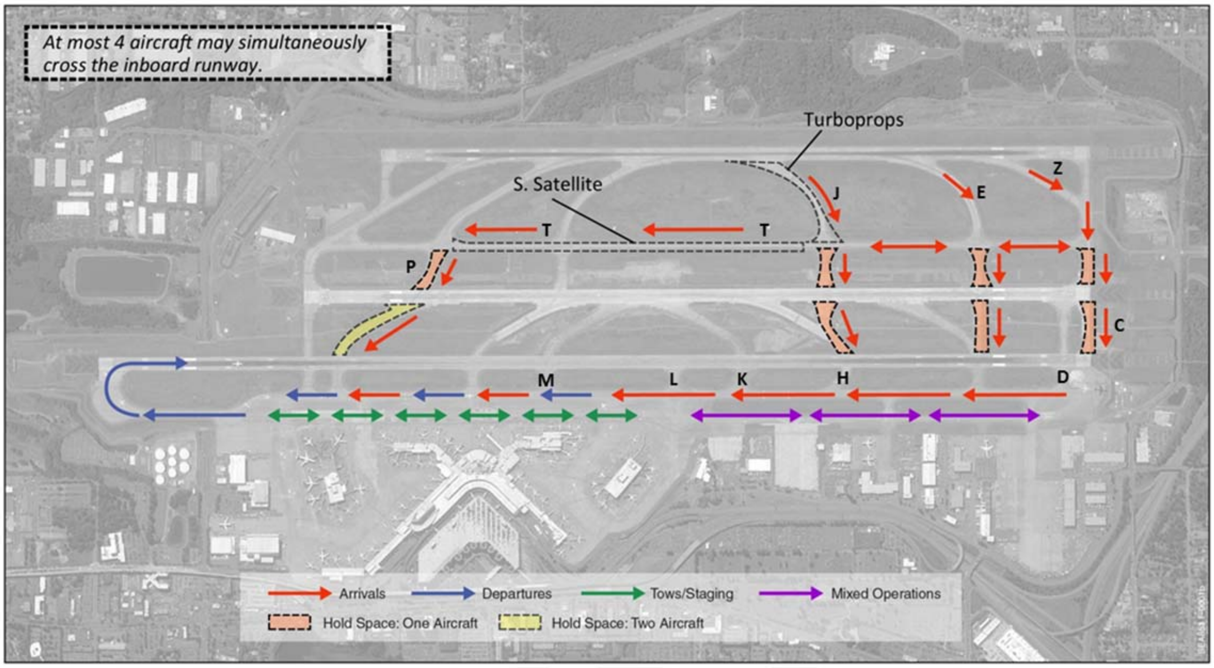
Figure 23
Simulated Taxi Routes—South Flow



In North Flow, aircraft were assumed to move about the airfield in a predominantly clockwise direction. Arrivals to the outboard runway with a final destination in the South Satellite terminal area were permitted to back-taxi on Taxiway T to cross the inboard runway near the south end of the airfield.

In North flow, turboprops arriving on the outboard runway were assigned to Taxiway J to exit in order to decrease runway occupancy time. Non-turboprops arriving on the outboard runway were assumed to use Taxiway E and Taxiway Z to exit two-thirds and one-third of the time, respectively. Cargo arrivals on the outboard runway were assigned Taxiway Z to exit. Inboard arrivals were permitted to use any of Taxiways D, K, L, or M to exit the runway. Figure 24 depicts the simulated taxi routes in North Flow.

Figure 24
Simulated Taxi Routes—North Flow

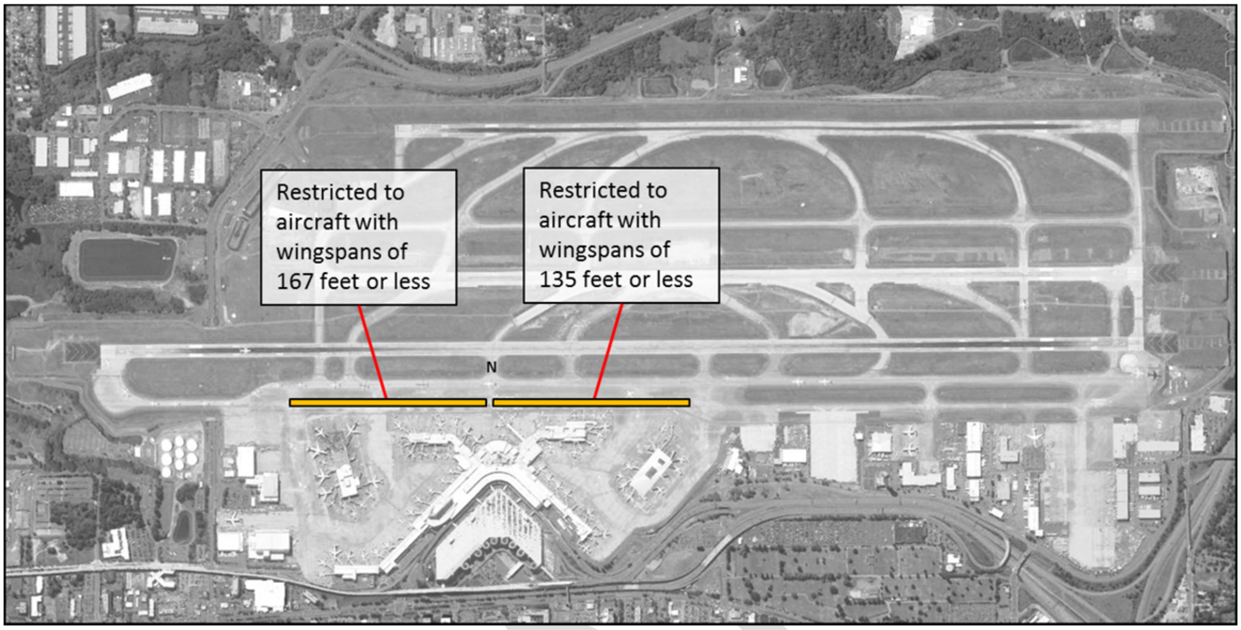


The following limits on runway crossings were assumed:

- At most one aircraft can physically fit on Taxiways C, E, J, N, P, and Q between Taxiway T and the center runway.
- At most one aircraft can physically fit on Taxiways C, E, H, and Q between the center runway and the inboard runway.
- At most two aircraft can physically fit on Taxiways N and P between the center runway and the inboard runway.

In all models, Taxilane W was reserved for towing and pushback operations only; arrivals and departures were required to use Taxiway B. In accordance with current airfield taxiing rules, Taxilane W north of Taxiway N was restricted to aircraft with wingspans of 135 feet or less, and Taxilane W south of Taxiway N was restricted to aircraft with wingspans of 167 feet or less. Figure 25 depicts the taxiway use restrictions on the inboard taxilanes.

Figure 25
Taxiway Use Restrictions



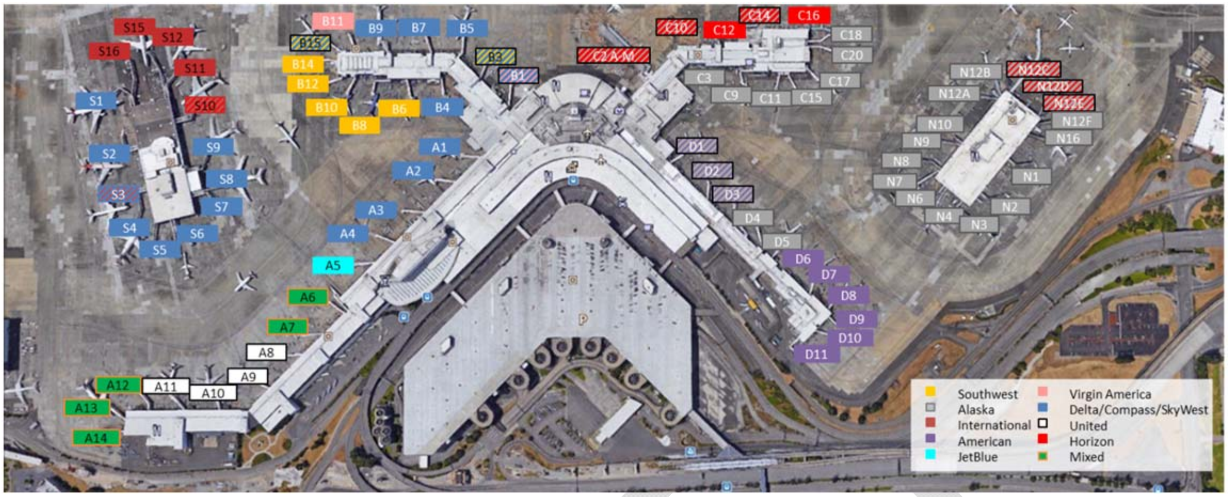
2.3.8 Gate Assignments

The simulated gate assignments reflect the gate assignments observed in the 2016 Aerobahn data. The simulation uses a single-day ADPM schedule with a higher-than-average demand level, so adjustments to the assignments were necessary to accommodate all flights. These adjustments include:

- Overnight Alaska flights can use gates in Concourse C West (Horizon's gates)
- Overnight Alaska and American flights can use gates in the South Satellite
- American can use select gates in Concourse A
- Non-Delta/SkyWest/Compass flights can use Delta gates in Concourse A overnight
- Southwest can use any gate in Concourse B
- United can use any gate in Concourse A
- Frontier can use a gate in the South Satellite

Figure 26 shows the gate allocations that were assumed in the simulations.

Figure 26
Simulated Airline Gate Allocations



2.3.9 Pushback, Runway Crossing, and Minimum Turnaround Times

In TAAM, the pushback time is defined as the pause between the detaching of the tug and an aircraft's self-propelled forward motion. This pause represents the time when the pilot may perform various pre-flight checks, start the engine, and allow ground vehicles to clear the area. Pushback times were defined for each aircraft type.

The runway crossing time is defined as the length of time for an aircraft to begin acceleration from a complete stop to cross an active runway. The runway crossing time can either be defined for specific aircraft types or for weight classes of aircraft (Light, Medium Light, Medium, Heavy, Heavy Plus, Super Heavy).

The minimum turn time is defined as the minimum length of time that an aircraft must remain on the ground between linked flights. Minimum turn times model the time it takes passengers to deplane, cabin crews to clean, refueling to occur, passengers to board, and other tasks associated with beginning and ending an operation.

The pushback times, runway crossing times, and minimum turn times that were used in the simulations are shown in Table 16.

Table 16

Pushback Time, Runway Crossing Time, and Minimum Turnaround Time by Aircraft Type

Aircraft Types	Pushback Time	Runway Crossing Time	Min Turnaround Time
CRJ7, CRJ9, DH8D	1.5 minutes	4 seconds	25 minutes
A320 series, B727 series, B737 series, DC10, E175, E190, MD80	1.5 minutes	6 seconds	40 minutes
B757 series	2 minutes	10 seconds	40 minutes
A300 series, A310 series, A330 series, A340 series, B767 series, MD11	3 minutes	10 seconds	40 minutes
B747 series, B777 series, B787 series	3.5 minutes	14 seconds	40 minutes

2.4 Results: Comparison of Model Outputs with Actual Performance Metrics

2.4.1 Runway Use

The following runway uses were achieved in the simulations. The tables below provide the target (input) and achieved (output) runway use percentages for all five TAAM models.

Table 17

Simulated Runway Use Percentages—South Flow VMC

		Percentage by Aircraft Class					
		Arrival			Departure		
Target Use		**16R**	**16C**	**16L**	**16R**	**16C**	**16L**
SF VMC	Heavy (4% of fleet)	25%		75%			100%
	Large (94% of fleet)	100%				60%	40%
	Small (2% of fleet)	100%				60%	40%

		Percentage by Aircraft Class					
		Arrival			Departure		
Achieved Use		**16R**	**16C**	**16L**	**16R**	**16C**	**16L**
SF VMC	Heavy (4% of fleet)	19%		81%			100%
	Large (94% of fleet)	100%				63%	37%
	Small (2% of fleet)	100%				89%	11%
	Overall	**97%**		**3%**		**60%**	**40%**

Table 18

Simulated Runway Use Percentages—South Flow MMC

Target Use		Percentage by Aircraft Class					
		Arrival			**Departure**		
		16R	**16C**	**16L**	**16R**	**16C**	**16L**
SF MMC	Heavy (4% of fleet)	25%		75%			100%
	Large (94% of fleet)	100%				25%	75%
	Small (2% of fleet)	100%				25%	75%

Achieved Use		Percentage by Aircraft Class					
		Arrival			**Departure**		
		16R	**16C**	**16L**	**16R**	**16C**	**16L**
SF MMC	Heavy (4% of fleet)	14%		86%			100%
	Large (94% of fleet)	100%				26%	74%
	Small (2% of fleet)	100%				56%	44%
	Overall	**97%**		**3%**		**26%**	**74%**

Table 19

Simulated Runway Use Percentages—South Flow IMC

Target Use		Percentage by Aircraft Class					
		Arrival			**Departure**		
		16R	**16C**	**16L**	**16R**	**16C**	**16L**
SF IMC	Heavy (4% of fleet)	25%		75%			100%
	Large (94% of fleet)	100%					100%
	Small (2% of fleet)	100%					100%

Achieved Use		Percentage by Aircraft Class					
		Arrival			**Departure**		
		16R	**16C**	**16L**	**16R**	**16C**	**16L**
SF IMC	Heavy (4% of fleet)	29%		71%			100%
	Large (94% of fleet)	100%					100%
	Small (2% of fleet)	100%					100%
	Overall	**97%**		**3%**			**100%**

Table 20
Simulated Runway Use Percentages—North Flow VMC

Target Use		Percentage by Aircraft Class					
		Arrival			Departure		
		34L	34C	34R	34L	34C	34R
NF VMC	Heavy (4% of fleet)	25%		75%			100%
	Large (94% of fleet)	100%					100%
	Small (2% of fleet)	100%					100%

Achieved Use		Percentage by Aircraft Class					
		Arrival			Departure		
		34L	34C	34R	34L	34C	34R
NF VMC	Heavy (4% of fleet)	32%		68%			100%
	Large (94% of fleet)	100%					100%
	Small (2% of fleet)	100%					100%
	Overall	**97%**		**3%**			**100%**

Table 21
Simulated Runway Use Percentages—North Flow IMC

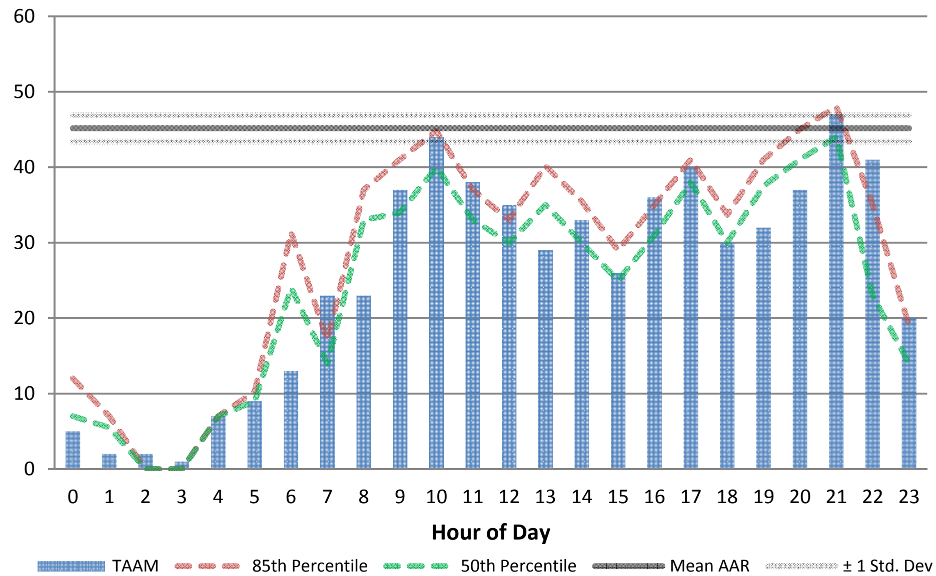
Target Use		Percentage by Aircraft Class					
		Arrival			Departure		
		34L	34C	34R	34L	34C	34R
NF IMC	Heavy (4% of fleet)	75%		25%			100%
	Large (94% of fleet)	100%					100%
	Small (2% of fleet)	100%					100%

