Regional Airport System Plan

Update 2000

Volume III

- Alternatives to New Runways
- Regional Airport Capacity and Delay
- Traffic
- Environment

METROPOLITAN TRANSPORTATION COMMISSION

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SAN FRANCISCO BAY CONSERVATION AND DEVELOPMENT COMMISSION

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ASSOCIATION OF BAY AREA GOVERNMENTS

Regional Airport Planning Committee

February 2001

Regional Airport System Plan

Update 2000

Sensitivity Analysis of Factors Affecting Airport Demand and Capacity

Regional Airport System Plan Update

Sensitivity Analysis of Factors Affecting Airport Demand and Capacity (including alternatives to new runways)

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1. Introduction

In September, 1999 the Regional Airport Planning Committee identified a number of strategies for "sensitivity" testing with respect to their likely impact on future airport system demand and capacity. The demand strategies tested the effect of various measures on reducing the number of flights projected to use SFO, OAK, and SJC in the future. The capacity-enhancing strategies tested the effect of various measures on increasing the capacity of the existing airport runways and Bay Area airspace (particularly related to poor weather when capacity is most constrained). This analysis was intended to complement the more complex and rigorous computer modeling of different future runway configurations at the three major airports. By evaluating the effectiveness of these various strategies, we can determine how significant a factor they would be as either alternatives to new/reconfigured runways or as complementary strategies to proposed runway improvements. This assessment is not intended to be a feasibility study of the strategies considered or to answer questions about how the strategies could be implemented.

The eight sensitivity tests are listed below:

- Runway Variations at San Francisco and Oakland International Airports.
- Construction of a New Airport in the North Bay or outside the Bay Area
- Air Service at Satellite Airports
- Use of Moffett Federal Airfield or Travis AFB for Air Cargo
- Diversion of Air Passengers to a future High Speed Rail System
- Benefits of new Air Traffic Control Technology
- Airport Access Controls (i.e., flight restrictions)
- Rapid Water/Rail Connections between SFO and OAK

Approach to the Analysis

Where possible we use a "pivot point" analysis to estimate changes in airport "demand" (projected number of flights) at each airport. By pivot point, we mean that we "pivot" off of our original forecasts[1] to estimate changes in aircraft takeoffs and landings at each airport that might occur as a result of a different set of demand assumptions. Figure 1 shows the projected average daily operations for each airport in 2010 and 2020, which constitutes the "basecase" for our analysis.

Figure 2 shows the sensitivity tests in relation to the forecasted number of aircraft operations in the different markets. For example, a new California High Speed Rail connecting the Bay Area with Los Angeles and San Diego via the Central Valley could reduce flights in the California and commuter (smaller cities, like those in the Central Valley) markets. Measures designed to restrict the number of

[1] Aviation Demand Forecasts for the Bay Area, Roberts Roach and Associates, February 2000

flights at an airport (termed "access" controls) could affect a number of markets, depending on how the controls are structured.

Where it is not possible to estimate changes in flight activity, we discuss the potential effects of various strategies in more qualitative terms relying on available literature and/or knowledge of the aviation industry.

Finally, as explained above, a detailed assessment of airport capacity and delay is being undertaken in a separate task using a computerized simulation model. We will use the information in this report to determine which strategies warrant testing with this simulation model.

Feasibility of Strategies

Some of the feasibility issues are alluded to under the topic of "Key Considerations" in each section of the report; however, this discussion is not intended to be exhaustive. Additional questions that would need to be addressed and satisfactorily answered include:

-Is there an airport sponsor or other authority to implement the strategy?
-Would the strategy make economic sense to an airline or public agency?
-How would passenger convenience be affected?
-Is there an appropriate funding source available (FAA, airlines, airports, transit operators)?
-When could the strategy be implemented-- in the near term, or far term?
-Would airport noise be increased or shifted from one area to another?
-Are there other important environmental issues, such as Bay resources or air quality?
-Is there public support for the proposed strategy?

FIGURE 1

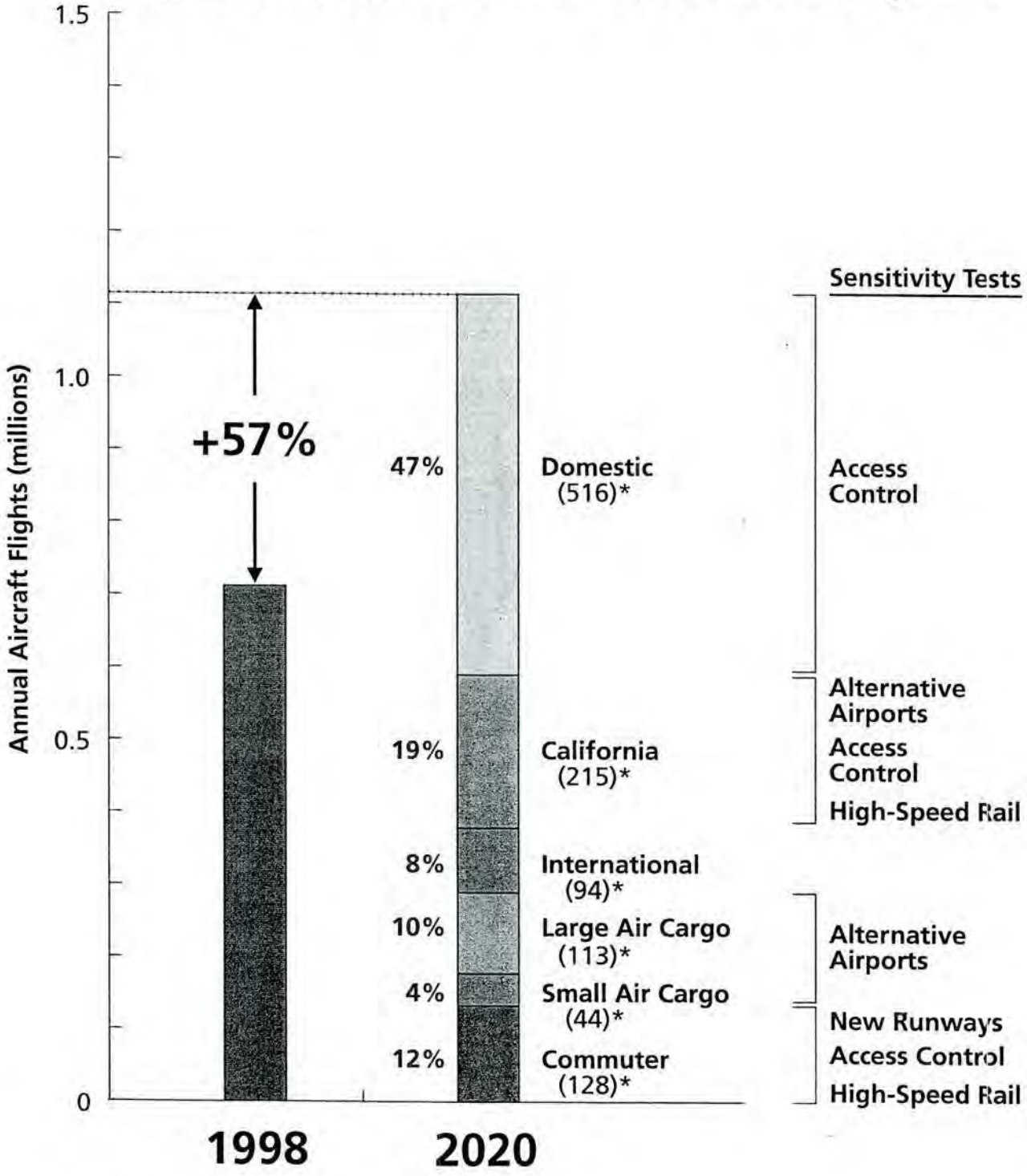
AVERAGE DAILY AIRCRAFT OPERATIONS BY AIRPORT

Airport	1998	2010	2020
San Francisco International			
Air Passenger	1,081	1,215	1,405
Air Cargo	33	65	117
General Aviation/Military	79	79	79
SFO TOTAL	**1,193**	**1,359**	**1,601**
Metropolitan Oakland International*			
Air Passenger	311	465	595
Air Cargo	101	156	214
General Aviation/Military	65	65	68
OAK TOTAL	**477**	**686**	**877**
San Jose International			
Air Passenger	359	454	612
Air Cargo	14	18	29
General Aviation/Military	407**	59***	59***
SJC TOTAL	**780****	**531**	**700**
GRAND TOTAL		**2,502**	**3,091**

Source: San Francisco Bay Area Aviation Demand Forecasts, Roberts Roach & Associates, February 2000

Figure 2

Sensitivity Tests and Bay Area Aircraft Commercial Flights



*(000) = Thousands of Annual Flights

Source: San Francisco Bay Area Aviation Demands Forecasts, Roberts Roach & Associates, February 2000

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2. Additional Runway Variations at SFO and OAK

Discussion

Both San Francisco International Airport (SFO) and Metropolitan Oakland International Airport (OAK) are currently evaluating a discrete set of runway configurations, which we have termed "primary runway alternatives" (See Exhibit 1). These alternatives are being evaluated separately through a computerized airport and airspace simulation model. In addition to these primary alternatives, this report assesses several other airfield concepts that could offer further operational flexibility and/or enhancement of airfield capacity. For OAK, the analysis discusses the potential for expanded use of the North Field (currently a general aviation facility) to augment the capacity of the South Field. For SFO, the main topic discussed is the future use of existing Runway 28L should the airfield be reconfigured as proposed by SFO.

Flexible Use of Oakland Airport North Field for Expanded Operations

Figures 3A and 3B illustrate the existing runway layout at Metropolitan Oakland International Airport and the new runway configurations currently under review. The North Field is Oakland's primary general aviation facility but also accommodates airline operations from time to time when the South Field is closed or under repair. Our analysis discusses expanded use of the North Field runways by airlines and by general aviation type aircraft currently required to use the South Field for noise abatement (see Key Considerations below).

Runway improvements that could increase the operational flexibility of the North Field include: 1) the extension of Runway 27L (shown as "N-1" in Figure 3B), or 2) realignment of Runway 9R/27L to parallel the South Field's Runway 11/29 (i.e., new Runway 11L/29R shown as "N-2" in Figure 3B).

Analysis

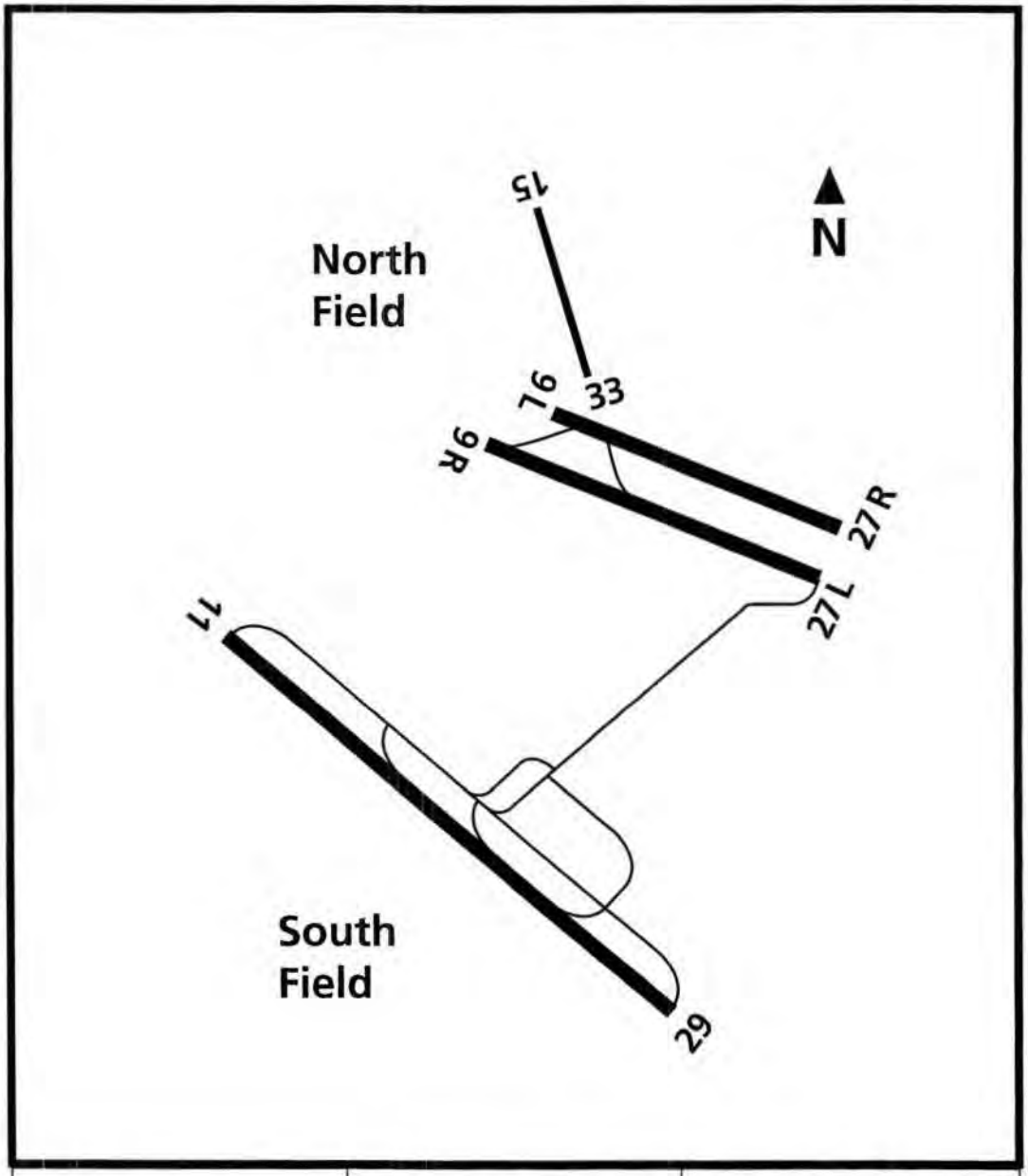
Airline use of North Field. The availability of an extended Runway 9R/27L or realigned new Runway 11L/29R for airline arrivals would significantly reduce departure delays that will occur on Runway 29 when arrivals impact waiting departures. These delays are expected to increase as air operations increase on the South Field. The Airport Development Program[2] discusses the potential for the North Field to handle up to 25% of the arrivals of B737 size aircraft. Runway 27L could be extended to 7,500-8,000 feet to better accommodate B737s, MD80s, and new regional jets. Realigning the North Field runways (new Runway 11L/29R) would allow parallel ILS approaches down to Category II (CAT II) minimums. Oakland's arrival capacity would double during either VFR or IFR conditions.

These runway improvements would operationally benefit Bay TRACON and OAK Tower by increasing their ability to assign turbojet aircraft to parallel runways that are greater than 4,300 feet apart. Unlike SFO or SJC, OAK would not require the installation

[2] Port of Oakland, Final Environmental Impact Report, Proposed Airport Development Program, December 1997

Figure 3A

Metropolitan Oakland International Airport Runways



Runway	Length (Feet)	Width (Feet)
11-29	10,000	150
9L-27R	5,453	150
9R-27L	6,212	150
15-33	3,366	75

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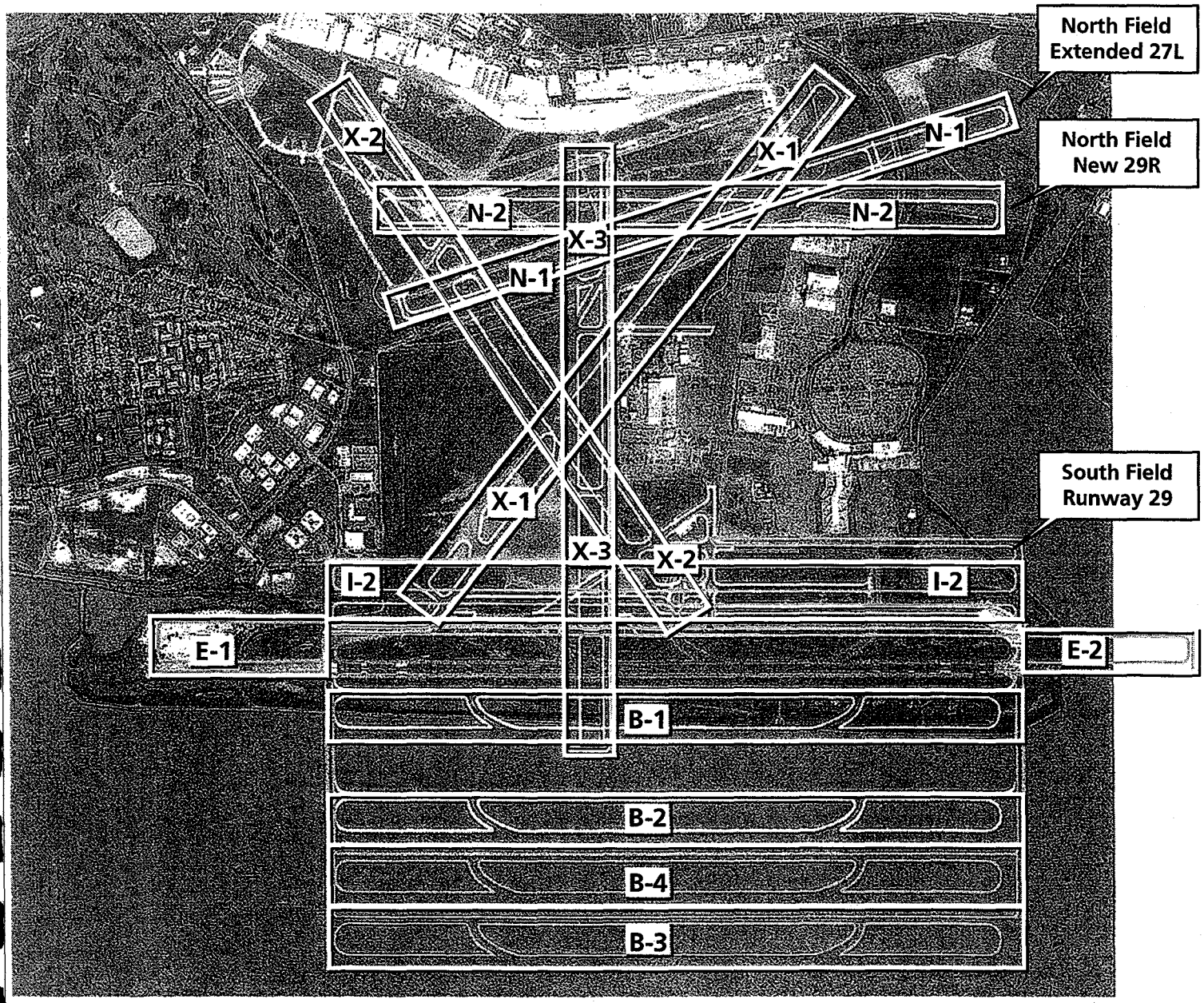
NOTE: Airport diagram redrawn from the *1997 Aviation Capacity Enhancement Plan,* FAA Office of System Capacity, December 1997.

Figure 3B

Oakland Airport Runway Configurations Under Study



of a Precision Radar Monitoring System (PRM) for ILS approaches due to the separation provided. Bay TRACON could conduct visual approaches to Runways 27R (General Aviation), extended Runway 27L/new Runway 29R (General Aviation), and South Field Runway 29 which would increase air carrier and commuter airline visual approaches by at least 30% over the existing capacity for Runway 29. Bay TRACON could increase the IFR arrival capacity to up to 60 approaches per hour for extended Runway 27L/new Runway 29R and Runway 29. During Southeast Plan operations, Bay TRACON would be able to conduct parallel instrument approaches to extended Runway 9R/ new Runway 11L and South Field Runway 11R.

Additionally, IFR departure capacity would increase by at least 30% by routing Runway 27L /new Runway 29R airline departures with turns to 350 degrees or greater after leaving 3,000 feet altitude with staggered departures off Runway 29 proceeding over Hunters Point or towards Point Reyes/Red Bluff at the same time. During Southeast Plan operations, departures off Runway 11 proceeding to the Los Angeles Basin or to the ocean could be released with 30 degree or greater southeast bound turns for separation from Runway 9R/new Runway 11L departures.

Expanded General Aviation Use of North Field. Noise abatement procedures require general aviation and smaller air cargo aircraft weighing more than 12,500 lbs. to depart from the South Field to reduce noise over Alameda. These aircraft include general aviation aircraft as well as smaller air taxi freighter aircraft used to feed cargo to Fed Ex for consolidation and transport by larger jets. As a result, the South Field runway is used by a number of aircraft that would otherwise be able to depart from the North Field. Allowing these aircraft to use the North Field for departures during periods of high delay on the South Field could improve overall airport operations.

Realignment of North Field Runway for Improved IFR Operations. Due to the intersection of the extended centerlines for the North Field and South Field runways (Runway 27 at North Field and Runway 29 at South Field), the operation of the two runways are dependent under instrument weather conditions. This means that only one arrival or departure can occur at a time from either runway. Even a small number of North Field IFR operations can have a significant effect on South Field operations during poor weather. Thus, realignment of the North Field Runway 27L to parallel the South Field Runway 29 would provide an IFR capacity improvement (although it may be a very costly improvement compared to the number of general aviation IFR operations).

Key Considerations

Community noise due to increased North Field operations would be a major concern. Using the North Field for expanded airline operations would impact nearby communities of Hayward, San Leandro, Castro Valley, San Lorenzo, Oakland, and Alameda.

Iincreased use of the North Field for departures by heavier aircraft would be prohibited by legal agreements put in place in the mid-70's stemming from a court case over airport expansion. To resolve the conflict, the Port of Oakland, City of Alameda, and developers of Bay Farm Island signed a Settlement Agreement which contains the following types of restrictions:

- Aircraft weighing over 12,500 lbs must takeoff from the South Field
- All four-engine piston aircraft must take off from the South Field

Realignment of Runway 27L on the North Field may result in a loss of North Field general aviation capacity, since the new runway would intersect all three existing runway, possibly reducing the utility of the overall runway system. The North Field is currently one of the nation's busiest general aviation airports.

Retain Flexibility in Use of Existing Runway 28L-10R at SFO for Departures with Strong Winds from the West.

Under initial plans for reconfiguring SFO runways, existing Runway 28L would be converted to a taxiway to improve aircraft circulation around the main terminal and to accommodate a class of New Large Aircraft (NLA) aircraft that may be introduced into the fleet in the future. Further analysis revealed that retaining existing Runway 28L for use as a runway under certain conditions could have important operational benefits (see Figure 4). For example, during strong west wind conditions, using Runway 28L for departures could help dissipate delays more quickly and efficiently. Other conditions that may warrant use of Runway 28L as part of a flexible use plan would be when:

- Any of the main runways are closed for emergencies or repairs
- Departure or arrival delays are forecasted to exceed 15 minutes
- The airport is recovering from major delays due to WOXOF (0 ceiling/0 visibility) weather conditions or other factors, in which case the runway would be used until the backlog of arrivals or departures is expelled
- Between the hours of 0700-2200 only—unless there are major arrival delays forecast to continue up to 2300
- Used only for turboprop, regional jet, and propeller aircraft departures between 0700 and 0900 and 2100 and 2200 hours--and not at all between 2200 and 0700 unless another runway is closed

Analysis

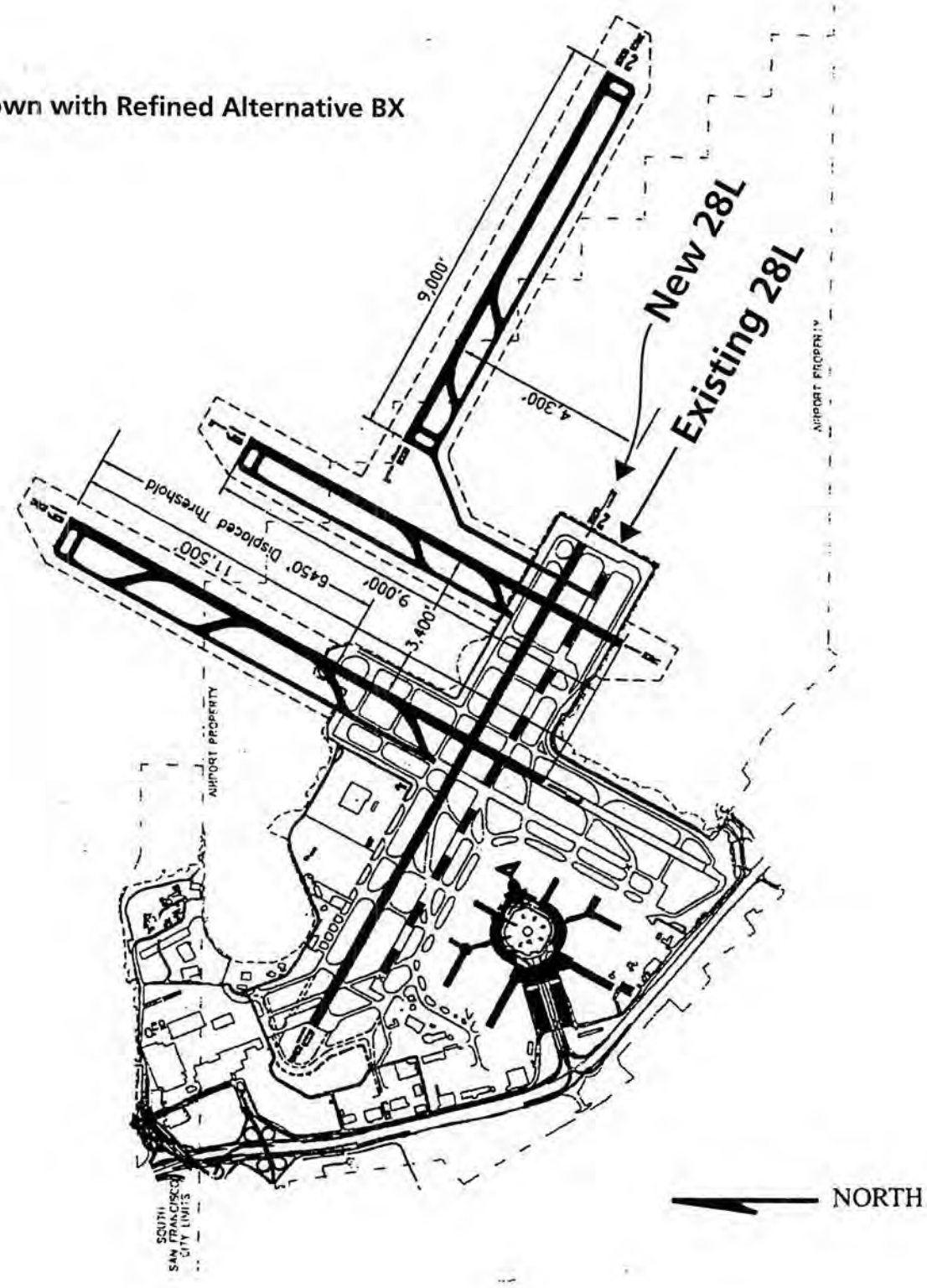
Retention of 28L as an optional use or full time runway could have several potential benefits.

- Capacity to conduct triple visual approaches to the three west runways.
- Use of Runway 28L for general aviation, turboprop, and Regional Jet aircraft would have the benefit of segregating these aircraft from the wake turbulence impacts and increased spacing required for large aircraft: B747, B767, B757, MD11, etc.
- Providing a third departure runway for west and northbound departures that are presently assigned to Runway 1L or are sequenced between arrivals on Runway 28L or Runway 28R.
- Having a third runway to process departures and arrivals when SFO experiences 0 ceiling/0 visibility or low ceiling/visibility conditions that have created major

Figure 4

Flexible Use of Existing SFO Runway 28L*

*Shown with Refined Alternative BX



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departure and arrival delays. When the weather conditions lift to permit the Tower to conduct visual operations, they would have three runways to reduce the departure or arrival volume. Today, SFO has only two north/south and two east/west runways to dissolve the backlog of traffic.

- Retaining 28L would provide increased capacity during conditions when the weather is changing from morning fog/low stratus clouds to visual conditions.
- Retaining Runway 28L as an active runway would give SFO an option when it is necessary to close one of the new west/east runways on a temporary or extended basis. Eventually, the new runways will require major repairs, installation of new embedded lighting guidance systems, or the closure of high speed taxiway exits for repair work. Giving up the utility of Runway 28L and not having it available during such conditions will be costly in delays and passenger inconvenience.
- Construction of a new Runway 28R separated from existing Runway 28R by 3,400 feet or more will permit the conduct of parallel ILS approaches down to CAT II/III minimums. If existing Runway 28R were closed during IFR conditions for repairs, Bay TRACON could continue to conduct parallel ILS approaches to existing Runway 28L and new Runway 28R because they would be separated by over 4,000 feet. The installation of a Precision Runway Monitor (PRM) would not be needed under such separation criteria between the runways. Bay TRACON would be able to maintain an IFR arrival rate of up to 60 aircraft per hour on existing Runway 28L and new Runway 28R with the temporary closure of existing Runway 28R.

Key Considerations

SFO's proposal for use of existing Runway 28L is only for departures and only for strong west wind conditions occurring 7-10% of the year; therefore, the flexibility discussed above exceeds that currently being discussed by the Airport. Decisions about the future use of Runway 28L would require FAA review and approval under the Airport Certification program covered by Federal Aviation Regulations Part 139 and further environmental review information (If the FAA were to approve its continued use as a runway, the SFO runway system designations for the three runways would change to Runway 28L, 28C, and 28R).

If existing Runway 28L is retained as a part time/optional use runway for departures only, communities on the Peninsula would enjoy some noise relief as arriving aircraft would be farther out in the Bay.

3. Air Service at Satellite Airports

Discussion

Just as Oakland and San Jose airports developed as satellite airports for low fare Southern California service, the advent of regional jets may make similar types of service economical at some of the Bay Area's smaller general aviation airports. Accommodating a limited amount of Bay Area air passengers at these airports would produce corresponding reductions in flights at OAK/SFO/SJC. The sensitivity test envisions a system of convenient satellite airports serving local air passengers who would otherwise be flying out of the three major airports.

The potential for air service at general aviation airports is based on the emergence of new regional jet technology, replacing turboprops currently used on the majority of commuter routes. Such jets would carry 40 to 90 passengers and provide the comfort and speed of larger jet aircraft, while generating lower noise levels than some existing business jets. Commuter airline service currently exists at Sonoma County Airport (Santa Rosa) and several commuter airlines have expressed interest in starting service to Los Angeles from Concord's Buchanan Field and Livermore airport. For the purpose of our analysis, we assume California corridor service would be provided at a number of Bay Area general aviation airports: NutTree (Vacaville), Napa County, Gnoss Field (Marin County), Livermore Municipal Airport, and South County (Morgan Hill). Moffett Airfield (under NASA control) and Travis AFB (under DOD control) are additional possibilities (See Figure 5).

Not all of the general aviation airports have the required runway length or navigational aids. Most of these airports will need the capability of Global Positioning System (GPS) or Instrument Landing System (ILS) instrument approaches to at least Category I or Category II minimums (see below) for stratus conditions and winter instrument weather conditions. Except at Buchanan Field and Gnoss Field, visual or instrument operations into these satellite airports should not have a major impact on the FAA's Bay TRACON or Oakland Center air traffic control operations. The future implementation of the Wide Area Augmentation System (WAAS) complimented by the Local Area Augmentation System (LAAS) will provide those airports with all weather navigation and approach capability down to Category II/III minimums. The FAA is projecting WAAS and LAAS GPS-based navigation and precision approach systems will be in place nationwide by 2010.

- Category I: Decision height no less than 200 feet above runway , visibility no less than ½ mile
- Category II: Decision height no less than 100 feet above runway, visibility no less than ¼ mile
- Category III: Decision height lower than 100 feet above runway, visibility less than ¼ mile

Analysis Assumptions

- The California corridor, the largest Bay Area air travel market, is the most likely candidate for new service due to the greater potential for airline profitability. However, since the California market is comprised of a number of airport destinations--Los Angeles (LAX), Burbank (BUR), Ontario (ONT), Orange County (SNA), San Diego (SAN) and various small cities (see Figure 6), it is unlikely that these airports would have service to all LA Basin/San Diego destinations.
- The main market would be "local" area air passengers--passengers originating in the immediate vicinity of these airports.
- Service at satellite airports would not affect the volume of connecting passengers at SFO, OAK, or SJC using these airports as transfer points between a domestic or international flight and a California Corridor flight.

Analysis Approach

We have analyzed a comprehensive system of satellite airports, which would provide the greatest potential reduction in future flight operations at OAK, SFO, and SJC. We disaggregate our county-level air passenger forecasts (Exhibit 2) into smaller geographic analysis zones, or "Super Districts" (Exhibit 3). We then define a local air passenger "catchment" area for each airport, which represents the likely Super District(s) from which these airports would draw air passengers. Without identifying specific city pairs, we have made the assumption that each airport could capture roughly 50% of the local California passengers in their catchment area. This assumption reflects our belief that air service would only be initiated to some of the California destinations, not all, in the same manner airlines currently serve selected California destinations from the three existing air carrier airports. A 50% market share for the California corridor will serve as a plausible sensitivity test.

To estimate the number of local flights out of each airport, we assume air service would be provided by regional jets, with seating capacity of 50 to 90 seats, depending on the satellite airport and forecast year. We assume larger jets for airports that would generate the most air passengers with 70% load factors in 2010 and 73% load factors in 2020.

Finally, we estimate the average daily flights reduced at San Francisco, Oakland, and San Jose airports due to passengers using the satellite airports. We attribute the flights eliminated at each of the three major airports based on the airports the air passengers would most likely have used in the absence of service at their local satellite airport.

