

Chapter 5 ALTERNATIVES

This Chapter summarizes the airfield and terminal alternatives formulated to meet the requirements associated with the forecast aviation demand at the Airport, as presented in Chapter 4.

5.1 APPROACH

Given the complexity of the George Bush Intercontinental Airport/Houston (Airport), the two major functional components, airfield and passenger terminals, were assessed separately in the alternatives formulation process. Subsequent to identification of the preferred terminal and airfield alternatives, the individual preferred alternatives will be combined to form a comprehensive Recommended Development Plan which will address other functional components of the airport including regional access, air cargo, general aviation, and airline and airport support facilities. The Recommended Development Plan will also identify the major phases necessary for orderly and financially feasible implementation of the major improvements identified.

As part of formulating alternatives, past planning efforts and documentation was reviewed, including:

- IAH Airport Master Plan, DMJM Aviation, 2006
- Terminal D Modernization Program, Project Definition Manual, HNTB, June 2013
- United Airlines Master Plan for Terminal B, United Airlines, January 2011

After formulation of a “longlist” of alternatives, each alternative was evaluated in a screening process with two phases. Primary screening evaluated whether or not the alternative, while feasible, would likely meet the goals and objective set forth at the outset of the master plan. Alternatives not likely to meet the goals and objectives were eliminated from further consideration. Alternatives that appeared likely to meet the goals and objectives were then subject to secondary screening evaluation.

The secondary screening evaluation involved a relative comparison of the alternatives within a sustainability framework. The sustainability framework includes a set of criteria revealing how each alternative would perform with respect to economic viability, operational efficiency, and environmental and social responsibility, thereby ensuring the alternative would provide a well-balanced solution. The individual criterion in secondary screening relate back to the goals and objectives to evaluate the extent to which an individual alternative would achieve a goal or objective relative to other options.

The goals are shown in bold text below, and the requisite objectives are the bullets below each goal.

Airfield: plan for a safe and operationally efficient airfield by meeting the following objectives:

- Provide sufficient airfield capacity to meet demand
- Minimize airfield delays
- Provide taxiways for optimal flow on the ground, including crossfield taxiways and circular flow around terminal complex
- Continue to plan for NextGen technological improvements
- Determine the ultimate airport layout
- Reduce or eliminate need for Modifications of Standards

Passenger Terminal: provide needed gate capacity and a consistent customer experience throughout the terminal complex by meeting the following objectives:

- Plan for high levels of service for the entire customer experience
- Provide sufficient aircraft gates to accommodate existing and prospective carriers
- Provide excellent concessions to delight the passenger
- Provide sufficient parking for remain-overnight aircraft
- Reflect Houston culture in the plan
- Leverage technology for improved passenger experience

Landside/Access: provide efficient airport access by meeting the following objectives:

- Provide for an appropriate level of service on access roadways and terminal curbsides during peak hour
- Plan for the link to METRORail
- Plan for the replacement of the Inter-Terminal Train (ITT)
- Address the parking imbalance between facilities
- Provide sufficient parking capacity to maintain or improve market share
- Provide for centralized receiving dock

Environment and City: provide an airport befitting the fourth largest city in the nation by meeting the following objectives:

- Optimize existing facilities through renewal or modernization where practical
- Minimize adverse environmental impacts of future development
- Seek input and address the concerns of stakeholders and users of the airport

Financial: provide an affordable plan by meeting the following objectives:

- Maintain a competitive cost structure that is attractive to airlines and other tenants
- Establish land use parameters to guide future developable property
- Plan for growth in non-aeronautical revenues including commercial development and concessions

It should be noted that some of the objectives will be addressed during the Recommended Development Plan phase of the project, and in this phase of analysis the intent is to not preclude them from being accomplished.

5.2 AIRFIELD ALTERNATIVES

This section describes the development and evaluation of airfield alternatives, as well as the preferred runway and taxiway alternatives.

The primary conclusions from the previously established facility requirements were as follows:

- Sufficient runway capacity exists to accommodate forecast demand through Planning Activity Level (PAL) 33 (which corresponds to 33 million enplaned passengers at the Airport), albeit marginally during east flow and under poor weather conditions. Average aircraft delays at the Airport are expected to remain at an acceptable level through PAL25, approaching unacceptable thresholds near PAL33.
- The length of Runway 15L-33R is adequate to accommodate long-haul departures from the Airport. However, consideration should be given to extending another runway in the case that Runway 15L-33R must be taken out of service.
- In the near term, projects should be undertaken to improve taxiway movements, namely to provide redundant crossfield taxiway capability, improve aircraft circulation in the terminal area, expedite runway crossings, and improve departure queuing and staging.

Accordingly, the development of airfield alternatives focused on providing additional runway capacity, extending a runway, and improving crossfield taxiing capability.

5.2.1 Airfield Alternatives Approach

The airfield alternatives analysis was conducted in coordination with an Airfield Subcommittee of the Master Plan Technical Advisory Committee, including representatives of the Houston Airport System, FAA (i.e., IAH Tower and Texas Airports Development Office), United Airlines, and the consultant team.

The development, analysis, and selection of airfield alternatives focused on the location of the next runway needed to meet demand, given that additional runway capacity is required to be in place at PAL33. The location and timing of the next runway informs the long term airfield plan and the supporting airfield infrastructure that will be needed to satisfy forecast demand through PAL40 and beyond. Alternatives for runway extensions and crossfield taxiways were also studied.

Evaluation criteria to assess alternatives and identify the preferred alternatives were developed based on the Master Plan goals and objectives established at the outset of the project. The airfield goal is to plan for a safe and operationally efficient airfield by meeting the following objectives:

- Provide sufficient airfield capacity to meet demand
- Minimize airfield delays
- Provide taxiways for optimal flow on the ground, including crossfield taxiways and circular flow around terminal complex
- Continue to plan for NextGen technological improvements
- Determine the ultimate airport layout
- Reduce or eliminate the need for Modifications of Standards

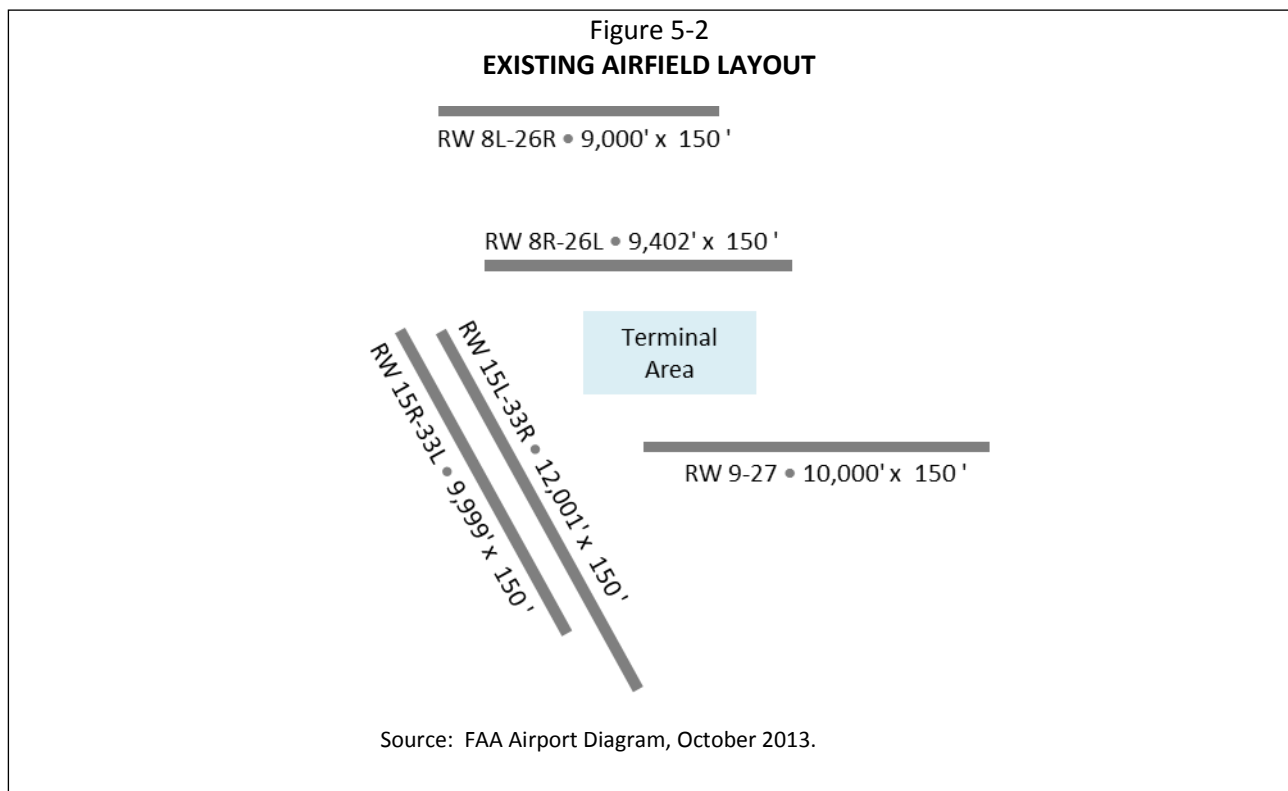
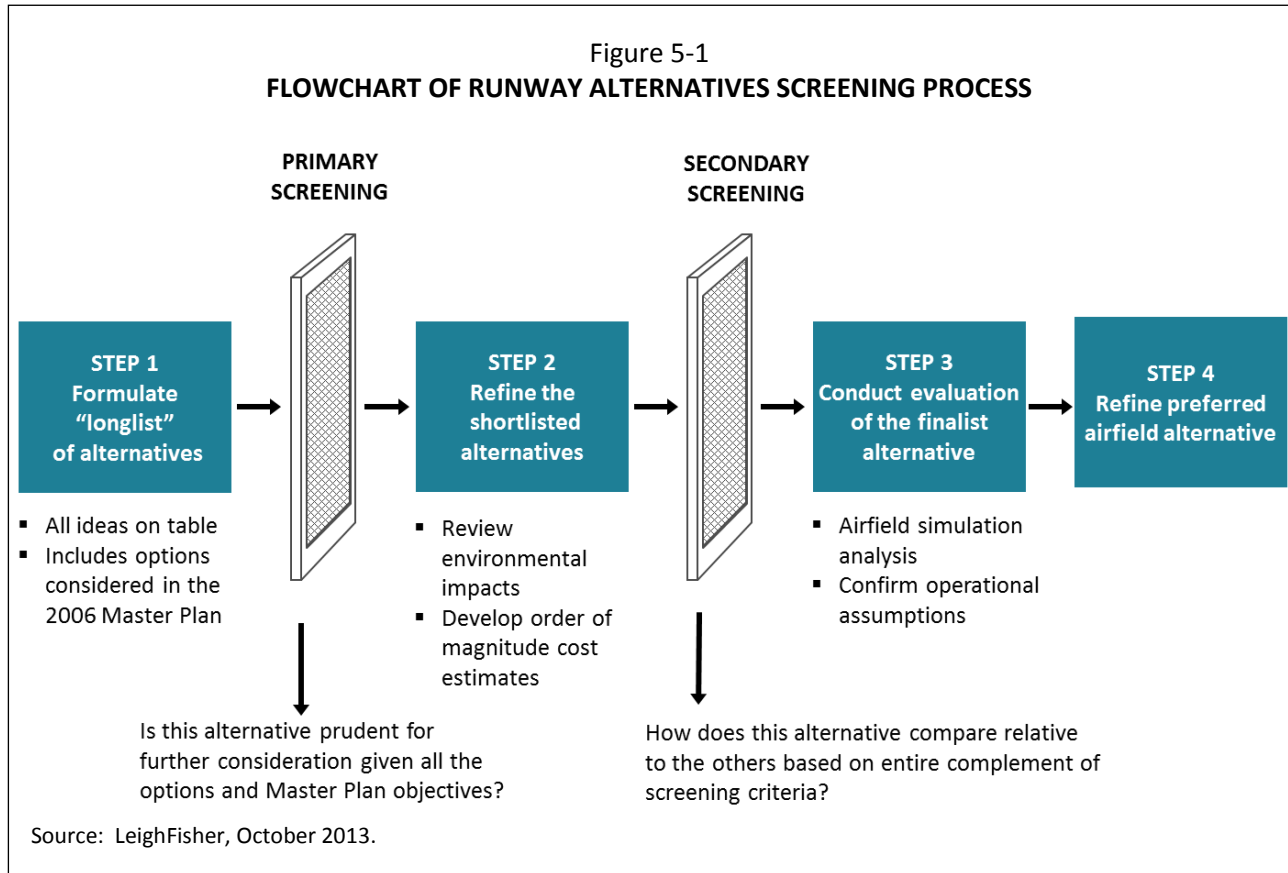
Using the aforementioned objectives, airfield alternatives were formulated and subjected to evaluation. In the case of the runway alternatives, a two-tier evaluation was used. The first tier was development of a longlist of runway alternatives based on review of past airfield planning efforts, including those considered in the previous master plan. These longlist alternatives were then screened to generate a shortlist of runway alternatives for further analysis. Based on agreed upon evaluation criteria, the shortlist alternatives were compared and a preferred runway alternative was selected. The runway alternatives process is shown in Figure 5-1.

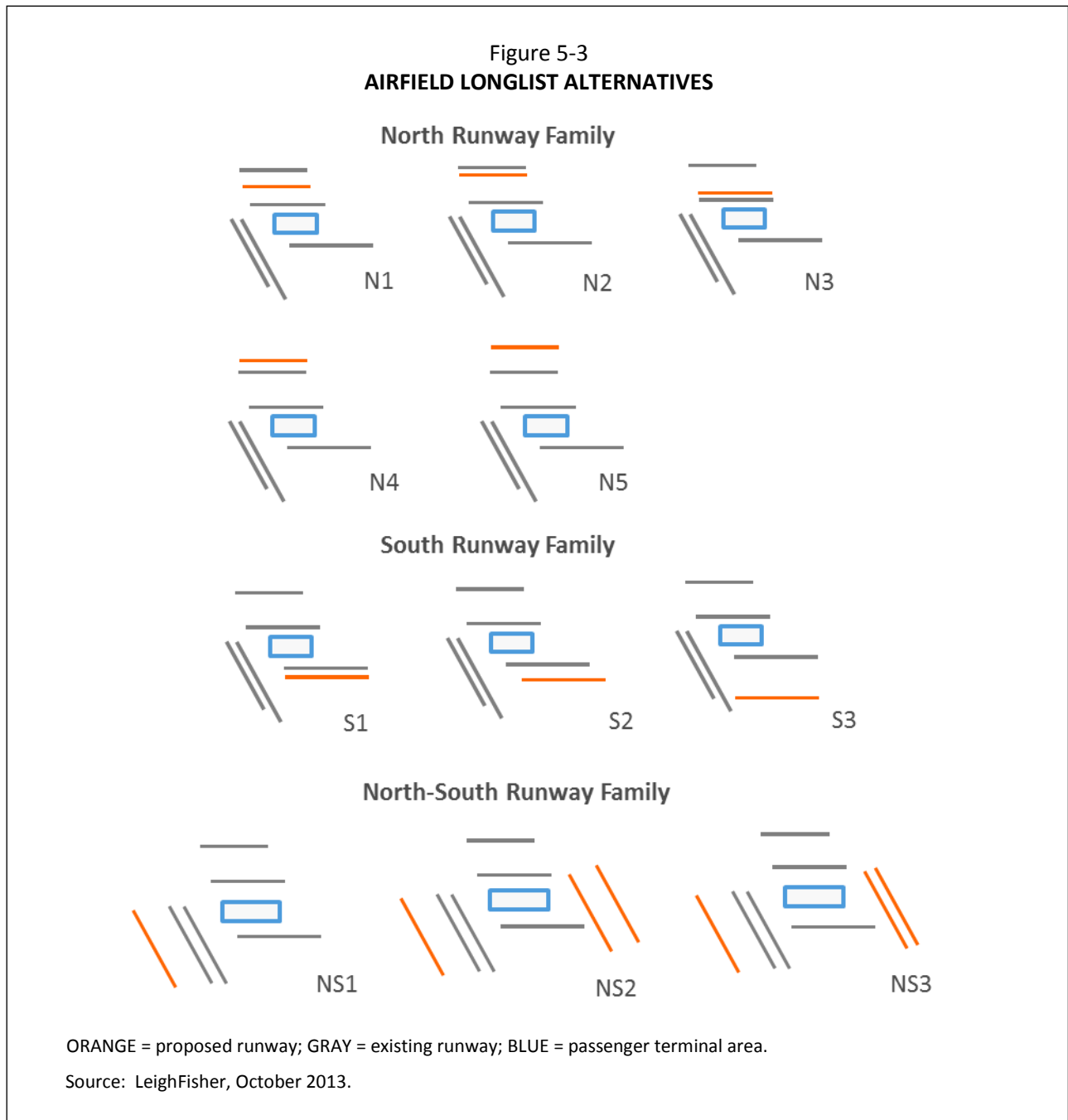
5.2.2 Longlist of Runway Alternatives

The existing airfield layout, including runway names and dimensions, is shown in Figure 5-2 for reference. Airfield alternatives were formulated cognizant of the alternatives considered in the 2006 Master Plan, which included a comprehensive evaluation of options. The centerline spacing of proposed runways to existing runways determines the operation and dependency of any new runway with the existing airfield. The runway centerlines of closely spaced alternatives would be spaced at least 1,200 feet from an existing runway centerline, but less than 2,500 feet, resulting in dependent operation. Widely spaced alternatives would be a minimum of 2,500 feet from an existing runway centerline, enabling independent operation of departures and arrivals. Three alternative families were identified, described in the following section and shown in Figure 5-3.

5.2.2.1 North Runway Family

Five north alternatives were evaluated, all of which involve a new runway to the north of the terminal area and existing Runway 8R-26L. Alternatives N1, N2, and N3 provide a new runway in between existing Runways 8R-26L and 8L-26R. The runway centerline of Alternative N1 would be located equidistant from the centerlines of Runways 8R-26L and 8L-26R, while in Alternative N2 the new runway would be closely spaced to Runway 8L-26R and in Alternative N3 the new runway would be closely-spaced to Runway 8R-26L. Alternatives N4 and N5 provide a new runway to the north of Runway 8L-26R. Alternative N4 would be closely spaced to Runway 8R-26L while Alternative N5 would be widely spaced.





5.2.2.2 South Runway Family

Three south runway locations were considered for a new runway to the south of existing Runway 9-27. Alternative S1 would be a closely spaced parallel runway to Runway 9-27. Alternatives S2 and S3 would provide a widely-spaced parallel runway to Runway 9-27, S2 being spaced at approximately 2,500 feet and S3 spaced at 5,000 feet or more.

5.2.2.3 North-South Runway Family

Three north-south runway locations were considered, involving additional runways parallel to the existing Runway 15-33 complex. Alternative NS1 includes an additional widely spaced parallel runway west of Runway 15R-33L. Alternatives NS2 and NS3 require more than one additional runway. Building additional runways in the 15-33 orientation would severely impact the use of the existing east-west runway system, making it essential to build more than one additional runway to provide adequate capacity. Alternative NS2 includes the same widely spaced runway as in NS1, but also includes a pair of widely spaced runways east of Runway 15L-33R and the terminal complex. Alternative NS2 would require a redevelopment of the taxiway infrastructure and would likely significantly impact operations on Runways 9-27 and Runway 8R-26L. Alternative NS3 includes the same runway that is part of Alternative NS1, but also includes a pair of closely spaced runways parallel to Runway 15L-33R to the east of the terminal complex. As in Alternative NS2, it was assumed that under this alternative Runways 9-27 and 8R-26L would be removed or be retained with limited utility.

5.2.3 Primary Runway Alternatives Screening

Following the identification of the longlist of runway alternatives, a primary screening was conducted to narrow the number of alternatives to be retained for further analysis. This evaluation centered on identifying “fatal flaws” that would prevent the alternative from being implemented or operating efficiently and alternatives that could provide equivalent or better capability than others with lesser impacts. These “fatal flaws” include the need for extensive property acquisition, unacceptable increases in noise exposure, other environmental impacts, provision of inadequate airfield capacity, and unacceptably long aircraft taxiing times. The primary screening of alternatives is described below.

Alternatives that included additional parallel runways to the 15-33 complex were eliminated (NS1, NS2, and NS3) for the following reasons:

- Additional runways in the 15-33 direction exacerbate existing runway dependencies (i.e., the dependence between arrivals to the east-west runways and the departures using the Runway 15-33 complex)
- Additional capacity is more easily achieved in east-west orientation (e.g., each of the proposed additional east-west runways provides a similar increases in airfield capacity)
- Land acquisition was deemed unrealistic and controversial
- Cost prohibitive due to land acquisition and relocation of residence and businesses
- The alternatives were not considered socially responsible or environmentally conscious given the aforementioned factors

Alternatives that included additional east-west parallel runways to the north of Runway 8L-26R (N4 and N5) also were eliminated for the following reasons:

- Equivalent capacity increases can be obtained using area within existing airport property (or with minimal acquisition)
- Taxiing times between the proposed runways and the terminal area would be unacceptably long
- Additional runway crossings would be required (i.e., aircraft departing or arriving the proposed runways would need to cross the centerlines of both Runways 8L-26R and 8R-26L)

- Land acquisition was deemed unrealistic and controversial
- Not considered socially responsible or environmentally conscious

Alternatives which do not provide sufficient additional capacity were eliminated. For example, in the North family alternatives, N2 would be dependent on Runway 8L-26R and N3 would be dependent on Runway 8R-26L. Alternative N1 provides the possibility for independent operations from both Runways 8R-26L and 8L-26R, so it was retained as the preferred alternative from the North family.

Following the primary screening of alternatives, four alternatives remained for further analysis: N1, S1, S2, and S3. These four alternatives form the “shortlist” of runway alternatives and are discussed in the following section.

5.2.4 Shortlist Runway Alternatives

Following the primary screening of the longlist airfield alternatives, the remaining alternatives were subjected to a rigorous screening and analysis.

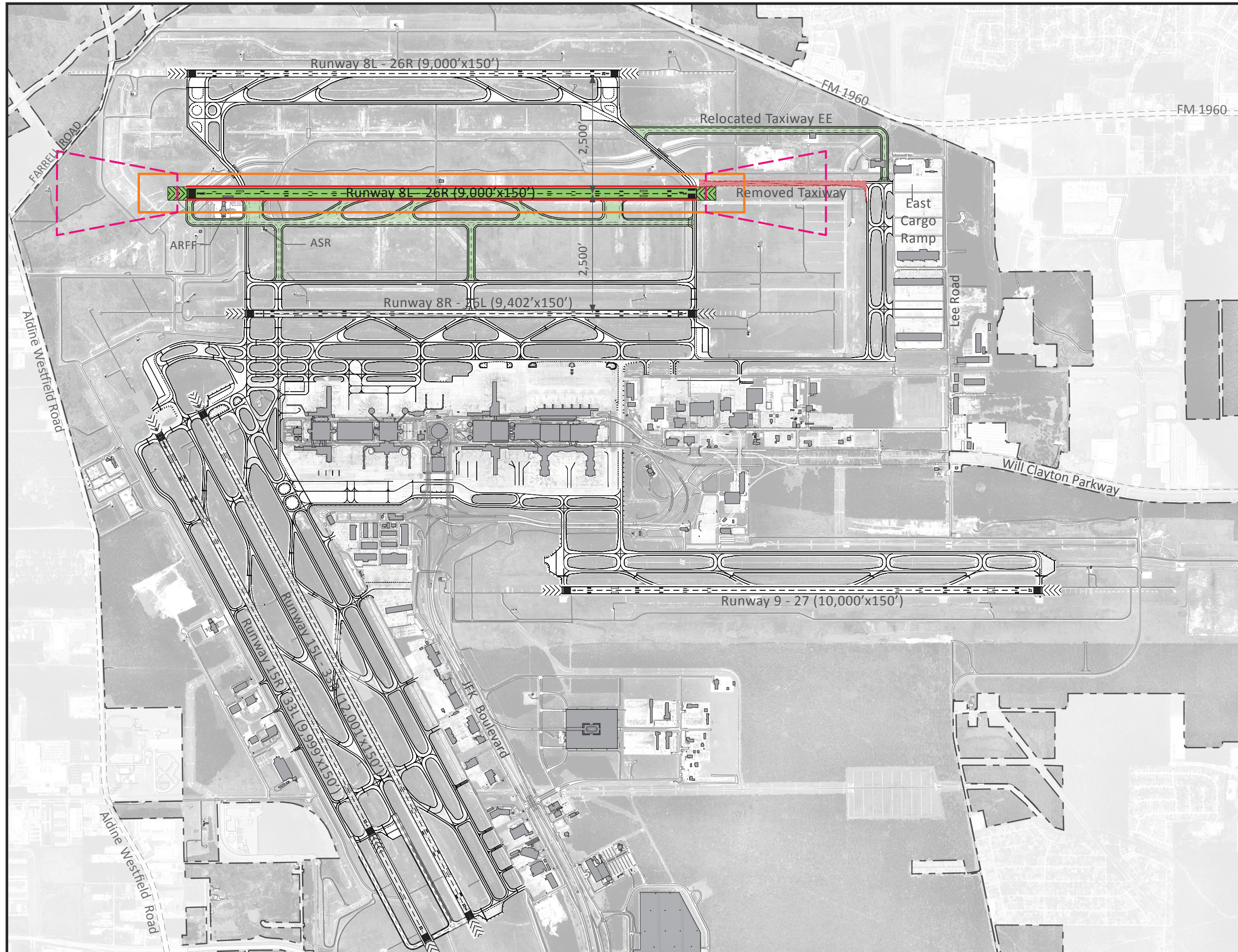
All alternatives assume the new runway would be built to meet Airplane Design Group (ADG) VI design standards. These standards require that the runway width be 200 feet and the shoulder width be 40 feet. Any new runway would have a supporting parallel taxiway meeting Taxiway Design Group (TDG) 8 standards, requiring a taxiway width of 82 feet with shoulders 40 feet in width. The centerlines of any new parallel taxiways are assumed to be 600 feet from the proposed runway centerline. Other taxiway additions or reconfigurations required to ensure airfield circulation were not considered at this stage in the evaluation. All new runways would be equipped with an instrument landing system on both ends to support precision approaches.

The physical and operational characteristics of the four alternatives remaining after primary screening are described in more detail in the following sections.

5.2.4.1 North 1

Alternative North 1 includes a new runway with centerline spaced 2,500 feet from both the centerlines of Runways 8L-26R and 8R-26L which would be used primarily by departures. The analysis considered two variations on Alternative North 1, assuming either independent departure operations in both east and west flow and all weather conditions (North 1A), or assuming a dependency between departures on the new runway and arrivals on Runway 26R during instrument meteorological conditions (IMC) in west flow (North 1B). The two variations of North 1 were considered to assess the operational benefit which independence in west flow provides in comparison with the additional runway length it would require.

The eastern end of the new runway in Alternative North 1A, shown in Figure 5-4, is aligned with the end of Runway 26L, and the western end is aligned with the west of the end of Runway 8L, making the runway length approximately 10,610 feet. In Alternative North 1B, shown in Figure 5-5, both ends of the new runway are aligned with the ends of Runway 8R-26L, making the length of the runway 9,402 feet. Taxiway EE would need to be realigned as part of both alternatives. Also, these alternatives would require relocation of the aircraft rescue and firefighting facility (ARFF) and airport surveillance radar (ASR).



LEGEND

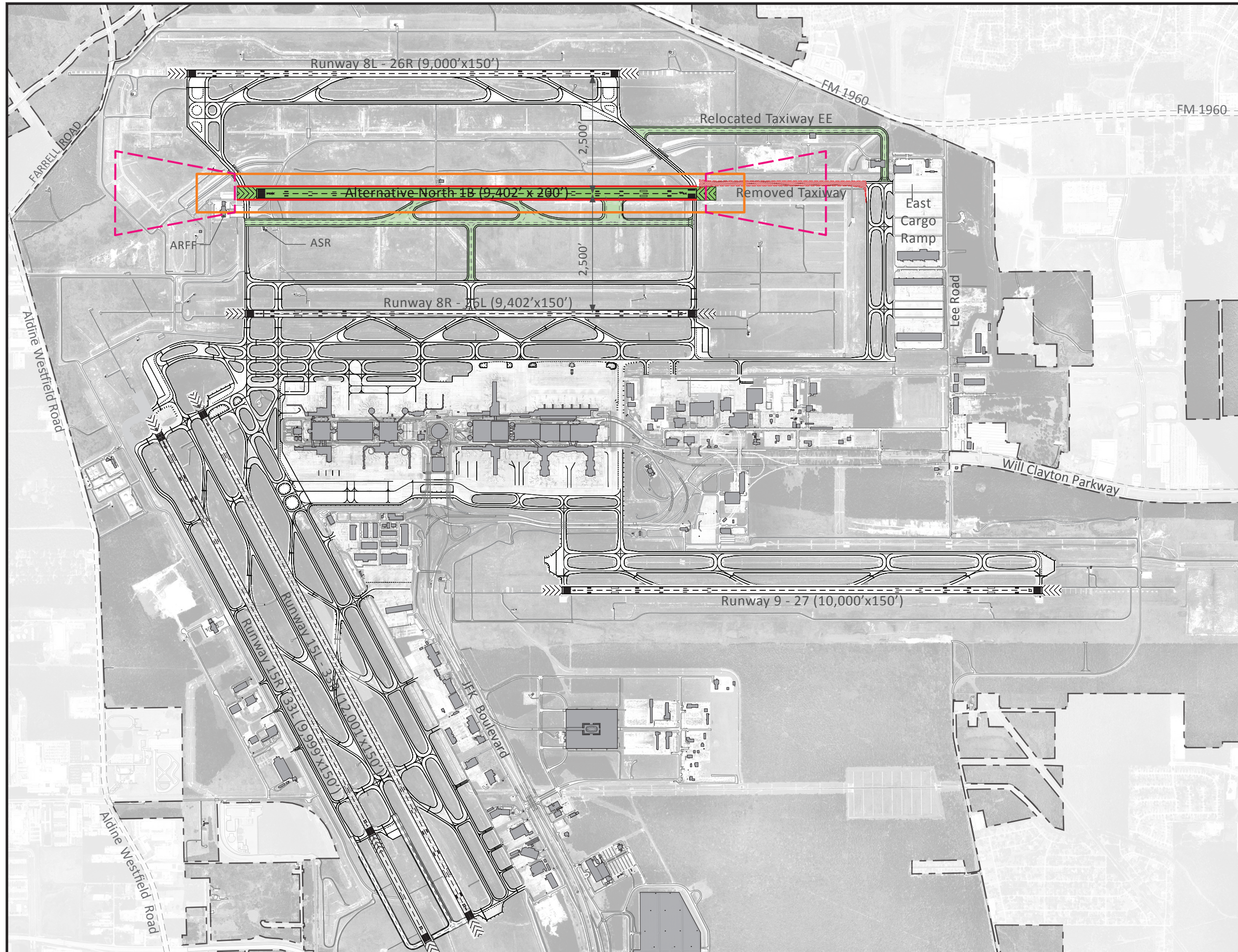
- Airport property line
- Runway protection zone (RPZ)
- Runway object free area (ROFA)
- Runway shoulders
- New runway pavement
- New taxiway pavement
- Pavement removal

Leigh | Fisher



Source: Source: HAS Records &
 IAH Airport Layout Plan, August 2006
 Prepared by: Leigh | Fisher
 October, 2013

Figure 5-4
 North 1A
 2,500' Spacing--independent



LEGEND

- Airport property line
- Runway protection zone (RPZ)
- Runway object free area (ROFA)
- Runway shoulders
- New runway pavement
- New taxiway pavement
- Pavement removal

Leigh | Fisher



Source: Source: HAS Records &
 IAH Airport Layout Plan, August 2006
 Prepared by: Leigh | Fisher
 October, 2013

Figure 5-5
North 1B
 2,500' Spacing--independent

The runway in Alternatives North 1A and North 1B are expected to be used primarily for departures, while the remaining runways would continue to be used as they currently are, meaning Runways 8L-26R and 8R-26R would continue to be used primarily for arrivals. Per FAA Order JO 7110.65, *Air Traffic Control*, 2,500 feet centerline spacing between parallel runways is the minimum allowable separation to allow independent departures and arrivals under IMC. However, the thresholds of the runways must be in alignment, or the threshold of the landing runway must be prior to the departure end of the adjacent runway in order for operations to take place independently. In other words, if the arrival threshold follows the departure end of runway, the runways cannot operate independently under IMC. This condition is referred to as an “adverse stagger.”

In Alternative North 1A, there are two options to eliminate the adverse stagger in west flow and mitigate the operational dependency, including:

1. Extending Runway 8L-26R to the east so that the runway ends of Runways 26L, 26R, and the east end of the new runway all align.
2. Providing the possibility for intersection departures from departure points on the new runway in line with the arrival threshold to Runway 26R. The resulting stagger between the departure point on the new runway and the Runway 26L arrival threshold would be an advantageous stagger.

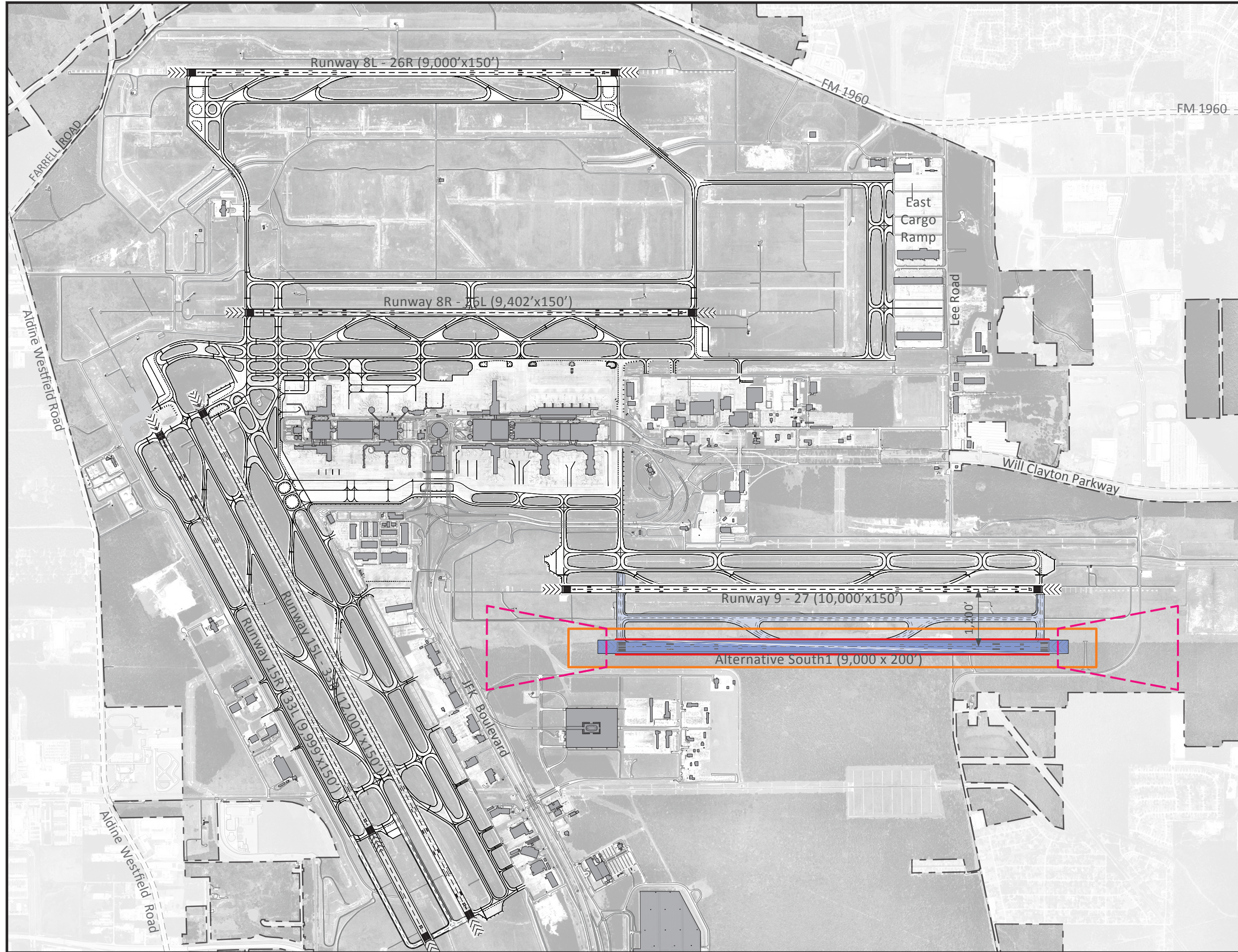
The second option for providing independence is preferred because of the implications of extending Runway 8L-26R. An extension of Runway 8L-26R could trigger property acquisition to the east of the existing runway and a relocation of Farm-to-Market 1960. Therefore, as shown in Figure 5-4, Alternative North 1A is assumed to enable independent operations through the use of departure points for intersection departures.