Achieved Use		Percentage by Aircraft Class					
		Arrival			Departure		
		34L	34C	34R	34L	34C	34R
NF IMC	Heavy (4% of fleet)	79%		21%			100%
	Large (94% of fleet)	100%					100%
	Small (2% of fleet)	100%					100%
	Overall	**99%**		**1%**			**100%**

2.4.2 Runway Throughputs

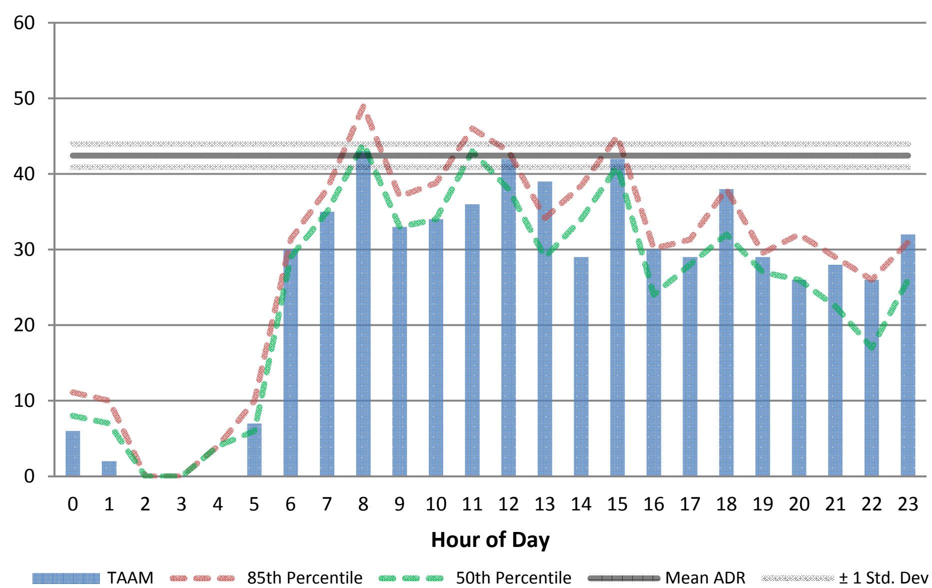
Each throughput graph below presents comparisons of simulated hourly arrival and departure throughputs with the 50th and 85th percentile of estimated throughputs obtained from the noise data for each flow-weather configuration at SEA. The mean called rates for each given configuration, plus or minus one standard deviation, are also shown on the graphs as horizontal lines.

Figure 27
Arrival Throughput—South VMC



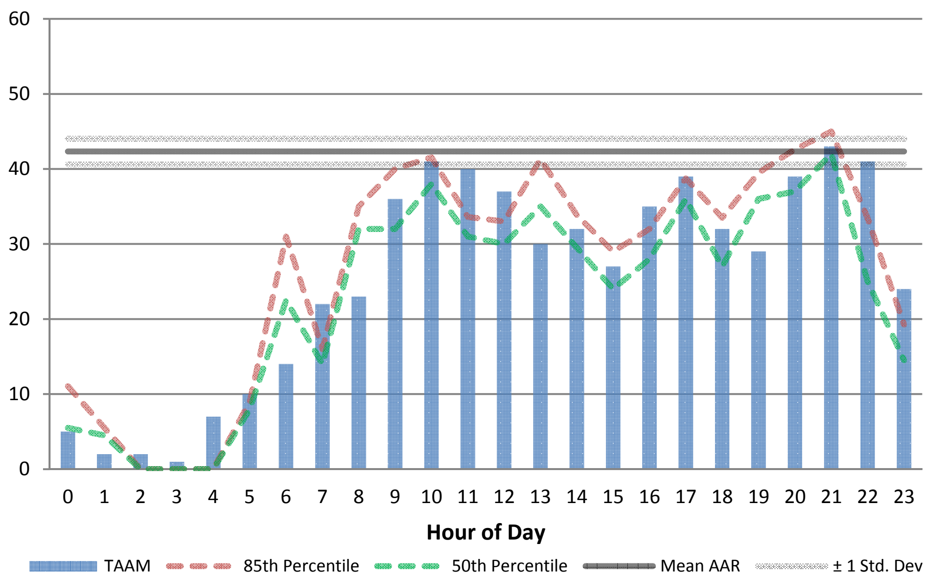
Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016;
FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

Figure 28
Departure Throughput—South VMC



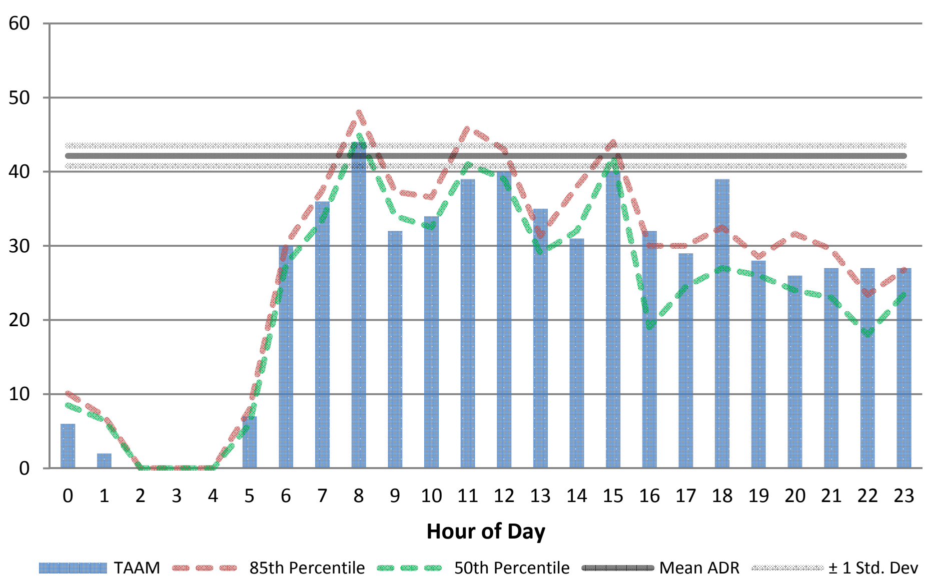
Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016;
FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

Figure 29
Arrival Throughput—South MMC



Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016; FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

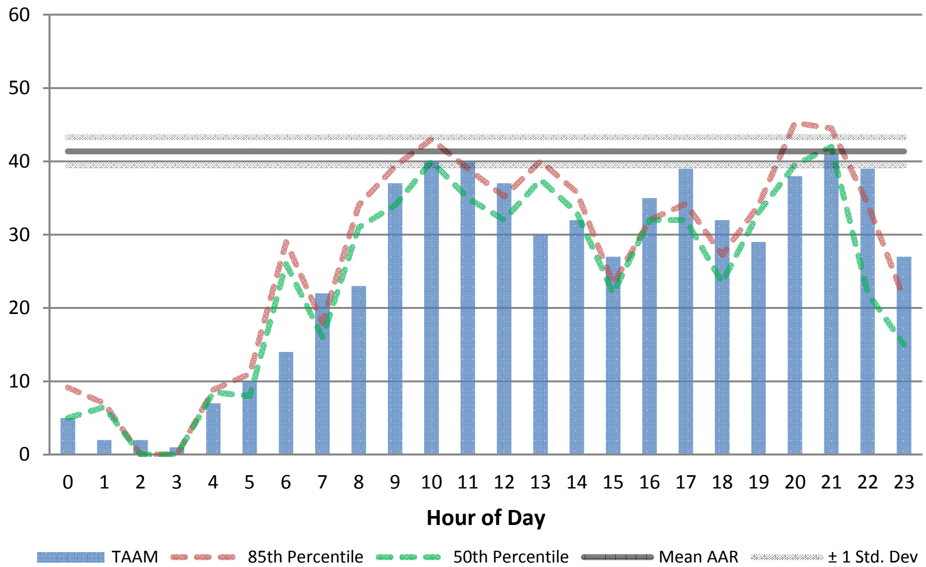
Figure 30
Departure Throughput—South MMC



Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016; FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

Figure 31

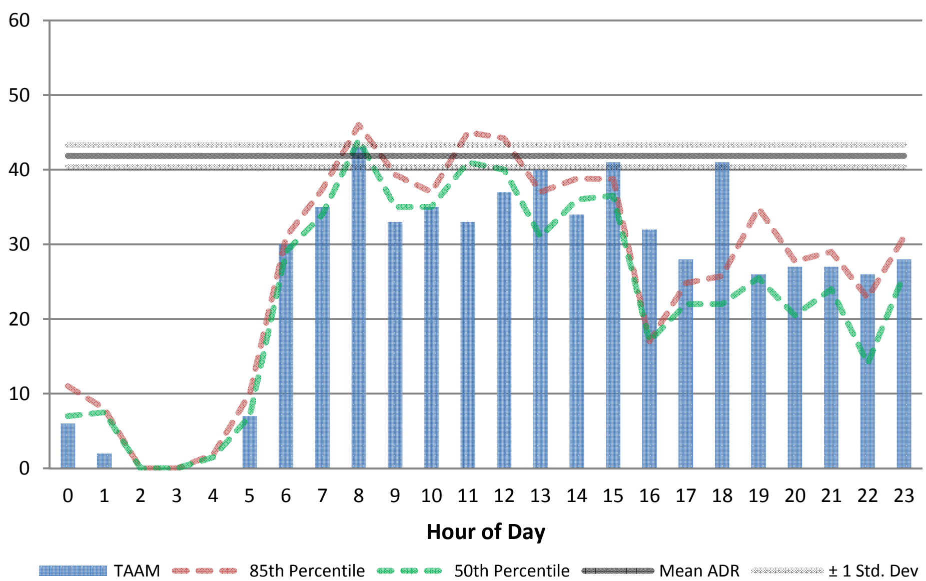
Arrival Throughput—South IMC



Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016; FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

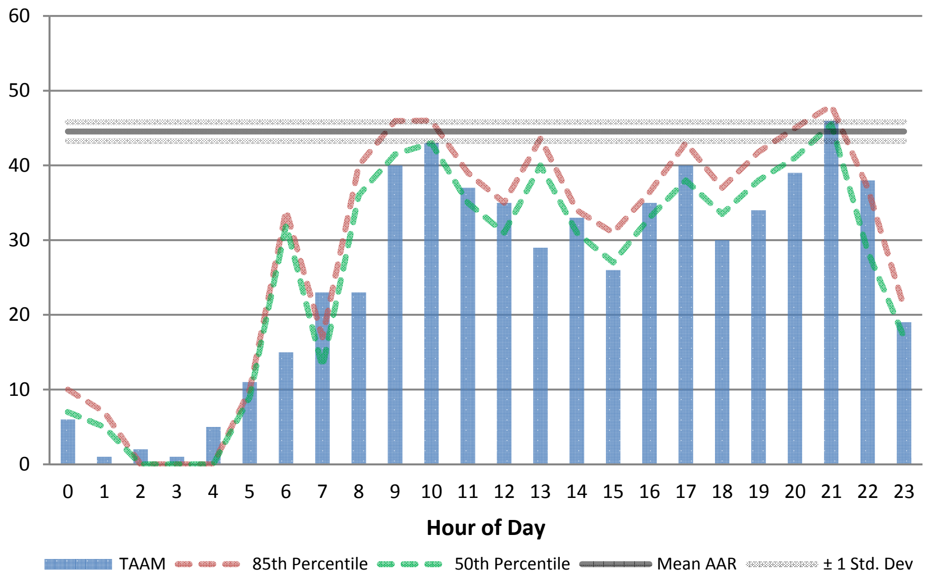
Figure 32

Departure Throughput—South IMC



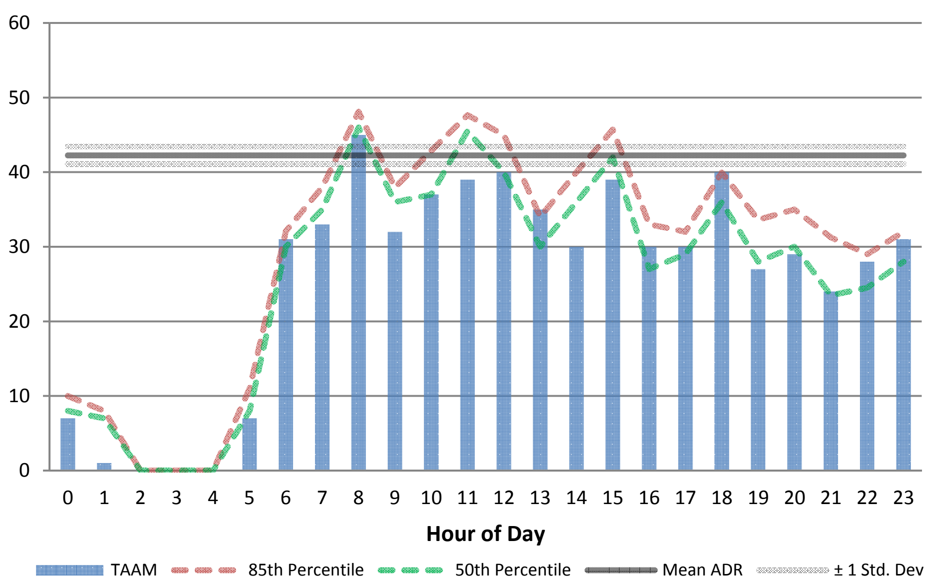
Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016; FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

Figure 33
Arrival Throughput—North VMC



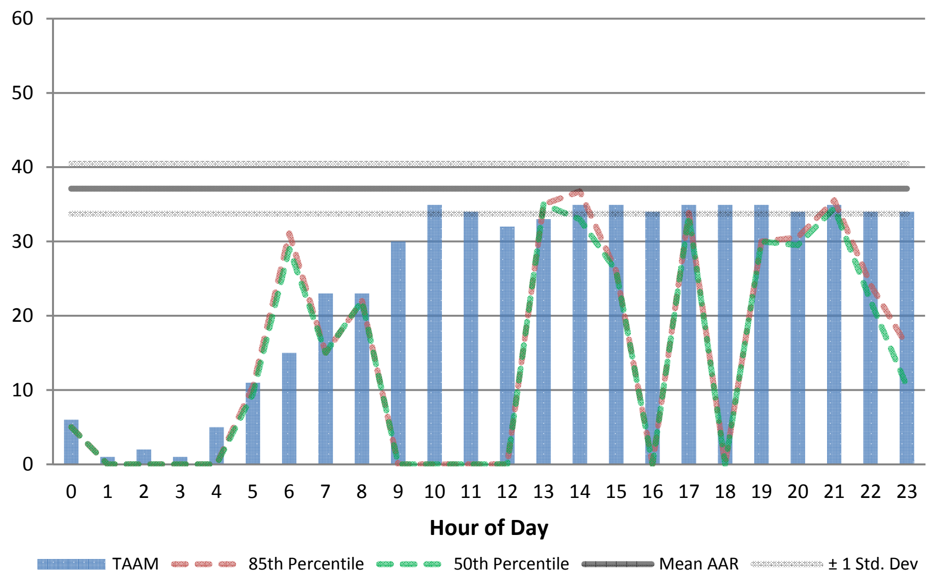
Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016; FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