Results

Compared to the total forecast of operations at each airport (including air cargo, general aviation, and military), this hypothetical satellite airport system could reduce average daily operations at SFO/OAK/SJC by 1% to 5% depending on the airport and forecast year. Figures 7A and 7B and Figure 8 show these results in tabular and graphic form. It appears that a system of satellite airports would reduce flights to a greater extent at OAK and SJC because the satellite airports in the analysis are more closely associated with the passenger catchment areas for these two airports, rather than the service area for SFO.

Key Considerations

Whether this service concepts fits with the route strategy of any existing airline is problematic. At present this concept does not fit well with the route strategies of any major network or point-to-point carrier, but that does not rule out commuter airlines or a new entrant airline. Major carriers prefer service at established airports to maximize their potential to fill seats. Initiating service at a new airport would involve considerable financial risk and could be expensive to provide, particularly if the airline does not have the type of aircraft suited to this service on hand. Because of the economics of this type of operation (airline and airport related costs), the fares may need to be higher than those offered by the established carriers at the existing airports. Also, the load factors assumed in our analysis reflect a mature market, and these levels would not be realized immediately upon initiation of service.

The viability of service would depend largely on the convenience offered, both is terms of shortened ground access times and the availability of an adequate choice of departure and arrival times. For example, despite the large population surrounding Long Beach airport in Southern California, airline service initiated at this airport has not matched expectations, largely it is believed, due to the lack of added convenience when matched against LAX. The same could be said of the hypothetical service at Moffett or several of the general aviation airports when matched against SFO, OAK or SJC.

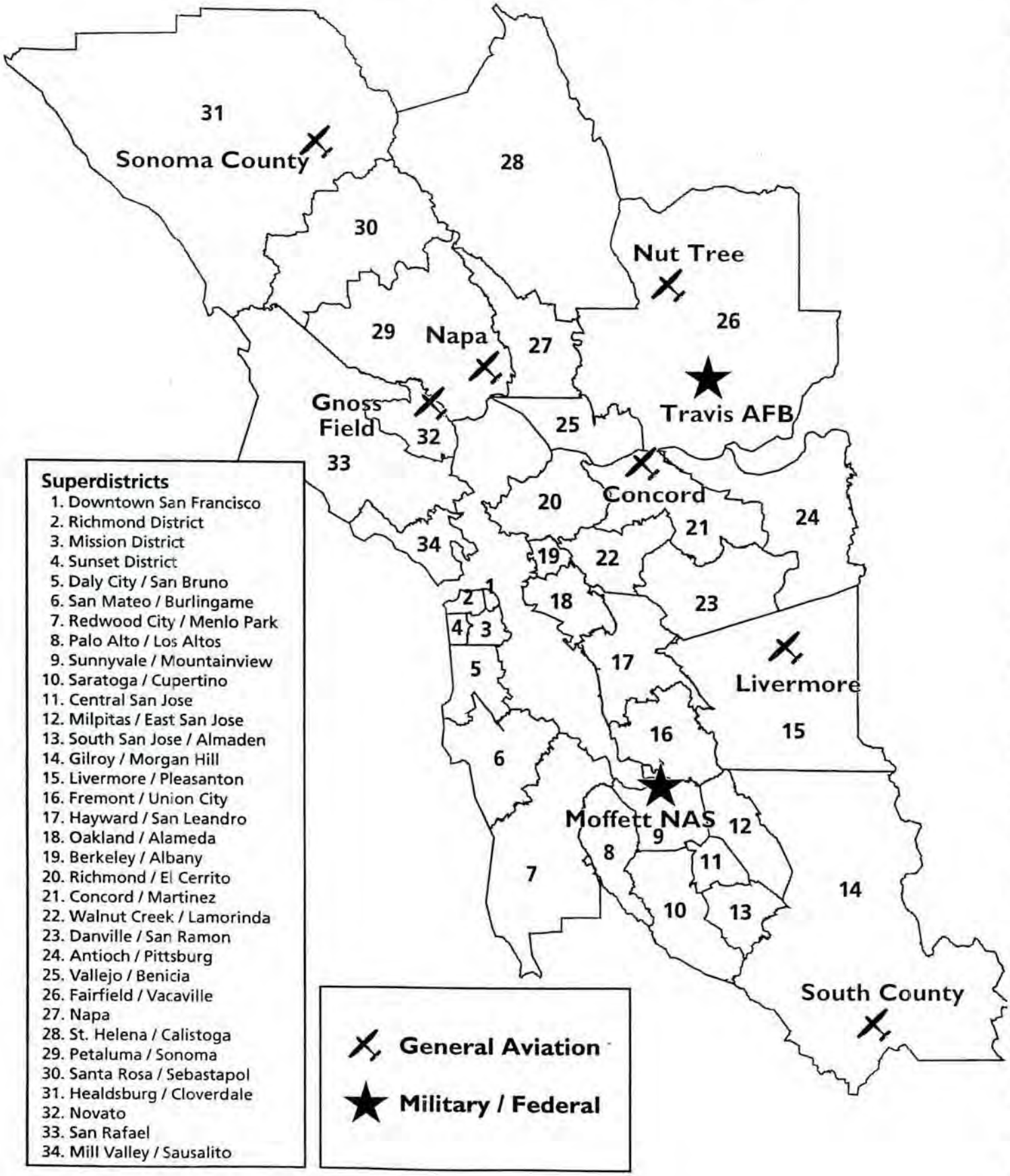
Noise produced by airline operations would be an obvious concern for communities contemplating new service.

Looking at Bay Area airspace issues, there are potential benefits from removing some commercial aircraft operations from the crowded terminal area airspace used by SFO, OAK, and SJC. While up to 169 daily flights by regional jets would be added at the various satellite airports, only 64 (2010) to 76 (2020) daily flights might be eliminated at OAK, SFO, and SJC. This disparity is due to fact that aircraft serving the California market at the major airports would be larger than the regional jets, therefore fewer aircraft flights would be eliminated. From a more global airspace perspective, the increase in flights in the already crowded California corridor could exacerbate enroute congestion between the Bay Area and Southern California. Additionally, these flights could also exacerbate conflicts in the Southern California airspace at capacity strained airports in this area.

Finally, it should be noted that the historic role of general aviation airports has been one of "relieving" the major air carrier airports, which is to say, providing an attractive alternative to entice small aircraft users to these facilities. This may well continue to be the most effective role these airports can play, particularly in the growing corporate aircraft market. Moffett Federal Airfield, in particular, may be a useful addition to the South Bay aviation system for corporate users if SJC runways become congested in the future.

Figure 5

Potential Satellite Airports



Superdistricts

1. Downtown San Francisco
2. Richmond District
3. Mission District
4. Sunset District
5. Daly City / San Bruno
6. San Mateo / Burlingame
7. Redwood City / Menlo Park
8. Palo Alto / Los Altos
9. Sunnyvale / Mountainview
10. Saratoga / Cupertino
11. Central San Jose
12. Milpitas / East San Jose
13. South San Jose / Almaden
14. Gilroy / Morgan Hill
15. Livermore / Pleasanton
16. Fremont / Union City
17. Hayward / San Leandro
18. Oakland / Alameda
19. Berkeley / Albany
20. Richmond / El Cerrito
21. Concord / Martinez
22. Walnut Creek / Lamorinda
23. Danville / San Ramon
24. Antioch / Pittsburg
25. Vallejo / Benicia
26. Fairfield / Vacaville
27. Napa
28. St. Helena / Calistoga
29. Petaluma / Sonoma
30. Santa Rosa / Sebastapol
31. Healdsburg / Cloverdale
32. Novato
33. San Rafael
34. Mill Valley / Sausalito

Figure 6

Percentage of California Corridor Air Passengers to Various Cities (2010 / 2020)

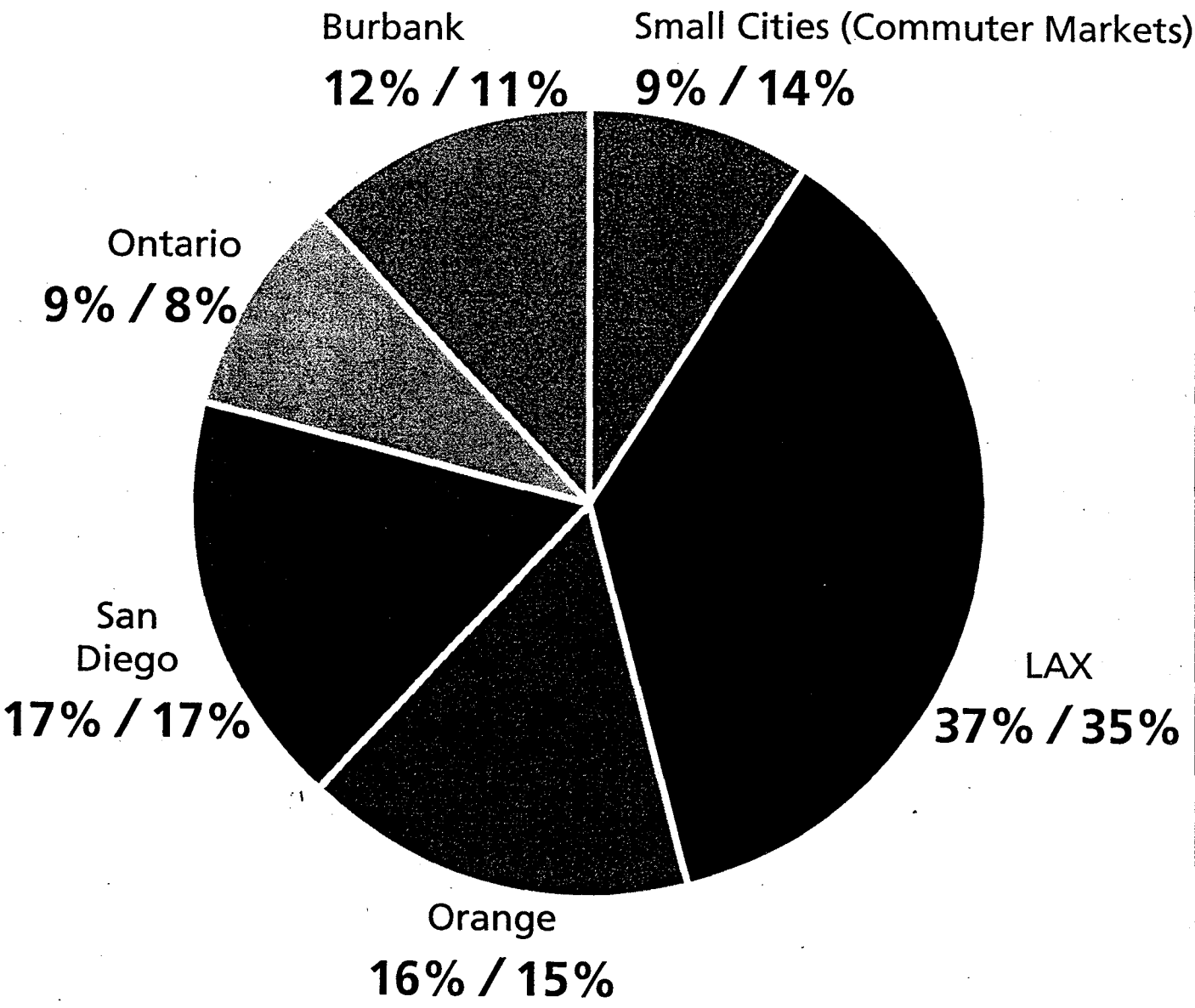


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FIGURE 7A

IMPACT OF AIR SERVICE AT ALTERNATIVE AIRPORTS
ON FLIGHTS AT SFO, OAK AND SJC FOR 2010

	California Air Passengers			Daily Flights Added[2]	Daily Flights Eliminated[3]		
Airport (Catchment Area/Superdistricts)	Annual	Annual Served[1]	Daily		SFO	OAK	SJC
Travis/Nut Tree (26)	92,040	46,020	126	4		1	
Moffett (9)	1,161,699	580,850	1,591	30			15
Concord (21-24)	1,259,224	629,612	1,725	35		16	
Sonoma (29,30,31)	438,325	219,162	600	17	3	3	
Napa (25,27,28)	412,550	206,275	565	16	2	3	
Marin (29,32-34)	652,090	326,045	893	26	4	4	
Livermore (15)	495,818	247,909	679	19		6	
South County (13,14)	567,430	283,715	777	22			7
TOTAL	5,079,176	2,539,588	6,956	169	9	33	22

[1] 50% of annual demand
[2] 70 seats per flight at Concord and Moffett and 50 seats at other airports; 70% load factor
[3] 154 seats with 70% load factor in 2010

FIGURE 7B

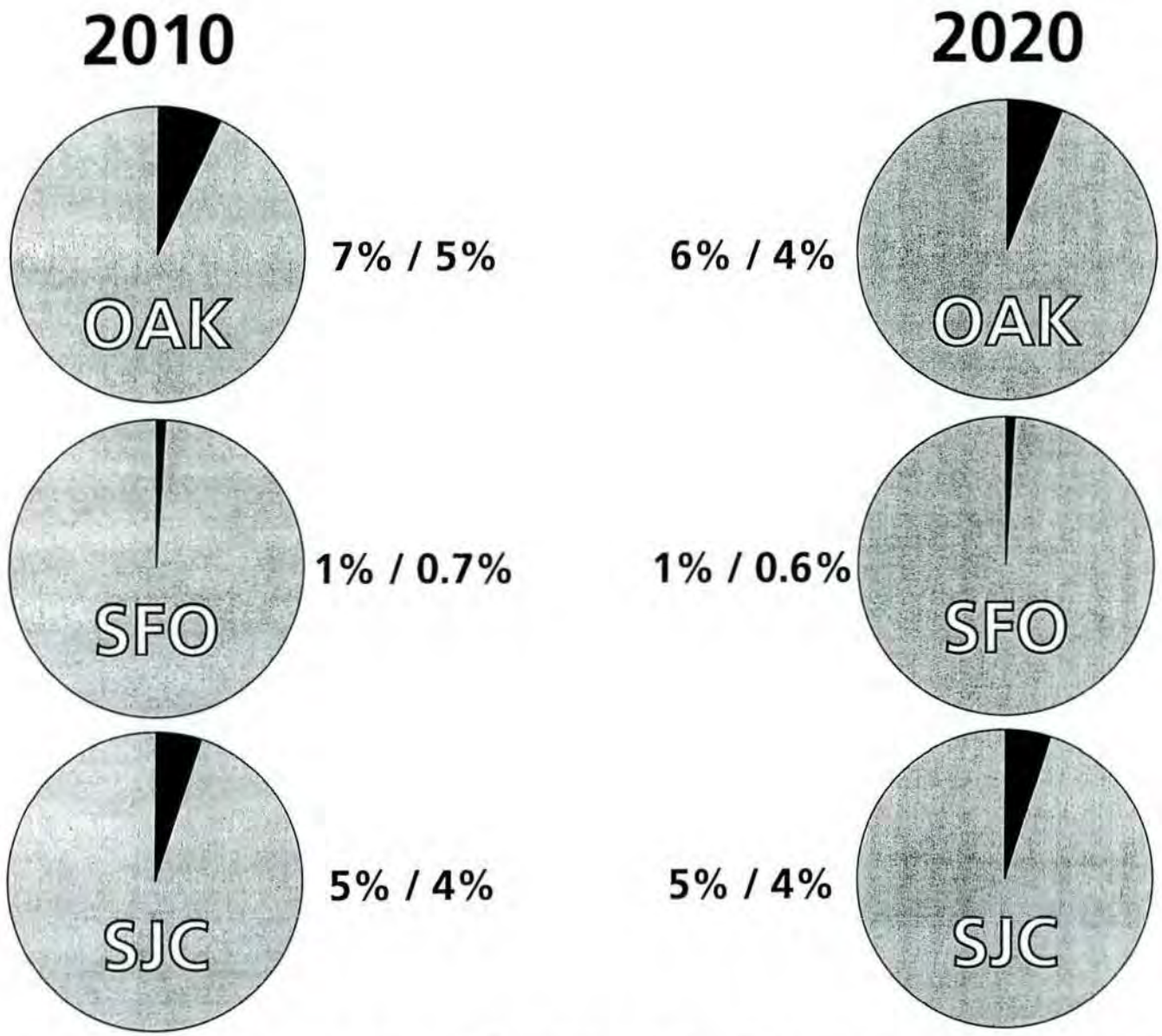
IMPACT OF AIR SERVICE AT ALTERNATIVE AIRPORTS
ON FLIGHTS AT SFO, OAK AND SJC FOR 2020

	California Air Passengers			Daily Flights Added[2]	Daily Flights Eliminated[3]		
Airport (Catchment Area/Superdistricts)	Annual	Annual Served[1]	Daily		SFO	OAK	SJC
Travis/Nut Tree (26)	108,157	54,079	148	3		1	
Moffett (9)	1,407,846	703,923	1,928	29			17
Concord (21-24)	1,568,189	784,095	2,148	33		19	
Sonoma (29,30,31)	549,322	274,661	752	15	3	4	
Napa (25,27,28)	342,067	171,034	468	9	2	2	
Marin (29,32-34)	779,183	391,137	1,072	21	5	4	
Livermore (15)	624,157	312,078	855	16		7	
South County (13,14)	735,816	367,908	1,008	20			9
TOTAL	6,114,737	3,058,915	8,379	146	10	37	26

Figure 8

Percentage Reduction in Flights at OAK, SFO, and SJC Due to Air Service at Satellite Airports

(% Commercial Passenger / % All Flights)



Airport-by-Airport Airspace Assessment
Because of airspace interactions can have regional effects, the specific airspace interactions that would be created by air service at each satellite airport are discussed below.

Buchanan Field (CCR): The length of Runway 19R/1L at 5,010 feet may be inadequate for fully loaded regional jet aircraft operations at Buchanan. The runway may have to be extended beyond 6,000 feet toward the nearby freeways. Radar coverage is attainable at approximately 1,000 feet over Buchanan from the Travis RAPCON and Bay TRACON radar sites. LA Basin-bound departures will encounter delays because of the eastbound departures off SFO and OAK. These departures may have to be "tunneled" out toward the Manteca VORTAC, at low altitudes, until clear of the SFO and OAK eastbound departure routes. A new southbound route may be possible via Skaggs VORTAC to Point Reyes VOR then direct to WAGES (Watsonville). Northbound regional jet departures to Portland or Seattle (if such service is provided) would be subject to similar delays and subsequently be blended into the SFO and OAK northbound departures routed over Red Bluff. Commuter arrivals from the LA Basin into Buchanan would likely be routed over Panoche and north of Sunol direct to the Buchanan VOR. They would receive the same enroute and terminal radar services as arrivals routed over Panoche to OAK. Regional jet commuter operations at Buchanan would encounter daily delays during the peak Bay Area traffic hours because of the necessity to weave those operations through the SFO, OAK, and SJC arrival and departure flows.

Gnoss Field (056): Gnoss Field has a single runway (31/13) that is 3,300 feet long and 60 feet wide and would have to be extended to at least 6,000 feet for fully loaded regional jet operations. Presently, radar coverage is nonexistent below approximately 3,000 feet in the vicinity of Gnoss Field from the Bay TRACON and Oakland Center radar sites. LA-bound commuter departures may have to be routed over the Point Reyes VORTAC and tunneled out at lower altitudes until clear of the SFO and SJC arrivals from Seattle, Portland, and Canada that are routed over Point Reyes to the Woodside VOR. These departures would likely encounter significant delays and be forced to operate below 11,000 feet until clear of the Point Reyes-Woodside traffic. Commuter arrivals from the LA Basin may have to be routed either over Big Sur and west of the coastline toward Sausalito or over Panoche and east of Buchanan Field to Gnoss. Either route would present numerous conflict resolution challenges for Oakland Center and Bay TRACON. Regional jet traffic to east or southbound destinations would be very difficult operationally and result in major delays during peak Bay Area traffic periods.

Livermore Municipal Airport (LVK): Livermore Airport's Runway 25/7L is 5,255 feet long and may have to be extended to accommodate fully loaded regional jet operations. Remote radar coverage is attainable down to approximately 1,000 feet in the vicinity of Livermore Airport from the Bay TRACON radar site. The airport is ideally located for commuter arrivals from the east and from the LA Basin. LA Basin turboprop or regional jet commuters would be routed over Panoche along the same routing for arrivals into OAK. Arrivals from the east (SAC, RNO, SCK, MOD) would be routed toward Tracy to Livermore Airport. Southbound departures would be routed toward Manteca to the LA Basin or Salinas-Santa Barbara and may be tunneled eastbound until clear of SFO and OAK departures routed over Linden and Stockton VORTACs. Departures would be subject to individual releases during peak Bay Area traffic periods, but would not encounter abnormal delays as those likely at Gnoss or Buchanan Field airports.

Napa County Airport (APC): Napa County's Runway 36L/18R is 5,931 feet long and should be adequate for fully loaded regional jet operations. Radar coverage is nonexistent below 2,000 feet over Napa airport from the Bay TRACON and Oakland Center radar sites. Travis RAPCON (Radar Approach Control) should be able to provide radar coverage down at least 1,000 feet in the vicinity of the Napa airport. Southbound commuter departures to the LA Basin would either be tunneled eastbound toward Manteca until clear of the SFO and OAK east and northbound departures or possibly be routed over Point Reyes to WAGES until clear of the Point Reyes-Woodside arrivals to SFO and SJC. Northbound departures would be blended into the OAK and SFO northbound departures routed over Red Bluff. Eastbound commuter departures to RNO, SAC, and MOD would encounter significant delays during peak Bay Area traffic periods.

Sonoma County Airport (STS): Runway 32/14, at 5,115 feet and may have to be extended to at least 6,000 feet to accommodate fully loaded regional jet operations. Radar coverage is nonexistent below 4,000 feet in the vicinity of Sonoma County Airport from the Oakland Center radar site. Sonoma County Airport is situated well north of the San Francisco Bay Area and could conduct regular regional jet commuter operations with little operational impact on the Bay Area arrival and departure routes. Southbound turbojet departures to the LA Basin could be routed over Point Reyes to WAGES and blended into the SFO and OAK southbound departures. Arrivals from the LA Basin would likely be routed over Panoche and east of Sunol to Sonoma County Airport.

South County Airport (Q99): South County Airport is also situated well south of the San Francisco Bay Area and would be able to conduct regional jet commuter operations with little impact on SJC arrivals and departures. Radar coverage is nonexistent below 4,000 feet over South County from the Bay TRACON or Oakland Center radar site. Southbound departures to the LA Basin and Santa Barbara would be routed over Avenal or Salinas. Arrivals from the south could be routed over Avenal or Panoche to South County.

Travis AFB (SUU): Operationally, serving air cargo, turbojet air carrier, or possible future New Large Aircraft (NLA) at Travis AFB would have little impact on the new Northern California TRACON (NOCAL) or Oakland Center – assuming a 2010 or later implementation time. Arrivals from the east would be routed over Sacramento for a long final approach into Travis AFB. Arrivals from the ocean and the northwest would be routed over Point Reyes (PYE) and Williams at an altitude above 10,000 feet until abeam Sausalito or Davis. Departures would have to be interweaved into the north and eastbound departures from OAK and SFO, but these aircraft could be easily sequenced. Oceanic departures (such as those by NLAs to the Far East) would be routed down the Delta over the Golden Gate Bridge.

Moffett Federal Airfield (NUQ): When the U.S. Navy had fighter jet/P3 operations at Moffett, it was always a "thread-the-needle" operation for Bay TRACON to sequence IFR arrivals and release IFR departures. The proximity of SJC necessitated a hold of SJC IFR departures until the Moffett southbound IFR departure (on the southland SID) passed. Regional jet commuter flights into and out of Moffett Federal Airfield would significantly impact SJC arrivals and departures. It would be necessary to hold SJC departures until the Moffett southbound commuters are east of SJC. IFR arrivals to Moffett would also delay SJC northbound and eastbound departures during missed approach weather conditions. Turbojet operations at Moffett would impact IFR arrivals approaching OAK from over Panoche or the southeast. East and northbound turbojet departures would have to be released on a right turn with a

climbing cross-over turn back to the northwest of SJC/Moffett similar to the existing SJC LOUPE Nine Departure route.

4. Use of Moffett Federal Airfield and/or Travis AFB for Air Cargo

Discussion

This sensitivity analysis considers the potential for relocating some existing or future air cargo operations to Moffett Federal Airfield (NASA) or Travis AFB to avoid increasing surface traffic and airside congestion at existing Bay Area commercial airports. As mentioned in the Introduction, we suspend for the moment the real world implementation issues associated with military and federal agency requirements, airline interest, and community acceptance, etc. We simply evaluate these sites on their logistical and operational merits.

As discussed in the Forecast Report, there are two basic types of air cargo operators: (1) the all-cargo airlines that provide door-to-door service, such as FedEx, Airborne, and UPS, referred to as "integrators", and (2) the combination passenger/cargo airlines and all-cargo airlines that generally provide only airport-to-airport cargo lift, such as United Airlines, Nippon Cargo Airlines, and Kitty Hawk, referred to as the "non-integrated" cargo carriers. The non-integrated cargo carriers rely on an extensive network of freight forwarders, consolidators, and others to move air cargo to or from the airport to the shipper or consignee, as appropriate. Each of the two different types of cargo operators have different location and operational requirements and generally serve different types of markets.

When evaluating the potential interest of air cargo carriers to move from the major Bay Area domestic/international airports to alternatives such as Moffett Airfield or Travis AFB, the effect of such a move on each type of carrier's operating environments must be considered.

Integrator Air Cargo Carriers. There are six integrator airlines serving the Bay Area – FedEx, UPS, Emery, BAX Global, DHL, and Airborne. The integrators rely on an extensive hub and spoke system, with their primary hubs located in the U.S. Midwest. The main customers for the integrator carriers are those shippers that require expedited time definite service with door-to-door delivery and in-route tracking. Much of the integrator's business is time sensitive and the integrator carriers must be physically located within close proximity to their major markets such as downtown San Francisco, Marin County, South Bay, Silicon Valley, East Bay, etc. It is important to their market strategy that they have early delivery times and late pick-up cutoff times as much of their cargo must be flown back to the primary Midwest hub located in a earlier time zone.

FedEx has an established hub at Oakland International which serves the local market as well as feeds into and out of the entire U.S. West Coast. Their Oakland location gives them access to San Francisco and the East Bay as well as interstate highway access to Southern California and to points north and east. UPS has their main West Coast hub in Ontario with a smaller local operation at Oakland, which supports their ground operation closely located to Oakland Airport. It is unlikely that either UPS or FedEx would relocate to an airport further away from the inner Bay Area core.

Unlike FedEx and UPS, the other integrator carriers operate aircraft only in the domestic market, but serve the their international market in the capacity of freight forwarders. The implications of this type of operation is that they must not only be physically close to their domestic customers in order to have cutoff times competitive with FedEx and UPS to meet their Midwest hub operations, but they must also

be physically located at an airport that gives them direct access to the multitude of international flights and destinations offered by combination carriers for their overseas markets.

For the these reasons it is unlikely that the integrator airlines will move from their existing locations at Oakland or San Francisco to either Moffett Federal Airfield or Travis AFB. However, for the integrator carriers operating at San Jose International Airport, Moffett offers a very desirable solution to the landside and airside constraints at San Jose airport, and if available for commercial operations, would most likely consider partial or complete relocation to Moffett.

Non-Integrator Carriers. All of the non-integrator carriers are currently located at San Francisco International. The primary reason is because of the network of freight forwarders located at SFO. The freight forwarder is the entity that generates most of the business for the cargo non-integrator carriers. For this reason alone, it is unlikely that the non-integrator, airport-to-airport carriers would relocate other than to perhaps Oakland International, as OAK builds up its own freight forwarder network.

There may, of course, be exceptions to this rule such as international charters or self contained operations such as the U.S. Postal Service (USPS), that may find a Moffett Airfield or Travis AFB a desirable location. But, by and large, it is unlikely that the preponderance of air cargo operators will be interested in relocation for the foreseeable future.

Key Considerations

The availability of either Moffett or Travis would be determined by the operating entity, which is NASA and the Air Force. Both airports would seemingly have excess runway capacity available for air cargo operations. In the case of Moffett Federal Airfield, NASA had proposed to allow commercial air cargo operations into Moffett Airfield as part of the Civil Reserve Air Fleet (CRAF) project in 1996[3]. As discussed in the Environmental Assessment for the proposed cargo operations, "The Federal Acquisition Streamlining Act signed by the President in October 1994, allows the Government to open up military airfields to commercial use by carriers supporting CRAF. In exchange for increasing the amount of aircraft they commit to the CRAF program, the CRAF carriers can gain access to these installations for their commercial business."

The Environmental Assessment reviewed various levels of air cargo operations per day and per year consistent with the Comprehensive Use Plan (CUP) prepared in 1994 to transfer stewardship of Moffett Airfield from the Navy to NASA. This NASA proposal was never affected, but it provides one example of how civil use might occur.

At Travis AFB a joint use agreement was maintained for a number of years to allow for some civil use, although the question of air cargo operations was not explicitly considered.

Using Ferries to Transport Air Cargo

This analysis also suggests that given the distinct cargo roles of SFO and OAK, there would not be a large demand for transfer of air cargo between the two airports via ferry or other ground mode. This is not to say that ferries might not play a role in the delivery of cargo to the airports from different locations in the Bay Area. For instance, a recent study evaluated the concept of loading South Bay air

[3] CRAF Air Cargo Operations, Draft Environmental Assessment, National Aeronautics and Space Administration, June 17, 1996

cargo on a ferry at Moffett Airfield for transport via water to Oakland Airport. The perceived benefit was in the shortened travel time and greater chance of on time delivery given the deteriorating travel conditions on Bay Area highways. Should this type of service make economic sense, it is likely the private companies involved in the air cargo industry could implement the service without a major public role except in providing the docking areas.

5. Future High Speed Rail Service

Discussion

Recently the California High Speed Rail Authority released a draft Business Plan[4] for development of a High Speed Rail system in California by 2016. Frequent High Speed Rail service operating at speeds up to 200 mph between San Francisco, Los Angeles, and San Diego via the Central Valley could provide a new alternative travel mode for a portion of the air travelers in the high volume California corridor. As such, there could be some potential to reduce the number of airline flights at San Francisco, Oakland, and San Jose airports in the future if fares and travel times are competitive.

In terms of alleviating airport congestion, HSR could provide several functions:

- It could carry air passengers who would otherwise be flying from the Bay Area to Southern California airports.
- It could carry air passengers who would otherwise be taking commuter flights from the Central Valley to SFO (or possibly OAK/SJC) airports.
- It could serve as a Bay Area and greater Bay Area ground access mode to OAK, SFO, and SJC, much like the BART and Caltrain system do today, but providing much faster service.
- It would offer all weather reliability.

Analysis Assumptions

- Figure 9 shows the various HSR route options as defined by the High Speed Rail Authority. There are two major surface alignment alternatives that would affect the number of air passengers that might choose to use HSR instead of a regularly scheduled airline flight.

  a) an "Inland" route that would serve the following air destinations: Fresno, Burbank, Los Angeles, Ontario/Riverside, and San Diego

  b) a "Coast" route that would serve Orange County instead of Ontario/Riverside

- A HSR system would not be in operation until 2016 at the earliest; therefore, we have based our analysis on the 2020 horizon year and forecast.
- High Speed Rail would eventually serve both the East Bay and West Bay; therefore, there is a potential for diversion of air travelers from all three airports.
- Introduction of an entirely new travel mode in a market presents a challenge in terms of forecasting future mode shares. HSR ridership would certainly be influenced by rider perceptions of travel times and fares compared to air service. For this analysis we have relied on the work of the HSR Authority in estimating diversion of air passengers to HSR.
- We have tested two diversion scenarios. The Authority projects a 56% diversion of air trips to HSR, assuming the average HSR fare is half that of air. In a sensitivity test by the Authority, HSR fares were assumed comparable to air fares. This assumption lowered the diversion of air travelers to 35%.

[4] California High Speed Rail Authority, Building a High Speed Train System for California-Draft Business Plan, January 2000.

Analysis Approach
Our sensitivity analysis is designed to estimate the potential reduction in flights at each Bay Area airport that would result from initiation of a competing HSR system. We have previously estimated the number of passengers and aircraft operations between each Bay Area airport and each California airport that is a potential HSR destination (Exhibit 4): Fresno, Los Angeles, Burbank, Orange County, Ontario, and San Diego. We are primarily interested in the local Bay Area origin/destination air passengers, as opposed to passengers connecting between flights at an airport, as the likely market for diversion to HSR.

We then apply the two air passenger diversion percentages above to the local air passengers traveling between city pairs to estimate HSR ridership in 2020. We also apply our forecast assumptions in terms of aircraft size and load factors in each market to estimate the number of flights eliminated at each airport due to air passengers taking HSR.

Results
Figures 10 and 11 show the calculated number of flights eliminated at each airport given the two different air passenger diversion estimates of 35% and 56%. Figures 10 and 11 also show the percentage reduction in aircraft takeoffs and landings for: 1) commercial passenger flights only, and 2) all flights projected to use each airports' runways. The reduction in flights at each airport considering all runway users (i.e. passenger, cargo and general aviation operations) and depending on the HSR route alignment would be:

- SFO flights would be reduced by 4-7%.
- OAK flights would be reduced by 5-9%.
- SJC flights would be reduced by 7-13%

Because Orange County is a larger air travel market from the Bay Area than the Ontario/Riverside area, the Coast HSR route would produce the largest diversion of air travelers to a future HSR system. Additionally, a HSR system would have a larger proportionate effect on aircraft operations at Oakland and San Jose Airports because the California corridor is a larger component of the air service provided at these airports.

Overall, the impact of HSR on elimination of smaller commuter aircraft (turboprops and regional jets) using Bay Area runways would be minimal. This is because the only Central Valley destination served by HSR and having significant flight activity would be Fresno (FAT). We have assumed a healthy diversion of Fresno passengers to HSR assuming that travelers from this area would find HSR a convenient ground access alternative to reach SFO; these flights would represent about a quarter of the projected SFO flight reduction attributable to HSR.