Alternative North 1B, shown in Figure 5-5, with the runway ends for the new runway aligned with Runway 8R-26L, operations would be independent in east flow (since the arrival threshold for Runway 8R would be in line with the departure end of the new runway, and the arrival threshold for Runway 8L would be behind the departure end of the new runway). However, in west flow departures using the new runway and arrivals to Runway 26R would be dependent since the departure end of the new runway is east of the threshold to Runway 26R, which is an adverse stagger.

5.2.4.2 South 1

Alternative South 1 is shown in Figure 5-6. It includes a new parallel runway to the south of Runway 9-27 at a centerline spacing of 1,200 feet. The spacing of 1,200 feet allows for a taxiway between existing Runway 9-27 and the new runway at the requisite ADG VI spacing of 600 feet from each runway centerline. However, since the centerline spacing between runways is less than 2,500 feet, no independence of operations between Runway 9-27 and the new runway under IMC weather conditions would be possible.

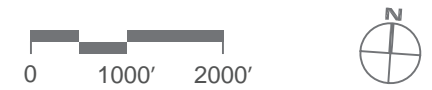
The new runway in alternative South 1 would be used primarily for arrivals, and Runway 9-27 would become primarily a departure runway. As drawn in Figure 5-6, the new runway is 9,000 feet long, which is the same length as Runway 8L-26R, also primarily an arrival runway. The western end of the runway is sited such that the runway protection zone (RPZ) for the west end of the new runway would be clear of John F. Kennedy Boulevard (JFK). No major facility relocation or property acquisition is required for implementation of this alternative.



LEGEND

- Airport property line
- Runway protection zone (RPZ)
- Runway object free area (ROFA)
- Runway shoulders
- New runway pavement
- New taxiway pavement
- Pavement removal

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Source: Source: HAS Records &
 IAH Airport Layout Plan, August 2006
 Prepared by: Leigh|Fisher
 October, 2013

Figure 5-6
 South 1
 1,200' Spacing

5.2.4.3 South 2

Alternative South 2 is shown in Figure 5-7. It includes a new parallel runway to the south of Runway 9-27 at centerline spacing of 2,800 feet. The western end is defined such that the proposed runway RPZ would be clear of JFK Boulevard. The centerline spacing of 2,800 allows for independence in both directions between arrivals on the new runways and departures on Runway 9-27. The additional 300 feet above the minimum runway centerline spacing of 2,500 feet mitigates the adverse stagger of 2,000 feet on the east end so that arrivals on the new runway would be independent of departures on Runway 9-27.

It is expected that the new runway in alternative South 2 would be used primarily for arrivals, and Runway 9-27 would be used primarily for departures. Notably, the utility of the new runway may be limited in west flow since arrivals likely could not take place simultaneously with departures from either Runway 15L or 15R.

This alternative would require relocation of airport facilities and property acquisition. The most notable relocation would be of the consolidated rental car center (CONRAC).

5.2.4.4 South 3

Alternative South 3 is shown in Figure 5-8. It includes a new parallel runway to the south of Runway 9-27 at centerline spacing of 5,000 feet. The spacing of 5,000 feet allows for operations independent from Runway 9-27 on the new runway. Additionally, at a spacing of 5,000 feet, it provides for the possibility of quadruple simultaneous arrivals in the future. Currently no standard exists governing the spacing of parallel runways to support simultaneous quadruple arrivals. However, a centerline separation of 5,000 feet is generally accepted as the likely requirement as it is the spacing requirement for simultaneous triple arrivals. Notably, the need for quadruple arrivals from a capacity perspective is not expected within the Master Plan planning horizon.

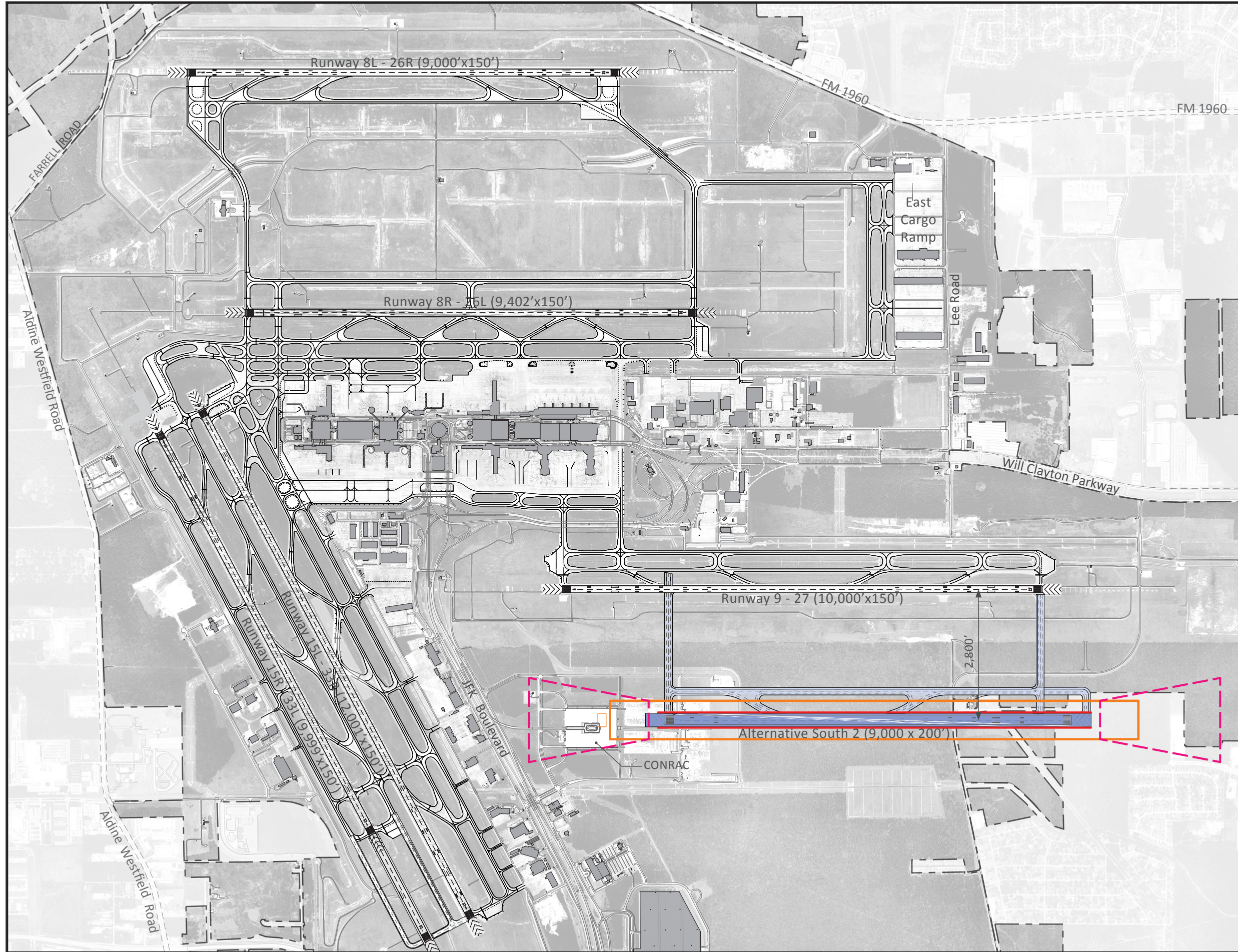
It is expected that the new runway in alternative South 3 would be used primarily for arrivals, and Runway 9-27 would be used primarily for departures. However, as in Alternative South 2, the utility of the new runway would be minimal in west flow since arrivals likely cannot take place simultaneously with departures from either Runway 15L or 15R.

This alternative would require significant property acquisition and residential relocations.

5.2.5 Secondary Screening

The four shortlisted airfield alternatives were evaluated in secondary screening assessing their ability to meet the evaluation criteria shown in Table 5-1. Evaluation criteria are segregated into three categories: financial, operational, and environmental. Each alternative is ranked on each criteria, green meaning good or advantageous, yellow meaning fair or neutral, and red meaning poor or disadvantageous.

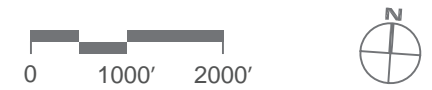
Table 5-1 summarizes the results of the screening evaluation and scores each alternative. For each criterion, the alternative was given a score of 3 for a positive outcome (green), 1 for a negative outcome (red) or 2 for an outcome in between (yellow). As shown, Alternative 1A resulted in the highest score of 33, identifying it as the preferred airfield alternative. Details regarding the individual criteria and the results follow.



LEGEND

- Airport property line
- Runway protection zone (RPZ)
- Runway object free area (ROFA)
- Runway shoulders
- New runway pavement
- New taxiway pavement
- Pavement removal

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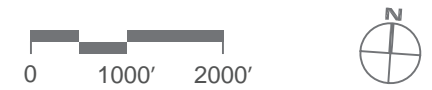
Figure 5-7
 South 2
 2,800' Spacing



LEGEND

- Airport property line
- Runway protection zone (RPZ)
- Runway object free area (ROFA)
- Runway shoulders
- New runway pavement
- New taxiway pavement
- Pavement removal

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Source: Source: HAS Records &
 IAH Airport Layout Plan, August 2006
 Prepared by: Leigh | Fisher
 October, 2013

Figure 5-8
South 3
 5,000' Spacing

Table 5-1
RUNWAY ALTERNATIVES EVALUATION MATRIX

Criteria	Description	Existing	North		South		
			1A	1B	1	2	3
			Indep.	Dep.	1,200'	2,800'	5,000'
Financial							
Capital cost estimate (a)	Total capital costs to be funded (\$M)	N/A	307	225	190	525	376
Airfield and aircraft operational costs	Average annual operational savings compared to existing based on delay and taxi time at PAL 40 (\$M)	N/A	566	434	126	186	183
<i>Financial Score</i>			5	6	4	3	4
Operational							
Hourly airfield capacity	Weighted hourly 50%-arrivals capacity from ACM (aircraft operations)	165	184	182	171	174	174
Average annual aircraft delay	Average annual aircraft delay per operation at PAL40 from ADM (minutes)	30.3	5.7	11.3	24.9	22.3	22.3
Taxi-in/Taxi-out time	Average unimpeded taxi times estimates by review of taxi paths (min)	5.3	5.9	5.9	5.3	5.4	5.5
Land use compatibility	Qualitative assessment of land uses within RPZ, navigational aids, and approach and departure surfaces	N/A	East cargo	East cargo	None	None	None
Airspace compatibility	Qualitative assessment of missed approach procedures and directional demand	N/A	Arrival/departure divergence	Arrival/departure divergence	Good	Arrival/departure divergence	Arrival/departure divergence
<i>Operational Score</i>			11	9	9	8	8
Environmental							
Wetlands	potential wetlands impacted (acres)	N/A	0.51	0.51	0.17	0	0.39
Floodplains	100-year floodplains to be built on (acres)	N/A	0	0	0	0	39
Section 303(c) Lands	Section 303(c) lands that would be impacted	N/A	0	0	0	0	0
Property acquisition	land to be acquired (acres)	N/A	0	0	0	183	412
Air quality	Aircraft taxi times; conformity determination	N/A	Construction impacts, taxi time	Construction impacts, taxi time	Construction impacts	Construction impacts	Construction impacts
Noise	homes within the noise contour	N/A	0	0	100 apartments	100 homes	550 homes
Degree of controversy	qualitative assessment pending public meetings	N/A	Possible	Possible	None	Likely	Likely
<i>Environmental Score</i>			17	17	18	16	10
Total Score			33	32	31	27	22
LEGEND	Negative outcome		Marginal outcome		Positive outcome		
Scoring	1	2	3				

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Source: LeighFisher, October 2013.

5.2.5.1 Financial Criteria

The financial evaluation of the five alternatives assessed both capital and operational costs.

Capital Cost Estimates. Rough order-of-magnitude cost estimates were prepared for each of the alternatives. These cost estimates included construction of the runway and supporting taxiways, demolition of any facilities needed to enable runway construction, drainage improvements, and necessary property acquisition, residential relocation, and environmental mitigation. Cost estimates also include “soft costs” and various contingencies.

A summary of the cost estimates for the alternatives is shown in Table 5-2. The least costly alternative is South 1, since it requires no demolition or relocation of existing facilities on airport property. Alternatives North 1A and 1B are the next most expensive alternatives, at between \$226 and \$308 million. Alternative South 3 is the next most costly, largely due to the property acquisition and noise mitigation measures that would be required. Alternative South 2 is most expensive due to the required demolition and relocation of the CONRAC in addition to property acquisition.

Table 5-2
RUNWAY ALTERNATIVE COST ESTIMATES
 (in millions of dollars)

Description	North 1A	North 1B	South 1	South 2	South 3
Demolition of existing facilities	\$ 2.3	\$ 2.3	\$ 0.0	\$ 8.0	\$ 4.6
Runway improvements	70.1	49.5	47.4	47.4	47.4
Taxiways improvements	72.6	57.9	44.1	54.0	66.6
Drainage improvements	9.2	3.7	16.0	7.0	6.2
Roadway improvements	6.8	0	0	8.7	8.7
Environmental mitigation	0	0	2.5	5.0	28.9
Property acquisition and relocation	<u>17.2</u>	<u>17.2</u>	<u> </u>	<u>174.1</u>	<u>55.2</u>
Subtotal	178.2	130.6	110.0	304.2	217.6
Contingencies	78.4	57.5	48.4	133.8	95.7
Design and construction management	<u>51.3</u>	<u>37.6</u>	<u>31.7</u>	<u>87.6</u>	<u>62.7</u>
Total	\$307.9	\$225.7	\$190.1	\$525.6	\$376.0

Source: Sunland Group, October 2013.

Aircraft Operating Cost. Average delay per operation and average unimpeded taxiing time (both described in the following section) were monetized relative to the existing airfield to estimate the net increase or decrease in aircraft operating cost at the PAL40 demand level.

The estimated delay and taxiing time savings as compared to the existing airfield layout were converted into savings in aircraft direct operating costs using current airline data obtained from the U.S. Department of Transportation (U.S. DOT) Form 41 filings for the most recent 12 month period available. Aircraft direct operating costs represent the direct, out-of-pocket operating costs that could be incurred in the air and on the ground by the aircraft operator. These include costs associated with crew, fuel and oil, insurance, taxes, and direct maintenance.

U.S. DOT Form 41 data, which are available for larger, established airlines, were supplemented with FAA-prescribed operating costs for general aviation, military, and air taxi aircraft. For general aviation, air taxi, and military aircraft unit direct operating cost estimates were taken from *Economic Values for FAA Investment and Regulatory Decisions*, published on December 31, 2004, by GRA Incorporated. Operating cost estimates from this report were adjusted to 2013 dollars using the producers' price index for the "air transportation, non-scheduled" category.

The PAL40 fleet mix was used to estimate the aircraft direct operating cost per minute depending on the phase of flight (i.e., gate, ground, or air). A weighted average of the three phases was applied to the delay savings, namely \$28.37 per minute, and the "ground" value was applied to differences in taxiing times, namely \$22.53 per minute. Costs for any passenger lost time were not included in this analysis.

As shown in Table 5-1, Alternative North 1A would provide the greatest aircraft operating cost savings in comparison to the existing airfield layout, at \$35 million annually by PAL40. Alternative North 1B has higher aircraft operating costs than North 1A due to runway dependencies in west flow. The south alternatives do not perform as well as the north alternatives, primarily due to the limited capacity increases they would provide in comparison to the existing airfield.

5.2.5.2 Operational Criteria

The operational criteria considered included airfield capacity, delay, and taxiing time as well as compatibility with land uses and airspace.

Hourly Airfield Capacity. Hourly airfield capacity was estimated using the FAA Airfield Capacity Model (ACM). Capacities for east flow and west flow under the three primary operating regimes at the Airport were averaged into a weighted 50%-arrivals capacity based on historical weather conditions and occurrence of runway uses. Effectively, this assumes a balanced airfield in which equal priority is given to arrivals and departures and is representative of traffic over an average day instead of considering an arrival or departure peak hour.

Figures 5-9 and 5-10 show the estimated capacity of each alternative as compared to the existing airfield under the three primary operating conditions. The peak hour demand at PAL25, PAL33, and PAL40 is also shown.

Figure 5-9 displays capacity in east flow, occurring approximately 30% of the time. During visual approaches/independent departures Alternatives North 1A and North 1B provide the most capacity benefit. In comparison, the south alternatives provide about 10 fewer operations per hour. For all alternatives, capacity under the two other operating regimes is equivalent.

Figure 5-10 displays capacity estimates for west flow, occurring approximately 70% of the time. Alternative North 1A and North 1B provide identical increases in capacity, except when under instrument approaches/dependent departures where the capacity of North 1B is 14 operations an hour less than North 1A. This is due to the adverse stagger associated with North 1B. Alternatives South 1, 2, and 3 offer no increase in capacity as compared to the existing airfield in west flow and capacity estimates are identical.

Weighted hourly capacity (Cw) was calculated using the capacity estimates from Figures B-9 and B-10 following the methodology in Advisory Circular AC 150/5060-5, *Airport Capacity and Delay*. The resulting estimates of Cw are shown in Figure 5-11.

As shown in Table 5-1 and Figure 5-11, North 1A provides the highest hourly capacity at 184 operations per hour compared to that of North 1B at 182 operations per hour. All of the South alternatives provide a similar capacity, South 1 providing 167 and South 2 and 3 each providing 173. The south alternatives perform worse than the north alternatives in terms of capacity because a proposed south runway would impact the departure capability of the existing Runways 15L and 15R during west flow, which is the primary runway use configuration at the Airport. So the South alternatives provide only a modest capacity gain over the existing runway configuration since the utility of a new South runway is limited.

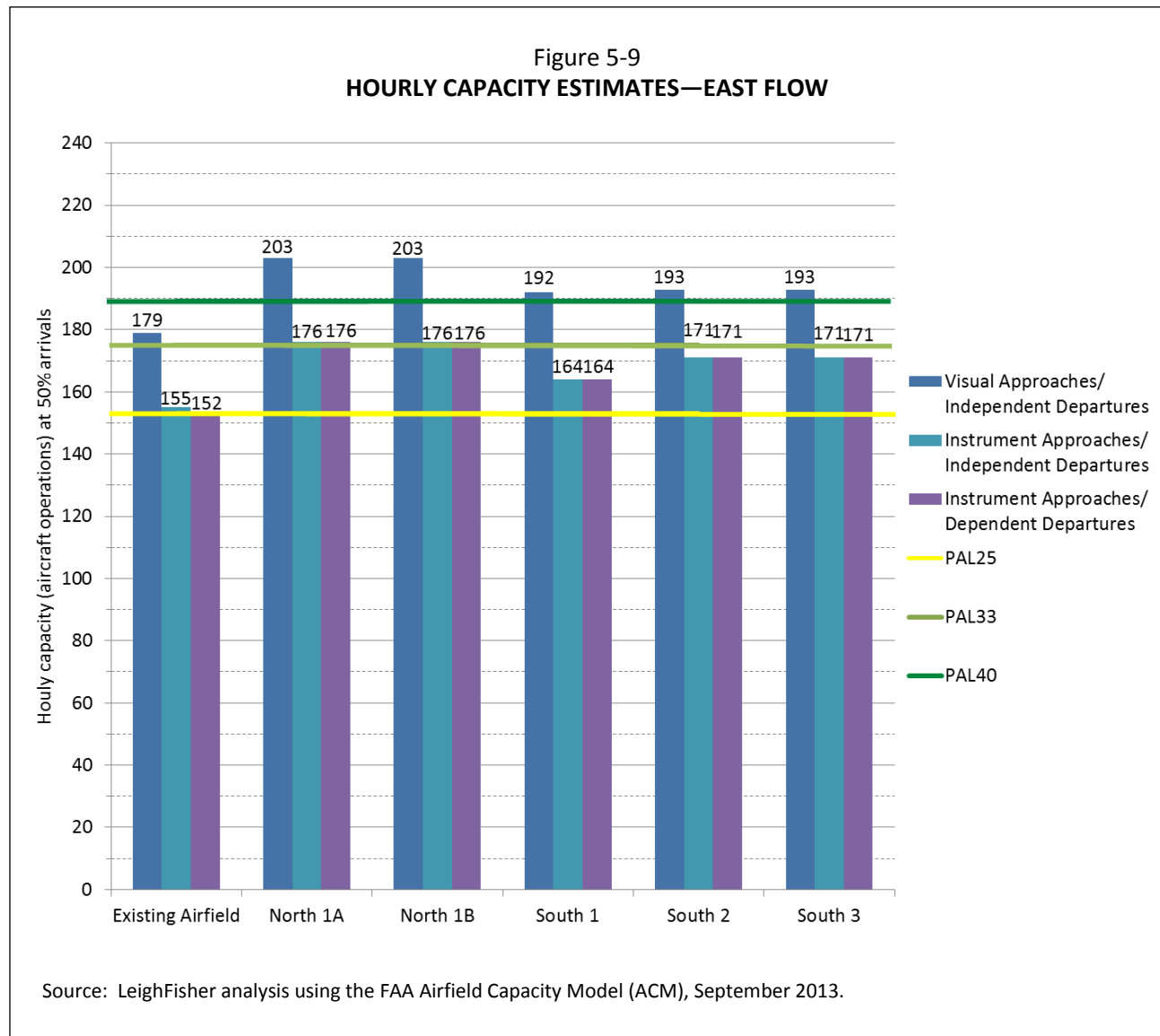
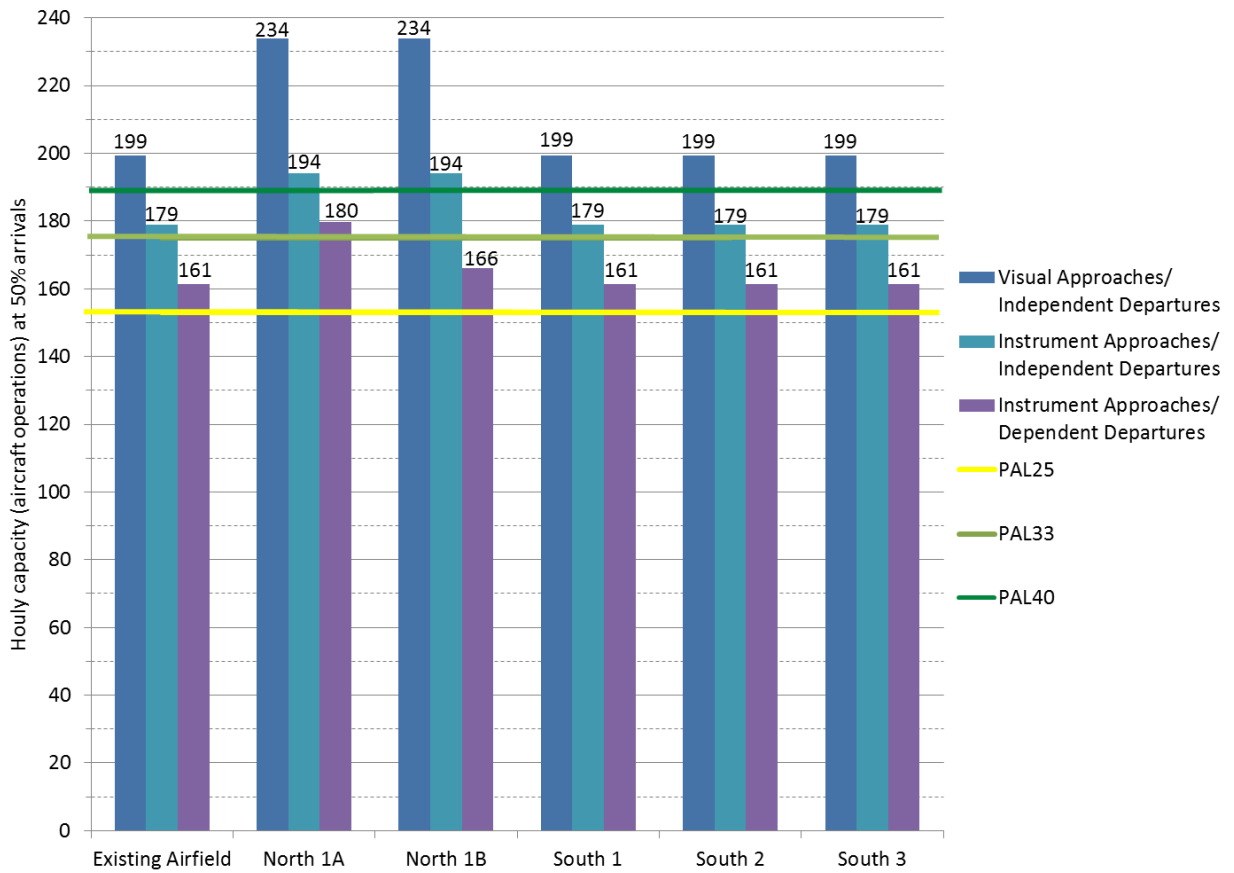
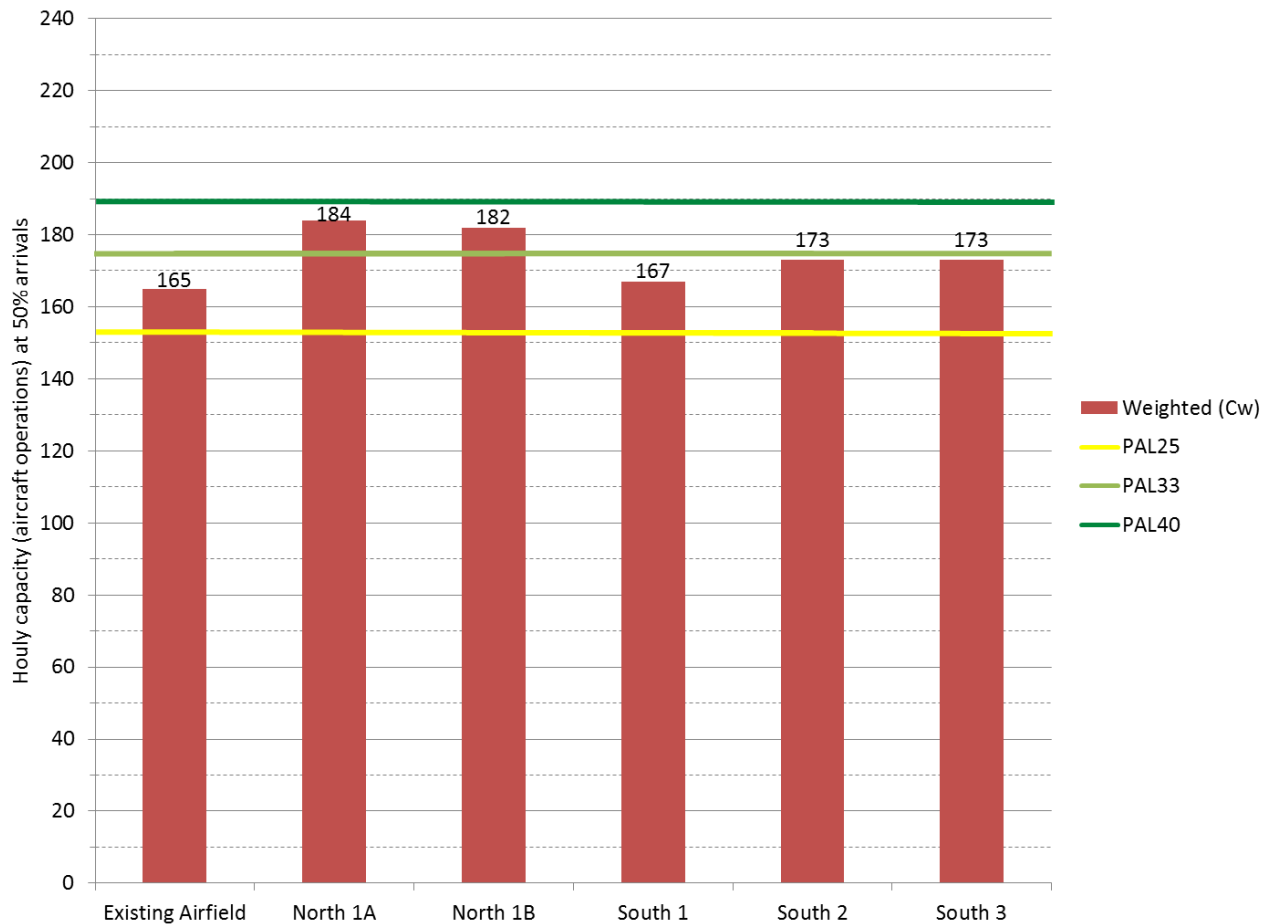


Figure 5-10
 HOURLY CAPACITY ESTIMATES—WEST FLOW



Source: LeighFisher analysis using the FAA Airfield Capacity Model (ACM), September 2013.

Figure 5-11
HOURLY CAPACITY ESTIMATES—WEIGHTED



Source: LeighFisher analysis using the FAA Airfield Capacity Model (ACM), September 2013.

Average Annual Aircraft Delay. Average annual aircraft delay at PAL40 was estimated using the FAA Annual Delay Model. Model inputs related to demand were derived from the future flight schedules, including monthly, daily, and hourly distribution of traffic, hourly percent arrivals, and annual operations. It is important to note that this method underestimates delay as compared with a simulation model because only delays related to queuing are captured (i.e., waiting to land or waiting to take off). These delay estimates do not capture delays related to apron congestion, taxiway operations, or airspace, and are therefore lower than what would be expected from a simulation model or in reality. Model inputs related to weather occurrence and runway use occurrence were derived from historical records from the FAA Aviation System Performance Metrics (ASPM) database.

Alternative North 1A is estimated to have the lowest average annual delay at 2.7 minutes per operation. Alternative North 1B has a slightly higher estimate of 2.9 minutes per operation due to the reduced capacity under west flow. As expected, South Alternatives 1, 2, and 3 showed the most delay, South 1 at 4.3 minutes per operation and South 2 and 3 at 4.1 minutes per operation. As expected, the delay levels of

the south alternatives showed very little difference from the estimated delay of the existing runway system given these alternatives provide minimal increases in airfield capacity.

Average Unimpeded Taxiing Time. Taxiing times were calculated for each alternative by measuring approximate taxiing distances for arrivals and departures to each runway end and averaging them based on estimated runway use. A constant average taxiing speed of 15 knots was assumed in estimating average taxiing time based on the average taxiing distance. The taxiing times reported were measured as unimpeded and do not consider taxiing delay.

The south alternatives had the lowest unimpeded taxiing times at 5.3 to 5.5 minutes per operation. These estimated taxiing times are similar to those estimated for the existing airfield at 5.3 minutes. The south alternatives result in minimal changes in taxiing times over the existing runway system because of the limited use of the new runway because of the dependencies with operations on Runways 15L and 15R. In comparison, the north alternatives had an average taxiing time of approximately 5.9 minutes per operation mainly due to increased use of the new runway for departures versus Runways 15L and 15R. In other words, it takes less time for aircraft to taxiing and depart Runway 15L and 15R than it would to depart from a new Runway 8C-26C.

However, these estimates of unimpeded taxiing time are not inclusive of any changes in congestion and delays on the taxiways which contribute to average aircraft taxiing times. It is likely that reductions in congestion and delays on the taxiways would offset some of the expected increases in unimpeded taxiing times, especially in the north alternatives since they provide the greatest capacity gains.

Land Use Compatibility. Land use compatibility refers to the clearance for the required land uses supporting a new runway including the runway protection zones (RPZ), navigational aids and associated critical areas, and approach and departure surfaces.

All alternatives were formulated to meet FAA design standards and required clearances. It is assumed that if the Airport does not currently own the property encompassed by the RPZ, it would be acquired. The cost of this property acquisition is taken into account as part of the cost estimate provided in the previous section. The south alternatives were aligned so that RPZs remain clear of JFK Boulevard.

Approach and departure surface clearance was evaluated for each of the alternatives under consideration. The most critical of these surfaces to protect for are expected to be the 50-to-1 Part 77 approach surface and 40-to-1 instrument departure surface. For Alternatives North 1A and 1B, the proximity of the central cargo apron could impact these surfaces. The aircraft with the tallest tail height with regularly scheduled service at the Airport is the Airbus A380. If an A380 was parked on the central cargo apron at the westernmost parking position, its tail would not penetrate a 50-to-1 or 40-to-1 surface. However, the one engine inoperative surfaces, which have a slope of 62.5-to-1, would be penetrated. As a practical matter, this would mean that airlines would need to confirm that the new runway would not impact their specific one engine inoperative procedures. However, since the departure points of alternatives North 1A and North 1B are identical to the existing ends of Runway 8R on the west and Runway 26R on the east, it is likely the proposed Runway 8C-26C would not cause impacts to airlines' one engine inoperable procedures since the runway is currently used for departures.

Both north alternatives require the removal and realignment of existing Taxiway EE so that any taxiing aircraft remain clear of the RPZ and the approach and departure surfaces.

Airspace Operational Capability. Airspace operational capability is a qualitative assessment of the flight procedures to be used for any new runway. Alternatives North 1A and 1B are best suited for northbound departures, which make up 45 to 50 percent of all departures from the Airport. In west flow, the new

runway would serve northbound departures, while Runway 15L would handle east/south and Runway 15R would handle west/south bound. In east flow, the new runway would serve northbound departures, while Runway 15L would handle north/east/south and Runway 15R would handle west/south bound. The south alternatives are not well suited to offloading directional demand given their dependencies with the existing departure Runways 15L and 15R.

The Airport currently runs triple independent approaches using the east-west runways. Alternatives which include the addition of an independent parallel runway (i.e., all alternatives except for South 1) would require additional coordination regarding procedures for missed approaches or go-arounds to ensure compliance with FAA divergence requirements. The issue related to missed approaches and go-arounds is addressed in a subsequent section of this paper.

5.2.5.3 Environmental Criteria

This section evaluates the environmental impacts of the runway alternatives. This assessment is based on available information, using quantitative methods where possible and supplemented by qualitative comparisons. The environmental impacts of each alternative are shown on Figures 5-12 through 5-16.

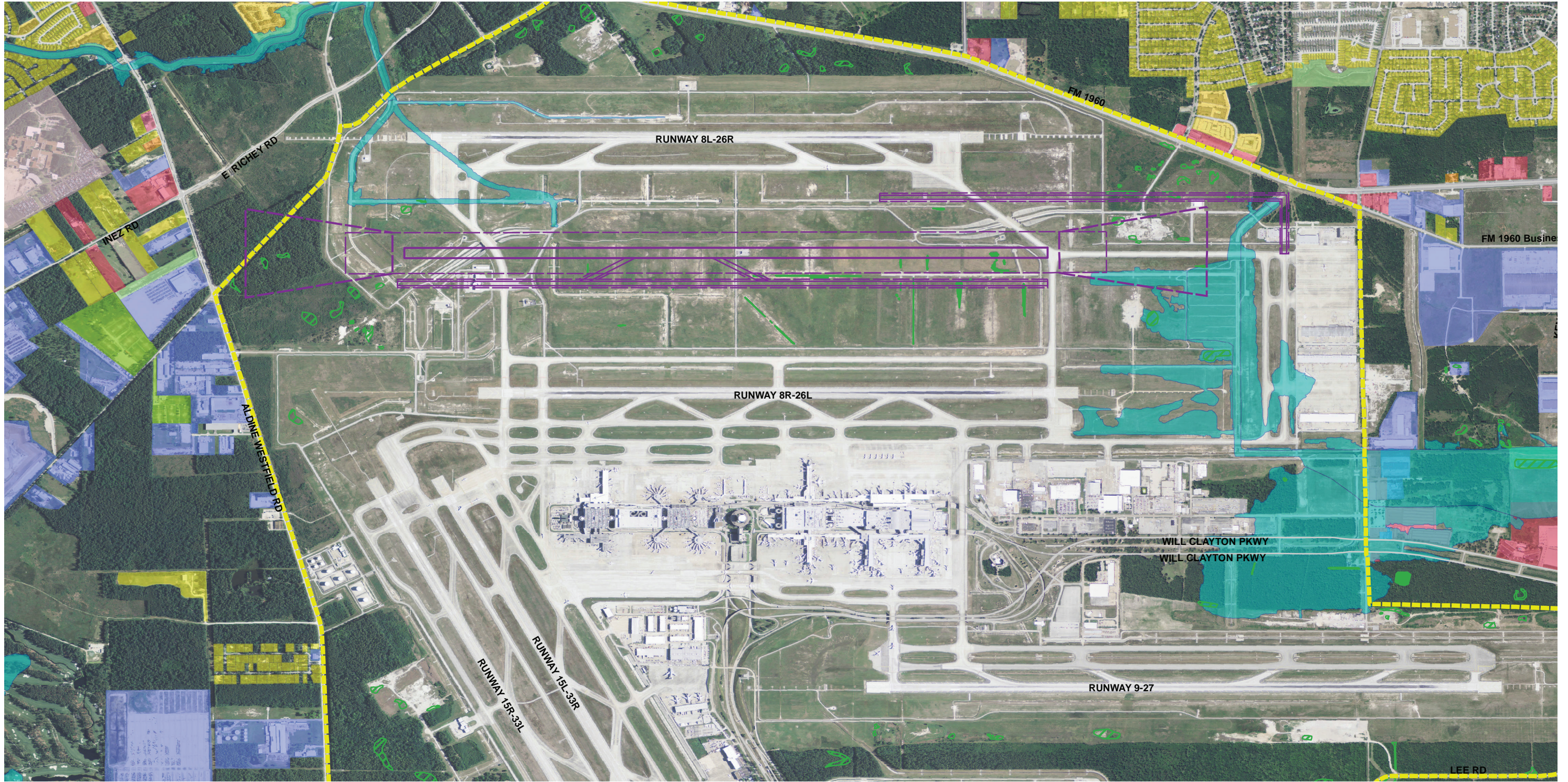
Wetlands. Delineated wetlands likely to be impacted were quantified using the 2010 survey conducted by the U.S. Army Corps of Engineers. Additionally, locations of potential wetlands not within the limits of the 2010 survey were identified through interpretation of 2010 false-color infrared aerial photographs available from the Texas Natural Resources Information System.

