



Paine Field Master Plan 2040

Chapter 4 | Facility Requirements

4

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4 Facility Requirements

4.1 Introduction

This chapter presents the future planning requirements for Airport facilities that will be needed in order to provide sufficient capacity to meet the projected demand throughout the planning period at Paine Field (PAE). In addition to providing sufficient capacity, consideration has been given throughout the project to providing acceptable levels of service for all Airport users. The requirements were calculated using Federal Aviation Administration (FAA) standards, where applicable, as well as established industry planning standards.

This Chapter is organized as follows:

1. Planning Activity Levels
2. Airfield Facilities
3. Passenger Terminal Facilities
4. Landside Access and Parking Facilities
5. Air Cargo Facilities
6. Aviation Support Facilities
7. Commercial Development

For the purposes of master planning, the requirements presented are tied to three Planning Activity Levels (PAL). The use of PALs rather than years provides PAE with flexibility to plan for the implementation of future projects based on actual growth in traffic, rather than a specific timeline. The associated activity levels for each PAL are shown in **Table 4-1, Planning Activity Levels**.

Table 4-1 Planning Activity Levels

Planning Activity Level	Million Annual Passengers (MAP)	Annual Operations ¹	Passenger Operations	General Aviation Operations	Based Aircraft	Peak Hour Passengers	Peak Hour Operations
Existing (2019)	1,022,046	137,995	16,660	116,694	536	330	78
PAL 1 (1.0 MAP)	1,022,046	148,473	16,660	125,131	563	330	84
PAL 2 (1.5 MAP)	1,535,412	155,028	18,741	129,350	592	596	85
PAL 3 (4.3 MAP)	4,322,426	187,303	41,506	138,282	654	1,368	93

¹ Includes Passenger, General Aviation, Air Cargo, Air Taxi, Military, and all other air carrier operations

Source: Landrum & Brown

Planning assumptions and factors were used to define the basis for calculating the demand/capacity relationships used to derive facility requirements from the peak hour demand forecasts in Chapter 3, *Aviation Activity Forecast*. These factors are unique to the facility type being assessed and must reflect PAE's development objectives in consideration of internal and external stakeholder feedback. The assumptions, planning and design standards used in determining the future requirements for each facility is provided in the various subsections throughout this chapter.

4.2 Summary of Facility Requirements

A summary of the forecast demand for each Planning Activity Level (PAL) and the resulting facility requirements is presented in **Table 4-2, Summary of Facility Requirements**.

4.2.1 Airfield Facilities

The airfield requirements and compliance with FAA standards analyzed the following topics; Airfield Capacity Analysis, Runway Length Analysis, Airfield Safety Areas, Runway Exits, Airfield Design Standards, Meteorological Conditions, and Airspace.

Summary of Airfield Requirements

- Existing runway system provides sufficient capacity through the planning period
- Various safety improvements to resolve non-standard airfield conditions
- Airfield taxiway/taxiway improvements to improve traffic flow
- Optimization of Rapid-Exit taxiways (RETs) for Runway 16R-34L
- Further airspace obstruction analysis required to ensure no obstacles or obstructions, on or around PAE

4.2.2 Passenger Terminal Facilities

The terminal requirements examine the passenger terminal building and associated terminal gates to meet the anticipated demand.

Summary of Passenger Terminal Requirements

- A total of seven contact gates and eight additional remote parking positions will be required in PAL 3
- The existing three contact gates will be sufficient to serve the PAL 2 demand
- The existing passenger terminal building (44,000 sf) will require incremental expansion through the planning period, requiring approximately 240,000 sf in PAL 3

4.2.3 Landside Access and Parking Facilities

The future facility needs for landside access and parking facilities are summarized in this section.

Summary of Landside Access and Parking Facilities Requirements

- The existing terminal curb will require incremental expansion through the planning period, requiring approximately 2,400 sf in PAL 3.

- The existing passenger parking space, 613 will require incremental expansion through the planning period, requiring a total of 2,593 spaces in PAL 3.
- Various segments of the terminal loop road and entrance to passenger curb will require improvements to maintain an acceptable level of service
- Various segments of the 100th St. SW will require improvements to maintain an acceptable level of service
- The intersection of 100th ST. SW and Airport Road will require major changes in order to maintain an acceptable level of service

Sound Transit Everett Link Extension

The Sound Transit Everett Link Extension is being planned to run along the east side of Airport Road. It will add 16 miles of light rail and six new stations connecting Snohomish County residents to the regional light rail network. This new link will give airport employees, tenants, and commercial service passengers another mass transit option of getting to and from the airport as well as the SW Everett Industrial Center. The alignment, as currently shown, would require a small amount of property along the west edge of the airport's Bomarc business park. In addition, one option under consideration for an Operations and Maintenance Facility (OMF), if selected, would have a small impact a vacant parcel of airport property at the SE corner of Airport Road & 100th. The facilities that Sound Transit is currently studying do not have impact on any runway approaches, Runway Protection Zones (RPZ's), or cause any other penetrations to airspace.

4.2.4 Air Cargo Facilities

As of fall 2021, FedEx acquired the lease for the Boeing Dreamlifter Operation Center. FedEx will occupy the 68,745-square-foot facilities as well as the aircraft ramp and parking lot, a total of 19 acres.

A new daily Boeing 757 Freighter flight will operate Monday through Friday between PAE and the FedEx Express World Hub in Memphis, Tennessee. The exact timing of this daily flight was undetermined at the time of the document. Additional air cargo facility needs will be based on future discussions with FedEx. At the time of this report, FedEx has not shared any details on future anticipated facility needs and annual tonnage numbers.

4.2.5 Aviation Support Facilities

The future facility needs for the aviation support facilities are summarized in this section.

Summary of Aviation Support Facility Requirements

- The current deicing positions will require expansion
- The location and staffing of the existing Aircraft Rescue and Firefighting (ARFF) facility is sufficient through the planning period
- General Aviation (GA) facilities will require expansion as the number of based aircraft expands from 563 to 654.
- Airport Support facilities, including Administration and Maintenance are both currently exploring new facilities. The new sites should be sufficient through the planning period.

- Various segments of the 100th St. SW will require improvements to maintain an acceptable level of service
- The intersection of 100th St. SW and Airport Road will require major changes in order to maintain an acceptable level of service

4.2.6 Future Technology

A new era of aviation technology is in developing phases such as electric planes, vertical take-off and landing electrically powered aircraft and urban air mobility. The Master Plan 2040 will consider potential land reservations to accommodate these emerging land uses.

Table 4-2 Summary of Facility Requirements

Facility	Existing	PAL 1 (1.0 MAP)	PAL 2 (1.5 MAP)	PAL 3 (4.3 MAP)
Passenger Terminal Facilities				
Total Building Area (sf)	44,000	46,210	81,480	239,030
• Public/Airline Areas	39,250	36,830	60,400	148,050
• Concession/Support Areas	4,750	9,380	21,080	90,080
Total Aircraft Stands	3	7	7	15
• Contact/Active Gates	3	3	3	7
• Inactive Gates	4	4	4	8
Landside				
Total Passenger Parking Spaces	971	613	921	2,593
• Premium Public Parking	647	328	493	1,398
• Economy Public Parking	308	225	337	950
• Valet Parking	60	60	90	255
Curb Length (Shared ¹) (sf)	518	518	1,043	2,394
Support Facilities				
Deicing Positions	3 (On-Gate)	3 (On-Gate) 2 (Central)	3 (On-Gate) 2 (Central)	7 (On-Gate) 4 (Central)
Commercial Fuel ² (JET A Gallons)	6 Tanks 360,000	2 Tanks 98,000	3 Tanks 128,000	6 Tanks 310,000
General Aviation Fuel (100L Gallons)	20,000	18,096	18,668	19,968
Air Cargo	-	Land Reservation to Support Future Growth		
Aircraft Maintenance (MRO)	350,000	Apron Reservation to Support Future Growth		
Aircraft Rescue and Firefighting (ARFF)	1 Station	Existing Facility Meets Demand		
Airport Support (sf)				
▪ Administration Building	14,543	12,329	13,599	26,558
▪ Maintenance Building	24,064	24,677	31,006	37,461
Flight Catering Building (sf)	-	2,045	3,128	9,111
General Aviation (sf)				
▪ FBO Terminal Building	16,500	17,700	18,300	19,587
▪ T Hangar Building	356,100	356,100	388,800	435,800
▪ Box Hangar Building	384,200	391,000	399,100	419,100
▪ Tie-Down Positions (count)	147	153	158	168
Ground Service Equipment (sf)				
▪ Apron Staging	98,103	98,103	98,103	228,906
▪ Maintenance and Storage	2,150	2,150	2,150	5,380
Police Building (sf)	1,652	2,500	2,811	6,226

¹ Assumes arrivals and departures share the same curb

² Assumes 2-day fuel reserves to serve commercial terminal only, utilizing existing 60,000 sf tanks

Source: Landrum & Brown

4.3 Airfield

The airfield requirements and compliance with FAA standards are exemplified in the following sections:

- Airfield Capacity Analysis
- Runway Length Analysis
- Airfield Safety Areas
- Runway Exits
- Airfield Design Standards
- Meteorological Conditions
- Airspace

4.3.1 Airfield Capacity Analysis

An airfield capacity analysis was conducted to evaluate the capacity of the existing airfield configuration and to determine if it will meet the forecast peak period demand over a 20-year planning horizon time and maintain an acceptable level of average delay per aircraft. The section below summarizes the methodology and conclusions from the airfield capacity analysis. Refer to **Appendix C** for additional detail and the range of scenarios used to assess the capacity of the existing airfield.

4.3.1.1 Methodology

To conduct the airfield capacity and delay analysis, SIMMOD fast-time simulation model was used in lieu of using the standard methodology for assessing capacity and delay as prescribed by the FAA in Advisory Circular (AC) 150/5060-5, *Airport Capacity and Delay*. Using simulation provides more flexibility to assess other operational variables that the FAA formulaic methodology is not equipped to assess. The following basic metrics were used in the simulation analysis:

- Simulate the south flow runway operating configuration as this is the primary operation at PAE
- Runway 16L-34R (3,004 ft. x 75 ft.) is a visual runway which serves small GA piston aircraft
- Runway 16R-34L (9,010 ft. x 150 ft.) is an air carrier runway which serves large jet aircraft
- GA traffic primarily operates on Runway 16L-34R and offloads to Runway 16R-34L when necessary
 - GA arrivals and departures primarily on Runway 16L-34R, however offload to Runway 16R-34L when demand peaks
 - Mixed use runway operation airspace separation (Runway 16L-34R) – three miles between arrivals to fit one departure in between
- Mixed use runway operation airspace separation (Runway 16R-34L) – 4.5 miles between arrivals to fit one departure in between. Increased separation due to jet aircraft and increased approach speeds.

4.3.1.2 20-Year Aviation Demand Forecast

The approved 20-year aviation demand forecast for PAE, and the design day flight operations were used as the basis for simulating aircraft movements in SIMMOD. Each demand level was evaluated to identify the peak hour capacity and average aircraft delays associated with the forecast demand levels.

Table 4-3, 20-Year Aviation Demand Forecast, provides a summary of the four primary simulated demand years and demand levels.

Table 4-3 20-Year Aviation Demand Forecast

Demand	2019	PAL 1	PAL 2	PAL 3
Annual Demand	137,995	148,473	155,028	187,303
Daily Demand	711	769	800	924

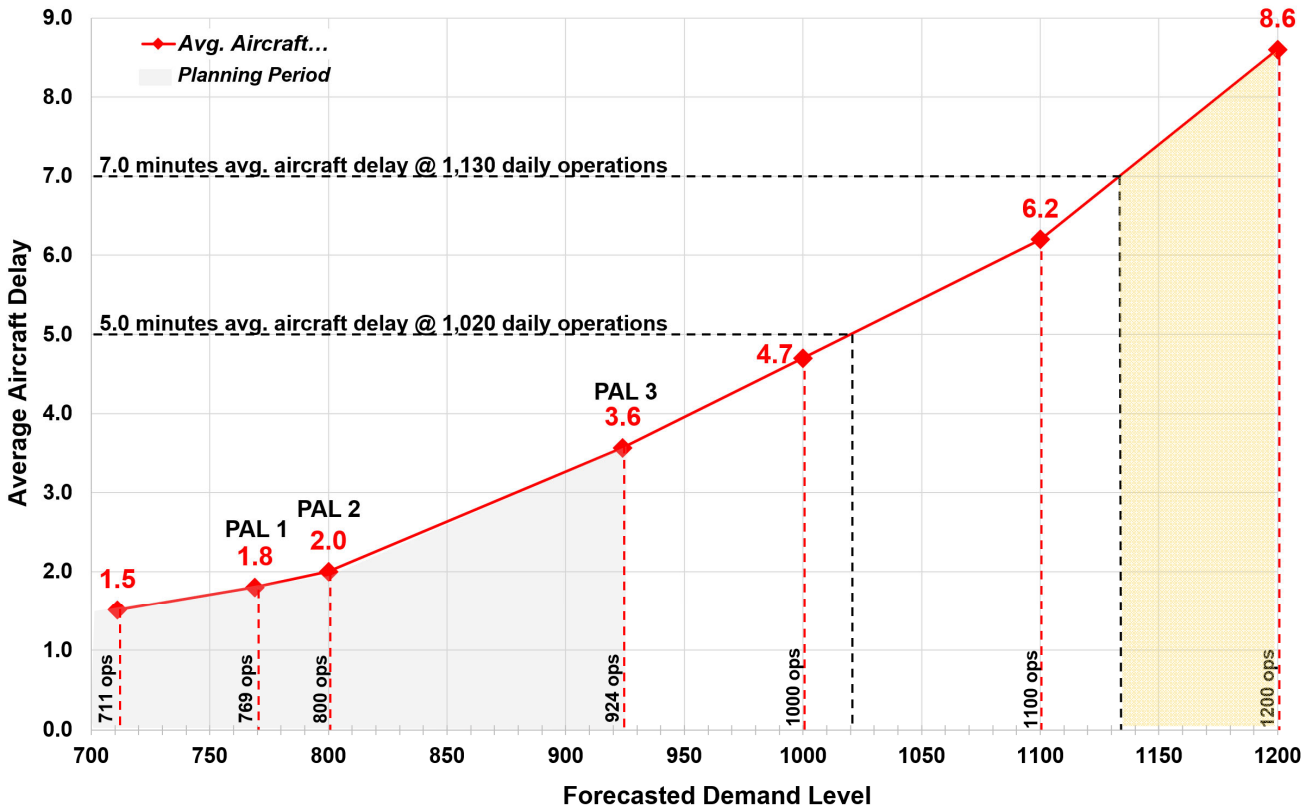
Source: Landrum & Brown

4.3.1.3 *Simulated Demand Levels*

Exhibit 4-1, Simulated Average Aircraft Delay, summarizes the simulated demand levels and the associated levels of average aircraft delay per operation. The results for the four demand years were processed, and it was determined that the average aircraft delay per operation did not exceed the 5.0-minute level of acceptable delay by the end of the 20-year planning timeframe. Therefore, it is assumed the existing airfield system at PAE can accommodate additional aircraft operations beyond the 907 daily operations forecasted in 2040.

Three additional simulation experiments were evaluated to assess the capacity and delays at demand levels beyond 907 daily operations. Simulation experiments assuming 1,000, 1,100, and 1,200 daily operations were conducted. The results indicate that at 5.0 minutes of average aircraft delay, the existing airfield can accommodate approximately 1,020 daily operations. At 7.0 minutes of average aircraft delay, the existing airfield can accommodate approximately 1,130 daily operations. It is estimated the maximum practical airfield capacity at PAE is roughly between **1,020–1,130** daily operations if GA traffic can utilize both runways and growth in commercial aviation traffic increases gradually rather than exponentially. Demand levels beyond the maximum practical capacity will result in excessive levels of delay that may not be acceptable to the airport operators or the aviation community which operates at PAE.

Exhibit 4-1 Simulated Average Aircraft Delay



Source: Landrum & Brown

The annual service volume for each runway operation was computed using the formula from the FAA as listed in AC 150/5060-5, *Airport Capacity and Delay*. It is estimated the annual service volume for PAE, assuming no delay, is approximately **267,500** operations annually.

Assuming an acceptable level of average aircraft delay between 5.0 - 7.0 minutes the ASV increases to **294,000** annual operations. To better understand the ability of the existing airfield to meet the projected demand in the 20-year planning timeframe, the percentage of runway capacity utilized was computed as summarized in **Table 4-4, *Estimated Airfield Capacity Utilization***.

Table 4-4 Estimated Airfield Capacity Utilization

Forecast Year	Forecast Annual Demand	% of Existing Runway Capacity Utilized (ASV)	% of Existing Runway Capacity Utilized (ASV with Delay)
2019	133,668	50%	45%
2025	147,174	55%	50%
2030	153,474	57%	52%
2040	185,171	69%	63%

Source: Landrum & Brown

4.3.1.4 Conclusions

The results of the simulation analysis indicate that PAE has enough runway capacity to accommodate future growth well beyond the 20-year planning timeframe.

The distribution of aircraft operations for both runways at PAE will likely change when demand grows, specifically when passenger commercial aviation activity increases. Mixing slower moving GA aircraft into the traffic stream with faster moving jet aircraft presents operational restrictions, increased air traffic management workload, and increased separation requirements which ultimately will impact runway capacity and delays.

To improve operational efficiency at PAE, the following airfield infrastructure is recommended

- Airfield taxilane/taxiway improvements for improved traffic flow, and
- High-speed runway exits taxiway improvements to reduce occupancy times.

4.3.2 Runway Length

To understand the adequacy of the runway length on Runway 16R-34L at PAE throughout the planning period, a runway length analysis was performed. The 2040 future fleet mix was used to evaluate the runway length needs for Runway 16R-34L. The use of this projected future fleet ensures the runway system will be capable of accommodating the aircraft users through the forecasted planning period (2040).

Takeoff and landing length requirements were calculated following the recommended guidance in FAA AC 150/5325-4b, *Runway Length Requirements for Airport Design*. These guidelines establish the process and considerations to assess existing runways and determine adequate runway length recommendations at a future planning level. It should be noted that the results of these calculations can differ from more detailed analysis that aircraft operators are capable of performing.

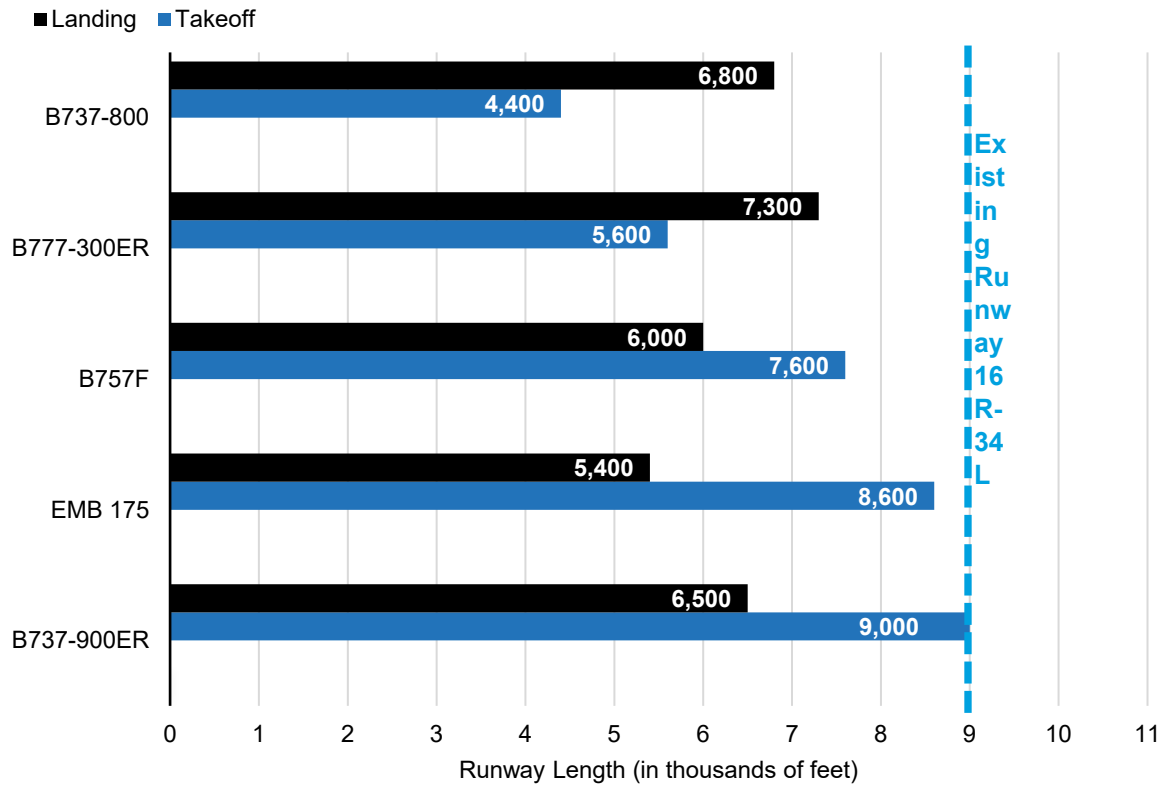
The more detailed calculations are often based on aircraft operational manuals and specific airline procedures. An analysis of the runway length requirements is provided in **Appendix D**.

4.3.2.1 Summary and Recommended Runway Length

The longest runway length requirement is the takeoff requirement for the B737-900ER. This aircraft depicts a runway length requirement of 9,000 feet taking 100 percent passenger payload and up to 8,000 pounds of cargo payload to Chicago O'Hare International Airport (ORD). All other takeoff and landing length requirements for aircraft above 500 annual operations are less than 9,000 feet. All takeoff and landing length requirements are summarized in **Exhibit 4-2, Summarized Runway Length Requirements**.

The critical aircraft for runway length at PAE is the B737-900ER with a destination to ORD through the forecasted planning period. According to the aviation activity forecast this aircraft is the most critical aircraft traveling the furthest destination that made up at least 500 operations annually in the future fleet mix per FAA AC 150/5000-17, *Critical Aircraft and Regular Use Determination*.

Exhibit 4-2 Summarized Runway Length Requirements



Note: The B737-900ER needs 9,000 feet of runway to takeoff with a full passenger load and can also accommodate around 8,000 pounds of additional belly cargo.

Source: Landrum & Brown

4.3.3 Airfield Safety Areas

There are three primary safety areas that provide for the safety of aircraft arriving and departing from the runways at an airport. These safety areas include the Runway Protection Zone (RPZ), Runway Safety Area (RSA), and Runway Object Free Area (ROFA).

The FAA prescribes the criteria to which each safety area must be maintained clear and what uses/objects are and are not allowed to exist within each. The following subsections evaluate each at PAE.