Key Considerations
Earlier proposals to construct HSR evoked varying responses from the airline industry, most notably the opposition by Southwest Airlines to a proposed HSR system in Texas. The opposition stems from the concern with subsidizing HSR with public dollars in direct competition with the private sector which must capitalize its investment through fare revenues.

Faced with a truly competitive environment in the California corridor, it can be assumed that the airlines will find ways to continue to make their product competitive as well, as that is essential to their continued profitability and business growth. This may occur through even more innovative ways to price their service and stimulate travel or through cross subsidization of routes, whereby the profitability of longer haul air routes cross subsidize the less profitable short haul air routes where there is competition with HSR.

HSR is intended to compete with air travel by shortening actual door-to-door travel times. For the Bay Area it appears that ground access times to HSR stations would not be that different from that to the airports given the proposed HSR alignment and station locations. Similarly for several major Southern California destinations the HSR stations would be located at or close to the existing airports (e.g. Burbank and Ontario airport stations and Irvine station).

Figure 9

High Speed Rail Routes Under Study

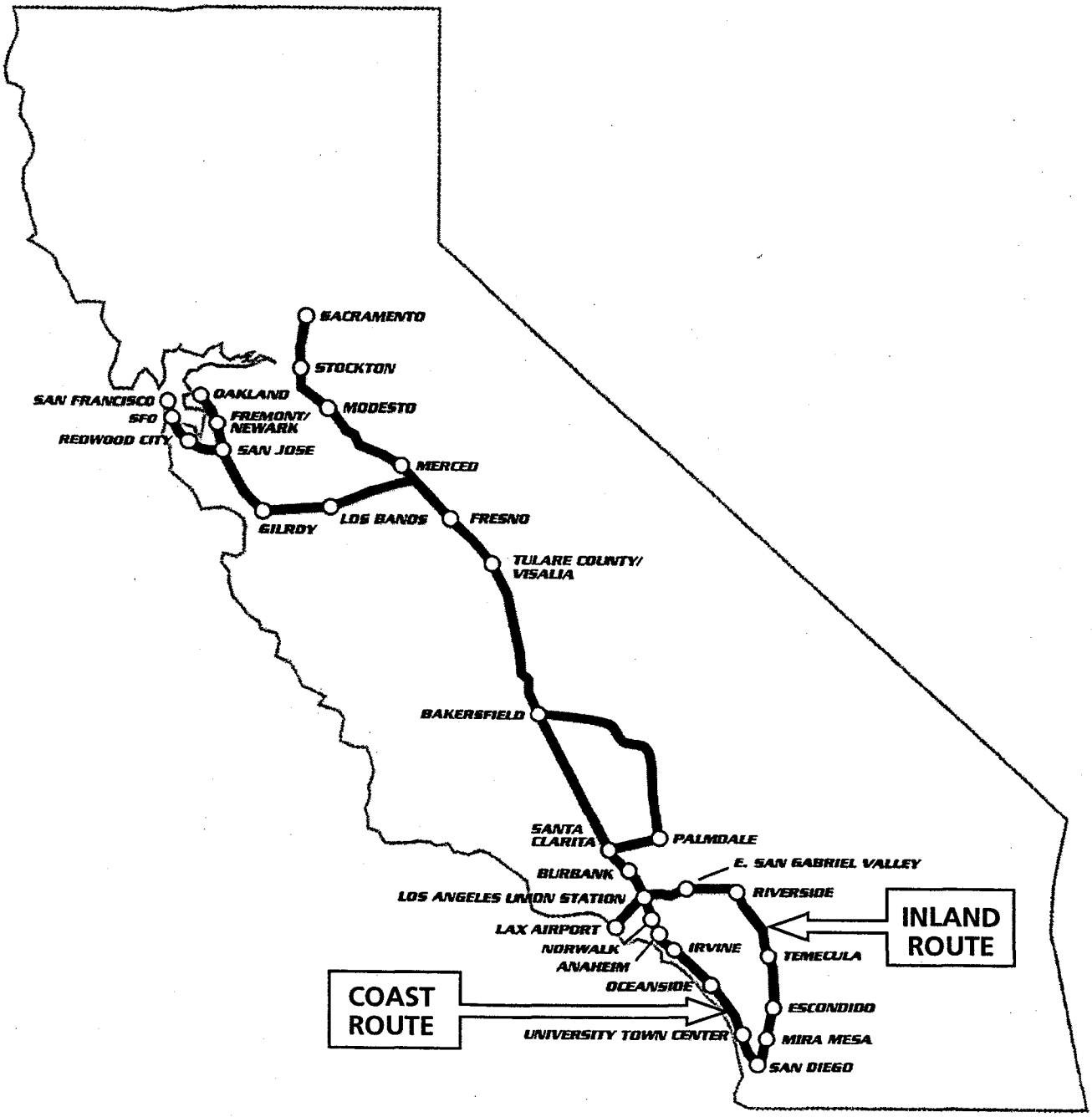


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FIGURE 10A
IMPACT OF HIGH SPEED RAIL (HSR) ON FLIGHTS AT SFO, OAK AND SJC (2020)
56% Diversion Scenario

ANNUAL PASSENGERS[5]				ANNUAL HSR PASSENGERS DIVERTED)			DAILY FLIGHTS ELIMINATED[6]		
	SFO	OAK	SJC	SFO	OAK	SJC	SFO	OAK	SJC
Inland Route									
LAX	3,165,681	2,002,974	2,074,294	1,772,781	1,121,665	1,161,587	45	30	30
BUR	737,335	1,026,193	817,147	412,908	574,668	457,602	11	15	11
ONT	444,022	784,736	482,915	248,652	439,452	270,432	7	11	7
SAN	1,381,897	965,829	1,128,690	773,862	540,864	632,066	20	14	13
FAT	513,875	--	159,920	385,406	--	119,940	30	--	20
TOTAL	**6,242,810**	**4,779,732**	**4,662,966**	**3,593,609**	**2,676,649**	**2,641,627**	**113**	**70**	**81**
PERCENT									
% of All Airport Passengers	10.2%	19.3%	18.4%	5.9%	10.8%	10.5%			
% of All Commercial Passenger Operations (Flights)							(8.0%)	(11.8%)	(13.2%)
% of All Flights, including Air Cargo, General Aviation and Military Operations							(7.1%)	(8.0%)	(11.7%)
Coastal Route									
LAX	3,165,681	2,002,974	2,074,294	1,772,781	1,121,665	1,161,587	45	30	30
BUR	737,335	1,026,193	817,147	737,335	574,668	457,602	11	15	11
SNA	887,234	1,052,527	1,199,589	496,851	799,920	671,770	11	20	16
SAN	1,381,897	965,829	1,128,690	773,862	540,864	632,066	20	14	13
FAT	513,875	--	159,920	385,406	--	119,940	30	--	20
TOTAL	**6,686,022**	**5,047,523**	**5,379,640**	**4,166,235**	**3,037,117**	**3,042,965**	**117**	**79**	**90**
PERCENT									
% of All Airport Passengers	10.9%	20.4%	21.3%	6.8%	12.3%	12.0%			
% of All Commercial Passenger Operations (Flights)							(8.3%)	(13.3%)	(14.7%)
% of All Flights, including Air Cargo, General Aviation and Military Operations							(7.3%)	(9.0%)	(12.9%)

[5] Total passengers minus connecting passengers (24%)
[6] Passengers per operation varies by market: LAX (106.2), BUR (102.2), ONT (108.8), SAN (108.8), SNA (111.6), FAT (35.2)

FIGURE 10B

IMPACT OF HIGH SPEED RAIL (HSR) ON FLIGHTS AT SFO, OAK AND SJC (2020)

35% Diversion Scenario

ANNUAL PASSENGERS[7]				ANNUAL HSR PASSENGERS DIVERTED			DAILY FLIGHTS ELIMINATED[8]		
	SFO	OAK	SJC	SFO	OAK	SJC	SFO	OAK	SJC
Inland Route									
LAX	3,165,681	2,002,974	2,074,294	1,107,988	701,041	726,003	28	18	19
BUR	737,335	1,026,193	817,147	258,067	359,168	286,001	7	10	7
ONT	444,022	784,736	482,915	155,408	274,658	169,020	4	7	4
SAN	1,381,897	965,829	1,128,690	483,664	189,302	395,042	13	5	10
FAT	513,875	--	159,920	256,938	--	79,975	20	--	6
TOTAL	**6,242,810**	**4,779,732**	**4,662,966**	**2,262,065**	**1,524,169**	**1,656,041**	**72**	**40**	**46**
PERCENT									
% of All Airport Passengers	10.2%	19.3%	18.4%	3.7%	6.2%	6.6%			
% of All Commercial Passenger Operations (Flights)							(5.1%)	(6.7%)	(7.5%)
% of All Flights, including Air Cargo, General Aviation and Military Operations							(4.5%)	(4.6%)	(6.6%)
Coastal Route									
LAX	3,165,681	2,002,974	2,074,294	1,107,988	701,041	726,003	28	18	19
BUR	737,335	1,026,193	817,147	258,067	359,168	286,001	7	10	7
SNA	887,234	1,052,527	1,199,589	310,532	368,384	419,856	7	9	10
SAN	1,381,897	965,829	1,128,690	483,662	189,302	395,042	13	5	10
FAT	513,875	--	159,920	256,938	--	79,975	20	--	6
TOTAL	**6,686,022**	**5,047,523**	**5,379,640**	**2,417,189**	**1,617,895**	**1,906,877**	**75**	**42**	**52**
PERCENT									
% of All Airport Passengers	10.9%	20.4%	21.3%	4.0%	6.5%	7.5%			
% of All Commercial Passenger Operations (Flights)							(5.3%)	(7.1%)	(8.5%)
% of All Flights, including Air Cargo, General Aviation and Military Operations							(4.7%)	(4.8%)	(7.5%)

[7] Total passengers minus connecting passengers (24%)

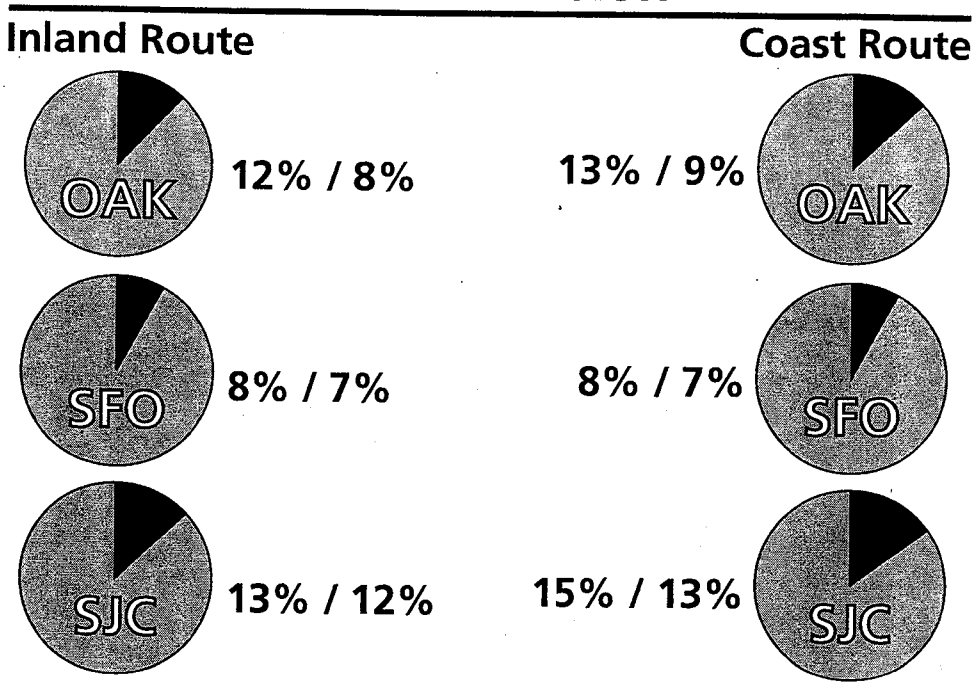
[8] Passengers per operation varies by market: LAX (106.2), BUR (102.2), ONT (108.8), SAN (108.8), SNA (111.6), FAT (35.2)

Figure 11

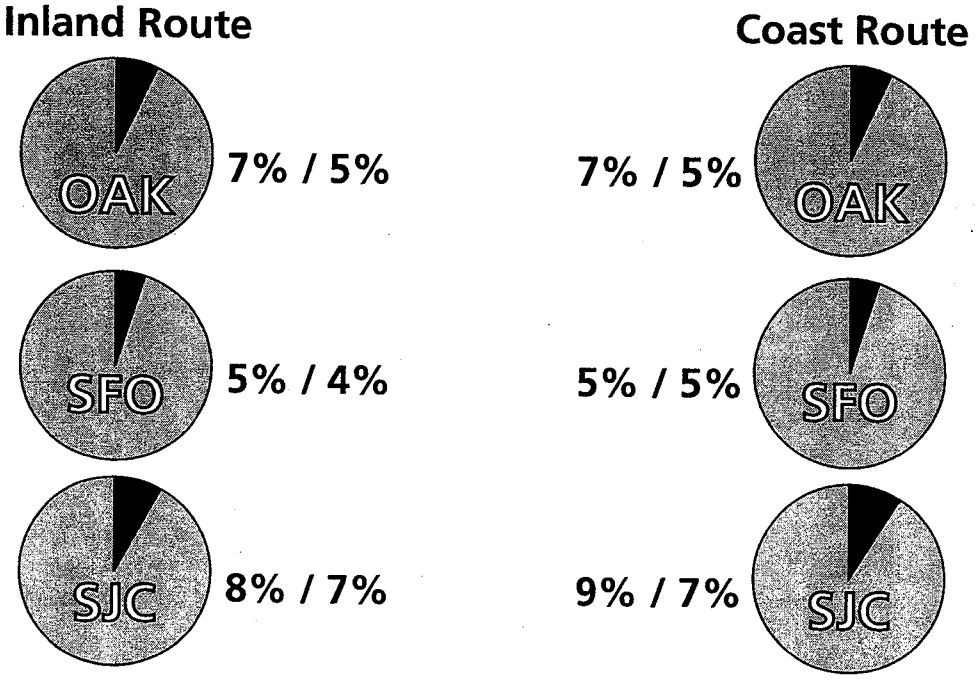
Percentage Reduction in Flights at OAK, SFO, and SJC Due to High Speed Rail (2020)

(% Commercial Passenger / % All Flights)

56% Diversion



35% Diversion



6. Benefits of New Air Traffic Control Technology

Discussion

Airport runway capacity is not a static value, but is affected by changing wind conditions, cloud ceiling (height above ground) and visibility, and changing aircraft mix and traffic volumes. At San Francisco Airport, delays are largely associated with weather conditions that dictate use of single runway instead of dual arrival runways (arrival rate of 30 aircraft per hour or less versus a maximum of 60 in good weather). Between 1996 and 1999, the percentage of hours SFO operated with arrival rates at 30 or less operations per hour was: 11% in 1996, 17% in 1997, 31% in 1998, and 23% in 1999[9]. Technological advances in ground and airborne navigational equipment now being developed could increase airspace efficiency and capacity and also help reduce noise and other environmental effects of air route and runway congestion.

The potential for reducing delays through technology at San Francisco (and in the future at San Jose Airport with its closely spaced air carrier runways) hinges on increasing the amount of time aircraft can land side-by-side under poor weather conditions-- or alternatively by providing new, appropriately spaced runways. The relationship between runway spacing and the types of visual and instrument operations that can take place is described in Figure 12.

Although there are a number of new air traffic control technologies under development, there are a number of issues common to the implementation of all of these technologies. These issues arise when transitioning from an environment where humans make most of the decisions (i.e., pilots and controllers) to an environment where decisions become more automated. The key issues are: the need for high system reliability and accuracy to ensure safe separation between aircraft, the need to build in safety margins in the event of system errors, the need to adequately protect aircraft from wake turbulence effects when aircraft are closely positioned in-trail or laterally (see Figure 13), the need to ensure pilots support and will use new systems, and liability issues. It is perhaps for many of these reasons that the pace of deployment of new technologies can be lengthy (witness the development of the Terminal Collision Avoidance System and runway Microwave Landing System (MLS)- - which was never installed because it was eventually overtaken by even better technology).

The following are the most significant technological advances that could affect airport and airspace capacity in the future.

Wide Area Augmentation Systems (WAAS)

WAAS will allow Global Positioning System (GPS) enroute navigation and Category I approaches to within seven meters accuracy to selected airports. Full WAAS certification is expected by 2002 with most IFR aircraft having full GPS/WAAS receivers by 2005. GPS/WAAS will eventually replace Category I ILS systems. WAAS, complimented by the Local Area Augmentation System (LAAS), will improve the Bay Area air traffic operations through shortened flight times enroute, improve cockpit situational awareness, reduce oceanic separation minimums, and more flexibility in selecting user-preferred routes. WAAS in itself will not reduce delays at SFO because its terminal area mission is to utilize GPS as the primary means for Category I approaches down to

[9] Charles River Associates and John F. Brown Company, Reducing Weather-Related Delays and Cancellations at San Francisco International Airport, April 2000

Figure 12

FAA Runway Separation Requirements

- **700 Feet** – This is the FAA's standard for minimum distance between parallel runways being used for simultaneous landing and takeoffs using visual flight rules.

- **1,200 Feet** – This is the FAA's recommended minimum distance between parallel runway serving aircraft in Design Group V (e.g., B-747 aircraft) and Design Group VI (e.g., NLAs).

- **2,500 Feet** – This is the FAA's required minimum separation between runways in order to meet wake turbulence requirements. Runways separated by less than 2,500 feet are treated as a single runway by air traffic control.

- **3,400 feet** – This is the FAA's minimum separation for dual simultaneous instrument approaches to parallel runways. This separation requires special radar and monitoring equipment that is referred to as a precision runway monitor.

- **4,300 Feet** – This is the FAA's standard for dual simultaneous instrument approaches to parallel runways using conventional instrumentation and radar.

- **5,000 Feet** – Where practical, the FAA recommends that a separation of 5,000 feet be considered when planning new runways.

Figure 13

FAA Final Approach Wake Turbulence Separations

Small aircraft behind large aircraft	**4 miles**
Small aircraft behind B757	**5 miles**
Small aircraft behind heavy aircraft	**6 miles**

Aircraft weight classes are defined as follows:

Small – Aircraft with maximum takeoff weights of less than 41,000 pounds.

Large – Aircraft with maximum takeoff weights of at least 41,000 pounds, but not more than 255,000 pounds.

Heavy– Aircraft with maximum takeoff weights exceeding 255,000 pounds.

Source: FAA Order 7110.65L, Air Traffic Control, February 26, 1998.

approximately 200 feet at qualified airports such as Livermore, South County, and Santa Rosa airports.

Local Area Augmentation System (LAAS)

LAAS is the second augmentation to the GPS signal and is intended to compliment the WAAS and provide a seamless satellite-based navigation system for all phases of flight within 25-30 miles of an airport. It will fulfill those requirements at locations where WAAS reception is unavailable. LAAS will also provide the extremely high accuracy and integrity necessary for Category II/III precision approaches to all runways at selected airports. The FAA has announced its intentions to install LAAS at 143 locations. LAAS, coupled with a Precision Runway Monitoring system (PRM), could permit simultaneous Category II/III approaches to parallel runways separated by at least 3,000 feet. Whether LAAS and PRM will permit a reduction of runway separation standards remains undetermined because of the concern for approach course transgressions and wake vortices hazards.

Automatic Dependent Surveillance (ADS)

ADS transmits position reports based on onboard navigational instruments and relies on datalink to transmit this information. ADS-B (the "B" stands for "Broadcast") is one form of ADS that will broadcast an aircraft's GPS position, identification, altitude, and intent information to all aircraft and ATC facilities. ADS-B will display other ADS-equipped aircraft in the vicinity, hazardous terrain, and severe weather data. ADS-B will eventually be used in areas of non-radar coverage to allow a reduction of separation standards during all phases of flight. ADS-B equipped regional commuters should be able to space themselves from other ADS-B equipped aircraft during IFR operations. This will reduce arrival and departure delays at alternative airports that lack radar coverage down to the field elevation. ADS-B would be a component of a system to reduce lateral aircraft spacing along with dual GPS and improved wake vortex detection. ADS-B will not in itself reduce delays at SFO or increase the capacity for parallel IFR approaches.

Center-TRACON Automation System (CTAS)

CTAS has introduced new computer automation tools to assist air traffic controllers in efficiently descending, sequencing, and spacing arrivals from up to 200 miles from an airport. CTAS have been installed in several major ATC facilities such as: Denver, Miami, Los Angeles, Fort Worth Centers and Dallas-Fort Worth TRACON. CTAS provides two functional capabilities: The Center Traffic Management Advisor (TMA) and the Passive Final Approach Spacing Tool (pFAST). The TMA provides the enroute controllers and the Center traffic management coordinators with the automation tools to manage the flow of traffic into selected airports. The pFAST tool helps TRACON controllers select the most efficient arrival runway sequence within 40 miles of an airport. The FAA plans to install the TMA at 15 Centers and pFAST at 22 TRACONs. CTAS will improve the efficient flow of arrival traffic to the Bay Area airports and should benefit runway capacity be reducing excess spacing between aircraft. However, this spacing can only be reduced to a point, because of the need to allow sufficient gaps in the arrival stream to enable aircraft departures on SFO's crossing runways. CTAS will not in and of itself increase the IFR approach capacity at SFO.

Required Navigation Performance (RNP)

RNP was introduced operationally by Alaska Airlines to increase the safety of instrument approaches into Juneau Airport (JNU), AK. With special training for the flight crews, RNP utilizes dual GPS systems and a moving map display for approaches along the Gastineau Channel into JNU. The preciseness of the GPS system allows the flight crew to display and follow the channel between areas of high mountainous terrain during instrument weather conditions. A combination of RNP and a Precision Runway Monitoring system could theoretically permit simultaneous instrument approaches at SFO down to Category I or Category II minimums. The ability to employ these systems in a closely spaced runway environment depends on resolving a number of issues: GPS reliability, potential centerline transgressions by aircraft, and wake vortices hazards.

Precision Runway Monitoring (PRM)

PRM allows simultaneous, independent instrument approaches at airports with closely spaced parallel runways such as: Minneapolis, St. Louis, Philadelphia, Boston, and JFK. The PRM system uses a high update radar system capable of providing the monitoring controller with less than two-second updates. PRM was commissioned at Minneapolis-St. Paul International Airport (MSP) in 1997. The results from conducting simultaneous instrument approaches at MSP, indicate that using PRM systems with offset ILS localizers will support independent approaches to parallel runways spaced 3,000 feet apart. A second PRM system is currently being installed at Philadelphia International Airport.

Recently, the Airline Pilots Association has issued a safety bulletin concerning ILS PRM approaches at MSP (ALPA Alert Bulletin 2000-2). ALPA recommends that flight crews always evaluate their ILS PRM status and notify Dispatch if they are unable to participate in ILS PRM approach procedures. Apparently, some flight crews are refusing to accept PRM approaches due to lack of training, captain's discretion, or equipment limitations. There may be a reluctance of some flight crews to accept ILS PRM approaches during poor weather conditions. PRM in and of itself will not improve the IFR capacity at SFO without a major change in the required spacing between parallel runways.

Simultaneous Offset Instrument Approaches (SOIA)

By using a combination of the PRM, and an offset ILS localizer and glideslope, it may be possible to reduce the weather " minimums" for simultaneous instrument approaches to parallel runways that are separated by 750 feet between centerlines. SOIA has the potential to increase the IFR approach capacity at SFO from approximately 30 to 38 arrivals per hour[10]. Figures 14a to 14e contrast SOIA with existing and future aircraft arrival scenarios at SFO. The impact of SOIA on airport capacity would depend on the frequency of occurrence of the type of weather during which SOIA would allow simultaneous approaches (estimated to be about 7% of the time). With the SOIA procedure, pilots on the offset approach would fly a straight-but-angled approach down to approach minimums of 1,600 feet and four miles visibility. At this point the aircraft would be about 3,000 feet apart, and pilots would need to be able to see each other or the approach would have to be discontinued.

[10] Federal Aviation Administration, Draft Environmental Assessment Simultaneous Offset Instrument Approach/Precision Runway Monitor Project to serve San Francisco International Airport, March 20, 2000

Several discontinued approaches could precipitate additional arrival delays. The Airline Pilots Association (ALPA) has expressed concerns about the safety of SOIA approaches in a recent article by Captain Ross Sagun (*Airline Pilot Magazine*, April 2000, p.13). Some of those concerns include:

- Protection against wake turbulence
- Inflight overtakes by a faster in trail aircraft
- Sequencing small aircraft in trail or wingtip-to-wingtip with larger aircraft
- Side-by-side formation sequencing by Air Traffic Control
- Placing TCAS (onboard Terminal Collision Avoidance System) in the TA ("Traffic Alert")-only mode, as opposed to RA ("Resolution Advisory") mode

It is also evident that SOIA will only provide an increment of needed capacity during poor weather. Figure 15 compares the estimated arrival demand at SFO in 1999, 2010, and 2020 against the SOIA/PRM aircraft arrival capacity.

Wake Vortex Detection and Avoidance

A possible new FAA technology remedy for ALPA's concerns about wake turbulence protection may be through the research efforts at NASA Langley called Project SOCRATES. Project SOCRATES addresses technologies necessary for the development of sensors and instruments for the detection, location, and tracking of aircraft-generated wake turbulence and other related turbulence phenomena. Project SOCRATES applies acousto-optic techniques previously developed for undersea warfare. An initial SOCRATES system was installed at JFK airport in 1998, and demonstrated the detection of acoustic signals from aircraft-generated wake vortices. In the FAA's *Technology R&D Fact Sheet* on Project SOCRATES there is a notation recommending that "...the SOCRATES Project support the priority program to implement Simultaneous Offset Independent Approaches at the San Francisco International Airport for closely-spaced parallel runways." However, it is not clear whether this project will provide the predictive reliability and protection required for reliance on this mode for aircraft separation.

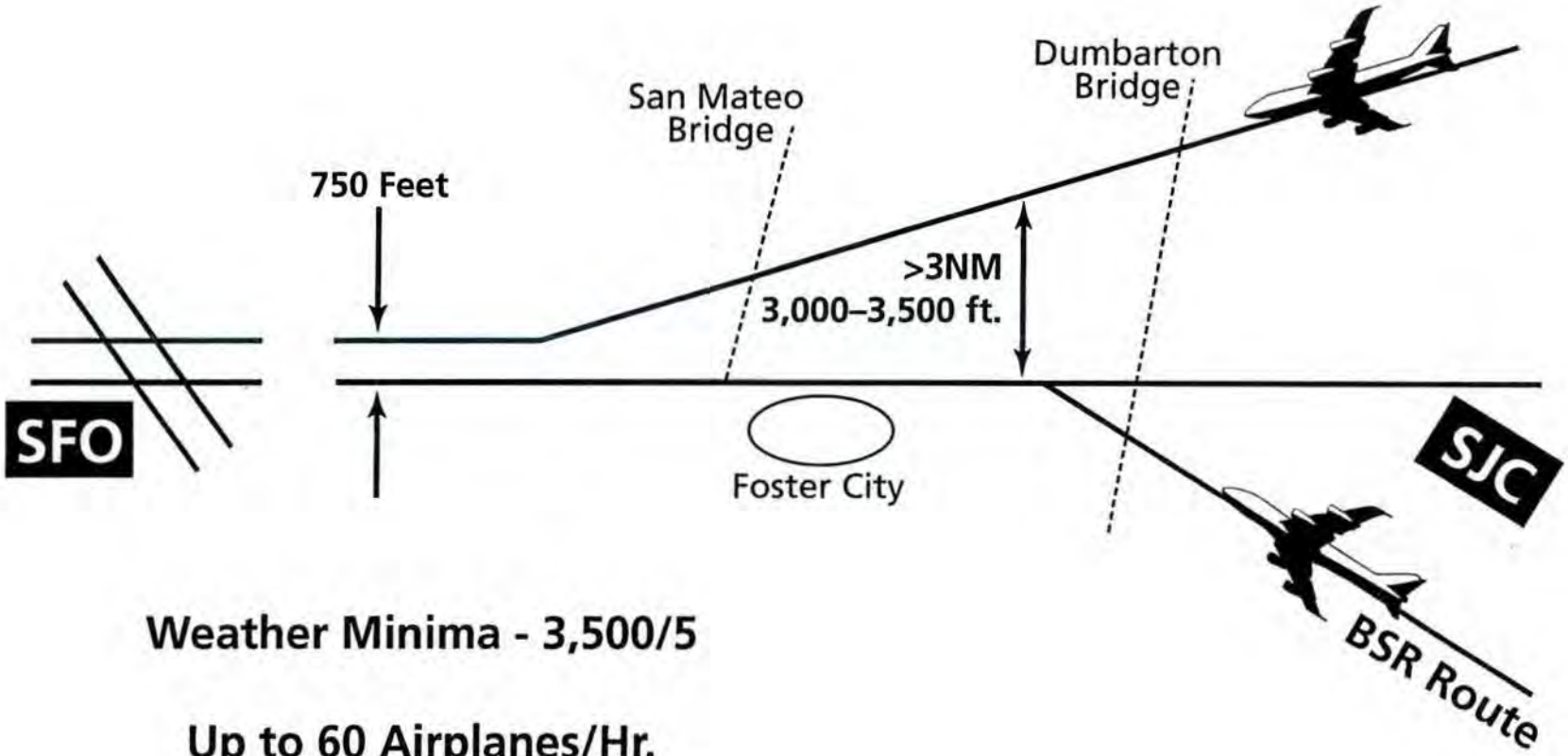
Another approach being developed by the Boeing Aircraft Company is the design of the aircraft wings to incorporate devices (ailerons and spoilers) that would create opposing vortices, reducing the power of the wake turbulence behind an aircraft. Sensors on board the lead aircraft would determine the strength of the vortices and transmit this information to the trailing aircraft which would set it ailerons and spoilers accordingly. By destroying or substantially lessening the force of these vortices, it would be possible to more closely space aircraft together. At SFO, the benefits would be moderated by the need to provide arrival gaps to allow for aircraft departures from crossing runways.

Other Considerations

Another "delay reduction" technique has to do with the FAA's flow control program. During poor weather, the FAA's central air traffic management facility holds aircraft on the ground until the weather clears at the destination airport. Currently, the system can call for flight cancellations even after the weather at the destination airport has cleared. This is due to the inaccuracies in the weather forecast data and use of "stale" weather information. The FAA has initiated a multi-faceted plan to reduce airport delays, in part, through shared use of better weather forecasting data. FAA's central flow control facility would also have more authority to manage air traffic working collaboratively with the airlines.

Figure 14a

Today's Side-By Operation



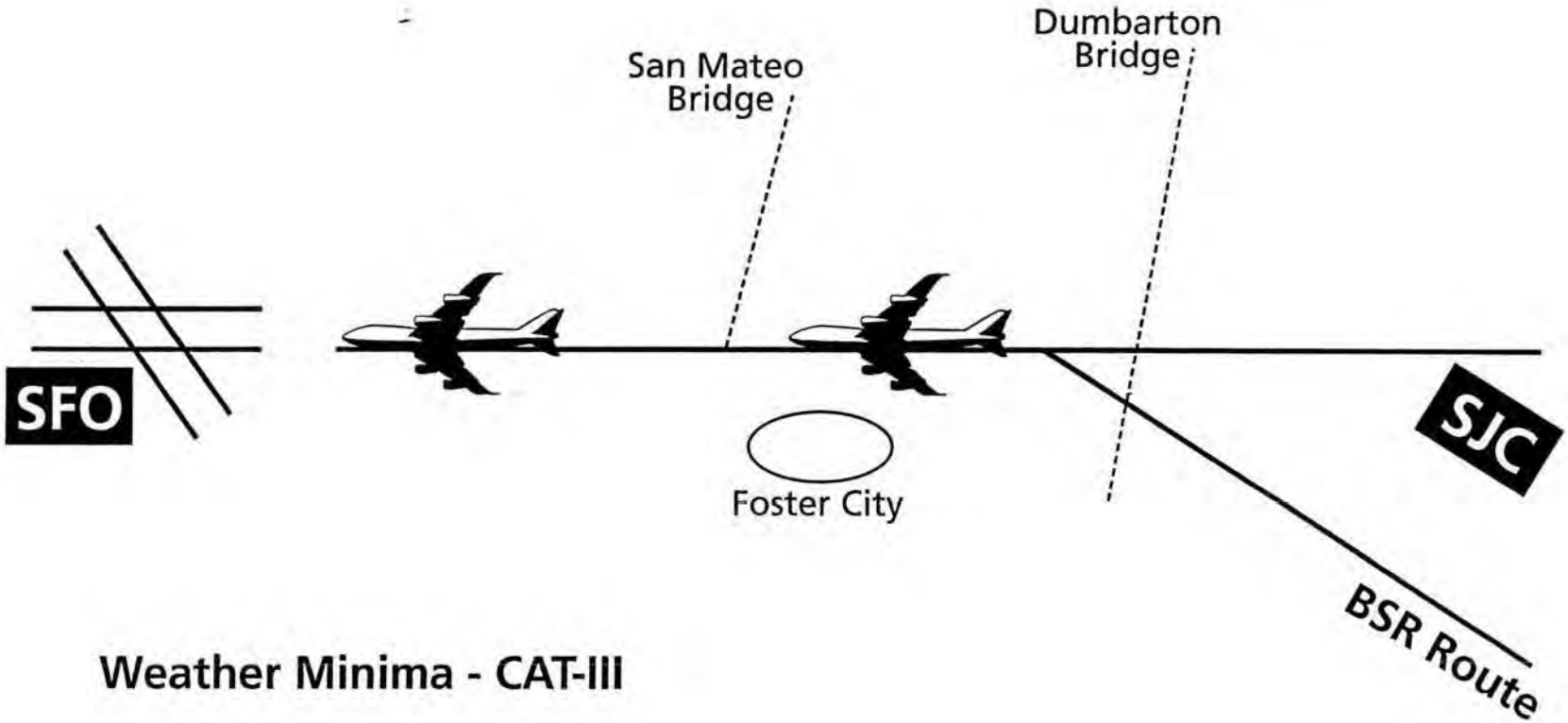
Weather Minima - 3,500/5

Up to 60 Airplanes/Hr.