Figure 34
Departure Throughput—North VMC



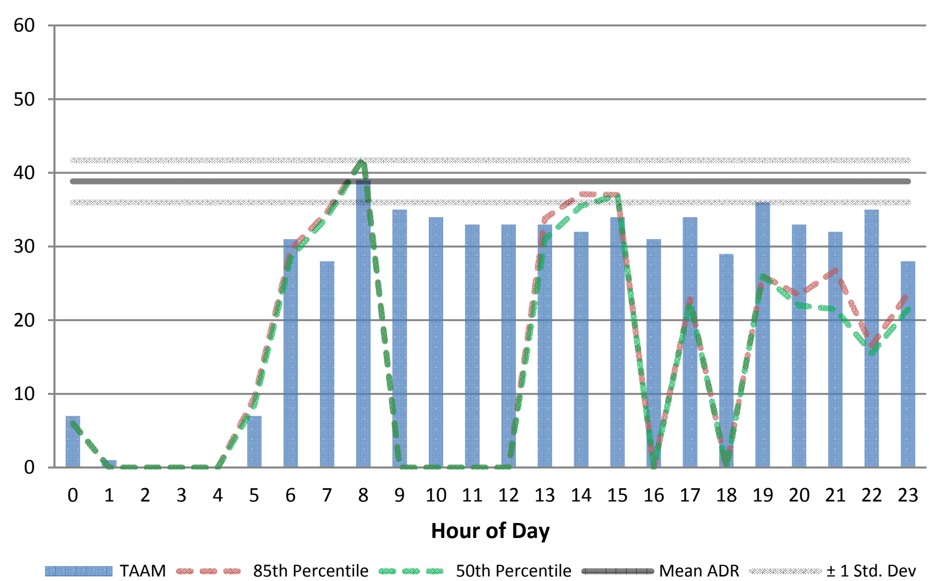
Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016; FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

Figure 35
Arrival Throughput—North IMC



Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016; FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

Figure 36
Departure Throughput—North IMC



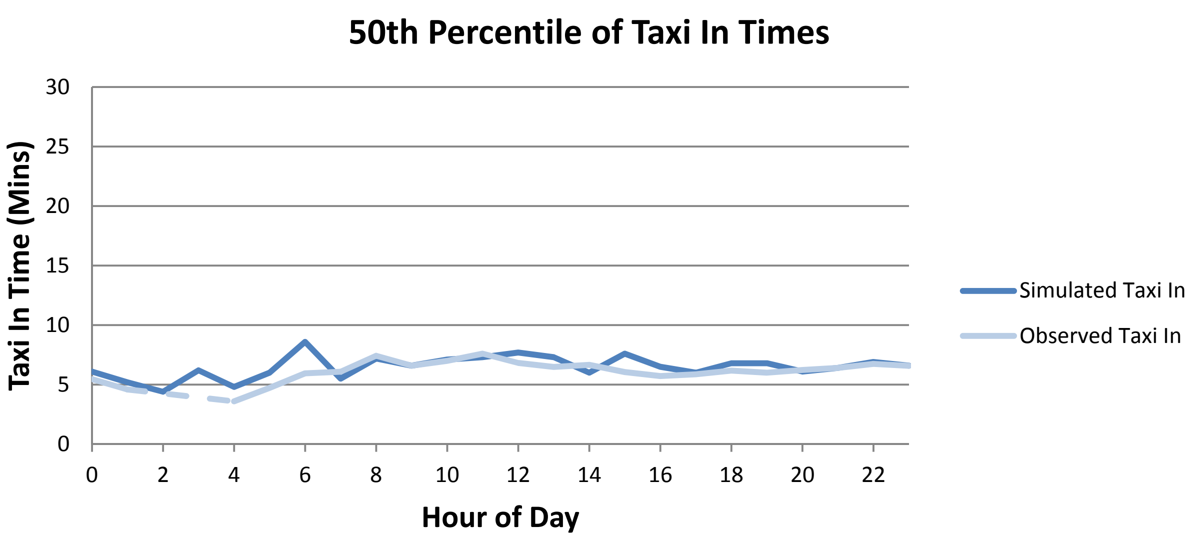
Sources: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016; FAA called rates data provided to LeighFisher, 6/29/2016-11/30/2016.

2.4.3 Taxi Times

Because departure queue management is unpredictable, it is impractical to calibrate the models using taxi-out times. However, taxi-in times are more consistent; therefore, the 50^{th} percentile (median) of taxi-in times for each hour are compared between each simulation and the actual data. The figures below compare the 50^{th} percentile of simulated taxi-in times and the 50^{th} percentile of observed taxi-in times from Aerobahn/FIS data.

Figure 37

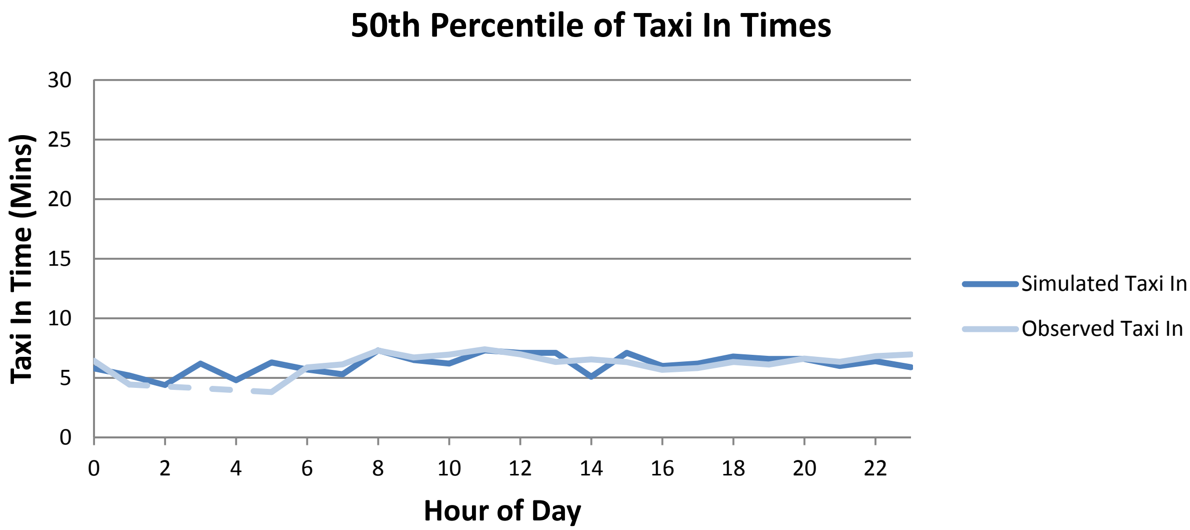
50^{th} Percentile of Achieved and Observed Taxi in Times—South Flow VMC



Source: Aerobahn Flight Details Report 5/12/2016-11/1/2016.

Figure 38

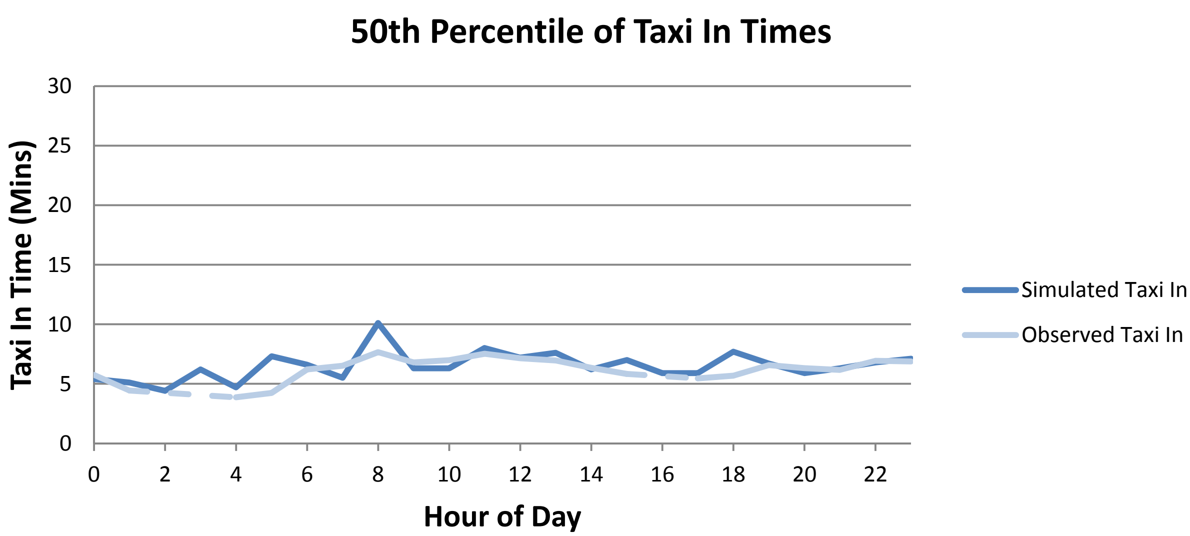
50th Percentile of Achieved and Observed Taxi in Times—South Flow MMC



Source: Aerobahn Flight Details Report 5/12/2016-11/1/2016.

Figure 39

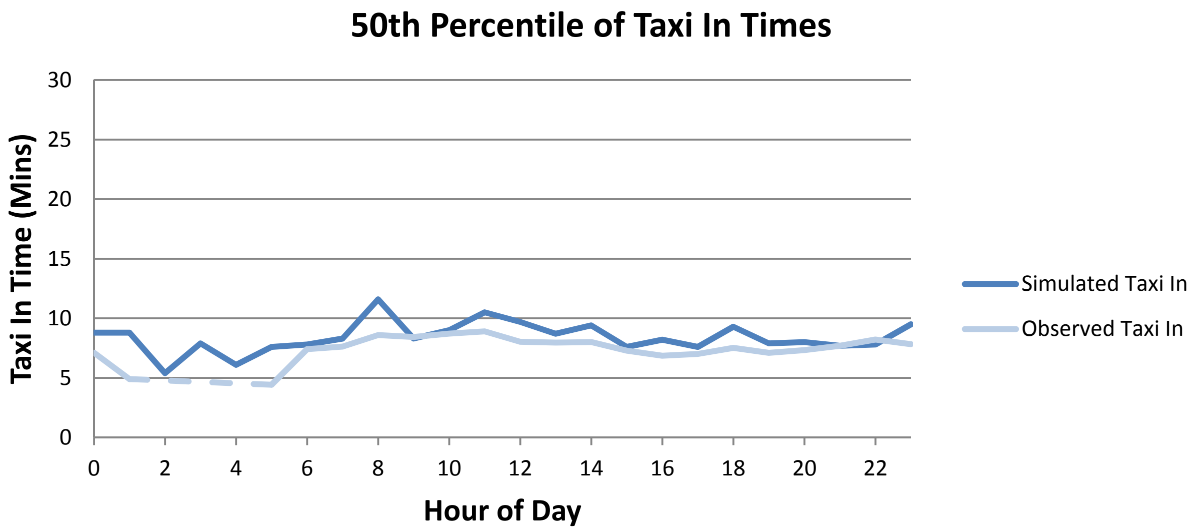
50th Percentile of Achieved and Observed Taxi in Times—South Flow IMC



Source: Aerobahn Flight Details Report 5/12/2016-11/1/2016.

Figure 40

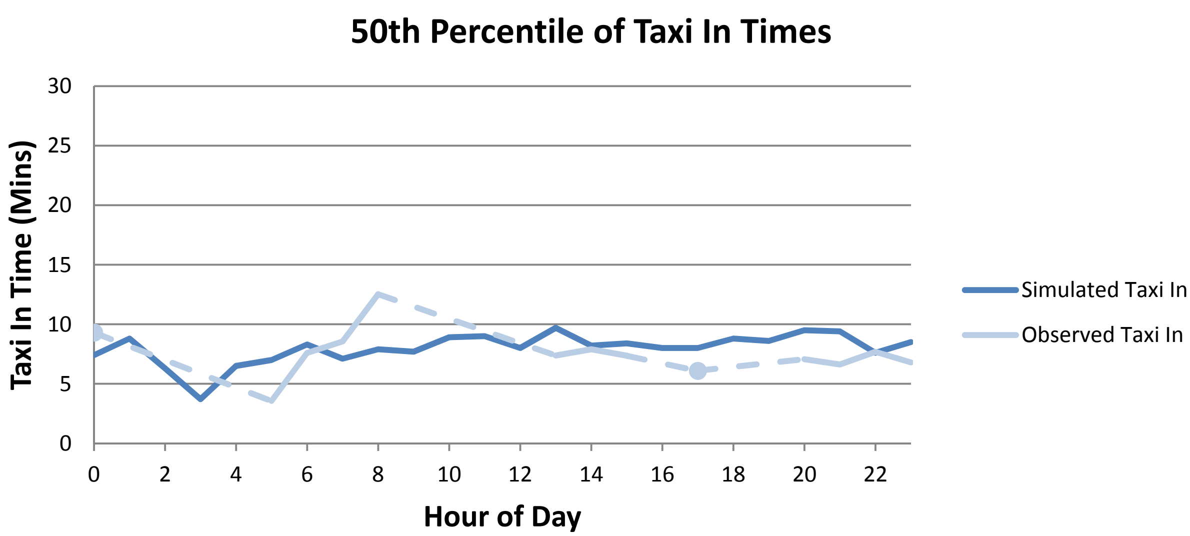
50th Percentile of Achieved and Observed Taxi in Times—North Flow VMC



Source: Aerobahn Flight Details Report 5/12/2016-11/1/2016.

Figure 41

50th Percentile of Achieved and Observed Taxi in Times—North Flow IMC



Source: Aerobahn Flight Details Report 5/12/2016-11/1/2016.

2.4.4 Simulated Delays

Generally, simulated delays tend to increase as the simulated weather condition worsens. Figure 42 and Figure 43 compare the arrival and departure delays across all five models.

Figure 42
Average Simulated Arrival Delays

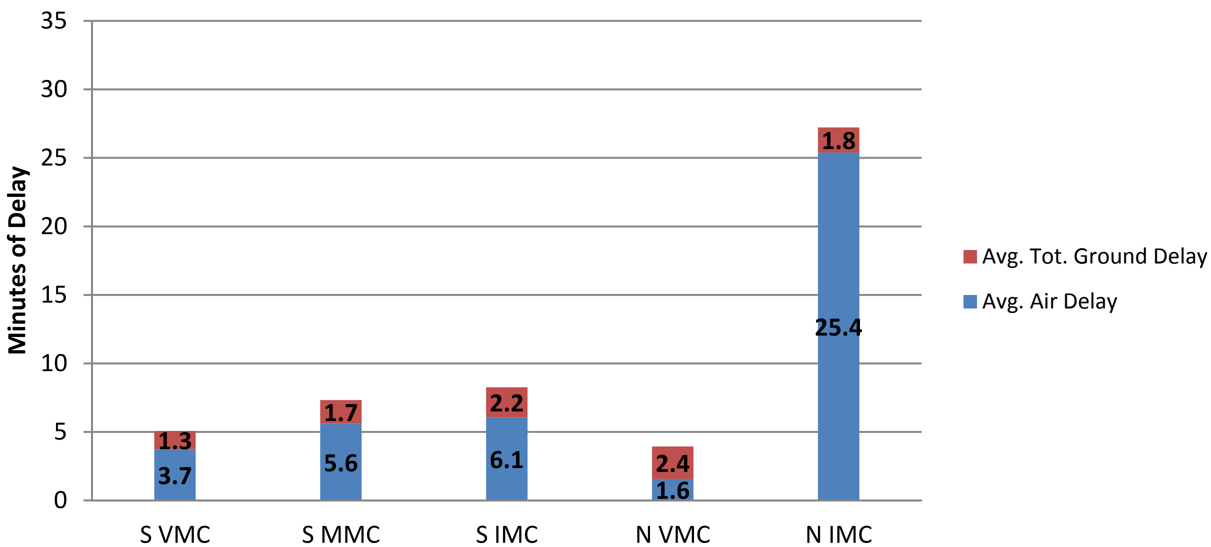
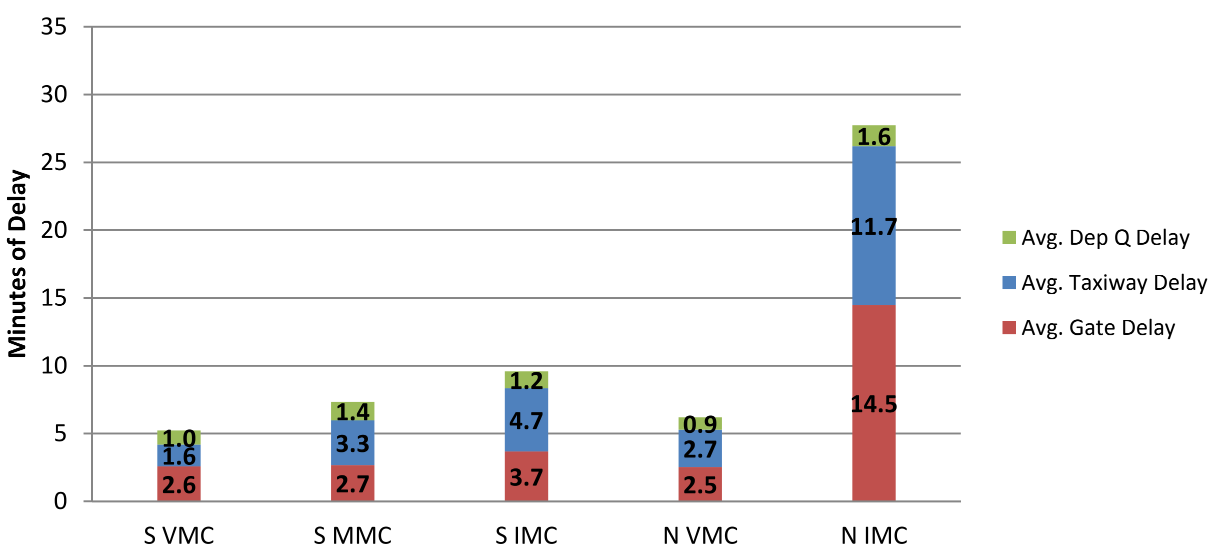


Figure 43
Average Simulated Departure Delays



2.4.5 Comparison of Simulated Delays with ASPM-Reported Delays

ASPM reports various kinds of aircraft delays, including:

- Delay relative to flight schedule (on-time performance)
- Delay relative to flight plan
- "Excess-travel-time" delays, which must be derived from reported data

Excess-travel-time delays refer to delay spent by aircraft (1) waiting on the ground to take off, (2) waiting in the air to land, and (3) assigned an expected departure clearance time (EDCT). Excess-travel-time delays are preferred for measuring airfield performance, as they reflect delays related to airfield capacity constraints, and they are measured with respect to flight plan times instead of published schedule times (so the effects of airline policy-related delays, such as built-in delays, are reduced). However, these delays are not perfect; they often do not correlate well with airfield simulation model delay estimates, and they may include some non-airfield capacity related delays such as en-route winds, convective weather, and gate availability. Regardless of their shortcomings, LeighFisher has used excess-travel-time delays to compare with the simulated TAAM delays.