The sites of Alternatives North 1A and North 1B encompass the most delineated wetlands, at approximately .6 acre for North 1A and 0.5 acres for North 1B. However, these particular wetlands are isolated and have little habitat value. The south alternatives would have a lesser impact on wetlands: South 1 encompassing one potential wetland of 0.17 acres, South 2 encompassing only 0.004 acres of delineated wetland, and South 3 containing one delineated wetland of 0.03 acres and 0.36 acres of potential wetlands.

Floodplains. The Federal Emergency Management Agency's Flood Insurance Rate Maps, last updated in 2007, were used to determine the limits of the 100-year floodplain. The only alternative which would impact the floodplain is Alternative South 3, which would encroach approximately 39 acres of floodplain.

Section 303(c) Lands. Volume 49, Section 303(c) of the United States Code encodes Section 4(f) of the Department of Transportation Act of 1966. It states, "[t]he Secretary may approve a transportation program or project requiring the use of publicly owned land of a public park, recreation areas or wildlife and waterfowl refuge, or land of an historic site of national, State, or local significance (as determined by the Federal State, or local officials having jurisdiction over the park, recreation areas refuge, or site) only if (1) there is no prudent and feasible alternative to using that land; and (2) the program or project includes all possible planning to minimize harm to the park, recreation area, wildlife and waterfowl refuges or historic site resulting from the use."

A review of off-Airport parks and recreational areas revealed that no Section 303(c) lands are expected to be impacted by any of the airfield alternatives under consideration.



Source: Listed in Report
 Prepared by: Quadrant Consultants Inc., 2013



LEGEND

Alternative North 1A

- Runway
- Taxiway
- Runway Protection Zone
- Runway Protection Zone



- IAH Boundary
- Wetlands
- Potential Wetlands
- 100-Year Floorplan

Land Use

- Church
- Commercial
- High Density Single-Family Residential
- Industrial



- Low Density Single-Family Residential
- Mobile Home
- Multi-Family Residential
- Noise Sensitive Institutional

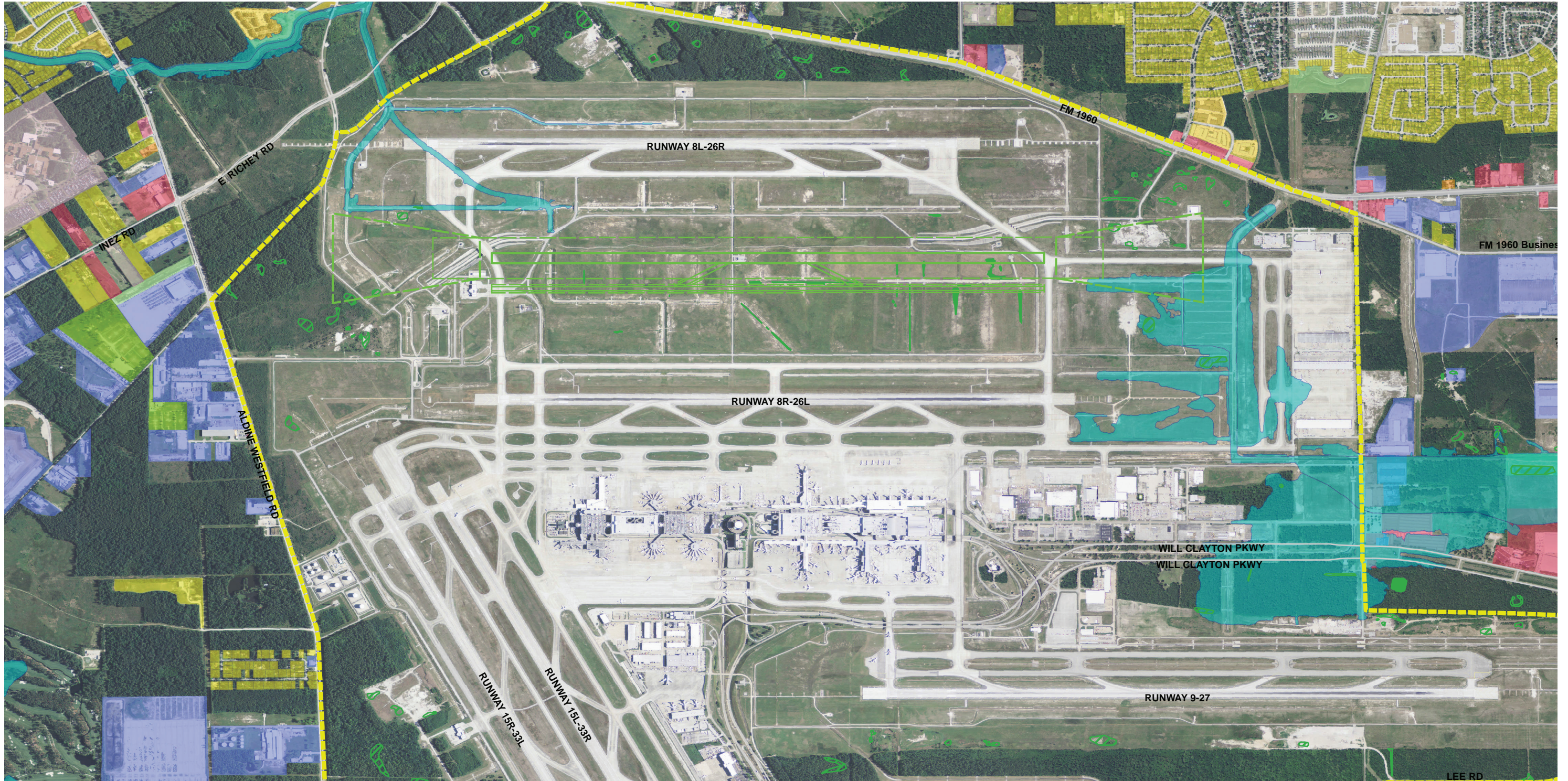


- Non-Noise Sensitive Institutional
- Private Park
- Public Park/Open spaces
- School



Figure 5-12
 North 1A

Environmental Conditions



Source: Listed in Report
 Prepared by: Quadrant Consultants Inc., 2013

Leigh | Fisher

LEGEND

- Alternative North 1A
- Runway
 - Taxiway
 - Runway Protection Zone
 - Runway Protection Zone

- IAH Boundary
- Wetlands
- Potential Wetlands
- 100-Year Floodplain

- Land Use
- Church
 - Commercial
 - High Density Single-Family Residential
 - Industrial

- Low Density Single-Family Residential
- Mobile Home
- Multi-Family Residential
- Noise Sensitive Institutional

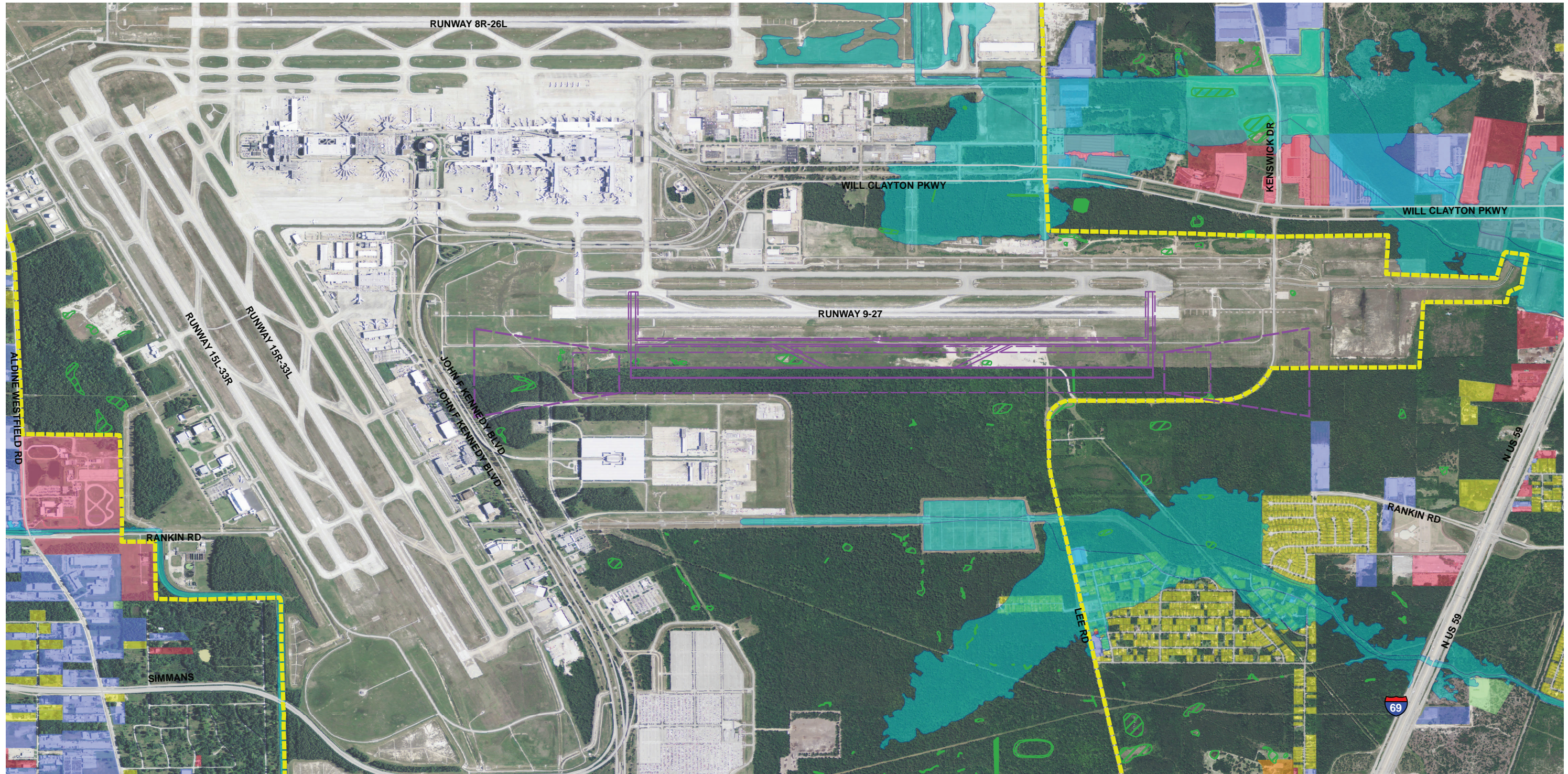
- Non-Noise Sensitive Institutional
- Private Park
- Public Park/Open spaces
- School

0 1000' 2000'



Figure 5-13
 North 1B

Environmental Conditions



Source: Listed in Report
 Prepared by: Quadrant Consultants Inc., 2013



LEGEND

- Alternative North 1A
- Runway
 - Taxiway
 - Runway Protection Zone
 - Runway Protection Zone

- IAH Boundary
- Wetlands
- Potential Wetlands
- 100-Year Floodplain

Land Use

- Church
- Commercial
- High Density Single-Family Residential
- Industrial

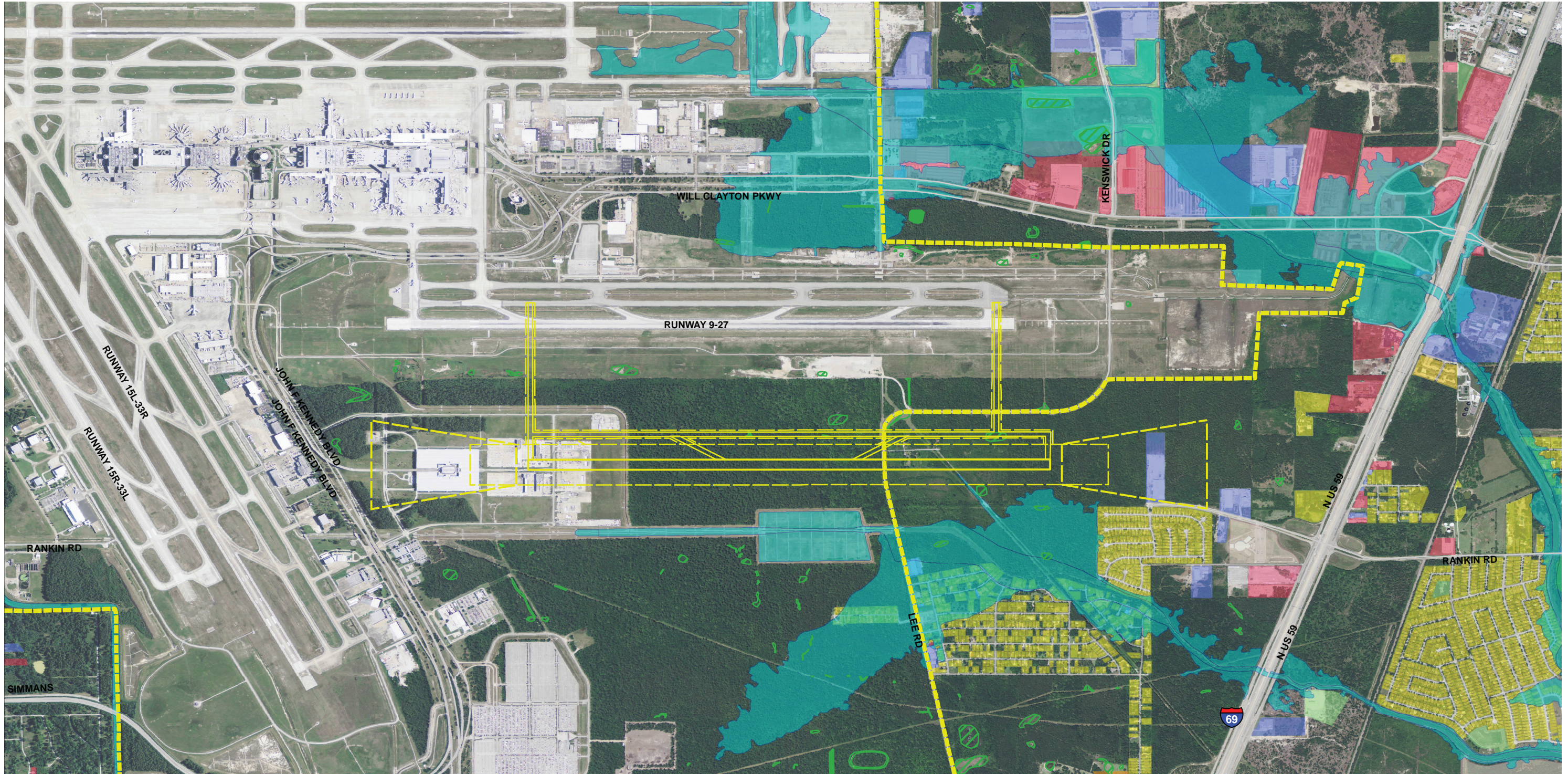
- Low Density Single-Family Residential
- Mobile Home
- Multi-Family Residential
- Noise Sensitive Institutional

- Non-Noise Sensitive Institutional
- Private Park
- Public Park/Open spaces
- School



Figure 5-14
 South 1

Environmental Conditions



Source: Listed in Report
 Prepared by: Quadrant Consultants Inc., 2013

Leigh | Fisher

LEGEND

Alternative North 1A

- Runway
- Taxiway
- Runway Protection Zone
- Runway Protection Zone

- IAH Boundary
- Wetlands
- Potential Wetlands
- 100-Year Floorplan

Land Use

- Church
- Commercial
- High Density Single-Family Residential
- Industrial

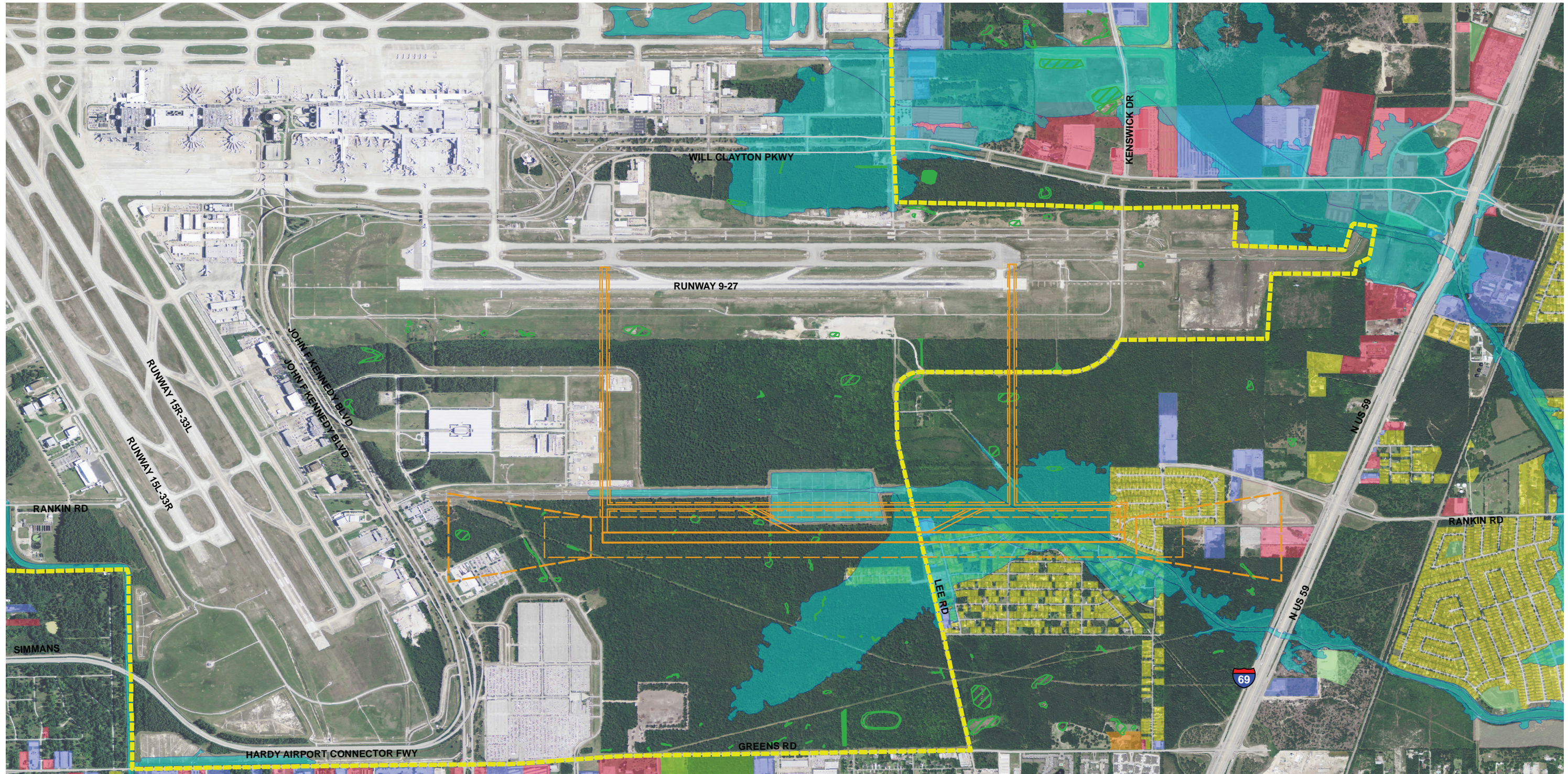
- Low Density Single-Family Residential
- Mobile Home
- Multi-Family Residential
- Noise Sensitive Institutional

- Non-Noise Sensitive Institutional
- Private Park
- Public Park/Open spaces
- School



Figure 5-15
 South 2

Environmental Conditions



Source: Listed in Report
 Prepared by: Quadrant Consultants Inc., 2013



LEGEND

- Alternative North 1A
- Runway
- Taxiway
- Runway Protection Zone
- Runway Protection Zone

- IAH Boundary
- Wetlands
- Potential Wetlands
- 100-Year Floodplain

Land Use

- Church
- Commercial
- High Density Single-Family Residential
- Industrial

- Low Density Single-Family Residential
- Mobile Home
- Multi-Family Residential
- Noise Sensitive Institutional

- Non-Noise Sensitive Institutional
- Private Park
- Public Park/Open spaces
- School



Figure 5-16
 South 3

Environmental Conditions

Property Acquisition. Any parcels of incompatible land use were assumed to be acquired with the construction of a new runway, specifically any off-Airport property within the RPZ. Alternatives North 1A, North 1B, and South 1 would not require property acquisition. South 2 would require the acquisition of approximately 183 acres, while South 3 requires the most property acquisition at approximately 412 acres. The 183 acres required by alternative South 2 is comprised primarily of industrial and single family residential land; whereas, the 412 acres required by South 3 is comprised primarily of single family residential land.

Air Quality. Air quality was assessed by using a proportional extrapolation from the 2012 emissions inventory at the Airport. Qualitative estimates were made of the likely increase in emissions with the addition of a new runway.

All alternatives are expected to have similar impacts on air quality during construction. Alternatives North 1A and North 1B would have the greatest impact on air quality after the runway is open due to the expected increase in aircraft taxiing times. Detailed air quality modeling must be undertaken as part of the subsequent environmental review process within the context of the local air quality conformance.

Noise. Noise contours generated in 2006 were used to approximate 65 DNL noise contours for the alternatives. These noise contours were overlaid onto land parcels provided by the Harris County Appraisal District, which publishes GIS information on all land parcels including size, land use, ownership, and appraised value. Homes or other noise-sensitive receivers were identified and quantified within each contour. Any residences within the contour are expected to be acquired, and costs for acquisition and relocation are included within the cost estimates for the alternatives.

Alternatives North 1A and North 1B are not expected to produce noise contours which would encompass additional residential area relative to the existing condition. The approximated 65 DNL contour for the south runway alternatives are all expected to encompass additional residential area. South 1 is estimated to contain approximately 100 apartment units within its contour. South 2 is expected to have about 100 homes within its contour. The estimated contour associated with South 3 is expected to contain approximately 550 homes, making it the most disruptive alternative with respect to noise.

5.2.5.4 Preferred Runway Alternative

Alternative North 1A was selected as the preferred alternative.

The south alternatives provide less capacity as compared to the north alternatives because of dependencies with the Runway 15-33 complex in west flow, the Airport's primary operating configuration. A new runway on the south side does not provide any new departure capacity in west flow since departures in the Runway 27 direction would directly intersect departures from Runways 15L and 15R. In good weather, arrivals to existing Runway 27 can be conducted independently with departures from Runways 15L and 15R.* However, the south runway alternatives do not provide any additional arrival capacity since the west end of the runway would be too close to Runway 15L to conduct any independent arrivals. While the Alternative South 1 capital costs are the least of the alternatives, it offers minimal increase in capacity from the existing airfield since it is closely spaced and therefore dependent on existing Runway 9-27. Alternative South 2 requires the relocation of the CONRAC and provides only a marginal increase in capacity over the existing airfield. Alternative South 3 requires extensive property acquisition and relocation of residential areas as well as providing minimal increases in capacity over the existing airfield.

*Recent rule changes under consideration by the FAA regarding converging runway operations (CRO), more specifically go-arounds and departures, could adversely affect this operation.

The screening process indicates that the north alternatives are more cost effective and offer greater operational benefits with fewer environmental impacts. Although North 1A is more expensive than Alternative North 1B from a capital cost perspective, it provides greater operational efficiency across all flow conditions and weather conditions, making it the preferred alternative. Alternative North 1A is the only alternative that provides an independent departure runway in west flow in all operating regimes which is valuable given west flow is the primary mode of operation at the Airport. Moreover, west flow is departure limited relative to east flow (i.e., east flow offers three departure runways and west flow only two), and any new runway would ideally be capable of operating departures independently to supplement the limited departure capacity of Runways 15L and 15R in all weather conditions.

5.2.6 Simulation Analysis of Preferred Runway Alternative

A simulation analysis was conducted to confirm that the preferred runway alternative would accommodate forecast levels of aviation demand at reasonable delay levels through the Master Plan's planning horizon and to verify the functionality of the preferred airfield alternative with the preferred terminal alternative. The visual simulation output also provides insight into the study of taxiing flows, runway crossings, and supporting taxiway improvements. Based on the FAA Airfield Capacity Model evaluation conducted in secondary screening, the preferred north runway alternative is expected to meet forecast demand through PAL40. The Total Airspace and Airport Modeller (TAAM) was used to conduct this analysis by modeling detailed aircraft movements on the airfield and within the airspace. Table 5-3 outlines the experimental design and the aviation demand levels modeled.

The model relies on operational assumptions for the preferred runway alternative, including gate use and availability, the supporting taxiways and corresponding taxiing flows, runway use preferences and dependencies, divergent missed approach procedures, and use of departure points which are described in details in the following section. Finally, the simulation results and the study conclusions are presented.

5.2.6.1 Annualization Methodology

Based on discussions with the Airfield Subcommittee, operating assumptions were developed to ensure the model accurately reflects the future conditions with the new runway. Individual results from each flow direction and weather condition were then annualized to produce a single metric representing a weighted annual average.

The airport operates in three predominant operating conditions: (1) visual approaches/independent departures, (2) instrument approaches/independent departures condition, and (3) instrument approaches/dependent departures. These operating conditions are related to the characteristics of the arrival and departure procedures rather than weather – namely visibility and ceiling – alone, since other factors such as haze and the pilot's ability to see the Airport affect the airport's ability to conduct visual approaches, even in visual meteorological conditions (VMC). According to FAA ATCT staff, visual approaches can be conducted only about 15% of the time, with instrument approaches being conducted the remaining 85% of the time. The airport operates predominantly in west and east flows, with west flow approximately 70% of the time, according to FAA's ASPM historical data. Table 5-4 summarizes the arrival and departure procedures used, as well as the percentage occurrences for each operating condition.

Table 5-3
TAAM EXPERIMENTAL DESIGN

Alternative	Runway Use	Operating Configuration	Demand Level
Alternative North 1A	West flow	Visual Approaches/Independent Departures	PAL25
			PAL33
			PAL40
		Instrument Approaches/Independent Departures	PAL25
			PAL33
			PAL40
	East flow	Instrument Approaches/Dependent Departures	PAL25
			PAL33
			PAL40
		Visual Approaches/Independent Departures	PAL25
			PAL33
			PAL40

Source: LeighFisher, August 2013.

Table 5-4
ASSUMED OPERATING CONDITIONS

Operating condition	East flow (%)	West flow (%)	Overall (%)
Visual Approaches/Independent Departures	4.5	10.5	15.0
Instrument Approaches/Independent Departures	21.7	50.6	72.3
Instrument Approaches/Dependent Departures	3.8	8.9	12.7
Overall:	30.0	70.0	100.0

Source: LeighFisher, based on discussion with FAA and historical record from FAA's ASPM database, August 2013.

The baseline model of the airfield was calibrated to FAA's facility reported runway throughput rates as well as FAA's ASPM performance metrics (e.g., average aircraft delay, average taxiing times) and was used as a basis for the simulation of the preferred airfield alternative. The preferred alternative model was also reviewed by the Airfield Subcommittee via visual validation (i.e., observing the TAAM display with realistic aircraft ground movements and movements within the airspace).

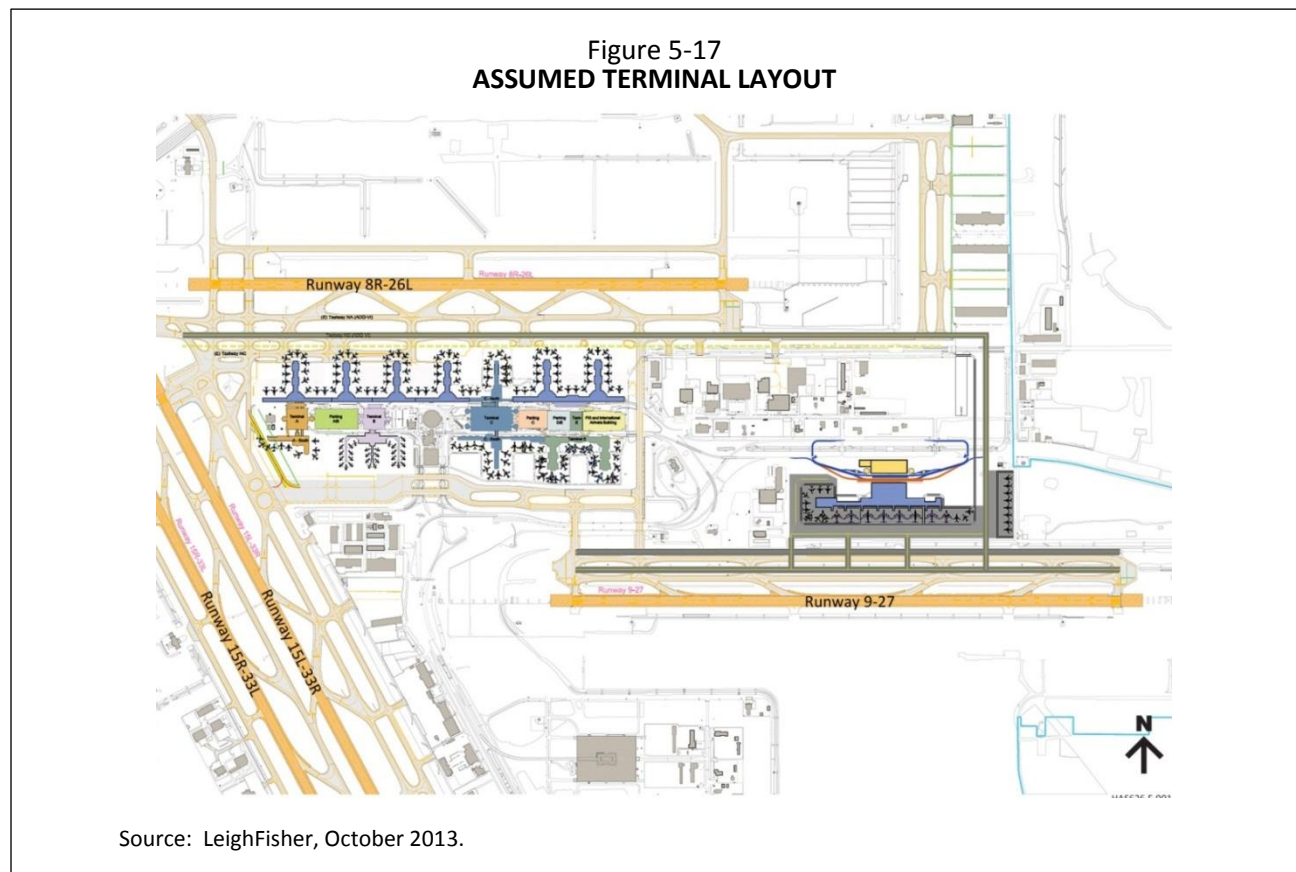
The simulation model produced estimates of various performance metrics, namely aircraft taxiing movements and times, and aircraft delay. Results of the simulation for the individual experiments are multiplied by the estimated percentage occurrence on Table 5-4 to obtain an annualized estimate of delay in minutes per operation, the primary metric used to assess airfield performance.

5.2.6.2 Modeling Assumptions

The TAAM model was developed and calibrated as part of the facility requirements task in coordination with the Airfield Subcommittee. For a detailed description of the operating assumptions used in the model, refer to Appendix B. Assumptions that were changed to reflect the preferred alternative are summarized in the following sections.

Terminal Layout. Based on the terminal requirements, additional gates will be required by PAL25 to accommodate forecast commercial passenger aircraft operations. Therefore, in assessing the preferred airfield alternative, the preferred terminal alternative was incorporated into the simulation in models for PAL25 demand levels and higher. The airfield modeling assumes the terminal layout depicted on Figure 5-17, which includes the following improvements:

1. Reconfiguration of Terminal B North and Terminal D concourses would be completed. The existing terminal area would be used exclusively by United Airlines.
2. The East Terminal would be completed and used to serve all other airlines, including foreign flag carriers and domestic carriers other than United.



Taxiway Structure and Taxiing Flows. The simulation includes several proposed taxiway improvements supporting the preferred runway alternative:

- A full-length parallel taxiway located south of the proposed Runway 8C-26C providing departure queuing capability
- Removal of existing Taxiway EE and relocation of the taxiway to the north so that it remains clear of the RPZ and any design surfaces associated with Runway 8C-26C
- A proposed end-around taxiway around the west end of Runway 8C-26C, designated as Taxiway NQ, to be used during west flow by arrivals on Runway 26L to avoid crossing Runway 26C
- A proposed Taxiway SL providing the East Terminal with access to the north airfield, which would also eliminate the risk of Taxiway SF as a single point of failure on the airfield

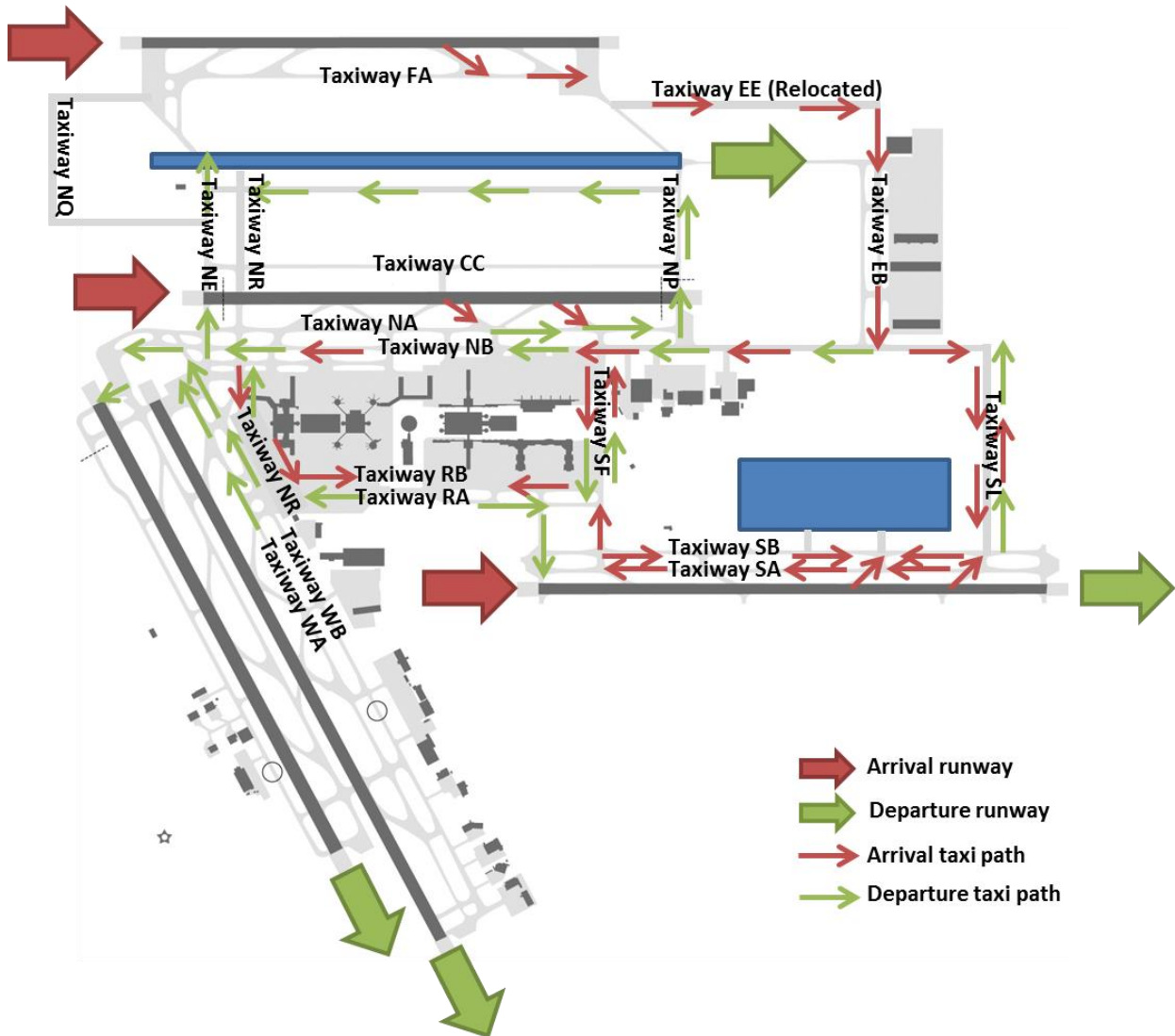
Departures using Runway 8C-26C would most frequently cross Runway 8R-26L at the far-end of the runway, i.e., via an extended Taxiway NP in west flow and Taxiway NR in east flow, as shown in Figures 5-18 and 5-19, respectively. In west flow, especially during periods of high arrival demand on Runway 26L, departures using Runway 26C would have to hold short and wait to cross, thereby queuing up on Taxiway NR at the intersections of Taxiway NA and NB. Similarly in east flow, during periods of high arrival demand on Runway 8R, departures for Runway 8C could queue up on Taxiway NA in the area north of Terminal D, waiting to cross Runway 8R. Therefore, it is important that the departure queue be managed to maintain a clear flow of traffic, which can be implemented via departure queue management and gate hold strategies.