Source: FAA

Figure 14b

Today's In-Trails ILS



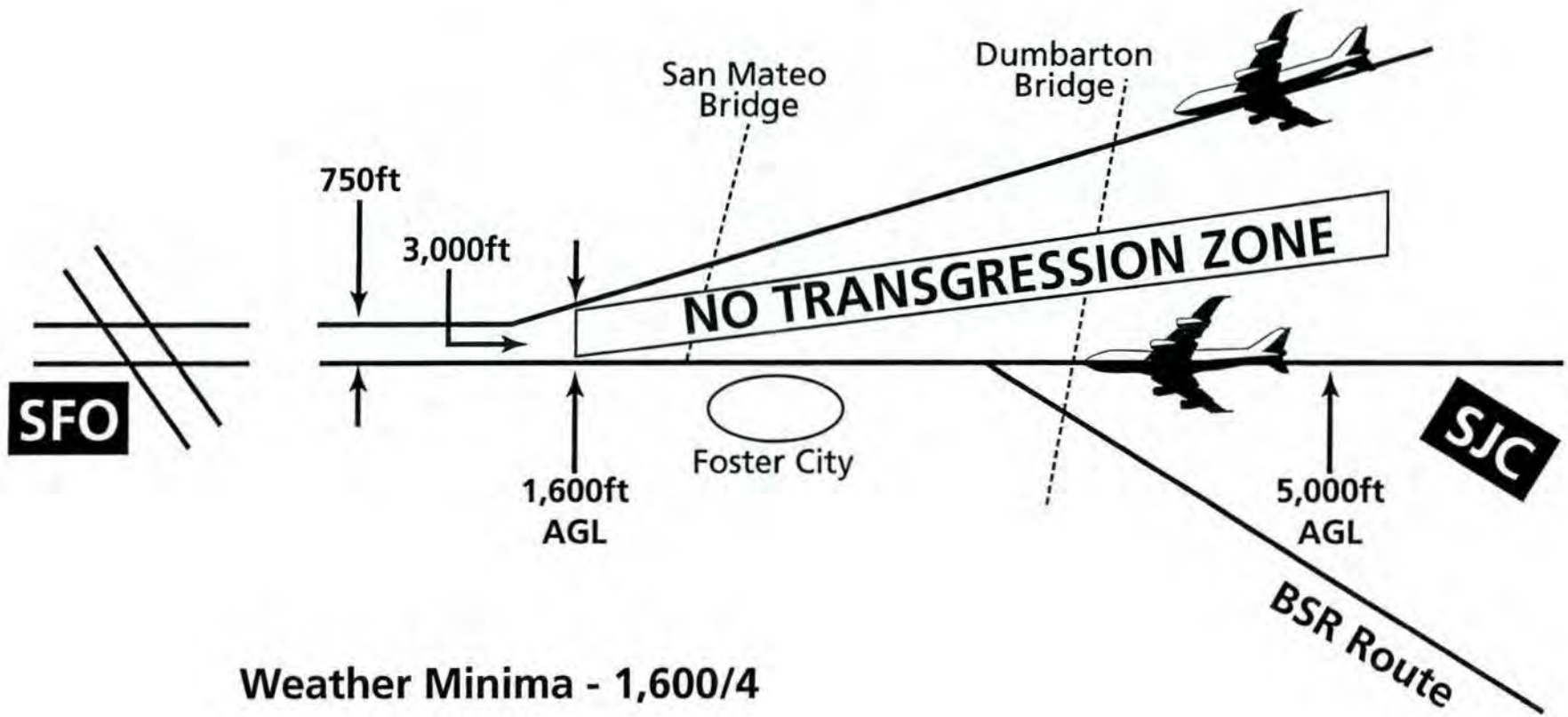
Weather Minima - CAT-III

Up to 30 Airplanes/Hr.

Source: FAA

Figure 14c

SOIA/PRM Operation (Simultaneous Offset Instrument Approaches/ Parallel Runway Monitor)



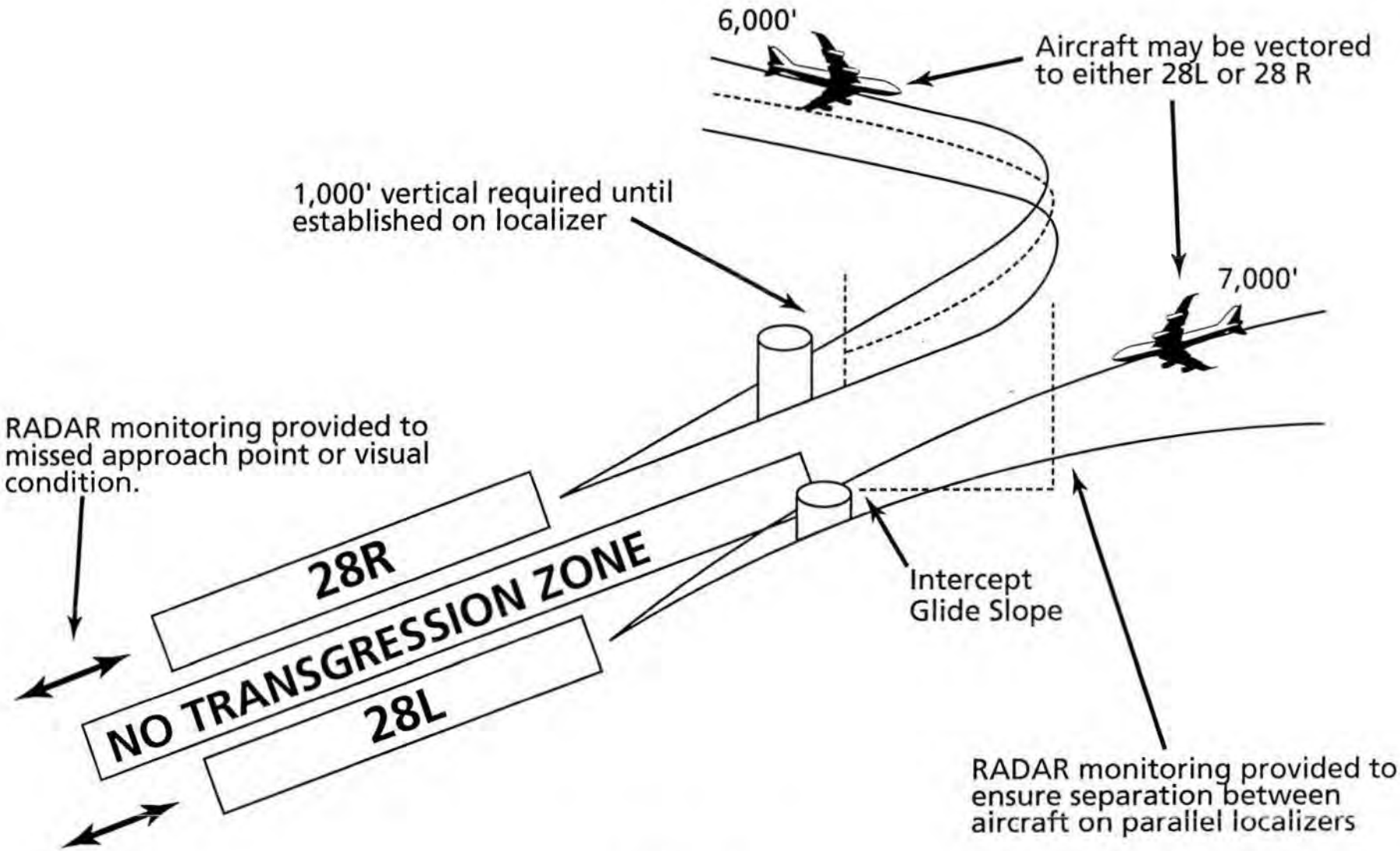
Weather Minima - 1,600/4

35-40 Airplanes/Hr.

Source: FAA

Figure 14d

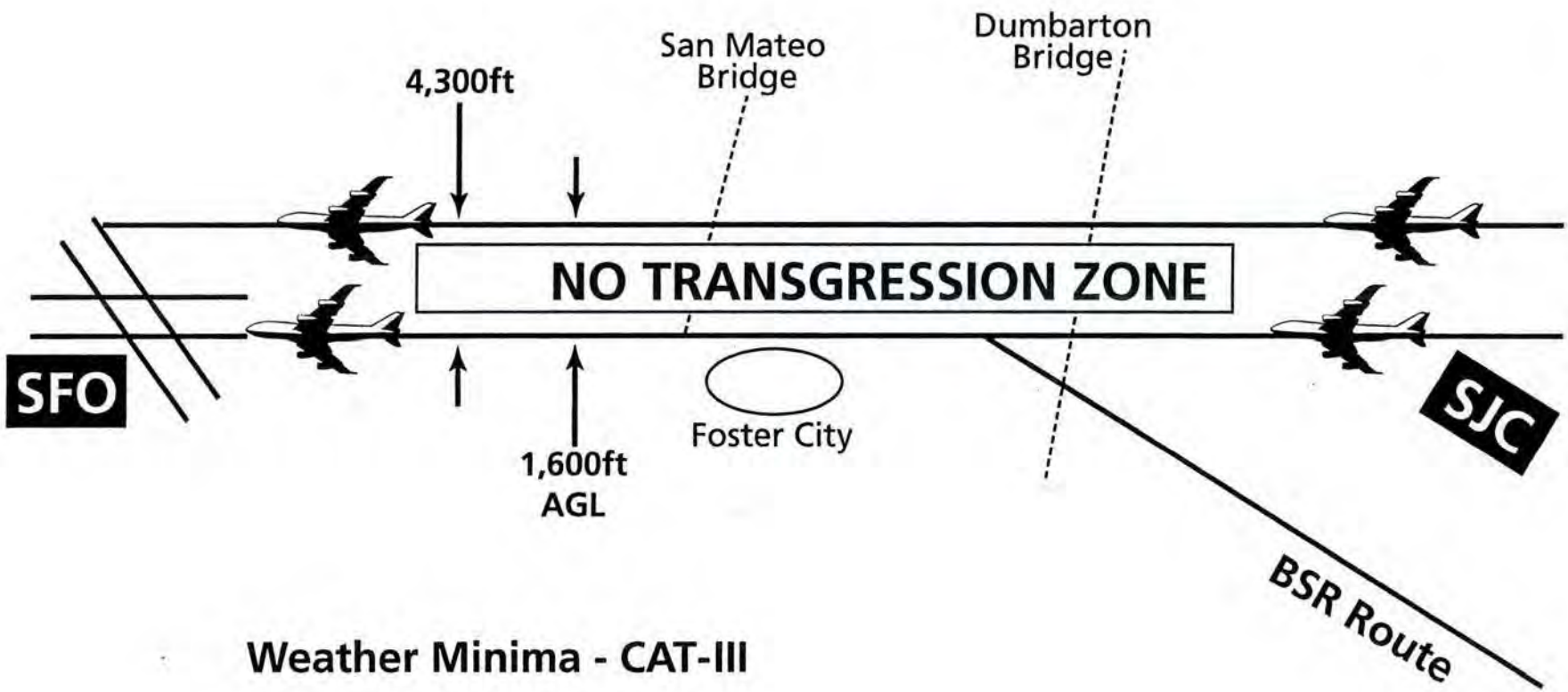
SOIA PRM Approaches (Simultaneous Close Parallel)



Source: FAA

Figure 14e

Simultaneous Parallel Instrument Approaches (Runways 4,300 Feet Apart)



Weather Minima - CAT-III

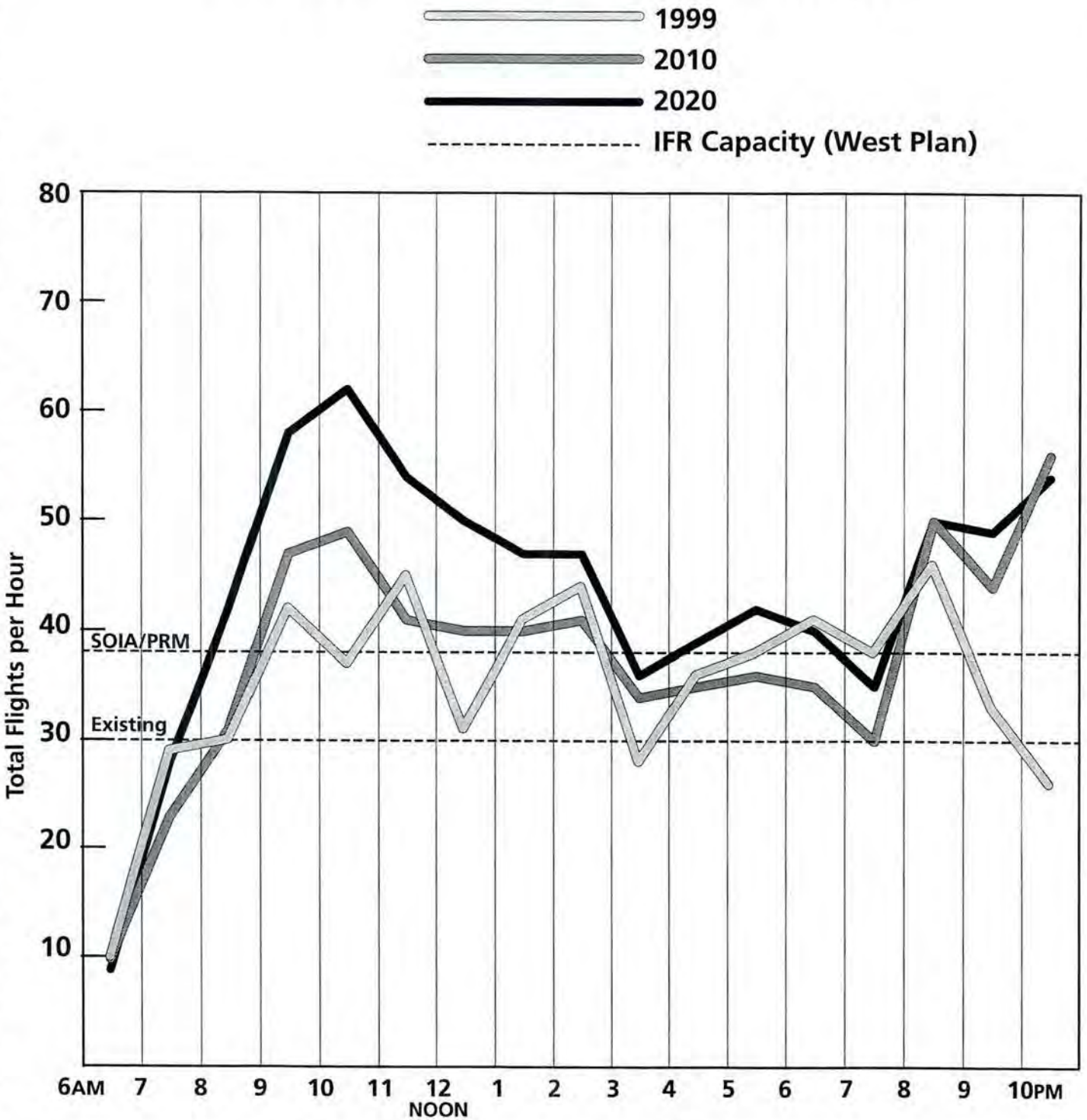
Up to 60 Airplanes/Hr.

Source: FAA

Questions have been raised concerning the impact of possible New Large Aircraft on runway and airspace capacity given the potential of this size of aircraft to generate wake vortices. As discussed above, there could be a need to apply increased separation to smaller trailing aircraft and/or stagger aircraft on parallel visual approaches to SFO. Preliminary wind tunnel tests performed by Airbus (manufacturer of the proposed A3XX-100 and A3XX-200) indicate that the effects would be about the same as a 747 type aircraft. Airbus is also looking at ways to design the wing to produce only short lived wake vortices.

Figure 15

Projected SFO Arrival Demand



Number of Hours At or Above IFR Capacity

	Existing	SOIA/PRM*
1999	12	6
2010	15	9
2020	16	13

*Standard Offset Instrument Arrivals / Precision Runway Monitor

7. Airport Access Controls

Discussion

With the Airline Deregulation Act of 1978, Congress provided more freedom for airlines to choose airports and routes, select schedules, and set fares. Congress also made it more difficult to restrict flights at an airport (control "access") after the airlines agreed to retrofit their aircraft fleets with the quietest aircraft and noise technologies (called "Stage 3" aircraft). The inevitable increase in air traffic has generated new interest in ways to manage the traffic at an airport to conserve capacity and control noise. Historically there have been a variety of efforts to impose operational limits on airports for different reasons: curfews to limit operations in noise sensitive hours, slot controls to limit flights at very congested airports (in the late 60's, the FAA imposed "slot" controls on several highly congested airports such as Chicago, Washington National, New York Kennedy, and New York La Guardia), and landing fees to spread out flight schedules and reduce congestion from severe peaks in activity. Congress recently enacted legislation to phase out the slot controls at the high density airports, as a means to foster further competition within the airline industry.

While not prohibiting noise or access restrictions, Part 161 of the Federal Aviation Regulations lays out the review process required for FAA approval (see Exhibit 5) under the Airport Noise and Capacity Act of 1990. Noise and access restrictions are defined in Part 161 as:

"restrictions that affect the operation of Stage 2 or Stage 3 aircraft, such as limits on the noise generated on either a single event or cumulative basis; a limit, direct or indirect, on the total number of Stage 2 or Stage 3 aircraft operations; a noise budget or noise allocation program that includes Stage 2 or Stage 3 aircraft; a restriction imposing limits on hours of operations; a program of airport-use charges that has the direct or indirect effect of controlling airport noise, and any other limit on Stage 2 or Stage 3 aircraft that has the effect of controlling airport noise. This definition does not include peak-period pricing programs where the objective is to align the number of aircraft operations with airport capacity".

While Part 161 explicitly excludes landing fees under its access review procedures, efforts to impose landing fees as demand management tools (most notably Massport's attempt at Boston Logan Airport) have been also been challenged as to whether they are justified and non-discriminatory. Landing fee structures aimed at limiting or excluding certain types of aircraft such as general aviation or small commuter aircraft are particularly susceptible to this type of challenge.

Analysis Approach

The purpose of our sensitivity analysis is not to design a regulatory approach or to forecast the success of implementing one. Rather, assuming that the effects of access controls would manifest themselves in fewer flight operations, we have followed the pivot point analysis approach to estimate the change in airline flights that would occur for two types of hypothetical access controls. SFO's recent delay study [11] pointed to the contribution of tight airline scheduling (not allowing enough time to turn aircraft around) and fleet sizes (number of small aircraft used for commuter service) on the delay problem (The SFO study did not go as far as to develop a proposed rule for submittal to the FAA). Our analysis addresses some of these same strategies and their effectiveness in 2020.

[11] Reducing Weather Related Delays and Cancellations at San Francisco International Airport, Charles River Associates and the John F Brown Company, April 2000.

Access controls that increase aircraft size. Perhaps access controls could encourage a shift from smaller to larger aircraft in certain markets. To test the effect of increased aircraft size on SFO flights in 2020, we assumed that all commuter aircraft markets would be served by 125 seat aircraft, instead of 50 seat aircraft and that all flights to Southern California would use 180 seat aircraft instead of 125-160 seat aircraft.

- For flights to Southern California, there would be about 29 fewer daily operations at SFO in 2020 (about 1% fewer daily operations on SFO's runways)
- Substituting larger passenger jets in commuter short haul markets would result in about 118 fewer daily operations in 2020 (a 7.3% reduction in daily operations on SFO runways).

Access controls that increase aircraft load factors. If access controls could be designed to increase aircraft load factors, already at historic highs, there would also be fewer aircraft operations. For example, increasing the average load factor for all passenger flights from 73% in 2020 (our realistic assumption) to 75% would reduce total passenger aircraft operations by 37 daily operations (about 2.3% of total daily operations on SFO runways).

Landing Fees. Appropriately structured fees (i.e., fees that are justified and implemented in a non-discriminatory manner) may have some effect on the type of aircraft using an airport or time of day of operations. Peak period charges will be less effective at airports where arrivals and departures are spread fairly uniformly throughout the day, such as at SFO (see Figure 16). Also, very high landing fees might discourage certain users, such as corporate general aviation. Elimination of all general aviation operations would reduce total flights on SFO runways by about 5% in 2020.

Other Considerations

These hypothetical sensitivity tests do not factor in the ability of airlines to make major adjustments in their fleet (cost and financing), or the potential problem of "backfilling" whereby airlines not affected by the rule add flights in response to the "freed up" capacity. Corporate general aircraft operators may willingly pay higher fees because of the location advantages of using SFO and such restrictions may not withstand legal challenge.

Figure 16

Scheduled Operations, by Hour, San Francisco International

Week of June ___, 1999

		Weekly			Average Daily			Percent of Operations		
		Arrivals	Departures	Total Operations	Arrivals	Departures	Total Operations	Arrivals	Departures	Total Operations
off peak	00:00 - 00:59	53	65	118	8	9	17	1.4%	1.6%	1.5%
	01:00 - 01:59		39	39		6	6		1.0%	0.5%
	02:00 - 02:59	19	11	30	3	2	4	0.5%	0.3%	0.3%
	03:00 - 03:59	5	5	10	1	1	1	0.2%	0.2%	0.1%
	04:00 - 04:59	1	2	3						
	05:00 - 05:59	23	3	26	3		4	0.5%		0.3%
shoulder	06:00 - 06:59	46	173	219	7	25	31	1.2%	4.3%	2.7%
peak hours	07:00 - 07:59	198	289	487	28	41	70	4.8%	7.1%	6.0%
	08:00 - 08:59	156	334	490	22	48	70	3.8%	8.3%	6.0%
	09:00 - 09:59	294	224	518	42	32	74	7.2%	5.5%	6.4%
	10:00 - 10:59	239	233	472	34	33	67	5.8%	5.7%	5.8%
	11:00 - 11:59	322	260	582	46	37	83	7.9%	6.4%	7.1%
	12:00 - 12:59	211	296	507	30	42	72	5.2%	7.2%	6.2%
	13:00 - 13:59	208	308	516	30	44	74	5.2%	7.6%	6.4%
	14:00 - 14:59	318	199	517	45	28	74	7.7%	4.8%	6.4%
	15:00 - 15:59	147	274	421	21	39	60	3.6%	6.7%	5.2%
	16:00 - 16:59	229	198	427	33	28	61	5.7%	4.8%	5.2%
	17:00 - 17:59	239	198	437	34	28	62	5.8%	4.8%	5.3%
	18:00 - 18:59	267	207	474	38	30	68	6.5%	5.2%	5.9%
	19:00 - 19:59	259	184	443	37	26	63	6.4%	4.5%	5.4%
	20:00 - 20:59	323	116	439	46	17	63	7.9%	2.9%	5.4%
	21:00 - 21:59	229	202	431	33	29	62	5.7%	5.0%	5.3%
	22:00 - 22:59	159	178	337	23	25	48	4.0%	4.3%	4.1%
shoulder	23:00 - 23:59	126	73	199	18	10	28	3.1%	1.7%	2.4%
	Totals									
	over 24 hours	4,071	4,071	8,142	582	580	1,162	100%	100%	100%
	within 16 peak hours	3,798	3,700	7,498	542	527	1,071	93%	91%	92%
	within peak and shoulders	3,970	3,946	7,916	567	562	1,130	97%	97%	97%

8. Rapid Water/Rail Connection Between SFO and OAK

Discussion

The idea of a single airport with "shared runways" has emerged from time to time as a possible means to balance the demand and supply of runway capacity at SFO and OAK. This concept implies that there are both passengers and airlines who would be indifferent to which airport they use as long as they could get quickly from one to the other. A rapid airport-to-airport surface connection is usually conceived of as a high speed ferry or underground rail line (obviously, these two concepts have vastly different costs). We see the following generic issues with the runway balancing concept.

The Do Nothing Scenario. We start by looking at the question of what would happen to runway utilization absent the proposed high speed connection between the two airport terminals. Under one set of assumptions, airlines may not perceive any advantage in shifting flights to OAK's less crowded runways and simply continue to accept the delays at SFO as the cost of doing business at this airport (in addition, airlines with higher operating costs may not wish to move services to other airports dominated by carriers offering lower fares). The fact that airlines have an investment in their existing route structure and in specific airport facilities cannot be discounted. Higher costs from delays would most likely be passed on to the passenger, and the continuing capacity "squeeze" could lead to larger aircraft and higher load factors.

For Oakland airport, the status quo may benefit incumbent carriers who could offer more effective competition given the more reliable arrival and departure schedules and overall lower level of delays. This is the situation that exists today, as most of the delayed flights at SFO are to the Western States where Oakland does have service matching that of SFO. In fact, our forecasts predict aggressive service expansion by incumbent carriers at Oakland for market reasons that do not require a connection between airports.

Slot Restrictions. An airport-to-airport connection might be needed if certain types of flights are "forced" from SFO to OAK, thus creating a requirement for Peninsula passengers to travel across the Bay. For the reasons noted in the previous section, it would be very difficult to enforce airport access controls that would operate in this manner.

Airline Connections. As explained in our earlier forecast report, each airline has a well defined route strategy. United's hub at San Francisco makes it unlikely that a significant number of their flights could be transferred to OAK on the other side of the Bay, since flight connections would be made physically more difficult for passengers and baggage.
Baggage transfers between different airlines at the two airports also present more complicated logistical issues, since point-to-point carriers like Southwest Airlines handle mainly local origin/destination passengers are their baggage system is not designed for connecting passengers.

Also, whereas an airline will hold a departing connecting flight for passengers on one of their delayed arriving flights, the passengers can usually get quickly from one gate to another. This would not be the case if the connecting flight is at the other airport and the passengers must get across the Bay.

Missed or Cancelled Flights: A rapid airport-to-airport connection would provide some attractiveness in terms of passengers being able to leave from one Bay Area airport and return via another. The most

likely occasion for using an airport-to-airport link in this manner would be a missed or cancelled flight on the return leg of a trip, requiring passengers to change their itinerary to land at the other airport (e.g., leave SFO then return via OAK). The relevant question would be the number of such trips compared to the magnitude of the investment in the airport-to-airport link.

Runway Flexibility in Poor Weather. Another rationale advanced for a connection between SFO and OAK terminals would be to enable aircraft to land at OAK if arrival delays become excessive at SFO. This intermittent use of OAK as a reliever to SFO would create logistical problems for the airlines in terms of crew placement, baggage handling, flight connections, etc. Also, according to a recent study of SFO flight delays [12], on a "bad weather" day a significant percentage of flights arrive one to 60 minutes late, meaning that an air passenger would have just as good a chance of arriving at SFO at the same time on the delayed flight as taking a diverted flight to OAK and then using the rapid airport connection to get back to SFO. In addition, this type of intermittent use would require that OAK develop "excess" terminal and gate capacity to handle peak traffic diversions. Finally, under severe weather conditions at SFO, OAK may also experience major delays and not have any arrival time advantage.

Perishable capacity. If the purpose of the airport-to-airport connection is to equalize use of the runways at both airports, this condition would only last a limited amount of time before the runways at one or both airports again reach capacity. If OAK handled more SFO traffic in the near term, OAK would face the prospect of needing new runways sooner than currently predicted.

Terminal and Gate Capacity. Any connection concept would require that the OAK terminals be expanded to handle the right number and mix of gates for the anticipated additional flights. The cost of terminal expansion at OAK and the rapid ground connection could exceed that of new runway construction at either airport.

Parking Supply. A rapid connection between airports could create uneven parking demands at one or both airports. For example, East Bay air passengers flying out of SFO might use OAK as an alternative to parking at SFO. OAK could then run out of space for its "own" passengers.

[12] Ibid, 3

9. Major New Airport

A concept that has been discussed for a number of years is the idea of constructing a new regional airport in the North Bay or other location outside the Bay Area. In past plans, the location of an airport in the North Bay has been variously identified as Hamilton AFB, Lakeville Rd (Marin County), Napa County airport, Travis AFB, or a new site. Various members of the public have also suggested a site near Skaggs Island, along Highway 37 in the North Bay. Outside the Bay Area, airport sites that have been suggested include Stockton, Sacramento, or the former Crows Landing Naval Air Station.

Historical Context

In a 1980 study the Regional Airport Planning Committee specifically addressed the role of the North Bay airports (North Bay Aviation Study[13]). The Committee concluded that the main function of the existing airports in the North Bay was to serve as reliever airports, meaning that they would assist in meeting regional aviation needs by accommodating smaller general aviation traffic that would otherwise find it necessary to use one of the air carrier airports. The study was conducted with participation of local jurisdictions and was instigated by the impending need to address the future of Hamilton AFB, given the intentions of the Department of Defense to abandon use of the base. The study further indicated that the reliever airport role was intended to be a permanent condition, ruling out the expansion of these airports for air carrier use.

For the purpose of this RASP update we have considered the following general issue areas with respect to a new airport in the North Bay or elsewhere (site undefined).

- Market potential
- Airline interest
- Facilities required
- Order of Magnitude Costs
- Ground access
- Environmental effects

Market Potential

For a new North Bay airport, we estimate passenger demand by considering both the number of air passengers within the airport's potential catchment area as well as the air markets served. We then convert this demand into the number of flights that would be diverted from SFO and OAK, since North Bay passengers presently and in the future would use both airports.

For the purpose of this sensitivity analysis, and not having a specific location for such an airport, we consider the entire North Bay as the catchment area for a new airport, meaning air passengers generated in the four North Bay counties of Marin, Napa, Solano, and Sonoma. This service area definition effectively represents the largest market that could be tapped with a centrally located air carrier facility. The four counties are projected to generate about 10% of the total California corridor air passengers and about 9% of the Domestic air passengers. We note that there could be some Contra Costa county air passengers who would "backtrack" to a North Bay site, but this number would be limited (particularly with a more northerly location).

[13] North Bay Aviation Study, MTC, 1980

The next issue is the identification of the most likely air passenger market(s). International air service would be an unlikely candidate given: 1) the need for a wide range of domestic connecting flights, and 2) the fact that San Francisco is a major destination for many of the international air passengers. Further, San Francisco Airport has recently constructed a state-of-the art $2.5 billion International Terminal that will serve the region's international passengers for years to come.

A more likely market in the near term would be North Bay air passengers traveling to and from the North Bay and Southern California. In this case, a new North Bay airport would serve a similar "satellite" function to that initially provided by OAK and SJC in their earlier days of airline service development. High volume markets such as Los Angeles/Burbank and San Diego could be economically viable, whereas service to smaller California commuter markets (e.g., Fresno, Stockton, and Bakersfield would probably not be). While there could also be a few high density shuttle markets outside of California, we assume that these markets would be developed in the longer term, such as service to Seattle, Portland, Phoenix and Las Vegas.

Our estimates of annual air passengers and diverted flights are shown in Figure 17. Again, these estimates are based on service being provided to LAX, BUR, ONT, SNA, and SAN in the 2010 horizon and to the specific out of state markets identified above in 2020. We assume the same aircraft size and load factors would apply to these markets as for SFO and OAK. Further, we assume that the North Bay airport would capture all passengers, without any "leakage" to the other airports (in reality a new airport would not capture all North Bay passengers, for a variety of reasons, but this assumption is consistent with the sensitivity approach).

The calculated flight reductions for SFO and OAK range between 1.9% and 3.4% depending on the airport and forecast year.

FIGURE 17

Hypothetical Demand at a North Bay Airport

COUNTY	ANNUAL AIR PASSENGERS*				AVERAGE DAILY FLIGHTS REDUCED			
	2010		2020		2010		2020	
	CALIF.	DOM.	CALIF.	DOM.	OAK	SFO	OAK	SFO
Marin	493,700		552,100	440,900				
Napa	249,800		294,100	270,200				
Solano	209,300		253,300	257,700				
Sonoma	498,700		590,400	466,100				
TOTAL	**1,451,500**		**1,689,900**	**1,434,900**	**13**	**24**	**30**	**44**
Passenger Flights Reduced (Percent)					2.8%	2.0%	5.0%	3.1%
Percent of all Flights (%)					1.9%	1.8%	3.4%	2.7%

CALIF. = California air passengers
DOM = Domestic air passengers to states outside of California
* Excludes connecting passengers who would continue to use SFO and OAK

Airline Issues
For the airlines, the major question would be the ability to fill up aircraft and return a profit on the new routes. The financial commitment for initiating service would be substantial given the continuing commitments to planned improvements at SFO/OAK/SJC by the existing carriers. Existing and/or new carriers would have to underwrite the cost of an entirely new facility, suggesting that a very large number of flights would have to be shifted to a new airport to spread the cost over multiple carriers.

A 1976 Feasibility Study of joint use of Travis AFB[14] included a reconnaissance of airline interest, and found that there was limited, if any, interest in initiating California type service at Travis AFB. There would have to be a robust local market for an airline to even consider the magnitude of investment required and duplication of facilities at existing airports.

Facilities Required
A new airport on open land would need to duplicate all the basic facilities provided at existing airports. Airlines would most likely require two runways, so that planes could get in and out if one runway is closed for repairs or emergencies. A new terminal, parking, circulation, access roads, air traffic control facilities, airline ground support and maintenance facilities, utilities, etc would need to be constructed and operational when the airport begins service. Ground access improvements could consist of new roads, widening of existing highways and local roads, new freeway interchanges, etc., depending on the site location.

Sufficient land would need to be acquired not only for the runways but also for safety areas and buffer zones around the runways.