4.3.3.1 Runway Protection Zones (RPZ)

The RPZ's function is to enhance the protection of people and property on the ground. This is best achieved through airport owner control over RPZ. Control is preferably exercised through the acquisition of sufficient property interest in the RPZ and includes clearing the RPZ areas (and maintaining them clear) of incompatible objects and activities.¹

For the purposes of this analysis, the evaluation of the RPZ was broken into two segments, the extended Object Free Area (OFA) of the runway end (formerly known as the central portion) and the remaining portion of the RPZ (formerly known as the outer portion of the RPZ). The reason for this segmentation was to identify the incompatibilities that affect a direct linear path of an aircraft within the RPZ versus those found outside the extended OFA portion of the RPZ. The following section is simply meant to identify incompatibilities that exist within each portion the RPZ. Draft Advisory Circular 150/5190-4B, *Airport Land Use Compatibility Planning* explains that a compatible land use in the RPZ is a land use that can co-exist with a nearby airport without constraining the safe and efficient operation of an airport by not exposing people living or working nearby to significant noise impacts or hazards. It is advisable for an airport to address any incompatibilities if/when the opportunity arises on a case-by-case basis.

At PAE, the incompatibilities described in the following section most notably relate to the protection of people and property.

Runway 16R

Most of the Runway 16R RPZ is off-airport property, while some portions are included in on-airport property. **Exhibit 4-3** depicts the incompatibilities within the Runway 16R RPZ.

Nodes of transportation and facilities located within each of the two portions of the RPZ are described in the following:

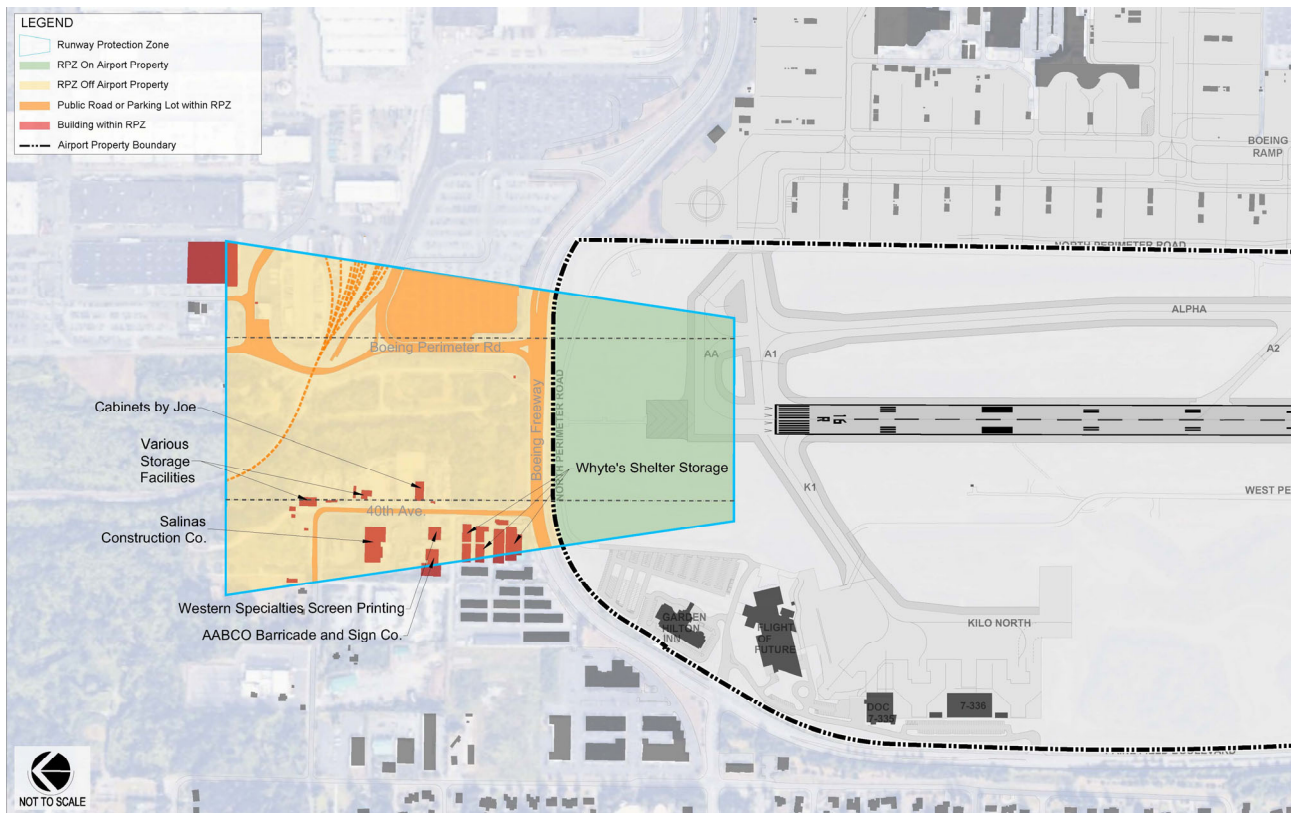
- Extended OFA portion of the RPZ
 - Transportation
 - Portions of Boeing Perimeter Road
 - Boeing Freeway
 - Portions of railway entering Boeing property
 - Businesses

¹ FAA AC 150/5300-13A, *Airport Design*.

- Cabinets by Joe (business)
- Other various storage facilities
- Remaining portion of the RPZ
 - Transportation
 - Portions of Boeing Freeway
 - Portions of 40th Avenue
 - Private Boeing roadways
 - Portions of railway entering Boeing property
 - Businesses
 - AABCO Barricade and Sign Company
 - Boeing
 - Salinas Construction Company
 - Western Specialties Screen Printing
 - Whyte’s Shelter Storage

North Perimeter Road is depicted in the on-airport portion of the Runway 16R RPZ. This road is considered a compatible land use because it can be monitored by PAE and is less frequently used compared to a public roadway. The remaining land uses in the aforementioned list are considered undesirable uses within the Runway 16R RPZ at PAE and should be further evaluated.

Exhibit 4-3 Runway 16R RPZ



Source: Landrum & Brown

Runway 34L

Most of the Runway 34L RPZ is on-airport property, with the exception of the southwest corner. **Exhibit 4-4, Runway 34L RPZ**, depicts the on- versus off-airport property lines within the RPZ, as well as incompatibilities within the Runway 34L RPZ.

Similar to the Runway 16R analysis, nodes of transportation and facilities located within each of the two portions of the RPZ are described in the following:

- Extended OFA portion of the RPZ
 - Transportation
 - Portions of Mukilteo Speedway
 - Businesses
 - Portions of Harbor Pointe Plaza
- Remaining portion of the RPZ
 - Transportation
 - Portions of Mukilteo Speedway
 - Businesses
 - Portions of Harbor Pointe Shopping Center

South Perimeter Road and West Perimeter Road are depicted in the on-airport portions of the RPZ. These are considered compatible land uses and can be monitored by PAE. They are used less frequently compared to a public roadway. The remaining land uses in the aforementioned list are considered incompatible land uses within the Runway 34L RPZ at PAE and should be further evaluated.

Exhibit 4-4 Runway 34L RPZ



Source: Landrum & Brown

Runway 16L-34R

Most of the land within the Runway 16R-34L RPZs are on-airport property. **Exhibit 4-5, Runway 16L-34R RPZ**, depicts the incompatibilities within the Runway 16L-34R RPZ.

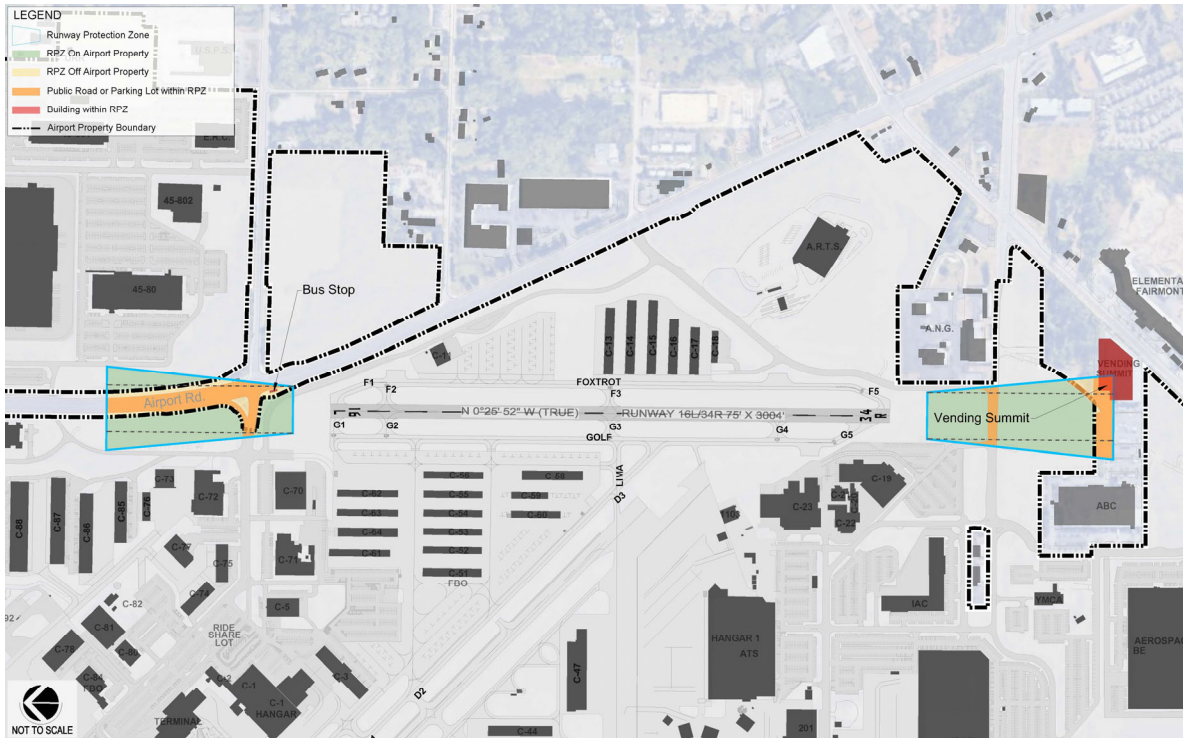
Nodes of transportation and facilities located within each of the two portions of the RPZ are described in the following:

- Extended OFA portion of the Runway 16L RPZ
 - Transportation
 - Portions of Airport Road
 - Small portion of 100th St. SW
 - 100th St. SW Station Bay (SB) bus stop and loading area
- Remaining portion of the Runway 16L RPZ
 - Transportation
 - Very small portion of Airport Road
 - Very small portion of 100th St. SW
- Extended OFA portion of the Runway 34R RPZ
 - Transportation
 - Portions of 112th St.

- Small portion of 100th St. SW
 - Businesses
 - Very small portion of Industrial Plating Corporation
- Remaining portion of the Runway 34R RPZ
 - Transportation
 - Very small portion of 112th St.
 - Very small portion of 100th St. SW
 - Businesses
 - Portion of Industrial Plating Corporation

The public roads and business within the Runway 16L-34R RPZs at PAE should be further evaluated.

Exhibit 4-5 Runway 16L-34R RPZ



Source: Landrum & Brown

Draft Advisory Circular 150/5190-4B, *Airport Land Use Compatibility Planning*, also states that the FAA expects airport sponsors to seek all possible opportunities to eliminate, reduce, or mitigate existing incompatible land uses. Examples may include land acquisition, land exchanges, right-of-first refusal to purchase, agreements with property owners on land uses, easements, or other such measures. FAA recommends anytime there is an update to the Airport Layout Plan (ALP) or Airport Master Plan, these incompatibilities should be evaluated. It is recommended at this time these incompatibilities be further analyzed in **Chapter 5, Concepts and Alternatives**, to come up with a plan to achieve compatibility within the RPZ, where possible.

4.3.3.2 Runway Safety Area (RSAs) and Runway Object Free Area (ROFAs)

FAA AC 150/5300-13A Change 1, *Airport Design*, prescribes the geometric standards for RSAs and ROFAs at airports in the U.S. The RSAs on both runways at PAE follow FAA design standards when it comes to the appropriate sizing of each RSA. Both RSAs for Runway 16R-34L are 250 feet from each side of the runway centerline (500 feet wide) and 1,000 feet beyond the end of the runway. Additionally, the RSAs for Runway 16L-34R measure 60 feet from each side of the runway centerline (120 feet wide) and have 240 feet beyond the end of the runway. The RSAs on both runways at PAE comply with the appropriate sizing and gradient standards as defined by the FAA in AC 150/5300-13B, *Airport Design*. The ROFA width for Runway 16R-34L is 800 feet wide, while the ROFA width for Runway 16L-34R is 250 feet wide. All ROFAs at PAE are also in compliance standards recommended by the FAA.

4.3.4 Runway Exits

The type, location, and number of runway exits depend on many factors including the separation distance of associated parallel taxiways, the length of the runway, any displacement of the arrival threshold, and the mix of the types of aircraft using the runway. The time it takes an aircraft to decelerate to a slow enough speed to exit the runway varies depending on the size and performance characteristics of the aircraft and condition of the runway. If exits are not placed at the point(s) where the majority of aircraft using the runway reach their exit speed, the aircraft must continue down the runway at a relatively low rate of speed until it reaches the next available exit taxiway. Runways with adequate and properly spaced runway exits allow capacity to be optimized by minimizing the runway occupancy times of arriving aircraft.

Generally, a greater number of runway exits are needed for a diverse fleet mix to allow all aircraft to exit the runway at their optimal speed. In addition, acute angled exits (30- and 45-degree exits) provide lower runway occupancy times compared to 90 degree exits. This is because aircraft can exit the runway at higher speeds with acute angled exits, thereby allowing the aircraft to exit the runway sooner.

4.3.4.1 Runway Exit Methodology

Runway exit analysis was conducted for Runway 16R-34L at PAE to evaluate the existing runway exits and identify the best placement of runway exits through the 2040 planning period. The new Version 3 release of the FAA's Runway Exit Design Interactive Model (REDIM) was used to evaluate and optimize the runway exits, as well as determine the average runway occupancy time (ROT) for Runway 16R and 34L arrivals based on the runway exit geometry. The ROT is the length of time required for an arriving aircraft to proceed from over the runway threshold to a point clear of the runway. An average ROT of 50 seconds or less, per commercial jet aircraft operation, is considered high efficiency. The number, type, and location of runway exits influences the ROT for each runway. This new version of REDIM uses real aircraft landing data from 30 major U.S. airports to determine typical landing patterns by aircraft type based on runway length; therefore, ROT results are influenced by factors outside of aircraft performance. These factors include available exits and terminal/parking locations at the analyzed airports and may result in higher ROT results.

REDIM uses a mix of airport specific fixed and variable inputs to perform its analysis. The main inputs include the following:

- Fleet Mix
- Airport Temperature
- Airport Elevation
- Surface Conditions

The aircraft fleet mix is a variable component used in REDIM. For PAE, the aircraft fleet used included the commercial and cargo fleet representative of annual operations through 2040 in the forecast. The aircraft fleet, along with the projected 2040 annual operations are listed in **Table 4-9, REDIM Aircraft Fleet Mix**. Aircraft that fall within the other commercial aircraft category in the forecast were not analyzed in the runway exit model for the following reasons:

- Most aircraft in the other commercial aircraft category made up less than 0.5 percent of the annual 2040 aircraft fleet² creating little impact to the overall exit analysis.
- Aircraft in the other commercial aircraft category represent aircraft arriving without passengers or belly cargo since they are either Boeing test flights or MRO traffic arriving for maintenance. The landing weights and exit locations of these PAE arrivals will vary drastically from what is depicted in REDIM since REDIM uses real aircraft landings carrying passengers and cargo from major airports throughout the US.

Table 4-9 REDIM Aircraft Fleet Mix

Aircraft Name	Aircraft Use	Aircraft Ops	Aircraft Mix Representation
B737-900ER	Passenger	20,753	48.54%
B757F	Cargo	1,248	2.92%
EMB 175	Passenger	20,753	48.54%

Source: Landrum & Brown

PAE explained that Taxiway A5 is used most of the time for south arrivals (predominant north flow), while Taxiway A6 is used the majority of the time in south flow. REDIM indicated minimal if any usage of Taxiway A5 and A6 for exit usage. This tends to be true for exits used by pilots using hard brakes to get off the runway closer to the passenger terminal. REDIM does not consider pilot preference and hard braking in specific cases at this time. While this may be convenient for the pilot of the existing fleet, the future fleet indicates the preference of differing exit locations.

Other general inputs used in REDIM include airport temperature, airport elevation, and surface conditions depicted in **Table 4-10, REDIM General Inputs**. Higher airport elevation results in higher ground speed leading to longer landing distances. The elevation at PAE is roughly 607 feet above sea level (ASL) and is not considered high enough to make a significant impact on landings. Similarly, a

² The B737-800 in the other commercial aircraft category made up 1.9% of the annual fleet, however, was not analyzed since it would perform similarly to the B737-900 on landings and exit location in REDIM.

higher airport temperature leads to lower air density and decreased aircraft performance resulting in increased ROT. At PAE, the mean max daily temperature is 73 degrees. Additionally, surface conditions affect the landing performance of aircraft. A wet runway results in increased rolling distances and more conservative ROT times than dry runway conditions.

Table 4-10 REDIM General Inputs

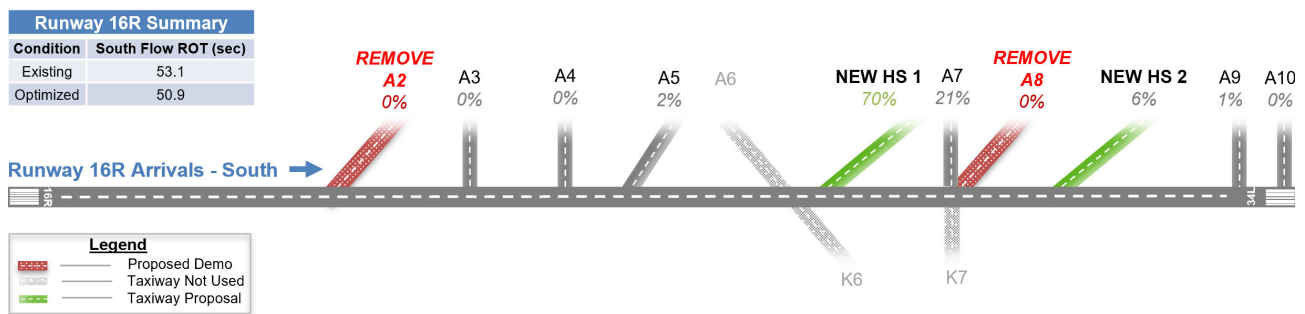
General Inputs	
Airport Elevation	607 ft
Airport Temperature	73°F
Surface Conditions	86% Dry, 14% Wet

Source: Landrum & Brown

4.3.4.2 Runway Exit Results

The Runway 16R arrivals were analyzed in REDIM for both the existing taxiway alignment and then the program was run in multiple iterations to determine optimized taxiway locations based on the inputs discussed in the methodology section. The most efficient and operationally viable exit options are depicted in **Exhibit 4-6, Runway 16R REDIM Results**.

Exhibit 4-6 Runway 16R REDIM Results



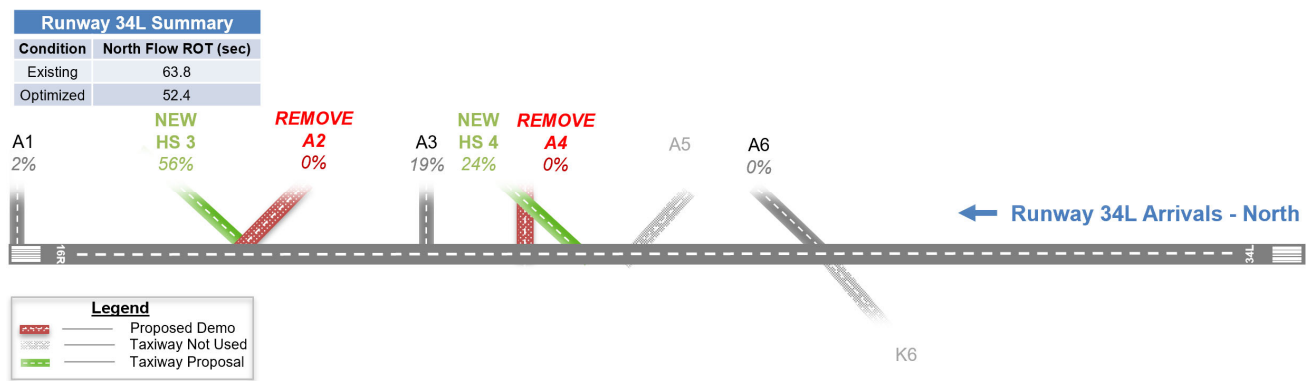
Source: Runway Exit Design Interactive Model V3 (REDIM-V3). Landrum & Brown

The results from REDIM and analysis conducted indicate the removal of two runway exits on Runway 16R. Taxiway A2 is recommended to be removed due to its lack of use being located so close to the Runway 16R threshold. This runway exit will also be removed to make room for a new high-speed runway exit further discussed in the Runway 34L REDIM results shown in **Exhibit 4-7, Runway 34L REDIM Results**. Additionally, Taxiway A8 that connects with Taxiway A7 is recommended for removal, as well. Taxiway A7 is recommended to stay, as it is used as the predominant connector taxiway to the southwest side of the airfield and is needed throughout the planning period. The removal of Taxiway A8 would allow for a more efficient high-speed taxiway (30-degree exit) that would better accommodate the majority of the fleet in the latter parts of the planning period through 2040, as well as eliminate any pilot

confusion when exiting at Taxiway A7 or for aircraft crossing at Taxiway A7. Fewer intersections between runway exits and the runway pose fewer hazards on the airfield. New High-Speed Exit 2 (HS 2) would only accommodate six percent of the 2040 fleet exiting the runway but is considered a replacement exit for Taxiway A8 and decreases the ROT on Runway 16R to under 51 seconds. These exits should be further analyzed **Chapter 5, Concepts and Alternatives**.

The Runway 34L arrivals were analyzed in REDIM for both the existing taxiway alignment and then the program was run in multiple iterations to determine optimized taxiway locations based on the inputs discussed in the methodology section. The most efficient and operationally viable runway exit options are depicted in **Exhibit 4-7, Runway 34L REDIM Results**.

Exhibit 4-7 Runway 34L REDIM Results



Source: Runway Exit Design Interactive Model V3 (REDIM-V3). Landrum & Brown

The results from REDIM and the consultant’s analysis indicate the removal of two runway exits on Runway 34L. Taxiway A2, as mentioned in the Runway 16R REDIM results is recommended to be removed for multiple reasons previously discussed, however, is depicted in **Exhibit 4-7, Runway 34L REDIM Results**, to portray its co-location with New High-Speed Exit 3 (HS 3). Taxiway A2 is recommended for removal at the end of its pavement life or prior to the construction of HS 3, whichever comes first. Additionally, Taxiway A4 is recommended for removal due to its proposed location to New High-Speed Exit 4 (HS 4). Proposed HS 3 (used 56 percent of the time) and HS 4 (used 24 percent of the time) could be used by the majority of the fleet on roughly 80 percent of the landings. Both exits are proposed 30-degree exits decreasing the overall Runway 34L ROT by over 10 seconds (down to 52.4 seconds). These exits should be further analyzed **Chapter 5, Concepts and Alternatives**.