Taxiing flows assumed with these improvements are shown on Figures 5-18 and 5-19.

Currently, Taxiway NR “dead-ends” into Taxiway WB and has limited use due to congestion on Taxiways NA and NB from departures using Runways 15L and 15R. Because of this limited use, Taxiway SF provides the single connection between the north and south airfield. In the event Taxiway SF was unavailable (e.g., disabled aircraft, pavement maintenance or failure), aircraft would likely need to be assigned an arrival runway based on their assigned gate or parking position. This would lead to severely reduced operational efficiency of the airfield, major delays, and likely flight cancellations. The extension of Taxiway NR would provide redundancy in crossfield taxiing capability to Taxiway SF. Additionally, the provision of Taxiway NR would reduce taxiing times for those aircraft using it, as well as reduce overall taxiing times due to reduced occurrence of head-to-head taxiing on Taxiway SF.

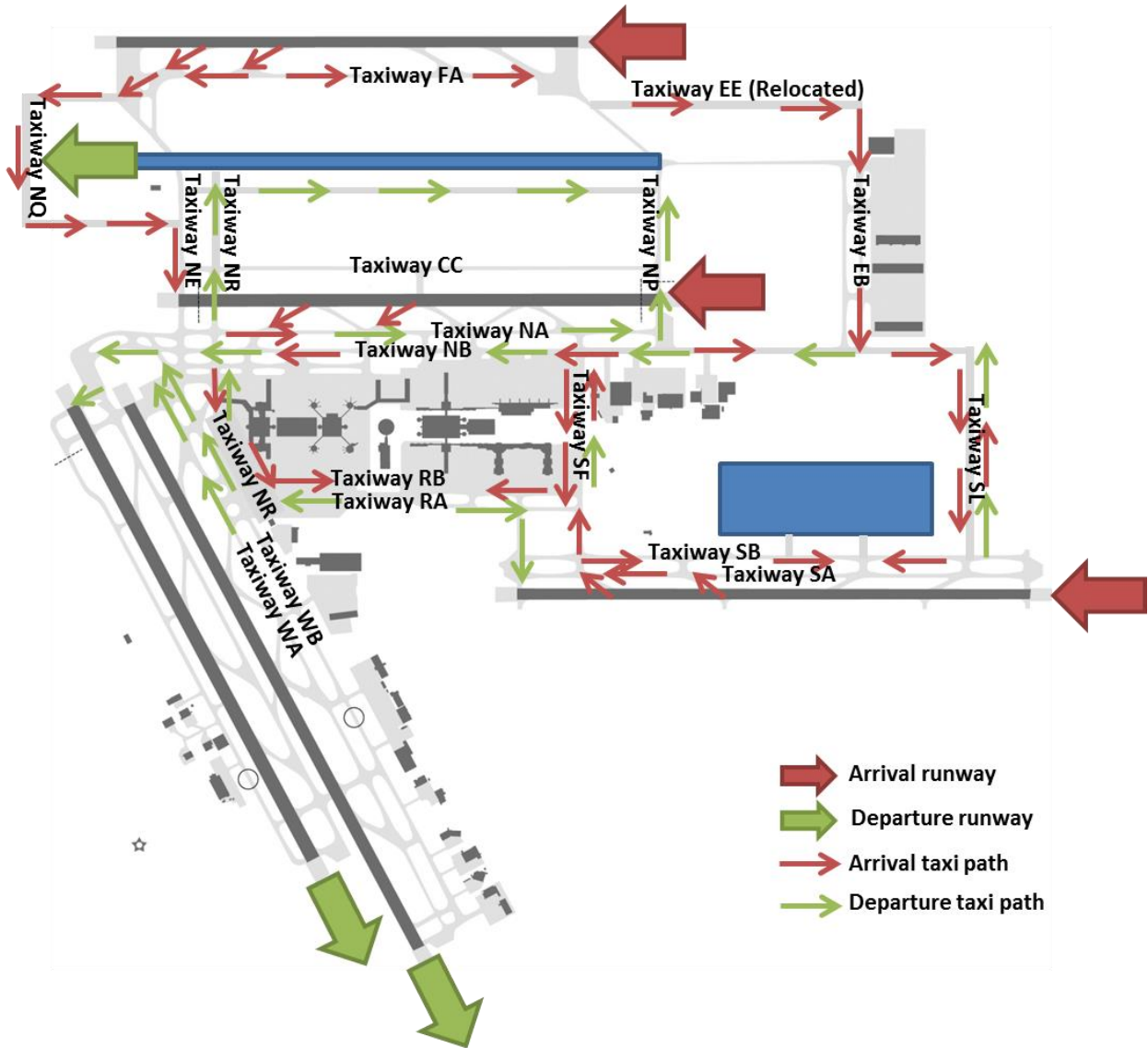
The airfield simulation assumes the extension of Taxiway NR to Taxiway RA, as illustrated in Figure 5-20, as it provides independent crossfield taxiway capability, primarily for aircraft arriving on Runways 8L-26R and 8R-26L which are parking on southwest side of the terminal area (i.e., Terminals A South and B South), at Central Cargo, or at the fixed base operators.

Figure 5-18
PREFERRED AIRFIELD ALTERNATIVE TAXIING FLOWS (WEST FLOW)



Source: LeighFisher, August 2013.

Figure 5-19
PREFERRED AIRFIELD ALTERNATIVE TAXIING FLOWS (EAST FLOW)



Source: LeighFisher, August 2013.

Figure 5-20
TAXIWAY NR EXTENSION



Source: LeighFisher, August 2013.

Runway Use and Dependencies. Table 5-5 summarizes the operating conditions, corresponding runway uses in east flow and west flow configurations, estimated hourly capacities, associated air traffic assumptions, and runway dependencies that were assumed in the simulation for the proposed Runway 8C-26C. Runway use was simulated in accordance with the runway configurations shown in Table 5-5.

In west flow, departing aircraft parked at Terminals D and E, East Cargo, and the East Terminal going to northbound destinations would be likely candidates for Runway 26C. With departures using Runways 15L, 15R, and 26C, Runways 26L, 26R, and 27 would be used primarily as arrival runways. Departures from Runway 26C would be operated independently from arrivals on Runways 26L and 26R, with the assumption that arrival and departure course divergence and mitigation of the adverse stagger between Runways 26R and 26C may be achieved through the use of departure points on Runway 26C (see following section, "Enabling assumptions"). "Independent departures" signifies no dependence between departures on Runways 15L and 15R and arrivals on Runway 27, as well as departures from Runways 15L and 15R being

conducted independently of one another (aside from requisite wake turbulence separation). “Dependent departures” signifies that departures from Runways 15L and 15R are held when an arrival on final approach to Runway 27 is within 2.0 nautical miles of landing. Additionally, a departure from either Runway 15R or 15L must be separated by at least 1.0 nautical mile from the previous departure from either runway.

In east flow, Runway 8C is used primarily for northbound departures. Since taxiing distance to Runway 8C is comparable to taxiing distance to Runway 15L and 15R, parking position does not have a large influence on runway selection. Moreover, runway selection is driven mainly by the departure’s destination. Operations on Runway 8C are conducted independently from arrivals on Runways 8L and 8R. Runway 9 would be used as an arrival runway when visual approaches are being conducted and as an offload departure runway when instrument approaches are being conducted. The existing dependency between Runways 15L and 15R and Runway 9 would continue to exist. In particular, in VMC “independent” departures from Runways 15L and 15R are held when an arrival on final approach to Runway 9 is within 2.0 nautical miles of landing. In IMC, “dependent” departures from Runways 15L and 15R are held when an arrival on final approach to Runway 9 is within 5.0 nautical miles of landing during instrument approach conditions.

5.2.6.3 Enabling Assumptions

In assessing simultaneous operations between Runway 8C-26C and Runways 8L-26R and 8R-26L, two major enabling assumptions were discussed with the Airfield Subcommittee and were confirmed to be reasonable:

- Departures from Runway 8C-26C can be conducted safely with appropriate course divergence with the missed approaches from Runways 8L-26R, 8R-26L, and 9-27
- Independent departure capability of Runway 8C-26C can be provided via use of departure points in both flow directions to mitigate the effects of an adverse stagger

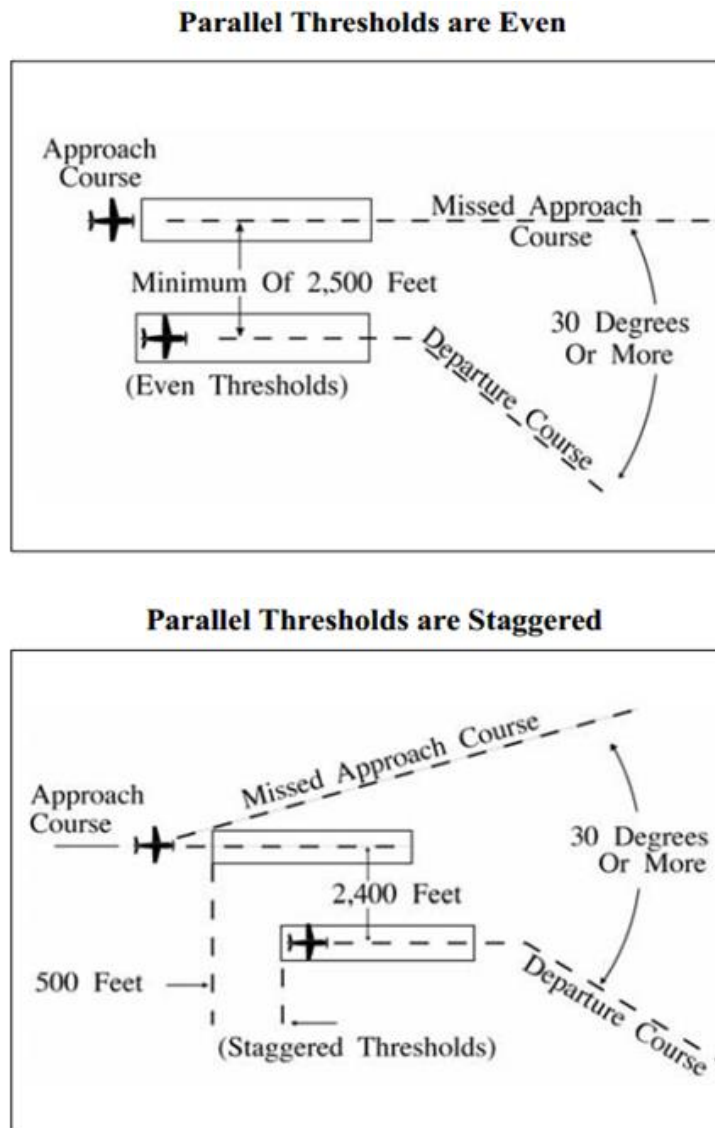
Divergent Missed Approach Courses. According to FAA Order JO 7110.65U, *Air Traffic Control*, at least 30-degree course divergence must be provided for simultaneous operations between an aircraft departing on a runway and the missed approach course of an aircraft on final approach to another parallel runway, as illustrated in Figure 5-21. The published missed approach procedures for Runways 8R-26L, 8L-26R, and 9-27, provide the necessary 30-degree course divergence requiring missed approaches from Runway 8R-26L to go straight out on runway heading, while those for Runway 8L-26R make a left turn in east flow or right turn in west flow and those to Runway 9-27 make a right turn in east flow or left turn in west flow. However, in practice, these charted missed approach procedures are rarely used according to the Airfield Subcommittee. Instead, radar vectors are issued to any aircraft performing a missed approach, which overrides the published missed approach procedure, unless communications are not possible between the pilot and air traffic control. Therefore, the addition of proposed Runway 8C-26C is not likely to interfere with the missed approach procedures, and departures can be operated independently of the missed approaches on the existing east-west parallel runway system.

Table 5-5
SUMMARY OF OPERATING ASSUMPTIONS
 George Bush Intercontinental International Airport

Operating conditions	Assumed runway use configuration		Estimated airfield capacities*	Approach procedures	Departure procedures	Arrival-departure dependencies	Other operating characteristics
	East flow (30%)	West flow (70%)					
Visual Approaches/Independent Departures 15.00%			East flow: Arrival = 117/hour Departure = 178/hour Overall = 203/hour West flow: Arrival = 117/hour Departure = 178/hour Overall = 234/hour	Visual approaches and visual separations are applied by the pilots.	Departures on Runway 15R are independent of departures on Runway 15L, aside from requisite wake turbulence spacing.	East flow: Departures on Runways 15L and 15R are held when arrivals to Runway 9 is within 2.0 nautical miles of the final approach, due to missed approach protection.	East flow: Departures on Runway 8C are independent of arrivals to Runways 8L and 8R when intersection departures are applied. West flow: Departures on Runway 26C are independent of arrivals to Runways 26L and 26R when intersection departures are applied.
	Runway 9 is used for arrivals only.	No dependencies.					
Instrument Approaches/Independent Departures 72.25%			East flow: Arrival = 97/hour Departure = 178/hour Overall = 176/hour West flow: Arrival = 97/hour Departure = 178/hour Overall = 194/hour	Instrument approaches and instrument separations are applied by the Tower.	Departures on Runway 15R are independent of departures on Runway 15L, aside from requisite wake turbulence spacing.	East flow: Departures on Runways 15L and 15R are held when arrivals to Runway 9 is within 2.0 nautical miles of the final approach, due to missed approach protection.	East flow: Departures on Runway 8C are independent of arrivals to Runways 8L and 8R when intersection departures are applied. West flow: Departures on Runway 26C are independent of arrivals to Runways 26L and 26R when intersection departures are applied.
	Runway 9 is used for arrivals during arrival-priority, and for departures during departure-priority (but not in mixed operations).	No dependencies					
Instrument Approaches/Dependent Departures 12.75%			East flow: Arrival = 97/hour Departure = 178/hour Overall = 176/hour West flow: Arrival = 97/hour Departure = 121/hour Overall = 180/hour	Instrument approaches and instrument separations are applied by the Tower.	Departures on Runway 15R are dependent of departures on Runway 15L, requiring one nautical mile separation between successive departures from either runway, given they are diverged by at least 15-degrees.	East flow: Departures on Runways 15L and 15R are held when arrivals to Runway 9 is within 5.0 nautical miles of the final approach, due to missed approach protection. West flow: Departures on Runways 15L and 15R are held when arrivals to Runway 27 is within 2.0 nautical miles of the final approach, due to missed approach protection.	East flow: Departures on Runway 8C are independent of arrivals to Runways 8L and 8R when intersection departures are applied. West flow: Departures on Runway 26C are independent of arrivals to Runways 26L and 26R when intersection departures are applied.
	Runway 9 is used for arrivals during arrival-priority, and for departures during departure-priority (but not in mixed operations).	Runway 27 arrivals dependent on departures from Runways 15L and 15R.					

* Arrival capacity is the maximum number of arrival operations during arrival-priority.
 Departure capacity is the maximum number of departure operations during departure-priority.
 Overall hourly capacity is the sum of arrivals and departures, assuming 50%-arrivals.

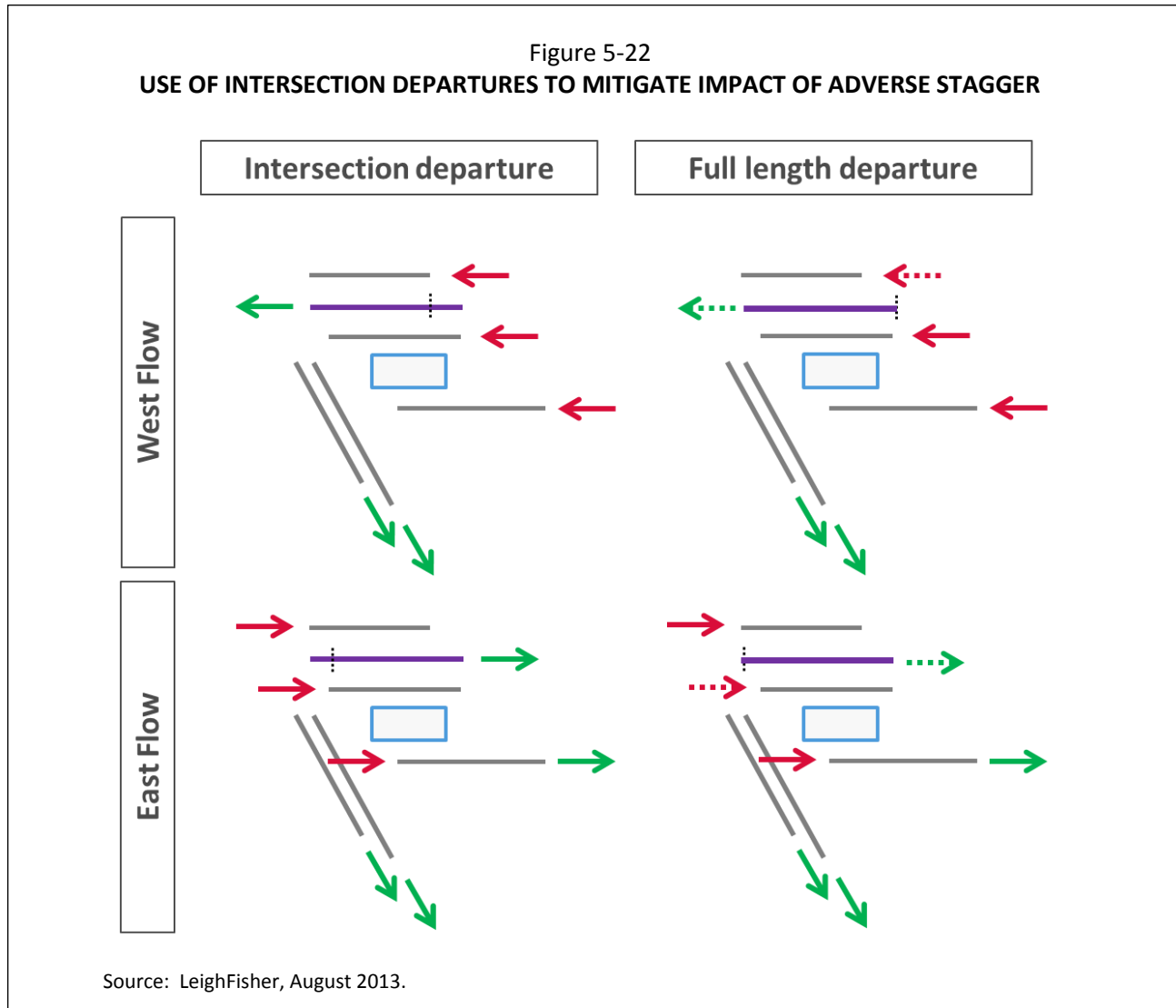
Figure 5-21
FAA CRITERIA ON ARRIVAL/DEPARTURE COURSE DIVERGENCE ON PARALLEL RUNWAYS



Source: FAA Order JO 7110.65U, *Air Traffic Control*, "Section 5-8-5, Departures and Arrivals on Parallel or Nonintersecting Diverging Runways."

Use of Intersection Departures. The separation of 2,500 feet between the centerlines of the north runway and Runways 8L-26R and 8R-26L allow for independent operations. According to FAA Order JO 7110.65, *Air Traffic Control*, independent operations between parallel arrival and departure runways separated by 2,500 feet can be conducted only when the runway thresholds are aligned or when the arrival threshold is behind

the departure threshold.* Therefore, to mitigate the impact of the adverse stagger with Runway 26R in west flow and with Runway 8R in east flow, the departures from Runway 8C-26C could take off from a departure point that is abeam the threshold of Runway 8R or 26R to allow for independent operations, as illustrated in Figure 5-22, the dotted lines denoting departure points. In the case an aircraft departs Runway 8C-26C full length, as shown in Figure 5-22, the arrival on Runway 26R would be dependent in west flow, or the arrival to Runway 8R would be dependent in east flow.



It is important to note that there are certain limitations in the use of intersection departures which may impact the utility of the north runway: (1) it is not mandatory for pilots to accept the clearance for an intersection departure from air traffic control and they may opt to use the full length of the runway for departure, and (2) any aircraft departing from a specified departure point following the departure of heavy aircraft, such as the Boeing 747 and Airbus A380, must be separated by 3 minutes due to wake turbulence requirements.

*The arrival threshold must be east of the departure threshold in west flow and west of the departure threshold in east flow.

5.2.6.4 Runway Use

The percentages of runway use modeled for each demand level are assumed consistent. In west flow, arrivals are balanced among Runways 26L, 26R, and 27, except during instrument approach conditions where the use of Runway 27 is reduced since departures from 15L and 15R are dependent on the arrival to Runway 27. In east flow, Runway 9 is used as an offload departure runway during marginal and instrument approach conditions, when Runways 15L and 15R are operated dependently to provide additional departure capacity. The modeled arrival and departure runway use percentages for PAL33 are shown on Figures 5-23 and 5-24.

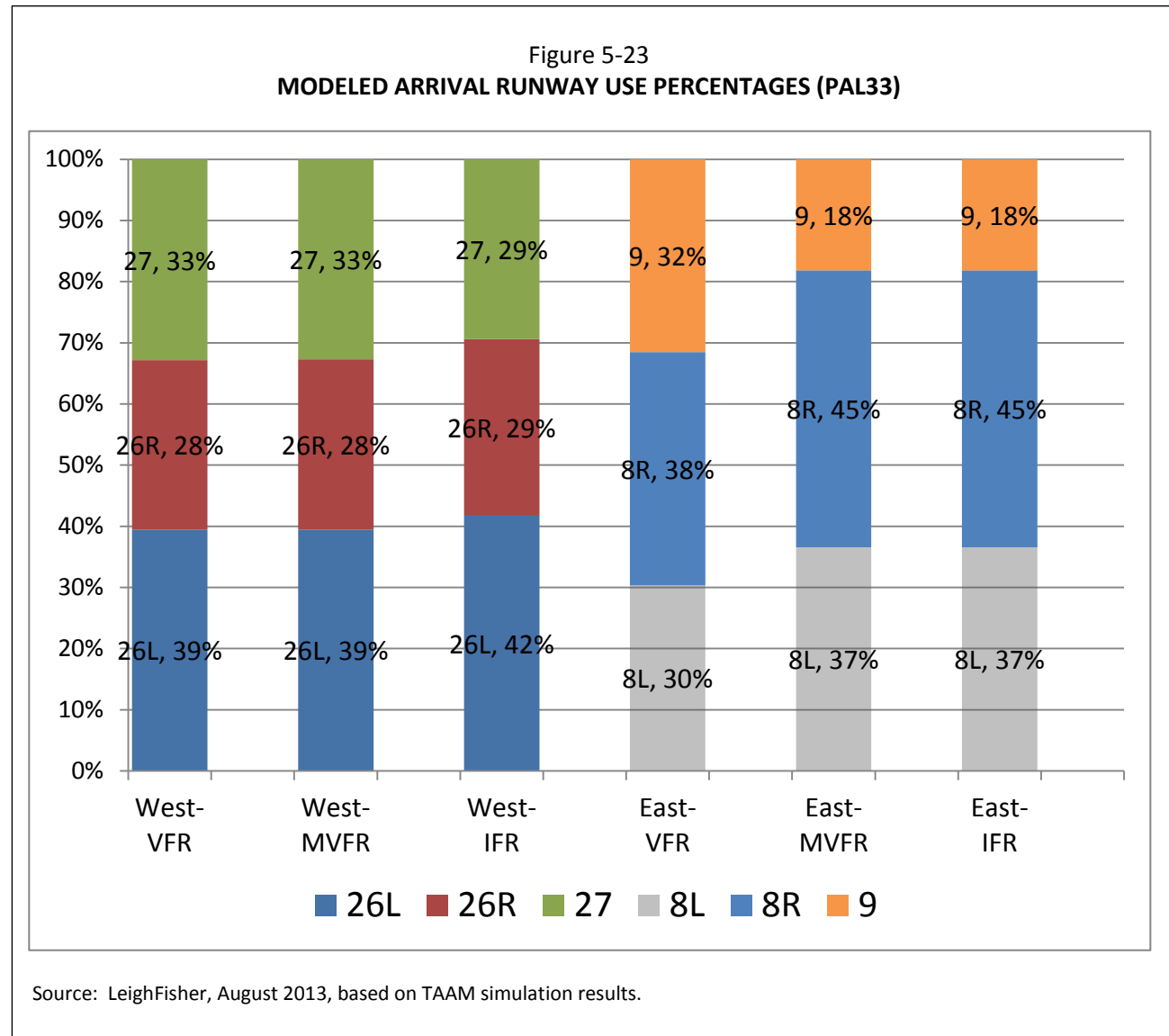
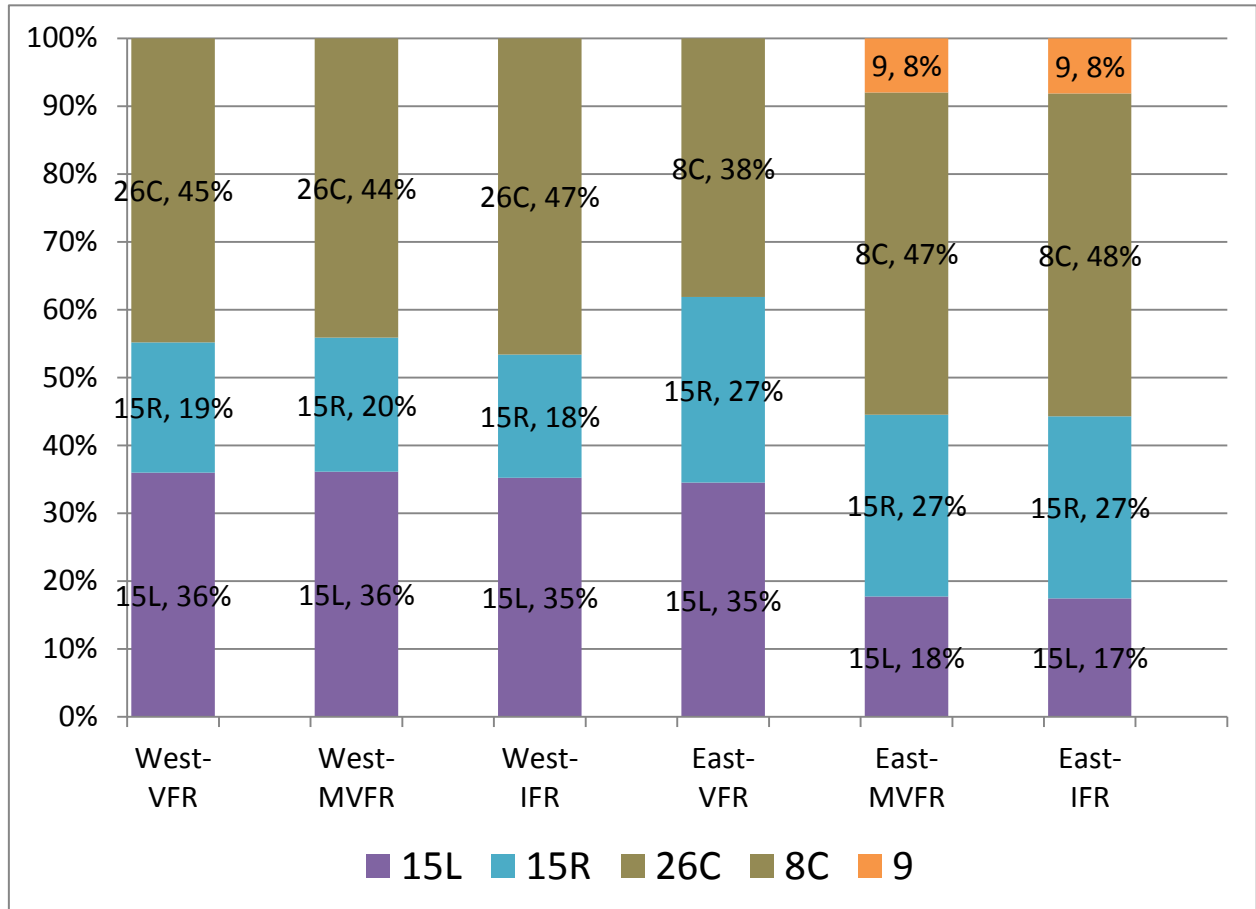


Figure 5-24
MODELED DEPARTURE RUNWAY USE PERCENTAGES (PAL33)
 George Bush Intercontinental Airport



Source: LeighFisher, August 2013, based on TAAM simulation results.

5.2.6.5 Simulation Results and Findings

The following section summarizes the simulation results in terms of average taxiing times and average aircraft delay.

Average Taxiing Times. It is estimated that the average unimpeded taxi-out times would be 10.2 minutes per operation for the preferred alternative as compared to 9.3 minutes per operation for the existing airfield at PAL25, as shown in Table 5-6. This relative increase is due in part to the longer taxiing distance from the terminal gates to Runway 8C-26C compared to the existing condition in which nearly all departures travel from their gate to Runway 15L or 15R. Additionally, aircraft using the East Terminal have longer taxiing distances as compared to the gate layout in the existing airfield.

Table 5-6
ESTIMATED AVERAGE UNIMPEDED AIRCRAFT TAXIING TIMES

Demand level	Airfield layout	Unimpeded taxiing times		Total taxiing times	
		Taxi-out (minutes/departure)	Taxi-in (minutes/arrival)	Taxi-out (minutes/departure)	Taxi-in (minutes/arrival)
2012	Existing	9.12	9.82	9.31	10.58
	North 1A	10.21	9.81	10.56	10.29
	Change:	+1.09	-0.01	+1.25	-0.29
PAL25	Existing	9.30	10.73	10.16	12.31
	North 1A	10.23	9.97	10.74	10.60
	Change:	+0.93	-0.76	+0.58	-1.71

Source: LeighFisher, August 2013, based on TAAM simulation results.

The average unimpeded taxi-in time is estimated to be reduced with the north runway because Runway 9 would be used more frequently as an arrival runway in east flow, with shorter taxiing distance to the terminal gates compared to the outboard Runway 8R. The reduction in average unimpeded taxi-in time would be approximately 45 seconds.

In addition, the estimated total taxiing times, which include taxiing delays, were compared. The average taxi-in time with the preferred alternative is reduced by 1.71 minutes per operation in PAL25 compared to those estimated with the existing airfield. The average taxi-out time with the preferred runway alternative is expected to increase as compared to the existing airfield, as stated previously, although the increase is somewhat offset by a reduction in taxiway delay (i.e., the change in total taxi-out time is smaller than the change in unimpeded taxi-out time).

Average Aircraft Delay. As shown in Table 5-7 and in Figure 5-25, the estimated average aircraft delay is 5.42 minutes per operation by PAL33, and 7.35 minutes per operation by PAL40. It is generally accepted by airlines and airports that 7 to 8 minutes average annual delay per operation would be satisfactory. Therefore, this analysis confirms that the preferred airfield alternative would be able to meet forecast demand through PAL40, albeit marginally during east flow and under instrument approaches/dependent departures conditions (which occurs infrequently, approximately 3.8% of the time).

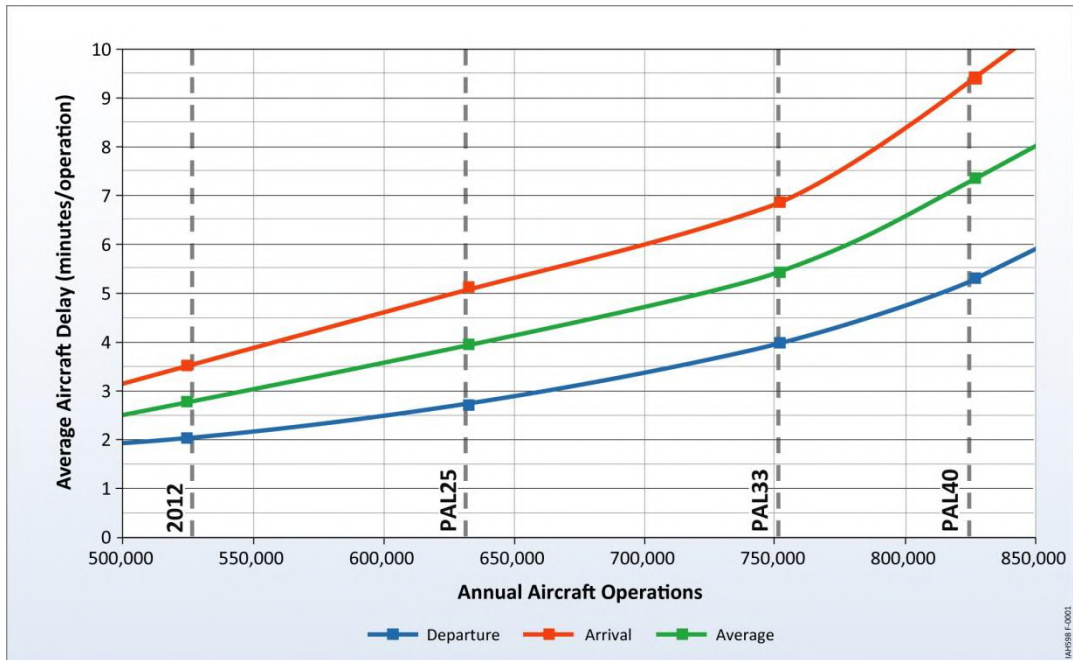
Figure 5-26 shows the delay curves associated with each operating condition. As shown, conditions with independent departures operate with acceptable levels of average annual delay through PAL40. However, under instrument approaches/dependent departures conditions, average annual delay increases rapidly following PAL33, becoming unacceptable by PAL40.