Costs
Given the facilities and land acquisition mentioned above, it is quite possible a new airport could cost several billion dollars in the future given escalation in construction and land costs and considering such unknowns as soil condition and mitigation costs.

Currently, the North Bay does not have a road network that is well developed in terms of meeting the needs of the existing population, let alone the growth projected for the future. While there is general agreement on improvements, such as widening Highway101 in Marin and Sonoma counties, there is limited funding presently available to make these improvements. East -West routes between the North Bay counties are even more constrained in their design and capacities, including Routes 12, 37, 116,and 121. Significant upgrades to one or more of these routes would require funds that have not been identified in MTC's long range Regional Transportation Plan. Improved transit service would be even more problematic given continuing constraints on sources of transit operating funds.

On the other hand, the existing airports are well positioned with respect to the existing transit infrastructure. The $1.5 billion BART extension to SFO will be completed in 2002 and funds are available to upgrade Caltrain commuter rail service on the Peninsula. OAK is just 3 miles from BART, and SJC is located between Caltrain on the west and the county light rail system on the east. Major highway and road improvements have and will also be taking place in the vicinity of these airports, such as road widenings, interchange improvements, and local road connections.

[14] Travis Air Force Base Joint Use Feasibility Study, MTC, 1976

In part as an alternative to a new commercial airport, the 1980 North Bay Aviation Study recommended that the concept of an off airport terminal be considered. Such a terminal or terminals could be a hub for frequent transit service to the region's major airports and provide air passengers with other amenities, including flight ticketing, information, and baggage handling.

Environmental Issues

From a land use perspective, the North Bay has extensive agricultural lands (vineyards, dairies, and pasture lands) as well as large tracts of wetland and aquatic resources of national importance (such as the San Pablo Bay National Wildlife Refuge). The North Bay counties are also experiencing the highest growth rates in the Bay Area and contain over half the land in the region projected to be available for future development. While the rural character suggests that there could be adequate open space to locate a new airport, the growing population also means that more people will be affected by aircraft arrival and departure routes into a new airport in the future (for example a site near Skaggs Island would be within a relatively close 10 miles of Vallejo, Napa, Petaluma and Sonoma). Because the area is largely rural, low ambient noise levels also mean that a new aircraft noise would create a significant noise source that does not presently exist (Indeed, even the new Denver airport, located far from downtown Denver, received numerous noise complaints because new flight patterns shifted noise over areas that had not experienced aircraft noise with the former downtown Stapleton Airport).

Near Route 37 and Skaggs Island, much of the land is held in public ownership for wildlife habitat, flood control, and treated municipal sewage processing and disposal. Future use of Skaggs Island Naval Base will likely be limited to wetland restoration and eco-tourism. Major public agency goals for this area include preservation of the habitat for birds and other wildlife, expansion of wetlands, and continued agriculture. Airports developed on private land in close proximity to Route 37 would not be consistent with the planned uses for the surrounding areas and could result in overflight of the San Pablo Bay Wildlife Refuge which is heavily used by migrating birds (possibly creating safety issues in terms of possible bird strikes or ingestion into engines). Such impacts would certainly need careful attention in the environmental review process.

Airport Sponsor

There would need to be a viable airport sponsor for any new airport. It is not clear who would sponsor a new airport—private interests, local communities, existing airports, or other entities. Without an identified or likely sponsor, the discussion of a new airport is largely academic.

Local Support

All potential airport sites would have certain drawbacks, but the main ingredient for successful implementation of a new airport would be strong local interest and support at the political and community level. This interest was not evidenced in the 1980 North Bay Aviation Study, nor is it evidenced today. Local interest could emerge if congestion and the inconvenience of getting to and from SFO and OAK grows, but there are other ways to address the inconvenience issue such as improved ground transportation as discussed above. Absent strong commitments to a new airport from the public, airlines, and local community leaders, the most likely outcome would be the type of opposition to airport expansion that was evidenced in the past debate over the future use of Hamilton AFB.

Other Airport Locations

Many of the issues with a North bay Airport would also apply to an airport at another location within or outside the Bay Area. The chief drawback of an airport outside the Bay Area would be the remote location and lack of convenience for passengers originating in or destined to the central Bay Area. Expansion of airports outside the Bay Area (e.g. Sacramento, Stockton, Crows Landing, etc.) would serve the out of region travelers that now come to the Bay Area airports, but these passengers are a small share of SFO passengers (3-4%) and many would still need to use SFO for domestic and most all of the international air service that would probably not be available at their local airport.

10. Summary

Figure 18 compares the effectiveness of the different sensitivity tests in terms of reducing flights at SFO in 2020. As noted at the bottom of the figure, the estimated reductions in flights for individual sensitivity tests cannot be added together because this would double count the effectiveness of the different measures.

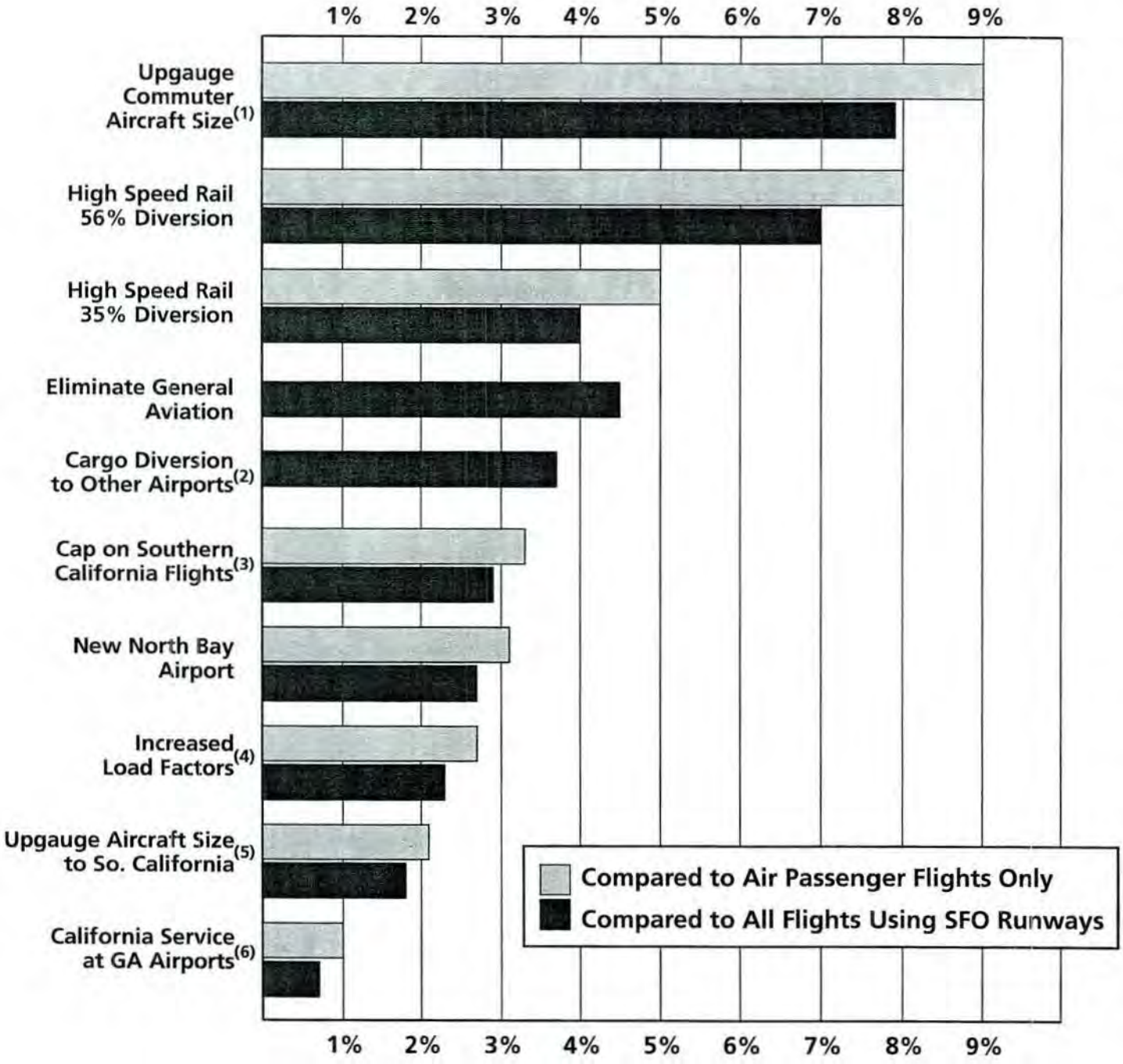
Also, one of the objectives of the report was to identify a strategy or group of strategies for testing in the airport and airspace capacity simulation model (SIMMOD) which will be used to analyze the capacity of the regional airport system under different assumptions. For modeling purposes, we suggest that the following strategies be evaluated at SFO - -the airport with the greatest amount of delay.

- Elimination of general aviation
- Increased commuter aircraft size
- Increased aircraft size for flights to Southern California

These are hypothetical strategies, whose feasibility and implementation potential have not been proven.

Figure 18

Projected Reduction in Operations at SFO (%) -2020-



(1) Aircraft size increased to 126 passengers
(2) Half of freighter (all cargo) flights
(3) Limit number of Southen California flights to 1998 levels
(4) Airline load factors increase from 73% to 75%
(5) Increase aircraft size to 180 seats
(6) So. Calif. service spread to General Aviation airports

NOTE: Reductions cannot be added together

SOURCE: Sensitivity Report - Factors Affecting Demand and Capacity

Exhibit 1

PRIMARY RUNWAY ALTERNATIVES

ALTERNATIVE	SFO	OAK	SJC
1 Master Plans	**Existing** No change in runways	**Master Plan** Airfield improvements include taxiways and aircraft holding bays only	**Master Plan** Air carrier runways extended to 11,000 ft. (700 ft. separation); various taxiway improvements
2	**Reconfigured BX/ F2** Independent "West Plan" arrivals and departures.	**Master Plan** (Same as above)	**Master Plan**
3	**Reconfigured A3** Independent arrivals but not departures.	**Master Plan** (Same as above)	**Master Plan**
4	**Existing** No change in runways	**New Inboard Runway** (750 ft. spacing). Staggered arrivals and departures required	**Master Plan**
5	**Existing** No change in runways	**New Outboard Runway** (2,500 ft. spacing, minimum) Independent arrivals and departures possible	**Master Plan**
6	**Reconfigured BX/F2/A3**	**New Outboard Runway** (Same as "5" above)	**Master Plan**

Exhibit 2

Figure C.6.

Air Passenger Forecasts by County and Air Market (Annual Passengers)

2010 Forecasts

County	California	Domestic	International	Total
Alameda	2,866,002	4,844,202	1,006,116	8,716,319
Contra Costa	1,471,057	2,624,788	788,165	4,884,011
Marin	542,509	1,133,220	284,887	1,960,616
Napa	274,490	657,725	120,228	1,052,443
San Francisco	4,042,355	10,657,895	4,077,021	18,777,271
San Mateo	1,651,659	5,774,660	1,791,437	9,217,757
Santa Clara	3,833,990	9,074,245	1,766,576	14,674,810
Solano	230,100	612,912	923,446	1,766,458
Sonoma	547,906	1,128,371	249,473	1,925,749
Bay Area Subtotal	15,460,069	36,508,018	11,007,349	62,975,435
Out of Region	1,041,233	2,704,486	775,707	4,521,427
TOTAL	**16,501,302**	**39,212,504**	**11,783,056**	**67,496,862**
Connecting Passengers				*14,811,017*
TOTAL AIR PASSENGERS				**82,307,879**

2020 Forecasts

County	California	Domestic	International	Total
Alameda	3,467,538	6,326,444	1,679,689	11,473,671
Contra Costa	1,825,598	3,515,983	1,346,900	6,688,481
Marin	641,853	1,445,586	465,276	2,552,715
Napa	342,067	885,807	208,033	1,435,908
San Francisco	4,704,231	13,377,059	6,542,141	24,623,432
San Mateo	1,955,898	7,380,929	2,932,687	12,269,514
Santa Clara	4,556,136	11,630,654	2,898,938	19,085,727
Solano	294,707	845,028	1,653,433	2,793,168
Sonoma	686,652	1,528,184	430,129	2,644,965
Bay Area Subtotal	18,474,681	46,935,675	18,157,227	83,567,582
Out of Region	1,279,094	3,704,777	1,391,809	6,375,681
TOTAL	**19,753,775**	**50,640,452**	**19,549,036**	**89,943,263**
Connecting Passengers				*21,184,101*
TOTAL AIR PASSENGERS				**111,127,364**

Exhibit 3A

2010 Air Passengers by Superdistrict

5/10/2000 (R2A forecast scenario)

#	County	Name	% of Total for each County	2010 Passengers
				TOTAL
1	San Francisco	Downtown San Francisco	65.0%	12,205,276
2	San Francisco	Richmond District	18.9%	3,544,132
3	San Francisco	Mission District	12.5%	2,349,671
4	San Francisco	Sunset District	3.6%	678,192
5	San Mateo	Daly City/San Bruno	37.9%	3,494,954
6	San Mateo	San Mateo/Burlingame	37.1%	3,416,212
7	San Mateo	Redwood City/Menlo Park	25.0%	2,306,592
8	Santa Clara	Palo Alto/Los Altos	13.2%	1,943,865
9	Santa Clara	Sunnyvale/Mountain View	30.8%	4,518,677
10	Santa Clara	Saratoga/Cupertino	15.9%	2,340,041
11	Santa Clara	Central San Jose	14.4%	2,112,647
12	Santa Clara	Milpitas/East San Jose	10.0%	1,474,657
13	Santa Clara	South San Jose/Almaden	11.1%	1,624,215
14	Santa Clara	Gilroy/Morgan Hill	4.5%	660,707
15	Alameda	Livermore/Pleasanton	16.5%	1,437,265
16	Alameda	Fremont/Union City	15.3%	1,333,401
17	Alameda	Hayward/San Leandro	16.0%	1,398,258
18	Alameda	Oakland/Alameda	33.9%	2,954,129
19	Alameda	Berkeley/Albany	18.3%	1,593,267
20	Contra Costa	Richmond/El Cerrito	14.5%	710,036
21	Contra Costa	Concord/Martinez	25.8%	1,258,374
22	Contra Costa	Walnut Creek/Lamorinda	24.6%	1,202,903
23	Contra Costa	Danville/San Ramon	23.2%	1,133,931
24	Contra Costa	Antioch/Pittsburg	11.9%	578,766
25	Solano	Vallejo/Benicia	62.1%	1,096,879
26	Solano	Fairfield/Vacaville	37.9%	669,579
27	Napa	Napa	62.2%	654,930
28	Napa	St. Helena/Calistoga	37.8%	397,513
29	Sonoma	Petaluma/Sonoma	40.9%	788,117
30	Sonoma	Santa Rosa/Sebastopol	45.0%	867,093
31	Sonoma	Healdsburg/Cloverdate	14.0%	270,539
32	Marin	Novato	16.3%	319,579
33	Marin	San Rafael	44.0%	862,872
34	Marin	Mill Valley/Sausalito	39.7%	778,166
TOTAL				62,975,434

Exhibit 3B

2020 Air Passengers by Superdistrict

5/10/2000 (R2A forecast scenario)

#	County	Name	% of Total for each County	2020 Passengers
				TOTAL
1	San Francisco	Downtown San Francisco	65.4%	16,103,595
2	San Francisco	Richmond District	18.4%	4,524,254
3	San Francisco	Mission District	12.7%	3,137,742
4	San Francisco	Sunset District	3.5%	857,841
5	San Mateo	Daly City/San Bruno	37.9%	4,644,445
6	San Mateo	San Mateo/Burlingame	37.2%	4,562,357
7	San Mateo	Redwood City/Menlo Park	25.0%	3,062,712
8	Santa Clara	Palo Alto/Los Altos	12.6%	2,399,336
9	Santa Clara	Sunnyvale/Mountain View	30.9%	5,890,694
10	Santa Clara	Saratoga/Cupertino	15.9%	3,042,170
11	Santa Clara	Central San Jose	14.4%	2,748,209
12	Santa Clara	Milpitas/East San Jose	10.1%	1,924,675
13	Santa Clara	South San Jose/Almaden	11.0%	2,104,849
14	Santa Clara	Gilroy/Morgan Hill	5.1%	975,795
15	Alameda	Livermore/Pleasanton	18.1%	2,076,277
16	Alameda	Fremont/Union City	15.1%	1,737,598
17	Alameda	Hayward/San Leandro	16.1%	1,843,640
18	Alameda	Oakland/Alameda	33.2%	3,807,972
19	Alameda	Berkeley/Albany	17.5%	2,008,183
20	Contra Costa	Richmond/El Cerrito	14.1%	944,559
21	Contra Costa	Concord/Martinez	25.0%	1,674,357
22	Contra Costa	Walnut Creek/Lamorinda	24.4%	1,630,077
23	Contra Costa	Danville/San Ramon	23.8%	1,594,188
24	Contra Costa	Antioch/Pittsburg	12.6%	845,301
25	Solano	Vallejo/Benicia	63.3%	1,766,891
26	Solano	Fairfield/Vacaville	36.7%	1,026,277
27	Napa	Napa	63.4%	910,882
28	Napa	St. Helena/Calistoga	36.6%	525,026
29	Sonoma	Petaluma/Sonoma	40.9%	1,082,840
30	Sonoma	Santa Rosa/Sebastopol	43.4%	1,146,939
31	Sonoma	Healdsburg/Cloverdate	15.7%	415,187
32	Marin	Novato	17.9%	456,571
33	Marin	San Rafael	43.5%	1,111,702
34	Marin	Mill Valley/Sausalito	38.6%	984,443
TOTAL				83,567,584

Exhibit 4

Disaggregation of Air Service Area Passengers
Domestic Airline Operations by Bay Area Airport and Aircraft Type
Calendar Years 2010 and 2020

				2010			2020		
Origin	Dest.	Airline	Aircraft	Operations	Passengers	Seats	Operations	Passengers	Seats
OAK	ABQ	WN	738	1,460	192,775	275,940	2,920	402,997	551,880
OAK	ABQ	WN	73G	1,460	151,976	217,540			
SFO	ACV	UA	ER4	2,190	76,498	109,500	7,300	266,533	365,000
SFO	ACV	UA	SF3	3,650	84,148	120,450			
SJC	ACV	AA	ER3				730	19,723	27,010
SJC	ACV	AA	ER4				2,190	79,960	109,500
SFO	ANC	AS	739	730	90,268	129,210	730	94,353	129,210
OAK	ATL	DL	738				1,460	172,713	236,520
SFO	ATL	DL	738	1,460	165,235	236,520	1,460	172,713	236,520
SFO	ATL	DL	763	1,460	222,354	318,280	730	116,208	159,140
SFO	ATL	DL	777	2,190	477,347	683,280	2,920	665,265	911,040
SFO	ATL	UA	320	730	76,498	109,500	1,460	159,920	219,000
SJC	ATL	DL	738	1,460	165,235	236,520	2,190	259,070	354,780
SJC	ATL	DL	763	1,460	222,354	318,280	1,460	232,416	318,280
SFO	AUS	UA	319	730	63,238	90,520	730	66,100	90,520
SJC	AUS	AA	738	1,460	165,235	236,520	1,460	172,713	236,520
OAK	BDL	WN	738				730	100,749	137,970
SFO	BDL	UA	320	730	76,498	109,500	730	79,960	109,500
SFO	BFL	UA	CR2	2,190	76,498	109,500	2,920	106,613	146,000
OAK	BHM	WN	738	730	96,387	137,970	2,920	402,997	551,880
OAK	BHM	WN	73G	1,460	151,976	217,540			
OAK	BNA	WN	738	730	96,387	137,970	730	100,749	137,970
OAK	BOI	WN	73G	730	75,988	108,770	730	79,427	108,770
SFO	BOI	UA	319	2,920	252,953	362,080	2,920	264,400	362,080
SJC	BOI	AS	73G	1,460	128,516	183,960	2,190	201,499	275,940
SFO	BOS	AA	738	730	82,618	118,260	1,460	172,713	236,520
SFO	BOS	AA	752	730	102,507	146,730			
SFO	BOS	UA	320	1,460	152,996	219,000	1,460	159,920	219,000
SFO	BOS	UA	763	2,190	333,531	477,420	1,460	232,416	318,280
SFO	BOS	UA	777				730	166,316	227,760
SJC	BOS	AA	738	1,460	165,235	236,520	2,190	259,070	354,780
SJC	BOS	AA	752	730	102,507	146,730			
OAK	BUF	WN	738				730	100,749	137,970
OAK	BUF	WN	73G				730	79,427	108,770
OAK	BUR	WN	733	8,030	768,549	1,100,110			
OAK	BUR	WN	73G	3,650	379,940	543,850	12,410	1,350,254	1,849,090
SFO	BUR	UA	319				3,650	330,500	452,600
SFO	BUR	UA	320	2,920	305,992	438,000	5,840	639,678	876,000
SFO	BUR	UA	733	3,650	321,291	459,900			
SFO	BUR	UA	735	2,190	168,295	240,900			
SJC	BUR	WN	733	2,920	279,472	400,040			
SJC	BUR	WN	73G	2,920	303,952	435,080	8,030	873,694	1,196,470
OAK	BWI	WN	738				1,460	201,499	275,940
OAK	BWI	WN	73G	730	75,988	108,770			
SFO	CEC	UA	CR2	1,460	50,999	73,000	3,650	133,266	182,500
SFO	CIC	UA	CR2				6,570	239,879	328,500
SFO	CIC	UA	J31	5,840	77,518	110,960			
SFO	CIC	UA	SF3	2,920	67,318	96,360	5,840	140,729	192,720
SFO	CLE	CO	738	730	82,618	118,260	1,460	172,713	236,520
SFO	CLE	CO	739				730	94,353	129,210
SFO	CLE	CO	73G	1,460	128,516	183,960			
SFO	CLT	US	319	730	63,238	90,520			
SFO	CLT	US	320	1,460	152,996	219,000	2,190	239,879	328,500
SFO	CLT	US	321	730	91,797	131,400			
SFO	CLT	US	332				730	148,192	202,940
SFO	CMH	HP	320				730	79,960	109,500

Disaggregation of Air Service Area Passengers
Domestic Airline Operations by Bay Area Airport and Aircraft Type
Calendar Years 2010 and 2020

				2010			2020		
Origin	Dest.	Airline	Aircraft	Operations	Passengers	Seats	Operations	Passengers	Seats
SFO	CVG	DL	738	2,920	330,471	473,040	2,190	259,070	354,780
SFO	CVG	DL	752				1,460	214,292	293,460
SFO	CVG	DL	763	730	111,177	159,140	730	116,208	159,140
OAK	DFW	AA	738	3,650	413,089	591,300	4,380	518,139	709,560
OAK	DFW	DL	738	1,460	165,235	236,520	2,190	259,070	354,780
SFO	DFW	AA	738	4,380	495,706	709,560	2,920	345,426	473,040
SFO	DFW	AA	763	1,460	222,354	318,280	2,190	348,625	477,420
SFO	DFW	AA	764	730	124,947	178,850	1,460	261,202	357,700
SFO	DFW	DL	738	2,190	247,853	354,780	2,190	259,070	354,780
SFO	DFW	DL	763	730	111,177	159,140	1,460	232,416	318,280
SFO	DFW	UA	320	2,190	229,494	328,500	2,920	319,839	438,000
SJC	DFW	AA	738	3,650	413,089	591,300	4,380	518,139	709,560
SJC	DFW	AA	763	1,460	222,354	318,280	1,460	232,416	318,280
SJC	DFW	AA	764	730	124,947	178,850	1,460	261,202	357,700
SJC	DFW	DL	738	1,460	165,235	236,520	2,190	259,070	354,780
OAK	DIA	UA	320	2,190	229,494	328,500	1,460	159,920	219,000
OAK	DIA	UA	321	730	91,797	131,400	1,460	191,903	262,800
OAK	DIA	WN	738	2,190	289,162	413,910	5,110	705,245	965,790
OAK	DIA	WN	73G	2,190	227,964	326,310	2,190	238,280	326,310
SFO	DIA	F9	320	2,190	273,862	392,010	2,920	381,675	522,680
SFO	DIA	UA	320	2,920	305,992	438,000	2,190	239,879	328,500
SFO	DIA	UA	321	3,650	458,987	657,000	4,380	575,710	788,400
SFO	DIA	UA	763	2,920	444,708	636,560	2,920	464,833	636,560
SFO	DIA	UA	777	2,190	477,347	683,280	2,920	665,265	911,040
SJC	DIA	UA	320	2,190	229,494	328,500			
SJC	DIA	UA	321	730	91,797	131,400	2,190	287,855	394,200
SJC	DIA	UA	763	730	111,177	159,140	1,460	232,416	318,280
SJC	DIA	WN	738	730	96,387	137,970	2,190	302,248	413,910
SJC	DIA	WN	73G	730	75,988	108,770			
OAK	DTW	WN	738				730	100,749	137,970
SFO	DTW	NW	320	730	76,498	109,500	2,190	239,879	328,500
SFO	DTW	NW	321	2,190	275,392	394,200	1,460	191,903	262,800
SFO	DTW	NW	332	1,460	283,552	405,880	1,460	296,384	405,880
SJC	DTW	NW	320				1,460	159,920	219,000
SJC	DTW	NW	321	1,460	183,595	262,800	730	95,952	131,400
OAK	EUG	WN	733				2,920	292,120	400,040
SFO	EUG	UA	733	1,460	128,516	183,960	4,380	402,997	551,880
SFO	EUG	UA	CR7	5,110	249,893	357,700	2,920	149,258	204,400
SJC	EUG	AA	ER4				3,650	133,266	182,500
SFO	EWR	CO	738	2,190	247,853	354,780	2,190	259,070	354,780
SFO	EWR	CO	764	730	124,947	178,850	730	130,601	178,850
SFO	EWR	UA	321				1,460	191,903	262,800
SFO	EWR	UA	767	1,460	184,615	264,260			
SJC	EWR	CO	738	730	82,618	118,260	1,460	172,713	236,520
SFO	FAT	UA	CR2	1,460	50,999	73,000	5,110	186,573	255,500
SFO	FAT	UA	CR7				3,650	186,573	255,500
SFO	FAT	UA	J31	8,030	106,587	152,570			
SFO	FAT	UA	SF3	2,920	67,318	96,360	5,840	140,729	192,720
SJC	FAT	AA	ER4	2,190	76,498	109,500	4,380	159,920	219,000
OAK	FLL	WN	738	730	96,387	137,970	730	100,749	137,970
OAK	GEG	WN	73G	1,460	151,976	217,540	1,460	158,853	217,540
SFO	GEG	UA	319	2,190	189,715	271,560	1,460	132,200	181,040
SFO	GEG	UA	320				730	79,960	109,500
SJC	GEG	AA	ER4				730	26,653	36,500
OAK	HNL	HA	332	730	188,360	202,940	1,460	381,645	405,880
SFO	HNL	AA	763	730	147,707	159,140	730	149,638	159,140

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				2010			2020		
Origin	Dest.	Airline	Aircraft	Operations	Passengers	Seats	Operations	Passengers	Seats
SFO	HNL	DL	763	730	147,707	159,140	730	149,638	159,140
SFO	HNL	HA	332	730	188,360	202,940	730	190,823	202,940
SFO	HNL	TZ	763				730	184,645	196,370
SFO	HNL	UA	777	2,190	634,189	683,280	2,920	856,643	911,040
SJC	HNL	AA	763	730	147,707	159,140	730	149,638	159,140
SJC	HNL	AA	764				730	168,171	178,850
SFO	IAD	UA	320	3,650	382,490	547,500	2,920	319,839	438,000
SFO	IAD	UA	321	730	91,797	131,400	1,460	191,903	262,800
SFO	IAD	UA	777	1,460	318,231	455,520	1,460	332,633	455,520
SJC	IAD	AA	738	1,460	165,235	236,520	2,190	259,070	354,780
OAK	IAH	CO	73G	730	64,258	91,980	1,460	134,332	183,960
SFO	IAH	CO	738	2,920	330,471	473,040	2,190	259,070	354,780
SFO	IAH	CO	739	1,460	180,535	258,420	2,190	283,058	387,630
SFO	IAH	CO	764	730	124,947	178,850	730	130,601	178,850
SFO	IAH	UA	320	1,460	152,996	219,000	2,190	239,879	328,500
SJC	IAH	CO	738	1,460	165,235	236,520	730	86,357	118,260
SJC	IAH	CO	73G	730	64,258	91,980	2,190	201,499	275,940
OAK	IND	WN	73G	730	75,988	108,770	1,460	158,853	217,540
SFO	IND	TZ	738	730	96,387	137,970	730	100,749	137,970
SFO	IND	TZ	752	730	117,807	168,630	730	123,138	168,630
OAK	JAX	WN	73G				730	79,427	108,770
SFO	JFK	AA	738				1,460	172,713	236,520
SFO	JFK	AA	764	730	124,947	178,850	730	130,601	178,850
SFO	JFK	AA	767	1,460	184,615	264,260			
SFO	JFK	DL	738				730	86,357	118,260
SFO	JFK	DL	764				730	130,601	178,850
SFO	JFK	DL	767	1,460	184,615	264,260			
SFO	JFK	DN	320	1,460	182,575	261,340	1,460	190,837	261,340
SFO	JFK	FF	332	730	191,245	273,750	730	199,899	273,750
SFO	JFK	TW	320	730	76,498	109,500	730	79,960	109,500
SFO	JFK	UA	321				2,920	383,807	525,600
SFO	JFK	UA	767	2,920	369,230	528,520			
SFO	JFK	UA	777	1,460	318,231	455,520	1,460	332,633	455,520
SFO	KOA	UA	763	730	147,707	159,140	730	149,638	159,140
OAK	LAS	HP	319	730	63,238	90,520	1,460	132,200	181,040
OAK	LAS	WN	733	7,300	698,681	1,000,100	5,110	511,210	700,070
OAK	LAS	WN	738				2,920	402,997	551,880
OAK	LAS	WN	73G	1,460	151,976	217,540	2,190	238,280	326,310
SFO	LAS	HP	320	1,460	152,996	219,000	4,380	479,759	657,000
SFO	LAS	HP	733	3,650	321,291	459,900	2,190	201,499	275,940
SFO	LAS	UA	320	5,110	535,485	766,500	6,570	719,638	985,500
SFO	LAS	UA	733	4,380	385,549	551,880	4,380	402,997	551,880
SJC	LAS	AA	738	4,380	495,706	709,560	5,840	690,852	946,080
SJC	LAS	HP	319	1,460	126,477	181,040	1,460	132,200	181,040
SJC	LAS	WN	733	5,110	489,077	700,070	2,920	292,120	400,040
SJC	LAS	WN	73G				2,920	317,707	435,080
OAK	LAX	UA	319	730	63,238	90,520	3,650	330,500	452,600
OAK	LAX	UA	320	730	76,498	109,500	2,190	239,879	328,500
OAK	LAX	UA	733	1,460	128,516	183,960			
OAK	LAX	UA	735	2,190	168,295	240,900			
OAK	LAX	WN	733	10,950	1,048,021	1,500,150			
OAK	LAX	WN	73G	7,300	759,879	1,087,700	18,980	2,065,095	2,828,020
SFO	LAX	AA	738	5,840	660,942	946,080	5,840	690,852	946,080
SFO	LAX	AS	734	730	74,968	107,310			
SFO	LAX	AS	73G				1,460	134,332	183,960
SFO	LAX	DL	738	2,190	247,853	354,780	2,190	259,070	354,780

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				2010			2020		
Origin	Dest.	Airline	Aircraft	Operations	Passengers	Seats	Operations	Passengers	Seats
SFO	LAX	UA	319				14,600	1,322,002	1,810,400
SFO	LAX	UA	320	11,680	1,223,966	1,752,000	7,300	799,598	1,095,000
SFO	LAX	UA	321				7,300	959,517	1,314,000
SFO	LAX	UA	733	16,790	1,477,939	2,115,540			
SJC	LAX	AA	738	5,840	660,942	946,080	7,300	863,566	1,182,600
SJC	LAX	UA	319				6,570	594,901	814,680
SJC	LAX	UA	733	4,380	385,549	551,880			
SJC	LAX	UA	735	1,460	112,197	160,600			
SJC	LAX	WN	733	6,570	628,813	900,090			
SJC	LAX	WN	73G	2,920	303,952	435,080	11,680	1,270,827	1,740,320
OAK	LGB	DN	73G				1,460	158,853	217,540
SFO	MCE	UA	ER4				5,840	213,226	292,000
SFO	MCE	UA	SF3	4,380	100,977	144,540	730	17,591	24,090
OAK	MCI	WN	738	730	96,387	137,970	730	100,749	137,970
OAK	MCI	WN	73G	730	75,988	108,770	730	79,427	108,770
OAK	MCO	WN	738	730	96,387	137,970	730	100,749	137,970
OAK	MCO	WN	73G	730	75,988	108,770	1,460	158,853	217,540
SFO	MCO	UA	319	730	63,238	90,520			
SFO	MCO	UA	320				730	79,960	109,500
SFO	MCO	UA	763	730	111,177	159,140	730	116,208	159,140
SJC	MCO	AA	738				730	86,357	118,260
OAK	MDW	WN	738	2,190	289,162	413,910	2,920	402,997	551,880
OAK	MDW	WN	73G	1,460	151,976	217,540	2,190	238,280	326,310
SFO	MEM	NW	319	730	63,238	90,520	1,460	132,200	181,040
SFO	MEM	NW	320	730	76,498	109,500	730	79,960	109,500
SFO	MEM	NW	321	730	91,797	131,400	730	95,952	131,400
SFO	MFR	UA	733				3,650	335,831	459,900
SFO	MFR	UA	735	1,460	112,197	160,600			
SFO	MFR	UA	CR7	3,650	178,495	255,500	2,190	111,944	153,300
SJC	MFR	AA	ER3				2,190	59,170	81,030
SFO	MIA	AA	738	1,460	165,235	236,520	1,460	172,713	236,520
SFO	MIA	AA	763	730	111,177	159,140	730	116,208	159,140
SFO	MIA	UA	319	730	63,238	90,520			
SFO	MIA	UA	320				730	79,960	109,500
SFO	MKE	YX	717	730	54,059	77,380	730	56,505	77,380
SFO	MKE	YX	M90	1,460	155,036	221,920	2,190	243,078	332,880
SJC	MKE	YX	717	730	54,059	77,380	730	56,505	77,380
SFO	MOD	UA	CR7				5,840	298,517	408,800
SFO	MOD	UA	ER4	2,190	76,498	109,500	5,110	186,573	255,500
SFO	MOD	UA	SF3	2,920	67,318	96,360			
SFO	MRY	UA	319	730	63,238	90,520	3,650	330,500	452,600
SFO	MRY	UA	ER4	5,110	178,495	255,500	2,190	79,960	109,500
OAK	MSP	NW	320	730	76,498	109,500	730	79,960	109,500
SFO	MSP	NW	321	2,190	275,392	394,200	2,190	287,855	394,200
SFO	MSP	NW	332	730	141,776	202,940	1,460	296,384	405,880
SFO	MSP	SY	738	1,460	192,775	275,940	1,460	201,499	275,940
SFO	MSP	UA	320	2,190	229,494	328,500	2,190	239,879	328,500
SJC	MSP	NW	320	1,460	152,996	219,000	2,190	239,879	328,500
OAK	MSY	WN	738	730	96,387	137,970			
OAK	MSY	WN	73G				1,460	158,853	217,540
SFO	MSY	UA	319	730	63,238	90,520			
SFO	MSY	UA	320				730	79,960	109,500
SFO	OGG	TZ	763	730	182,262	196,370	730	184,645	196,370
SFO	OGG	UA	763	730	147,707	159,140	730	149,638	159,140
OAK	OKC	WN	733	1,460	139,736	200,020	1,460	146,060	200,020
OAK	ONT	WN	733	5,110	489,077	700,070			