The proposed improvements provide an improved ROT condition for Runway 15R/34L. Additionally, the exact locations of the high-speed exits must consider the existing airfield geometry and their ability to provide capacity improvements, while improving non-standards airfield elements. The exact timing of these projects should be evaluated as PAE grows in commercial activity and optimization of the runway exits are ready for additional planning.

Runway 16L-34R was not analyzed using REDIM, as the capacity of the GA runway is not in question. Runway 16L-34R depicts adequate taxiways for a GA runway of its size. The runway includes one to

two runway exits on each side in both the north and south direction with one central connecting taxiway, which is centrally located.

4.3.5 Airfield Design Standards

Airfields are designed in accordance with the FAA guidelines and requirements at the time of construction as described in FAAAC 150/5300-13A Change 1, *Airport Design*, and based on the size of the aircraft expected to operate at an airport. Airfield design requirements for PAE were determined by evaluating the current airfield geometry and comparing it to the most recent FAA airport design standards.

4.3.5.1 Critical Aircraft

The critical aircraft determines the applicable design standards for facilities on PAE including runways, taxiways, and other facilities. FAA Advisory Circular 150/5000-17, *Critical Aircraft and Regular Use Determination*, defines a critical aircraft as the most demanding aircraft type, or grouping of aircraft with similar characteristics, that makes regular use of PAE. Regular use is at least 500 annual operations, including both itinerant and local operations but excluding touch-and-go operations.

The FAA classifies critical aircraft by three parameters for the purpose of airport geometric design:

- Aircraft Approach Category (AAC): classified according to aircraft approach speeds.
- Airplane Design Group (ADG): defined by its wingspan and tail height, whichever is most restrictive.
- Taxiway Design Group (TDG): based on the dimensions of the aircraft undercarriage.

Different aircraft types may represent the critical aircraft for separate design components of PAE. In terms of airfield design criteria, the airfield at PAE is split between the east side (small GA side) and the west side (business jets, as well as narrow- and wide-body aircraft side). The east side uses Runway 16L-34R and its associated taxiways, while the west side uses Runway 16R-34L and its associated taxiways. The critical aircraft components are depicted in **Table 4-11, Future Critical Aircraft Components**, for PAE. The table defines the critical aircraft for each airfield design component at PAE based on the forecasted aircraft fleet through 2040.

Table 4-11 Future Critical Aircraft Components

Critical Aircraft Design Component	Future Critical Aircraft
General Airfield Components	
Aircraft Approach Category (AAC)	West Side: B777-300ER ¹ (AAC – D) East Side: Piper PA-42 (AAC – B)
Airplane Design Group (ADG)	West Side: B777-300ER ¹ (ADG – V) East Side: Piper PA-42 (ADG – I)
Taxiway Design Group	West Side: B777-300ER ¹ (TDG – 6) East Side: Piper PA-42 (TDG-2A)
Runway Components (West Side: Runway 16R-34L)	
Runway Design Code (RDC)	B777-300ER (RDC D-V)
Runway Length	B737-900ER ²
Runway Components (East Side: Runway 16L-34R)³	
Runway Design Code (RDC)	Piper PA-42 (RDC B-I)
Runway Length	Piper PA-42/Beech Baron 58

¹ The B777-300ER is an aircraft found in the other commercial aircraft category of the forecast and makes up roughly 560 annual operations in 2040.

² The B737-900ER has a longer takeoff length in the runway length analysis than the B777-300ER.

³ Critical aircraft runway design components for Runway 16L-34R calculated using existing 2019 AEDT landing report for PAE and project operations for 2030 and 2040.

Source: FAA Advisory Circular 150/5000-17, Critical Aircraft and Regular Use Determination. Landrum & Brown

For the west side of the airfield, the critical aircraft for Aircraft Approach Category (AAC), Airplane Design Group (ADG), and Taxiway Design Group (TDG) is the B777-300ER, which is part of the other commercial aircraft category of the forecast. It is the largest design aircraft that has over 500 operations annually by 2040. For the east side of the airfield, the critical aircraft for Aircraft Approach Category (AAC), Airplane Design Group (ADG), and Taxiway Design Group (TDG) is the Piper PA-42.

The critical aircraft for runway length differs from that of the general airfield components. The B737-900ER requires a longer takeoff length for Runway 16R-34L, as discussed in the runway length analysis section of this chapter. Additionally, the critical aircraft for Runway 16L-34R is the Piper PA-42.

FAA AC 150/5300-13A Change 1, *Airport Design*, uses a coding system to relate airport design criteria to the operational and physical characteristics of the critical aircraft at an airport.

4.3.5.2 *Runway Design Code*

The FAA uses a Runway Design Code (RDC) to determine the design standards for an individual runway and parallel taxiway. The RDC is based on the airport reference code (ARC) of the critical aircraft and the approach visibility minima of each runway. The critical aircraft with regular use defines the AAC and ADG components of RDC, whereas the runway’s lowest visibility published on an instrument approach chart determines the visibility component. The visibility minima used to help determine the RDC for each runway are in **Table 4-12, *Visibility Minima Definitions***.

Table 4-12 **Visibility Minima Definitions**

Runway Visual Range (in feet)	Flight Visibility Category (statute mile) ¹
5000	Not lower than 1 mile
4000	Lower than 1 mile but not lower than ¾ mile
2400	Lower than ¾ mile but not lower than ½ mile
1600	Lower than ½ mile but not lower than ¼ mile
1200	Lower than ¼ mile

¹ Two other visibility categories include non-precision approach (NPA) which is an instrument approach based on a navigation 1523 system that provides course deviation information, but no glidepath 1524 deviation information. The other visibility category would be a visual approach (V), which is not suitable for Instrument Flight Rules (IFR).

Note: RVR values are not exact equivalents.

Source: FAA AC 150/5300-13A Change 1, *Airport Design*.

Based on the critical aircraft and the recommended approach visibility minimums in Table 2-4, *Instrument Approach Procedures* of **Chapter 2, Inventory**, the future RDC for each runway end is listed in **Table 4-13, Future Runway Design Code (RDC) by Runway End**.

Table 4-13 Future Runway Design Code (RDC) by Runway End

Runway End	Runway Design Code (RDC)
16R	D-V-1200 ¹
34L	D-V-RVR ²
16L	B-I-VIS ³
34R	B-I-VIS ³

¹ Representative of Instrument Landing System Category II (ILS- CAT II (SA)), which would require Special Aircrew and Aircraft Certification. Otherwise, the ILS on Runway 16R requires 18 RVR or 1800 runway visual range in feet.

² Non-Precision Approach, which is an instrument approach based on a navigation 1523 system that provides course deviation information, but no glidepath 1524 deviation information

³ Visual approach meaning it is not suitable for Instrument Flight Rules (IFR) operations

Sources: FAA AC 150/5300-13A Change 1, *Airport Design*. Landrum & Brown

The RDC requirements are presented in **Table 4-14, Runway Design Criteria**, and are based on AC 150/5300-13B, Change 1. The runway dimensional requirements are the same for both D-V categorized RDCs except for the RPZ sizes, which varies by the visibility component.

Table 4-14 Runway Design Criteria

Standard Category	Dimensions (feet)		
	D-V-1200 RWY 16R	D-V-RVR RWY 34L	B-I-V RWY 16L-34R
Runway Width	150	150	60
Runway Shoulder Width	35	35	10
Blast Pad Width	220	220	80
Blast Pad Length	400	400	60
Runway CL to Parallel Taxiway/Taxilane CL	500	500	150
Runway CL to Holding Position	250	250	125
RSA Width	500	500	120
ROFA Width	800	800	240
RSA and ROFA Length beyond Runway End	1,000	1,000	240
RSA and ROFA Length prior to Landing Threshold	600	600	240
Approach RPZ Length	2,500	1,700	100
Approach RPZ Inner Width	1,000	500	250
Approach RPZ Outer Width	1,750	1,010	450
Departure RPZ Length	1,700	1,700	1,000
Departure RPZ Inner Width	500	500	250
Departure RPZ Outer Width	1,010	1,010	450

Note: CL = Centerline; RSA = Runway Safety Area; ROFA = Runway Object Free Area; RPZ = Runway Protection Zone; OFA = Object Free Area.

Source: FAA AC 150/5300-13A Change 1, *Airport Design*.

4.3.5.3 Taxiway Pavement Geometry

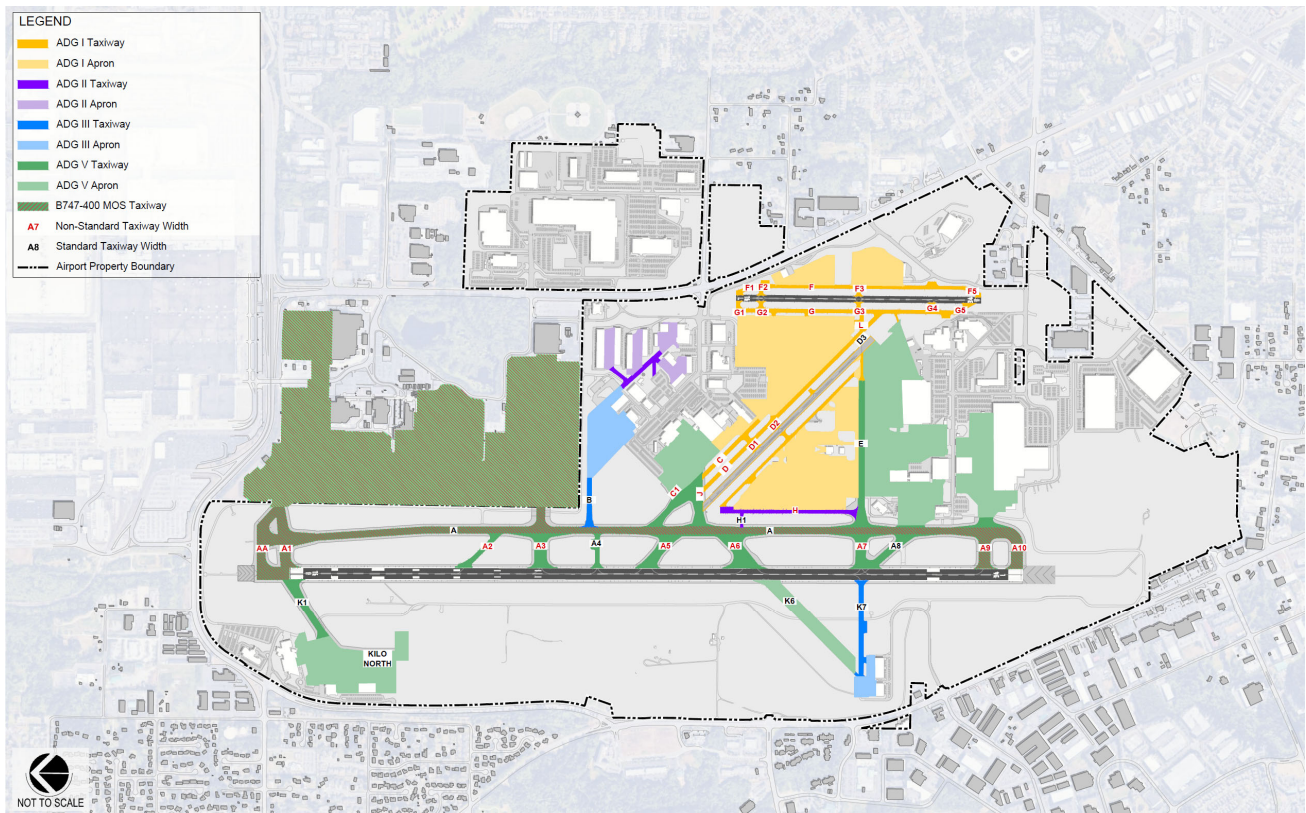
The taxiway geometry at PAE was evaluated to identify the pavement geometrics that do not currently meet the FAA design parameters and are part of recent proposed airfield configuration changes or are considered existing complex geometries. At PAE, the taxiway geometry is broken up into three parts, which include taxiways serving:

- Runway 16R-34L: Offers surrounding taxiway geometry considered ADG-V on the west side of the airfield
- Runway 16L-34R: Offers surrounding taxiway geometry considered ADG-I on the east side of the airfield

- Decommissioned Runway 11-29: Offers centrally located taxiway geometry considered ADG-I, that used to surround decommissioned Runway 11-29

Each taxiway at PAE is color-coded in **Exhibit 4-8, Taxiway Geometry based on Airplane Design Group (ADG)** and depicts the three ADGs represented on the airfield. Some taxiways are non-standard in geometry and identified in red on the exhibit. These taxiways may be larger or smaller than the FAA recommended geometry. Non-standard taxiways should be corrected at the end of their useful pavement life or when a project involving that taxiway is completed.

Exhibit 4-8 Taxiway Geometry based on Airplane Design Group (ADG)



Note: Taxilane E is located outside of a movement area and thus defined as a taxilane instead of a taxiway.
Sources: FAA AC 150/5300-13A Change 1, *Airport Design*. Landrum & Brown

The FAA recommended taxiway design criteria for ADG- I, III, and V are shown in **Table 4-15, Taxiway Design Standards based on Airplane Design Group (ADG)**. It is recommended the west side of the airfield conform to ADG V, while the east side of the airfield may stay at ADG I. Currently, the taxiways located between the east and west sides of the airfield are categorized as ADG III. These taxiways will be reviewed on a case-by-case basis in the alternatives analysis and specific recommendations will be made, where needed.

Table 4-15 Taxiway Design Standards based on Airplane Design Group (ADG)

Standard Category	ADG I (ft)	ADG III (ft)	ADG V (ft)
Taxiway Safety Area Width	49	118	214
Taxiway OFA Width	89	186	320
Taxilane OFA Width	79	162	276
Taxiway Centerline to Fixed or Movable Object	44.5	93	160
Taxilane Centerline to Fixed or Movable Object	39.5	81	138

Note: OFA = Object Free Area.
 Source: FAA AC 150/5300-13A Change 1, *Airport Design*.

Additionally, previous guidance on taxiway design was based only on ADGs.

ADGs are based on wingspan and tail height, but not the dimensions of the aircraft undercarriage. The design of pavement fillets must consider undercarriage dimensions and are considered with the Taxiway Design Group (TDG). Pavement width requirements for taxiing airplanes are based on TDG. The TDG 6 requirements for the west side of the airfield associated with the taxiways at PAE are included in **Table 4-16, Taxiway Design Standards based on Taxiway Design Group (TDG)**. The east side of the airfield meets TDG 1A through 2 requirements. It is recommended that TDG requirements be further evaluated on a case-by-case basis in **Chapter 5, Concepts and Alternatives**.

Table 4-16 Taxiway Design Standards based on Taxiway Design Group (TDG)

Standard Category	TDG 2A (ft)	TDG 6 (ft)
Taxiway Width	35	75
Taxiway Edge Safety Margin	7.5	15
Taxiway Shoulder Width	15	30

Note: OFA = Object Free Area.
 Source: FAA AC 150/5300-13A Change 1, *Airport Design*.

4.3.5.4 Lighting and Navigational Aids (NAVAIDs)

The instrumentation and lighting systems available on a runway determine the ability of an aircraft to land in poor weather conditions. In addition, if there are obstructions to the approach surface of a runway, the minima are increased, which limits the amount of time a runway can be used.

Runway Approach Capabilities

Runway 16L-34R is used only by small GA aircraft. This runway is a visual approach runway, and it is recommended this runway remains a visual runway in the future.

However, Runway 16R-34L is a precision runway on the Runway 16R end and offers satellite approach procedures on the Runway 34L end. **Table 2-4 in Chapter 1, *Inventory*** depicts the existing instrument approach procedures for Runway 16R-34L. Runway 16R offers an instrument landing system (ILS) Category II system for special aircrew and aircraft certification (ILS- CAT II (SA)) which require a minimum ceiling of 100 feet and visibility of 1200 RVR. Additional standard ILS equipment is also available, as well as, satellite-based Area Navigation (RNAV) approaches on both the Runway 16R and 34L ends. RNAV is a method of navigation that permits aircraft operation on any desired flight path within the coverage of ground- or space-based navigation aids, or within the limits of the capability of self-contained aids, or a combination of these. Runway 34L is a non-precision runway but offers a satellite based RNAV Global Positioning System (GPS), which requires a minimum ceiling of 436 feet and minimum visibility of three quarters of a mile (3/4).

At this time, all instrument approaches are considered sufficient and no additional instrument approaches or upgrades are recommended at this time. If landings in south flow became more prevalent, then an instrument approach may be considered on the Runway 34L end.

Runway and Taxiway Lighting

As described in **Table 2-3 of Chapter 2, *Inventory***, runway edge lighting (high intensity) and centerline lighting are both prevalent on Runway 16R-34L and considered adequate throughout the planning period. Additionally, a Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights (MALSR) approach lighting system is located on the Runway 16R end to support the ILS CAT II (SA) approach.

PAE could potentially upgrade the MALSR to an Approach Lighting System with Sequenced Flashing Lights (ALSF-1/ALSF-2) in the future.

Visual slope indicator lights are located on both Runway 16R and 34L ends in the form of a set of four-box lights of Precision Approach Path Indicators (PAPI). Additionally, Runway 16L and 34R includes same lights on both sides of the Runway 16L-34R ends with a set of two-bow lights to provide vertical guidance for GA pilots landing on Runway 16L-34R.

Taxiway lighting information was presented in **Table 2-2 of Chapter 1, *Inventory***. The majority of taxiways at PAE have medium intensity taxiway lighting. Although PAE is implementing guard lights at Taxiway AA, A1, A7, A9 and K1, lighting on all taxiways is recommended in the future. Additionally, the runway entrance taxiways do not have in-pavement hold lighting. This is recommended for entrance taxiways at both the Runway 16R and 34L ends. Hold lighting is meant to increase the visibility of a hold line and can help to reduce runway incursions.

4.3.5.5 Modifications of Standards (MOS)

As a condition of receiving federal grants for airport improvements, airports must comply with design standards adopted by the FAA. These standards are necessary for the safety, efficiency, and economy of the national airport system and users. However, when local conditions do not allow an airport to meet standards, the FAA provides a process for airport sponsors to apply for a MOS for airport design standards to maintain an adequate level of safety.

MOS enhance or maintain airfield capacity and efficiency by assuring that aircraft can safely operate when current standards are not met. There are currently two MOS at PAE, detailed below.

The separation distance between Runway 16R-34L centerline and Taxiway A does not meet the runway-to-taxiways separation standards, as defined by FAA AC 5300-13A, *Change 1, Airport Design*. The non-standard section occurs on the north end, near the Runway 16R threshold. On Runway 16R-34L design capability, Aircraft Approach Category (AAC) D – Airplane Design Group (ADG) V (D-V), the FAA standard for runway-to-taxiway separation is 500'. The current separation varies from 500' to 425'. PAE currently has a MOS allowing for the reduced separation.

Additionally, there is a MOS that affects operations on the taxiways when the B747-800 uses the airfield. The taxiways at Paine Field are design group V, however, the B747-800 falls in the design group VI category, as defined by FAA AC 5300-13A, *Change 1, Airport Design*. The MOS allows B747-800 operations on the design group V taxiway system, even though the aircraft exceeds the taxiway design standards.

MOS will be further reviewed and potentially addressed, in the alternatives process, to maintain an adequate level of safety at PAE and comply with FAA design standards.

4.3.5.6 Hot Spots

Hot Spots 1 and 2 at PAE were previously discussed in **Section 2.2.6** in **Chapter 1, Inventory**. This section of the facility requirements chapter discusses the deviation further and provides general recommendations to develop alternatives in **Chapter 5, Concepts and Alternatives**.

Hot Spot #1

The first hotspot (HS-1) is described by the FAA as “Taxiway A between Taxiways A9 and A10 not visible from the ATCT.”³ The airport maintenance facility, east of Taxiway A near the Runway 34L end creates a line of sight (LOS) issue for the Airport Traffic Control Tower (ATCT) coupled with a pavement dip along Taxiway A in the same area.

This indicates the controllers in the ATCT cannot clearly see aircraft moving along Taxiway A on the south side of PAE due east of Runway 34L end. This could cause miscommunication between aircraft entering/exiting the Runway 34L end. The recommendation for HS-1 is to conduct a LOS analysis under ATCT support facility requirements to further evaluate the severity of the LOS issue. Upon identification of the severity of the issue, alternatives should be developed to come up with different options to resolve this hot spot issue in the future.

Hot Spot #2

The second hotspot (HS-2) is described by the FAA as “Aircraft enter Runway 16R full length via Taxiway A1 unless Taxiway AA is specified by ATC.”⁴ This is considered a hot spot due to the confusing geometry associated with the taxiways in the area along with the entry points to the Runway 16R end.

³ FAA Chart Supplement NW, 5 November 2020 to 31 December 2020.

⁴ FAA Chart Supplement NW, 5 November 2020 to 31 December 2020.

PAE is currently evaluating options to mitigate the HS-2, which will be included in the Master Plan when the preferred alternative is selected by PAE.