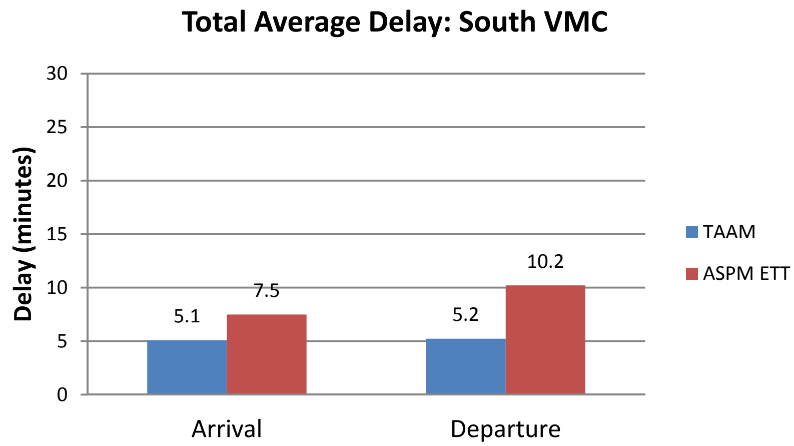
Excess-travel-time delays are calculated using airborne delays, gate hold delays, taxiing delays, and Expected Departure Clearance Time (EDCT) delays. EDCT delays are delays due to ground delay programs or ground stops. For arrivals, EDCT delay is incurred at the up-line airport but is due to capacity constraints at the destination airport; therefore, it is added to the destination airport's airborne and taxi-in delay. For departures, EDCT delay is incurred at the origin airport but is due to capacity constraints at the down-line airport; therefore, it is subtracted from the origin airport's taxi-out delay.

In summary, excess-travel-time delays are calculated as follows:

- Arrival excess-travel-time delay = airborne delay + taxi-in delay + EDCT delay for all arrivals
- Departure excess-travel-time delay = gate departure delay + taxi-out delay – EDCT delay for all departures

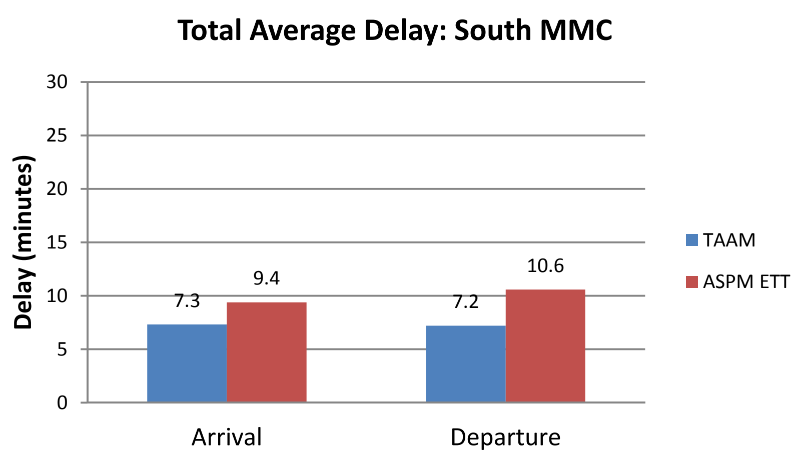
Figure 44 through Figure 48 show the excess-travel-time (ETT) delays calculated using ASPM-reported delays for the *Reopened II* period compared with simulated TAAM delays. It is critical to note that ASPM does not report delays that are less than 1 minute. Therefore, the reported excess-travel-time delays may be inflated, as they are based on a biased sample.

Figure 44
TAAM and ASPM ETT Delays—South VMC



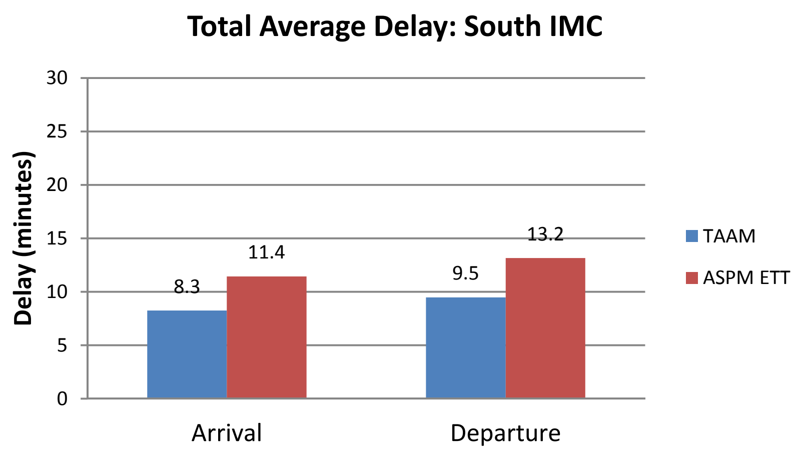
Source: LeighFisher analysis of ASPM Flight Plan, EDCT, and Schedule Delays, 6/29/2016-11/30/2016.

Figure 45
TAAM and ASPM ETT Delays—South MMC



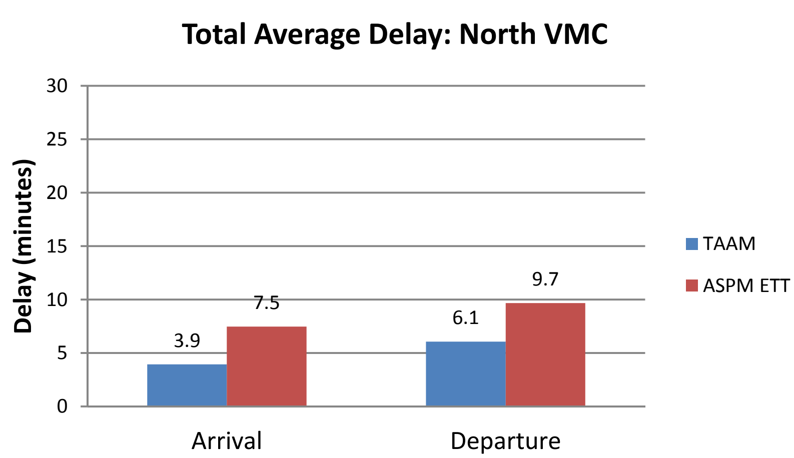
Source: LeighFisher analysis of ASPM Flight Plan, EDCT, and Schedule Delays, 6/29/2016-11/30/2016.

Figure 46
TAAM and ASPM ETT Delays—South IMC



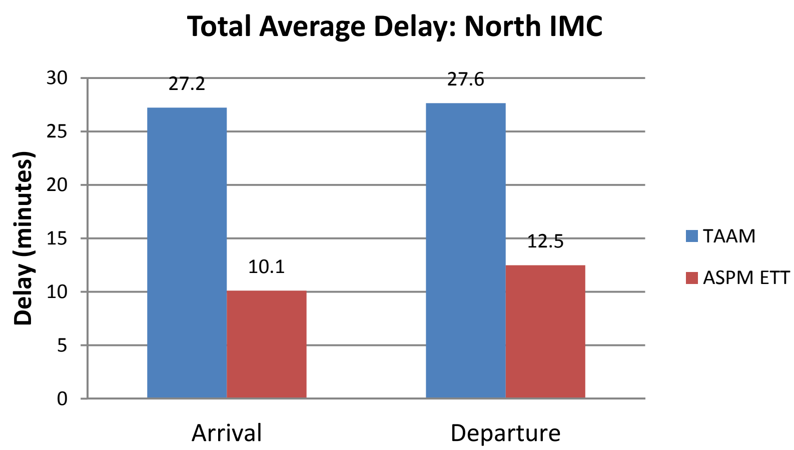
Source: LeighFisher analysis of ASPM Flight Plan, EDCT, and Schedule Delays, 6/29/2016-11/30/2016.

Figure 47
TAAM and ASPM ETT Delays—North VMC



Source: LeighFisher analysis of ASPM Flight Plan, EDCT, and Schedule Delays, 6/29/2016-11/30/2016.

Figure 48
TAAM and ASPM ETT Delays—North IMC



Source: LeighFisher analysis of ASPM Flight Plan, EDCT, and Schedule Delays, 6/29/2016-11/30/2016.

2.4.6 North IMC Delay Adjustment

As shown in Figure 48, simulated delays in the North IMC model significantly exceeded ASPM-reported delays during historical North IMC hours. There are at least two probable causes for this discrepancy. First, the North IMC model assumed that these operating conditions occurred for an entire day. When run for a full day, queues that form early in the day compound, with delays propagating to all flights in the queue. Analysis of historical data from the *Reopened II* period revealed that North IMC has only been observed for short periods of at most five consecutive hours. Periods of increased throughput capacity have followed these observed North IMC periods, which allowed the Airport to recover.

Second, the North IMC model assumed that all scheduled operations flew to completion. In practice, airlines might cancel flights that would experience high delays during these conditions. Cancellations would result in a reduced operating schedule and, consequently, lower delays for the operations that do fly.

Therefore, annualized simulated delays may be artificially high due to the inclusion of an all-day North IMC model. To account for some of the overrepresentation of North IMC simulated delays, LeighFisher, the Port of Seattle, and the FAA agreed upon a procedure to adjust the weighting of the simulated North IMC delay values in annualization. The procedure is outlined below.

1. Set some Airport Acceptance Rate (AAR) for each 15-minute block. (For North IMC, the AAR was set to 7).
2. Count the number of flights scheduled to arrive in each 15-minute block during the design day.
3. If the number of scheduled arrivals in each 15-minute bloc k exceeds the AAR, cap the number of arrivals in that block by the AAR. Assume that the Airport can only accommodate these flights.
4. Calculate the percentage of arrivals that can be accommodated during the design day as a result of Steps 1 through 3.
5. Weight the annualization percentage of North IMC by the percentage calculated in Step 4.

The results of Steps 1 through 5 for the baseline schedule are shown in Table 22.

Table 22
North IMC Annualization Weighting Procedure—Baseline DDFS

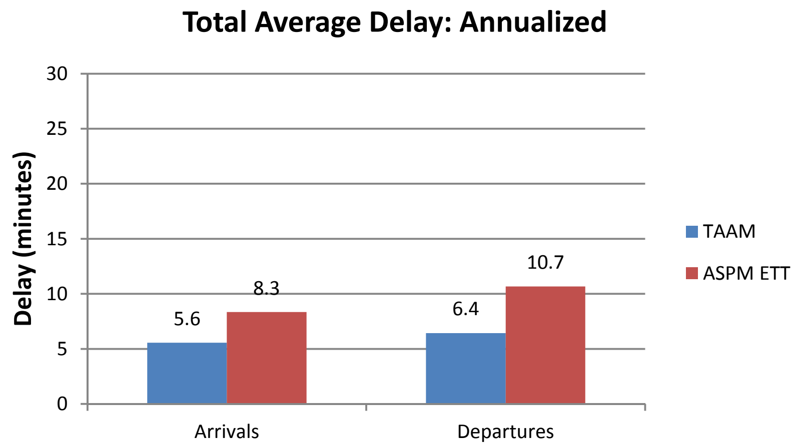
	Value	Formula
Design Day Scheduled Arrivals	612	(a)
Capped Arrivals	453	(b)
Weight	74.02%	(c) = (b)/(a)
North flow IMC Frequency	2.18%	(d)
ADPM Adjustment Factor	0.9166	(e)
North IMC Annualization Weight	1.46%	(f) = (c)*(d)*(e)

The simulated annualized delay with this updated North IMC weight are shown below in Table 23, and a comparison of annualized simulated delays with annualized ASPM-reported delays is also shown in Figure 49.

Table 23
Simulated Arrival and Departure Delays

	Arrivals							Departures							
	Avg. Air Delay	Avg. Taxi Delay	Avg. Gate Delay	Avg. Total Ground Delay	Avg. Taxi	Avg. Unimpeded Taxi	Avg. Total Delay	Avg. Gate Delay	Avg. Taxiway Delay	Avg. Dep Q Delay	Avg. Taxi	Avg. Dep. Time	Avg. Unimpeded Taxi	Avg. Total Delay	Weight
S VMC	3.7	1.3	0.0	1.3	6.4	5.1	5.1	2.6	1.6	1.0	12.0	14.5	9.3	5.2	33.45%
S MMC	5.6	1.7	0.0	1.7	6.7	5.0	7.3	2.7	3.3	1.4	13.6	16.5	9.1	7.3	10.99
S IMC	6.1	2.2	0.0	2.2	7.1	4.9	8.3	3.7	4.7	1.3	14.8	18.6	9.0	9.6	20.28
N VMC	1.6	2.4	0.0	2.4	9.3	6.9	3.9	2.5	2.8	0.9	11.0	13.7	7.5	6.2	24.96
N IMC	25.4	1.8	0.0	1.8	8.8	6.9	27.2	14.5	11.7	1.6	20.6	35.2	7.5	27.7	1.46
Annualized							**5.6**							**6.4**	

Figure 49
TAAM and ASPM ETT Delays—Annualized



Source: LeighFisher analysis of ASPM Flight Plan, EDCT, and Schedule Delays, 6/29/2016-11/30/2016.