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Origin	Dest.	Airline	Aircraft	Operations	Passengers	Seats	Operations	Passengers	Seats
OAK	ONT	WN	73G	4,380	455,928	652,620	9,490	1,032,547	1,414,010
SFO	ONT	UA	319				2,920	264,400	362,080
SFO	ONT	UA	320				2,920	319,839	438,000
SFO	ONT	UA	733	4,380	385,549	551,880			
SFO	ONT	UA	735	1,460	112,197	160,600			
SJC	ONT	WN	733	2,920	279,472	400,040			
SJC	ONT	WN	73G	2,920	303,952	435,080	5,840	635,414	870,160
OAK	ORD	AA	738	730	82,618	118,260	730	86,357	118,260
OAK	ORD	UA	320	1,460	152,996	219,000	2,190	239,879	328,500
SFO	ORD	AA	738	2,920	330,471	473,040	2,190	259,070	354,780
SFO	ORD	AA	752	1,460	205,014	293,460	2,920	428,584	586,920
SFO	ORD	AA	763	1,460	222,354	318,280	1,460	232,416	318,280
SFO	ORD	TZ	752	1,460	235,614	337,260	1,460	246,276	337,260
SFO	ORD	UA	320	3,650	382,490	547,500	2,920	319,839	438,000
SFO	ORD	UA	321	1,460	183,595	262,800	2,920	383,807	525,600
SFO	ORD	UA	763	2,190	333,531	477,420	2,190	348,625	477,420
SFO	ORD	UA	777	2,190	477,347	683,280	2,920	665,265	911,040
SJC	ORD	AA	738	1,460	165,235	236,520	2,190	259,070	354,780
SJC	ORD	AA	752	1,460	205,014	293,460	2,190	321,438	440,190
SJC	ORD	AA	763	1,460	222,354	318,280	1,460	232,416	318,280
SJC	ORD	UA	321	1,460	183,595	262,800	1,460	191,903	262,800
OAK	PDX	AS	734	1,460	149,936	214,620			
OAK	PDX	AS	738				1,460	172,713	236,520
OAK	PDX	AS	73G	3,650	321,291	459,900	4,380	402,997	551,880
OAK	PDX	WN	733	5,110	489,077	700,070			
OAK	PDX	WN	73G				6,570	714,840	978,930
SFO	PDX	AS	734	2,920	299,872	429,240	1,460	156,721	214,620
SFO	PDX	AS	738				1,460	172,713	236,520
SFO	PDX	AS	73G	2,190	192,775	275,940	2,920	268,665	367,920
SFO	PDX	DL	CR7	1,460	71,398	102,200	1,460	74,629	102,200
SFO	PDX	UA	319	2,920	252,953	362,080	2,190	198,300	271,560
SFO	PDX	UA	320	2,920	305,992	438,000	4,380	479,759	657,000
SJC	PDX	AA	738	2,190	247,853	354,780	2,190	259,070	354,780
SJC	PDX	AS	73G	3,650	321,291	459,900	4,380	402,997	551,880
SJC	PDX	WN	733	2,190	209,604	300,030			
SJC	PDX	WN	73G	2,190	227,964	326,310	5,110	555,987	761,390
SFO	PHL	UA	320	1,460	152,996	219,000	2,190	239,879	328,500
SFO	PHL	US	320	1,460	152,996	219,000			
SFO	PHL	US	321	1,460	183,595	262,800	2,190	287,855	394,200
SFO	PHL	US	332	1,460	283,552	405,880	2,920	592,768	811,760
SJC	PHL	US	320	730	76,498	109,500	730	79,960	109,500
OAK	PHX	HP	319	2,190	189,715	271,560	1,460	132,200	181,040
OAK	PHX	HP	320	1,460	152,996	219,000	3,650	399,799	547,500
OAK	PHX	WN	738				2,190	302,248	413,910
OAK	PHX	WN	73G	4,380	455,928	652,620	2,920	317,707	435,080
SFO	PHX	HP	319	5,110	442,668	633,640	4,380	396,600	543,120
SFO	PHX	HP	320	2,190	229,494	328,500	3,650	399,799	547,500
SFO	PHX	UA	319	5,110	442,668	633,640	5,840	528,801	724,160
SFO	PHX	WN	738	1,460	192,775	275,940	2,190	302,248	413,910
SFO	PHX	WN	73G	2,920	303,952	435,080	1,460	158,853	217,540
SJC	PHX	AA	738	2,190	247,853	354,780	2,920	345,426	473,040
SJC	PHX	HP	319	2,920	252,953	362,080	1,460	132,200	181,040
SJC	PHX	HP	320	730	76,498	109,500	3,650	399,799	547,500
SJC	PHX	WN	738				1,460	201,499	275,940
SJC	PHX	WN	73G	2,190	227,964	326,310	1,460	158,853	217,540
SFO	PIT	UA	319	730	63,238	90,520			

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				2010			2020		
Origin	Dest.	Airline	Aircraft	Operations	Passengers	Seats	Operations	Passengers	Seats
SFO	PIT	UA	320				1,460	159,920	219,000
SFO	PIT	UA	332	730	141,776	202,940	1,460	296,384	405,880
SFO	PIT	US	319	1,460	126,477	181,040			
SFO	PIT	US	320	1,460	152,996	219,000	2,190	239,879	328,500
SJC	PIT	US	320	730	76,498	109,500	730	79,960	109,500
SFO	PSP	AS	734	2,190	224,904	321,930			
SFO	PSP	AS	73G				2,190	201,499	275,940
SFO	PSP	UA	CR2	2,920	101,997	146,000	2,920	106,613	146,000
SJC	PSP	AS	734	730	74,968	107,310			
SJC	PSP	AS	738				730	86,357	118,260
OAK	PVD	WN	738				1,460	201,499	275,940
SFO	RDD	UA	CR2				7,300	266,533	365,000
SFO	RDD	UA	J31	5,840	77,518	110,960			
SFO	RDD	UA	SF3	2,920	67,318	96,360	3,650	87,956	120,450
OAK	RDU	WN	738				730	100,749	137,970
SJC	RDU	AA	752	730	102,507	146,730	730	107,146	146,730
OAK	RNO	WN	733	7,300	698,681	1,000,100	2,190	219,090	300,030
OAK	RNO	WN	73G				5,840	635,414	870,160
SFO	RNO	UA	319	1,460	126,477	181,040	1,460	132,200	181,040
SFO	RNO	UA	320	3,650	382,490	547,500	4,380	479,759	657,000
SJC	RNO	AA	738	730	82,618	118,260	3,650	431,783	591,300
SJC	RNO	AA	M80	2,920	293,752	420,480			
SJC	RNO	WN	733	2,920	279,472	400,040			
SJC	RNO	WN	73G				3,650	397,134	543,850
OAK	SAN	WN	733	8,760	838,417	1,200,120			
OAK	SAN	WN	73G				11,680	1,270,827	1,740,320
SFO	SAN	UA	319	6,570	569,144	814,680	5,110	462,701	633,640
SFO	SAN	UA	320	5,110	535,485	766,500	7,300	799,598	1,095,000
SFO	SAN	WN	733	5,840	558,945	800,080			
SFO	SAN	WN	73G				5,110	555,987	761,390
SJC	SAN	AA	738	4,380	495,706	709,560	5,840	690,852	946,080
SJC	SAN	WN	733	7,300	698,681	1,000,100			
SJC	SAN	WN	73G				7,300	794,267	1,087,700
OAK	SAT	WN	733	1,460	139,736	200,020			
OAK	SAT	WN	73G				1,460	158,853	217,540
SFO	SBA	UA	319				2,190	198,300	271,560
SFO	SBA	UA	735	2,190	168,295	240,900			
SFO	SBA	UA	CR2	2,190	76,498	109,500	2,190	79,960	109,500
SJC	SBA	UA	CR2	2,190	76,498	109,500	2,920	106,613	146,000
SFO	SBP	UA	CR7	2,920	142,796	204,400	2,920	149,258	204,400
OAK	SEA	AS	738	2,920	330,471	473,040	2,190	259,070	354,780
OAK	SEA	AS	739				2,190	283,058	387,530
OAK	SEA	AS	73G	2,920	257,033	367,920	2,920	268,665	367,920
OAK	SEA	WN	738	2,190	289,162	413,910	2,920	402,997	551,880
OAK	SEA	WN	73G	8,030	835,867	1,196,470	10,220	1,111,974	1,522,780
SFO	SEA	AS	738	1,460	165,235	236,520	4,380	518,139	709,560
SFO	SEA	AS	739	2,920	361,070	516,840	2,920	377,410	516,840
SFO	SEA	AS	73G	3,650	321,291	459,900	2,190	201,499	275,940
SFO	SEA	UA	319	2,190	189,715	271,560	1,460	132,200	181,040
SFO	SEA	UA	320	9,490	994,473	1,423,500	10,950	1,199,397	1,642,500
SJC	SEA	AA	738	2,920	330,471	473,040	3,650	431,783	591,300
SJC	SEA	AS	738	1,460	165,235	236,520	1,460	172,713	236,520
SJC	SEA	AS	739	1,460	180,535	258,420	2,920	377,410	516,840
SJC	SEA	AS	73G	3,650	321,291	459,900	2,920	268,665	367,920
SJC	SEA	WN	738	1,460	192,775	275,940	1,460	201,499	275,940
SJC	SEA	WN	73G	2,920	303,952	435,080	3,650	397,134	543,850

Disaggregation of Air Service Area Passengers
Domestic Airline Operations by Bay Area Airport and Aircraft Type
Calendar Years 2010 and 2020

				2010			2020		
Origin	Dest.	Airline	Aircraft	Operations	Passengers	Seats	Operations	Passengers	Seats
OAK	SLC	DL	738	730	82,618	118,260	1,460	172,713	236,520
OAK	SLC	DL	CR7	730	35,699	51,100			
OAK	SLC	WN	733	2,190	209,604	300,030	1,460	146,060	200,020
OAK	SLC	WN	738	1,460	192,775	275,940			
OAK	SLC	WN	73G	730	75,988	108,770	5,110	555,987	761,390
SFO	SLC	DL	738	3,650	413,089	591,300	3,650	431,783	591,300
SFO	SLC	DL	764	730	124,947	178,850	730	130,601	178,850
SFO	SLC	UA	320	2,920	305,992	438,000	4,380	479,759	657,000
SJC	SLC	AA	738	1,460	165,235	236,520	2,190	259,070	354,780
SJC	SLC	DL	738	1,460	165,235	236,520	1,460	172,713	236,520
SJC	SLC	WN	733	1,460	139,736	200,020			
SJC	SLC	WN	73G	730	75,988	108,770	2,920	317,707	435,080
SFO	SMF	UA	CR2				10,950	399,799	547,500
SFO	SMF	UA	J31	8,760	116,277	166,440			
SFO	SMF	UA	SF3	5,840	134,636	192,720	3,650	87,956	120,450
OAK	SNA	AS	738	1,460	165,235	236,520	3,650	431,783	591,300
OAK	SNA	AS	73G	2,190	192,775	275,940			
OAK	SNA	WN	73G	6,570	683,891	978,930	8,760	953,121	1,305,240
SFO	SNA	AS	738	3,650	413,089	591,300	3,650	431,783	591,300
SFO	SNA	UA	320	1,460	152,996	219,000	1,460	159,920	219,000
SFO	SNA	UA	321				4,380	575,710	788,400
SFO	SNA	UA	752	3,650	512,536	733,650			
SJC	SNA	AA	738	5,840	660,942	946,080	7,300	863,566	1,182,600
SJC	SNA	WN	73G	5,840	607,903	870,160	6,570	714,840	978,930
OAK	STL	WN	73G	2,190	227,964	326,310	2,920	317,707	435,080
SFO	STL	TW	319	1,460	126,477	181,040	2,190	198,300	271,560
SFO	STL	TW	320	4,380	458,987	657,000	1,460	159,920	219,000
SFO	STL	TW	332				1,460	296,384	405,880
SFO	STL	UA	320	730	76,498	109,500	1,460	159,920	219,000
SJC	STL	TW	320	730	76,498	109,500	1,460	159,920	219,000
SJC	STL	TW	717	2,190	162,176	232,140	2,190	169,515	232,140
SFO	STS	UA	CR7	730	35,699	51,100	2,920	149,258	204,400
SFO	STS	UA	ER4	4,380	152,996	219,000	2,920	106,613	146,000
SJC	STS	AA	ER3				1,460	39,447	54,020
SJC	STS	AA	ER4				2,920	106,613	146,000
SFO	TPA	DN	752	730	117,807	168,630	730	123,138	168,630
OAK	TUS	WN	733	2,190	209,604	300,030			
OAK	TUS	WN	738				730	100,749	137,970
OAK	TUS	WN	73G	730	75,988	108,770	2,190	238,280	326,310

Exhibit 5

Subpart A--General Provisions

Sec. 161.1 Purpose.

This part implements the Airport Noise and Capacity Act of 1990 (49 U.S.C. App. 2153, 2154, 2155, and 2156). It prescribes:

(a) Notice requirements and procedures for airport operators implementing Stage 3 aircraft noise and access restrictions pursuant to agreements between airport operators and aircraft operators;

(b) Analysis and notice requirements for airport operators proposing Stage 2 aircraft noise and access restrictions;

(c) Notice, review, and approval requirements for airport operators proposing Stage 3 aircraft noise and access restrictions; and

(d) Procedures for Federal Aviation Administration reevaluation of agreements containing restrictions on Stage 3 aircraft operations and of aircraft noise and access restrictions affecting Stage 3 aircraft operations imposed by airport operators.

Sec. 161.3 Applicability.

(a) This part applies to airports imposing restrictions on Stage 2 aircraft operations proposed after October 1, 1990, and to airports imposing restrictions on Stage 3 aircraft operations that became effective after October 1, 1990.

(b) This part also applies to airports enacting amendments to airport noise and access restrictions in effect on October 1, 1990, but amended after that date, where the amendment reduces or limits aircraft operations or affects aircraft safety.

(c) The notice, review, and approval requirements set forth in this part apply to all airports imposing noise or access restrictions as defined in Sec. 161.5 of this part.

Sec. 161.5 Definitions.

For the purposes of this part, the following definitions apply:

Agreement means a document in writing signed by the airport operator; those aircraft operators currently operating at the airport that would be affected by the noise or access restriction; and all affected new entrants planning to

provide new air service within 180 days of the effective date of the restriction that have submitted to the airport operator a plan of operations and notice of agreement to the restriction.

Aircraft operator, for purposes of this part, means any owner of an aircraft that operates the aircraft, i.e., uses, causes to use, or authorizes the use of the aircraft; or in the case of a leased aircraft, any lessee that operates the aircraft pursuant to a lease. As used in this part, aircraft operator also means any representative of the aircraft owner, or in the case of a leased aircraft, any representative of the lessee empowered to enter into agreements with the airport operator regarding use of the airport by an aircraft.

Airport means any area of land or water, including any heliport, that is used or intended to be used for the landing and takeoff of aircraft, and any appurtenant areas that are used or intended to be used for airport buildings or other airport facilities or rights-of-way, together with all airport buildings and facilities located thereon.

Airport noise study area means that area surrounding the airport within the noise contour selected by the applicant for study and must include the noise contours required to be developed for noise exposure maps specified in 14 CFR part 150.

Airport operator means the airport proprietor.

Aviation user class means the following categories of aircraft operators: air carriers operating under parts 121 or 129 of this chapter; commuters and other carriers operating under parts 127 and 135 of this chapter; general aviation, military, or government operations.

Day-night average sound level (DNL) means the 24-hour average sound level, in decibels, for the period from midnight to midnight, obtained after the addition of ten decibels to sound levels for the periods between midnight and 7 a.m., and between 10 p.m. and midnight, local time, as defined in 14 CFR part 150. (The scientific notation for DNL is Ldn).

Noise or access restrictions means restrictions (including but not limited to provisions of ordinances and leases) affecting access or noise that affect the operations of Stage 2 or Stage 3 aircraft, such as limits on the noise generated on either a single-event or cumulative basis; a limit, direct or indirect, on the total number of Stage 2 or Stage 3 aircraft operations; a noise budget or noise allocation program that includes Stage 2 or Stage 3 aircraft; a restriction imposing limits on hours of operations; a program of airport-use charges that has the direct or indirect effect of controlling airport noise; and any other limit on Stage 2 or Stage 3 aircraft that has the effect of controlling airport noise. This definition does not include peak-period pricing programs where the objective is to align the number of aircraft operations with airport capacity.

Stage 2 aircraft means an aircraft that has been shown to comply with the Stage 2 requirements under 14 CFR part 36.

Stage 3 aircraft means an aircraft that has been shown to comply with the Stage 3 requirements under 14 CFR part 36.

Sec. 161.7 Limitations.

(a) Aircraft operational procedures that must be submitted for adoption by the FAA, such as preferential runway use, noise abatement approach and departure procedures and profiles, and flight tracks, are not subject to this part. Other noise abatement procedures, such as taxiing and engine runups, are not subject to this part unless the procedures imposed limit the total number of Stage 2 or Stage 3 aircraft operations, or limit the hours of Stage 2 or Stage 3 aircraft operations, at the airport.

(b) The notice, review, and approval requirements set forth in this part do not apply to airports with restrictions as specified in 49 U.S.C. App. 2153(a)(2)(C):

(1) A local action to enforce a negotiated or executed airport aircraft noise or access agreement between the airport operator and the aircraft

Sec. 161.305 Required analysis and conditions for approval of proposed restrictions.

Each applicant proposing a noise or access restriction on Stage 3 operations shall prepare and make available for public comment an analysis that supports, by substantial evidence, that the six statutory conditions for approval have been met for each restriction and any alternatives submitted. The statutory conditions are set forth in 49 U.S.C. App. 2153(d)(2) and paragraph (e) of this section. Any proposed restriction (including alternatives) on Stage 3 aircraft operations that also affects the operation of Stage 2 aircraft must include analysis of the proposals in a manner that permits the proposal to be understood in its entirety. (Nothing in this section is intended to add a requirement for the issuance of restrictions on Stage 2 aircraft to those of subpart C of this part.) The applicant shall provide:

(a) The complete text of the proposed restriction and any submitted alternatives, including the proposed wording in a city ordinance, airport rule, lease, or other document, and any sanctions for noncompliance;

(b) Maps denoting the airport geographic boundary, and the geographic boundaries and names of each jurisdiction that controls land use within the airport noise study area;

(c) An adequate environmental assessment of the proposed restriction or adequate information supporting a categorical exclusion in accordance with FAA orders and procedures regarding compliance with the National Environmental Policy Act of 1969 (42 U.S.C. 4321);

(d) A summary of the evidence in the submission supporting the six statutory conditions for approval; and

(e) An analysis of the restriction, demonstrating by substantial evidence that the statutory conditions are met. The analysis must:

(1) Be sufficiently detailed to allow the FAA to evaluate the merits of the proposed restriction; and

(2) Contain the following essential elements needed to provide substantial evidence supporting each condition for approval:

(i) Condition 1: The restriction is reasonable, nonarbitrary, and nondiscriminatory. (A) Essential information needed to demonstrate this condition includes the following:

(1) Evidence that a current or projected noise or access problem exists, and that the proposed action(s) could relieve the problem, including:

(i) A detailed description of the problem precipitating the proposed restriction with relevant background information on factors contributing to the proposal and any court-ordered action or estimated liability concerns; a description of any noise agreements or noise or access restrictions currently in effect at the airport; and measures taken to achieve land-use compatibility, such as controls or restrictions on land use in the vicinity of the airport and measures carried out in response to 14 CFR part 150; and actions taken to comply with grant assurances requiring that:

(A) Airport development projects be reasonably consistent with plans of public agencies that are authorized to plan for the development of the area around the airport; and

(B) The sponsor give fair consideration to the interests of communities in or near where the project may be located; take appropriate action, including the adoption of zoning laws, to the extent reasonable, to restrict the use of land near the airport to activities and purposes compatible with normal airport operations; and not cause or permit any change in land use, within its jurisdiction, that will reduce the compatibility (with respect to the airport) of any noise compatibility program measures upon which federal funds have been expended.

(ii) An analysis of the estimated noise impact of aircraft operations with and without the proposed restriction for the year the restriction is expected to be implemented, for a forecast timeframe after implementation, and for any other years critical to understanding the noise impact of the proposed

restriction. The analysis of noise impact with and without the proposed restriction including:

(A) Maps of the airport noise study area overlaid with noise contours as specified in Secs. 161.9 and 161.11 of this part;

(B) The number of people and the noncompatible land uses within the airport noise study area with and without the proposed restriction for each year the noise restriction is analyzed;

(C) Technical data supporting the noise impact analysis, including the classes of aircraft, fleet mix, runway use percentage, and day/night breakout of operations; and

(D) Data on current and projected airport activity that would exist in the absence of the proposed restriction.

(2) Evidence that other available remedies are infeasible or would be less cost-effective, including descriptions of any alternative aircraft restrictions that have been considered and rejected, and the reasons for the rejection; and of any land use or other nonaircraft controls or restrictions that have been considered and rejected, including those proposed under 14 CFR part 150 and not implemented, and the reasons for the rejection or failure to implement.

(3) Evidence that the noise or access standards are the same for all aviation user classes or that the differences are justified, such as:

(i) A description of the relationship of the effect of the proposed restriction on airport users (by aviation user class); and

(ii) The noise attributable to these users in the absence of the proposed restriction.

(B) At the applicant's discretion, information may also be submitted as follows:

(1) Evidence not submitted under paragraph (e)(2)(ii)(A) of this section (Condition 2) that there is a reasonable chance that expected benefits will equal or exceed expected cost; for example, comparative economic analyses of the costs and benefits of the proposed restriction and aircraft and nonaircraft alternative measures. For detailed elements of analysis, see paragraph (e)(2)(ii)(A) of this section.

(2) Evidence not submitted under paragraph (e)(2)(ii)(A) of this section that the level of any noise-based fees that may be imposed reflects the cost of mitigating noise impacts produced by the aircraft, or that the fees are reasonably related to the intended level of noise impact mitigation.

(ii) Condition 2: The restriction does not create an undue burden on interstate or foreign commerce. (A) Essential information needed to demonstrate this statutory condition includes:

(1) Evidence, based on a cost-benefit analysis, that the estimated potential benefits of the restriction have a reasonable chance to exceed the estimated potential cost of the adverse effects on interstate and foreign commerce. In preparing the economic analysis required by this section, the applicant shall use currently accepted economic methodology, specify the methods used and assumptions underlying the analysis, and consider:

(i) The effect of the proposed restriction on operations of aircraft by aviation user class (and for air carriers, the number of operations of aircraft by carrier), and on the volume of passengers and cargo for the year the restriction is expected to be implemented and for the forecast timeframe.

(ii) The estimated costs of the proposed restriction and alternative nonaircraft restrictions including the following, as appropriate:

(A) Any additional cost of continuing aircraft operations under the restriction, including reasonably available information concerning any net capital costs of acquiring or retrofitting aircraft (net of salvage value and operating efficiencies) by aviation user class; and any incremental recurring costs;

(B) Costs associated with altered or discontinued aircraft operations, such as reasonably available information concerning loss to carriers of operating profits; decreases in passenger and shipper consumer surplus by aviation user class; loss in profits associated with other airport services or other entities: and/or any significant economic effect on parties other than aviation users.

(C) Costs associated with implementing nonaircraft restrictions or nonaircraft components of restrictions, such as reasonably available

information concerning estimates of capital costs for real property, including redevelopment, soundproofing, noise easements, and purchase of property interests; and estimates of associated incremental recurring costs; or an explanation of the legal or other impediments to implementing such restrictions.

(D) Estimated benefits of the proposed restriction and alternative restrictions that consider, as appropriate, anticipated increase in real estate values and future construction cost (such as sound insulation) savings; anticipated increase in airport revenues; quantification of the noise benefits, such as number of people removed from noise contours and improved work force and/or educational productivity, if any; valuation of positive safety effects, if any; and/or other qualitative benefits, including improvements in quality of life.

(B) At the applicant's discretion, information may also be submitted as follows:

(1) Evidence that the affected carriers have a reasonable chance to continue service at the airport or at other points in the national airport system.

(2) Evidence that other air carriers are able to provide adequate service to the airport and other points in the system without diminishing competition.

(3) Evidence that comparable services or facilities are available at another airport controlled by the airport operator in the market area, including services available at other airports.

(4) Evidence that alternative transportation service can be attained through other means of transportation.

(5) Information on the absence of adverse evidence or adverse comments with respect to undue burden in the notice process required in Sec. 161.303, or alternatively in Sec. 161.321, of this part as evidence that there is no undue burden.

(iii) Condition 3: The proposed restriction maintains safe and efficient use of the navigable airspace. Essential information needed to demonstrate this statutory condition includes evidence that the proposed restriction maintains safe and efficient use of the navigable airspace based upon:

(A) Identification of airspace and obstacles to navigation in the vicinity of the airport; and

(B) An analysis of the effects of the proposed restriction with respect to use of airspace in the vicinity of the airport, substantiating that the restriction maintains or enhances safe and efficient use of the navigable airspace. The analysis shall include a description of the methods and data used.

(iv) Condition 4: The proposed restriction does not conflict with any existing Federal statute or regulation. Essential information needed to demonstrate this condition includes evidence demonstrating that no conflict is presented between the proposed restriction and any existing Federal statute or regulation, including those governing:

(A) Exclusive rights;

(B) Control of aircraft operations; and

(C) Existing Federal grant agreements.

(v) Condition 5: The applicant has provided adequate opportunity for public comment on the proposed restriction. Essential information needed to demonstrate this condition includes evidence that there has been adequate opportunity for public comment on the restriction as specified in Sec. 161.303 or Sec. 161.321 of this part.

(vi) Condition 6: The proposed restriction does not create an undue burden on the national aviation system. Essential information needed to demonstrate this condition includes evidence that the proposed restriction does not create an undue burden on the national aviation system such as:

(A) An analysis demonstrating that the proposed restriction does not have a substantial adverse effect on existing or planned airport system capacity, on observed or forecast airport system congestion and aircraft delay, and on airspace system capacity or workload;

(B) An analysis demonstrating that nonaircraft alternative measures to achieve the same goals as the proposed subject restrictions are inappropriate;

(C) The absence of comments with respect to imposition of an undue burden on the national aviation system in response to the notice required in Sec. 161.303 or Sec. 161.321.

Sec. 161.307 Comment by interested parties.

(a) Each applicant proposing a restriction shall establish a public docket or similar method for receiving and considering comments, and shall make comments available for inspection by interested parties upon request. Comments must be retained as long as the restriction is in effect.

(b) Each applicant shall submit to the FAA a summary of any comments received. Upon request by the FAA, the applicant shall submit copies of the comments.

Sec. 161.309 Requirements for proposal changes.

(a) Each applicant shall promptly advise interested parties of any changes to a proposed restriction or alternative restriction that are not encompassed in the proposals submitted, including changes that affect noncompatible land uses or that take place before the effective date of the restriction, and make available these changes to the proposed restriction and its analysis. For the purpose of this paragraph, interested parties include those who received direct notice under Sec. 161.303(b) of this part, or those who were required to be consulted in accordance with the procedures in Sec. 161.321 of this part, and those who commented on the proposed restriction.

(b) If there are substantial changes to a proposed restriction or the analysis made available prior to the effective date of the restriction, the applicant proposing the restriction shall initiate new notice in accordance with the procedures in Sec. 161.303 or, alternatively, the procedures in Sec. 161.321. These requirements apply to substantial changes that are not encompassed in submitted alternative restriction proposals and their analyses. A substantial change to a restriction includes, but is not limited to, any proposal that would increase the burden on any aviation user class.

(c) In addition to the information in Sec. 161.303(c), a new notice must indicate that the applicant is revising a previous notice, provide the reason for making the revision, and provide a new effective date (if any) for the restriction.

(d) If substantial changes requiring a new notice are made during the FAA's 180-day review of the proposed restriction, the applicant submitting the proposed restriction shall notify the FAA in writing that it is withdrawing its proposal from the review process until it has completed additional analysis, public review, and documentation of the public review. Resubmission to the FAA will restart the 180-day review.

Sec. 161.311 Application procedure for approval of proposed restriction.

Each applicant proposing a Stage 3 restriction shall submit to the FAA the following information for each restriction and alternative restriction submitted, with a request that the FAA review and approve the proposed Stage 3 noise or access restriction:

(a) A summary of evidence of the fulfillment of conditions for approval, as specified in Sec. 161.305;

(b) An analysis as specified in Sec. 161.305, as appropriate to the proposed restriction;

(c) A statement that the entity submitting the proposal is the party empowered to implement the restriction, or is submitting the proposal on

Regional Airport System Plan

Update 2000

Regional Airport Capacity and Delay

Regional Airport System Plan Update 2000

Regional Airport Capacity and Delay
Final Report

Prepared for the

Regional Airport Planning Committee

by

Bechtel Infrastructure Corporation, January, 2001

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This report focuses on analyzing airport and air space capacities for various airport runway configurations under consideration to accommodate projected commercial aviation traffic growth in the Bay Area out to the year 2020. The findings presented in this report are based on new analyses as well as information from other aviation studies that have been completed over the last several years. The report discusses analytical tools, critical issues, and effects of proposed runway solutions.

The modeling was used to assess capacity and delay based primarily on existing airspace procedures and it was not the purpose of the analysis to explore any redesign of the airspace.

1.1 BACKGROUND

The Bay Area has three commercial carrier airports: San Francisco International Airport (SFO), Metropolitan Oakland International Airport (OAK), and San Jose International Airport (SJC). Passenger traffic at all three airports has increased dramatically over the last 10 years, growing from about 21 million enplaned (boarding) passengers in 1990 to more than 32 million enplaned passengers in 1999. Aircraft operations (comprised of commercial passenger, all-cargo and general aviation) for all three airports have also been increasing steadily, though at a slower pace, rising from about 1.13 million operations in 1990 to about 1.26 million operations in 1999.

Passengers and operations are projected to grow in the future, therefore an assessment is needed to quantify the impacts of projected ("unconstrained") demand on the three airports in terms of runway capacity, aircraft delay, and airspace interactions.

In 1999, the SFO-Runway Reconfiguration Study examined a series of alternative runway configurations for SFO that could reduce aircraft delay and noise impacts on surrounding residents. SFO currently has two pairs of intersecting parallel runways, and the study identified 32 runway alternatives. Following a thorough technical evaluation, three of these were determined to be worthy of further study and are evaluated in this report. Each alternative improves on the existing airport runway system by increasing capacity, decreasing delays, decreasing noise, and decreasing unnecessary expenditures currently incurred both by passengers and airlines.

One of the studies upon which this report is based is the San Jose International Airport Master Plan Update (SJMP), completed in 1996. Currently there is a single air carrier runway at SJC. The SJMP provides for the addition of a second air carrier parallel runway (now under construction), which will give the airport a dual dependent runway system and increased capacity.

At Oakland Metropolitan International Airport (OAK), studies of the runway system have also identified alternatives for expansion of air carrier capacity. OAK currently has a single air carrier runway in the South Field, although a second runway in the North Field (27R) is sometimes used for air carrier landings only. Two alternatives have been identified for the addition of a new parallel runway in the South Field.

The analysis in this report will consider the three runway alternatives identified for SFO, the two alternatives for adding a runway at OAK, and the additional runway under construction at SJC. Combinations of these alternatives give a variety of different runway capacities for the three airports and for the Bay Area as a whole. They also create different air route interactions that are analyzed for their impacts on airspace capacity.