4.3.5.7 Prevention of Runway and Taxiway Incursions

The FAA defines a runway incursion as “any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and takeoff of aircraft.”⁵ FAA AC 150/5300-13A Change 1, *Airport Design*, provides the following guidance on how to design taxiways and taxilanes in a way that enhances safety by reducing the probability of both runway and taxiway incursions. The FAA recommends specific taxiway and runway intersection layouts to enhance safety on the airfield. Deviations from these standards are common at airports across the country including PAE and are further depicted in **Exhibit 4-9, Deviation of Taxiway Intersection Standards**. Additionally, the alternatives analysis will assess ways to correct these issues. The FAA recommended safety enhancements are identified below along with any deviations on the PAE airfield:

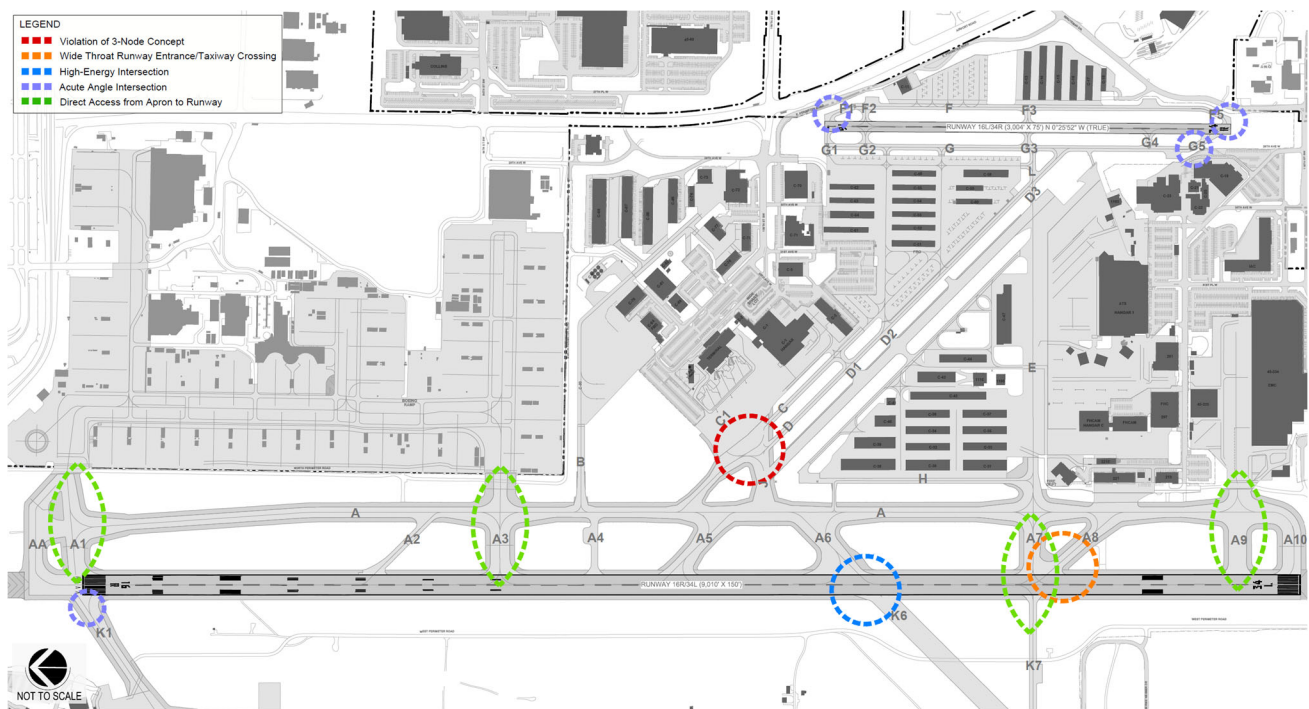
- Keep taxiway systems simple by using the three-node concept. The three-node concept means a pilot should have no more than three choices at an intersection (preferably left turn, right turn, and straight). The taxiway intersection near the terminal ramp where Taxiways C1, C, J, and D all merge depicts an example that violates the three-node concept.
- Avoid wide expanses of pavement with taxiway-to-runway interfaces. For example, a high-speed runway exits and taxiway crossing causing a wide entrance to the runway should be avoided. For example, Taxiway A7 and A8 may present confusion for aircraft exiting the Runway in either direction since the entrance point to both taxiways are connected without an island separating the two. Additionally, aircraft crossing at Taxiway K7 could potentially end up on Taxiway A8 instead of A7 too. Removal of Taxiway A8 to make room for a new high-speed exit is recommended, so this should resolve the wide expanse of pavement concern for this intersection, too. The removal of Taxiway A8 should be further evaluated in **Chapter 5, Concepts and Alternatives** along with its replacement HS exit.
- Reduce the need for aircraft to cross runways and avoid “high-energy” intersections. High-energy intersections are intersections in the middle third of the runway, the portion of the runway where a pilot can least maneuver to avoid a collision is kept clear. Taxiway K6 on the west side should be eliminated, so aircraft do not cross Runway 16R-34L at Taxiway K6 and A6.
- Aircraft on the southwest side of Runway 16R-34L should use Taxiway K7 to access the east side of the runway, while aircraft on the northwest side of the runway should use Taxiway K1. This area is further depicted in **Exhibit 4-9, Deviation of Taxiway Intersection Standards**, as a potential hazard on the airfield.
- Provide right angle intersections (between two taxiways and between a taxiway and a runway). Do not use acute angle runway exits as a runway entrance point or as a runway crossing. There are five instances where this occurs at PAE. All five of these intersections should be further evaluated in Chapter 5, Alternatives. The five instances include:
 - Taxiway K1 at the Runway 16R end

⁵ https://www.faa.gov/airports/runway_safety/news/runway_incursions/

- Taxiway C and A intersection
 - Taxiway D and G intersection
 - Taxiway G5 and Runway 34R end
 - Taxiway F5 and Runway 34R end
- Avoid dual-purpose pavements. Do not use runways as taxiways and vice versa. There are no examples of this at PAE.
 - Do not construct taxiways that lead directly from an aircraft parking apron to a runway without requiring a turn. There are taxiways that connect aircraft parking aprons directly to a runway without requiring the aircraft to perform a turn at PAE. These include:
 - a. Taxiway A1 from the Boeing Apron to the Runway 16R end
 - b. Taxiway K7 and A7 across Runway 16R-34L
 - c. Taxiway A3 from the Boeing Apron to Runway 16R
 - d. Taxiway A9 from the EMC Hangar (Building 45-334) to the Runway 34L end

Please note, alternatives to improve the direct access conditions of Taxiway A3 and A9 will not be explored. Both taxiways have controlled access and no further analysis to improve the condition was required, based on condition with FAA during the Master Plan process.

Exhibit 4-9 Deviation of Taxiway Intersection Standards



Note: Alternatives to improve existing conditions for Taxiway A3 and A9 will not be considered, per discussion with FAA.
 Source: FAA AC 150/5300-13A Change 1, *Airport Design*. Landrum & Brown

4.3.6 Meteorological Conditions

Weather can determine runway orientation and dictate the amount of time a runway can be in use. Periods of low visibility due to weather conditions such as fog or snow are a major factor in determining the need for navigational aids.

4.3.6.1 Temperature

Temperature data for PAE was obtained from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) U.S. Climate Normals Data for the years 1981 to 2010.⁶ On average, August is the hottest month of the year with a mean daily maximum temperature of 72.4 degrees Fahrenheit.

4.3.6.2 Wind Direction and Speed

Wind, cloud ceiling, and visibility were also obtained from the NCEI. The data for this analysis represents the period beginning December 1, 2006 to November 30, 2020, a total of 122,724 observations. The findings of this meteorological review indicate the existing runway alignment provides approximately 99 percent wind coverage for aircraft types with a maximum crosswind component of 10.5 knots in all weather conditions. Therefore, the existing runway layout with dual parallel runways (Runway 16R-34L and Runway 16L-34R) satisfies the recommended 95 percent coverage for airports without the need for a crosswind runway. **Table 4-17, Summary of Wind and Weather Observations**, presents a quantitative summary of the observations utilized in this analysis.

Table 4-17 Summary of Wind and Weather Observations

Weather Categories	Occurrence	Combined Wind Coverage (Runway 16L-34R and Runway 16R-34L)			
		10.5 kts	13.0 kts	16.0 kts	20.0 kts
All Weather	100%	99.3%	99.9%	100%	100%
VMC	86.6%	99.3%	99.9%	100%	100%
IMC	13.4%	99.1%	99.8%	100%	100%

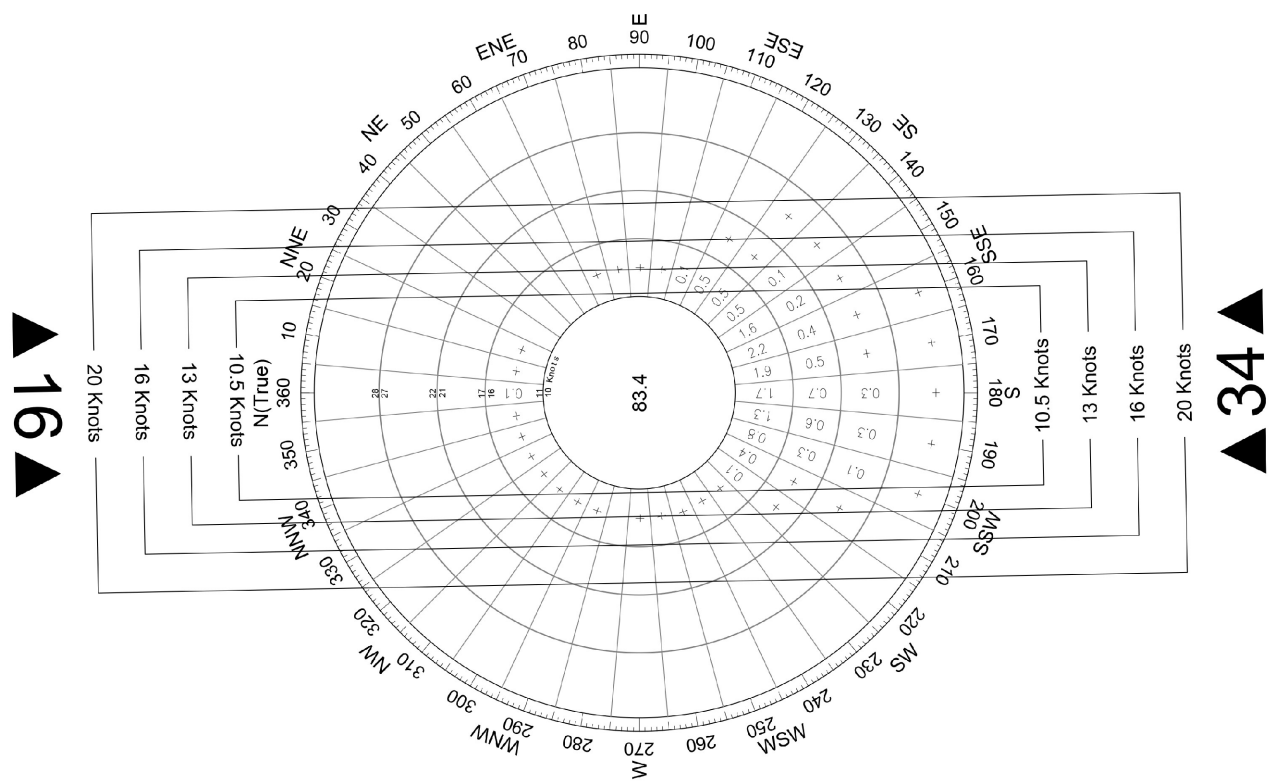
Notes: IMC -instrument meteorological conditions
kts - knots
VMC - visual meteorological conditions
Sources: NCEI; Landrum & Brown

Additionally, a resulting output of this weather analysis is what is known as a windrose. A windrose is a series of concentric circles and radials extending from the center of the circles. Each concentric circle corresponds to a wind velocity, while each radial corresponds to a wind direction. The percentage of observations is then plotted between the circle and radials to indicate the percent of time when that

⁶ Climate Normals are three-decade averages of climatological variables including temperature and precipitation. This product is produced once every ten years. The 1981–2010 U.S. Climate Normals dataset is the most recent release of NCEI’s Climate Normals.

condition occurs. Percentages of less than 0.1 percent are expressed in the windrose with a "+".
Exhibit 4-10, PAE All Weather Windrose, presents the all-weather windrose for PAE.

Exhibit 4-10 PAE All Weather Windrose



Note: Crosswind boxes are shown relative to true north to align with analysis. Runway identifier numbers have been maintained for consistency.

Sources: NCEI; Landrum & Brown

4.3.6.3 Weather Conditions

Independent of wind direction, cloud ceiling and visibility conditions at an airport determine the air traffic control (ATC) procedures in effect. Cloud ceiling is the height above the earth’s surface of the lowest layer of clouds not classified as “thin” or “partial.” Visibility is the ability to see and identify prominent, unlit objects by day and prominent lighted objects at night. Ceiling and visibility may vary with other weather conditions such as cloud conditions, fog, precipitation, and haze.

Visual Meteorological Conditions (VMC) exist when the cloud ceiling is at least 1,000 feet above ground level and the visibility is at least 3 miles. Weather conditions below VMC are defined as Instrument Meteorological Conditions (IMC). There are three different IMC categories – CAT I, II, and III. **Table 4-18, IMC Categories**, describes the ceiling and visibility definitions for each category and the percent time each condition is expected to occur at PAE in an average year. PAE has published approach procedures with Special Authorization (SA) or SA (GPS) approach minimums that require aircrew and aircraft certification. Therefore, the percent of time weather conditions allow approaches to each runway end will vary based on the approved instrument approach.

Table 4-18 IMC Categories

Category	Minima	Percent Occurrence
CAT I	HAT or minimum descent altitude not lower than 200 feet and with either a visibility not less than ½ statute mile or an RVR not less than 1,800 feet ¹	11.1%
CAT II	HAT lower than 200 feet but not lower than 100 feet and an RVR not less than 1,200 feet	1.6%
CAT III	HAT lower than 100 feet, or no HAT and an RVR less than 1,200 feet	0.7%

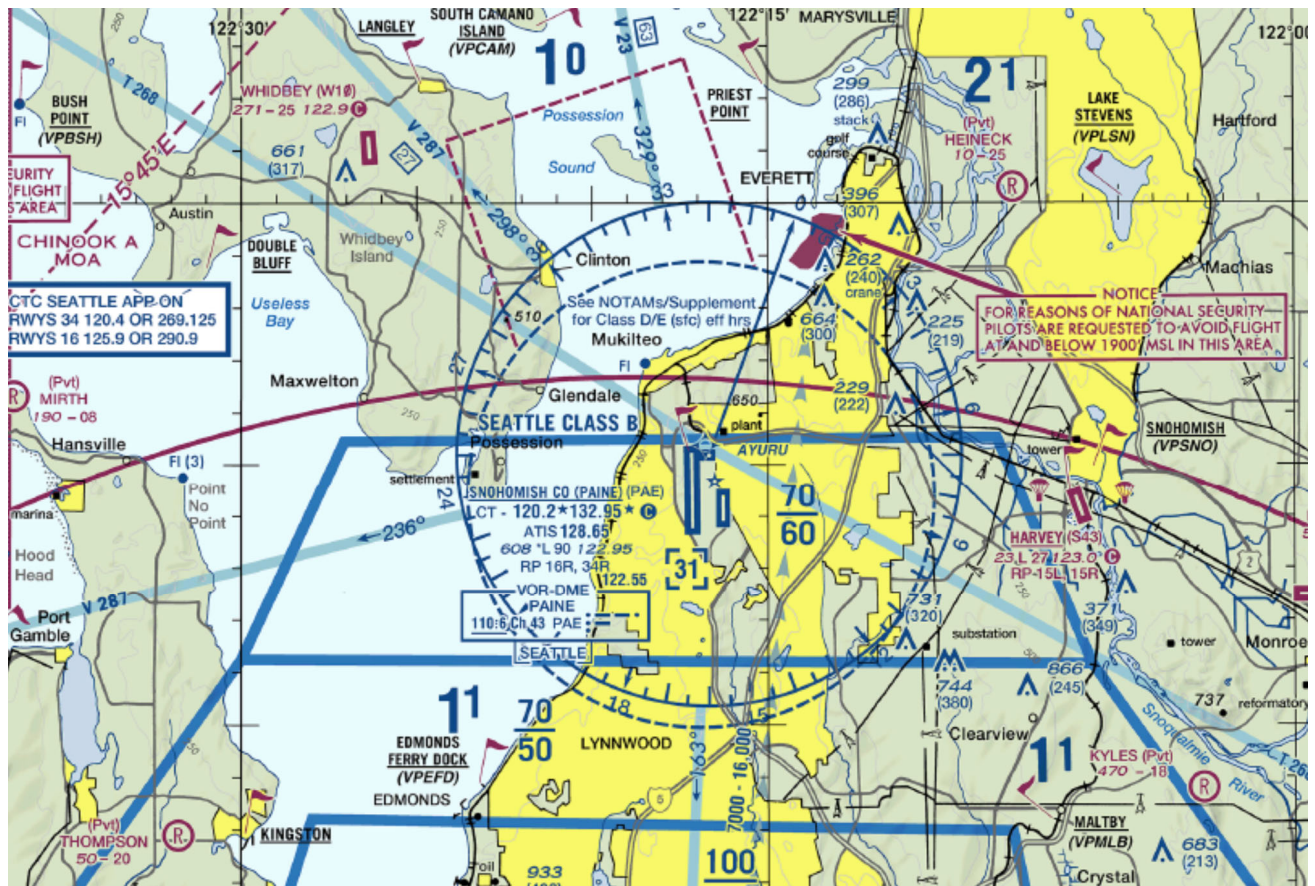
Notes: HAT - height above threshold, RVR- runway visual range
¹ Note this is for a runway with centerline and touchdown zone lighting. Otherwise RVR must be 2,400 ft. Also, special minimums may be established for a particular airport.

Sources: FAA AC 150/5300-13A, Change 1, *Airport Design*, 2/26/2014. NCEI; Landrum & Brown

4.3.7 Airspace

Airspace within the U.S. consists of several airspace levels defined by the FAA. Airspace levels range from Class A through G. The airspace levels are necessary to ensure the safety and separation of aircraft traffic utilizing the country’s airports and airspace. The airspace closely surrounding PAE is classified as part of the Seattle Class B airspace. However, north of the Runway 16R threshold, the airspace turns into Class C (Mode C) airspace. The Class C (Mode C) airspace consists of a 30NM rang surrounding Seattle-Tacoma International Airport (SEA). These airspace boundaries are depicted in **Exhibit 4-11, Surrounding Airspace**.

Exhibit 4-11 Surrounding Airspace



Note: Maroon circle identifies the 30NM Class C (Mode C) airspace surrounding SEA, while the thick blue pentagon identifies the Seattle Class B airspace, which also surrounds PAE.

Source: FAA Seattle Terminal Area Chart (TAC), Effective November 5, 2020 through February 25, 2021

Federal Aviation Regulation (FAR) Part 77, *Objects Affecting Navigable Airspace*, defines criteria for the analysis of obstructions. A primary focus of Part 77 is the establishment of standards for determining obstructions to safe flight in the vicinity of an airport. FAR Part 77 also sets forth requirements for notifying the FAA of certain proposed construction or alternation activities and provides for aeronautical studies of obstructions to air navigation. While it is the responsibility of the FAA to determine the effect of these obstructions on the safe and efficient use of airspace, it is the airport operator’s responsibility to ensure that aerial approaches to PAE remain adequately cleared and protected.

FAR Part 77 defines specific airspace areas around an airport that cannot contain any protruding objects. These airspace areas are referred to as “Imaginary Surfaces.” The dimensions of the Part 77 surfaces vary depending on the type of runway approach. Runway 16R at PAE has an ILS approach and is considered a precision instrument runway, which in turn requires the area to remain clear of obstructions and is larger than for a runway that is only used in visual conditions.

The FAR Part 77 imaginary surfaces for the runways at PAE are defined as follows:

- **Primary Surface (PS)** – Longitudinally centered on the runway at the same elevation as the nearest point on the runway centerline.
The primary surface extends 200 feet beyond the end of each runway. The width of the primary surface depends on the runway type. The primary surface for Runway 16R-34L is 1,000 feet wide to accommodate a precision 50:1 approach on Runway end 16R and 250 feet wide for Runway 16L-34R for the visual 20:1 approach.
- **Transitional Surface (TS)** – Extends outward and upward at a right angle to the runway centerline at a slope of 7:1 from the sides of the primary and approach surfaces. The transitional surfaces extend to where the horizontal surface is intercepted at a height of 150 feet above the airport elevation.
- **Horizontal Surface (HS)** – A horizontal plane located 150 feet above the established airport elevation, covering an area from the transitional surface to the conical surface. The perimeter is derived by swinging arcs from the center of each end of the primary surface and connecting the adjacent arcs by lines tangent to those areas. The radius of each arc is 10,000 feet for all runway ends at PAE.
- **Conical Surface (CS)** – Extends upward and outward from the perimeter of the horizontal surface at a slope of 20:1, for a distance of 4,000 feet.
- **Approach Surface (AS)** – Longitudinally centered on the extended runway centerline, the approach surface extends outward and upward from the end of the primary surface. The slope and dimensions of the approach surface are based on the type of approach on each runway end.

As part of this Master Plan Update, an aerial survey effort conforming to guidelines published in FAA Advisory Circular 150/5300-18B was undertaken. This aerial survey provides the master planning team with data to document penetrations to the Part 77 surfaces. Findings from this aerial survey obstruction analysis is documented in **Table 4-19**.

4.3.7.1 Aerial Survey Obstruction Analysis

Surveyed objects were categorized into manmade and vegetation categories and analyzed in relation to the above described Part 77 surfaces, and Threshold Siting surfaces. On-Airport vegetation penetrations to the surfaces are the most heavily represented obstruction type.

Table 4-19, Airspace Surface Penetrations (Part 77 & Threshold Siting Surface), summarizes the penetrations identified in the survey analysis by type, location, and runway. Various levels of tree removal efforts have been completed by PAE after the aerial survey obstruction analysis was performed. The obstructions that were removed after the aerial survey are not accounted for in the table below.

A more detailed airspace analysis will be conducted as part of the ALP. Penetrations to the surfaces analyzed in the ALP airspace analysis will be identified and considered for mitigation efforts.

Table 4-19 Airspace Surface Penetrations (Part 77 & Threshold Siting Surface)

Description	Off-Airport		On-Airport			Total
	Manmade	Vegetation	Ground	Manmade	Vegetation	
16L-34R	-	11	20	57	81	169
16R-34L	2	98	81	89	1,074	1,344
Total	2	109	101	146	1,155	1,513*

*Total does not account for the trees removed after October 2020.

Notes: 1. Objects that penetrate multiple surfaces are counted for each surface in the table. Total number of unique obstacles may be less than the total number of penetrations reflected in the table.
 2. Pole/light, fence, sign, runway light, building, flagpole, NAVAID, water tower, street sign, utility pole, utility box, windsock, post, hangar, AWOS, pole, and control tower are considered manmade objects in the analysis.

Sources: Quantum Spatial; Landrum & Brown

4.3.8 Airfield Summary

A summary of the airfield requirements and improvements to meet the anticipated demand within the planning period are summarized.

Summary of Airfield Requirements Analysis

- Existing runway system provides sufficient capacity through the planning period
- Existing Runway 16R-34L provides sufficient width and length to accommodate the anticipated fleet mix
- Various safety improvements to resolve non-standard airfield conditions are required
- Airfield taxilane/taxiway improvements to improve traffic flow
- Optimization of Rapid-Exit taxiways (RETs) for Runway 16R-34L
- Further airspace obstruction analysis required to ensure no obstacles or obstructions, on or around PAE, affect aviation safety or operations

4.4 Passenger Terminal Facility

This section includes the facility requirements associated with the terminal building and the associated passenger apron area. Terminal requirements were developed to meet the approved traffic peak hour forecasts presented in **Table 4-20, FAA Approved Aviation Activity Forecast**.

Table 4-20 FAA Approved Aviation Activity Forecast

Forecast	2019	PAL 1	PAL 2	PAL 3
Million Annual Passengers	1.0	1.0	1.5	4.3
Peak Hour				
Two-way	330	330	596	1,368
One-way	198	198	375	920
Peak Hour ATMs				
Two-way	5	5	5	11
One-way	3	3	3	7

Source: Landrum & Brown

Requirements were generated for aircraft parking positions and the primary terminal building components including the departing and arriving areas.