Table 5-7
ESTIMATED AVERAGE AIRCRAFT DELAY

Demand level	Annual operations	Operating condition	Average aircraft delay (minutes/operation)	
			East flow	West flow
2012	524,551	Visual approaches/ Independent Departures	2.59	2.59
		Instrument Approaches/ Independent Departures	2.94	2.70
		Instrument Approaches/ Dependent Departures	3.24	2.90
		Overall	2.03	
PAL25	632,658	Visual approaches/ Independent Departures	3.36	3.50
		Instrument Approaches/ Independent Departures	4.42	3.76
		Instrument Approaches/ Dependent Departures	5.14	4.18
		Overall	3.95	
PAL33	751,980	Visual approaches/ Independent Departures	4.90	4.45
		Instrument Approaches/ Independent Departures	6.15	4.98
		Instrument Approaches/ Dependent Departures	8.20	6.38
		Overall	5.42	
PAL40	826,940	Visual approaches/ Independent Departures	6.44	5.13
		Instrument Approaches/ Independent Departures	9.60	5.89
		Instrument Approaches /Dependent Departures	19.73	7.98
		Overall	7.35	

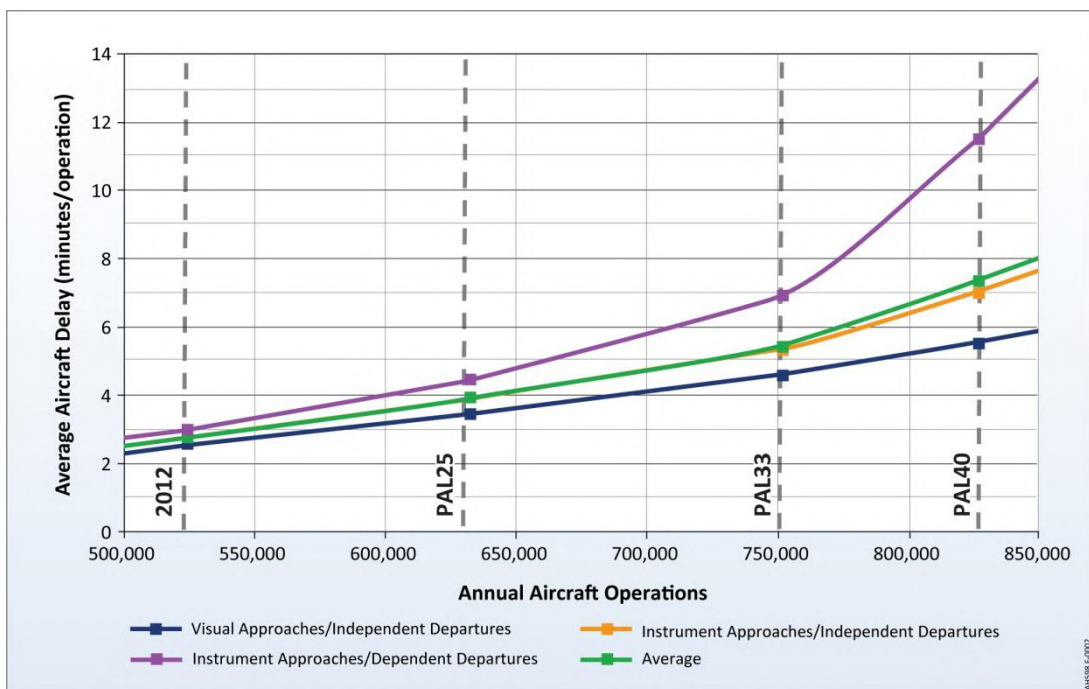
Source: LeighFisher, August 2013, based on TAAM simulation results.

Figure 5-25
AVERAGE ANNUAL AIRCRAFT DELAY



Source: LeighFisher, October 2013.

Figure 5-26
AVERAGE ANNUAL AIRCRAFT DELAY BY OPERATING CONDITION



Source: LeighFisher, October 2013.

5.2.6.6 Long Term Airfield Development

Given that the preferred runway alternative is expected to provide adequate runway capacity through PAL40, the need for an additional runway is not likely to materialize until after the planning period. However, prudent planning suggests that land be reserved for at least one additional another east-west runway to be constructed beyond the planning period.

Land should be reserved for a fifth east-west parallel runway south of existing Runway 9-27. At such time, the airfield would likely be operated largely in the east-west direction and use of the Runway 15-33 complex would largely cease. Therefore, a south runway would increase airfield capacity since there would no longer be dependencies with operations on Runways 15R and 15L. Alternative South 1 is expected to provide the most capacity benefit with minimal cost. A high-level assessment was conducted to estimate the airfield hourly capacity and annual service volume (ASV) for the preferred north runway along with Alternative South 1. The ASV of the airfield with proposed Runway 8C-26C and Alternative South 1 was estimated at 947,800 annual operations, providing capacity well beyond the demand forecast in the Master Plan.

5.2.6.7 Conclusions

The simulation results confirm that the preferred airfield alternative would meet forecast demand levels through PAL40, with an average annual delay of 7.4 minutes per operation. The adverse impact of additional runway crossings on airfield capacity resulting from aircraft crossing Runway 8R-26L to depart the proposed Runway 8C-26C can be minimized via the use of end-around taxiways and the recommended supporting taxiway infrastructure.

Given the maximum acceptable range for average annual delay should be approximately 7 to 8 minutes per operation is expected to be met with the north runway, the next runway is expected to be needed beyond the planning period of the Master Plan. However, for master planning purposes, the potential location for one or two additional east-west parallel runways should be considered so that space is reserved as part of the long-term plan.

5.2.7 Runway Extension Alternatives

Currently, the longest runway at the Airport is Runway 15L-33R at 12,001 feet. An extension to another runway is recommended to provide a redundant long-haul departure runway in the case that Runway 15L-33R must be taken out of service (e.g., for maintenance or rehabilitation).

Three options for providing a redundant runway for long-haul departures were considered:

- Extend Runway 9-27 to the east by approximately 2,000 feet
- Extend Runway 8R-26L to the east by approximately 2,000 feet
- Extend Runway 15R-33R to the southeast by approximately 2,000 feet

The extension to Runway 9-27 was discarded because it would have increase noise exposure to the North Hollow neighborhood, assuming the arrivals threshold was relocated 2,000 feet east to align with the extended runway end. Additionally, in the configuration that the Airport operates in most frequently, Runway 27 is not used for departures given its interaction with operations on the primary departure runways, Runways 15L-33R and 15R-33L. Additionally, taxi time to an extended Runway 27 would be increased significantly from the terminal complex in comparison to using Runway 15L.

The extension to Runway 8R-26L was also discarded because it would require a costly relocation of the East Cargo complex. Although this extension would provide short taxi distances and minimal environmental impacts, it is not the most logical candidate for a departure runway since Runway 8R-26L primarily accommodates arrivals. The use of the runway for departures would disrupt established taxi flows and arrival operations.

An extension to Runway 15R-33L is preferred because it would have minimal impact on existing Airport facilities and would not require a change to runway use. Runway 15R-33L is already a primary departure runway, and its extension would allow more flexible assignment of Runways 15R-33L and 15L-33R for departure. This runway extension also provides an opportunity to align the ends of Runways 15L and 15R as well as 33L and 33R, reducing wake turbulence dependencies between departures from both runways. This runway extension would require removal of the VHF omni-directional range (VOR), and coordination with the FAA would be required to confirm the timing and replacement of the VOR with alternate navigational aids.

5.2.8 Taxiway Alternatives

Although the existing runway system is expected to provide adequate capacity through PAL33, the flow of aircraft on the ground will become increasingly congested. One of the primary issues is the flow of aircraft between the north and south runways and north and south terminal aprons. To provide additional bi-directional north/south capability, options for crossfield taxiway flow were explored on both the west and east sides of the terminal complex.

For the west side of the terminal complex, an extension to Taxiway NR is recommended. For the east side of the terminal complex, a parallel taxiway to Taxiway SF is recommended. These taxiway recommendations are summarized below, and covered in more detail in Appendix C, *Master Plan Taxiway Recommendations*.

5.2.8.1 Taxiway NR Extension

Taxiway NR currently connects Taxiway CC north of Runway 8R-26L west of the terminal complex to Taxiway WB. An extension of Taxiway NR is proposed to (1) provide a shorter taxi route for aircraft arriving on Runways 8L-26R or 8R-26L to the south apron, and (2) upgrade Taxiway NR for use by larger aircraft.

A summary of the Taxiway NR project is described below:

- The portion of Taxiway NR to the west of the terminal complex is currently limited to aircraft with wingspans less than 125 feet. This project would upgrade this portion of the taxiway to accommodate Airplane Design Group (ADG) V aircraft, and extend Taxiway NR to Taxiway RA.
- Currently, the majority of arrivals from Runways 8L-26R destined for the south apron are routed via the east end of the terminal complex on Taxiway SF. This circuitous routing increases aircraft taxiing distances and times, and also increases conflicts on Taxiway SF leading to aircraft delays.
- An extension of Taxiway NR would provide a southbound route to the south apron, primarily for aircraft parking at the south concourses of Terminals A and B, which would not conflict with existing flows of aircraft using Taxiways WA and WB northbound to taxi to Runways 15L or 15R for departure.

Taxiway NR would also mitigate the disruption to airfield efficiency in the event that Taxiway SF would be unavailable. With Taxiway NR extended to Taxiway RA, aircraft destined for the south apron arriving to the north airfield would be able to taxi around the west end of the terminal complex more freely.

5.2.8.2 Crossfield Taxiway SL

Crossfield taxiway alternatives were considered to provide (1) a second crossfield taxiway, eliminating Taxiway SF as a single point of failure for airfield circulation, and (2) bi-directional northbound and southbound aircraft movement, reducing aircraft taxiing delay associated with conflicts on existing Taxiway SF.

In the next 15 to 20 years, Taxiway SF will be required to be out of service for a number of months while its bridges over Will Clayton Parkway, North Terminal Road, and South Terminal Road are reconstructed. Further, it is possible that the taxiway will be unavailable during shorter periods of time because of more routine maintenance or a disabled aircraft. In the event that the taxiway is unavailable, taxi time delays would be untenable and air traffic control workload would be increased.

While Taxiway SF is out of service, all crossfield aircraft movements would need to be routed around the west side of the terminal complex. Aircraft destined for the gates on the south apron of Terminals A, B, C and E from the north airfield, or aircraft destined to or from Runway 9-27 from the north apron would taxi around the west side of the terminal complex. The proposed construction of Taxiway NR would provide some crossfield capability in the case that Taxiway SF is out of service. However, aircraft arriving in east flow would have to “back-taxi” the length of Runways 8R and 8L to reach Taxiway NR, and operations between the north apron and Runway 9-27 would face a similar circuitous taxi route. Further, there would be head-to-head congestion created to the north, west, and south of the terminal complex due to the circuitous routings and conflicts between existing taxi patterns and re-routed crossfield movements.

With regard to air traffic controller workload, if Taxiway SF were unavailable, aircraft would likely need to be assigned their arrival or departure runway based on their assigned gate or parking position. This level of coordination between air traffic control and the airlines would lead to severely reduced operational efficiency of the airfield, major delays, and likely flight cancellations.

It should be noted that a primary use of crossfield Taxiway SF is to provide access between the north airfield complex and aircraft gates on the south side, predominantly for the aircraft operations of United Airlines. In addition to the single point of failure issue, having a single crossfield taxiway makes bi-directional flow between the north and south aprons and the north and south airfield complex challenging, given the need for Taxiway SF to serve both northbound and southbound aircraft movements.

Given these considerations, the master plan evaluated several alternative locations for the second crossfield Taxiway SL.

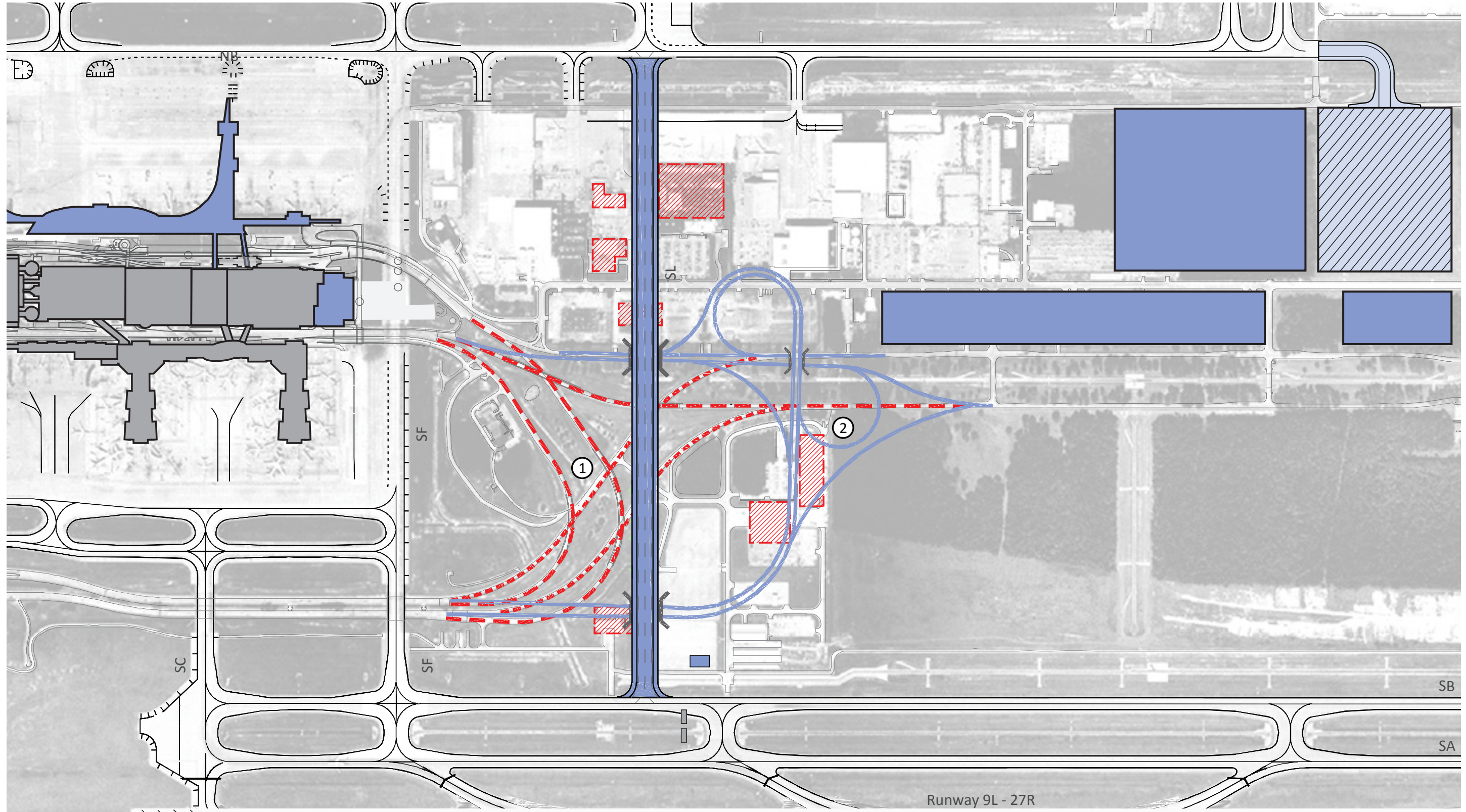
The findings of the alternatives analysis are:

- Alternatives located further east than the end of Runway 26L provide little or no reduction in aircraft operating time due to increases in taxi distances.
- To ensure future flexibility in use, a second crossfield taxiway must allow for a connection to the south apron, requiring the extension of Taxiways RA and RB. Given this requirement, the reconstruction of the Will Clayton Parkway/John F. Kennedy Boulevard (WCP/JFK) interchange would be required for all alternatives at some point in time. Alternatives for this interchange relocation were evaluated as part of the master plan. The key criteria in developing these alternatives included: maintaining all points of access between WCP and JFK while accommodating the new crossfield taxiway; minimizing the footprint of the interchange to reserve space for other land uses; and minimizing costs by avoiding three vertical levels of bridge structure. Another movement considered was the return to terminal access on Will Clayton Parkway since the current

signalized return-to-terminal movement is insufficient to meet demand in the future. The new WCP/JFK interchange would provide a free flowing return-to-terminal movement to provide sufficient capacity for motorists returning to the terminal area. Additional evaluation criteria considered the feasibility and cost of constructing the new interchange. Figure 5-27 shows the proposed relocated WCP/JFK interchange.

The preferred location of the crossfield taxiway is aligned with the end of Runway 26L as it maximizes aircraft delay reduction with a minimal increase in taxi time, providing the maximum reduction in aircraft operating time of any alternative.

Further information regarding Taxiway SL and the evaluation of alternative locations may be found in Appendix C, *Master Plan Taxiway Recommendations*.



5.3 TERMINAL AND LANDSIDE ALTERNATIVES

This section describes the development and evaluation of the terminal and landside alternatives. Alternatives were formulated to meet the aircraft gate requirements established in the facility requirements task.

Similar to the airfield alternatives, terminal and landside alternatives were developed and evaluated through an integrated and collaborative approach. Working in close collaboration with the Houston Airport System (HAS) and the Technical Advisory Committee, a set of goals and objectives were established for the Master Plan project. The goals and objectives identified for passenger terminal and landside access were:

Passenger Terminal: provide needed gate capacity and a consistent customer experience throughout the terminal complex by meeting the following objectives:

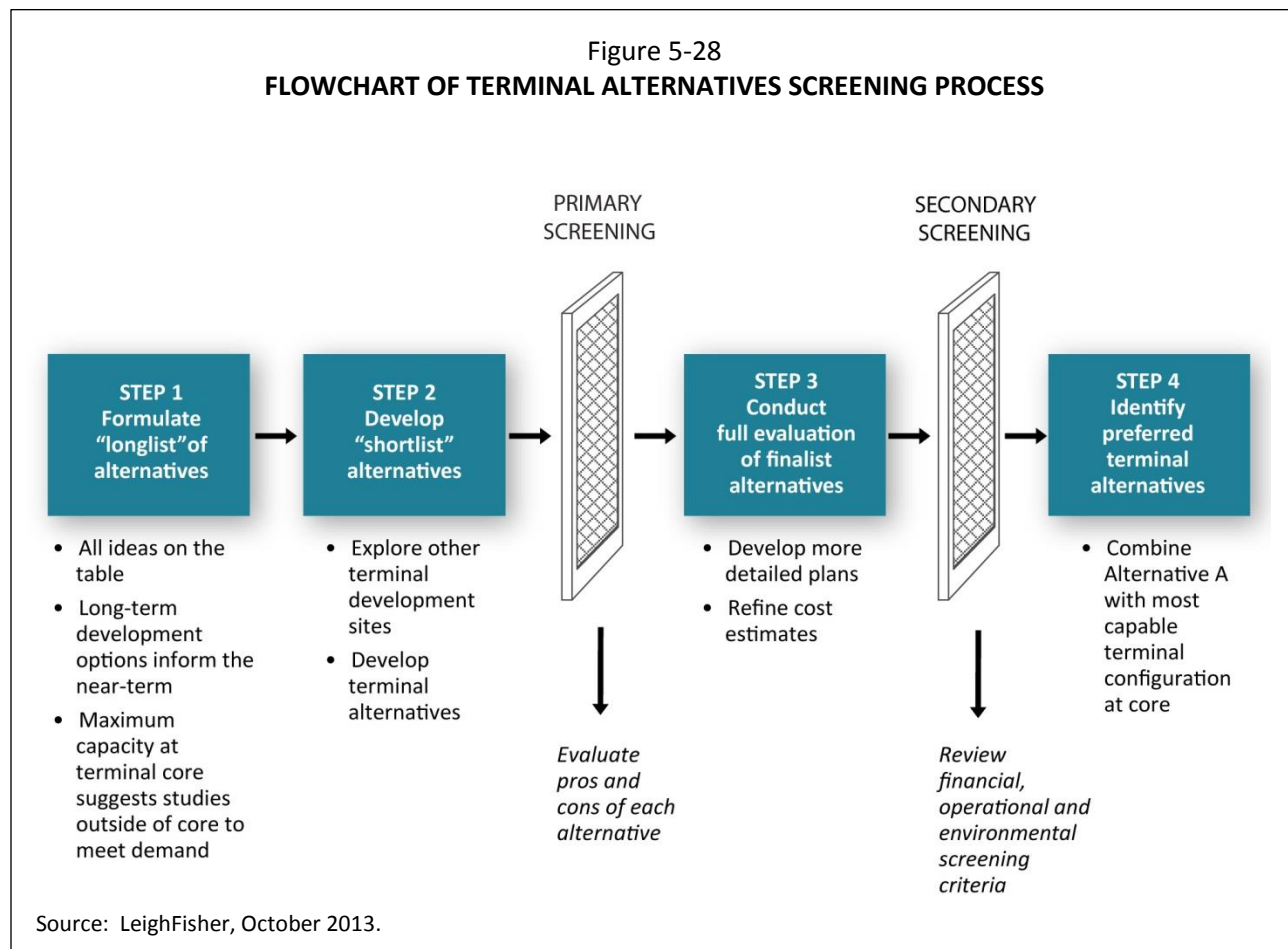
- Plan for high levels of service for the entire customer experience
- Provide sufficient aircraft gates to accommodate existing and prospective carriers
- Provide excellent concessions to delight the passenger
- Provide sufficient parking for remain-overnight aircraft
- Reflect Houston culture in the plan
- Leverage technology for improved passenger experience

Landside/Access: provide efficient airport access by meeting the following objectives:

- Provide for an appropriate level of service on access roadways and terminal curbsides during peak hour
- Plan for the link to METRORail
- Plan for the replacement of the Inter-Terminal Train (ITT)
- Address the parking imbalance between facilities
- Provide sufficient parking capacity to maintain or improve market share
- Provide for centralized receiving dock

A longlist of alternatives was formulated based on long-term development options to inform near-term strategies. Insufficient capacity associated within the existing terminal area required exploration of sites outside of the existing terminal area to meet future demand for aircraft gates. A shortlist of three alternatives was generated to assess potential development sites. Through primary screening of the alternatives, two finalists were selected for further evaluation. Detailed plans and cost estimates prepared for each alternative which were then subject to secondary screening evaluation. These screening criteria were established to evaluate financial, operational, and environmental impacts of each alternative, which led to the ultimate selection of a preferred terminal alternative. Figure 5-28 illustrates a flowchart of the terminal alternatives screening process.

Figure 5-28
FLOWCHART OF TERMINAL ALTERNATIVES SCREENING PROCESS



5.3.1 Aircraft Gate Requirements

Overall airport gate requirements established in previous analyses were used to inform the estimated number of aircraft gates required to meet three Planning Activity Levels (PALs). PALs 25, 33 and 40, each corresponding to the number of enplaned passengers expected during that timeframe were used so that future development can be planned to come online when activity dictates rather than an arbitrary year in the future. The range of years at which the planning activity levels could come to fruition corresponds to the baseline aviation demand forecast; for example, PAL33 could occur as early as 2028 or as late as 2037.

Two sets of gate requirements were developed as shown on Table 5-8. The first set of requirements assumes all airlines to continue operating within the existing terminal area. The second set of requirements assumes the foreign flag and all domestic carriers, except United Airlines, would relocate their operations to a shared facility outside the existing terminal area. Accordingly, the second set reports the number of gates, assuming that all airlines other than United share gates.

Table 5-8 presents absolute gate counts estimated for each aircraft size category. A "narrowbody equivalent" (NBEQ) gate count, which adjusts for aircraft size by indexing all gates to a standard size is also shown. The standard aircraft used in these tables was a Boeing 737-900 winglet aircraft with a wingspan of 117.4 feet. NBEQ gate is a common metric used to compare alternatives.

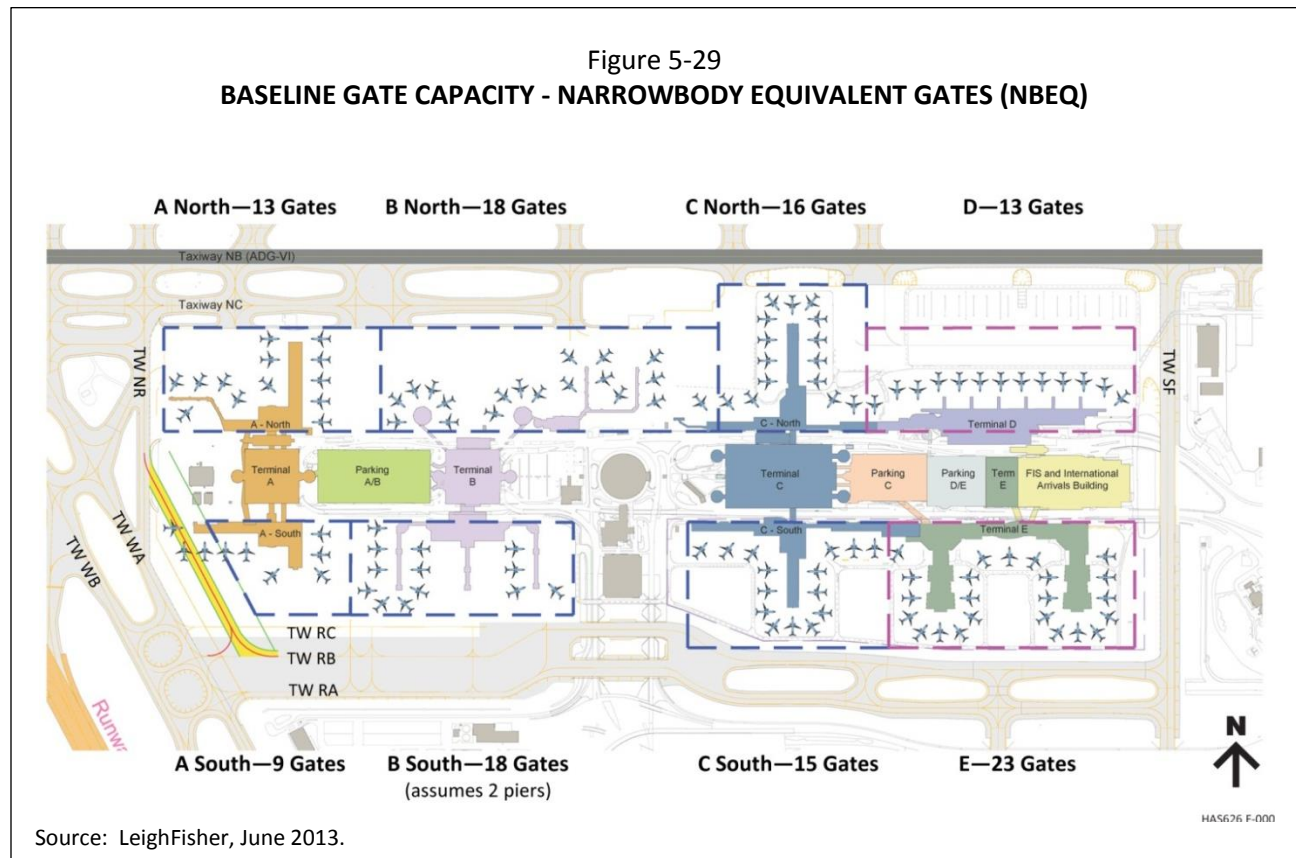
Table 5-8
AIRCRAFT GATE REQUIREMENTS

All carriers (a)													
	ADG II		ADG III		ADG IV		ADG V		ADG VI (b)		Total	NBEQ	
	Dom	Int'l	Dom	Int'l	Dom	Int'l	Dom	Int'l	Dom	Int'l			
Existing	66	-	36	18	17	8	-	9	-	-	154	125	
PAL 25 2019-2023	43	9	56	18	6	3	-	10	-	2	147	139	
PAL 33 2028-2037	47	8	83	30	2	1	-	11	-	4	186	178	
PAL 40 2034-2048	39	4	89	47	1	1	4	11	-	6	202	204	
Foreign Flag and non-United Airlines domestic carriers													
	ADG III		ADG V		ADG VI		Total		NBEQ				
PAL 25 2019-2023	8		6		1		15		21				
PAL 33 2028-2037	10		4		4		18		27				
PAL 40 2034-2048	16		1		6		23		32				
United Airlines only													
	ADG II		ADG III		ADG IV		ADG V		Total		NBEQ		
PAL 25 2019-2023	50		60		11		6		127		116		
PAL 33 2028-2037	52		99		8		7		166		154		
PAL 40 2034-2048	41		103		16		15		175		177		
Notes: (a) Based on 2012 flight schedule. (b) 2013 Schedule includes 1 international ADG VI. Source: LeighFisher 2013, Table C-2 Facility Requirements Working Paper.													
HAS626 F-0014													

5.3.2 Evaluation of Terminal Complex Capacity

The existing terminal area is constrained by taxiways on all four sides as shown in Figure 5-29. Marking the northern boundary is Taxiway NB. The western edge is bounded by Taxiway NR with the proposed angled segment. Taxiway RC forms the border to the south and Taxiway SF to the east. Given the capacity of the existing terminal area of approximately 125 NBEQ, a number of redevelopment options were evaluated to

determine if the existing terminal area could be reconfigured to meet future demand. The maximum number of aircraft gates capable of being accommodated in the existing terminal area was determined for each of the redevelopment options.



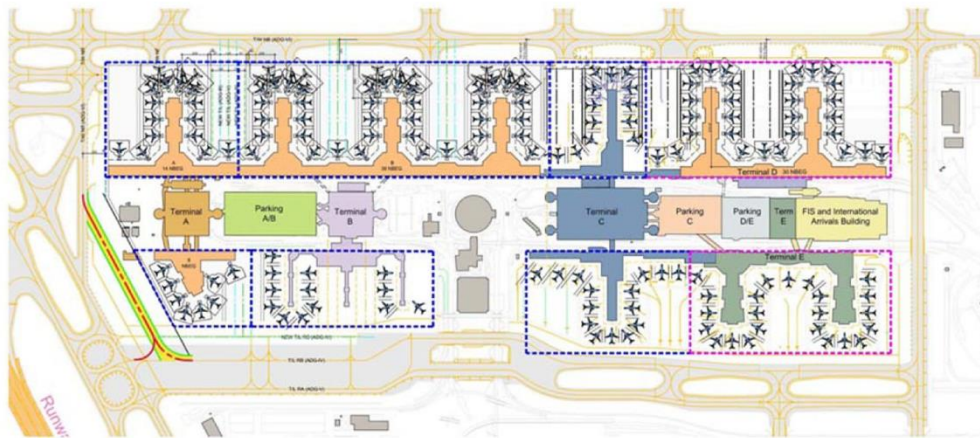
5.3.2.1 Pier Concept Family

Two pier concepts were developed as shown in Figure 5-30. Both Pier Concepts 1 and 2 show two piers at Terminal D to maximize use of the apron available.

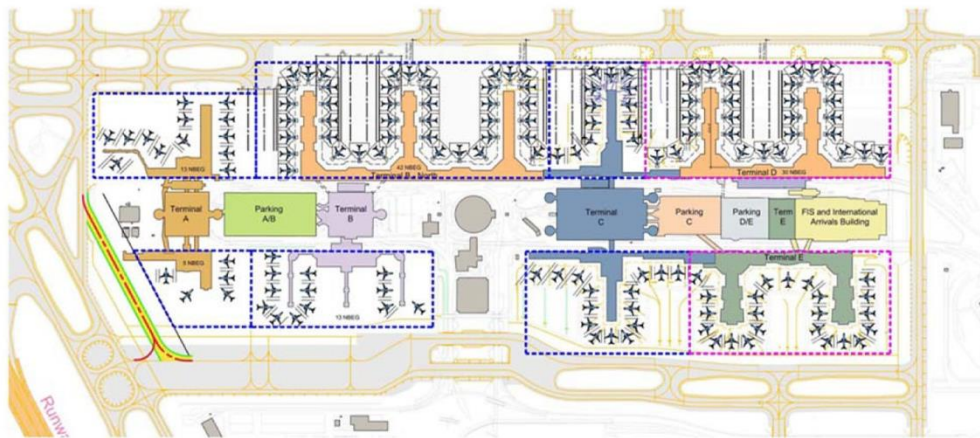
In Pier Concept 1, four new concourse piers would be constructed to serve Terminals A and B to the north. These piers would primarily accommodate narrowbody aircraft, with larger widebody aircraft parked diagonally at the end of each concourse. Deeper aprons serving the gates at the end of the concourse are provided, assuming aircraft do not pushback onto the active Taxiway NB. On the south side, the concourse serving Terminal A would be reconfigured to align with the new angled segment of Taxiway NR. This concept would yield a total of approximately 162 NBEQ gates.

Pier Concept 2 retained both the existing concourses that would serve Terminal A. The Terminal B north concourses are longer than those in Pier Concept 1 which maximizes the ability to accommodate narrowbody aircraft, at the expense of widebody parking positions. Pier Concept 2 would accommodate a total of approximately 165 NBEQ gates. Pier concepts maximize use of available apron space and present the least impact to existing terminals and roadways. However, pier concepts are not particularly well-suited to accommodate widebody aircraft as compared to linear and satellite terminal concepts explored in subsequent analysis.

Figure 5-30
PIER CONCEPT FAMILY



Pier concept 1 (162)



Pier concept 2 (165)

Source: LeighFisher, June 2013.

HAS676 F-000

5.3.2.2 Linear Concept Family

Two linear terminal concepts were considered. Both concepts preserve the eastern half of the terminal area as shown on Figure 5-31.

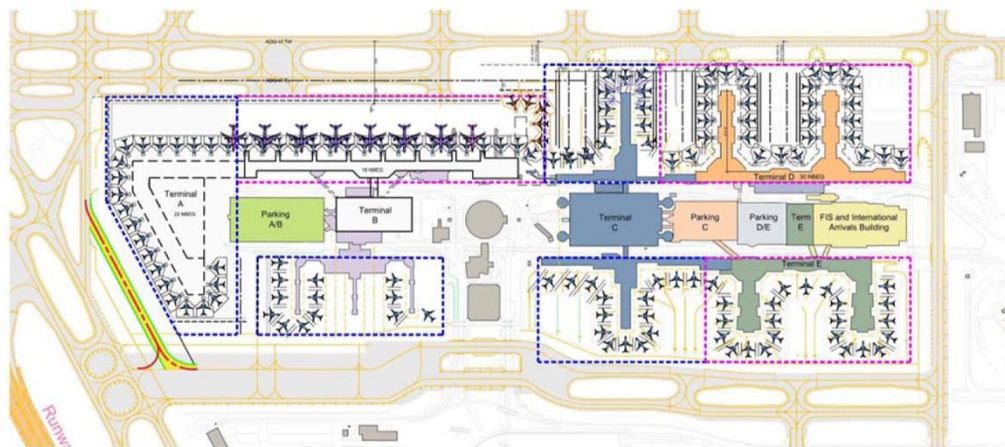
On the west side, Linear Concept 1 indicates expanded Terminals A and B to handle additional processing capability and a linear concourse running east-west with a deeper apron able to accommodate more widebody aircraft. The concourse continues to wrap around the west end of Terminal A with apron depth

enough to handle narrowbody or smaller aircraft. Concourse B-south would remain as is currently. This concept would provide 142 total NBEQ gates.

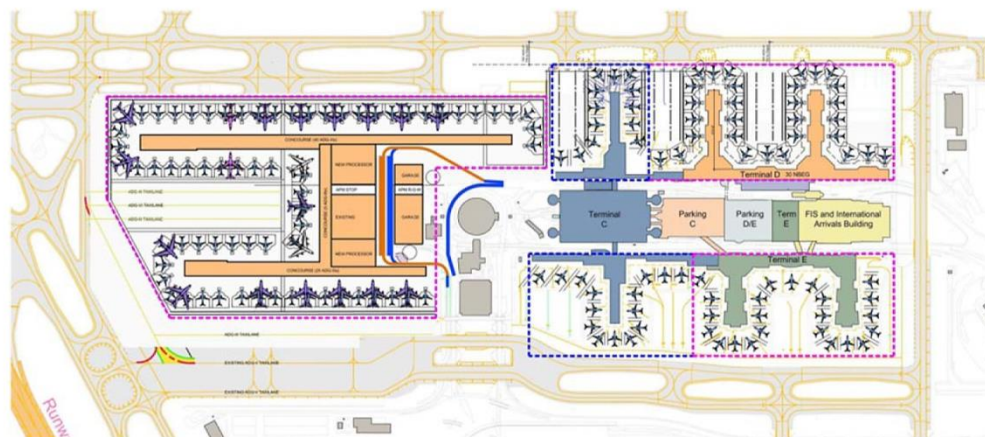
Linear Concept 2 centralizes Terminals A and B into one processing facility with an H-terminal configuration that can accommodate many widebody aircraft on the north and south sides. However, constructability of this concept while maintaining the integrity of the existing operation would be challenging, and the construction costs may be prohibitive due to radical changes to the roadways and facility structures. This concept is able to yield a total of approximately 152 NBEQ gates.

Both linear concepts require radical changes to terminals, curbsides, and roadways to alleviate congestion.

Figure 5-31
LINEAR CONCEPT FAMILY



Linear concept 1 (142)



Linear concept 2 (152)



Source: LeighFisher, June 2013.

HAS636 E-000

5.3.2.3 *Satellite Concept Family*

Three satellite terminal concepts were under consideration, all of which retained the existing east quadrant of the terminal core, as shown on Figure 5-32. Satellite concourses rely on an underground people mover system to transport passengers back and forth between the main terminal processor and their gates.

Satellite Concept 1 consolidates Terminals A and B into one centralized terminal with a new parking structure partly situated over the existing hotel site. A mixture of pier and linear concourses make up the west central terminal area. To the far west of the centralized terminal area is a north-south oriented satellite concourse with an apron deep enough to maneuver without pushing back onto Taxiway NR. This concept provides a total of approximately 152 NBEQ gates.