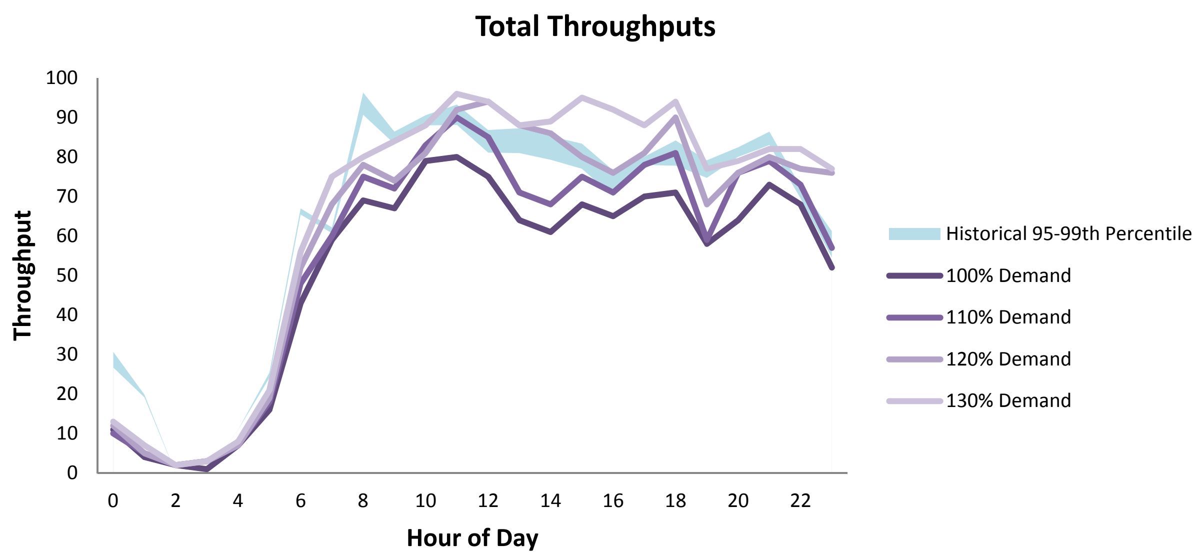
3 MAXIMUM SUSTAINABLE THROUGHPUT ESTIMATION

The objective of this exercise was to estimate the maximum throughput at SEA given current airfield operating regimes. After the development of the calibrated baseline models, demand was artificially amplified to estimate the maximum sustainable throughputs assuming 2016 airfield operation practices. Demand was incrementally scaled up by 10% until the airfield reached its saturation point. The number of existing gates on the airfield was found to be insufficient with as little as a 10% increase in demand; therefore, additional artificial gates were added to the baseline layout in order to accommodate increased demand and achieve higher throughputs. The airfield was considered to reach its saturation point if one or more of the following occurred during the simulation run:

- Arrival and/or departure queue was non-empty more than two hours after the design day is complete
- Total throughputs stopped growing with demand increase
- More than 5 terminations attributable to inadequate gates occurred

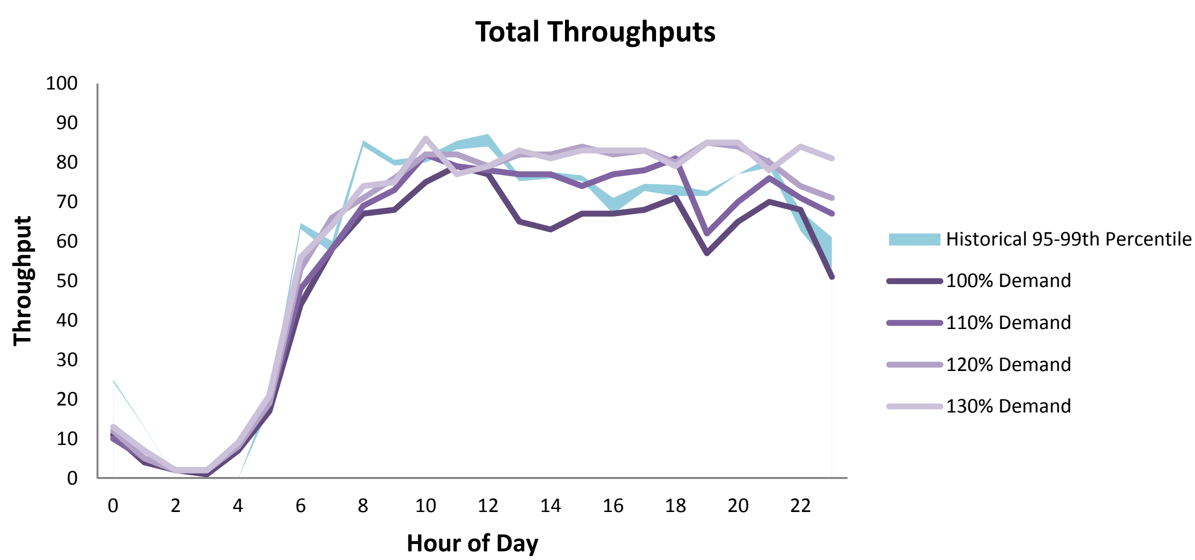
Figure 50 through Figure 54 present the simulated hourly total throughputs with scaled-up demands, as well as the range between 95th and 99th percentile of observed throughput in the data (shown in blue).

Figure 50
Total Throughputs with Scaled-up Demands—South Flow VMC



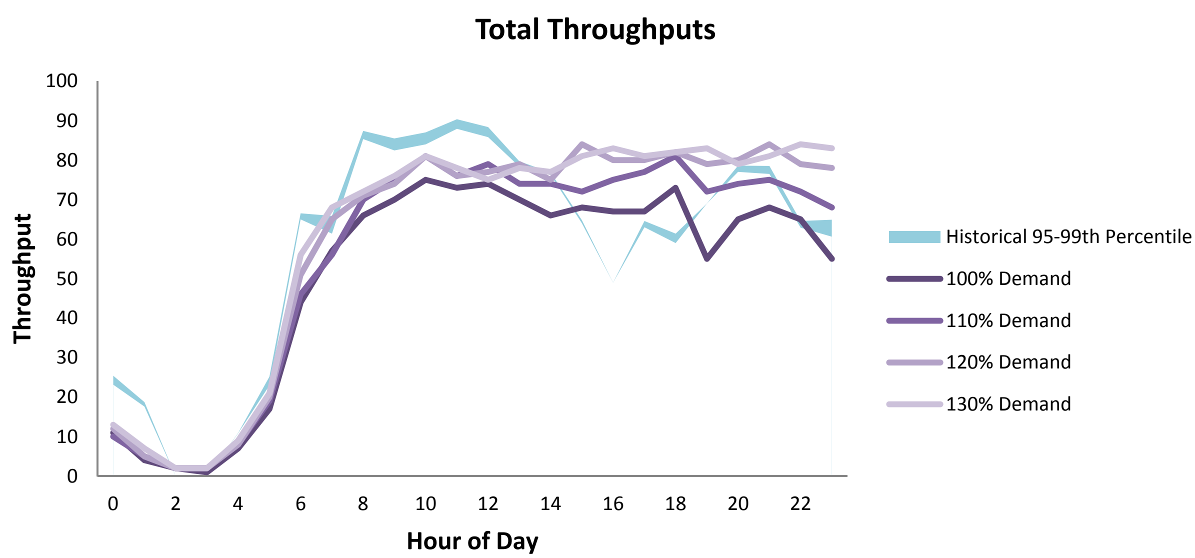
Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

Figure 51
Total Throughputs with Scaled-up Demands—South Flow MMC



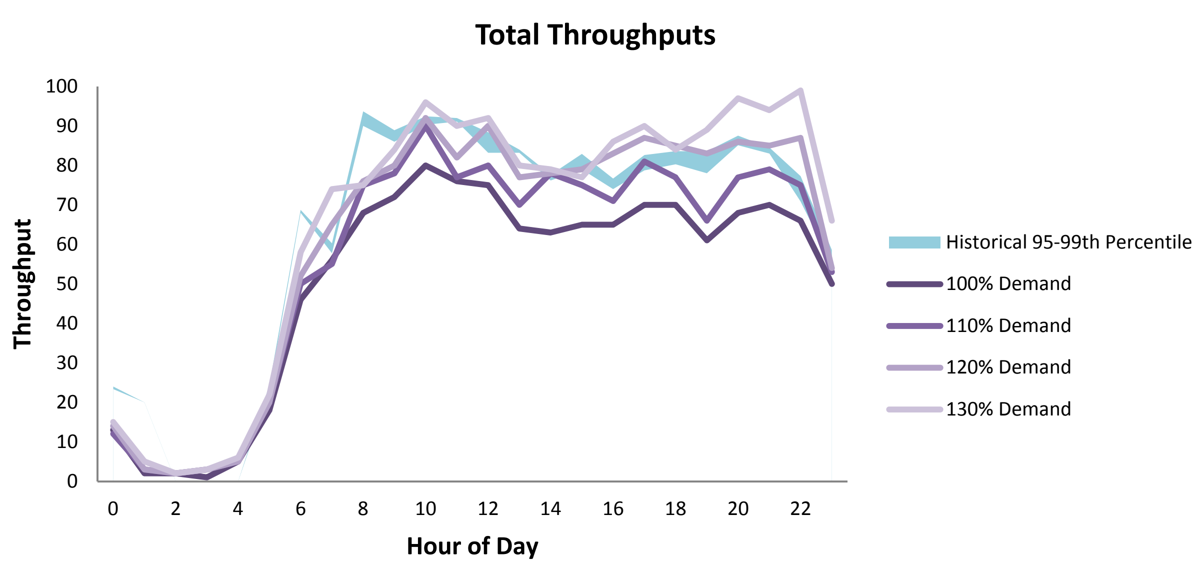
Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

Figure 52
Total Throughputs with Scaled-up Demands—South Flow IMC



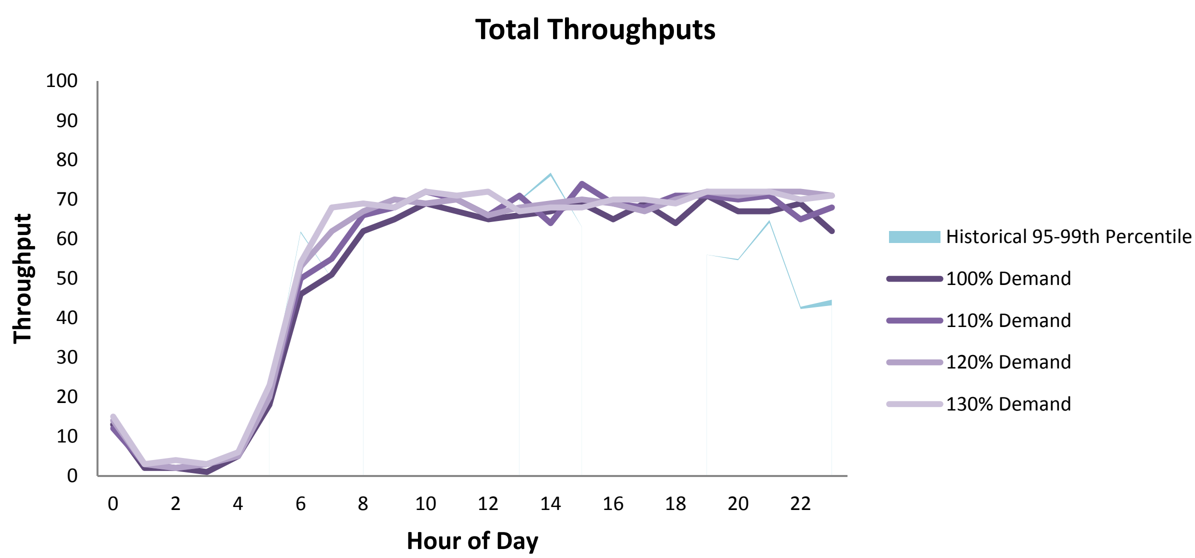
Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

Figure 53
Total Throughputs with Scaled-up Demands—North Flow VMC



Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

Figure 54
Total Throughputs with Scaled-up Demands—North Flow IMC



Source: Noise Office data provided by the Port of Seattle, 6/29/2016-11/29/2016.

All five of the models achieved saturation at 130% of the current demand level. Many of the maximum achieved throughputs fall between the 95th and 99th percentile of observed hourly throughputs, suggesting that the airfield occasionally reaches its capacity measured on an hourly basis.

The results of this experiment suggest that departure throughput is a bottleneck on airfield capacity. When the departure throughput is not high enough, gate holds on departures were implemented in the models, which lead to higher gate occupancy. Consequently, the continuous influx of arrivals was unable to gate, so the arrival rate must be slowed.

The departure throughput may be reduced by various causes, including (but not limited to):

- Inboard runway arrivals. ATCT controllers estimate that each inboard arrival takes out 3-4 departure slots. Increased demand levels would also see an increase in inboard arrivals.
- Frequency of runway crossings. As demand increases, the number of runway crossings of the departure runway(s) also grows. More frequent runway crossings introduce additional departure delays and further constrain the capacity of the airfield.
- Number of runway crossing points. In North flow, there are four assumed runway crossing points, and there are three in South flow. Having additional crossing points allows more aircraft to cross at one time, reducing the total number of departure holds implemented to allow runway crossings.

4 FUTURE-YEAR MODELS

4.1 Approach

Various NextGen technologies may become available at Seattle-Tacoma International Airport in the future, but no specific technology is certain to be implemented. It is reasonable and consistent with typical capacity planning efforts to assume that implementation of one or more of these technologies will lead to changes in runway throughputs. To consider this range of possibilities, LeighFisher created models to represent “Low”, “Medium”, and “High” operational efficiency improvements for each of the five flow-weather configurations under each demand level. The “Low” improvement model used the same runway configuration and calibrated separations as in the baseline models, and the target throughputs approach those achieved in the Maximum Sustainable Throughput (MST) Experiment. The “Medium” improvement model sought to achieve 3-4 additional operations per hour (roughly a 5% increase in throughputs) over the calibrated MST throughputs. The “High” improvement model sought to achieve 6-8 additional operations per hour (roughly a 10% increase in throughputs) over the calibrated MST throughputs. Therefore, each of the five flow-weather configurations was simulated under the three demand levels and under three operational improvements.

In addition, LeighFisher also examined the effects of changing runway use; more specifically, the effects of moving heavy arriving jets off of Runway 16L/34R. Each of the five flow-weather configurations was simulated under the three demand levels and under the “Low”, “Medium”, and “High” improvement scenario. The details of this Alternate Operating Regime are outlined in Section 4.2.3.2.

Figure 55 summarizes the classifications of the experiments run.

Figure 55
Summary of Future-Year Experiments

Target Total Simulated Throughput

Operating Regime	Low	Medium	High
Existing Regime	*MST + 0 ops/hour*	*MST + 3-4 ops/hour*	*MST + 6-8 ops/hour*
Alternate Regime: No inboard arrivals	*MST + 0 No arrivals on 16L/34R*	*MST + 3-4 No arrivals on 16L/34R*	*MST + 6-8 No arrivals on 16L/34R*

4.2 Assumptions: Input Parameters

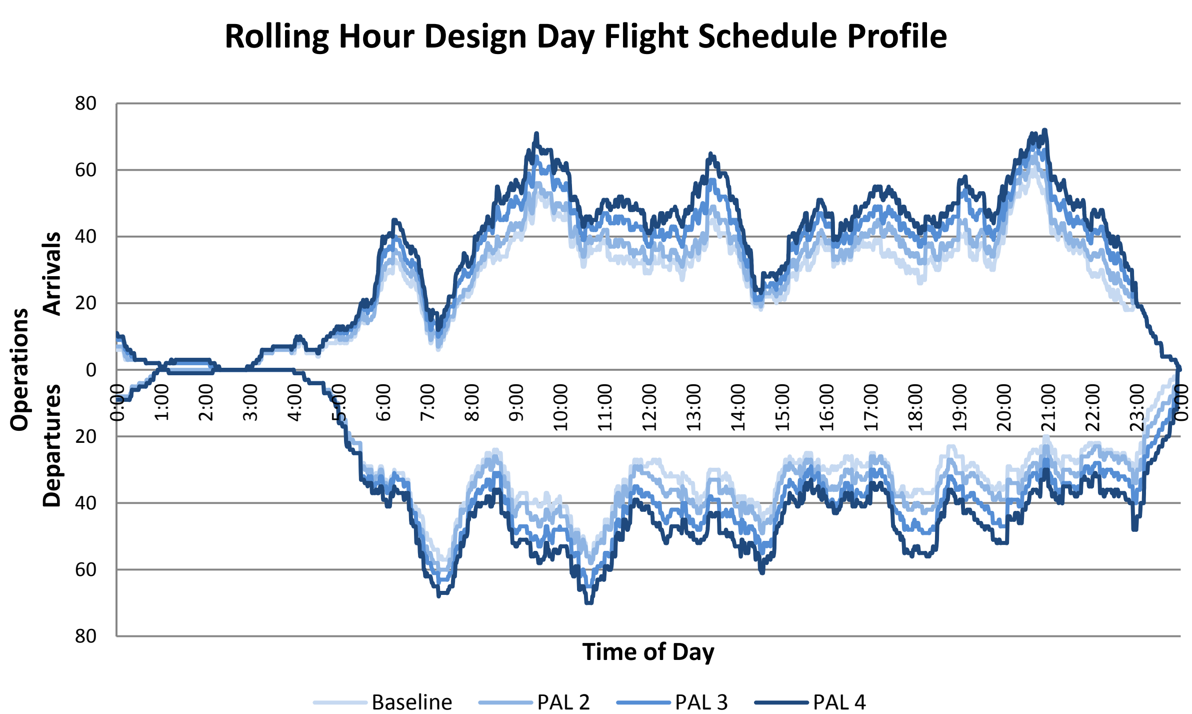
4.2.1 Design Day Flight Schedule

Table 24 and Figure 56 summarize the design day flight schedules used in the future-year simulations.