4.4.1 Passenger Aircraft Gate Requirements

Aircraft parking capacity is impacted by several factors including the number of aircraft on the ground at any particular time during the day, the types of aircraft utilizing PAE, and any operating restrictions on the use of the parking positions.

There are two types of parking positions at PAE: 1) parking positions connected to the terminal building, referred to as “contact gates”, and 2) stand parking positions that do not allow for active loading and unloading aircraft parking, referred to as “inactive parking positions.” Inactive parking positions are mainly used for overnight parking at PAE.

The following requirements identifies an “active aircraft”:

- Aircraft on the ground 30 minutes after arrival
- Aircraft on the ground 60 minutes prior to departure

To provide an estimate for the baseline number of aircraft parking positions required at PAE, an aircraft on the ground analysis was conducted using the published flight schedules for the design day for 2019. The time between an arrival and a departure for each aircraft is referred to as the time on the ground. The sum of all aircraft on the ground for each 5-minute bucket across the day is calculated to provide an understanding of how many aircraft are on the ground at any particular time of the day.

The result of the analysis provides an estimate of the number of total required aircraft parking positions. According to the aircraft on the ground analysis, there were three gates required for active use and an additional four gates required for inactive use.

The results of the baseline aircraft on the ground analysis were scaled according to the peak hour aircraft operations forecast. This method assumes that share of aircraft that remain at PAE overnight would remain constant and time on the ground would remain relatively consistent over the forecast period. **Table 4-21, *Parking Position Requirements***, presents the parking position requirements for commercial passenger operations at PAE.

Table 4-21 Parking Position Requirements

Aircraft Code	Existing	2025	2030	2040
Contact Gates	3	3	3	7
Inactive Parking Positions	0	4	4	8
Total Gates	3	7	7	15

Source: Landrum & Brown

4.4.2 Passenger Terminal Building Requirements

Adequate passenger terminal facilities are essential to meeting forecast aviation activity and ensuring adequate levels of service and operational reliability for passengers, airlines, and other business partners. Planning guidelines and assumptions used to determine required passenger terminal facilities are described in the following paragraphs. While the analysis yields an overall building footprint over the planning activity levels, the primary purpose of this exercise is to determine if additional land will be required beyond which already exists within the existing Propeller leased area.

Facilities requirements for the passenger terminal building and aircraft stands were developed using an analytical model developed by Landrum & Brown. The basis for the Landrum & Brown model is planning guidelines published in the International Air Transport Associations (IATA) *Airport Development Reference Manual*; and FAA Advisory Circular (AC) 150/5360-13, *Planning and Design Guidelines for Airport Terminal Facilities*.

The model is supplemented with facilities provided at comparable airports (benchmarks) and knowledge of industry-wide trends in construction of passenger terminals. The model also considers planning and operational input provided by PAE and site observations of existing conditions. For master planning purposes, it is assumed that future terminal facilities will be developed to meet IATA Level of Service (LOS) C. The level of service is a measure of the quality of service provided inside the terminal, in terms of ease of flows and delays. LOS C corresponds to acceptable delays and good levels of comfort.

4.4.2.1 Processing Areas Assumptions

Requirements for passenger terminal buildings were prepared individually for the major functional areas (e.g., departure-related processors or secondary areas). Requirements for the various functions within each major category were based either on the volume of activity (e.g., passengers or baggage) to be accommodated during peak periods or industry-accepted standards and allowances.

Requirements based on activity were derived by mathematically relating the projected peak volume of activity to a number of other variables, including:

- Passenger dwell times and flow rates
- Baggage volumes and flow rates
- Processor sizes
- Maximum allowable queue sizes or times
- Space required per unit of queue
- Space required per unit volume

Assumptions for processing rates, queue length, and spatial requirements were based on IATA LOS C standards. LOS is a measure of the quality of service provided inside the terminal in terms of ease of flow and propensity for delays. LOS C corresponds to a situation of overall good levels of service, where flows are stable, delay levels are acceptable, and a good level of comfort is provided.

Professional judgment was employed throughout the analytical model to reflect conditions local existing conditions. Assumptions for each processor are provided in the following sections.

Passenger processing assumptions are presented in **Table 4-22, *Passenger Terminal Assumptions***.

Table 4-22 Passenger Terminal Assumptions

Terminal Area	Assumption
Check-in	
Passengers	
Ratio of Pax in Business/First Class	10%
Ratio of self-check passengers (kiosks)	70%
Ratio of Passengers Using Traditional Check-in Facilities	10%
Ratio of Passengers Using Home Check-in (Express Check In)	20%
Additional counters to account for schedule changes	15%
Self Service Kiosks	
Process Time per Kiosk (in seconds)	80
Maximum Queuing Time (in minutes)	3
Area required per Kiosk including Queue	50
Bag-Drop	
Process (throughput) Time per Passenger (in seconds)	60
Maximum Queuing Time (in minutes)	5
Traditional Check-in	
Process (throughput) Time per Passenger (in seconds)	90
Maximum Queuing Time (in minutes) y class	20
Maximum Queuing Time (in minutes) j class	5
Security	
Departure Screening	
Standard	75%
TSA Pre	25%
Percentage of Additional Traffic (employees, crew)	10%
Process (throughput) Time per Passenger at Security (in seconds)	24
Maximum Queuing Time (in minutes)	10
Support Areas as percent Security Hall	17%
Baggage Claim	
Average claim device occupancy (in minutes)	30
Length of bag claim exposure to passengers (Linear Feet)	150
Area per incline type unit for Code C	4200
Baggage Drop-off	
Area per unit for Code C (SF)	1650
Gate Lounges	

Common Lounge	
percent of peak hour passengers at lounge	100%
Average area per passenger (SF)	18
Concessions	
Area per million passengers	7000 to 8000
F&B Airside	90%
F&B Landside	10%
Concession Support	
Percentage of total concessions for storage	10%

Source: Landrum & Brown

4.4.3 Terminal Space Program Summary

The gross floor areas presented in **Table 4-23, Terminal Requirements by Planning Activity Level**, includes the processing units as well as the principal terminal areas requirements to meet the forecast demand for the entire planning period. It should be noted that the requirements are programmatic in nature, based on forecasted peak hour volumes at defined planning activity level during the planning period. The program however does not imply a specific design configuration and is intended to be a guideline for future design. It is important to note that the configuration of the facility can have considerable impact on future space needs beyond that which can be determined by analysing the volumes of activity.

The existing terminal area is approximately 44,000 square feet (including the covered but outdoor baggage areas) and satisfies activity levels associated with 2019 demand levels. PAL 1 represents activity levels in the 1 million annual passenger range, which is similar to 2019 traffic levels. To reach PAL 2 it is estimated that some modifications might be needed to accommodate demand at satisfactory levels of service.

By PAL 3, when planning activity levels reach 4.3 million passengers, the terminal will need to expand to approximately 239,000 square feet, or by another 195,000 square feet. It is assumed that at that point in time, additional land will be required for a terminal expansion, additional parking and modified access roads and curbside. All areas of the terminal will need to be expanded to accommodate additional aircraft parking positions and passenger processing.

Table 4-23 Terminal Requirements by Planning Activity Level

Space Designation	2019	PAL 1	PAL 2	PAL 3
	Unit	Unit	Unit	Unit
Combined Check-in (counter area & queue area)				
Full-Service Check-in and Bag Drop Positions	4	4	5	9
Kiosks	4	4	7	16
Outbound Baggage (sorting area w/ 4 cart units)	3	3	4	8
Transfer & Misread inputs	1	1	1	1
Baggage Screening Devices	1	2	2	3
Domestic Baggage Claim				
Number of belts for CAT C	1	1	2	4
Business Class Lounges	-	-	-	2
Passenger Security Screening				
Number of Screening Units - Standard	1	1	2	5
Number of Screening Units - TSA Pre	1	1	1	2
Airline Spaces				
Check-in (counter area & queue area)	-	1,530	2,140	4,200
Airline Ticketing Offices (ATO)	-	120	180	410
Outbound Baggage (sorting area w/ 4 cart units)	-	4,930	6,520	12,850
Transfer & Misread inputs	-	1,600	1,600	1,600
Hold Baggage Screening	-	2,900	3,320	4,840
Baggage Claim Hall area	-	4,240	8,480	16,980
Inbound Baggage Drop-off	-	1,650	3,300	6,600
Baggage Service Offices	-	500	900	2,060
Gate Departure Lounge (common)	-	3,564	6,750	16,560
Business Class Lounges	-	-	-	18,400
Airline Operations	-	1,600	7,500	17,500
Airline Spaces	25,250	22,634	40,690	102,000
Public Spaces				
Check-in Lobby	-	2,000	2,500	4,500
Arrivals Greeters Hall	-	386	731	1,794
Concourse/Circulation Departure Corridor	-	3,243	4,865	19,458
Other	-	8,570	11,620	21,200
Public Spaces	14,000	14,199	19,716	46,952
Concession Space				
	2,750	6,770	15,230	42,820
Terminal Support Spaces				

	2,000	2,610	5,850	47,260
Total Building Area	44,000	46,213	81,486	239,032

Source: Landrum & Brown

4.5 Landside Access and Parking

The following analysis of the ground transportation areas include the capacities and facility needs of the terminal access roads, terminal curb front, and vehicle parking areas.

4.5.1 Airport Access Roads

4.5.1.1 Trip Generation

The peak-hour trip generation calculations have been performed for the planning activity levels. The operation information included the total number of seats and load factors. Additional employment information was not provided, but it was assumed employee trips would account for 10 percent of the passenger generated trips.

Vehicle load factors ranged from 1.5 passengers per vehicle to 2.4 passengers per vehicle, as identified in the 2012 Environmental Assessment.

These same load factors were used to generate low and high trip generation estimates for the three horizon years. The high trip generation estimates were identified as preferred.

The peak-hour trip generation is anticipated to range between 152 trips and 242 trips PAL 1; increasing to between 273 trips and 437 trips serving PAL 2 and between 627 trips and 1,003 trips for PAL 3.

The high, low, and average trip generation estimate are summarized in **Tables 4-24, Peak Hour Trip Generation Estimates (High) Preferred** through **4-26, Peak Hour Trip Generation Estimates (Average)**.

Table 4-24 Peak Hour Trip Generation Estimates (High) Preferred

Planning Level	Seats	Load Factor	Vehicle Occupancy	Passenger Trips	Employee Trips	Total Trip
PAL 1	380	86.9%	1.5	220	22	242
PAL 2	686	86.9%	1.5	397	40	437
PAL 3	1,550	88.3%	1.5	912	91	1,003

Sources: PAE Environmental Assessment, 2019; Century West Engineering

Table 4-25 Peak Hour Trip Generation Estimates (Low)

Planning Level	Seats	Load Factor	Vehicle Occupancy	Passenger Trips	Employee Trips	Total Trip
PAL 1	380	86.9%	2.4	138	14	152
PAL 2	686	86.9%	2.4	248	25	273
PAL 3	1,550	88.3%	2.4	570	57	627

Sources: PAE Environmental Assessment, 2019; Century West Engineering

Table 4-26 Peak Hour Trip Generation Estimates (Average)

Planning Level	Low Trip Generation	High Trip Generation	Average Trip Generation
PAL 1	152	242	197
PAL 2	273	437	355
PAL 3	627	1,003	815

Sources: PAE Environmental Assessment, 2019; Century West Engineering

4.5.1.2 Roadway Impacts

A preliminary roadway analysis was completed for 100th St. SW, west of Airport Road and for the intersection of 100th St. SW at Airport Road. The roadway analysis was performed using information published in the ACRP 40, *Airport Curbside and Terminal Area Roadway Operations* (2010), specifically **Table 4-27, Levels of Service for Airport Terminal Area Access and Circulation Roadways**. The intersection of 100th Street SW at Airport Road was analyzed using the Synchro software.

The Sound Transit Everett Link Extension will give airport employees, tenants, and commercial service passengers another mass transit option of getting to and from the airport. The arrival of the Everett Link will be at the end or slightly outside of this master planning window and was not factored into this traffic analysis. However, it is assumed the arrival of the Everett Link at PAE would have a positive impact on alleviating congestion.

Table 4-27 Levels of Service for Airport Terminal Area Access and Circulation Roadways

Criteria	Level of service				
	A	B	C	D	E
	Free-flow speed = 50 mph				
Minimum speed (mph)	50.0	50.0	50.0	48.9	47.5
Maximum volume/capacity ratio	0.28	0.45	0.65	0.86	1.00
Maximum service flow rate (passenger cars/hour/lane)	550	900	1,300	1,710	2,000
Maximum flow (vehicles/hour/lane) (a)	440	730	1,050	1,380	1,620
	Free-flow speed = 45 mph				
Minimum speed (mph)	45.0	45.0	45.0	44.4	42.2
Maximum volume/capacity ratio	0.26	0.43	0.62	0.82	1.00
Maximum service flow rate (passenger cars/hour/lane)	490	810	1,170	1,550	1,900
Maximum flow (vehicles/hour/lane) (a)	400	650	940	1,250	1,530
	Free-flow speed = 40 mph				
Minimum speed (mph)	40.0	40.0	40.0	39.0	38.0
Maximum volume/capacity ratio	0.26	0.42	0.61	0.82	1.00
Maximum service flow rate (passenger cars/hour/lane)	450	740	1,060	1,400	1,750
Maximum flow (vehicles/hour/lane) (a)	360	600	860	1,130	1,410
	Free-flow speed = 35 mph				
Minimum speed (mph)	35.0	35.0	34.0	34.0	33.0
Maximum volume/capacity ratio	0.26	0.42	0.61	0.80	1.00
Maximum service flow rate (passenger cars/hour/lane)	410	670	980	1,280	1,600
Maximum flow (vehicles/hour/lane) (a)	330	540	790	1,030	1,290
	Free-flow speed = 30 mph				
Minimum speed (mph)	30.0	30.0	30.0	29.6	29.0
Maximum volume/capacity ratio	0.26	0.41	0.60	0.79	1.00
Maximum service flow rate (passenger cars/hour/lane)	370	600	870	1,150	1,450
Maximum flow (vehicles/hour/lane) (a)	300	480	700	930	1,170
	Free-flow speed = 25 mph				
Minimum speed (mph)	25.0	25.0	25.0	24.8	24.0
Maximum volume/capacity ratio	0.25	0.40	0.59	0.79	1.00
Maximum service flow rate (passenger cars/hour/lane)	310	500	740	990	1,250
Maximum flow (vehicles/hour/lane) (a)	250	400	600	800	1,010

mph Miles per hour

(a) Flow rates adjusted to account for 0.95 heavy vehicle factor and 0.85 driver population factor due to occasional or unfamiliar users.

Source: Leigh Fisher, based on information presented in Transportation Research Board, National Research Council, *Highway Capacity Manual*, Exhibits 21-2 and 21-3, December 2020.

The analysis identified as many as approximately 1,000 peak-hour trips along 100th Street SW and the terminal roadways. Table 4-1 from *ACRP 40 Airport Curbside and Terminal Area Roadway Operations* provides maximum service flow rates for different free-flow speeds and different levels of service at airports. The speed limit along 100th St. SW is posted at 15-miles per hour (MPH), but Table 4-1 only provides estimates down to 25-mph. Based on 1,000 peak-hour trips at 25-mph, it would require two lanes in each direction to maintain LOS-C. LOS-C is considered the minimum acceptable level of service for airport roadways with a lack of alternative travel paths or LOS-D. LOS-D is acceptable for roadways with alternative paths in the event the preferred path becomes congested. However, a speed of 15-mph could require 3 to 4 lanes to maintain LOS-C or LOS-D conditions, especially where there are conflicts, such as entrances/exits to/from parking areas, roadway curvature, and the presence of pedestrians. **Exhibit 4-12, *Curbside and Roadway Levels of Service***, depicts the typical levels of service A through E, with LOS-C highlighted as the minimum acceptable service level and is recommended level for this analysis.

Exhibit 4-12 Curbside and Roadway Levels of Service



Note: Computed simulated images designed to mock real world conditions. Generated to support planning level analysis, does not necessary reflect reality.

Source: Century West Engineering

Exhibit 4-13, *Anticipated Levels of Service by PAL*, depicts the LOS of the PAE entrance roads for each Planning Activity Level, assuming no improvements to existing facilities. To maintain a LOS-C, the following areas will require improvements within the planning period:

Curves and Roads Adjacent to Terminal Parking:

- Turnaround curve at end of terminal loop road performs at a LOS-F during the peak in PAL 1
- Entrance to passenger curb drops below a LOS-C in PAL 1

100th St. SW Segment from Terminal Parking to Airport Road Intersection:

- Portions of segment drop below a LOC-C in PAL 1
- Airport exiting traffic from 100th St. SW, approaching Airport Road, performs at LOS-D in PAL 1

100th St. SW and Airport Road Intersection:

- Exit from 100th St. SW, approaching Airport Road, performs at LOS-F in PAL 1
- To maintain an acceptable level of service, the intersection is anticipated to need major changes. Options include the construction of a large roundabout or alternative access scenarios such as a free eastbound right-turning lane or off-site parking and waiting area.

Exhibit 4-13 Anticipated Levels of Service by PAL



Note: Conditions assume no incremental improvements to serve demand
Source: Century West Engineering

4.5.2 Terminal Parking Lots

The analysis includes a review of the facility needs for each of the terminal parking areas at PAE. The terminal parking is intended to accommodate commercial airline service passengers. At PAE, there are three premium parking lots with a total of 971 stalls including three premium lots with 647 stalls, one economy lot with 308 stalls, and one ground transportation lot with 16 stalls. The premium parking lots are the closest to the terminal building and are the most convenient for passengers. These lots provide both short-term and long-term parking.

Based on *ACRP 25 Airport Terminal Planning and Design (2010)*, the number of parking stalls range from 900 to 1,400 stalls per million enplaned passengers, with 25 to 35 percent of those stalls designated for short-term use. Terminal vehicle parking counts for 2019 were compared to baseline enplanements. These data suggested that a standard of 1,200 parking stalls per one million enplaned passengers (0.0012 multiplier) is appropriate at PAE. The multiplier was applied to forecasted enplanements to estimate the number of parking stalls that will be required over the 20-year planning period. By the end of the planning period, approximately 2,593 parking stalls will be needed to satisfy forecasted peak demand. The existing terminal parking capacity is adequate to satisfy forecasted demand through PAL 2, at which time additional parking will be needed to accommodate terminal users. The current premium/economy/valet mix ratio is assumed to be maintained over the planning period and was applied to total terminal parking estimates. Due to limited land available within the terminal area, an on-site parking structure such as a multi-floor parking garage should be evaluated to address parking demand. Anticipated parking needs are summarized in **Table 4-28, Terminal Parking and Curb Requirements Summary**.

In 2020 a ground transportation lot near the terminal was constructed with a drive-through lane with adjacent passenger loading zones to accommodate taxis, hotel and rental car shuttles, and rideshare services. The lot also provides 16 diagonal parking stalls available for passenger pick-ups and drop-offs. These stalls serve as an on-site cell phone lot, as they offer free short-term parking of 10 minutes or less. Parking data for the ground transportation lot is limited, but discussions with Airport staff suggest the 16 stalls are adequate to meet 2019 demand. It is assumed the lot meets 2019 needs, and the demand for this type of parking will grow proportionally with passenger enplanements. Based on those assumptions, additional ground transportation parking will be needed beyond PAL 1 as passenger activity recovers from the current pandemic levels. A total of 68 stalls will be required at the end of the planning period to accommodate the drop-off and pick-up of passengers. Ground transportation parking requirements through the planning period are summarized in **Table 4-28, Terminal Parking and Curb Requirements Summary**.

Parking lots should be designed to enhance passenger safety and minimize walking distances between the lots and terminal building. To increase safety, it is recommended to avoid passengers crossing traffic whenever feasible. Options include constructing elevated or tunneled passenger walkways between parking lots and the terminal building.

Typical terminal planning metrics identifies a maximum walking distance for passengers of 1,000 feet. A distance beyond this should consider utilizing shuttle buses for connectivity. However, parking pricing, physical siting constraints, and privately-owned remote lots should also be considered.

4.5.3 Rental Car Parking

At this time all rental car parking facilities, are located off the Airport property. A dedicated shuttle transports passenger to and from the terminal and rental car facilities.

As such, there is no immediate need for rental car parking at PAE. However, locating at least some rental car providers on the property would have the advantages of increasing passenger convenience and bringing additional revenue to PAE. These considerations are considered in **Chapter 5, Concepts and Alternatives**.

Car rental data were not available for PAE's rental car providers, and a standard method for estimating rental car parking demand is not defined in FAA or ACRP guidance. In lieu of standard methodology, a planning estimate of 0.75 stalls per peak-hour arrival passenger was used to approximate parking demand. Using this metric, an estimated 149 parking stalls would be needed to accommodate all current rental car parking demand. The need would increase to an estimated total of 690 stalls by the end of the 20-year planning period. Rental car parking requirements are summarized in **Table 4-28, Terminal Parking and Curb Requirements Summary**.

It should be noted the above estimates assume that all car rental services would be relocated to PAE. However, it is likely that individual carriers would elect to expand some of their existing operations to the airport property at different times through the planning period. As such, the actual demand for rental car parking on PAE would likely be lower than the estimates provided and would increase as rental agencies elect to offer or increase service on the property.

4.5.4 Terminal Curb Front

The terminal curb front should accommodate a variety of vehicles including private vehicles, ride-share vehicles, taxis, limousines, mass transit buses, potential shuttles from light rail stops, buses for rental cars, lodging and remote lots. Inner lanes of the curb front are used as a short-term parking position, allowing enough time for vehicles to pull in, stop, load or unload passengers and their luggage, and then pull out. Dependent on available curb front length and the number of passengers, it may be required for an airport to have multiple lanes or pedestrian island for loading and unloading of passengers.

PAE has approximately 578 feet of terminal curb front for private and disabled passenger pick-ups/drop-offs and valet service.

ARCP 40, *Airport Curbside and Terminal Area Roadway Operations* guidance provides a method of estimating terminal curb front demand based on peak hour passenger counts, dwell time, and distance required for a vehicle to maneuver at the curb. For the Paine Field terminal, an estimated dwell time of three minutes, and an estimated distance of 35 feet per vehicle were used in calculating required curb space. The calculation resulted in 1.75 feet of curb space needed for each peak-hour passenger. Applying this metric to the forecasted peak hour passenger numbers confirms the existing 578 feet of curb front is sufficient for the current demand. However, the curb will require expansion beyond PAL 1 and require 2,394 feet by the end of the planning period.

Table 4-28, Terminal Parking and Curb Requirements Summary summarizes the terminal parking and curb requirements at PAE.