Satellite Concept 2 shows two north-south oriented satellite concourses, one with an apron deep enough to handle widebody aircraft and another with an apron depth able to accommodate narrowbody or smaller size aircraft. A consolidated terminal building running north-south is shown which would require substantial reconstruction of the roadway infrastructure and a possible elimination of the hotel site. Satellite Concept 2 can accommodate up to a total of 159 NBEQ gates, the most amongst the three satellite concepts under consideration.

Satellite Concept 3 rotates the terminal and concourse into an east-west direction. The linear concourse attached to the terminal building is capable to handle widebody aircraft given the available apron depth. A satellite concourse south of the terminal building can accommodate narrowbody aircraft and a few larger size aircraft at the corner. This concept requires a complete rebuild of the terminal roadway and parking infrastructure, but preserves the existing hotel site. Satellite Concept 3 would provide a total of approximately 142 NBEQ gates, the least of the three satellite concepts considered.

All three satellite concepts would require radical changes to terminals, curbsides, and roadways to alleviate congestion.

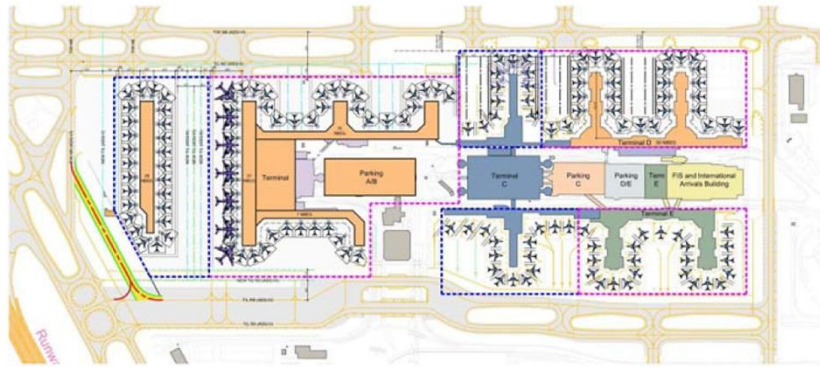
5.3.2.4 *Findings Regarding the Existing Terminal Area*

All seven alternatives to redevelop the western half of the existing terminal area would be capable of serving the required number of narrowbody equivalent gates at PAL25. However, none of the alternatives were able to produce the 178 NBEQ gates required to meet PAL33 demand. Satellite alternatives provided a maximum of 159 NBEQ gates; linear alternatives offered a maximum of 152 NBEQ gates, the least among all long-listed alternatives. Pier alternatives provide the two most efficient configurations, capable of accommodating a maximum of 165 NBEQ positions.

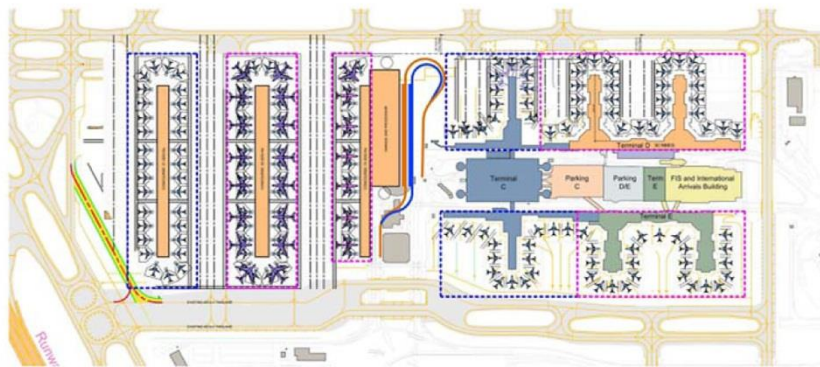
Redeveloping the western half of the terminal core also poses challenges, including: (1) maintaining the integrity of existing operations while reconstruction would occur, (2) relative high cost of redevelopment due to phasing requirements, (3) provision of additional aircraft parking positions would only further exacerbate the terminal roadway and curbside congestion, and (4) the redevelopment of concourses would not provide additional apron space required to increase capacity.

Given the capacity limitation and challenges, alternatives that would provide additional capacity outside the existing terminal area were explored.

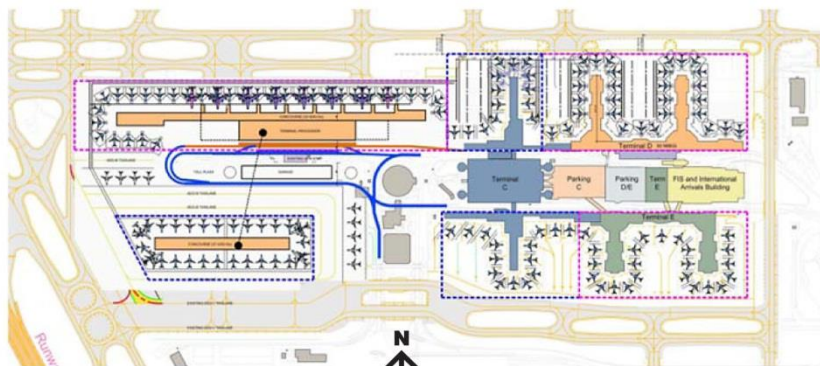
Figure 5-32
SATELLITE CONCEPT FAMILY



Satellite concept 1 (152)



Satellite concept 2 (159)



Satellite concept 3 (142)

Source: LeighFisher, June 2013.

5.3.3 Terminal Roadways and Curbsides

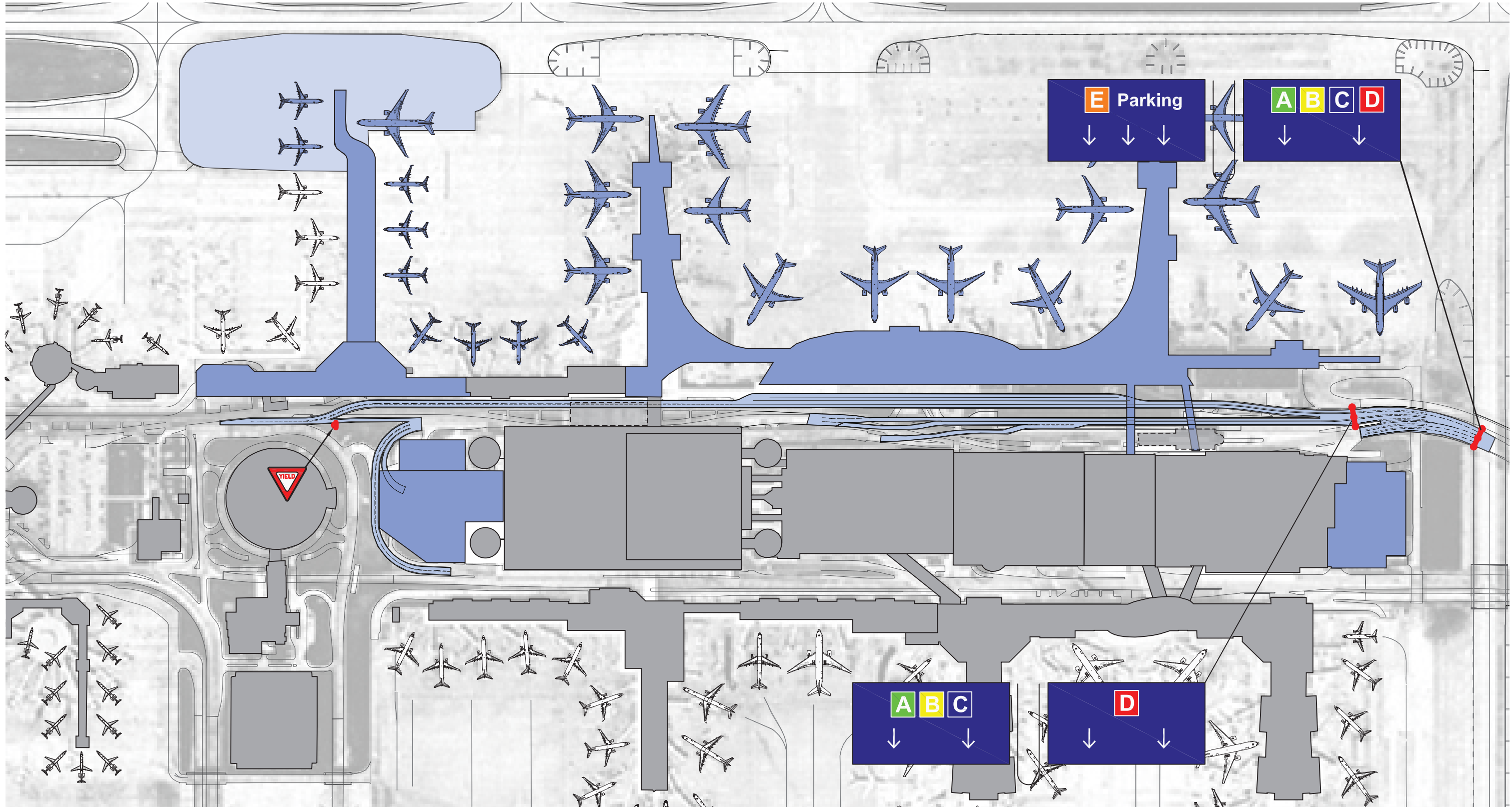
The existing roadways and curbsides currently experience congestion during the peak hours, delaying passengers traveling to and from the terminal area. Alternatives considered to accommodate the additional demand at future PALs include adding bypass roadways, double-decking the roadway system, using parallel curbsides, and simplifying weaving areas and decision points. Assuming all activity would be accommodated within the existing terminal area, the volume of vehicles using the roadways would exceed the capacity of future roadway modifications in the existing footprint between the terminal buildings, parking structures, and TerminalLink automated people mover (APM) alignment. This capacity constraint is due to vertical expansion of the roadway system being limited on the north side of the terminal by the existing TerminalLink alignment, while horizontal expansion of the existing roadways is limited by both the existing buildings and the TerminalLink support columns.

One alternative to mitigate these capacity constraints considered was the relocation of the façade of terminal buildings proposed for reconstruction to allow for horizontal expansion of the roadways and the addition of a bypass roadway outside of the TerminalLink support columns. The addition of a bypass roadway on the north side of the terminal complex would allow passengers to avoid congestion caused by the overflow of private motorists waiting to pick up passengers at the arrivals curbsides. As part of the bypass roadway reconfiguration, the terminal area roadways at the entrance to the airport off of Will Clayton Parkway would also be reconfigured to simplify wayfinding for motorists by reducing the number of decision points and creating a binary decision instead of a three-way decision point. Figure 5-33 shows the proposed reconfiguration of North Terminal Road at Terminals C, D, and E.

A bypass roadway on North Terminal Road around Terminals A and B was also considered. The location of the TerminalLink APM columns limited the functionality of the bypass, leading to inefficient merging and diverging points that would not improve the overall roadway operations.

Alternatives to reduce curbside congestion include physical changes to the curbsides such as widening and lengthening the curbs, and operational changes including reducing dwell times, reconfiguring the terminal area curbside lanes, and reallocating space among the different vehicle types. Physical modifications under the existing terminal configurations are limited by the lengths of the sides of the terminal buildings. The existing dwell times at the private vehicle arrivals curbsides are much longer than the average dwell times found at many other airports. A reduction in these dwell times would reduce the curbside congestion that currently leads to overflow of vehicles onto the terminal area roadways.

At PAL33 and PAL40, the curbside alternatives are dependent on the configuration of the preferred terminal concept. Consideration was given to providing a consolidated terminal building that would enable longer, linear curbsides, the potential for dual level curbsides (with departing passengers dropped off at ticketing on the upper level and arriving passengers picked up on the lower level), or separate inner and outer curbsides for private and commercial vehicles, respectively. In evaluating these options, the implementation of dual level curbsides was constrained by the TerminalLink APM columns and the length that would be required to reach the required elevations before diverging from or merging with the at-grade portion of the terminal roadways.



5.3.4 Parking

Parking alternatives were planned to accommodate all growth in parking demand on the Airport campus to ensure that adequate Airport property is reserved for this land use. All terminal area parking facility capacity was considered together, whether the existing facilities are currently used for public or for employee parking, recognizing that it would be a policy decision to determine how the limited close-in parking spaces would be allocated between the public and employees in the future.

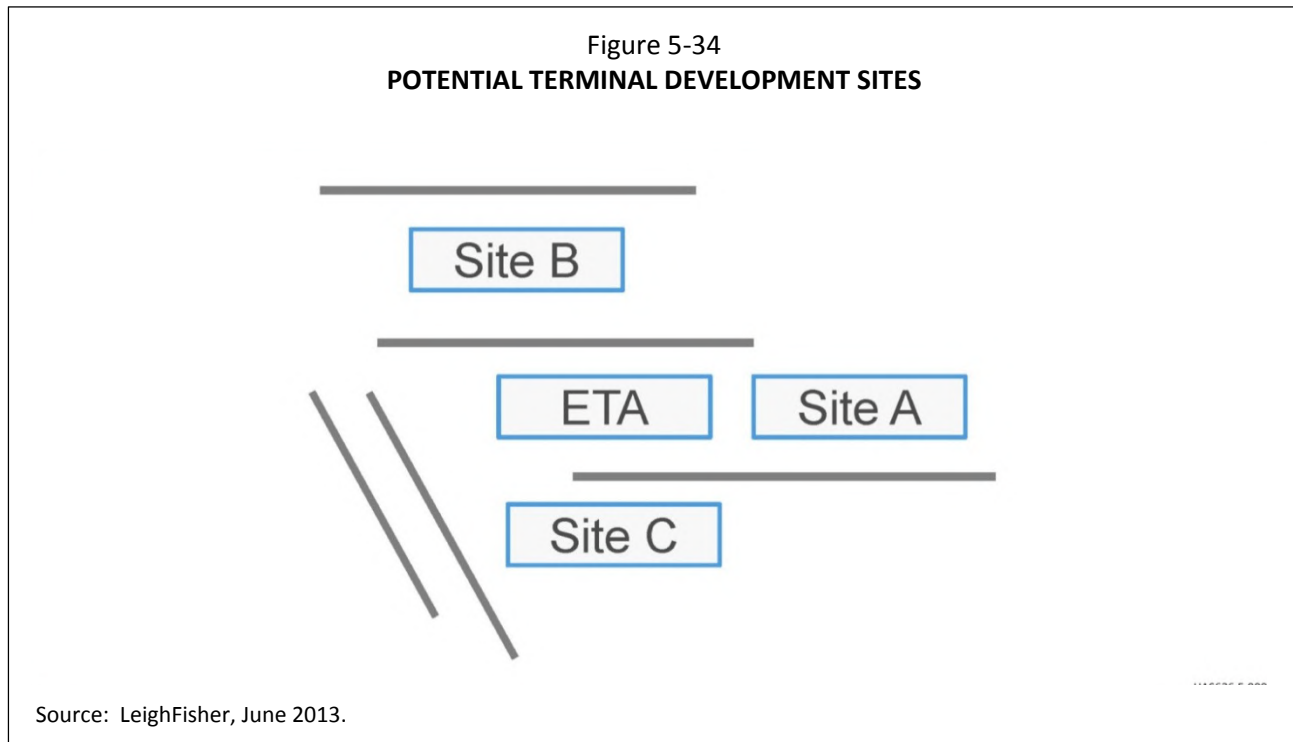
The alternatives considered to accommodate the future terminal area parking demand included combinations of three concepts: (1) construction of new parking facilities, (2) expansion of existing parking facilities, and (3) maximizing parking spaces within the footprint of existing facilities. A no build alternative was also considered, where all future parking would be accommodated either remotely or at off-airport parking facilities. Although this alternative would result in the lowest capital cost, the negative impacts to the Airport's revenue, poor customer service levels, and congestion caused by the lack of close-in parking resulted in this option being discarded. Locations available to accommodate new or expanded parking facilities within the terminal area were dependent on the selected terminal concept family. As a result, detailed close-in parking alternatives were only developed for the preferred terminal concept family.

Alternatives considered to accommodate remote parking demand included expansion of surface parking facilities at the EcoPark lot, construction of new surface parking lots similar to the current EcoPark lot, and construction of remote parking structures, both within the existing EcoPark lot and on greenfield sites.

5.3.5 Terminal Development Sites

To address the inability of the existing terminal area to provide the necessary number of aircraft gates to meet long-term demand, alternative sites outside the terminal core were evaluated. Each of the sites explored were large enough in size to accommodate the number of additional aircraft parking positions required at PAL40. The three sites, designated as Sites A, B and C, evaluated are shown in Figure 5-34.

- Site A is the area directly to the east of the existing terminal core and Taxiway SF between the extended runway centerlines of Runways 8R-26L and Runway 9-27
- Site B is the area located in between the two existing Runways 8R-26L and 8L-26R
- Site C is the area south of Runway 9-27 where the CONRAC is currently located, east of Runway 15L-33R and John F. Kennedy Boulevard (JFK)



While Site B appears to provide sufficient space for a new terminal, the site has no access to the regional roadway network. Moreover, it was determined in the airfield alternatives evaluation that this real estate is ideally suited for the airport's fourth parallel runway. Accordingly, Site B was not considered a realistic option. Accordingly, terminal development alternatives were formulated for Sites A and C. Two terminal alternatives were analyzed on Site A, designated as Alternatives A and B. Alternative A, shown on Figure 5-35, involves a linear concourse oriented in an east-west direction served by Will Clayton Parkway (WCP) in its existing alignment. Alternative B, shown on Figure 5-36, includes multiple linear concourses running in a north-south orientation, requiring WCP to be depressed below grade. Alternative C, shown on Figure 5-37, was the only layout developed to explore the suitability of Site C for future terminal development.

5.3.6 Primary Screening

The primary screening evaluation identified which of the alternatives were most worthy of further consideration. The following questions are addressed in primary screening:

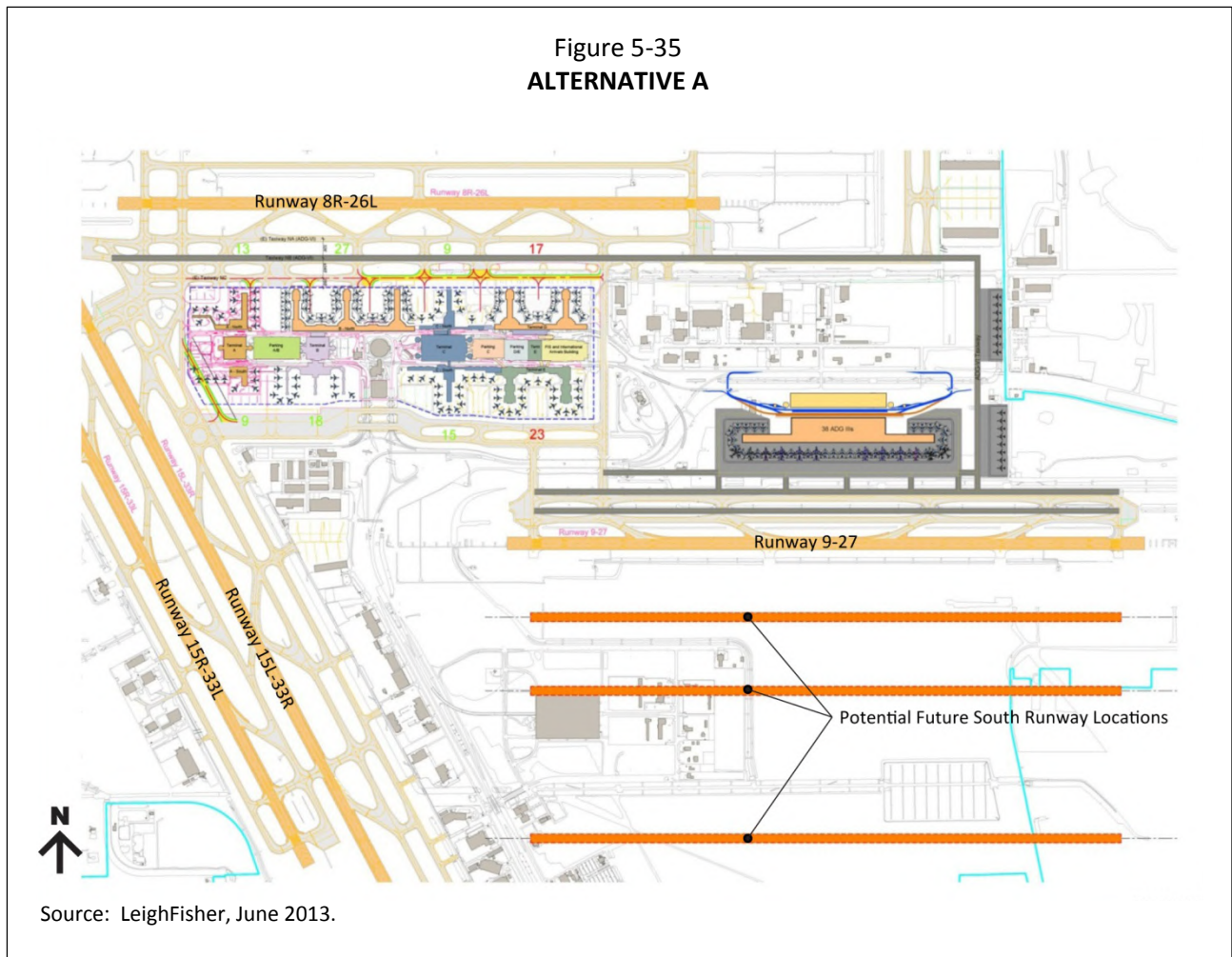
- Does this alternative concept have any fatal flaws?
- What are the pros and cons of this concept?
- Could this alternative be implemented in time to serve the forecast demand at an acceptable level of service?

5.3.6.1 Alternative A

Alternative A is located on Site A, as shown in Figure 5-35, on a near-greenfield site east of the JFK and WCP interchange, south of WCP and west of Lee Road. The terminal would require its own supporting infrastructure, including: a crossfield taxiway, terminal access roadways and curbsides, as well as a parking garage. The terminal would be oriented in an east-west direction and would likely include a linear

concourse which is partially “double-loaded” meaning aircraft could park on both sides of the concourse at the ends. The terminal would operate as a unit terminal connected to the existing terminal area via shuttle bus or APM in the long-term.

Alternative A would involve minimal impact to the existing airport operation during construction and its first phase would be achievable without displacing any existing facilities. Further, WCP would remain on its existing alignment and at grade. The terminal site would also be centrally located on the airfield minimizing aircraft taxi times to Runway 8L-26R. Alternative A does have one notable disadvantage, especially relative to Alternative B: airfield circulation. With a long linear terminal, aircraft taxiing between the north and south airfields would need to taxi to the far east end of the campus or use the congested Taxiway SF. This concern is mitigated by two factors: 1) the crossfield taxiway at the far east end of the airfield would eliminate the risk of a single point of failure at Taxiway SF and 2) additional crossfield taxiways may be provided on the west side of the terminal in a later phase. Given Alternative A’s relative merits, this alternative was retained for further evaluation in secondary screening.

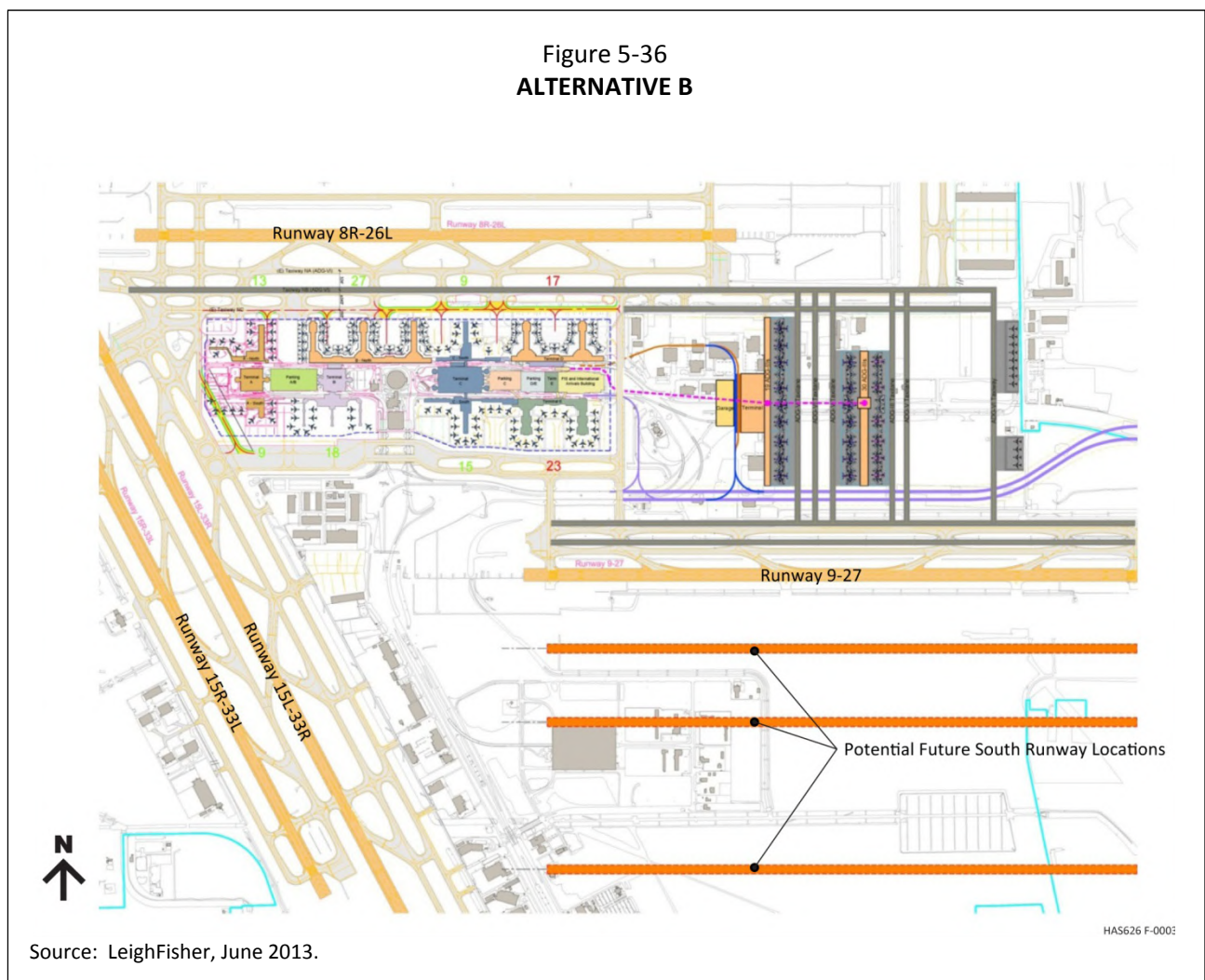


5.3.6.2 Alternative B

Alternative B, like Alternative A, is located on Site A, east of Taxiway SF and west of Lee Road as shown in Figure 5-36. Likewise, the terminal would require its own supporting infrastructure, including: crossfield

taxiways, terminal curbside and access roadways, and a parking garage. Unlike Alternative A, the terminal would be oriented in a north-south direction and would likely include an initial phase with a linear concourse with subsequent phases of double-loaded satellite concourses. This configuration would operate similar to other connecting hub airports, like Atlanta Hartsfield Jackson International Airport and Denver International Airport.

Alternative B offers minimal impact to the existing operation and the best airfield circulation of the alternatives. Like Alternative A, it is centrally located on the airfield for maximum operational efficiency. In addition, Alternative B would provide excellent expansion capability with additional satellite concourses to both the east and west. However, Alternative B has one major challenge: Will Clayton Parkway would require realignment and major excavation efforts to place the roadway below grade so that it may pass under the taxiways and aircraft apron. Given the drainage infrastructure and engineering challenges associated with this type of improvement, the alternative may be cost prohibitive; however, given that Alternative B is likely the most operationally efficient alternative from an airfield perspective, it was retained for secondary screening which would permit exploration of the challenges associated with WCP.



5.3.6.3 *Alternative C*

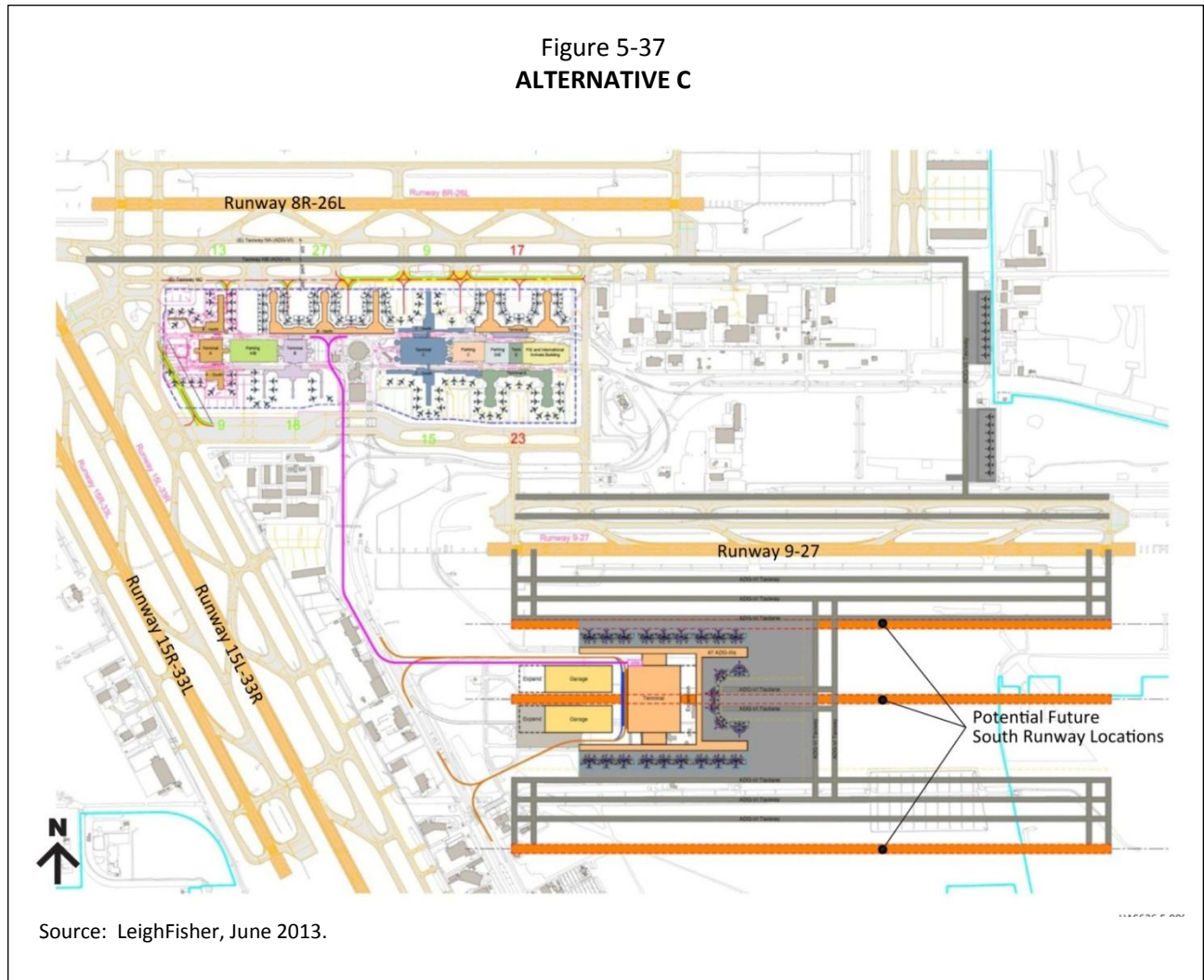
Alternative C is located on Site C south of Runway 9-27 as shown in Figure 5-37. The H-shaped concourse would require its own supporting infrastructure including a parking garage, terminal access roadways and curbside, and extensive new taxiway infrastructure.

Alternative C would involve minimal impact to the existing airline commercial service operation, and it provides the opportunity to grow the facility into a single terminal for the entire airport over time. However, the location on the south airfield is problematic for the following reasons:

- The distance between the existing terminal area and the site is greatest among the alternatives requiring the longest connection time for passengers resulting in a compromised level of customer service
- Aircraft would have to taxi unacceptably long distances to Runways 8R-26L and 8L-26R, as well as the proposed Runway 8C-26C
- The airfield would become unbalanced, with more demand for the southern runways than the northern runways
- The potential locations for a future parallel runway to the south of Runway 9-27 would be limited by the placement of the terminal
- The location would require the relocation of the CONRAC

One of the primary objectives of HAS is to provide a consistent customer experience throughout the terminal complex and to ensure high levels of service for all customers. Alternative C, with its long connecting distances between terminals, would result in an unacceptable level of service. Further, the terminal would be located south of all three existing east-west runways, resulting in unacceptably long aircraft taxi times. Long airfield taxi times result in unnecessary fuel burn and increased operational costs to the airlines. Because it cannot meet the established objectives, Alternative C was eliminated from further consideration.

Figure 5-37
ALTERNATIVE C



5.3.7 Shortlist Terminal Alternatives

The shortlist of terminal alternatives, Alternatives A and B, were refined for further evaluation to assist in selection of a preferred terminal alternative. To enable a comprehensive evaluation, each alternative was refined with additional detail as described in the following paragraphs.

5.3.7.1 Alternative A

Situated on a greenfield site, east of the existing terminal core and south of WCP, the proposed passenger terminal would be centrally located on the campus with a linear concourse running in the east-west direction that would be capable of accommodating approximately 30 narrowbody aircraft gates. An ADG-VI crossfield taxiway would be required such that large foreign flag aircraft could taxi to the north and west runways. The terminal building would occupy a total area of approximately 500 thousand square feet with a 5-level parking structure located directly to the north. A dual-level roadway system would be provided from WCP with the arrivals level located at-grade and the departures level elevated above.

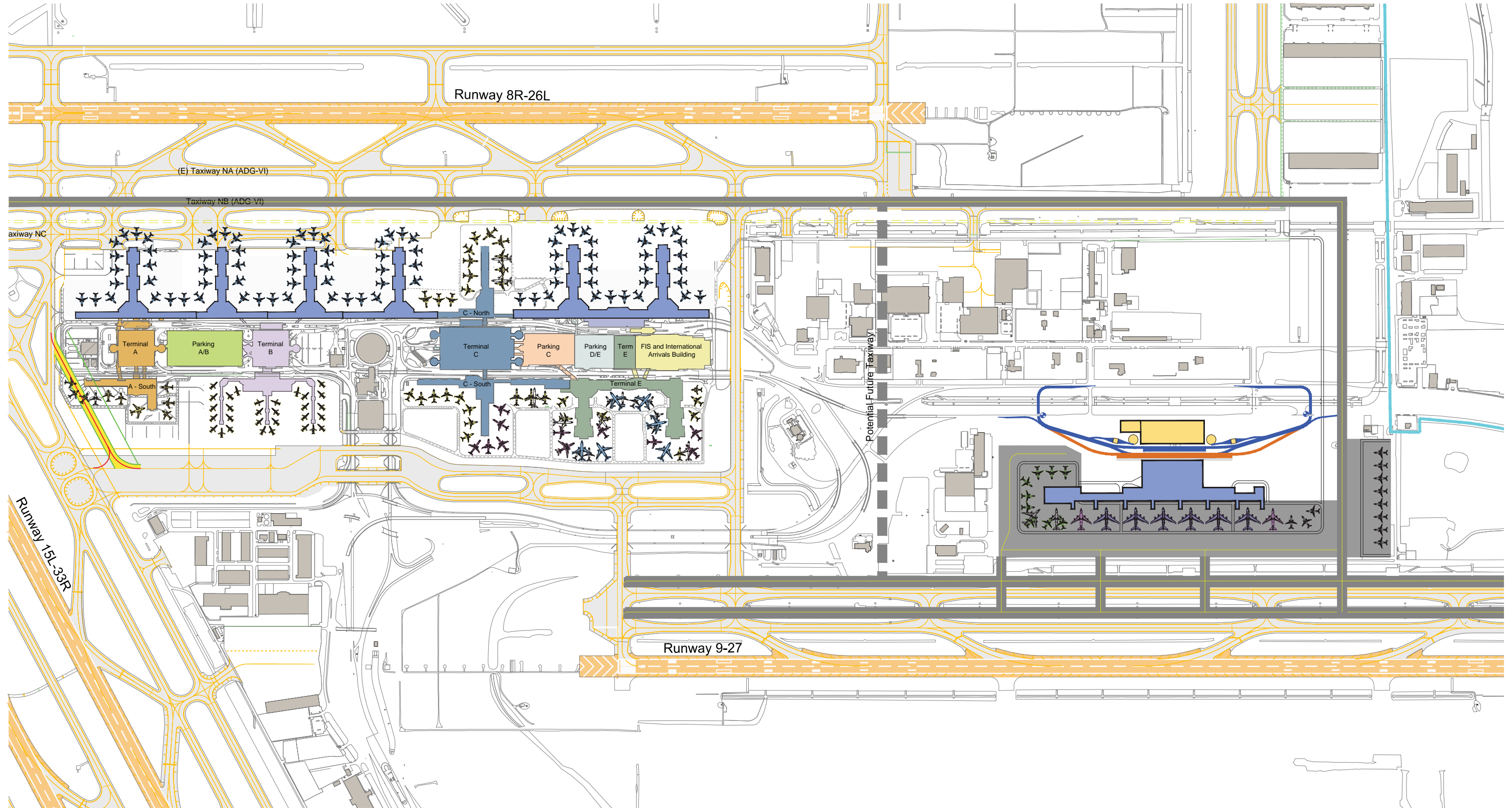
The terminal would have four levels: (1) baggage claim, (2) lower mezzanine, (3) departure concourse, and (4) upper mezzanine. The terminal facility and aircraft gates would be designed to accommodate both international and domestic arrivals (i.e., “swing” gates). Conceptual plans for each level are illustrated on Figures 5-38 to 5-44.