Table 24
Design Day Flight Schedules Summary

	PAL 2			PAL 3			PAL 4		
	Arrival	Departure	Total	Arrival	Departure	Total	Arrival	Departure	Total
Operations									
ADPM Operations	670	677	1347	769	774	1543	850	856	1706
Peak Hour Operations	65	61	103	69	65	115	72	70	127
Peak Hour Start Time	8:44 PM	7:16 AM	9:31 AM	8:44 PM	10:36 AM	9:29 AM	8:55 PM	10:36 AM	9:29 AM
Fleet Mix									
Wide Body	49	49	98	59	59	118	61	63	124
Narrow Body	383	389	772	444	449	893	488	493	981
Regional Jet	111	111	222	130	130	260	156	156	312
Turboprop	127	128	255	136	136	272	145	144	289
Market Segment									
Passenger	651	658	1309	749	755	1504	829	835	1664
Cargo	17	16	33	18	16	34	19	18	37
General Aviation	2	3	5	2	3	5	2	3	5

Figure 56
Rolling Hour Design Day Flight Schedule Profile



4.2.2 Airspace Structure

The airspace structure assumed in the future-year simulations was identical to that assumed in the baseline calibrated simulations (See Section 2.3.2).

4.2.3 Runway Use

4.2.3.1 Existing Operating Regime

The runway use splits assumed in the "Existing Operating Regime" future-year simulations were identical to those assumed in the baseline calibrated simulations (See Section 2.3.3).

4.2.3.2 Alternate Operating Regime

The following runway use percentages were assumed as inputs to the "Alternate Operating Regime" models.

- South VMC
  - Heavy arrivals: 75% on 16C, 25% on 16R
  - Non-heavy arrivals: all on 16R
  - Heavy departures: all on 16L
  - Non-heavy departures: 50% on 16C, 50% on 16L
- South MMC
  - All arrivals on 16R
  - Heavy departures: all on 16L
  - Non-heavy departures: 25% on 16C, 75% on 16L
- South IMC
  - All arrivals on 16R
  - All departures on 16L
- North VMC
  - All arrivals on 34L
  - All departures on 34R
- North IMC
  - All arrivals on 34L
  - All departures on 34R

Under this operating regime, arrivals that had previously landed on the inboard runway were moved off of the inboard runway. In South VMC, the arrival stream that previously used the inboard runway was shifted to the center runway. In MMC, IMC, and North VMC, the arrival stream that previously used the inboard runway was added to the outboard arrival queue. Consequently, in MMC and IMC, arrival delay increased due to the required full wake turbulence separation between consecutive arrivals to the outboard runway.

In South VMC, fewer departures were assumed to use the center runway than in the Existing Operating Regime in order to curb the effects of arrivals using the center runway.

4.2.4 Wake Turbulence Separations and Buffers

The FAA minimum separation requirements are specified in Tables 14 and 15 in Section 2.3.6. In the "Medium" and "High" improvement models, these minima may be reduced in an effort to achieve the target throughputs.

4.2.9.1 "Low" Improvement Models

In these models, the present-day FAA minimum separation requirements were assumed to be unchanged. In addition, the separation buffers achieved in the calibration exercise were generally assumed to remain unchanged, except in cases where arrivals must be slowed such that all aircraft could be assigned a gate. The buffers applied to the FAA minimum separation requirements are displayed below in Table 25 and Table 26.

Table 25
Wake Turbulence Buffers: "Low" Improvement, Existing Operating Regime

	Existing Operating Regime							
	Baseline		PAL 2		PAL 3		PAL 4	
	Arrival	Departure	Arrival	Departure	Arrival	Departure	Arrival	Departure
South VMC	1.0 nm	0.1 min	1.0 nm	0.1 min	1.0 nm	0.1 min	1.0 nm	0.1 min
South MMC	0.5 nm	0.1 min	0.5 nm	0.1 min	0.5 nm	0.1 min	0.5 nm	0.1 min
South IMC	0.5 nm	0.2 min	0.5 nm	0.2 min	0.5 nm	0.2 min	0.7 nm	0.2 min
North VMC	0.5 nm	0.0 min	0.5 nm	0.0 min	0.5 nm	0.0 min	1.1 nm	0.0 min
North IMC	1.2 nm	0.0 min	1.2 nm	0.0 min	1.2 nm	0.0 min	1.3 nm	0.0 min

Table 26
Wake Turbulence Buffers: "Low" Improvement, Alternate Operating Regime

	Altered Operating Regime							
	Baseline		PAL 2		PAL 3		PAL 4	
	Arrival	Departure	Arrival	Departure	Arrival	Departure	Arrival	Departure
South VMC	N/A	N/A	1.0 nm	0.1 min	1.0 nm	0.1 min	1.0 nm	0.1 min
South MMC	N/A	N/A	0.5 nm	0.1 min	0.5 nm	0.1 min	0.5 nm	0.1 min
South IMC	N/A	N/A	0.5 nm	0.2 min	0.5 nm	0.2 min	0.6 nm	0.2 min
North VMC	N/A	N/A	0.5 nm	0.0 min	0.5 nm	0.0 min	0.6 nm	0.0 min
North IMC	N/A	N/A	1.2 nm	0.0 min	1.2 nm	0.0 min	1.2 nm	0.0 min

4.2.9.2 "Medium" Improvement Models

These models primarily focused on loosening the bottleneck on departures. To that end, the following rules dictated how the simulated buffers were reduced.

- If there was a non-zero departure separation buffer in the “Low” Improvement model, reduce that buffer by up to 0.2 minutes.
- If the departure separation buffer was zero and the model is VMC or MMC, minimum radar separations only behind small aircraft may be reduced from 60 seconds to 48 seconds (separation buffer of -0.2 min).
- The arrival separation buffer may be reduced by up to one-third as long as all flights can gate upon arrival.

Table 27 and Table 28 below display the buffers used in these models.

Table 27
Wake Turbulence Buffers: “Medium” Improvement, Existing Operating Regime

	Existing Operating Regime							
	Baseline		PAL 2		PAL 3		PAL 4	
	Arrival	Departure	Arrival	Departure	Arrival	Departure	Arrival	Departure
South VMC	N/A	N/A	0.7 nm	0.0 min*	1.0 nm	0.0 min*	0.9 nm	0.0 min*
South MMC	N/A	N/A	0.5 nm	0.0 min	0.5 nm	0.0 min	0.5 nm	0.0 min
South IMC	N/A	N/A	0.5 nm	0.1 min	0.6 nm	0.1 min	0.5 nm	0.1 min
North VMC	N/A	N/A	0.5 nm	0.0 min*	0.6 nm	0.0 min*	0.5 nm	0.0 min*
North IMC	N/A	N/A	1.2 nm	0.0 min	1.15 nm	0.0 min	1.35 nm	0.0 min

*Separation buffer behind “Light” or “Medium Light” departing aircraft in VMC was -0.2 min.

Table 28
Wake Turbulence Buffers: “Medium” Improvement, Alternate Operating Regime

	Altered Operating Regime							
	Baseline		PAL 2		PAL 3		PAL 4	
	Arrival	Departure	Arrival	Departure	Arrival	Departure	Arrival	Departure
South VMC	N/A	N/A	0.7 nm	0.0 min*	0.95 nm	0.0 min*	1.0 nm	0.0 min*
South MMC	N/A	N/A	0.5 nm	0.0 min	0.5 nm	0.0 min	0.5 nm	0.0 min
South IMC	N/A	N/A	0.5 nm	0.1 min	0.5 nm	0.1 min	0.5 nm	0.1 min
North VMC	N/A	N/A	0.5 nm	0.0 min*	0.5 nm	0.0 min*	0.5 nm	0.0 min*
North IMC	N/A	N/A	0.9 nm	0.0 min	1.1 nm	0.0 min	1.15 nm	0.0 min

*Separation buffer behind “Light” or “Medium Light” departing aircraft in VMC was -0.2 min.

4.2.9.3 “High” Improvement Models

These models represent a scenario with successful deployment of potentially many NextGen technologies not just at SEA, but also across the entire National Airspace System. Many of the “High” improvement models assumed that changes to the FAA’s minimum separation standards may occur, with reductions in separations by up to 0.3 nmi (in the PAL 2 South MMC and South IMC arrival separations). These changes in minimum separations would not just affect SEA, but would affect all airports across the country.

Table 29 and Table 30 below display the separation buffers used in these models. The FAA's minimum separation standards have been relaxed for those models that have negative separation buffers.

Table 29
Wake Turbulence Buffers: "High" Improvement, Existing Operating Regime

	Existing Operating Regime							
	Baseline		PAL 2		PAL 3		PAL 4	
	Arrival	Departure	Arrival	Departure	Arrival	Departure	Arrival	Departure
South VMC	N/A	N/A	-0.2 nm	-0.2 min	-0.2 nm	-0.2 min	0.8 nm	-0.2 min
South MMC	N/A	N/A	-0.3 nm	-0.1 min	0.0 nm	-0.1 min	0.3 nm	-0.1 min
South IMC	N/A	N/A	-0.3 nm	0.0 min	0.3 nm	0.0 min	0.45 nm	0.0 min
North VMC	N/A	N/A	0.0 nm	-0.2 min	0.1 nm	-0.2 min	0.9 nm	-0.2 min
North IMC	N/A	N/A	0.9 nm	-0.2 min	1.0 nm	-0.2 min	1.1 nm	-0.2 min

Table 30
Wake Turbulence Buffers: "High" Improvement, Alternate Operating Regime

	Altered Operating Regime							
	Baseline		PAL 2		PAL 3		PAL 4	
	Arrival	Departure	Arrival	Departure	Arrival	Departure	Arrival	Departure
South VMC	N/A	N/A	-0.2 nm	-0.2 min	-0.2 nm	-0.2 min	0.3 nm	-0.2 min
South MMC	N/A	N/A	-0.3 nm	-0.1 min	0.3 nm	-0.1 min	0.3 nm	-0.1 min
South IMC	N/A	N/A	-0.3 nm	0.0 min	0.3 nm	0.0 min	0.3 nm	0.0 min
North VMC	N/A	N/A	-0.2 nm	-0.2 min	-0.2 nm	-0.2 min	0.0 nm	-0.2 min
North IMC	N/A	N/A	0.7 nm	-0.2 min	0.8 nm	-0.2 min	0.9 nm	-0.2 min

4.2.5 Airfield Improvements

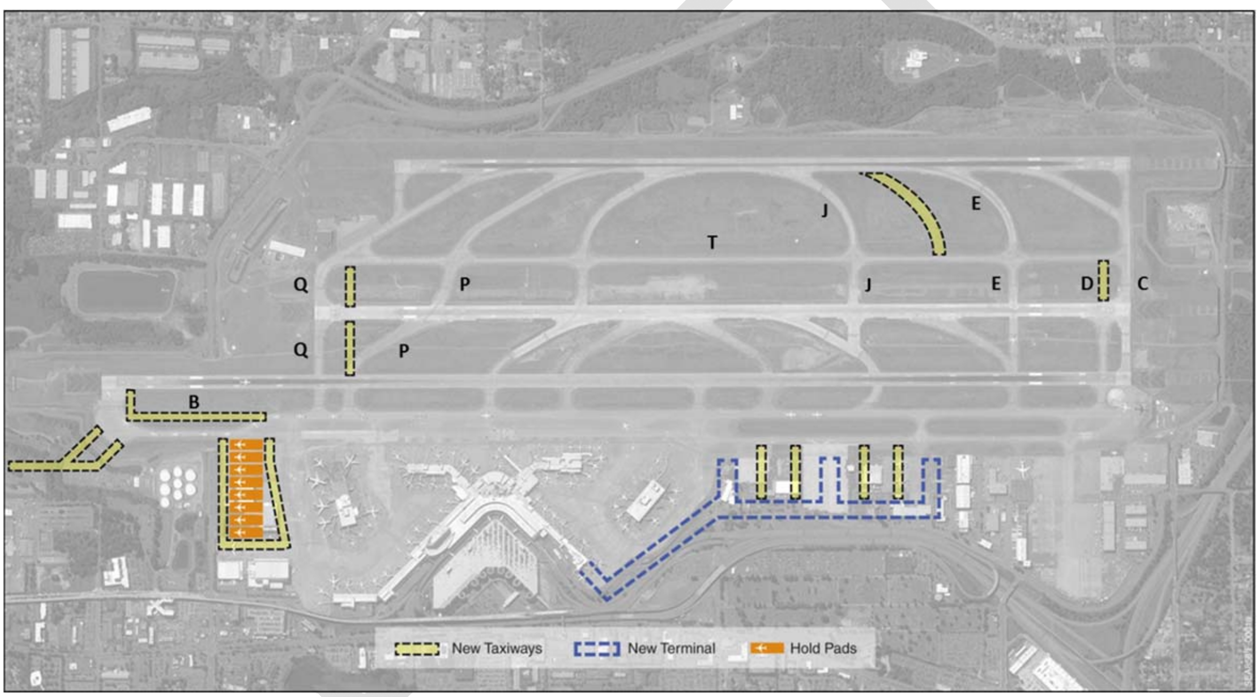
In accordance with the Sustainable Airport Master Plan, the airfield layout assumed in the models includes proposed physical infrastructure improvements. These improvements include:

- Construction of three new terminal piers north of the North Satellite, providing additional passenger gates
- Extension of Taxiway B at the south end of the airfield
- Relocation of cargo operations to a new apron area southeast of Runway 16L/34R

- Addition of hold pads south of the South Satellite with a wrap-around taxilane
- Construction of a fourth northward-facing high-speed exit off of Runway 16R/34L between Taxiway J and Taxiway E
- Addition of a parallel runway crossing point between Runway 16C/34C and Taxiway T south of Taxiway C
- Addition of a parallel runway crossing point between Runway 16L/34R and Taxiway T north of Taxiway Q

The above changes are taken as given for the PAL 2, PAL 3, and PAL 4 models. These airfield improvements are shown in Figure 57.

Figure 57
Infrastructure Improvements to Airfield for PAL 2, 3, and 4



4.2.6 *Runway Dependencies*

The runway dependencies assumed in the future-year simulations were identical to those assumed in the baseline calibrated simulations (See Section 2.3.4).

4.2.7 *Taxi Paths and Runway Crossings*

The addition of the new passenger terminal, more runway crossing points, and the relocated cargo facility enables more flexibility in crossing locations than in the baseline models. The changes in the future-year models' taxi paths from the baseline models' taxi paths are summarized below.

- Arriving aircraft heading to the new passenger terminal may use Taxiways H and J to cross the runways.
- Arriving cargo aircraft may use Taxiway Q to cross the runways.
- The additional runway crossing points may be used.