Table 4-28 Terminal Parking and Curb Requirements Summary

Parking	Criteria	Existing	PAL 1	PAL 2	PAL 3
Total Passenger Parking	1,200 stalls/1M Enplan.	971	613	921	2,593
Premium Lots ¹	53.54% Total Pass. Parking	647	328	493	1,388
Economy Lots ¹	36.64% Total Pass. Parking	308	225	337	950
Valet Parking ¹	9.82% Total Pass. Parking	60	60	90	255
Rental Car Parking	0.75 stalls/PH Pass. (Depart)	-	149	281	690
Ground Transportation Parking	31 stalls/1M Enplanement	16	16	24	68
Terminal Curb Front (Feet)	1.75 feet/PH Pass. (Total)	578	578	1,043	2,394

¹ Mix based on 2019 parking data.
 Source: Century West Engineering

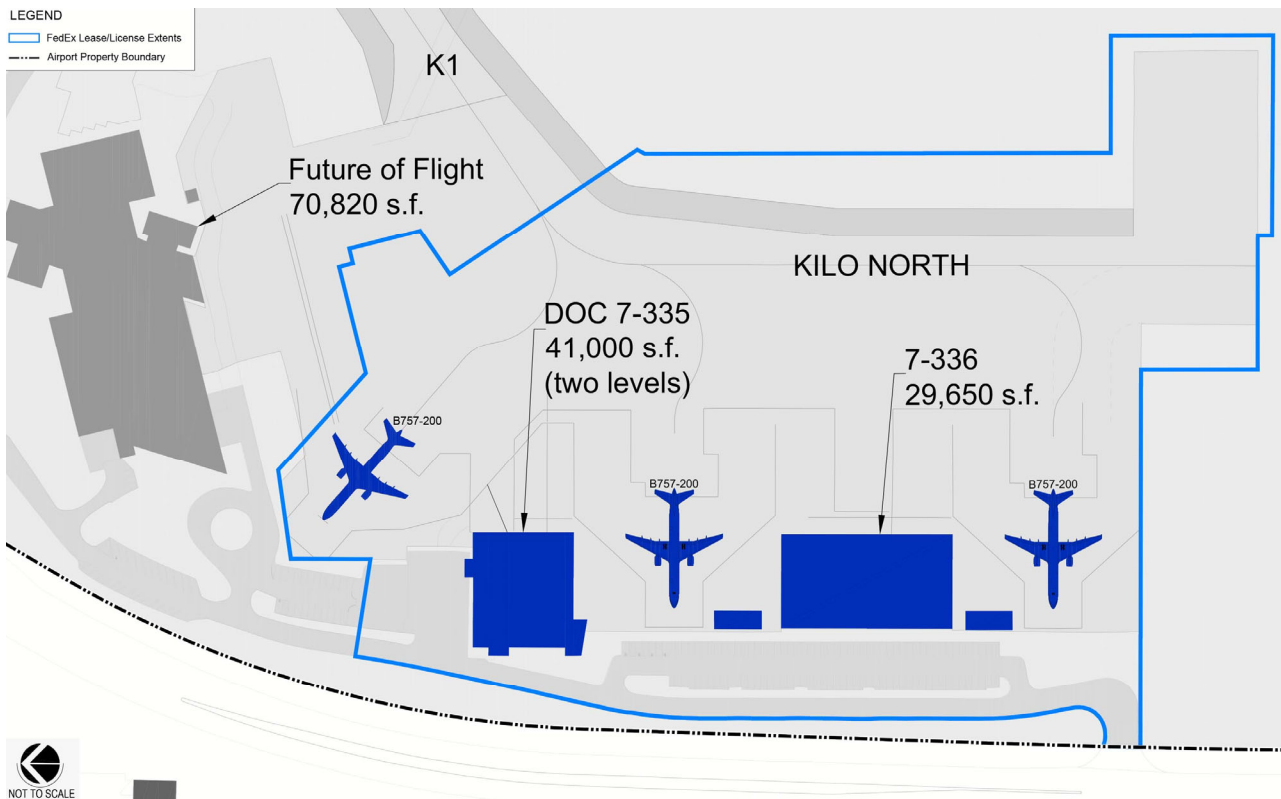
4.6 Air Cargo

Air cargo at PAE is mostly generated by Boeing, shipping aircraft manufacturing parts and assembly program needs. As of the fall of 2021, FedEx acquired the lease for the Boeing Dreamlifter Operation Center. FedEx will occupy the 68,745-square-foot facilities as well as the aircraft ramp and parking lot, a total of 19 acres.

A new daily Boeing 757 Freighter flight will operate Monday through Friday between PAE and the FedEx Express World Hub in Memphis, Tennessee. The site offers three ADG-VI parking positions that will accommodate the anticipated fleet mix and has the ability to accommodate growth in the current footprint. Air cargo facility needs will be based on future discussions with FedEx. At the time of this report, FedEx has not shared any details on future anticipated facility needs and annual tonnage numbers.

Exhibit 4-14, FedEx Lease Area, illustrates how three B757 Freighter could be parked on the FedEx leased area.

Exhibit 4-14 FedEx Lease Area



Note: Building numbers reflect previous nomenclature used by Boeing. Apron is referred to as the Paine Field Ramp (PAER) today.

Source: Landrum & Brown

4.7 Support Facilities

The support facilities are an integral part of the Airport system. Without these support facilities, the servicing of aircraft and processing of passengers would not be possible. This section identifies the future support facilities requirements throughout the 20-year planning period.

Factors such as aircraft size, demand type and passenger and operation volumes are key drivers of these facility requirements. The support facilities discussed in this section have been divided according to the following categories:

- ATCT
- Aircraft Deicing
- Aircraft Fuel
- Aircraft Maintenance – Maintenance, Repair and Overhaul (MRO)
- Aircraft Rescue and Firefighting (ARFF)
- Airport Support
 - a. Airport Administration
 - b. Airport Maintenance
- Flight Catering
- GA
- Ground Service Equipment (GSE)
- Police/Security

The support facility requirements analysis is a foundation for the development of the support facility alternatives process. The methodology and results of these facility requirements are presented in the following sections.

4.7.1 Airport Traffic Control Tower

The ATCT is owned and operated by the FAA. The following section includes a high-level ATCT Shadow Study to examine the ATCT's ability to see the following two areas:

- Hot Spot 1, Located at A9 and A10.
- Entire length of Taxiway E

Controllers in the ATCT are required to see all areas of PAE for which air traffic control services are provided. They can do this either visually or through security cameras. These areas are classified as "movement areas," and encompass the runways and parallel taxiway systems including their associated safety areas. Taxiways, apron areas and hangar areas are considered "nonmovement areas," meaning aircraft movement in these areas is not provided with air traffic control services. Before an aircraft leaves a nonmovement area, it must contact air traffic and receive taxiing instructions.

The ATCT at PAE is located near the midfield of the airfield just to the north of the passenger terminal. The ATCT cab floor finished elevation is located at 162' above grade. The grade at the base of the tower is 593.5' MSL (height above sea mean level).

FAA Order 6480.4B establishes the general siting criteria for all aspects of the ATCS site:

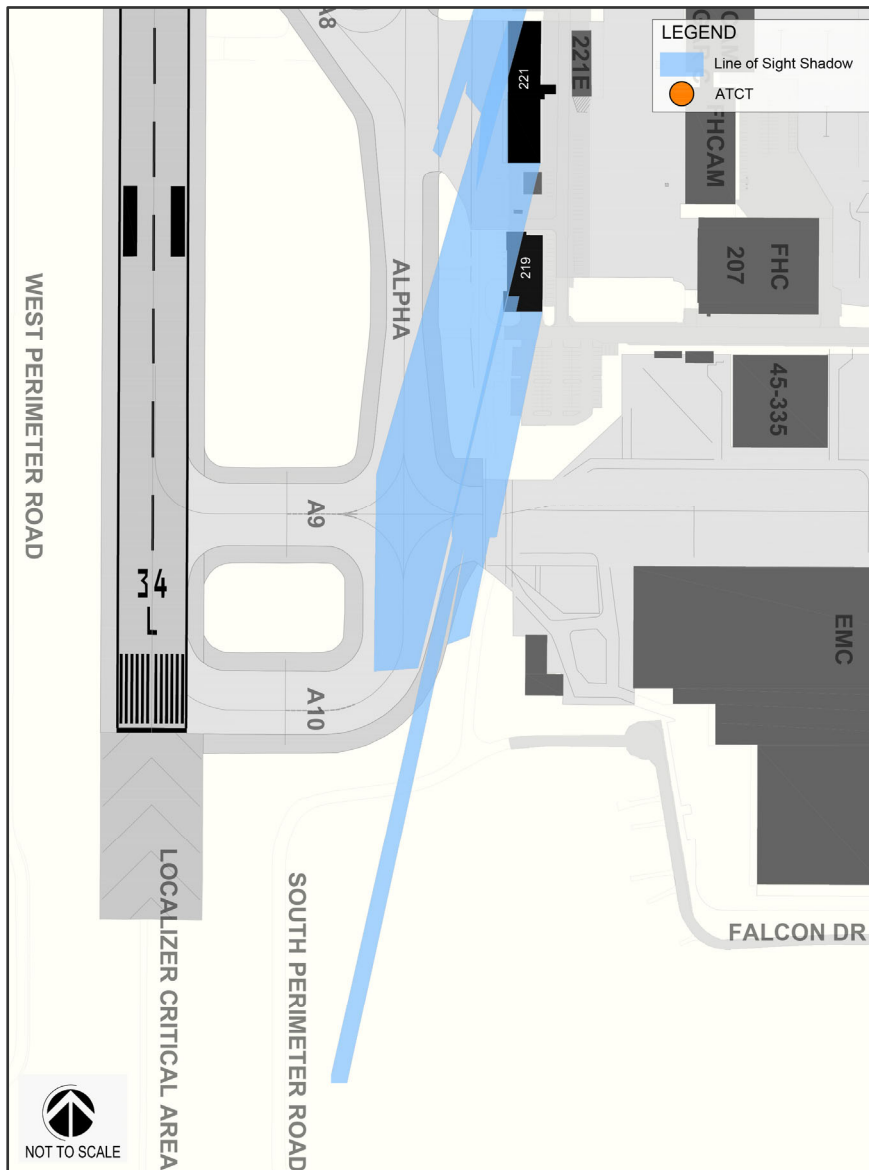
- **Appendix D (2)(b)(ii)** defines the eye level for a line-of-sight analysis as being five feet above cab floor height. For the PAE tower, the analysis uses an eye level of 760.5 feet (162 + 593.5 + 5).
- Paragraph 2-4b from Order 6480.4B describes the requirements for an unobstructed view of all controlled movement areas of an airport to include all runways, any other landing areas, and air traffic in the vicinity of PAE. Additionally, indicates there must be an unobstructed view of all taxiways and ramp areas from the ATCT cab. There are additional criteria that should be met; however, this analysis focuses only looking at the shadows created by facilities located on the airfield. **Exhibit 4-15, ATCT Line of Sight Overview**, shows an overview of the airfield from the ATCT looking south, where several instances of line-of-sight issues have been identified.

Source: Landrum & Brown

4.7.1.1 *Hot Spot 1*

As reported in the FAA Hot-Spot diagram, there is a lack of visibility from the ATCT to the area between Taxiway A9 and A10, identified as Hot Spot (HS-1). HS-1 is along Taxiway Alpha from just north of the entrance into the EMC building at taxiway A9 continuing along Taxiway Alpha through the turn onto Taxiway A10 at the entrance to runway 34L. A shadow analysis was prepared to identify the “shadows” or “shadowed segments” of airfield that currently exist. “Shadow” refers to the part of the aircraft operating area that would be shielded from view by the control tower. The shadows along Taxiway Alpha range from 6 feet at the north and south extents with a bump up to 11 feet at the intersection of Taxiways Alpha and A9. There are also significant shadows at the movement boundary from the Everett Modification Center (EMC) building at Taxiway A9 with shadows up to 39 feet and are shown in **Exhibit 4-16, Hot Spot 1 Shadow**.

Exhibit 4-16 Hot Spot 1 Shadow

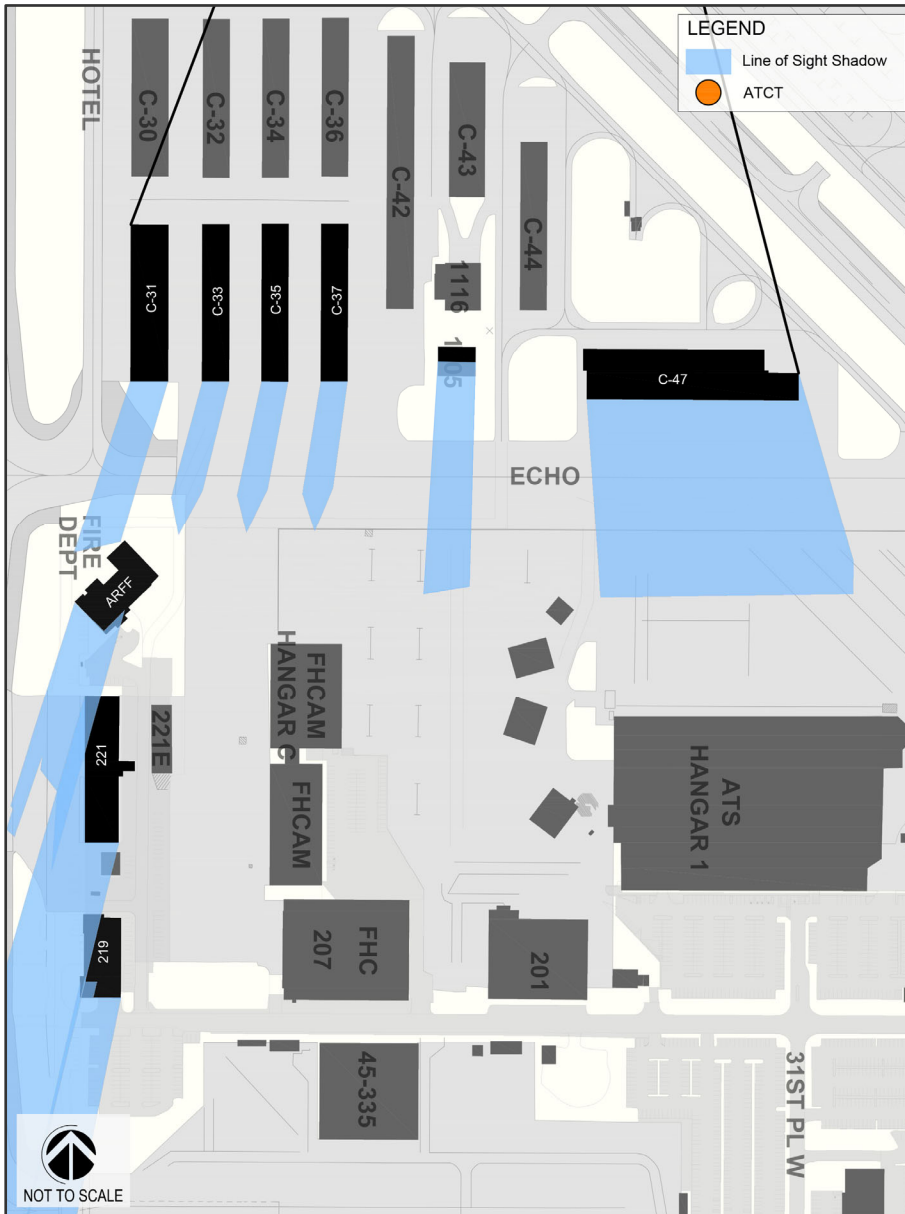


Source: Landrum & Brown

4.7.1.2 Taxilane E

A shadow analysis was performed on the entire length of existing Taxilane E (Echo). The ATCT staff have indicated that portions of Taxilane Echo are not visible for the ATCT today. The shadow study indicates that there are areas of obscured visibility along Taxilane Echo that range in width from 70 feet to 480 feet. The height of the shadows varies from two feet up to 14 feet. **Exhibit 4-17, Shadow Details Along Taxilane Echo**, shows the details of the shadowing effect along Taxilane Echo.

Exhibit 4-17 Shadow Details Along Taxilane Echo



Source: Landrum & Brown

4.7.2 Aircraft Deicing

The deicing of aircraft is critical to ensure safe operations during winter weather, including sleet, snow, and ice. According to the FAA’s “clean aircraft” concept⁷ and associated guidance, the FAA requires

⁷ An aircraft cannot depart when frost, ice, or snow is adhering to the wings, control surfaces, or propellers of an aircraft (*FAA 14 Certified Flight Regulations (CFR) Sections 121.629 and 135.227*). The presence of even minute amounts of frost, ice, or snow on particular aircraft surfaces can cause potentially dangerous degradation of aircraft performance and unexpected changes in aircraft flight characteristics.

that all critical surfaces of an aircraft be free of contamination prior to takeoff. In order to achieve this “clean aircraft” concept during winter weather, deicing of aircraft is required, which involves removing frost, snow, and ice. The deicing process is accomplished with a combination of physical removal techniques and the application of specialized deicing and anti-icing products. Additionally, deicing may be followed by anti-icing, which prevents the development of further surface contamination accumulation prior to takeoff.⁸

4.7.2.1 Existing Deicing Process

The current deicing process at PAE occurs in two different locations and serve different airport users. Each of the positions on the airfield have the capability of performing deicing and anti-icing operations and are equipped with deicing fluid runoff collection. The two deicing locations at PAE include:

- **Centralized Deicing Facility:** One deicing position serves GA tenants on the east side of Taxiway A1 near the Runway 16R end prior to takeoff - serving aircraft up to a 737-500
- **Terminal Gate Deicing:** Three deicing positions are provided at the passenger terminal gates A1, A2, and A3 - serving aircraft up to B737-900

It is anticipated as peak hour departures grow throughout the planning period, so will the need for additional deicing pads to minimize departure delays and maintain aircraft safety.

4.7.2.2 Deicing Methodology

The analysis presented in this section focuses only on determining the anticipated needs of commercial aircraft deicing operations and whether these deicing operations should remain at the terminal gates or be relocated to a centralized deicing facility, similar to the GA deicing pad along Taxiway A1. GA deicing operations at the Taxiway A1 deicing pad are considered sufficient throughout the planning period, and no further facility requirements were completed for GA deicing.

The use of terminal gates to deice and/or anti-ice aircraft is the most common option used today. Consequently, terminal gates that cannot meet storm water discharge permitting regulations should be upgraded environmentally to adequately handle the future demand for aircraft deicing and/or anti-icing treatments, as well as allow acceptable taxiing times to reach the departure runway. For this reason, requirements were calculated for both a centralized deicing facility and additional terminal gate deicing.

The future deicing position requirements at PAE are directly related to the number of aircraft that need to be deiced or anti-iced, as well as the average amount of time required to deice each aircraft throughout the planning period. To ensure PAE will have sufficient aircraft deicing capacity under peak departures, the peak hour departure forecast was used in this analysis.

An aircraft deicing procedure at the PAE terminal gates occurs prior to push back from the gate and adds to the aircraft time at the gate. A typical deicing operation includes the time used to turn the engines off (when applicable), the time to conduct the deicing application, the time to notify the pilot that deicing is complete, and the time to restart the engines (when applicable).

⁸ Sited from the Transportation Research Board (TRB) Airport Cooperative Research Program (ACRP) Report 14 - *Deicing Planning Guidelines and Practices for Stormwater Management Systems*.

The amount of time spent deicing each aircraft depends on various factors, including:

- Amount of snow/ice accumulated on the aircraft
- Rate at which additional precipitation is falling
- Time needed to position the aircraft and deicing equipment
- Number of deicing trucks dedicated to each aircraft
- Type of deicing trucks operated
- Size of the aircraft

Deicing times for North American airports were benchmarked for deicing conditions. **Table 4-29, *Deicing Time per Aircraft***, shows average deicing times for narrowbody aircraft from each benchmarked airport. The overall average deicing time was 18 minutes on the pad. This would equate to total deicing time at the gate, whereas a centralized deicing facility would require additional maneuvering times for aircraft to enter and exit the centralized pad. For a centralized pad at PAE, an additional 10 minutes (five minutes to enter, and five minutes to exit) per aircraft was added to the 18 minutes on the pad. These two deicing times per aircraft (18 minutes for terminal gate deicing and 30 minutes for centralized pad deicing) were used to calculate the deicing requirements for commercial aircraft operations in this section.

Table 4-29 Deicing Time per Aircraft

Airport	Deicing Times (in minutes)
	Narrowbody
Cleveland Hopkins (CLE)	12
Baltimore-Washington (BWI)	20
Denver (DEN)	15
Kansas City (MCI)	25
Ottawa (YOW)	n/a
Minneapolis (MSP)	20
ORD (United)	16.5
Average	18

Source: Landrum & Brown

The narrowbody fleet serving PAE throughout the planning period is representative of primarily Embraer 175 (E-175) and Boeing 737-900 aircraft. The proposed aircraft fleet and benchmarked deicing times were then used to determine the requirements based on the peak hour departures.

4.7.2.3 Deicing Requirements

The requirements were calculated for both expanding the terminal gate deicing pads as demand for gates grow and the relocation the commercial aircraft deicing operations to a centralized deicing pad.

Centralized aircraft deicing facilities are facilities where aircraft receive deicing/anti-icing treatment away from the gate, along taxi routes leading to the departure runway.

Scenario 1: Retain Deicing Operations at Terminal Gates

The peak hour departures and the requirements for terminal gates with deicing capabilities are shown in **Table 4-30, Terminal Gate Deicing Requirements**, and are representative of requirements through PAL 3. These terminal gate positions represent a 20-minute deicing timeframe for each aircraft but also consider additional overall turnaround time.

Table 4-30 Terminal Gate Deicing Requirements

Segment	Existing	PAL 1	PAL 2	PAL 3
Peak Hour Departures	3	3	3	7
Contact Gate Requirement	3	3	3	7
Terminal Gate Deicing Position	3	3	3	7

Source: Landrum & Brown

Scenario 2: Build Centralized Deicing Pad

The peak hour departures and the requirements for a centralized deicing pad are shown in **Table 4-31, Centralized Deicing Pad Requirements**, and are representative of requirements through PAL 3. The centralized deicing pad positions reflect a 30-minute deicing timeframe for each aircraft, which includes time for entering and exiting the pad. The 30-minute per aircraft planning factors indicates that each deicing position on a centralized deicing pad can service two aircraft per hour, if needed.

Table 4-31 Centralized Deicing Pad Requirements

Segment	Existing	PAL 1	PAL 2	PAL 3
Peak Hour Departures	3	3	3	7
Centralized Deicing Position ¹	3	2	2	4

1 Assumes each aircraft will take 30 minutes per deicing operation

Source: Landrum & Brown

Summary

There are advantages and disadvantages to deicing at the terminal gate versus deicing at a centralized deicing pad. If deicing was conducted at each gate, deicing capabilities would need to be installed at each of the seven gates (three exist today) required through PAL 3.

Whereas, if a centralized facility was developed, a total of four deicing positions would be needed at that pad through PAL 3.