The baggage claim level includes areas for FIS secondary inspection, ticket re-check, domestic baggage claim, concessions, public restrooms and support, and baggage makeup. A total of eight carousel devices would be provided: four exclusively for international passengers located inside the FIS secondary inspection, three exclusively for domestic use with space to expand, and 1 swing device capable of serving either international or domestic operations. Airline operations and other supporting infrastructure would be located below the concourses.

The lower mezzanine level would provide: a domestic holdroom on the west end serving smaller aircraft; areas for FIS primary inspection and Customs and Border Patrol offices; airport support spaces; an explosive detection system (EDS) screening matrix; and the sterile corridor for international passengers to travel from their arriving gate through the FIS and to the arrivals lobby below. This level would also provide a direct connection to the parking garage.

The departure concourse level would include curbside access opening to a large ticketing lobby with check-in modules oriented in the north-south direction, public restrooms, a centrally located security screening checkpoint, passenger holdrooms, and ample circulation space. A major concessions mall would capture passengers downstream of the security checkpoint with additional concession nodes dispersed throughout the concourse. The concourse level would provide access to all gates and access to the lower mezzanine level hold room through a vertical circulation core on the west end.

The upper mezzanine level above would have a centralized concession area and four airline clubrooms located directly above passenger holdrooms. The clubrooms allow direct and private access to the aircraft.

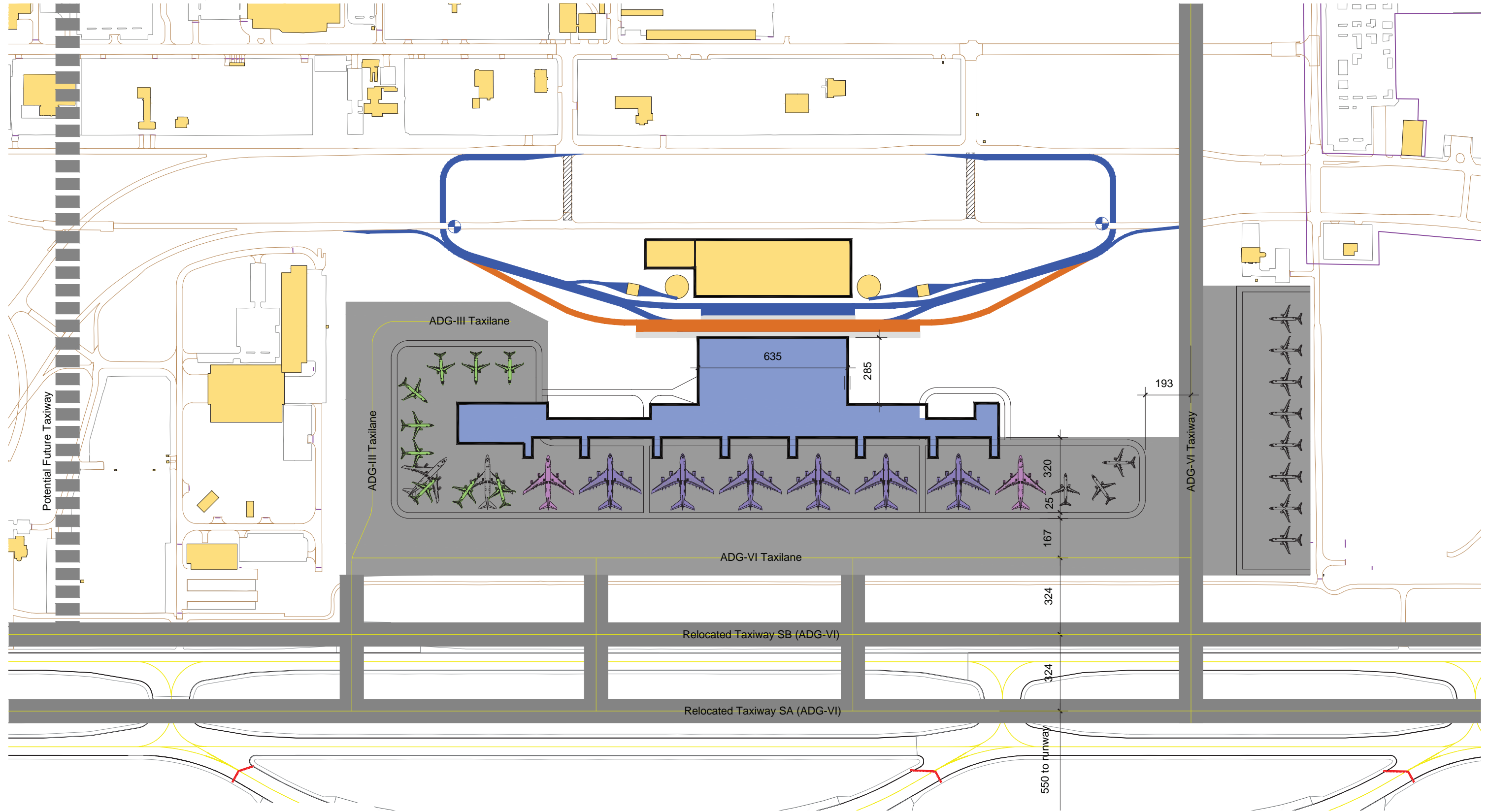


LEGEND

- At-grade Roadway
- Elevated Roadway
- Parking Structure
- Terminal/concourse
- Aircraft parking apron
- ✈ ADG-VI parking position
- ✈ ADG-V parking position
- At-grade Roadway
- Elevated Roadway



Figure 5-38
Alternative A
 Location Plan



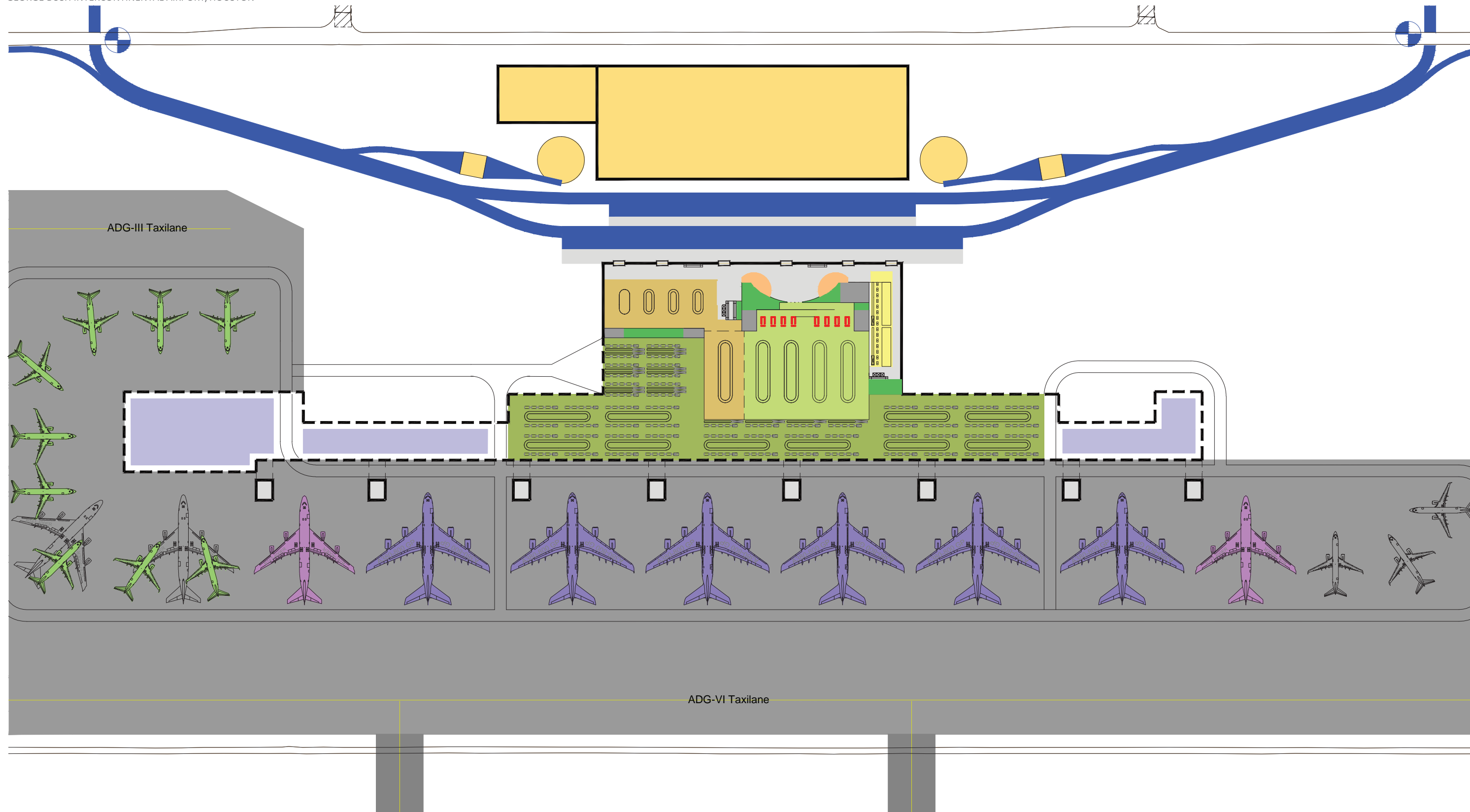
LEGEND

- At-grade Roadway
- Elevated Roadway
- Parking Structure
- Terminal/concourse

- Aircraft parking apron
- Aircraft parking apron
- ✈ ADG-VI parking position
- ✈ ADG-V parking position
- ✈ At-grade Roadway
- ✈ Elevated Roadway



Figure 5-39
Alternative A
Terminal Complex Site Plan



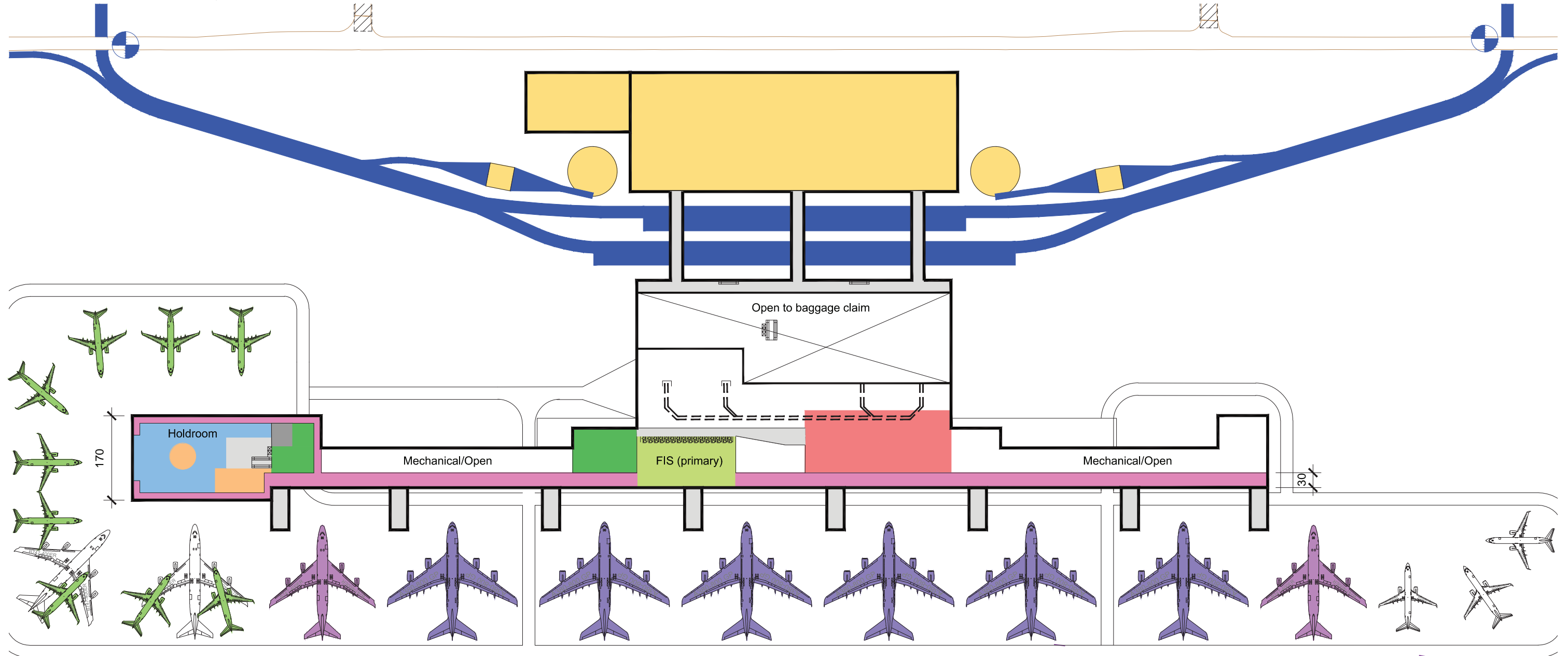
LEGEND

- At-grade Roadway
- Parking structure
- FIS secondary inspection and baggage claim
- Concessions
- Restrooms
- Airline/airport space
- Ticket re-check
- Baggage makeup
- Domestic baggage claim
- Office/other

- ADG-VI parking position
- ADG-V parking position
- ADG-III parking position
- RON parking position



Figure 5-40
Alternative A
Baggage Claim Level

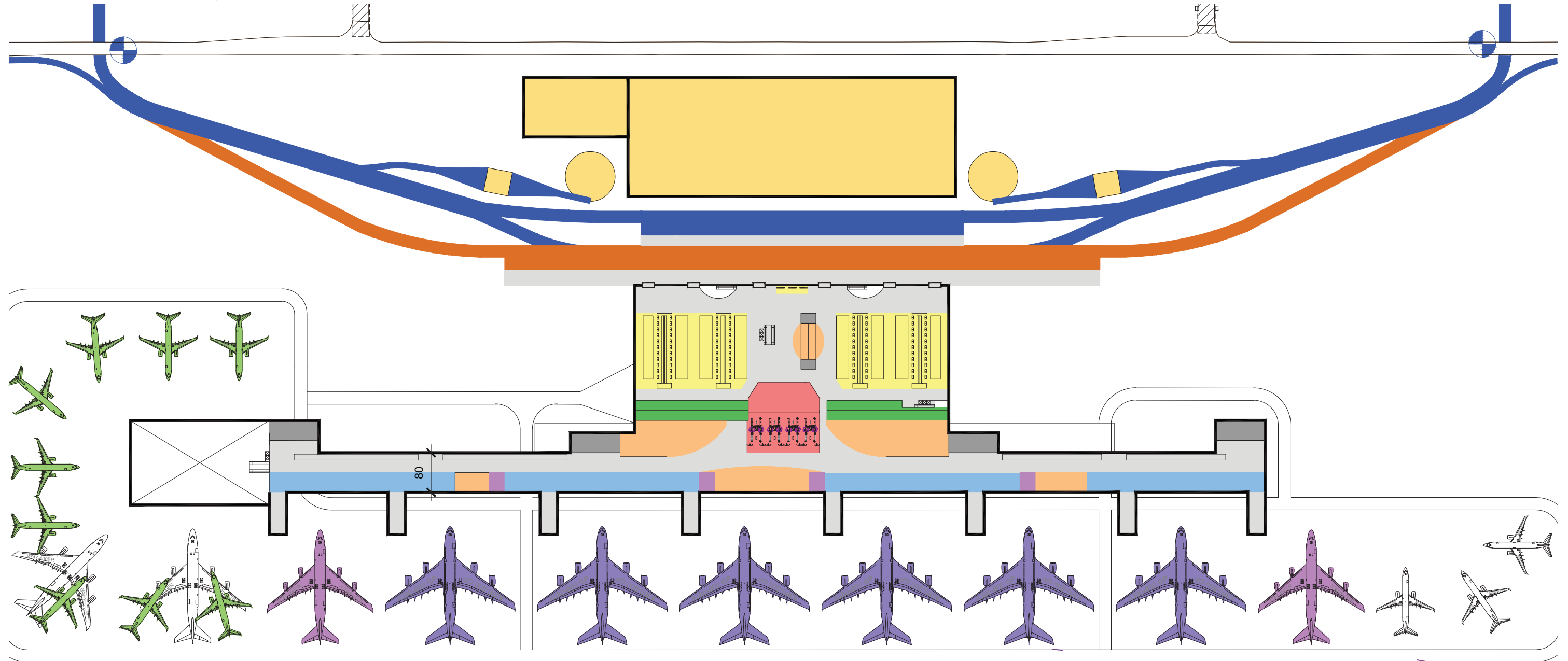


LEGEND

- | | | | | |
|------------------------|--------------------------|--------------------------|----------------------|-------------------------|
| At-grade Roadway | Parking structure | Sterile corridor | Office/other | ADG-VI parking position |
| Holdroom | Circulation/ped bridge | EDS matrix | Concessions | ADG-V parking position |
| Domestic baggage claim | FIS (primary inspection) | ADG-III parking position | RON parking position | |



Figure 5-41
Alternative A
Lower Mezzanine Level



LEGEND

- At-grade Roadway
- Elevated roadway
- Parking structure
- Check-in lobby

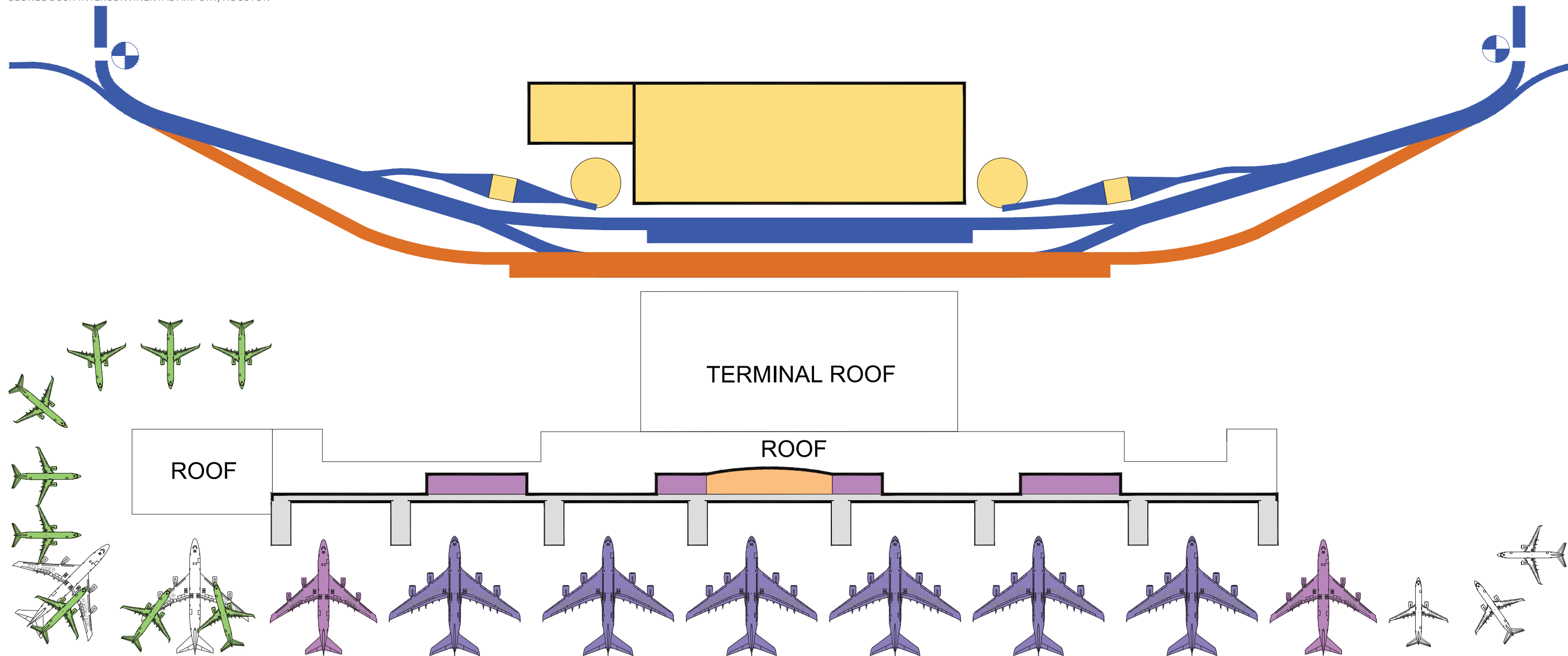
- Circulation/curbside
- Security checkpoint
- Concessions
- Airline clubroom entrance

- Holdroom
- Office/other
- Restrooms
- RON parking position

- ADG-VI parking position
- ADG-V parking position
- ADG-III parking position



Figure 5-42
Alternative A
 Concourse Level



LEGEND

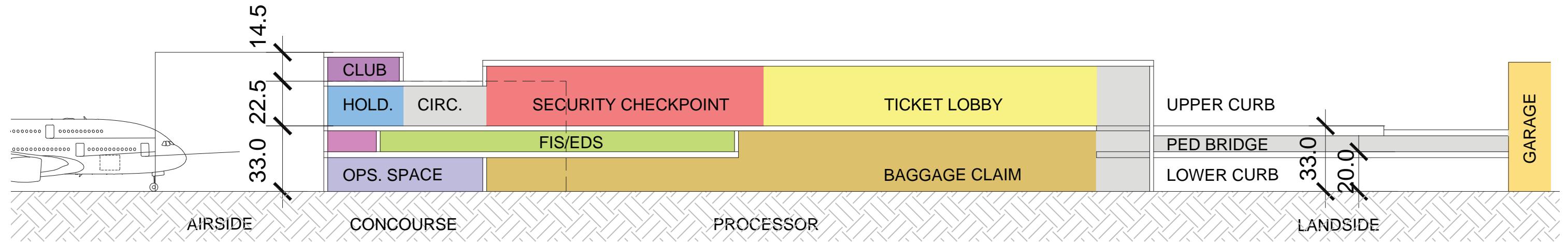
- At-grade Roadway
- Elevated Roadway
- Parking Structure
- Concessions

- Airline clubroom
- ADG-VI parking position
- ADG-V parking position

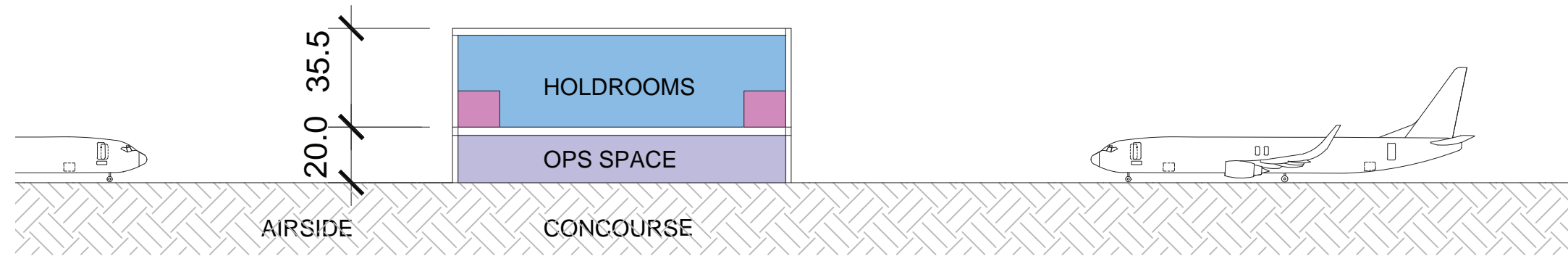
- At-grade Roadway
- Elevated Roadway



Figure 5-43
Alternative A
 Upper Mezzanine Level



SECTION THROUGH TERMINAL PROCESSOR AND CONCOURSE



SECTION THROUGH WEST CONCOURSE

5.3.7.2 *Alternative B*

Alternative B is located east of the WCP and JFK interchange. Alternative B, unlike Alternative A, would require the relocation of existing facilities, including WCP, HAS airfield maintenance group, and airline maintenance hangars. The terminal building would be oriented in a north-south direction. Like Alternative A, the terminal building would be four levels with functions on each level being the same. The major difference with Alternative A is the terminal would be connected to satellite concourses. Passengers would be required to take an APM to transfer from the terminal to the satellite concourse. Conceptual plans for each level of the terminal building are illustrated on Figures 5-45 to 5-51.

5.3.8 *Secondary Screening evaluation*

Terminal alternatives A and B were evaluated in the secondary screening evaluation by assessing their relative ability to meet the criteria listed in Table 5-9. Evaluation criteria are categorized as follows: financial, operational, and environmental. For each criterion, the alternative was given a score of 3 for a positive outcome (green), 1 for a negative outcome (red) or 2 for an outcome in between (yellow). As shown, Alternative A resulted in the highest score of 38, identifying it as the preferred terminal alternative. Details regarding the individual criteria and the results follow.

5.3.8.1 *Financial Criteria*

The financial evaluation of the two alternatives included primarily capital construction costs.

Capital Cost Estimate. Order of magnitude cost estimates were prepared for the alternatives which include costs for: site preparation, demolition and relocation of any facilities on the site, construction of the new building, supporting aprons and taxiways, accompanying parking structures, and expansion to the central plant. Additionally, cost estimates include allocations for various contingencies and soft costs including architectural design and engineering, as well as construction management.

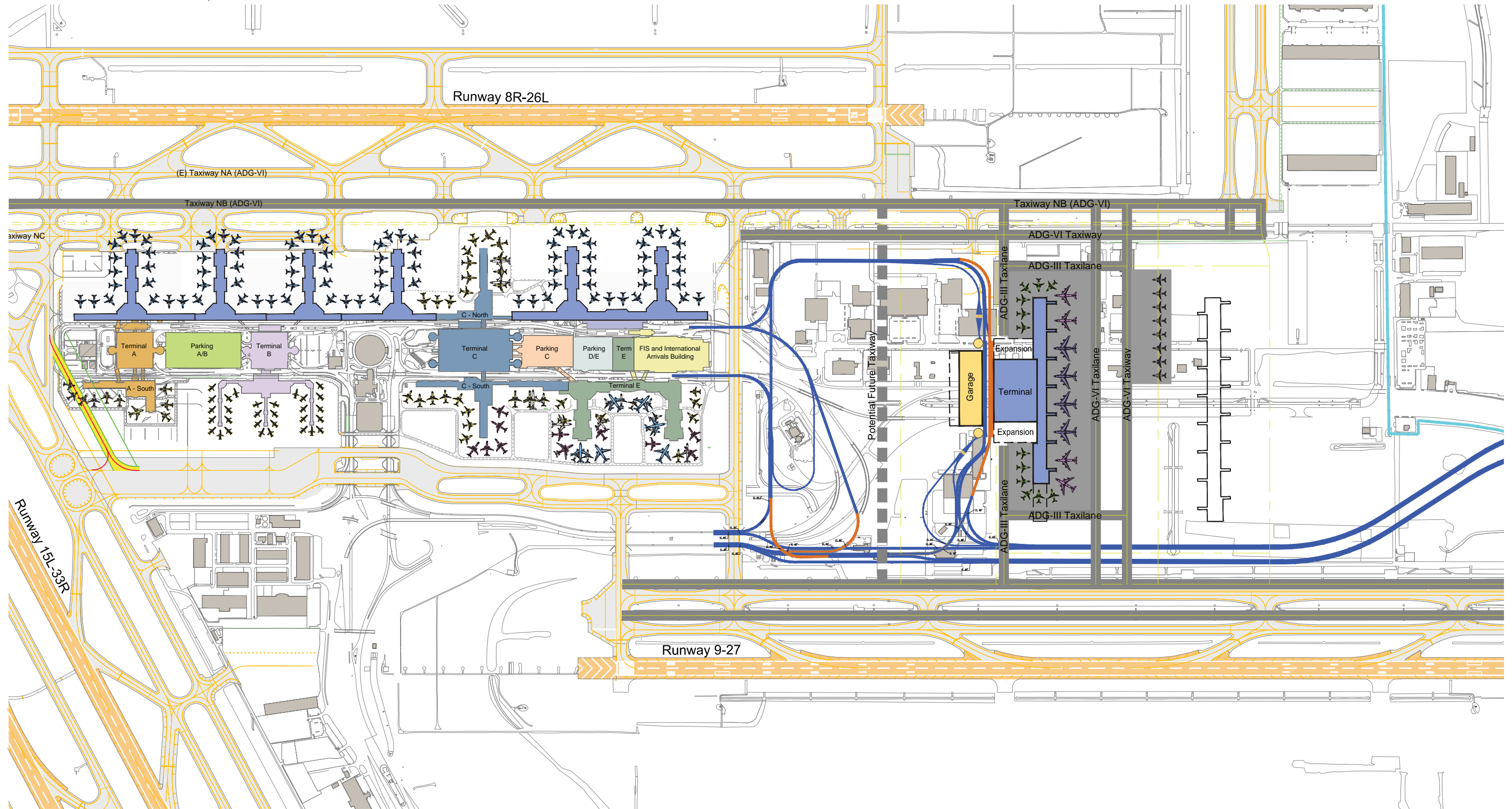
The cost estimates for the alternatives are shown in Table 5-10. Alternative B is expected to cost approximately 50% more than Alternative A, primarily because of the facility relocations and enabling projects associated with realignment and lowering of WCP.

Cost per New Aircraft Gate. Each alternative considered provides 20 new aircraft gates. The cost per gate for Alternative A was \$54 million versus an estimated \$81 million for Alternative B.

5.3.8.2 *Operational Criteria*

The operational criteria considered included constructability, passenger level of service, passenger travel time, and motorist wayfinding.

Constructability. Constructability was assessed qualitatively based on the needed site preparation for each alternative. Alternative A requires little in the way of site preparation, the main requirement being wetlands and floodplain mitigation. In comparison, Alternative B requires demolition and relocation of existing facilities, including a HAS office building, United Airline maintenance hangar, and two above-grade storage tanks. More importantly, Alternative B also requires WCP to be realigned and trenched below grade and construction of several taxiway bridges. Therefore, Alternative A is superior to Alternative B with respect to constructability.

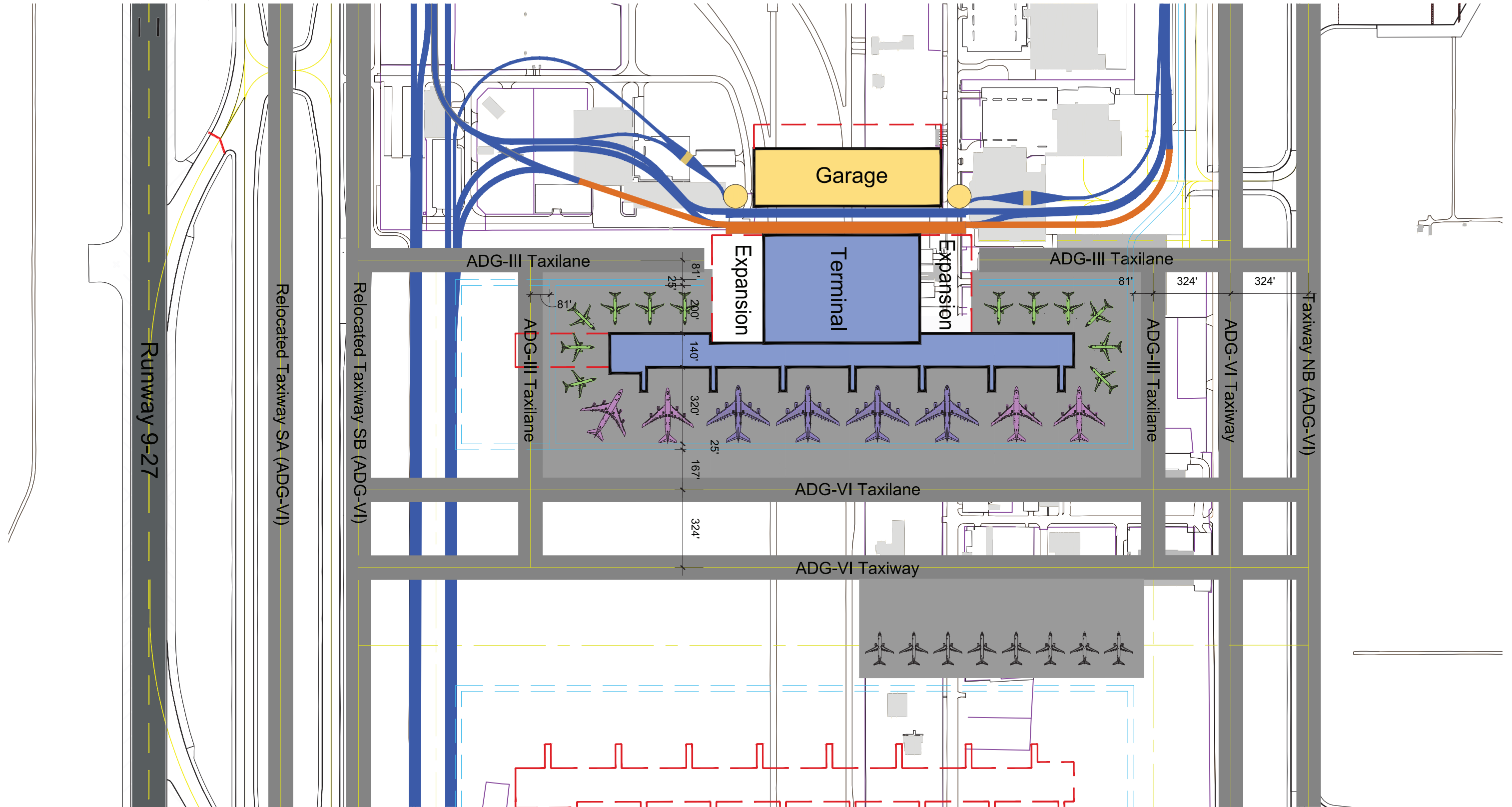


LEGEND

- At-grade Roadway
- Elevated Roadway
- Parking Structure
- Terminal/concourse
- Aircraft parking apron
- ✈ ADG-VI parking position
- ✈ ADG-V parking position
- ✈ At-grade Roadway
- ✈ Elevated Roadway