Figure 58
Simulated Future-Year Taxi Routes—South Flow

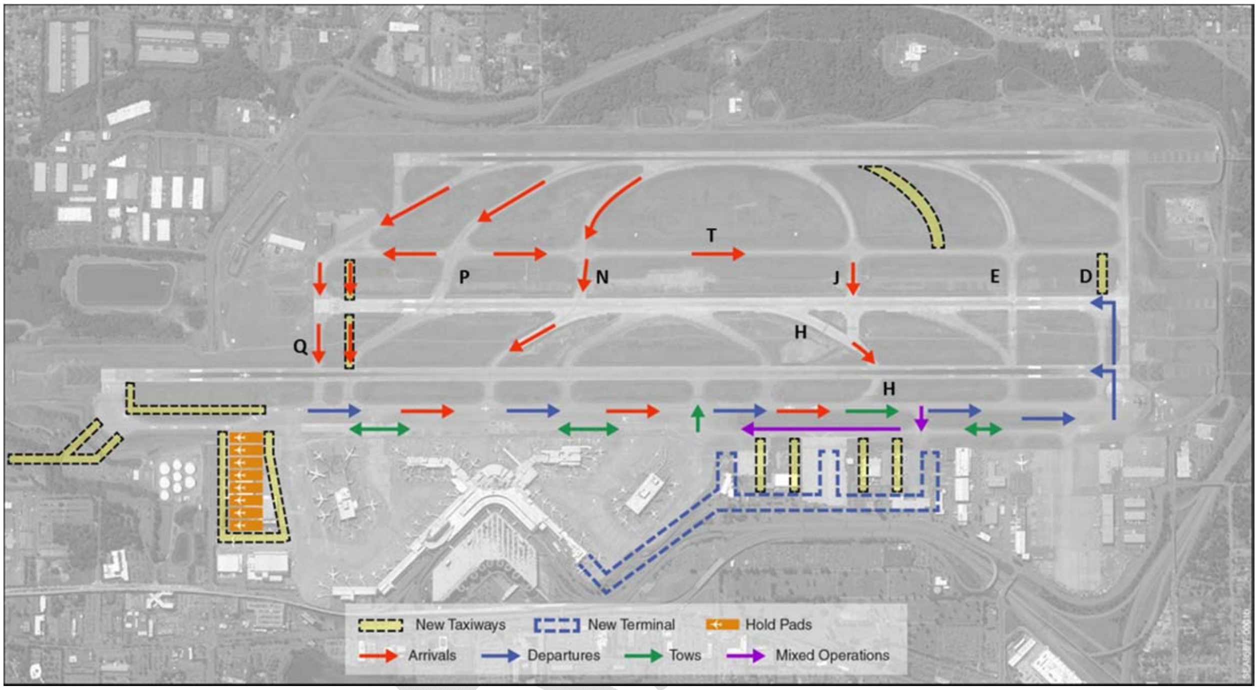
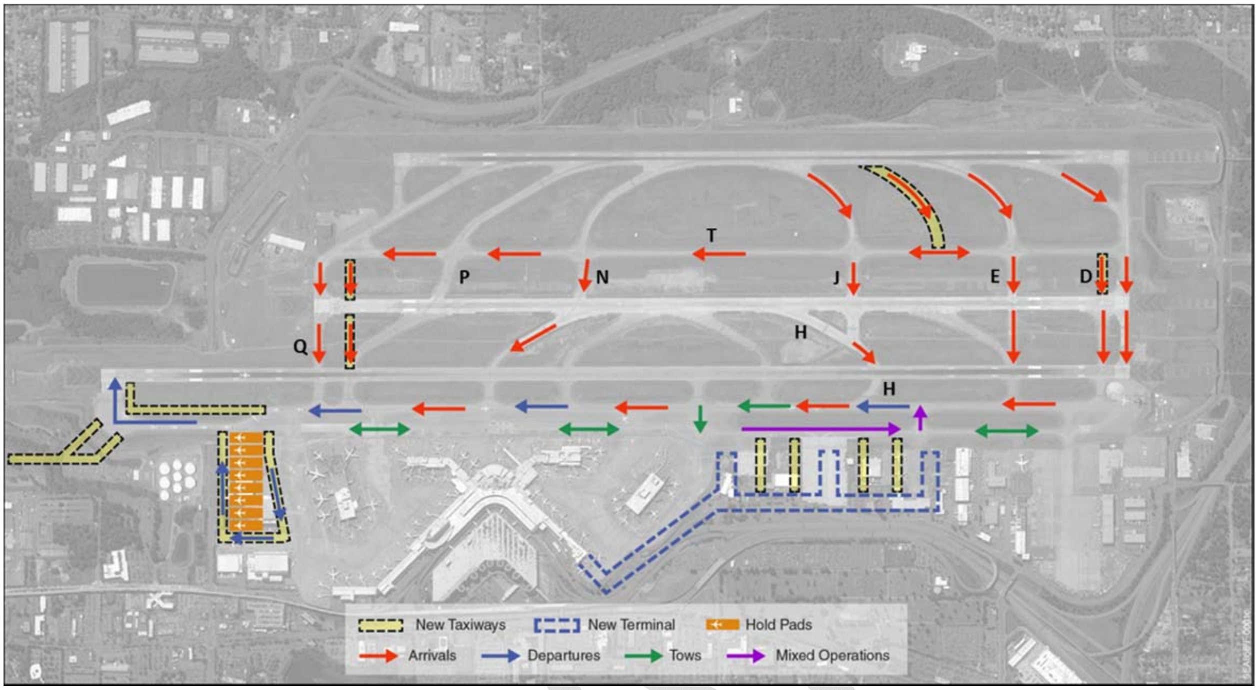


Figure 59
Simulated Future-Year Taxi Routes—North Flow



Four crossing points were simulated in South flow, and seven crossing points were simulated in North flow. South flow supported fewer crossing points than North flow due to the location of the departure queue.

In order to simplify the models and reduce head-to-head conflict, aircraft were assumed to taxi in front of the new terminal in a counter-clockwise direction in South flow; similarly, aircraft were assumed to taxi in a clockwise direction in front of the new terminal in North flow.

4.2.8 Gate Assignments

Due to the lack of historical data, the construction of the new terminal, and the movement of the International Arrivals Facility to Concourse A, aircraft were assigned to groups of gates based on their size and/or airline. Table 31 below summarizes aircraft gate assignments assumed in the future-year simulations.

Table 31
Simulated Future-Year Gate Allocations

Gate Area	Airline(s)	Aircraft Size Restrictions
New Terminal	American, Frontier, Hawaiian, JetBlue, Southwest, Spirit, Sun Country, United, Virgin America	None; wide-body gates available
Concourse A	All international, Delta, SkyWest, Compass	Gates A06-A14 reserved for wide-body international
Concourse B	Delta, SkyWest, Compass	None; priority to Delta wide-body
Concourse C	Alaska, Horizon	None
Concourse C West	Horizon (SkyWest/Compass overflow)	Turboprops only
Concourse D	Any (except international)	None
North Satellite	Alaska, Horizon	None
South Satellite	Delta, international, SkyWest/ Compass overflow	None; priority to wide-body
South Aviation Support Area (SASA)	All cargo	None
GA Terminal	All general aviation	None

4.2.9 Pushback, Runway Crossing, and Minimum Turnaround Times

The pushback times, runway crossing times, and minimum turnaround times assumed in the future-year simulations were identical to those assumed in the baseline calibrated simulations (See Section 2.3.9).

4.3 Results

4.3.1 North IMC Delay Adjustment

As discussed in Section 2.4.6, the North flow IMC model is believed to overestimate delays that would occur during these conditions in practice due to the effects of compounding queues and lack of simulated flight cancellations. For this reason, an additional adjustment was applied to the North IMC model's annualization weight. The adjustment is designed to account for some of the causes of the higher simulated delays and was agreed to in consultation with the Port of Seattle and the FAA.

The value of this adjustment factor depends on the design day flight schedule. Therefore, the North IMC delay adjustment factors for the PAL 2, 3, and 4 schedules were derived using the methodology described in Section 2.4.6. The calculations are shown below in Table 32.

Table 32
North IMC Annualization Weighting Procedure—PAL 2, 3, and 4 DDFS

	PAL 2	PAL 3	PAL 4	Formula
Design Day Scheduled Arrivals	670	769	850	(a)
Capped Arrivals	476	494	506	(b)
Weight	71.04%	64.24%	59.53%	(c) = (b)/(a)
North flow IMC Frequency	2.18%	2.18%	2.18%	(d)
ADPM Adjustment Factor	0.9166	0.9166	0.9166	(e)
North IMC Annualization Weight	1.41%	1.27%	1.18%	(f) = (c)*(d)*(e)

The calculated weights above were applied to each annualization in the subsequent sections.

4.3.2 Simulated Delays

Figure 60 and Figure 61 present the annualized delays for each of the three improvement scenarios. These values were achieved using the same annualization factors and ADPM adjustment factor as outlined in the calibration exercise (Section 2.2.3 and Section 2.3.1, respectively) with the North IMC Delay Adjustment factors calculated in Table 32.

Figure 60
Existing Operating Regime Annualized Delay

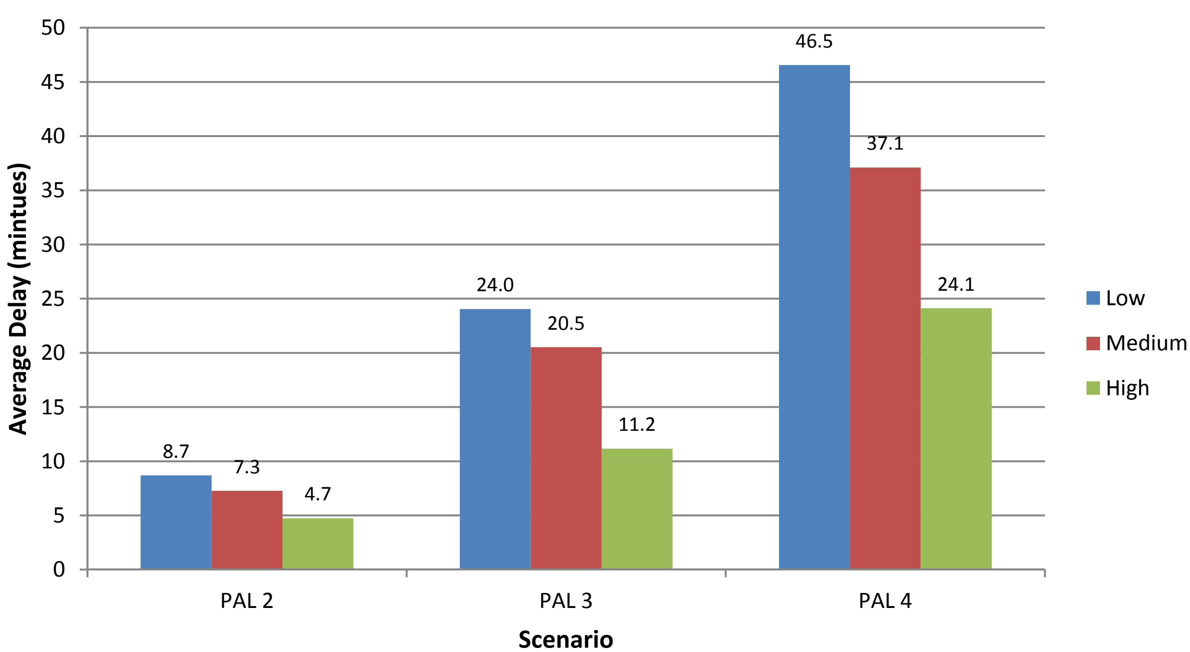
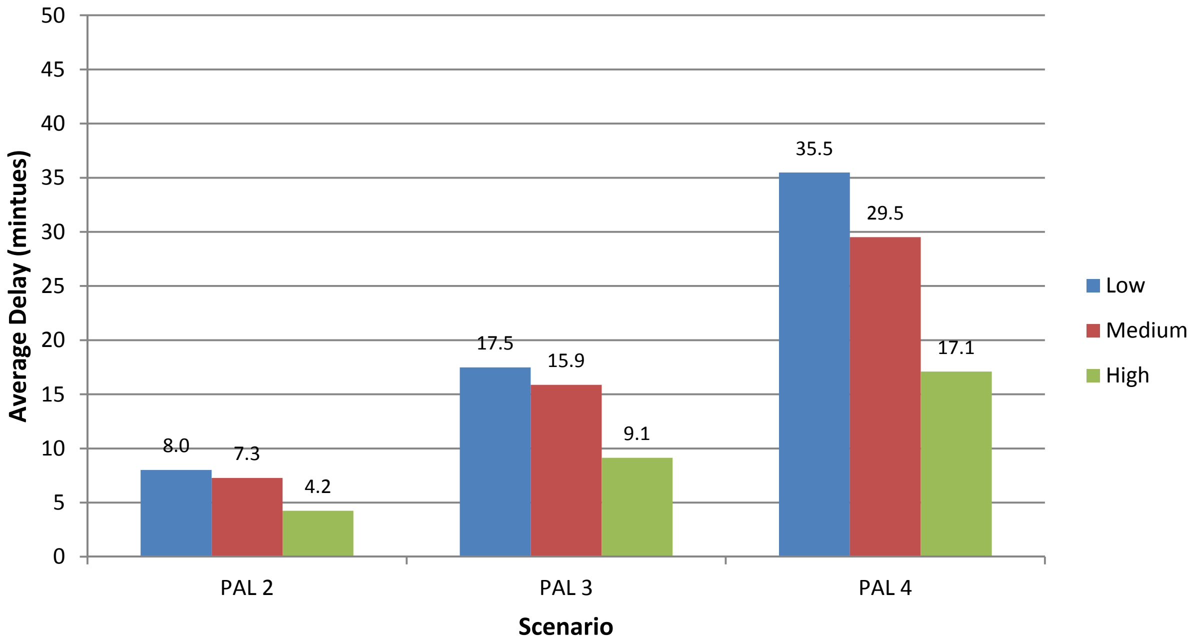


Figure 61
Alternate Operating Regine Annualized Delay



Below are bar charts showing the simulated average delay for each flow-weather configuration. Each bar chart represents a demand level. Each flow-weather configuration has three stacked bars attributed to it. The bars that are lightest in color correspond to the “Low” improvement models; the bars that are darkest in color correspond to the “High” improvement models; the bars that are in the middle in color correspond to “Medium” improvement models. The blue portion of the stacked bars represents the lesser of the two values returned when comparing the Existing Operating Regime model results to the Alternate Operating Regime model results. If a blue bar has a green bar on top, then the value returned from the Existing Operating Regime model exceeded that of the Alternate Operating Regime model by the height of the green bar. Similarly, if a blue bar has a red bar on top, then the value returned from the Alternate Operating Regime model exceeded that of the Existing Operating Regime model by the height of the red bar.

The delay values presented in these charts are not weighted by the ADPM adjustment factor. Similarly, the North IMC delay values presented are not weighted by the North IMC delay adjustment factor.