1.2 OBJECTIVES

This report provides an assessment of how well the commercial carrier airport runways and Bay Area airspace will accommodate projected demand over the next 20 years from 2000 to 2020, primarily by estimating average aircraft delay. The key questions to be answered include the following:

- What happens if the airports "do nothing" or do not improve runway capacity?
- What are the effects of "demand management" strategies on projected delays?
- What are the impacts of new air traffic control technologies?
- What are the effects of the different runway reconfigurations at SFO?
- What are the effects of adding a new runway at OAK?
- What are the effects of the new commercial air carrier runway under construction at SJC?
- What is the overall effect on the Bay Area of different combinations of the SFO, OAK and SJC runways?

1.3 MODELING SOFTWARE

The primary tool used in this analysis is SIMMOD, an advanced computer simulation program approved by the FAA for modeling runway systems and airspace interactions. The computer simulation model captures the interactions between runways at the three airports and the applicable airspace procedures, thus assessing how existing and proposed runways will handle the forecasted level of aircraft operations in the future.

SIMMOD quantifies airport and airspace capacity data; it does this by measuring delay incurred by aircraft. Average delay per aircraft arrival or departure varies between the different runway alternatives, and hence is a measure of the efficiency of the alternative runway systems proposed. In addition to testing the runway alternatives, several operational variations, or "sensitivity tests" have been run to measure the impact of modifying air traffic levels through regulatory means (demand management) and introducing new air traffic control (ATC) technologies and operating procedures.

1.4 REPORT ORGANIZATION

This report is presented in a parallel manner to the work process as follows:

- Section 1, *Introduction*, outlines the study background, objective, and organization of the report.
- Section 2, *Study methodology*, presents the work process, describes the simulation software, defines ultimate and practical capacity, and discusses key variables affecting airspace and airfield capacity and delay.
- Section 3, *Existing Delays at Bay Area Airports*, illustrates existing runway layouts, presents delay and capacity results from SIMMOD, and validates the SIMMOD model for existing conditions at the three Bay Area airports.
- Section 4, *Managing Demand to Accommodate Future Traffic with Existing Runways*, presents the impact of introducing demand management techniques at SFO, as well as the benefits of air traffic control technology enhancements.
- Section 5, *Adding New Area Runways to Accommodate Future Traffic*, analyzes new runway alternatives for SFO and OAK, and presents the SIMMOD delay and capacity results for years 2010 and 2020.
- Section 6, *Comparison of Delay and Capacity for All Alternatives*, tabulates years 2010 and 2020 results for various scenarios and highlights key differences.

This section presents the work process, describes the simulation tool utilized, defines airfield and airspace capacity and delay, and acquaints the reader with key variables that affect Bay Area airport and airspace capacity and delay.

2.1 WORK PROCESS

Figure 2-1 presents the work tasks that may be grouped into four steps:

- **Model Verification.** To ensure that the simulation model provides accurate results, SIMMOD capacity and delay results for 1999 are compared and calibrated against actual performance at the three Bay Area airports.
- **Demand Management Alternatives.** The impact of various demand management and technology improvement options at SFO are analyzed to minimize delay for years 2010 and 2020.
- **New Runway Alternatives.** Eleven (11) combinations of various runway alternatives at SFO and OAK are analyzed for years 2010 and 2020.
- **Summary of Results.** Delay and capacity results for all simulation runs are tabulated and key differences are highlighted.

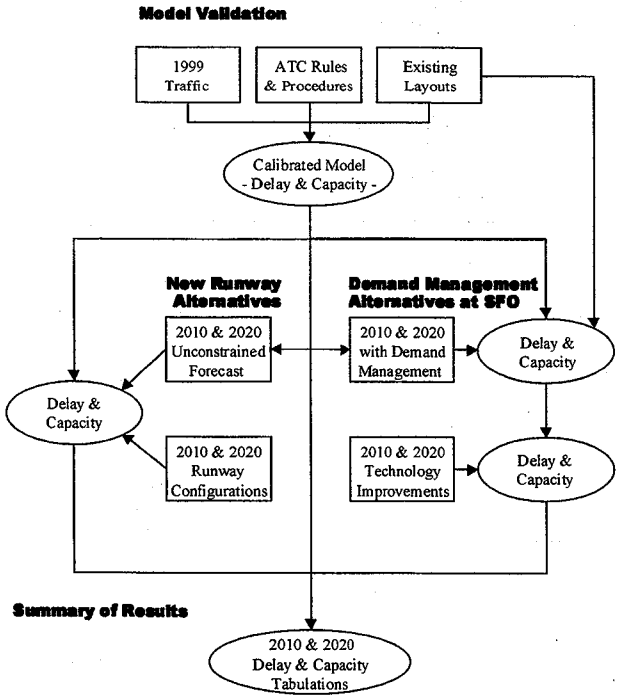


Figure 2-1 Regional Airport Delay and Capacity Study Process

2.2 SIMULATION MODELING SOFTWARE

Analysis of airport capacity and delay is performed using SIMMOD, an FAA-approved computer program. This program is capable of capturing all the interactions between runways at multiple airports and the airspace procedures, thus assessing how existing and proposed runways will handle the forecasted level of aircraft operations in the future.

2.2.1 Description of Software

SIMMOD is an aircraft movement simulation model developed and sponsored by the FAA. The model is graphic and user friendly with a flexible output analysis and reporting module. There is no limit to the number of airports or size of terminals and airspace, so it is ideal for modeling the Bay Area's multi-airport environment. SIMMOD input can be grouped into the following three categories:

- *Airfield-related*: includes physical layout of airports and operational parameters such as gate, taxiway, and runway structure; airlines' use of gates; taxiway routings between gates and runways; departure lineup strategies; and aircraft landing and takeoff characteristics.
- *Airspace-related*: includes airspace routings; airspace sectorization; airspace separation standards including wake turbulence; arrival and departure procedures, and required separations; metering and flow constraints; and strategies for resolving potential conflicts.
- *Simulation event*: allows the user to specify the aircraft departure and arrival (demand) schedules for existing and future conditions and the desired changes in operating conditions, including runway use configurations, terminal routing plans, and flow and metering constraints.

SIMMOD models airports and airspace networks as a series of nodes connected by links. A node is a point in a coordinate system where SIMMOD evaluates an aircraft's position with respect to other aircraft. A link defines the path between two nodes. Aircraft move from one node to another only along a defined link. SIMMOD maintains airfield (ground) and airspace nodes as separate groups. The flight schedules and the simulation clock work together to process SIMMOD events in the proper sequence.

SIMMOD simulates the movement of each aircraft on the ground and in the air. SIMMOD has extensive statistical reports on aircraft delays in the air, on the ground, and at gates. Travel time in the air and on the ground (taxiing) is also tracked. Hourly request for runway use is also compared with actual hourly aircraft arrivals and departures with the hourly number of aircraft processed. Most of the statistics can be broken down by airline, runway, and/or gate. When comparing airport and airspace improvement alternatives, SIMMOD can be used to identify and quantitatively evaluate the various impacts on capacity and delay. It also provides a 2D animation and playback interface that allows planners to see the simulation unfold and to investigate specific problems.

2.2.2 Event Files

Event files are lists of arriving and departing aircraft operations. Each record (line) of an event file, contains a movement ID, an airline and flight number, a movement time, an aircraft type, a direction (arrival and departure), the airport at which the aircraft lands or takes off, a market served (last airport for an arrival or next airport for a departure), an air route used, and the gate or apron at which the flight starts or ends. The movement time is the scheduled departure time, but for an arrival it is the time at which the aircraft enters the airspace of the model. This last time is the scheduled arrival time minus the time it takes to fly through the model airspace, land and taxi to the gate without any delay.

There are two ways of specifying the event file: either as a list of independent flights (as if every flight represented a separate physical aircraft), or with some connected flights (where a specific departure is the same physical aircraft as a specific arrival). In the first case, no matter how bad arrival delays are, the departing flights will leave their gate at their scheduled time. In the second case a connected flight cannot depart until it has first arrived and spent a minimum turnaround time at the gate (depending on the aircraft type).

The second case is more realistic, especially when airports experience lengthy arrival delays as is the case at SFO during bad weather conditions (known as Instrument Flight Rules, or IFR). This approach was used for all the cases simulated in this study.

2.2.3 Airspace Structure and Separation Rules

SIMMOD defines the airspace structure as a set of links and nodes, with each air route composed of a series of connected links. The nodes are fixes, i.e. navigational aids (navaids) such as VORs, VORTACs, DMEs, and NDBs, or intersections of radials from these navaids. Aircraft assigned to a specific route progress from node to node along the links that define that route.

How an aircraft is released from the node at the start of a link is determined by the strategy chosen, and by local parameters such as link capacity and link aircraft speed type. The simplest strategy assumes that the link and its end node have sufficient capacity and therefore that aircraft are released from the first node as soon as they arrive, provided they do not violate the default ATC separation rules. More complex strategies look ahead to the next node to see how many aircraft are already there and whether there is room left for another one, while taking into account the number of aircraft already on their way.

SIMMOD can also slow down an aircraft (within the limits of acceptable speeds for that aircraft type on that link type) and/or delay its release time if the preceding aircraft is slower, so that by the time it arrives at the end node the separation minimum is not breached.

When two links merge into one, different merging strategies are also available: The merging node can just accept aircraft on a first come, first served basis. Or, it can slow down aircraft on one link while speeding up those on the other link so that seamless merging occurs; it can even select aircraft from each link so as to minimize the required separation. For example, on final approach, an aircraft sequence Heavy – Small – Heavy – Small would require 15 miles of the

link, while the sequence Heavy – Heavy – Small – Small would require only 13.5 miles. ("Heavy" and "small" refer to aircraft weight categories.)

In general, the alternatives simulated in the study are based on the more complex strategies, because they tend to be more realistic, meaning they more closely replicate how the FAA actually manages the airspace.

2.2.4 Runway and Taxiway Structure

The arriving air routes end at the runway edge (interface), and start at the runway end for departures. The ground structure is defined by the links and nodes that connect these interface points with the terminal's gates (and/or apron positions) via the network of runways/exits/taxiways/taxilanes.

For arriving aircraft, as soon as the landing roll is completed SIMMOD looks for the nearest exit. If the exit is a high-speed exit (30 degree or less) and the aircraft's own speed has dropped to 60 knots or less, then the aircraft can use the exit. However for the other types of exits, the aircraft's speed must drop to nearly zero. From there, the program computes the route that gives the minimum time to the destination gate or apron position, based on link attributes such as maximum speed, aircraft type allowed, passing option, occupancy by other aircraft and capacity limit. If an airport has a circulation plan that mandates the use of specific taxiways for different aircraft types, then an override taxipath can be added in the event file for those aircraft that are affected.

For departing aircraft, the program computes the optimum route in a similar fashion: from the gate to the departure queue of the corresponding runway. When the aircraft has reached the head of the queue and is given the clearance to take-off, it completes the take-off roll and by the time it crosses the end threshold (i.e. by the time it is airborne) it is passed to the airspace structure via the interface point.

More that one departure queue can be assigned to a given runway in order to serve aircraft coming from different aprons of the airport. However delay can occur when taxiing aircraft have to cross an active runway, because all the time and distance separations from the table of runway procedures must be met before the aircraft can be given runway crossing clearance.

2.2.5 Runway Procedures

This procedure specifies for each operation and aircraft weight group what other operation and aircraft weight group it will block and for how long. For example, at SFO, a heavy aircraft on final for 28R, will block departures on 1L and 1R from two nautical miles (nm) away from the threshold (in VFR) until it has crossed the intersecting runways 1L and 1R.

A departing heavy aircraft on 1R will block any other aircraft from departing on 1R until a separation of 5 nm is achieved, due to the wake vortex separation rule. The same departure by a heavy on 1R should clear the 28R and 28L intersections before arrivals bound for these runways have crossed their corresponding threshold. If an approaching aircraft should cross the threshold

of 28R or 28L before the departing aircraft has crossed the corresponding runway, it would have to abort landing and execute a missed approach procedure. This occurs only very rarely because the two nautical mile rule generally allows enough time for the departing aircraft to clear the intersection.

San Francisco International Airport, with its two pairs of intersecting runways, requires a relatively complex set of air traffic control procedures. To maximize runway capacity in good weather conditions (VFR) with westerly winds, the aircraft of the two streams of arrivals heading for 28R and 28L must be paired together on final approach. In other words, two aircraft have to fly more or less side by side, with the next pair following about 4 nm behind.

This separation allows enough time for two departing aircraft on 1L and 1R to take off as soon as the landing aircraft have crossed the departing runways, and for the next two landing aircraft to pass the threshold of their runway after the departing aircraft have cleared the intersections.

SIMMOD is capable of modeling this pairing process, which is necessary to model SFO accurately.

2.3 DEFINITION OF AIRSPACE AND AIRFIELD CAPACITY AND DELAY

Capacity is a measure of processing capability and is quantified by the number of aircraft operations that can be processed during a specific unit of time, such as an hour or an entire year. Delay is calculated in terms of average minutes of delay per aircraft arrival and/or departure during various weather conditions, using Instrument Flight Rules (IFR) procedures or Visual Flight Rules (VFR) procedures.

The "ultimate" capacity of an airfield system is the theoretical maximum number of continuous aircraft operations that an airfield can accommodate during a specified interval of time. On a practical level:

- Airfields experience peaking patterns where two or more aircraft often need to use the airfield at the same time, which will result in at least one aircraft experiencing slight delays.
- During peak periods, demand may exceed capacity; in these cases the aircraft will queue and wait until a landing or takeoff slot is available.
- It is rare for flights from all over the world to approach or depart an airspace in perfect and continuous sequence without any delay.

Thus, delays can determine the capacity of an airfield and an airspace network. Practical capacity is the number of aircraft operations that can be accommodated during a specific interval of time corresponding to a tolerable level of average delay. Acceptable flight delay may vary between different airports, but experts in the aviation industry agree that facilities and airspace can perform adequately with an average annual delay of 3 to 5 minutes maximum per aircraft.

"Experience shows that delay increases gradually with rising levels of traffic until the practical capacity of an airport is reached, at which point the average delay per aircraft operation is in the range of 3 to 5 minutes. Delays increase rapidly once traffic demand increases beyond this

level. An airport is considered to be congested when average delay exceeds 5 minutes per operation. Beyond this point delays are extremely volatile, and a small increase in traffic, adverse weather conditions, or other disruptions can result in lengthy delays that upset flight schedules and impose a heavy workload on the air traffic control system."[1]

Source: U.S. Department of Transportation, Federal Aviation Administration, Report to Congress, *National Plan of Integrated Airport Systems (1998-2002)*, March 1999

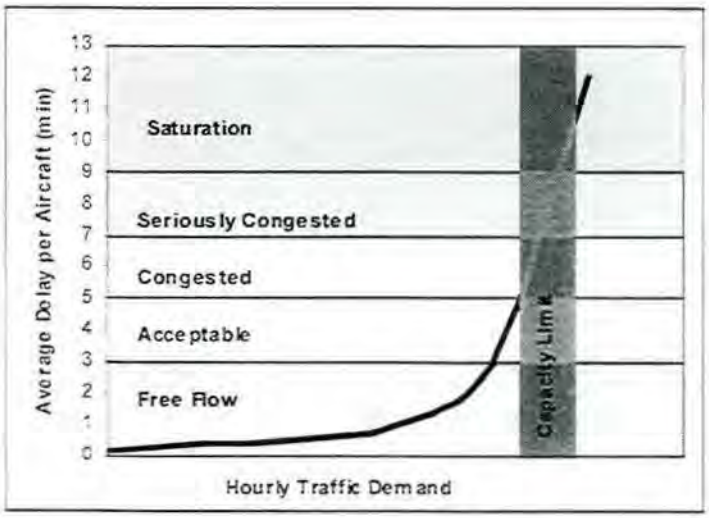


Figure 2-2 Influence of Aircraft Delay on Airfield Capacity

Delays above 5 minutes affect airline schedule integrity and can create extensive passenger inconvenience when flights are cancelled or diverted. When the airport is operating at reduced capacity, a large share of all arriving flights will be delayed or cancelled, and delays can typically average an hour or more, with frequent flyers routinely experiencing two to three hour delays. It should be pointed out that "modeled" delays are not directly comparable to other commonly quoted delay statistics from the FAA and Bureau of Transportation Statistics. These data track airline on-time performance and delays throughout the national airspace system, whereas this analysis focuses exclusively on what happens within the Oakland air route center airspace extending out about 150 nm. Delay information for Bay Area airports is summarized in the appendix using FAA CODAS data for 1997 and 1998.

2.4 FACTORS AFFECTING DELAY ON RUNWAYS AND AIRSPACE

Aircraft and passenger delays occur for many reasons. In Section 2.3, the definition of delay was provided. In this section, the factors affecting delay are presented and discussed. The purpose of this discussion is to orient the reader on the causes of airport delay. The following four factors have the most significant impact on delay:

[1] Federal Aviation Administration Report to Congress, *National Plan of Integrated Airport Systems (1998-2002)*, March, 1999, at 10.

- Weather Conditions – Weather at the airport, especially as it affects visibility
- Airfield Layout –Configuration of runways (parallel, intersecting or combinations)
- Fleet Mix – Mix of aircraft, by size and type, using the airport
- Traffic Peaks – Periods when traffic volumes reach high points during the day

Of the four factors, weather has the most significant effect. It also directly impacts the other factors because it determines the rules under which aircraft are operated. Better understanding of all these factors will help to identify the source of delays at Bay Area airports, and to develop solutions to relieve congestion.

2.4.1 Weather Conditions

Weather affects airport operations in a number of ways. Wind direction and strength combined with visibility conditions (range and ceiling) require different runway use combinations and result in different airport capacities at the three Bay Area airports. While wind may change the direction of aircraft operations, it generally does not inhibit capacity. However, SFO normally has aircraft arrive on runways 28L and 28R and depart on 1L and 1R except when westerly winds exceed 20 nm per hour. In this condition, runways 1L and 1R cannot be used for departures. All aircraft must then use runways 28L and 28R for arrivals and departures, reducing SFO from four runways to two. This occurs at SFO between 7% and 10% of the time.

Visibility has a significant effect on capacity and defines the two main weather-related conditions under which aircraft operate. These are visual flight rules (VFR) and instrument flight rules (IFR). In good weather, skies are clear and VFR is in effect, typically allowing simultaneous use of close parallel runways because pilots can see nearby aircraft. When the cloud ceiling is low and visibility is poor, however, IFR is in effect and aircraft require greater separation. Under IFR conditions with closely spaced parallel runways (less than 4,300 feet separation or 3,400 under certain conditions), only one runway can be used. Since this is the situation with SFO, only a single runway can be used for arrivals during IFR conditions.

Table 2-1 shows the proportion of VFR to IFR conditions for the three Bay Area airports. SFO is affected the most by weather, which often means that the airport loses one of its two landing runways, thereby cutting the capacity from a maximum of 60 arrivals per hour to 30 or less per hour.

Table 2-1
Percentage of Visibility Conditions

	VFR (Good Weather)	IFR (Bad Weather)
San Francisco	80.0%	20.0%
Oakland	79.5%	20.5%
San Jose	85.0%	15.0%

Source: San Jose International Airport Master Plan, Draft 1996.

Bad weather is typically the main cause of delay at Bay Area airports. There are two types of bad weather that affect operations: 1) Bad weather in the morning during the summer due to low ("stratus") clouds, and 2) Bad weather all day, usually in the winter, due to seasonal storms with gusting southeasterly winds.

While bad weather mornings are about twice as frequent as bad weather all day, there is a greater chance of flight cancellations when weather is bad all day. When the weather is bad only in the morning, the airport has a chance to recover with delayed flights (similar to recovery following peak periods described in Section 2.4.4). When the weather is bad all day, the airport is often unable to accommodate all of the scheduled flights, leading to cancellations or diversions.

SFO's recent analysis shows that:

- On good weather days, 83% of the flights arrived on time (within 15 minutes of their scheduled arrival time)
- On days when weather was bad in the morning, 67% of the flights arrived on time
- On days when weather was bad all day, only 48% of the flights arrived on time[1]

Also, with poorer weather, more flights are cancelled, ranging from an average of 2% on good weather days to about 10% on days when the weather is bad all day.[1]

2.4.2 Runway Layout

The capacity of an airfield is determined in part by its configuration. Once a runway's capacity is exceeded, the airfield begins to experience delays. Two layout characteristics are the primary determinants of capacity. These are lateral spacing (between parallel runways) and intersecting runways. Other airfield characteristics that affect capacity are location of high speed exits, and taxiway configuration. The two major runway layout characteristics are:

Lateral Spacing – San Francisco currently has two pairs of parallel runways with each pair spaced 750 feet, which is adequate for simultaneous landings and takeoffs in VFR.conditions. San Francisco does not have adequate separation, however, under IFR conditions for independent simultaneous operations, as shown in the standards in Table 2-2.

[1] "Reducing Weather Related Delays and Cancellations at San Francisco International Airport," Charles River Associates and John F. Brown Company, April 2000.

Table 2-2
Runway Separation Standards Using IFR for Parallel Streams

Operation	Minimum Separation
Simultaneous approaches	4,300 feet
Simultaneous approaches (radar) *	3,000 feet
Simultaneous departures (non-radar)	3,500 feet
Simultaneous departures (radar) **	2,500 feet
Simultaneous approach and departure	2,500 feet

*Under consideration by FAA with high update radar and monitoring equipment.
** When the departure tracks diverge by at least 15° on each side, simultaneous departures in IFR are possible even for runways as close as 750 feet.

Oakland and San Jose do not currently have parallel runways, but San Jose has one under development, and Oakland has future plans that include a new parallel runway. A narrower runway separation limits aircraft throughput, especially for arrivals and under IFR conditions. Wider runway separation allows for more operational flexibility and therefore a higher capacity. If runway thresholds are staggered, separation may be reduced or increased, depending on the amount of stagger and which runways are used for arrivals and departures. FAA provides complete guidelines for runway separation.

Intersecting Runways – When runways intersect, the throughput is limited by the obvious need to coordinate the cross traffic. The capacity of intersecting runways is dependent upon the location of the intersection; the manner in which runways are operated for takeoffs and landings (known as the runway use strategy); and the aircraft mix. The farther the intersection is from the takeoff end of the runway and the landing threshold, the lower the capacity. The maximum capacity is achieved when the intersection is close to the takeoff and landing threshold.

With two intersecting runways, departures are typically held on one runway, while an arriving aircraft lands on the intersecting runway. This dependent operation can be further complicated when a runway intersects parallel runways or more so when two sets of parallel runways intersect. In this case, operations must be synchronized into arrival pairs and departure pairs to maximize the window for intersecting traffic. In the case of the three Bay Area airports, only SFO has intersecting runways; OAK and SJC do not.

2.4.3 Fleet Mix

The fleet mix at a given airport affects the flow of departure and arrival streams due to the varying characteristics of different aircraft and their impact on one another. Standards for minimum separation (headway) between arriving and departing aircraft must be met; this limits the flow of operations and hence is a factor affecting delay. Size, based on weight, determines the minimum separation between aircraft. Smaller aircraft must have adequate separation behind larger aircraft due to the wake turbulence created by the larger aircraft. Table 2-3, below, is a definition of the four aircraft groups FAA has designated to determine aircraft separation. The B757 is in its own category because its weight places it in the "Large" category, however its

wake characteristics are like a "Heavy" aircraft. Table 2-3 shows typical aircrafts that are representative of these categories.

Table 2-3
Aircraft Categories for Wake Separation

Heavy	Gross weight greater than 300,000 lbs. – B747, Airbus 340
B757	B757
Large	Gross weight greater than 12,500 lbs. but less that 300,000 lbs. – B737, Airbus 320
Small	Gross weight less than 12,500 lbs. – Citation II, Beech Baron

In an arrival stream, the order in which aircraft of different weights are allowed to approach must be considered. Using the aircraft categories above, final approach wake turbulence separation, measured in nautical miles, is determined by the order of the arriving aircraft. In a departure stream, the order in which aircraft of different weights are allowed to takeoff must be similarly considered. Also, the mix of turboprops and jets is another factor determining departure separation, since turboprops climb in altitude more slowly than jets do. Greater separation must be provided between a jet following a turboprop, in order to give the turboprop sufficient time to reach the point at which it leaves the jet route.

As an example of the application of these rules, for San Francisco, the separations presented in Table 2-4 are followed. This table shows separations within 10 nautical miles of the airport and in the larger airspace (general) as well as in VFR and IFR conditions.

Table 2-4
Minimum SFO Trailing Aircraft Separations (in nautical miles)

		Trailing Aircraft							
		Final Approach (within 10 nm)				General			
Conditions	Leading Aircraft	Heavy	B757	Large	Small	Heavy	B757	Large	Small
Visual Flight Rules	Heavy	2.9	3.6	3.6	4.5	4.0	4.0	5.0	5.0
	B757	2.9	2.9	2.9	3.7	4.0	4.0	4.0	5.0
	Large	2.5	2.5	2.5	2.7	4.0	4.0	4.0	4.0
	Small	2.5	2.5	2.5	2.5	4.0	4.0	4.0	4.0
Instrument Flight Rules	Heavy	4.0	4.0	4.0	6.0	4.0	4.0	5.0	5.0
	B757	4.0	4.0	4.0	5.0	4.0	4.0	4.0	5.0
	Large	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	Small	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

2.4.4 Traffic Peaks

As mentioned above in discussing runway layout, every airfield has capacity limits. When that capacity is exceeded, delays result. During peak periods, the airfield capacity may be exceeded for a brief or sustained period depending on the peak's duration. In the case of a brief or sustained peak, a queue begins to form which results in delay. For a shorter peak, the queue will begin to dissipate in the time following, and delays will decrease as the volume reduces back to or below capacity. For a more sustained peak, however, the recovery time is much longer and the delays persist. Sometimes, the impact of a long peak has a ripple effect that can be felt throughout the day. If there are significant peaks that begin to overlap, the airport may experience a low level of service and not recover all day.

Figure 2-3 illustrates what happens when capacity is exceeded during most of the day. The upper curve is the cumulative demand curve, i.e., aircraft arriving in the airport area since midnight. The lower curve is the cumulative number of aircraft that have been processed (landed). For an aircraft arriving at 1800 (6 p.m.), the tower may tell the pilot "you are number 420 and we are currently serving number 320. Your estimated landing time will be about 2200 (10 p.m.)". This implies a four hour delay. This figure also shows that once capacity is exceeded, the delays just keep growing.

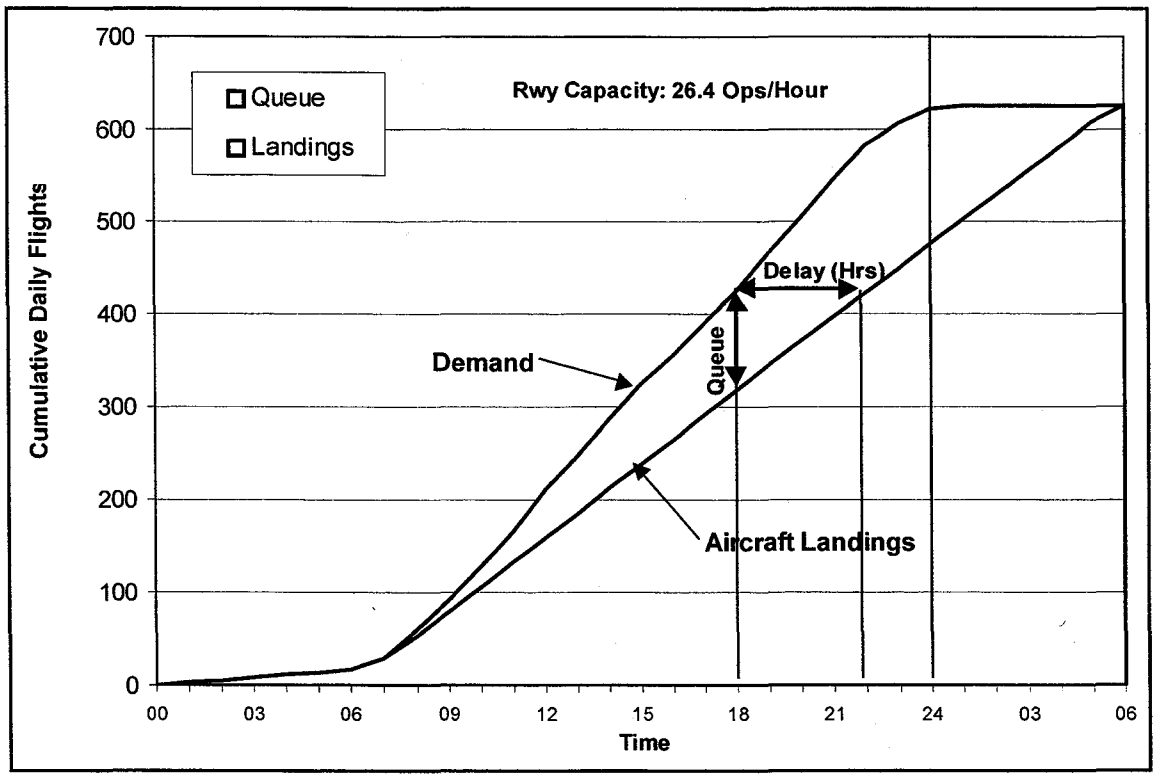


Figure 2-3 Build-up of Queue Length when Demand Exceeds Capacity

Using SIMMOD and taking into account the factors discussed in the previous section, this section describes the existing runway and airspace conditions at the three Bay Area airports, and quantifies the delays determined through simulation for 1999. These delays can then be compared to actual delays experienced at the three airports, in order to validate the model.

3.1 EXISTING AIRCRAFT OPERATIONS AND AIRLINE FLIGHT SCHEDULES

Data for 1999, as logged by the control tower, were used as input to the simulation to provide the number of aircraft operations (each arrival or departure is one operation), the schedule of arrivals and departures, the types of aircraft, and the origin/destination of each aircraft. This data is developed as a flight schedule over the full 24 hours of airport operations for the average day of the peak traffic month (ADPM) which was a mid-week day in August 1999. Figures 3-1, 3-2 and 3-3 show graphically the 1999 flight schedules for each of the three airports involved in the simulations.

3.1.1 SFO Flight Schedule

As shown in Figure 3-1, the ADPM flight schedule includes about 1241 daily arrivals and departures. Ninety percent of the flights are commercial passenger aircraft, 5% are all-cargo flights and 5% are general aviation flights. The arrival peak occurs from 11AM to 12PM, when 45 flights land. The departure peak occurs from 1PM to 2PM when 46 flights take off. Overall, from 7AM to 9PM the number of operations falls in a relatively narrow range (66-88 ops/hour) and is a pattern typical of a mature airport operating near capacity.

3.1.2 OAK Flight Schedule

As shown in Figure 3-2, the ADPM flight schedule includes about 548 daily arrivals and departures for the South Field. Sixty-three percent of the flights are commercial passenger aircraft, 24% are all-cargo flights and 13% are general aviation flights. The arrival peak occurs from 5 p.m. to 6 p.m., when 20 flights arrive. The departure peak occurs from 6 a.m. to 7 a.m. when 26 flights depart. The reason for the imbalance between arrivals and departures is that some cargo aircraft use the North Field for landing and therefore do not appear in the graph below.

3.1.3 SJC Flight Schedule

As shown in Figure 3-3, the ADPM flight schedule for the main air carrier runway includes about 473 daily arrivals and departures. Seventy-nine percent of the flights are commercial passenger aircraft, 6% are all-cargo flights, and 15% are general aviation flights. The busiest arrival peak occurs from 7PM to 8PM, when 19 flights arrive. The busiest departure peak occurs from 6AM to 7AM when 24 flights depart.