Figure 5-45
Alternative B
 Location Plan



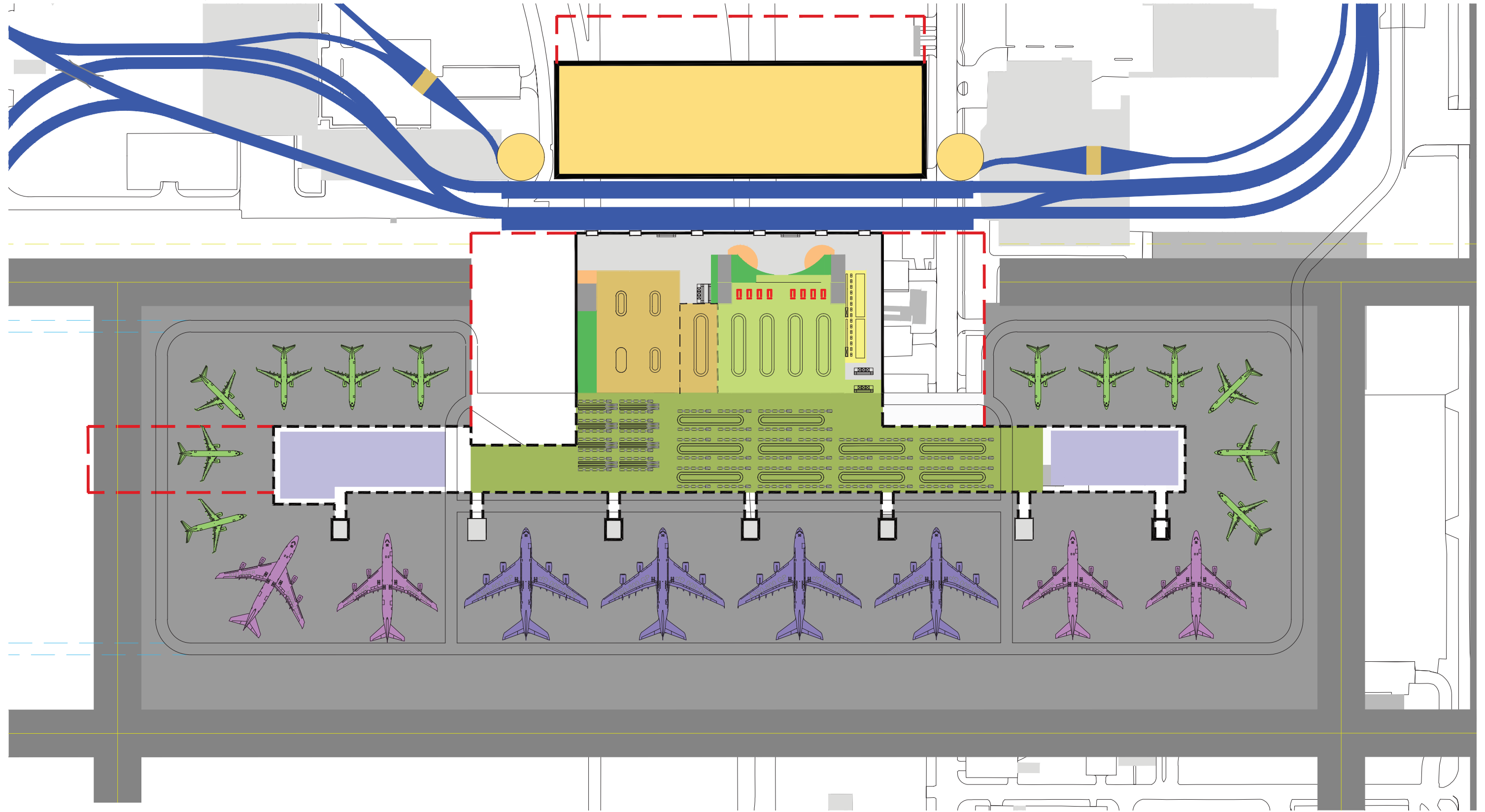
LEGEND

- At-grade Roadway
- Elevated Roadway
- Parking Structure
- Terminal/concourse

- Aircraft parking apron
- Remove roadway
- ✈ ADG-V parking position
- ✈ At-grade Roadway
- ✈ ADG-VI parking position
- ✈ Elevated Roadway



Figure 5-46
Alternative B
 Terminal Complex Site Plan



LEGEND

- At-grade Roadway
- Parking structure
- Circulation/curbside
- Domestic baggage claim

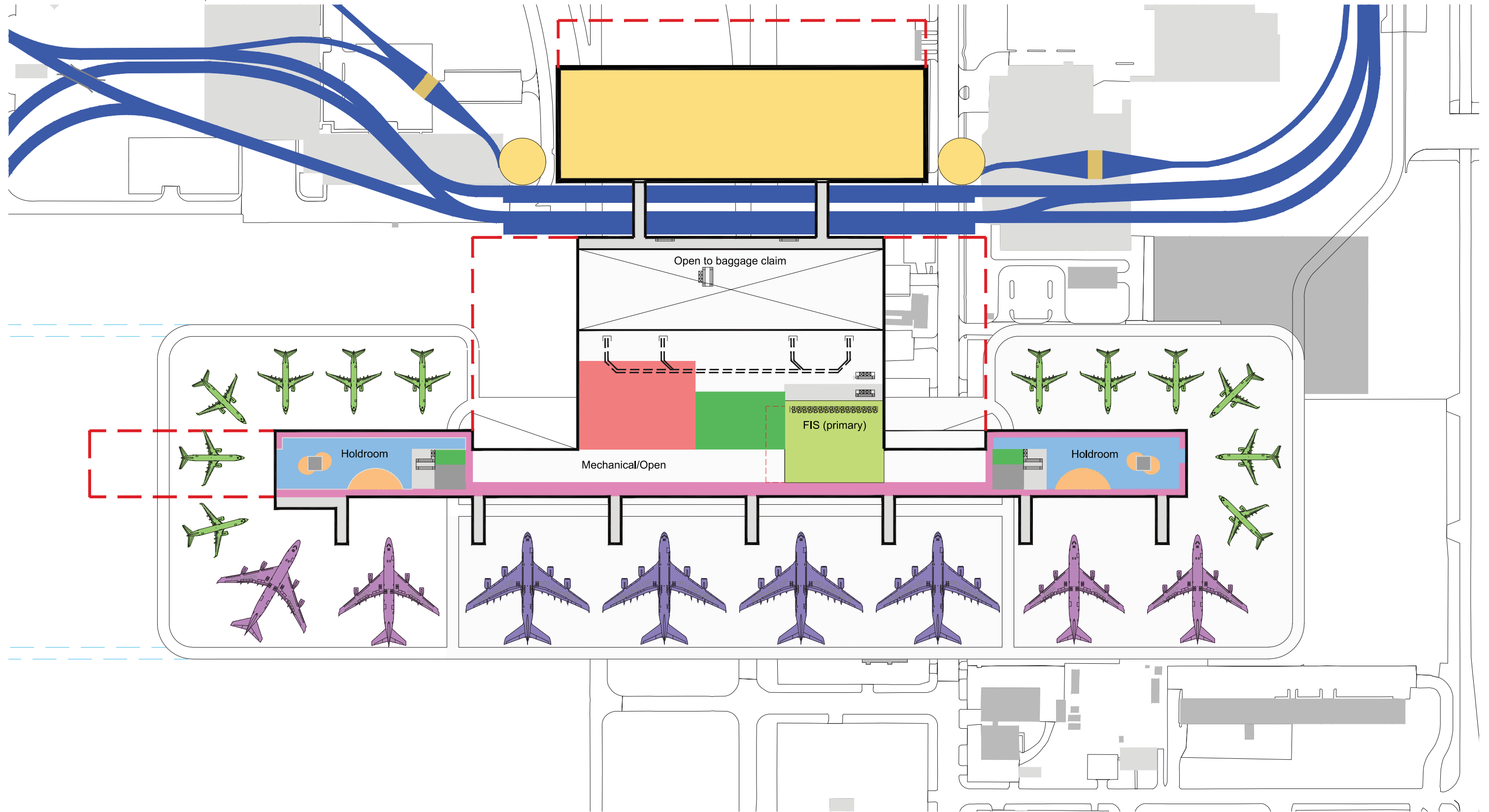
- FIS secondary inspection and baggage claim
- Ticket re-check
- Baggage makeup

- Concessions
- Restrooms
- Airline/airport space
- Office/other

- ADG-VI parking position
- ADG-V parking position
- ADG-III parking position
- RON parking position



Figure 5-47
Alternative B
Baggage Claim Level

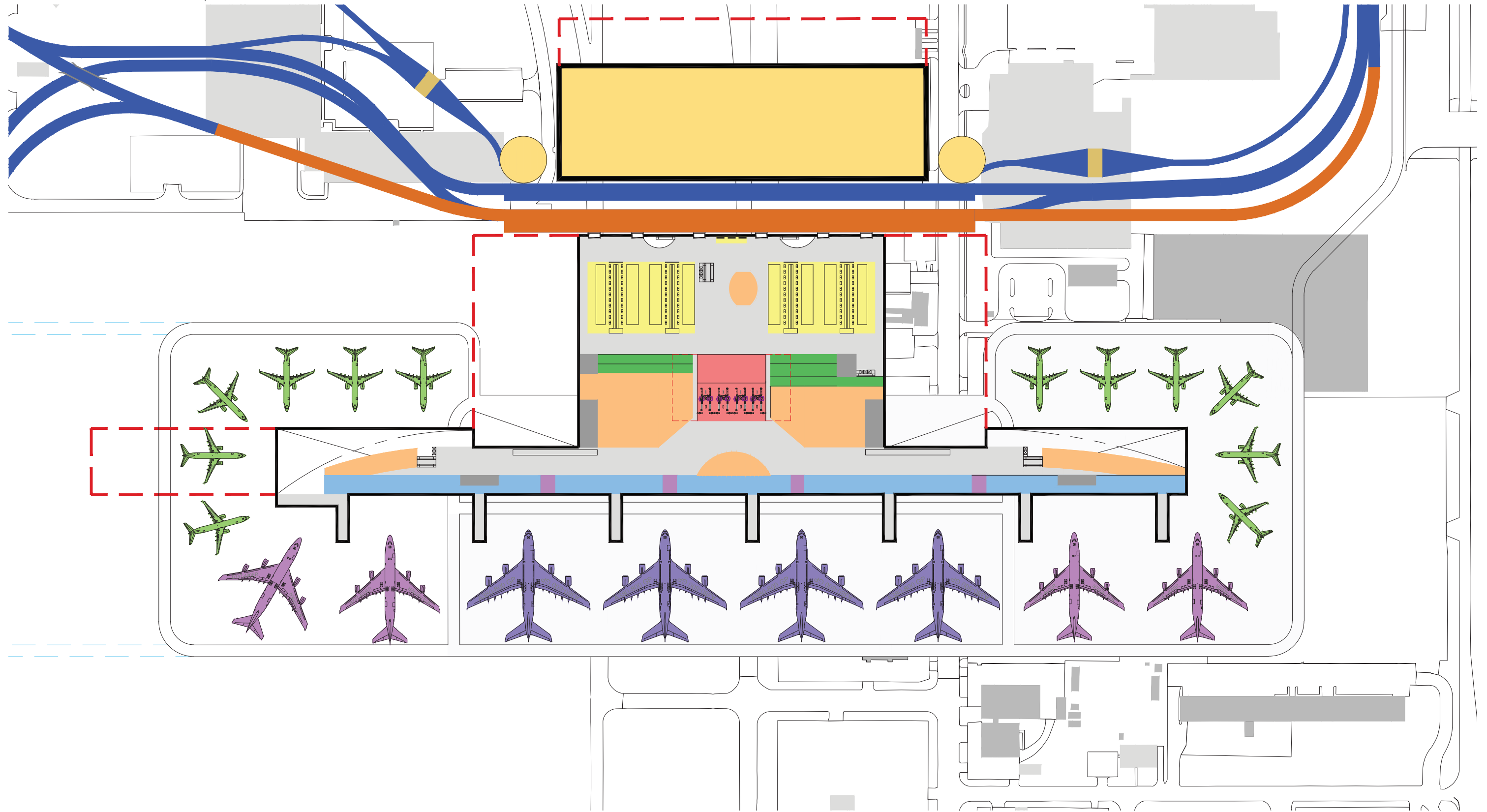


LEGEND

- At-grade Roadway
 - Parking structure
 - Holdroom
 - Domestic baggage claim
- Sterile corridor
 - Circulation/ped bridge
 - EDS matrix
 - FIS (primary inspection)
- Office/other
 - Concessions
 - ADG-III parking position
 - RON parking position
- ADG-VI parking position
 - ADG-V parking position



Figure 5-48
Alternative B
Lower Mezzanine Level



LEGEND

- At-grade Roadway
- Elevated roadway
- Parking structure
- Check-in lobby

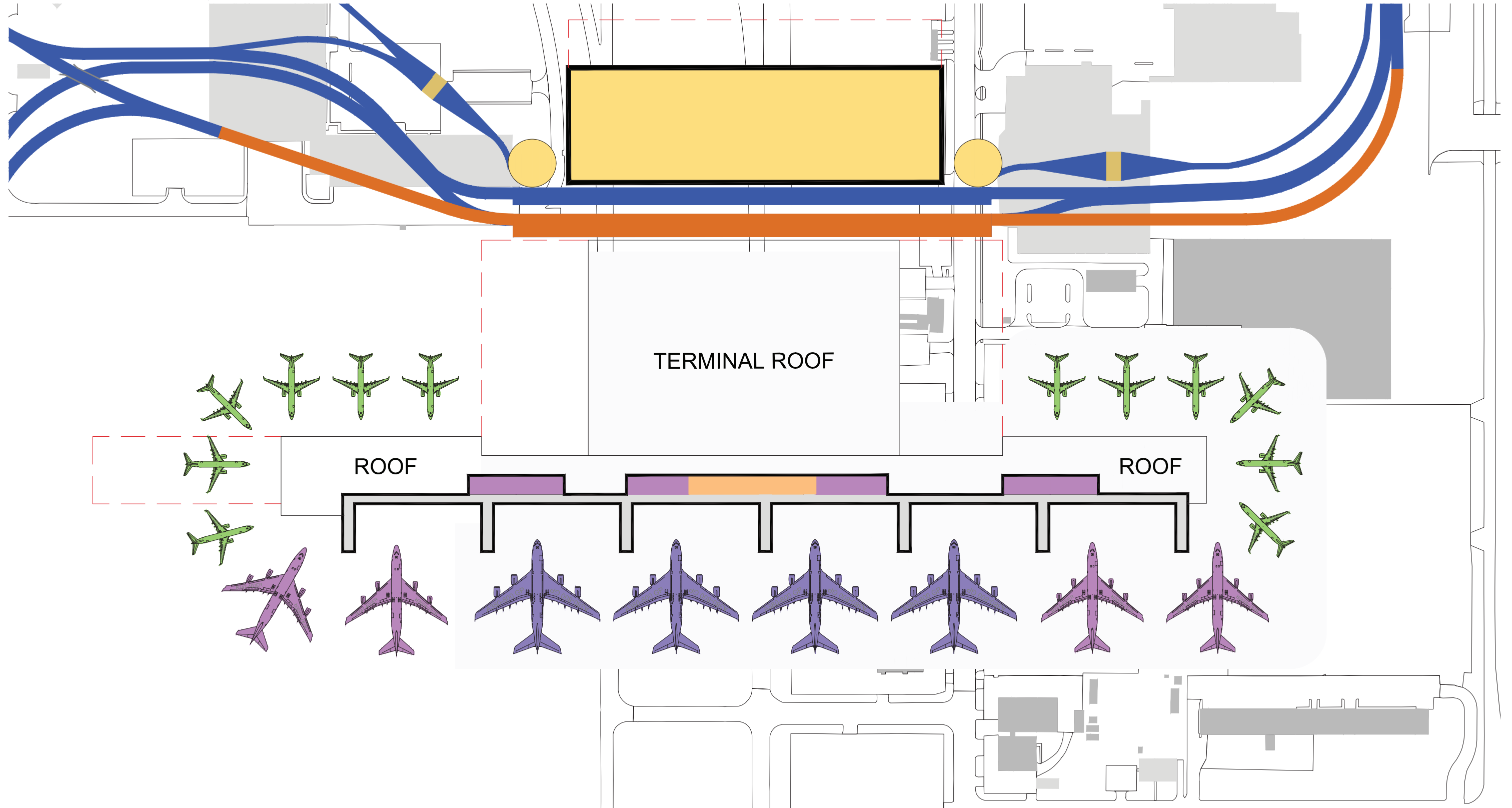
- Circulation/curbside
- Security checkpoint
- Concessions
- Airline clubroom entrance

- Holdroom
- Office/other
- Restrooms
- ✈ RON parking position

- ✈ ADG-VI parking position
- ✈ ADG-V parking position
- ✈ ADG-III parking position



Figure 5-49
Alternative B
 Concourse Level



LEGEND

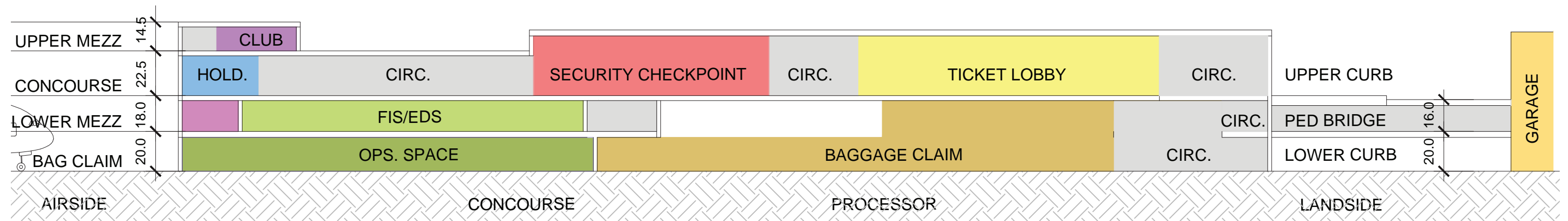
- At-grade Roadway
- Elevated Roadway
- Parking Structure
- Concessions

- Airline clubroom
- ADG-VI parking position
- ADG-V parking position

- At-grade Roadway
- Elevated Roadway



Figure 5-50
Alternative B
 Upper Mezzanine Level



SECTION THROUGH TERMINAL PROCESSOR AND CONCOURSE



SECTION THROUGH ADG-III HOLDROOM

Table 5-9
TERMINAL ALTERNATIVES EVALUATION MATRIX

Criteria	Description	Alternative A	Alternative B
Financial			
Capital cost estimate	Total capital costs to be funded (\$B)	\$1.1	\$1.6
Cost per new aircraft gate	Cost per aircraft gate (\$M)	\$54	\$81
<i>Financial Score</i>		6	2
Operational			
Constructability	Qualitative assessment of ability to implement the project	Good	Poor
Meets gate requirements	Number of new gates and flexibility for expansion	20	20
Passenger level of service			
Baggage claim	Distance from aircraft to inbound makeup (feet)	2,750	2,450
Walking distance	Distance from furthest gate to curbside	1,960	1,700
Ease of connections	Qualitative assessment	Airside shuttle for UA connections	Airside shuttle for UA connections
Passenger travel time between terminals (secure)	Quantitative assessment based on distance from apron to apron (min)	7.1	2.5
Travel distance between terminals—to C	Quantitative assessment based on length of route (miles)	2.0	1.3
Travel distance between terminals—from C	Quantitative assessment based on length of route (miles)	1.4	1.5
Motorist wayfinding	Qualitative	Good	Poor
<i>Operational Score</i>		20	19
Environmental			
Wetlands	Potential wetlands impacted (acres)	0.5	0
Floodplains	100-year floodplains to be built on (acres)	74	47
Section 303(c) Lands	Section 303(c) lands that would be impacted	0	0
Relocation	Relocations of facilities and infrastructure	Ditch	HAS gas station, HAS office building, United hangar, two above-ground tanks
Air quality	Aircraft taxi times; conformity determination	Construction impacts	Construction impacts
Degree of controversy	Qualitative assessment pending public meetings	None likely	None likely
<i>Environmental Score</i>		12	15
Total Score		38	36
LEGEND	Negative outcome	Marginal outcome	Positive outcome
Scoring	1	2	3

Source: LeighFisher, October 2013.

Table 5-10
ALTERNATIVE COST ESTIMATES
 (in millions of dollars)

Description	Alternative A	Alternative B
Environmental mitigation	\$ 1.3	\$ 0.0
Building relocation	0.0	132.1
Taxiway infrastructure	37.5	109.1
Apron	59.1	44.0
Site work	49.3	129.0
Building	397.4	445.5
Parking structures	60.0	61.8
Central plant expansion	<u>16.1</u>	<u>15.8</u>
Subtotal	\$ 620.6	\$ 937.2
Contingency	273.1	412.4
Design and construction management	<u>178.7</u>	<u>269.9</u>
Total	\$1,072.4	\$1,619.5

Source: Sunland Group, October 2013.

Meets Gate Requirements. Both alternatives could grow to meet the gate requirements at PAL33 and PAL40. However, Alternative B would require another satellite concourse as opposed to extension of the existing concourse in the case of Alternative A. Therefore, Alternative A is better positioned to meet gate requirements through the planning period.

Passenger Level of Service.

- **Baggage claim:** The baggage travel distance from aircraft parking position to baggage claim device was used to assess passenger wait times for baggage claim. Inbound baggage distance was measured from the furthest aircraft gate to the inbound makeup device, and then from the makeup conveyor to the furthest baggage claim device. The total travel distance measured for Alternative A is approximately 2,750 feet. Assuming an average travel speed of 270 feet per minute (440 feet per minute on baggage tug and 100 feet per minute on baggage belt), this calculates to approximately 10.2 minutes of passenger wait time. The total baggage travel distance measured for Alternative B is 2,450 feet, which equates to approximately 9.1 minutes of passenger wait time.

According to the IATA’s Airport Development Reference Manual, 0-12 minutes is within acceptable level of service range for the maximum wait time at baggage claim area. Alternatives A and B are similar in terms of wait time, with Alternative B having a slightly lower estimated wait time.

- **Walking distance:** The distance from aircraft parking position to curbside was used to assess passenger walking distance. An assumed passenger travel path was taken from the furthest curbside at the east to the furthest aircraft gate at the west. The total distance measured for Alternative A is approximately 1,960 feet while for Alternative B it measures 1,700 feet. From a passenger level of service perspective, shorter walking distances are preferable. Alternative B offers a lesser walking distance, however it does require the passenger to take an APM from the satellite concourse to the passenger terminal.

- **Ease of connections.** Both alternatives would require a connection to be provided for passengers connecting to and from the existing terminal area. However, these connecting flows are expected to be minimal given the facility would likely accommodate all air carriers other than United Airlines. In fiscal year 2012, an average of approximately 307 passengers per day connected between airlines expected to be in the new terminal and United Airlines. A secure bus connection would provide an adequate level of service to these passengers. Both alternatives would have similar bus service, and therefore are equivalent in the ease of passenger connections.

Passenger Travel Time Between Terminals. Secure connection travel time assumed the use of a bus traveling at 15 miles per hour between the edge of the apron of the east terminal and the edge of the apron of the existing terminal area. In Alternative A, the location of the secure roadway requires the bus to travel around the eastern edge of the eastern terminal to cross WCP. This circuitous route results in a minimum travel time of 7.1 minutes in Alternative A, whereas the proximity of the edges of the two aprons in Alternative B allows for a minimum secure connecting travel time of 2.5 minutes.

Travel Distance Between Terminals (to and from Terminal C). Non-secure connecting travel distance was measured from the east terminal to Terminal C in the existing terminal area. The travel distance in Alternative A was 2.0 miles compared to the 1.3 miles in Alternative B.

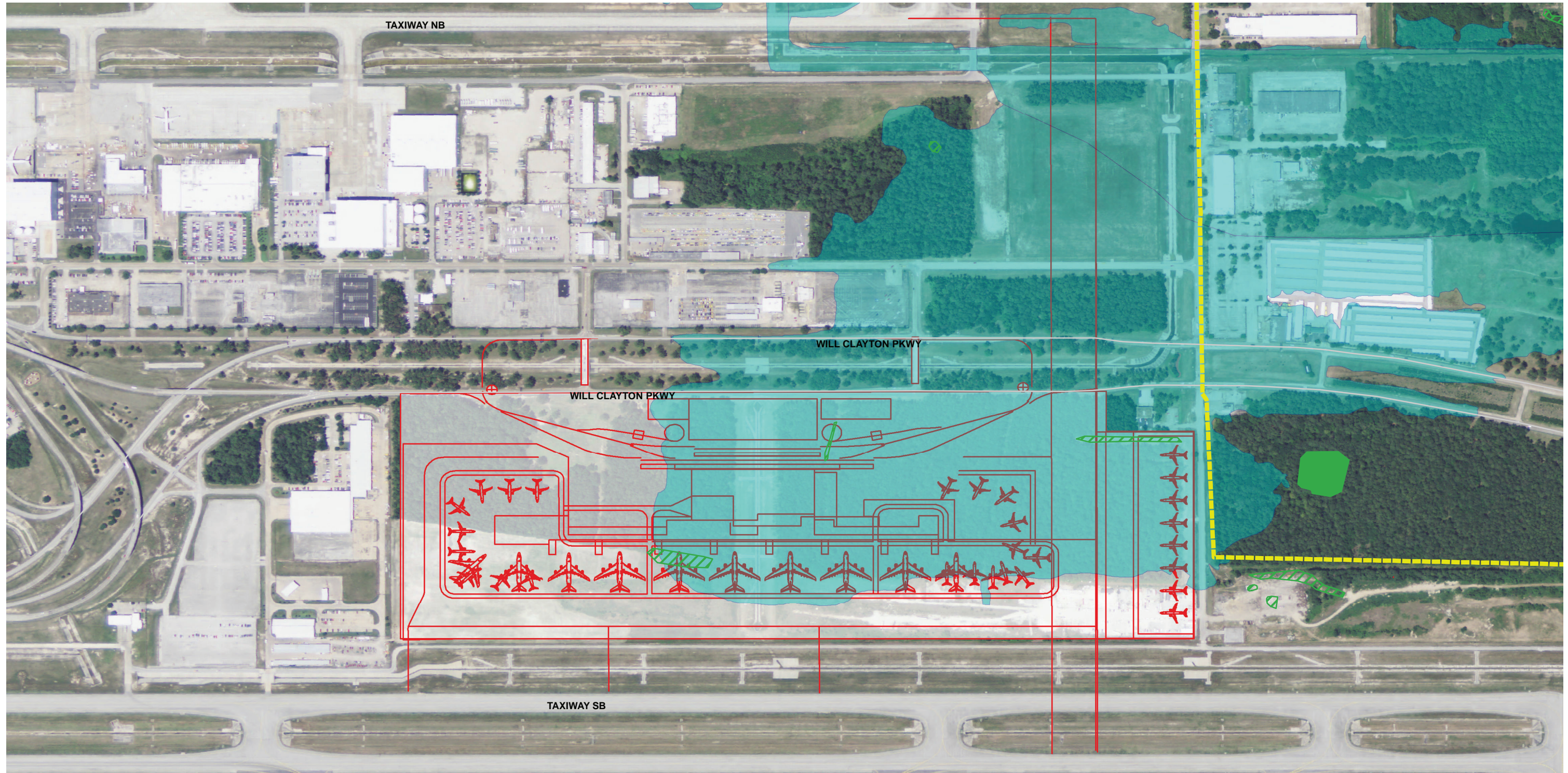
Non-secure connecting travel distance was also measured from Terminal C in the existing terminal area to the east terminal. The travel distance in both alternatives was comparable, at 1.4 miles in Alternative A and 1.5 miles in Alternative B. The travel distances vary depending on whether you are traveling to Terminal C or from Terminal C because of the orientation of the terminal in the alternatives. For example, Alternative A requires passengers to travel east away from the terminal area before looping back toward the existing terminal area.

Motorist Wayfinding. Ease of motorist wayfinding would be better in Alternative A than Alternative B. The depressed roadways beneath the taxiways in Alternative B would limit visibility and result in drivers being unable to use their surroundings to assist them in navigating to the terminal roadways. Additionally, the grade changes result in closely-spaced decision points and difficult weaving sections approaching the east terminal.

5.3.8.3 Environmental Criteria

This section evaluates the environmental impacts of the airfield alternatives. This assessment is based on available information, using quantitative methods where possible and qualitative comparisons where quantitative assessment is not possible. Each alternative is superimposed on the location of potential wetlands and floodplains on Figures 5-52 and 5-53.

Wetlands. Delineated wetlands likely to be impacted were quantified using a 2010 survey conducted by the U.S. Army Corps of Engineers. Additionally, locations of potential wetlands were compiled in areas that were not delineated in 2010 from interpretation of 2010 false-color infrared aerial photographs available from the Texas Natural Resources Information System.



Source: Listed in Report
 Prepared by: Quadrant Consultants Inc., 2013

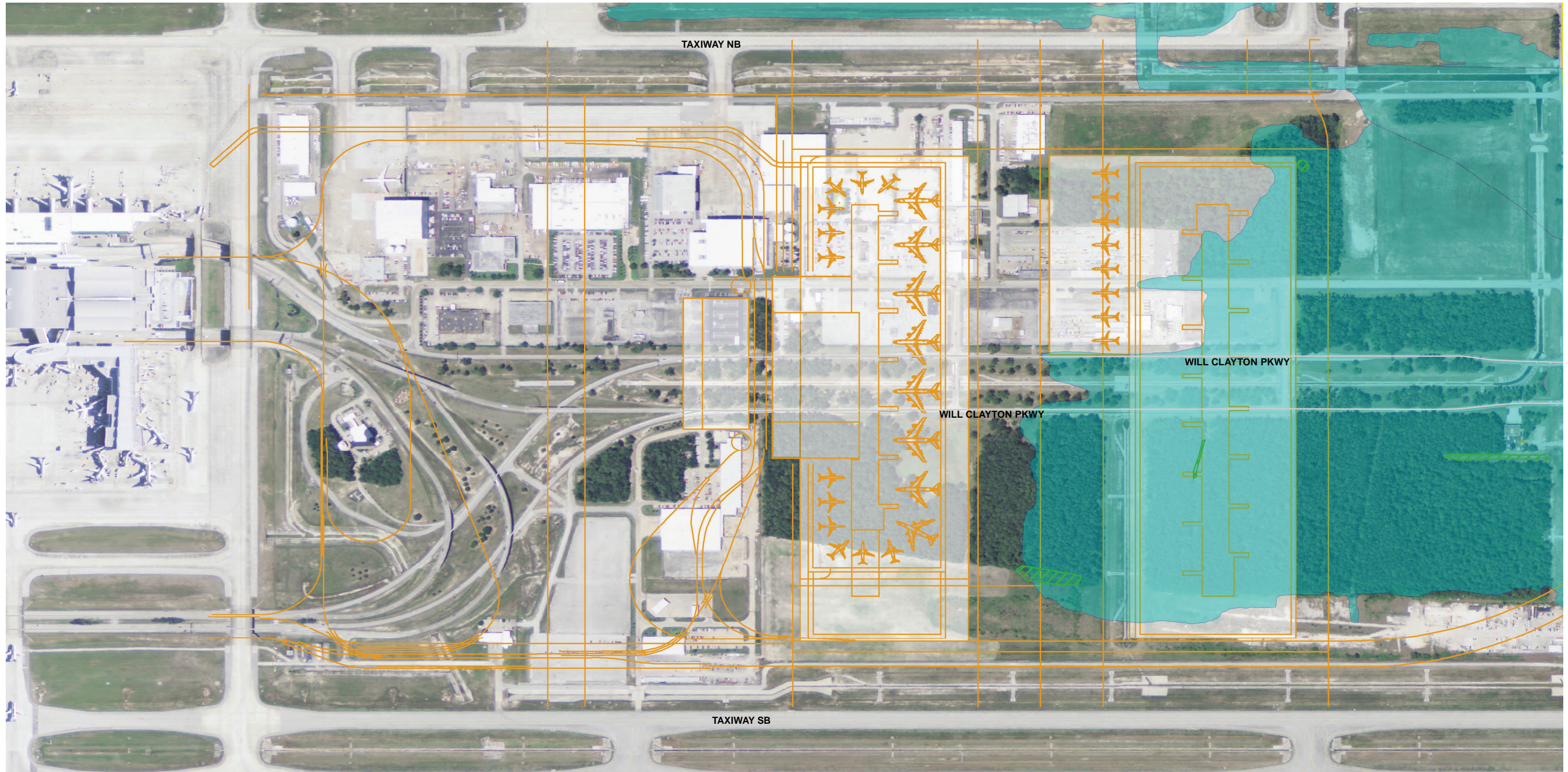
Leigh | Fisher

LEGEND

- IAH Boundary
- Wetlands
- Potential Wetlands
- 100-Year Floorplan
- Terminal Alternative A



Figure 5-52
Alternative A
 Environmental Conditions



Source: Listed in Report
 Prepared by: Quadrant Consultants Inc., 2013

Leigh | Fisher

LEGEND





-  IAH Boundary
-  Wetlands
-  Potential Wetlands
-  100-Year Floorplan



Figure 5-53
Alternative B
 Environmental Conditions

The Alternative A site would not encroach any delineated wetlands, but would encompass approximately 0.5 acres of potential wetlands, and mitigation is assumed to be required to build this terminal. The site of Alternative B does not appear to encroach any delineated or potential wetlands, so it is not likely that wetlands would be affected by this alternative.

Floodplains. The Federal Emergency Management Agency's Flood Insurance Rate Maps, last updated in 2007, were used to determine the limits of the 100-year floodplain. Alternative A would encroach on approximately 74 acres of the 100-year floodplain. Floodplain mitigation would be required for this alternative. Alternative B would impact approximately 47 acres of floodplain.

Section 303(c) Lands. Volume 49, Section 303(c) of the United States Code encodes Section 4(f) of the Department of Transportation Act of 1966. It states, "The Secretary may approve a transportation program or project requiring the use of publicly owned land of a public park, recreation areas or wildlife and waterfowl refuge, or land of an historic site of national, State, or local significance (as determined by the Federal State, or local officials having jurisdiction over the park, recreation areas refuge, or site) only if (1) there is no prudent and feasible alternative to using that land; and (2) the program or project includes all possible planning to minimize harm to the park, recreation area, wildlife and waterfowl refuges or historic site resulting from the use."

Review of off-Airport parks and recreational areas revealed that no Section 303(c) lands are expected to be impacted by either of the terminal alternatives under consideration.

Relocation of Existing Facilities. Existing airport facilities and infrastructure on the proposed sites of the terminal alternatives were examined to determine the extent that existing facilities would be displaced by the terminal and supporting facilities. Alternative A would require relocation of one drainage ditch on Airport property. Alternative B requires relocation of a HAS office building, an auto fueling facility, a United Airlines maintenance hangar, and two above-ground storage tanks. Therefore, Alternative B has greater impacts on existing Airport facilities and infrastructure.

Air Quality. The terminal buildings in both alternatives considered are not expected to have significant impacts on air quality. There would however be temporary impacts to air quality during construction. Detailed air quality modeling should be undertaken at the time of an environmental assessment within the context of the local air quality conformance.

Degree of Controversy. It is unlikely that construction and operation of the terminals in either alternative would cause controversy, given that neither alternative involves relocation of residential property or land acquisition.

5.3.8.4 Secondary Screening Evaluation Results

The results of the evaluation process suggest that Alternatives A and B perform similarly in relation to the operational and environmental criteria. As far as the operational criteria, Alternative A is more favorable with respect to constructability and motorist wayfinding, while Alternative B has more favorable passenger travel times. Alternative A would have a greater impact on wetlands and floodplains, while Alternative B would require extensive facility relocations. Results of the financial comparison differentiate the alternatives with Alternative B expected to cost approximately \$500 million more than Alternative A. Therefore, Alternative A was selected as the preferred terminal alternative.

5.3.9 Preferred Terminal Alternative

The preferred terminal alternative involves construction of additional piers in the existing terminal area to maximize its capability. In the near-term, reconstruction of Terminal D to accommodate additional international arrival operations is warranted to keep pace with increasing international passenger demand. Further, the construction of additional domestic concourses should be planned for the Terminal B north apron, similar to that shown in Figure 5-38.

In the long-term, construction of an “East Terminal” may be warranted similar to that depicted in the Alternative A drawings. Alternatively, the existing terminal area could be expanded in the event that Taxiway SF was relocated. With the relocation of Taxiway SF and various airport facilities, notably the Airport Traffic Control Tower, both Terminal D and Terminal E could accommodate additional concourse piers. Both options will be reserved within the Recommended Development Plan described in Chapter 6.

5.4 CONCLUSIONS

Alternatives were evaluated within a sustainability framework to ensure that the Recommended Development Plan (RDP) would provide a well-balanced solution in terms of economic viability, operational efficiency, and environmental and social responsibility. The secondary screening evaluation revealed the relative merits of individual alternatives selected for inclusion within the RDP.

Specifically, the alternatives evaluation process has demonstrated the following key findings:

1. The existing airfield should be augmented by a fourth parallel runway, to be designated Runway 8C-26C, located equidistant from existing Runways 8R-26L and 8L-26R. Runway 8C-26C would serve primarily as a departure runway, providing a third departure runway in both east and west flow.
2. A fifth parallel runway is not necessary within the planning horizon of the master plan. Nonetheless, prudent planning dictates that land be reserved for a future runway parallel to and south of existing Runway 9-27.
3. The terminal complex can accommodate approximately 165 narrowbody aircraft parking positions, which is insufficient to meet the forecast demand beginning at PAL33. Further, the most efficient configuration of additional terminal concourses in the terminal complex would be accomplished through additional piers perpendicular to North and South Terminal roads.
4. Beyond PAL33, the existing terminal platform may be expanded to the east of Taxiway SF, or an East Terminal may be considered similar to that described as Alternative A. Both the expansion of the existing platform and the location of Alternative A should be reserved for future terminal development in the long-term.

Taken together, these findings form the foundation for the RDP.