Figure 62
PAL 2 Total Average Delays

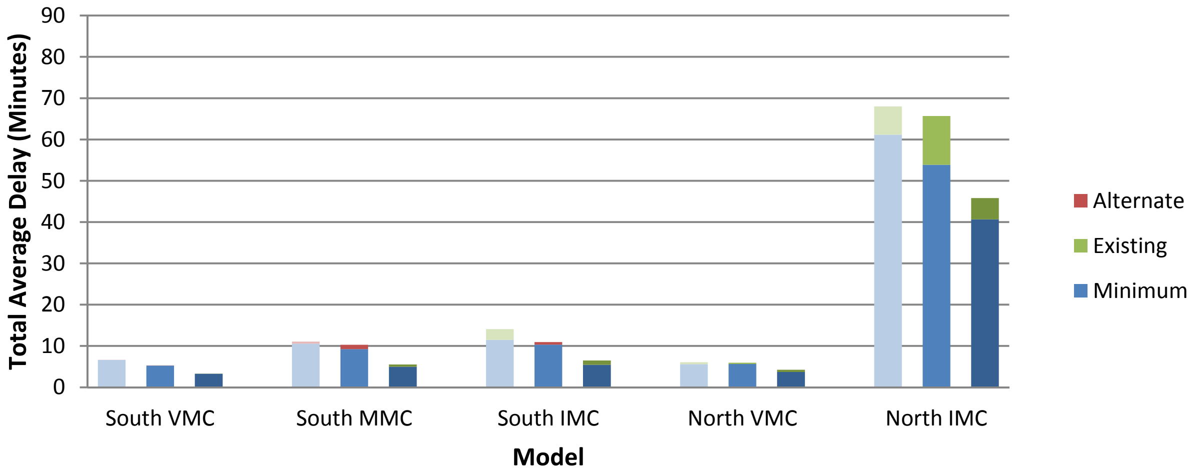


Figure 63
PAL 3 Total Average Delays

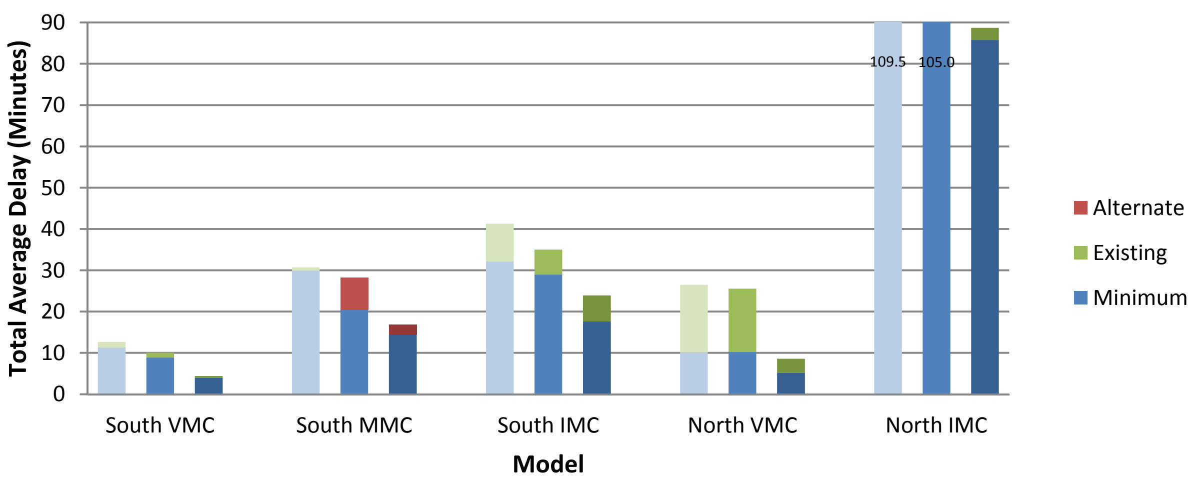
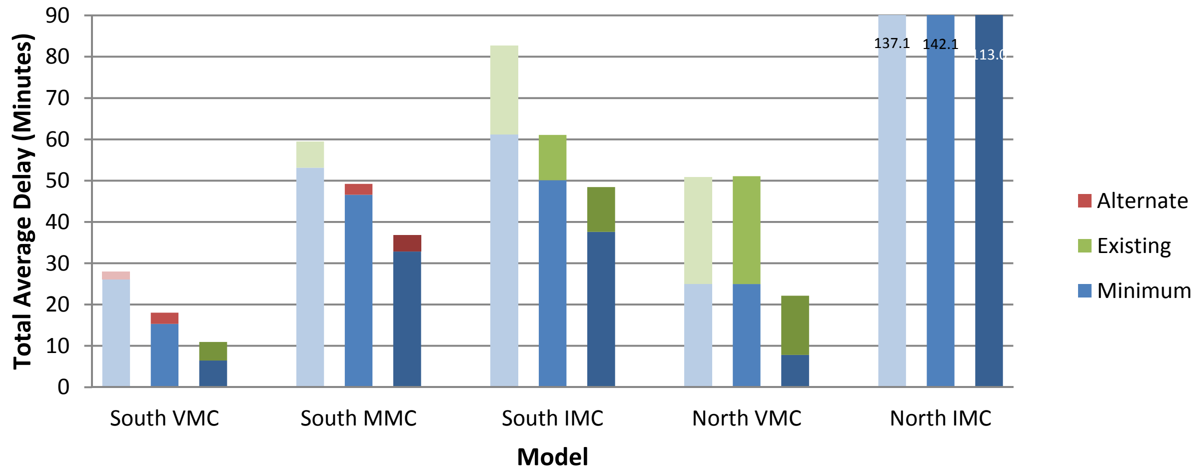


Figure 64
PAL 4 Total Average Delays



4.3.3 Taxi Times

The following six bar charts (Figure 65 through Figure 70) can be interpreted in the same manner as the delay stacked-bar charts. See Section 4.3.2 to review the interpretation.

Figure 65
PAL 2 Taxi-In Times

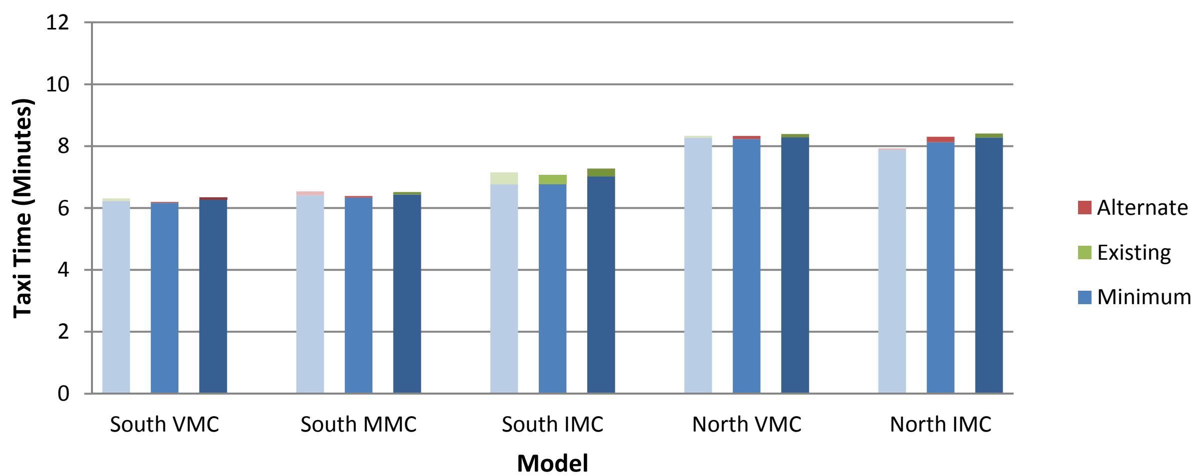


Figure 66
PAL 2 Taxi-Out Times

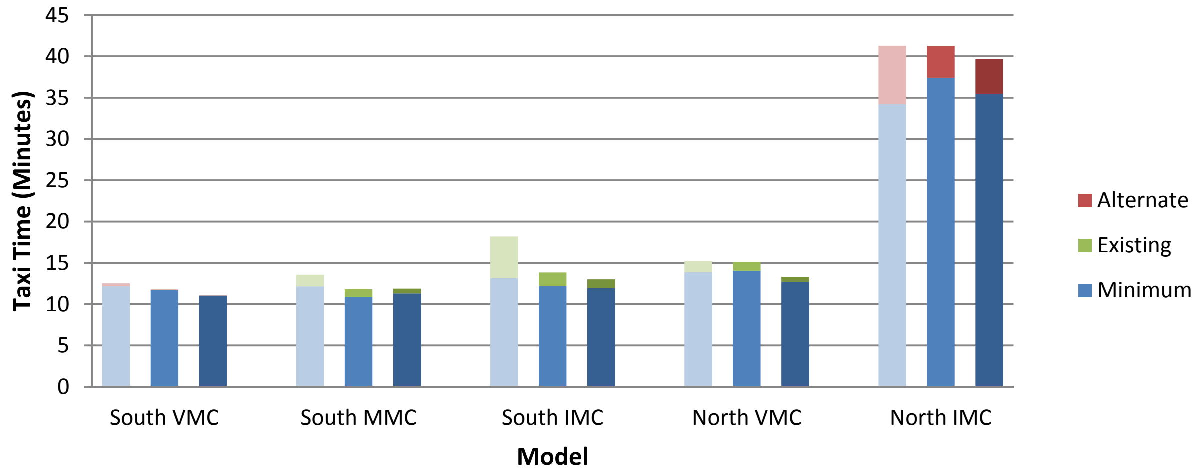


Figure 67
PAL 3 Taxi-In Times

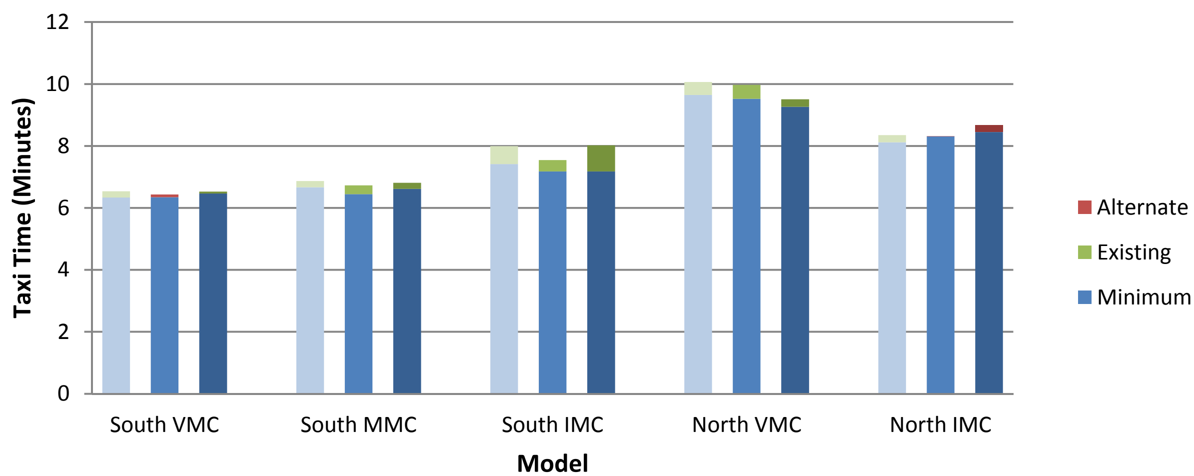


Figure 68
PAL 3 Taxi-Out Times

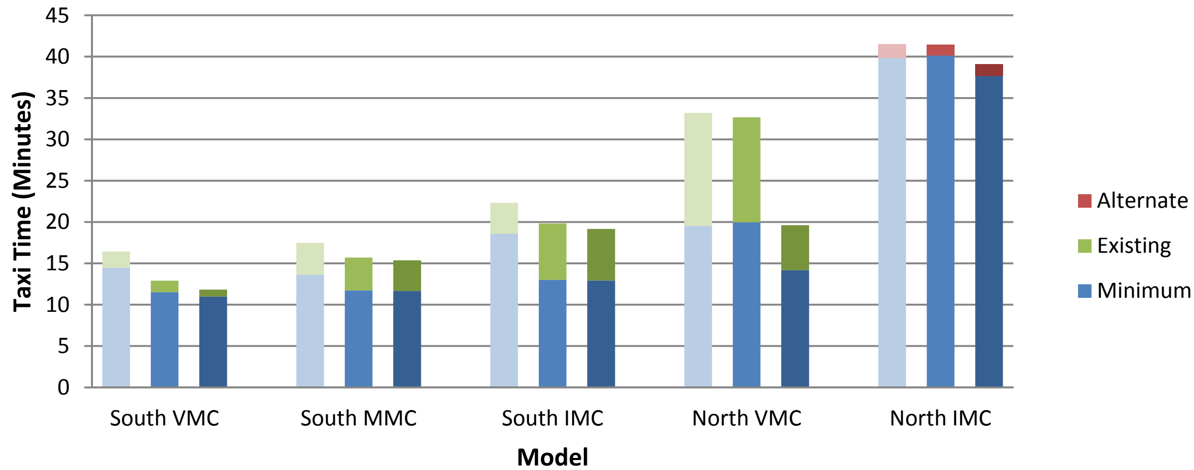


Figure 69
PAL 4 Taxi-In Times

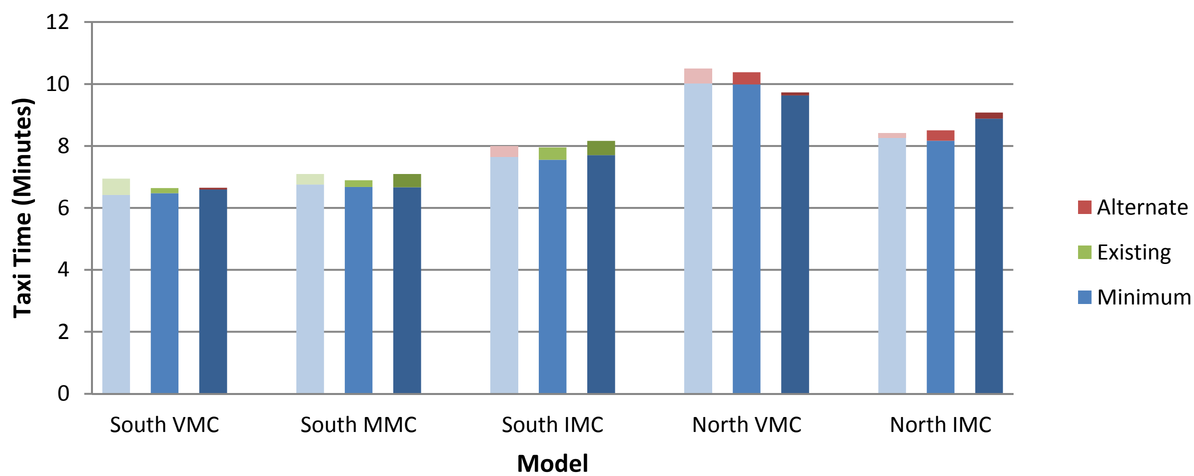
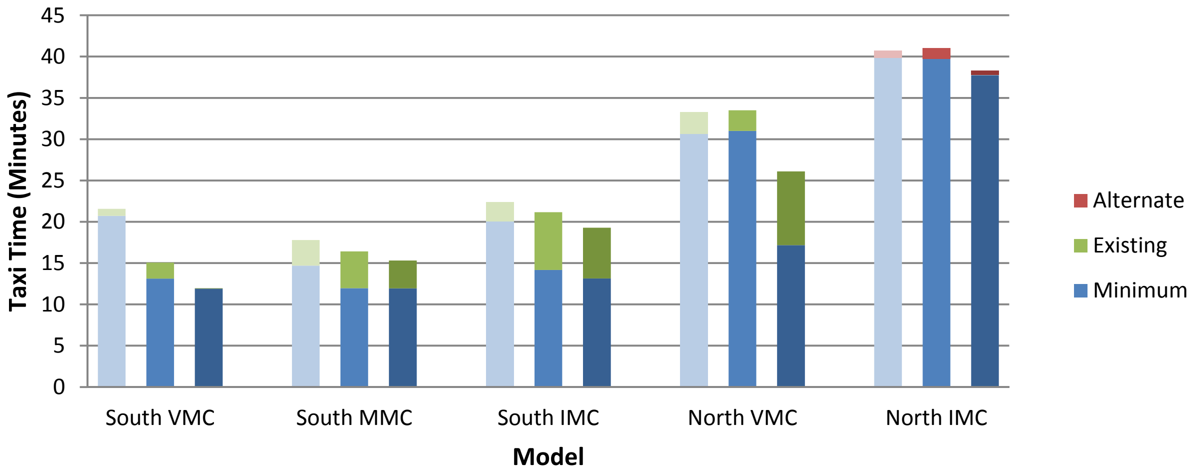


Figure 70
PAL 4 Taxi-Out Times



4.3.4 Mix of Operating Regimes

The simulated results suggest the following three conclusions:

- As demand increases, delays in single-departure-runway configurations (South IMC, North VMC, and North IMC) could be reduced by moving heavy arriving jets off of the inboard runway.
- In South MMC, average delays may be lower if aircraft continue to arrive on the inboard runway. This is because the departure delay savings achieved by moving arrivals off the inboard runway are overshadowed by the increase in arrival delay resulting from a single arrival queue.
- In South VMC, departures can freely flow from the center runway while a heavy jet lands on the inboard runway. So heavy jets can arrive on the inboard runway without a substantial adverse impact on airfield performance.

Based on these three conclusions, LeighFisher annualized the simulated delay numbers by combining the ideal operating regime for each flow-weather configuration. The operating regime assumed for each configuration is shown below in Table 33.

Table 33
Operating Regime Selected for Each Configuration in "Mixed" Annualization

Flow-weather Configuration	Operating Regime
South VMC	Existing
South MMC	Existing
South IMC	Alternate
North VMC	Alternate
North IMC	Alternate

Assuming these operating regimes for each configuration, the following annualized delay values arise (weighted by the ADPM adjustment factor and the North IMC Delay Adjustment factor).

Figure 71
Mix of Operating Regimes Annualized Delay