Deicing at the terminal gate is convenient for passenger aircraft maneuverability, deicing crew and equipment, as well as it saves on fuel and reduces the time the aircraft is in a movement area on the airfield. However, deicing at the gate can contribute to delay at the gate if another aircraft is waiting to enter a gate position. Deicing at the gate can also cause congestion amongst ground equipment and personnel.

One of the benefits of a centralized deicing pad is that the deicing facilities are closer to the departure runway, which minimizes the taxiing time between start of treatment and takeoff (holdover time). This allows aircraft to avoid changing weather conditions encountered when aircraft have longer taxi routes.

The alternatives analysis in the next chapter will determine which type of deicing facility should be used at PAE through the planning period by using the information from this section of the facility requirements.

4.7.3 Aircraft Fuel

The primary goal of any aviation fuel distribution system is to ensure the fuel is safe, easily accessible, and available to aeronautical users without interruption or unreasonable delay. The aircraft fuel farm at PAE is operated by Propeller Aero Services. This facility consists of both Jet-A and 100 Low Lead (100LL) fuel.

The aircraft fuel facilities at PAE currently support 360,000 gallons of Jet-A fuel in six aboveground tanks, which hold 60,000 gallons each. Propeller Aero Services currently maintain a two-day supply, which is less than the industry standard for aviation fuel supply. It is recommended that a commercial fuel provider should maintain a total capacity for three days' supply of aviation fuel. In this manner, PAE is assured that fuel is available during peak demand in the event of a disruption in the fuel delivery system.

The fuel requirements for PAE were calculated using the design day flight schedule to determine the number of departures for each ADG. A representative aircraft was selected for each ADG based on the largest aircraft fuel tank capacity of each group. The number of departures per ADG is then multiplied by the fuel load associated with each representative aircraft. A fuel uplift factor is applied to account for a non-empty fuel tanks to be filled to capacity.

4.7.3.1 Commercial Air Service Jet-A Fuel

In terms of Jet-A aircraft fuel, the analysis considers the forecasted departure design day operations and the largest forecasted aircraft fleet mix for each type of operation. This includes:

- Commercial Aircraft: ADG III (E-175 and B737-900)
- Air cargo ADG IV (B757F)
- GA Jet aircraft ADG I and ADG II (Cessna 510 Citation Mustang and Falcon 2000)

Additionally, fuel requirements for PAE assume 45 percent of fuel uplift per operation. The results of the Jet-A fuel facility requirements are presented in **Table 4-32, Jet-A Aircraft Fuel Facility Requirements**. Additionally, **Table 4-33, Jet-A Aircraft Fuel Supply Requirements**, present the Jet-A fuel storage needs for a range of supply levels from 1 to 7-day supply storage.

Table 4-32 Jet-A Aircraft Fuel Facility Requirements

Fuel Farm Requirements	PAL 1	PAL 2	PAL 3
Daily Fuel Consumption (Gallons)	49,000	64,000	155,000
Number of Fuel Tanks ¹	2	3	6

1 Assumes usage of existing 60,000 gallon tanks
 Source: Landrum & Brown

Table 4-33 Jet-A Aircraft Fuel Supply Requirements

Fuel Farm Requirements	PAL 1	PAL 2	PAL 3
1-Day Supply	49,000	64,000	155,000
2-Day Supply	98,000	128,000	310,000
3-Day Supply	147,000	192,000	465,000
4-Day Supply	196,000	256,000	620,000
5-Day Supply	245,000	320,000	775,000
6-Day Supply	294,000	384,000	930,000
7-Day Supply	343,000	448,000	1,085,000

Source: Landrum & Brown

4.7.3.2 General Aviation 100LL Fuel

The GA community is served by a 20,000-gallon aboveground tank located adjacent the main fuel farm and a 3,000-gallon aboveground tank of 100LL located in the central ramp area west of hangar C-51 that is used as a self-service fueling area. This totals 23,000 gallons of 100LL aircraft fuel at PAE.

The 100LL aircraft fuel requirements were computed using the forecasted design day departures for GA multiplied by the overall maximum aircraft fuel load. Due to the variety of GA aircraft serving PAE, an average fuel tank size was calculated. This resulted in using a planning factor of 65-gallons per GA aircraft in this analysis.

The fuel requirements for PAE were calculated applying a factor of 40 percent for fuel uplift per operation. The results of the fuel facility requirements are presented in **Table 4-34, 100LL Aircraft Fuel Storage Requirements**.

Table 4-34 100LL Aircraft Fuel Storage Requirements

Fuel Farm Requirements	PAL 1	PAL 2	PAL 3
Daily Fuel Consumption (Gallons)	9,100	9,400	10,000
Number of Fuel Tanks ¹	1	1	1

1 Assumes usage of existing 20,000 gallon tanks
 Note: 100LL fuel storage is rounded up to the nearest 100. Rounding 100LL to the nearest 1,000 did not depict a proper growth representation, as shown in the forecast.
 Source: Landrum & Brown

Additionally, **Table 4-35, 100LL Aircraft Fuel Storage Requirements**, reflect the 100LL fuel storage needs for a range of supply levels typically used at airports. The analysis shows the existing 20,000-gallon aboveground and the 3,000-gallon self-service tank are sufficient for the GA operations at PAE through PAL 3, assuming a 2 day supply remains sufficient for GA operations.

Table 4-35 100LL Aircraft Fuel Storage Requirements

Fuel Farm Requirements	PAL 1	PAL 2	PAL 3
1-Day Supply	9,100	9,400	10,000
2-Day Supply	18,100	18,700	20,000
3-Day Supply	27,200	28,100	30,000
4-Day Supply	36,200	37,400	40,000
5-Day Supply	45,300	46,700	50,000
6-Day Supply	54,300	56,100	60,000
7-Day Supply	63,400	65,400	69,900

Note: 100LL fuel storage is rounded up to the nearest 100. Rounding 100LL to the nearest 1,000 did not depict a proper growth representation, as shown in the forecast.
 Source: Landrum & Brown

4.7.4 Aircraft Maintenance, Repair and Overhaul (MRO)

The major MRO tenant at PAE is Aviation Technical Services Incorporated (ATS), located on the south ramp. The total ATS site is approximately 1.2 million square feet with several facilities, highlighted by the 325,000 square foot hangar. ATS performs airframe services for all major airlines, primary clients include Southwest Airlines, Delta, and Alaska Airlines.

ATS’s business model and operations at PAE are unique compared to a traditional maintenance facility, commonly operated at commercial airports. Future facility needs for traditional airline maintenance facilities are typically calculated by applying planning growth factor comparing the existing facilities against the projected annual passenger operations. That methodology is not appropriate to project

future ATS facility needs at PAE. While ATS indicated that its operations will grow in the future, it indicated that the current sizing of hangar facilities, warehouse, storage, fleet mix, and landside facility needs will be adequate over the planning period

However, ATS did indicate that additional area would improve its airside operations. Additional land to expand ATS ramp area is recommended east of the current site, but not as far as to conflict with Runway 16L-34R operations. It is not anticipated that additional MRO facilities will operate at PAE in the future. If an additional MRO decided to operate at PAE, additional facility requirements and land reservation should be considered.

4.7.5 Aircraft Rescue and Firefighting (ARFF)

The ARFF Station at PAE is located at the intersection of the Taxiway A and Taxilane E on the South Ramp. The facility has a footprint of approximately 14,600 square feet.

There is an additional facility North of Taxilane E of approximately 8,600 square feet dedicated to fire vehicles maintenance (Building 1116).

4.7.5.1 ARFF Index

The type of aircraft rescue and firefighting equipment and quantity of fire extinguishing agents needed for a required level of protection at an airport is indicated as the ARFF Index.

The *Document 403 Standard for Aircraft Rescue and Fire-Fighting Services at Airports of the National Fire Protection Association (NFPA)* and the 14 Code of Federal Regulations (CFR) *Part 139.315 Aircraft Rescue and Firefighting* determine the level of protection based on the largest passenger aircraft scheduled into PAE. The airport category for a given aircraft shall be based on the overall length of the aircraft fuselage width and an average of five or more average daily scheduled departures of the longest aircraft. Moreover, according to the Paragraph C in CFR Part 139.315, when there are fewer than five average daily departures of the longest air carrier aircraft serving an airport, the Index required for will be the next lower index group than the index group prescribed for the longest aircraft.

Table 4-36, ARFF Index Determination, depicts the airport category by the width of aircraft for ARFF Index Determination.

Table 4-36 ARFF Index Determination

Airport Category		Length of Aircraft (ft)
NFPA	FAA	
1	A	30
2		39
3		59
4		78
5		90
6	B	90-126
7	C	127-160
8	D	161-200
9	E	200+
10	E	

Sources: *Standard for Aircraft Rescue and Fire-Fighting Services at Airports (NFPA 403)*, 2018 Edition
14 CFR Part 139.315, *Aircraft Rescue and Firefighting: Index Determination*
Landrum & Brown

The longest aircraft in both the existing and future fleets were analyzed to determine the ARFF Index in PAE.

The current ARFF Index for PAE is based upon the Embraer 175 aircraft (E-175). The E175 has a length of approximately 104 feet (Index B) and meets the threshold minimum for daily departures. The determination establishes ARFF Index B as appropriate at PAE. The forecast assumes the E-175 will be transitioned out and replaced with the Boeing 737-900 during the planning period.

With a length of 138 feet, the longer Boeing 737-900 will meet the minimum threshold of daily departures by PAL 2 and continue into PAL 3. Therefore, the future ARFF index for PAE will be Index C.

4.7.5.2 Extinguishing Agents and Personnel

The minimum amount of water for foam production requires accordance to the ARFF Index C at PAE.

Table 4-37, *Extinguishing Vehicles*, shows the minimum requirements for ARFF Index C.

Table 4-37 Extinguishing Vehicles

ARFF Index		Number of Vehicles
NFPA	FAA	
7	C	2 ¹

Note: 1-Minimum number of ARFF vehicles at an airport
 Source: Standard for Aircraft Rescue and Fire-Fighting Services at Airports (NFPA 403), 2018 Edition.

During flight operations and 15 minutes prior and 15 minutes following, ARFF personnel shall be readily available to staff the rescue and fire-fighting vehicles and to perform firefighting and rescue operations. Staffing levels shall be established based on the demands of PAE but not lower than the ARFF Index B presented in **Table 4-37, Extinguishing Vehicles**.

In accordance with the National Fire Protection Act (NFPA) 403, one or more of the following types of primary agents shall be used for aircraft fire fighting involving hydrocarbon fuels:

- Aqueous Film-forming foams (AFFF)
- Fluoroprotein foam (FP)
- Protein foam (P)
- Fluorine-free synthetic foam

All ARFF vehicles responding shall carry either one or both of the following categories of complementary agents:

- Potassium-based dry chemical
- Halogenated agent

As listed in the ARFF equipment inventory, PAE currently meets the minimum number of two ARFF vehicles and includes the provision of an additional vehicle in order that the minimum requirements are maintained during periods when the vehicles are out of service.

4.7.5.3 ARFF Response Time Analysis

An ARFF response-time analysis was conducted for the PAE airfield to review the current facility could appropriate respond to an aircraft emergency on the airfield. The *14 CFR Part 139.319, Aircraft Rescue and Firefighting: Operational Requirements*, provides guidance on the performance criteria of ARFF vehicles at an airport.

The response times, in accordance to the Paragraph H of the 14 CFR Part 139.319 requires the following:

- 2.i - Within three (3) minutes from the time of the alarm, at least one required aircraft rescue and firefighting vehicle must reach the midpoint of the farthest runway serving air carrier aircraft from its assigned post or reach any other specified point of comparable distance on the movement area that is available to air carriers, and begin application of extinguishing agent.

- 2.ii - Within four (4) minutes from the time of alarm, all other required vehicles must reach the point specified in (2.i) from their assigned posts and begin application of an extinguishing agent.

For this analysis, the response times from the ARFF station was calculated by measuring various routes that the ARFF vehicles would take from the station to the midpoint and end points of each runway at PAE; Runway 16R-34L and Runway 16L-34R. These routes were then analyzed to determine the respective lengths of the straight-away and curved portions along each route.

Table 4-38, ARFF Response Time Assumptions, presents the assumptions used for this analysis. The results of the analysis concluded that the current ARFF station location with the existing airfield configuration are sufficient to meet the three-minute response time required under 14 CFR Part 139 regulations and reaches the farthest runway serving air carrier aircraft. The analysis shows that further northwest point of the airport can be reached in less than four min.

Table 4-38 ARFF Response Time Assumptions

Assumptions	Value
Average Curve Speed	35 mph
Average Straight Speed	69.5 mph
Turnout Time	40 sec
Time in/out of turn	12 sec
Shortest Distance	Along paved surface, including runways and taxiways

Source: Landrum & Brown

Table 4-39, ARFF Response Time Analysis, and **Exhibit 4-18, ARFF Response Times**, present the estimated response times for the PAE airfield.

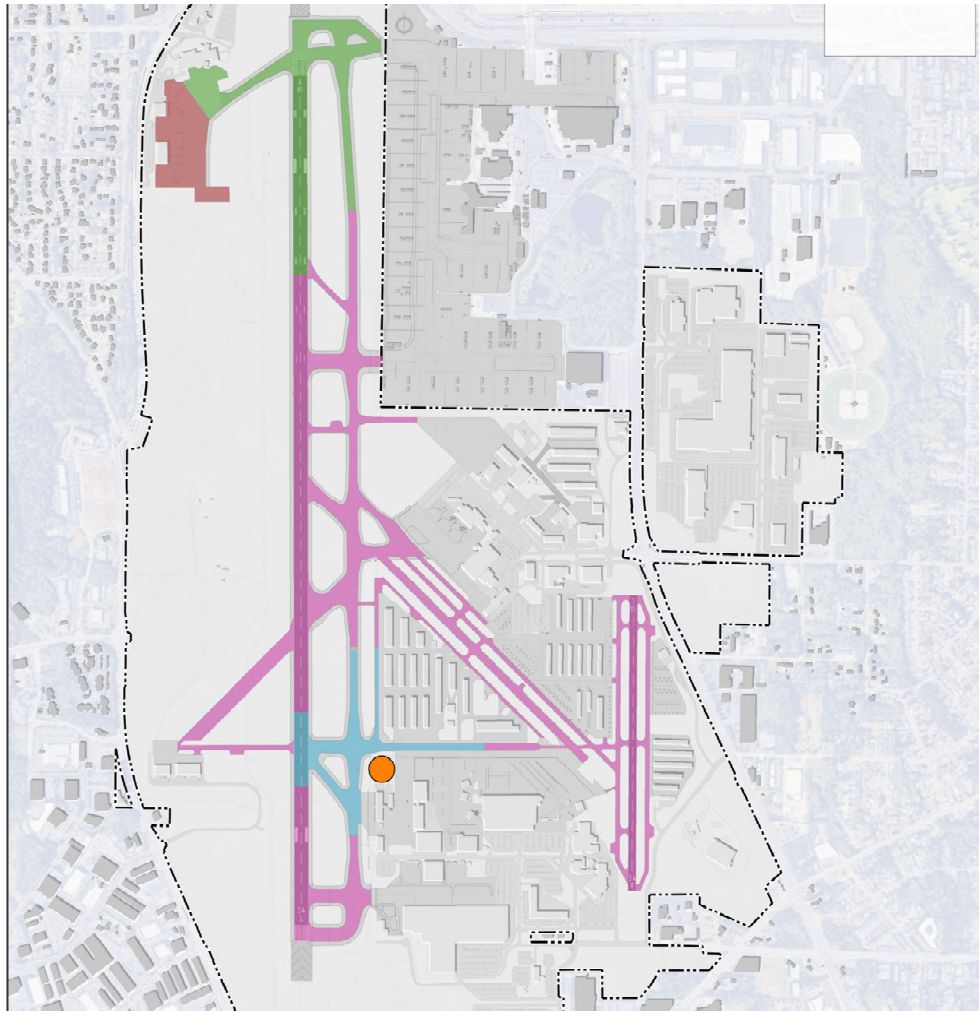
Table 4-39 ARFF Response Time Analysis

Location	Distance (ft)	Length Straight (ft)	Length Curved (ft)	Response Time (min, sec)
34L Threshold – RWY route	7,873	7580	293	2:39
34L Threshold - TWY route	7,683	7,499	184	2:36
34L/16R Midpoint	3,373	3,090	283	2:07
16R Threshold	2,832	2,544	288	1:49
34R Threshold	4,243	3,819	424	2:17
34R/16L Midpoint	2,782	2,501	281	1:49
16L Threshold	4,254	3,798	455	2:18
Critical Nonmovement Area-RWY route*	9,489	8,906	580	3:10
Critical Nonmovement Area-RWY route*	9,414	8,996	418	03:08

Note: *This critical Nonmovement area is the farthest point of the airport (apron of building 7-335 and 7-336). Even though these facilities do not have to be covered within 3 minutes from the time of the alarm according to regulation, they are covered in less than 4 minutes.

Source Landrum & Brown

Exhibit 4-18 ARFF Response Times



Source: Landrum & Brown

4.7.6 Airport Support

4.7.6.1 Airport Administration

The existing Airport Administration is located in two facilities, Buildings C-2 and C-3. Building C-2 is approximately 6,387 square feet, and 100 percent of the facility is utilized for airport administration including the police. Additionally, Building C-3 is approximately 24,844 square feet, but only 32.83 percent of the facility, which represents 8,156 square feet for airport administration.

County staff is actively looking to relocate and consolidate airport administration services into a single facility. The County has identified the vacant Employment Resource Center (ERC) building, located in the Bomarc Business Park, as a candidate to consolidate airport administration staff. Snohomish County are planning on occupying the second level of the two-level office building, representing an area of 10,400 square feet. The following analysis assumes most of the airport administration employees will be relocated to this building in PAL 1. Some airport administration services that require airside

adjacency may remain in the Building C-2 and C-3. The existing Airport administration areas are summarized in **Table 4-40, Airport Administration Areas**.

Table 4-40 Airport Administration Areas

Airport Administration Building	Airport Administration Area (sf)
Building C-2	6,387
Building C-3	8,156
TOTAL	14,543

Source: Landrum & Brown

Based on industry standards, area assumptions for Airport Administration are presented in **Table 4-41, Airport Administration Assumptions**.

Table 4-41 Airport Administration Assumptions

Assumptions	
Passenger Airport Operations / Employee	300 ATMs / Employee
Offices, Toilets, Archive	107.6 sf / Employee
Site Area	2.1

Source: Landrum & Brown

Table 4-42, Airport Administration Requirements, presents the results of this requirements analysis. The current Airport Administration facilities, in addition with the ERC facility, may be sufficient through the planning period. The analysis shows a small deficit of 1,615 square feet by the end of the planning period. The new site will provide appropriate landside facilities to include adequate parking and access for administration employees.

Table 4-42 Airport Administration Requirements

Airport Administration	Existing Area	PAL 1*		PAL 2		PAL 3	
		Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)
Total Building Area	14,543	12,329	12,614	13,599	11,344	26,558	(1,615)

*Assumes ERC building is occupied in PAL 1
Source: Landrum & Brown

4.7.6.2 Airport Maintenance

Airport support facilities offer storage, airport maintenance and other similar uses dedicated to keeping PAE in efficient operating condition. The airport maintenance staff, offices, equipment, and storage facilities are spread out across PAE. **Table 4-43, Existing Airport Maintenance Areas**, details PAE maintenance facilities and their dedicated areas.

Table 4-43 Existing Airport Maintenance Areas

Airport Maintenance Facility	Building Area (sf)	Site Area (sf)
Building C-3*	4,502	N/A
Building 219	5,872	30,663
Building 221*	5,984	N/A
Building 221E	5,959	9,833
Building 1105	4,748	23,580
TOTAL	27,064	64,076

Note: Only a portion of the building serves Airport Maintenance functions
Source: Landrum & Brown

The facility requirements for airport support were calculated using annual operations, generating a planning factor based on the existing facilities. The assumptions used to calculate the requirements are presented in **Table 4-44, Airport Maintenance Assumptions**.

Table 4-44 Airport Maintenance Assumptions

Assumptions	
Existing Airfield Maintenance Building	27,064
Planning Factor	0.20 sf / Annual Operation
Site Area	2.25

Source: Landrum & Brown

Table 4-45, Airport Maintenance Requirements, summarizes the facility requirements for airport maintenance at PAE.

Table 4-45 Airport Maintenance Requirements

Airport Maintenance	Existing area	PAL 1		PAL 2		PAL 3	
		Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)
Building Area	27,064	24,677	2,388	31,006	(3,941)	37,461	(10,396)
Site Area	64,076	55,523	8,553	69,763	(5,687)	84,286	(20,210)

Source: Landrum & Brown

The analysis shows that Airport Maintenance facilities will need to be expanded in the planning period. The various airport maintenance sites are spread out across PAE and can be optimized to a more traditional airport maintenance campus to consolidate facilities in a single location. PAE has indicated the desired to consolidate PAE maintenance facilities in one single on airport campus.

The consolidation of PAE maintenance facilities to the new campus, should strive to meet the sizing requirements outlined in this document. Depending on the location of a consolidated campus, it is likely that airside dependent vehicles will remain in some of their existing sites. A new site should provide for appropriate landside to include adequate parking and access for airport maintenance employees.

4.7.7 Flight Catering

Although there is no existing flight catering facility for passenger airlines currently serving PAE, PAE is planning on supplying food for the first few flights in the morning. The meals will arrive at PAE prepackaged via a service vehicle and loaded directly onto the plane.

As commercial service grows at PAE, it is recommended that provision be made for a traditional on-airport catering facility. As the number of passengers increases along with new flight routes, it is possible that Propeller may develop a catering facility to enhance the services it provides to the airlines.

Catering facilities provide in-flight food and beverage items for departing passengers and should be located as close as possible to the terminal building with access to both airside and landside areas. Flight catering facilities can also be located offsite airport property but require a small facility on airport to ease catering trucks the delivery to aircraft.

A traditional catering facility is planned based upon the daily demand for airline meals and forecasted departing passengers throughout the planning period. **Table 4-46, Flight Catering Assumptions**, presents industry assumptions used to calculate the requirements for a future flight catering facility at PAE.

Table 4-46 Flight Catering Assumptions

Assumptions	Planning Factor
Short-Haul (domestic)	50 minutes
Airline Service	Legacy Carriers
Daily meals	0.3 meals / departing passengers
Flight Catering Facility	4.3 square feet / meal
Site Planning Factor	2.4 x Facility Footprint

Source: Landrum & Brown

The following analysis presents the proposed area that it is recommended to be preserved for the development of an onsite catering facility at PAE. The analysis presents the requirement for daily meals within the planning period and is based on passenger carriers and existing and future nonstop PAE-served routes.

Existing and future routes were analyzed and a rate of 0.3 meals per passenger was found to be appropriate to be used for legacy carriers and for destinations that range up to three-hour flights. ORD was the only route for PAL 3 over the established long-haul time with 3 hours and 55 minutes, the catering facility can continue to be sized under the same established ratio.

The catering facility is assumed to be single level with landside and airside areas located within a site area, using a planning factor of 2.4 multiplied by the building footprint to determine the overall site need. The building area can be maximized in the future by adding a mezzanine level within the facility. The ultimate decision to develop a catering facility at PAE is unknown at this point, stakeholder coordination with the passenger terminal operator, airport, and airlines will drive that decision. The results of the catering facility requirements are presented in **Table 4-47, Flight Catering Facility Requirements**.

Table 4-47 Flight Catering Facility Requirements

Assumptions	PAL 1	PAL 2	PAL 3
Daily Required Meals	476	728	2,119
Building Area (sf)	2,045	3,128	9,111
Site Area (sf)	4,703	7,195	20,954

Source: Landrum & Brown

4.7.8 General Aviation (GA)

This GA section presents the facility requirements needed to meet the forecast demand for the general aviation facilities at PAE. GA demand is driven by GA operations both local and transient, as well as, aircraft based at PAE.

The GA facility requirements developed in this section include requirements for three types of GA facilities at PAE:

- FBO Facilities
- Aircraft Hangars
- Aircraft Tie-Downs

GA at PAE is unique in that the airfield is vastly diverse with not only passenger, cargo, and Boeing test aircraft but also a wide variety of GA aircraft. PAE offers a place for each type of aircraft on the airfield and GA makes up a large land use area on-airport property. GA operations and based aircraft at PAE are prevalent and continues to grow. There is a current wait list totalling 230 potential tenants, who are waiting for space on PAE for a hangar. The GA tenants waiting for space include smaller aircraft operators requiring space for T-hangar, up to larger corporate jet operators that will much larger box hangars.

The future GA land reservations may differ depending on tenant or based aircraft growth, as well as overall growth of transient operations at PAE. The future support facility needs are based on what is currently based and operating at PAE and its anticipated growth, as depicted in **Chapter 3, Forecast**.

4.7.8.1 General Aviation Facility Requirements Methodology

The GA facility requirements will help determine GA land use reservation throughout both the short- and long-term planning periods. The methodology for determining the GA facility requirements is explain in the following subsections.

Fixed-Based Operator (FBO) Facilities

Historical GA operations, as well as projected GA operations growth throughout the planning period were used to determine the facility requirements for the FBO facilities and aprons located on the landside. It is important to note the GA operations (both historical and forecasted), used in this analysis, represent both transient and local GA operations, which are all customers of the PAE FBOs.

Existing FBO facility utilization assumptions were also calculated since all FBO facilities are utilizing their facility space at 100 percent.

Currently, there are three FBOs located in three different buildings. Combined, the FBOs encompass the following areas:

- **FBO Terminal Facilities Area:** Represents close to 17,000 square feet combined on the airfield, which represent area used for serving crew and passenger needs, support equipment maintenance and storage, office space, catering, meeting space, and other FBO support functions
- **FBO Hangar Area:** Represents over 27,000 square feet of combined hangar area on the airfield, which is used to predominantly house transient aircraft
- **FBO Apron Area:** Represents over 73,000 square feet of combined apron area for aircraft parking of both transient and local aircraft operations; FBO facilities C-3 and C-84 include an apron area, while C-51 does not have a dedicated apron for parking aircraft, so apron requirements were not calculated for this facility.

The planning factors used to calculate the FBO requirements are depicted in **Table 4-48, FBO Requirements – Planning Factors**.

Table 4-48 FBO Requirements – Planning Factors

Facility	Planning Factor Methodology	Planning Factor
FBO Terminal Facilities Area	Feet/Total GA Operations *Relative to each FBO facility	0.14
FBO Hangar Area		0.23
FBO Apron Area		0.62

Source: Landrum & Brown

Aircraft Hangars

Historical based aircraft and projected growth of based aircraft throughout the planning period were used to determine the facility requirements for aircraft hangars. Aircraft hangars that are not used by the FBOs at PAE are either owned or leased by individuals, businesses, or clubs (i.e., flight clubs on the airfield). PAE offers several box hangars that are all unique in size. Aircraft hangars were divided into two categories for analysis:

- **T-Hangars:** Requirements are based on historical and projected single-engine aircraft based at PAE (including existing T-, L-, and T-L hangars), which are identified in **Chapter 3, Forecast**. Currently, PAE has over 350 T-hangars, in which nearly all of them are occupied, at any given time. The T-hangars at PAE comprise over 356,000 square feet in total with an average T-hangar size of approximately 1,000 square feet. This area was used to determine future total area needed for T-hangars throughout the planning period.
- **Box Hangars:** Requirements are based on historical and projected multi-engine and jet aircraft (which comprise roughly 10 percent of the GA tenants), as well as helicopters. Existing box

hangars at PAE are representative of hangars identified by PAE as 45-Rectangle, 50-by-50-foot hangars, and 60-square foot hangars. Currently, PAE has nearly 60 multi-engine aircraft, jets, and helicopters based at PAE. Existing and potential tenants have expressed interest in developing additional box hangars, specifically for corporate jets. The box hangars at PAE comprise over 384,000 square feet with tenants using a minimum of 2,000 square feet per aircraft/helicopter in this category. Requirements were calculated by using the growth of the based multi-engine aircraft, helicopters, and jets throughout the planning period.

Aircraft Tie-Downs

PAE offers 146 tie-down positions and are currently 100 percent leased. The tie-down positions are predominantly leased by the FBOs; utilizing some tie-down positions to serve transient aircraft for overnight and short-term leases. The existing tie-down area at PAE represents over 225,000 square feet of parking area that includes aircraft wingtip clearances and ample room for aircraft maneuvering on the aprons. The average tie-down space per aircraft at PAE ranges from 600 to 1,200 square feet. The tie-down demand at PAE in the future is driven by a compound annual growth rate (CAGR) of 0.64 percent.

4.7.8.2 General Aviation Facility Requirements

The facility requirements throughout the planning period were calculated for PALs 1, 2, and 3, as identified in **Chapter 3, Forecast**. These planning level requirements were determined for each of the three types of GA facilities at PAE (FBO Facilities, Aircraft Hangars, and Aircraft Tie-Downs).

Fixed-Based Operator (FBO) Facilities

FBO facility requirements were calculated for FBO terminal facilities, hangars, and aprons. **Table 4-49, FBO Facilities Requirements**, identifies total FBO requirements for PAE throughout the planning period.

The requirements indicate the need for approximately 3,100 square feet of additional terminal facility area for passengers, crews, visitors⁹, and FBO staff through PAL 3. An additional 13,500 square feet of apron area is required by PAL 3 to accommodate future GA operations growth. Some of the GA operations growth will expect more hangar space through PAL 3, which includes approximately 5,000 additional square feet for parking aircraft in the FBO hangars for overnight stays and short-term leases.

Table 4-49 FBO Facilities Requirements

FBO Facilities	Existing Area (sf)	PAL 1		PAL 2		PAL 3	
		Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)
Terminal	16,500	17,700	(1,200)	18,300	(1,800)	19,587	(3,100)
Hangar	27,100	29,100	(2,000)	30,000	(3,000)	32,112	(5,000)

⁹ Visitors may include individuals that are not categorized as crew, passengers, or FBO staff. These individuals represent people coming in for business meetings, people picking up or dropping off passengers, people coming to socialize with passengers or crew, or other various reasons.

Apron ¹	73,000	78,300	(5,300)	81,000	(7,900)	86,535	(13,500)
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1 FBO facilities C-3 and C-84 include an apron area, while C-51 does not have a dedicated apron for parking aircraft so apron requirements do not include C-51.

Note: Requirements are rounded to the nearest 100 square feet.

Source: Landrum & Brown

Aircraft Hangars

Aircraft Hangar requirements were calculated for both T-hangars and box hangars at PAE. **Table 4-50, Aircraft Hangar Requirements**, identifies estimated aircraft hangar requirements for PAE throughout the planning period assuming the same rate structure policies.

Based upon the average overall size of a T-hangar at PAE, it is estimated by PAL 3, approximately 79,700 square feet of additional T-hangar area is needed. This equates to 76 individual stalls inside T-hangars throughout the planning period. The deficit in T-hangar area is exclusively for the T-hangar footprint and does not account for taxiway area or maneuvering area on an apron outside of the T-hangar. An example of the overall area for T-hangars including the buildings and taxiing area is illustrated in **Exhibit 4-19, Example of T-Hangar Area Requirements**.

Unlike single-engine aircraft at PAE; the multi-engine aircraft, jets and helicopters that utilize box hangars at PAE are not expected to grow in the same proportion as single-engine aircraft that use the T-hangars, but they are expected to grow some throughout the planning period.

This growth is reflected by the additional need of approximately 34,900 square feet of box hangar area through PAL 3, which may translate to needing an additional 14 box hangars sized at approximately 2,500 square feet a piece. The size and demand for future box hangars will be more specifically driven by interested private parties needs and also depend on the size of aircraft being housed in each hangar.

It is also important to note that corporate aircraft growth through PAL 3 represents over 30 percent of the box hangar need. There is currently private party interest in expanding the box hangars at PAE to include more corporate aircraft hangars on the west side. If this comes to fruition, these hangars will likely require more than 2,500 square feet of hangar space per aircraft and will be developed on a case-by-case basis. Corporate hangars are an often unique in size and function, which is mostly client/tenant driven.

Table 4-50 Aircraft Hangar Requirements

Facility	Existing Area (sf)	PAL 1		PAL 2		PAL 3	
		Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)
T-Hangar	356,100	366,600	(10,500)	388,800	(32,700)	435,800	(79,700)
Box Hangar	384,200	391,700	(7,500)	399,100	(14,900)	419,100	(34,900)

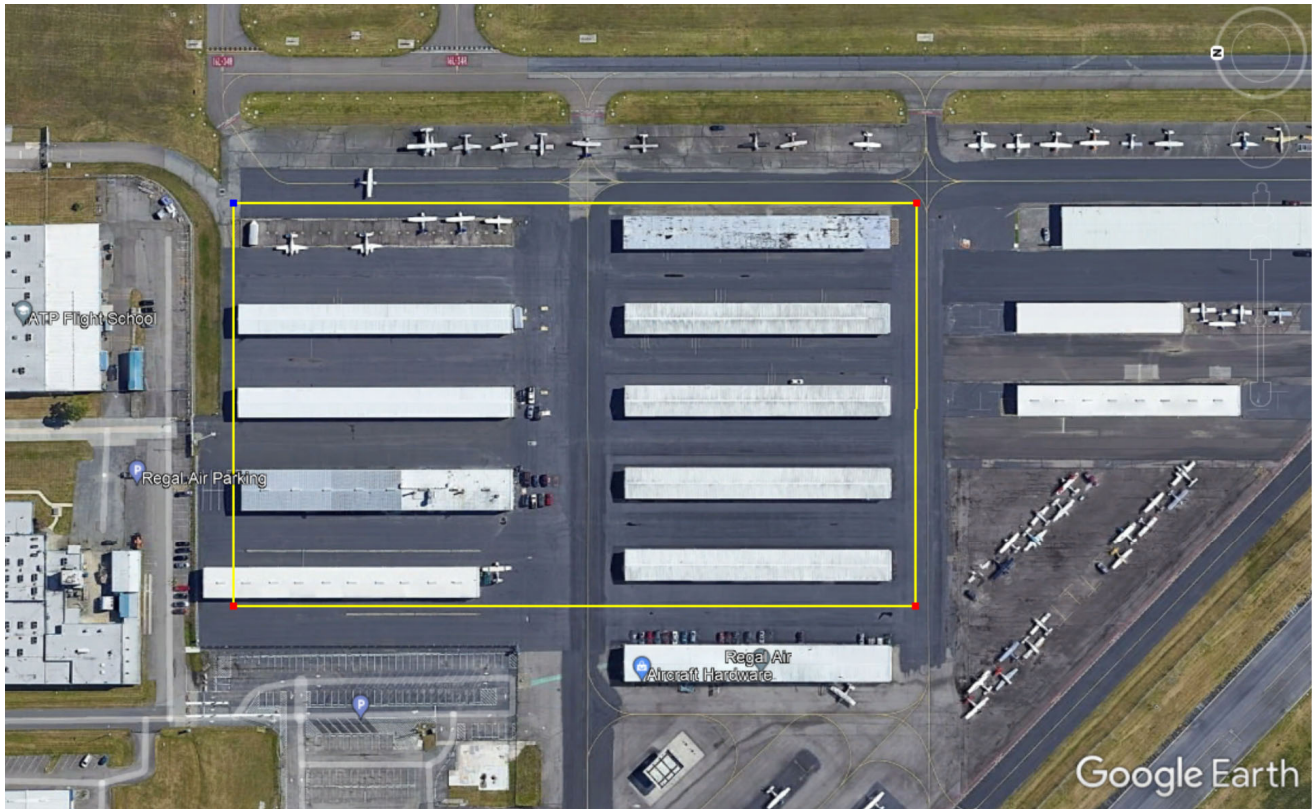
Note: Note: Requirements are rounded to the nearest 100 square feet.

Source: Landrum & Brown

Aircraft Tie-Downs

Aircraft tie-down requirements were calculated for PAE and are depicted in **Table 4-51, Tie-Down Position Requirements**. PAE is unique, in that its mild climate makes tie-downs a popular option for a lot of single-engine based aircraft at PAE. As smaller local and itinerant aircraft grow at PAE, so will the need for tie-downs. It is anticipated an additional 21 tie-down positions are needed through PAL 3, which is equivalent to 168 total tie-down positions. In the *Alternatives Analysis*, wingtip clearances and maneuvering area will be calculated to determine the total area needed based on the location chosen for the proposed tie-downs.

Exhibit 4-19 Example of T-Hangar Area Requirements



Sources: Landrum & Brown, Google Earth

Table 4-51 Tie-Down Position Requirements

Tie-Downs	Existing Positions (#)	PAL 1 (#)		PAL 2 (#)		PAL 3 (#)	
		Required	Surplus/ (Deficit)	Required	Surplus/ (Deficit)	Required	Surplus/ (Deficit)
# of Positions	147	153	(6)	158	(11)	168	(21)

Source: Landrum & Brown

The Master Plan 2040 will strategically identify areas at PAE that can potentially accommodate future GA facilities in the following chapters. The growth of GA is directly related to the projected forecasted growth of based aircraft at PAE. Ultimately, the exact timing and future growth of GA facilities at PAE will depend upon third-party developers.

4.7.9 Ground Service Equipment Requirements (GSE)

Traditional GSE along with the GSE storage and maintenance facilities are generally located near the Terminal area.

4.7.9.1 GSE Apron Area Requirements

The existing GSE equipment in PAE for commercial operations is stored on the passenger terminal apron and Building C-5 (east of the terminal building). The passenger terminal ramp occupies 81,794 square feet and provides space for three aircraft gates (A1, A2, and A3), six GSE staging areas, and circulation-free area. In addition, there are three GSE off-ramp areas of 16,309 square feet in total located around the Terminal building that provide support areas to on-apron areas. **Tables 4-52, GSE Apron Area Composition**, presents the composition of the on-apron area.

Table 4-52 GSE Apron Area Composition

GSE Apron Area	Gates (sf)			Total Existing Area (sf)	Existing Average Area per Gate (sf)
	A1	A2	A3		
Gate Area	20,386	20,038	20,147	60,572	20,191
On-Apron Area	9,601			9,601	3,200
Circulation/Free Area	11,622			11,622	3,874
Total				81,794	27,265

Source: Landrum & Brown

The existing GSE on-apron and off apron areas are sufficient for the GSE operations that occur in PAE. By considering existing apron area as adequate for their operations, areas were calculated to accommodate peak terminal passenger operations. The future gate requirements drive the amount of GSE area required to accommodate operations. As contact gates are added, it is required that an approximately 27,000 square feet of GSE staging area on the ramp be provided. The requirement for GSE areas throughout the planning period are presented in **Table 4-53, GSE Apron Area Requirements**.

Table 4-53 GSE Apron Area Requirements

GSE Area	Existing Area (sf)	PAL 1		PAL 2		PAL 3	
		Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)
Gates	3	3	-	3	-	7	4
Gate Area	60,572	60,572	-	60,572	-	141,334	(80,762)
On-Apron Area	9,601	9,601	-	9,601	-	22,401	(12,801)
Circulation/Free Area	11,622	11,622	-	11,622	-	27,117	(15,495)
Off-Apron Area	16,309	16,309	-	16,309	-	38,053	(21,745)

Source: Landrum & Brown

It is assumed the existing GSE ramp staging is sufficient through PAL 2. Additional GSE ramp space will be required if the number of contact gates expand beyond the existing gates.

4.7.9.2 GSE Storage and Maintenance

Commercial GSE Storage and Maintenance facilities are located North of the Passenger Terminal building in building C-5, Alaska Airlines and McGee Air Services. The currently facility does not have direct airside access. Areas for GSE Storage and Maintenance are presented in **Table 4-54, GSE Maintenance and Storage Areas**.

Table 4-54 GSE Maintenance and Storage Areas

GSE Maintenance and Storage Facility	Building Area (sf)	Site Area (sf)
Building C-5	17,459	127,314

Source: Landrum & Brown

Based on industry standards, area assumptions for GSE Storage and Maintenance requirements are presented in **Table 4-55, GSE Storage and Maintenance Assumptions**.

Table 4-55 GSE Storage and Maintenance Assumptions

Assumptions	Values
Percentage of GSE vehicles in Maintenance	10%
Average Floor Area per Vehicle	10%
Circulation	50%
Floor Area Losses Factor (Staircases, Columns)	10%

Site Area Ratio	2.4
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Source: Landrum & Brown

With the tenant’s staying in the storage and maintenance area (Building C-1), the analysis determined that the GSE Storage and Maintenance areas are sufficient for the entire planning period as shown in **Table 4-56, GSE Storage and Maintenance Area Requirements**, however, is recommended to provide proximity to the apron as it will ease the GSE operations between the apron and the maintenance facility.

Table 4-56 GSE Storage and Maintenance Area Requirements

GSE Storage and Maintenance	Existing Area	PAL 1		PAL 2		PAL 3	
		Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)
Building Area (sf)	17,459	2,152	15,307	2,152	15,307	5,380	12,079
Site Size (sf)	127,314	5,380	121,934	5,380	21,934	12,912	114,402

Source: Landrum & Brown

4.7.10 Police/Security

The Police/Security facilities at PAE consist of the Sheriffs and security office from Propeller Airports. Both are located in Building C-3. As the Building C-3 is occupied by different tenants, only 6.14 percent is dedicated to the Police, divided in 1,381 square feet – Sheriffs and 144 square feet – Security office for a total of 1,525 square feet. Future Police/Security facility requirements are based on a planning factor ratio using annual passenger operations. The assumptions used to calculate the requirements are presented in **Table 4-57, Police/Security Planning Factor**.

Table 4-57 Police/Security Planning Factor

Facility	Planning Factor
Police/Security Building	0.15 sf / Passenger

Source: Landrum & Brown

The analysis shows additional building/office space is anticipated to be required by PAL 1. The results of the Police/Security facility requirements are further depicted in **Table 4-58, Police/Security Requirements**.

Table 4-58 Police/Security Requirements

Government/ Police	Existing area	PAL 1		PAL 2		PAL 3	
		Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)	Required (sf)	Surplus/ (Deficit)
Building Area	1,525	2,499	(974)	2,811	(1,286)	6,226	(4,701)

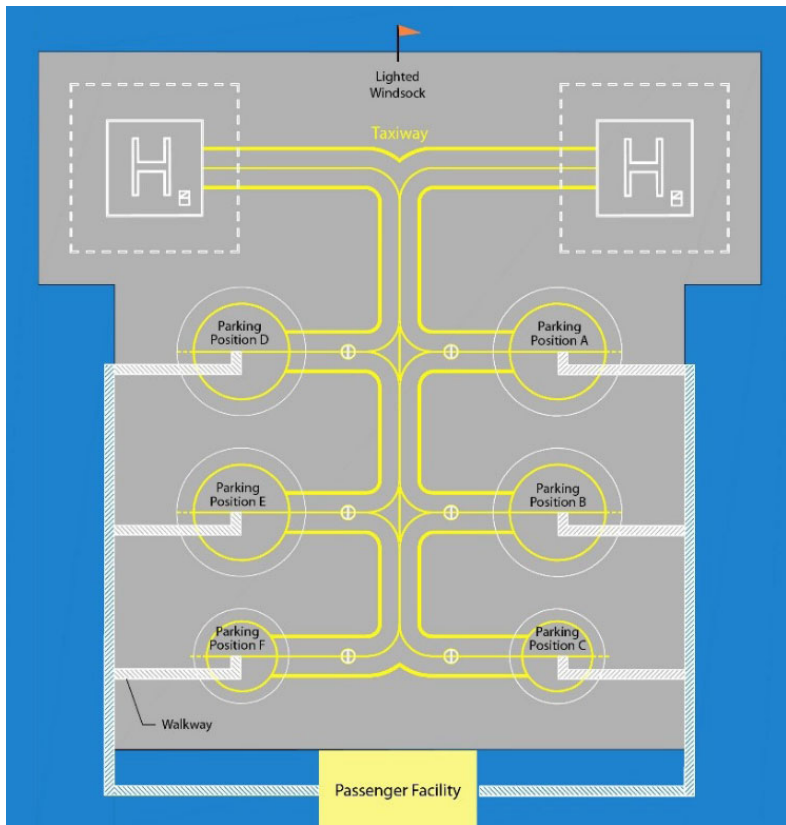
Source: Landrum & Brown

4.8 Other Aviation Related Commercial Facilities

Urban air mobility (UAM), also known as Advanced Air Mobility, refers to urban transportation systems that move people by air and is a new mode of transportation and is very quickly evolving. These transportation systems are developed in response to traffic congestion. Urban air mobility is a subset of a broader Advanced Air Mobility concept that includes other use cases than intracity passenger transport. NASA describes Advanced Air Mobility as including small drones, electric aircraft, and automated air traffic management among other technologies to perform a wide variety of missions including cargo and logistics. To a large degree, these aircraft are similar to helicopters in that they fundamentally operate with vertical take-off and landing characteristics.

There are a number of technology companies that are in advanced stages of development of these highly automated aircraft, including Joby Aviation, Terrafugia, Kitty Hawk, Volocopter and Lillium, to name a few. While it is not currently possible to predict the requirements for such facilities at PAE, it is important to establish general parameters around the size, and potential adjacencies required for UAMs to exist. UAM aircraft could operate on top of existing infrastructure such as parking structures or could operate from a newly developed plot of land. Current heliport regulations require FATOs with simultaneous operations to be planned with at least 200 ft (60 m) of lateral separation. Facility designs for future UAM vertiports will be similar the current heliport regulations and site plans. **Exhibit 4-20, *Typical Helicopter Site Layout***, shows a typical helicopter airside plan. However, requirements could vary for vertiports depending on the aircraft dimensions, procedures, and layout.

Exhibit 4-20 Typical Helicopter Site Layout



Source: Landrum & Brown