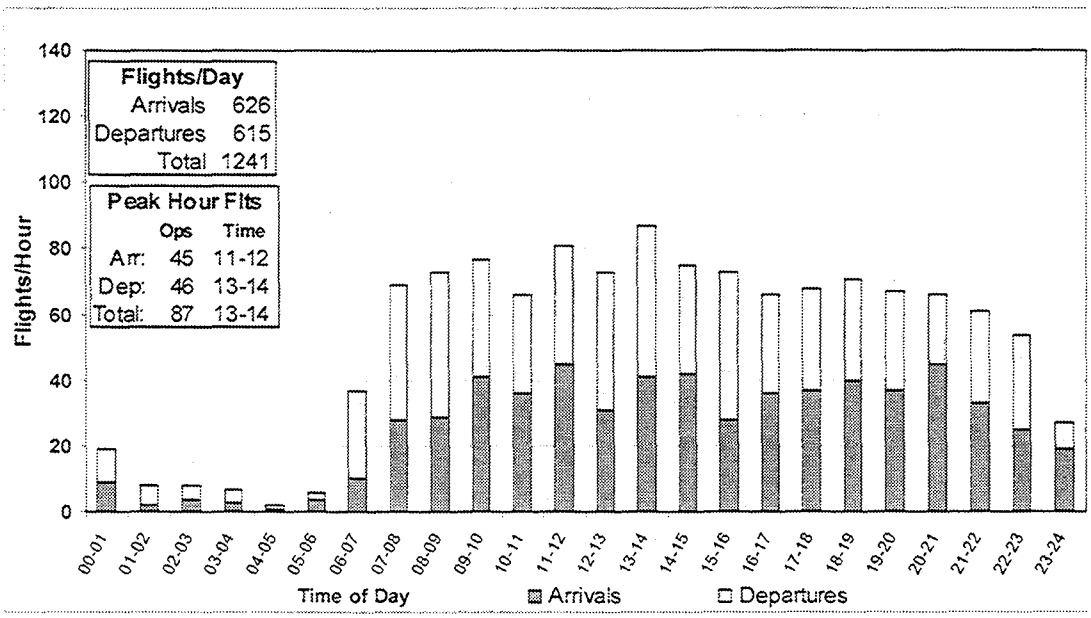


Figure 3-1 SFO Hourly Traffic Demand – Mid-week August 1999

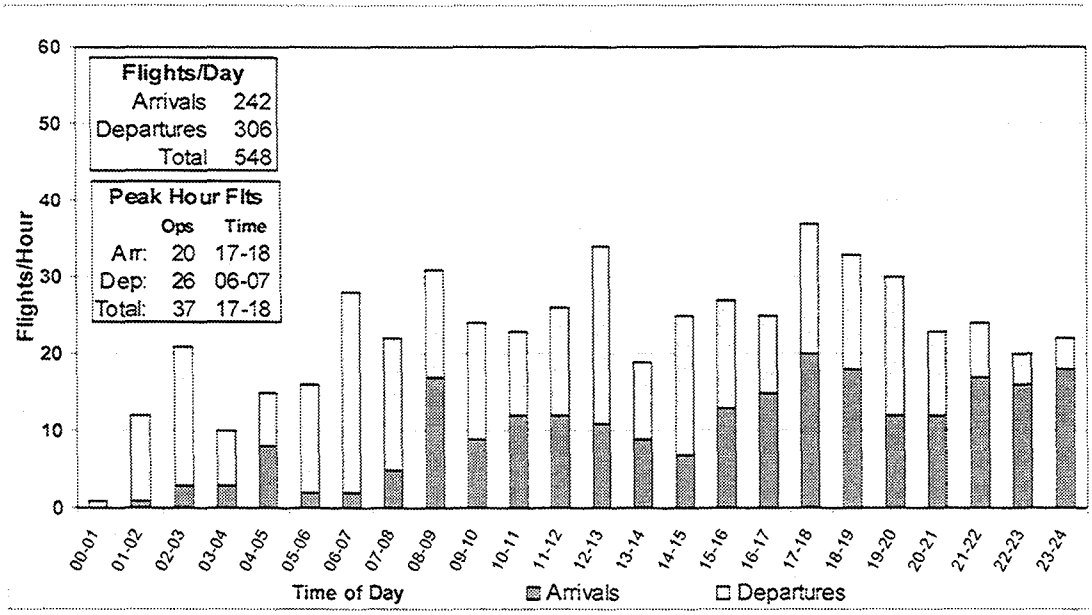


Figure 3-2 OAK Hourly Traffic Demand – Mid-week August 1999

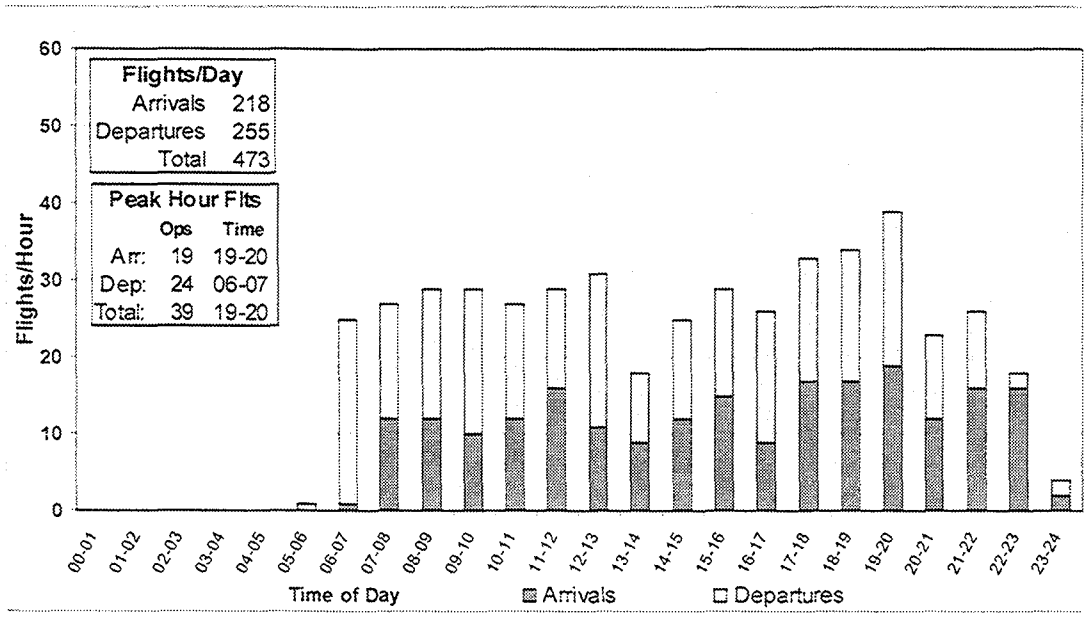


Figure 3-3 SJC Hourly Traffic Demand – Mid-week August 1999

3.2 EXISTING RUNWAY LAYOUTS AND OPERATING PROCEDURES

To determine the baseline of capacity and delay, the existing airport runway layouts for SFO, OAK, and SJC were modeled in SIMMOD. Figures 3-4, 3-5, and 3-6 show the existing runway/taxiway configuration of each airport.

Two basic airspace flow plans are used by air traffic control (ATC) to guide aircraft into and out of the three Bay Area airports, the West Plan and the Southeast Plan. The West Plan is used about 95% of the time and responds to the prevailing winds in the Bay Area which generally blow from a westerly direction. The Southeast plan is used only when strong winds (above 20 knots) blow from the southeast, which generally occurs during winter storms. The preferred approach/departure procedures for each traffic flow plan are shown in the figures below.

3.2.1 SFO Runway Configuration and Operating Procedures

As shown in the figure below, the existing runway configuration is composed of two close parallel runways oriented in an east-west direction (runway 10L/28R and runway 10R/28L); the runways are intersected by two close parallel runways oriented in a north-south direction (runway 1L/19R and runway 1R/19L).

Each pair of runways is categorized by the FAA as closely spaced since they are separated by only 750 feet measured between runway centerlines. During good weather conditions when VFR is used, two independent streams of arrivals can be sequenced on the closely spaced pairs of runways. However, during IFR conditions of low ceiling and poor visibility, only one stream of

arrivals can be handled safely, cutting runway capacity in half. For departures, two streams can be handled safely in VFR conditions. In IFR conditions, paired departures are permitted if visual separation can be maintained until aircraft have a 15 degree diverging heading and are established on course. Otherwise, departure procedures require a 1 mile staggered separation distance for diverging heading, a 3 to 5 mile separation with standard radar depending upon aircraft fleet mix (heavy vs. non-heavy aircraft), or a 5 mile radar separation if small follows heavy. Procedures used during VFR and IFR conditions for both the West Plan and Southeast plans are shown below.

For the West Plan VFR shown in Figure 3-4 A, the following procedures are typically followed:

- Arriving flights on 28L and 28R are paired for simultaneous landings, and each pair of aircraft must follow about 4 nm apart. This leaves sufficient space to allow a pair of aircraft to depart on these runways.
- Departures on 1R and 1L can be released only after arriving flights have crossed runway 1L.
- Departures for long-haul heavy flights must take place on 28R because of its length. These departures must be sequenced in a free slot of the 28R arrival stream.

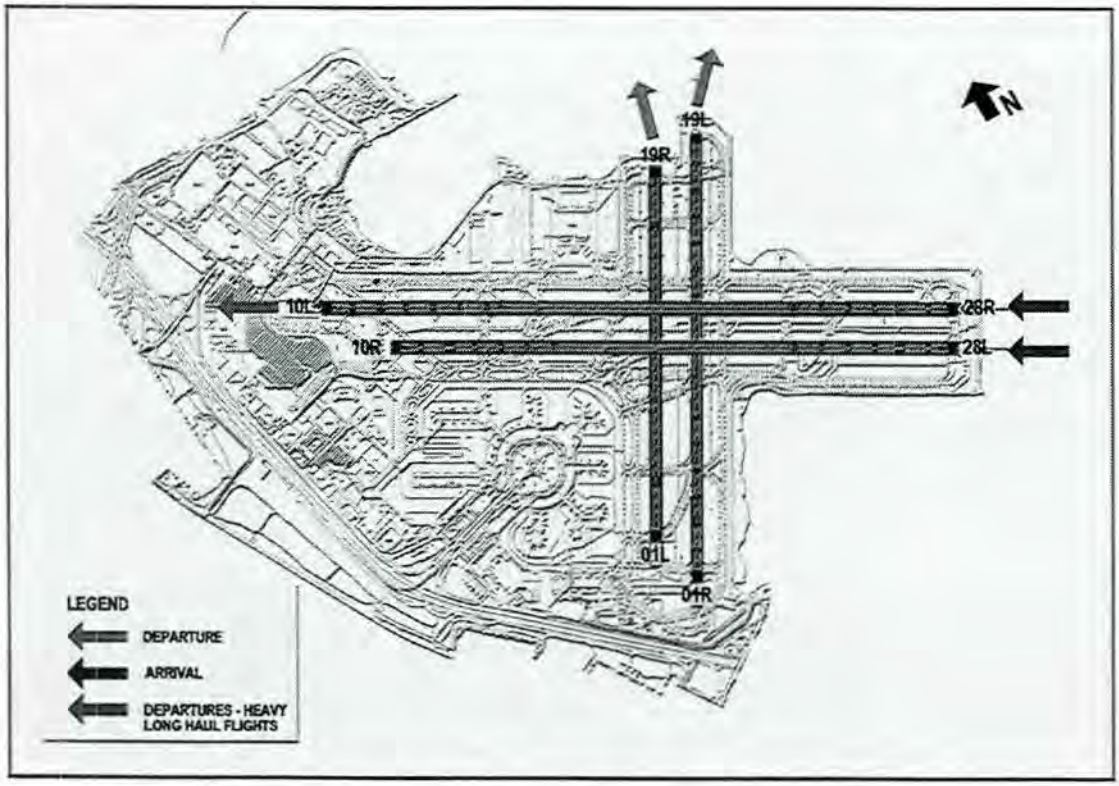


Figure 3-4A Existing SFO Airport Configuration with West Plan VFR Procedures

For the West Plan IFR shown in Figure 3-4 B, the following procedures are typically followed:

- During IFR conditions, arriving flights are restricted to a single runway, and use 28R because that runway is equipped with Category II and III Instrument Landing Systems (ILS).
- Arriving flights on 28R are separated from 4 to 6 nm depending on aircraft size and wake turbulence separation requirements.
- Departing flights use 1L and 1R and must be sequenced between flights arriving on 28R.
- Departures for long-haul heavy flights must take place on 28R because of its length. These departures must be sequenced in a free slot of the 28R arrival stream.

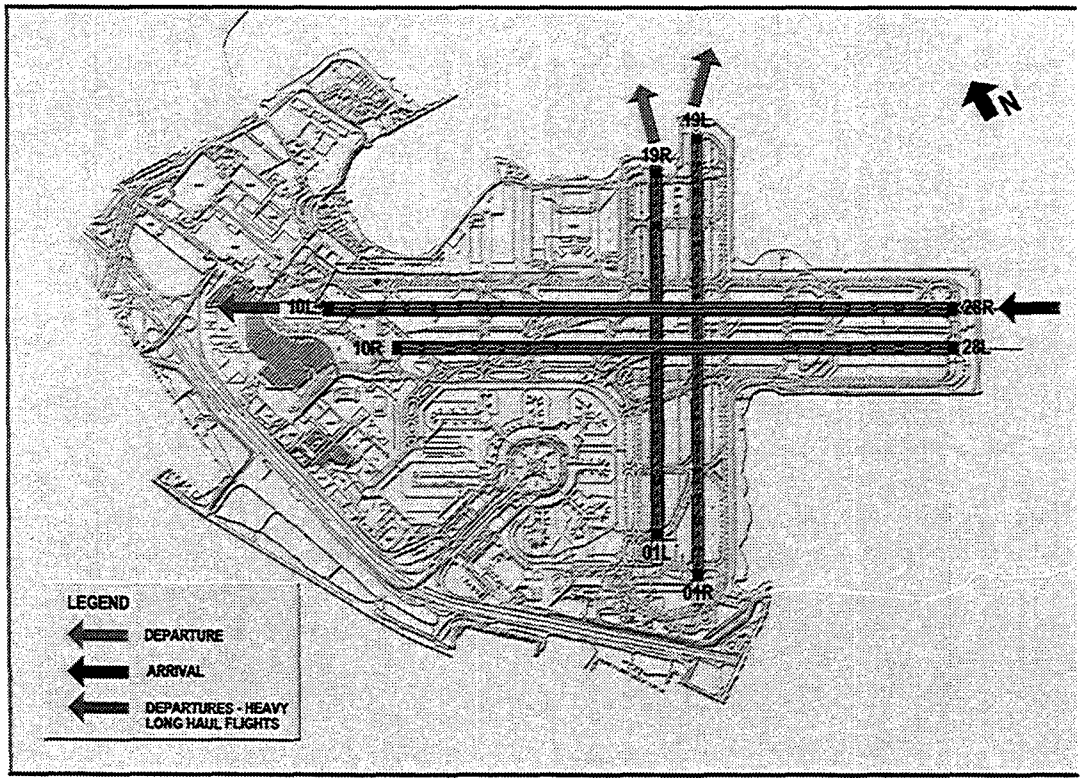


Figure 3-4B Existing SFO Airport Configuration with West Plan IFR Procedures

For the Southeast Plan IFR shown in 3-4 C, the following procedures are typically followed:

- The Southeast Plan is implemented when prevailing storm winds create a southerly crosswind of 20 knots or greater, affecting landings on runways 28L and 28R.
- In the Southeast Plan, arriving flights are limited to a single runway and use runway 19L because it has Category II and III ILS. Arriving flights are separated according to wake turbulence requirements.
- Departing flights use runways 10L and 10R in a staggered way because the departing routes do not diverge sufficiently. This becomes equivalent to a single runway.

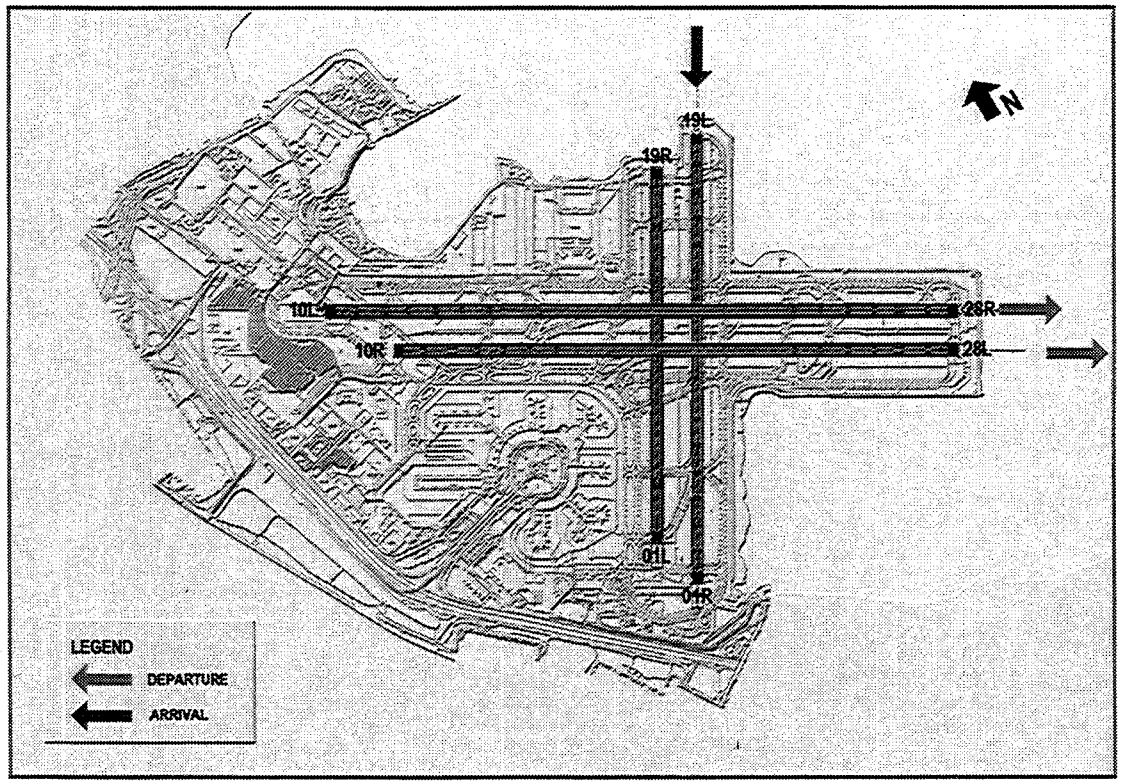


Figure 3-4C Existing SFO Airport Configuration with SE Plan IFR Procedures

3.2.2 OAK Runway Configuration and Operating Procedures

As shown in Figure 3-5, OAK has a single commercial air carrier runway in the South Field (runway 11/29), with a length of 10,000 feet. It also has three shorter runways in the North Field, used primarily for general aviation operations. However, 27R can be used for landing small cargo aircraft and thus does contribute to commercial aircraft capacity. Since there is only a single commercial air carrier runway at OAK, the following operating procedures for both VFR and IFR conditions are typically followed:

- Arriving flights use runway 11/29, separated according to wake turbulence requirements. In the West Plan runway 29 and 27R are used.
- Departing flights use runway 11/29, sequenced between arriving flights according to wake turbulence requirements.

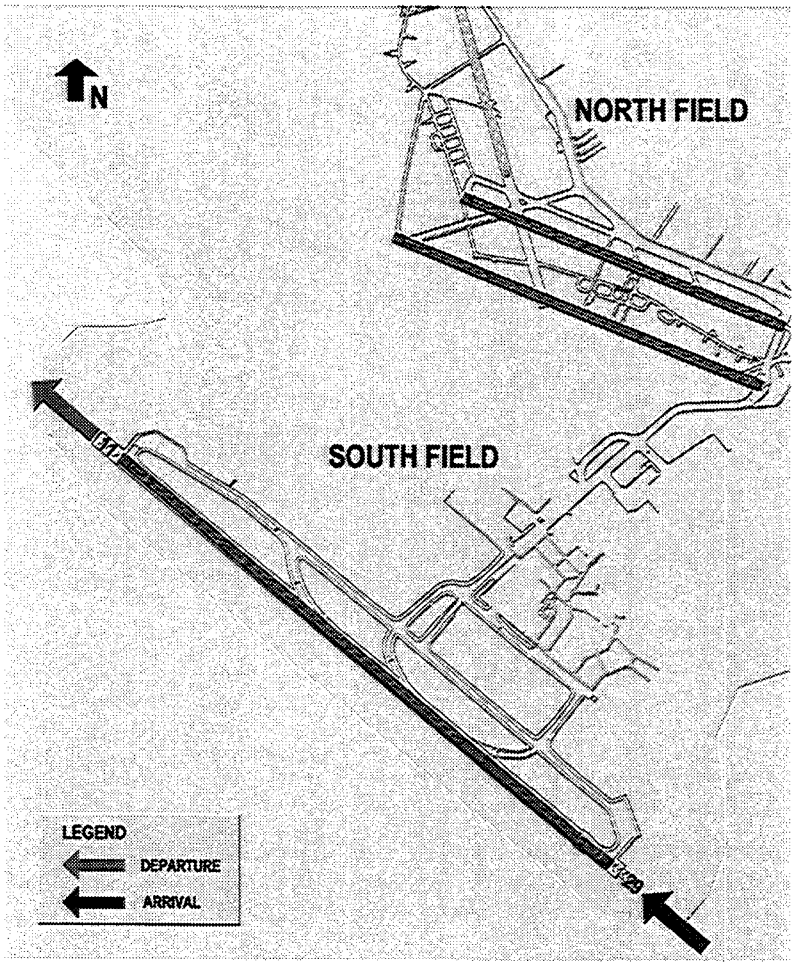


Figure 3-5 OAK Existing Airport Configuration

3.2.3 SJC Runway Configuration

As shown in Figure 3-6, SJC presently has a single commercial air carrier runway (runway 30L/12R) with a length of 10,200 feet. In addition, there are two shorter runways used for general aviation operations that do not affect commercial air carrier capacity. Since there is only a single commercial carrier runway, the following operating procedures for both VFR and IFR conditions are typically followed:

- Arriving flights use runway 12/30, separated according to wake turbulence requirements.
- Departing flights use runway 12/30, sequenced between arriving flights according to wake turbulence requirements.

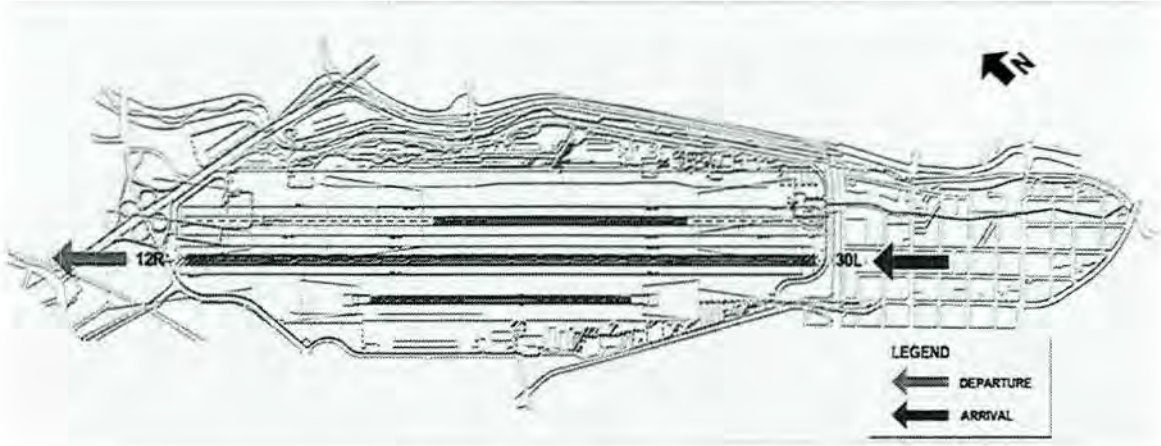


Figure 3-6 SJC Existing Airport Configuration

3.3 EXISTING AIRSPACE STRUCTURE

In the Bay Area, arrivals and departures occur in almost all directions. The east and south sectors are the busiest because they serve US domestic flights and Southern California flights. Detailed airspace routes and procedures have been developed to guide aircraft to/from the appropriate runways at each of the airports under the West and Southeast Plan operating conditions.

3.3.1 West Plan

As shown below in a diagram developed by the San Francisco International Airport, the three-dimensional interaction of approaches and departures at the three airports is tightly controlled by the Oakland ARTCC, the Bay TRACON and the control tower of each airport. The air routes with their fixes and merge points have been incorporated in the simulation utilizing the procedures specified by ATC.

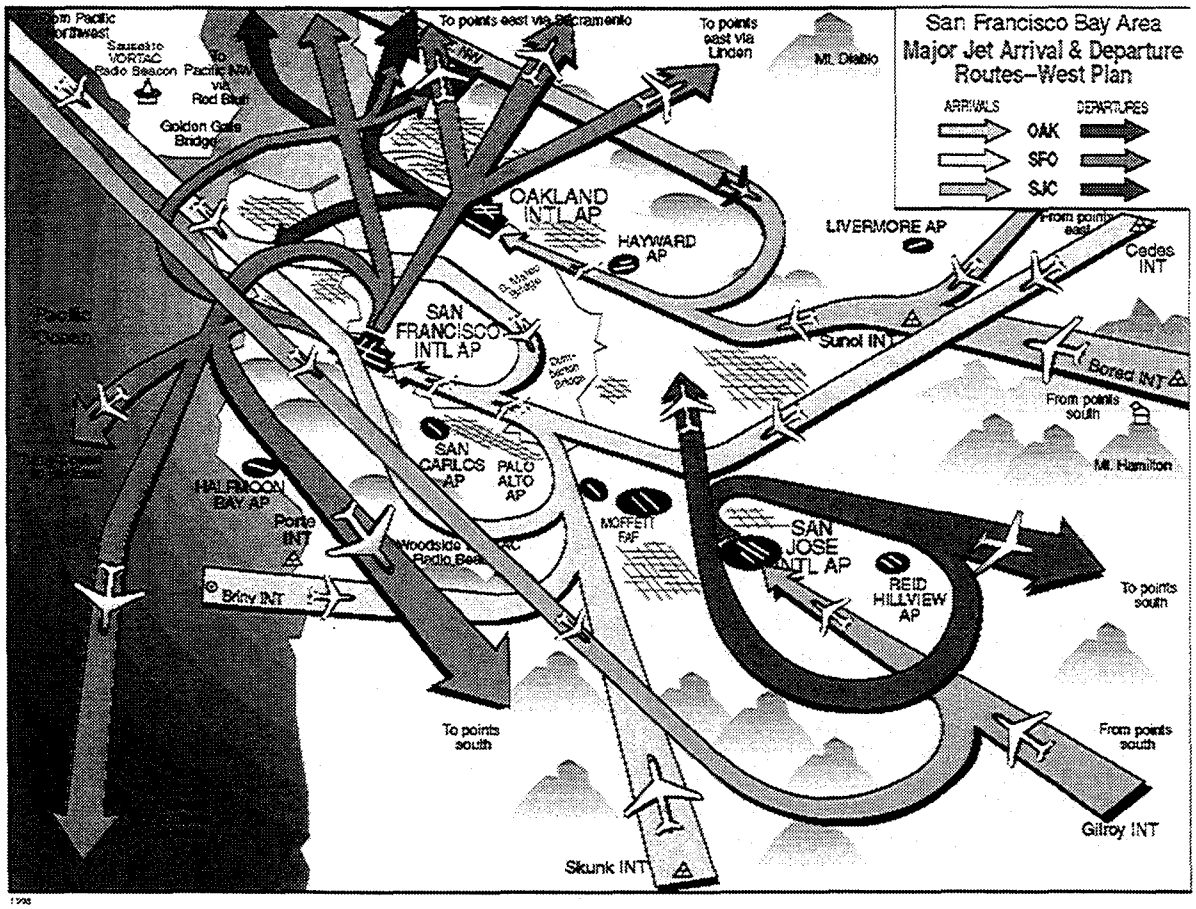


Figure 3-7 Airspace Diagram-West Plan

Source: SFO Planning Department

3.3.2 Southeast Plan

As shown in Figure 3-8 below, the existing air routes for the Southeast Plan are used when strong winds from the southeast make use of the West Plan inadvisable. The routes and procedures have been modeled in the simulation of the Southeast Plan.

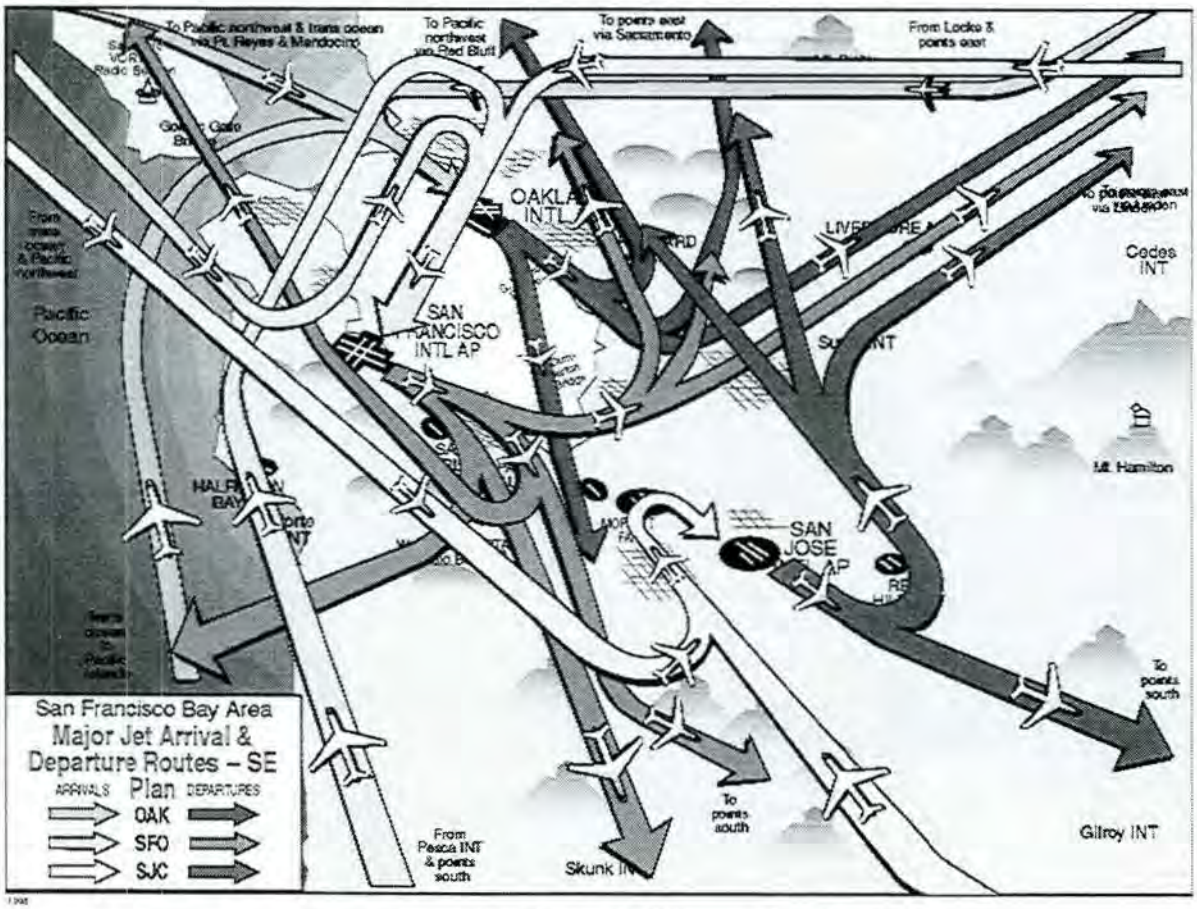


Figure 3-8 Airspace Diagram-Southeast Plan

Source: SFO Planning Department

3.4 SIMULATION RESULTS – ANNUAL DELAYS 1999

The results of the simulation runs are shown below for each airport.

Annual average delays are shown in minutes-per-aircraft for 1999 by one of the three weather-related conditions as follows:

- West Plan VFR: this condition occurs about 80% of the time annually
- West Plan IFR: this condition occurs about 15% of the time annually
- Southeast Plan IFR: this condition occurs about 5% of the time annually

Delays may occur in both arrivals and departures. Delays are quantified in different segments of a flight, including:

- Air: delays by aircraft in flight within the Oakland ARTCC airspace only. In reality, during bad delays at SFO, flights can be held at origin airports , delayed while en route or even cancelled.
- Ground: may include taxi-in, taxi-out, or gate hold delays
- Queue: for departures only, aircraft may be held in a queue awaiting a slot for take-off

As shown in Figure 2-2, average delays of 3 - 5 minutes or less per operation are considered acceptable.

3.4.1 SFO Delays

As shown in Table 3-1, the results of the simulation indicate that for West Plan VFR, which is utilized about 80% of the year, arrival delays are acceptable, averaging about 3.99 minutes per flight. Departure delays, however, average about 6.07 minutes per flight, a bit above acceptable limits. In total, the combined average for West Plan VFR arrivals and departures is about 3.51 minutes per flight, close to acceptable limits.

Table 3-1
SFO Delays-1999

Runs	*Arrival Delays (min)*				*Departure Delays (min)*					*Total Delays*	
	No. Ops	Air	Ground	Total	No. Ops	Air	Ground	Queue	Total	No. Ops	Total
West VFR	626	2.31	0.00	2.31	615	0.31	0.01	4.60	4.74	1241	3.51
West IFR	626	149	0.00	149	615	0.03	0.01	5.73	5.78	1241	77.80
SE IFR	626	93.7	0.02	93.7	615	2.15	0.00	6.45	8.61	1241	51.54
All Plans*				28.99					5.10		17.15

*Weighted average based on the percentage of time each operating plan is utilized on an annual basis

For West Plan IFR, however, which is used about 15% of the year during poor weather visibility, the arrival delays rapidly escalate. This is due to the severe restrictions on capacity imposed when arrivals must be reduced to a single runway. Here, delays keep growing throughout the day. The simulation indicates that, under 1999 traffic levels, average arrival delays mount to almost 149 minutes per flight. Such extreme delays frequently lead to outright flight cancellations or diversion to alternate airports. Average departure delays rise to 5.78 minutes per flight.

For Southeast Plan IFR, which is used about 5% of the year during poor weather visibility when strong winds blow from the southeast, runway use is again effectively restricted to a single runway, leading to extensive delays in both arrivals and departures. For arrivals, the delays

mount to 93.7 minutes per flight and for departures to 8.61 minutes per flight. The arrival delays represent extreme delays that may lead to flight cancellations or diversions.

As a final measure of overall delay, the weighted average of delays under all three weather conditions was calculated based on their annual utilization. The weighting represents West Plan VFR (80%), West Plan IFR (15%) and Southeast Plan IFR (5%), giving a weighted average of 28.99 minutes for arrivals, 5.10 minutes for departures and a combined average of arrival and departure delays of 17.15 minutes.

3.4.2 OAK Delays

As shown in Table 3-2, the annual delays at Oakland with 1999 levels of traffic for West Plan VFR and West Plan IFR fall well under acceptable limits. For the Southeast Plan IFR, arrival delays add up to 1.58 minutes per flight while departure delays mount to 3.80 minutes per flight. During IFR conditions, some commercial aircraft that normally land on the North Field have to use the South Field. In order to mirror actual conditions, the model approximates this impact by increasing aircraft separation during IFR on the South Field.

Table 3-2
OAK Delays-1999

Runs	*Arrival Delays (min)*				*Departure Delays (min)*					*Total Delays*	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
West VFR	242	0.51	0.00	0.51	306	0.11	0.00	1.02	1.13	548	0.86
West IFR	242	1.14	0.00	1.14	306	0.09	0.00	0.79	0.88	548	0.99
SE IFR	242	1.58	0.00	1.58	306	2.87	0.00	0.92	3.80	548	2.82
All Plans*				0.65					1.25		0.99

*Weighted average based on the percentage of time each operating plan is utilized on an annual basis

3.4.3 SJC Delays

As shown in Table 3-3, delays for West Plan VFR and IFR fall well under acceptable minimums. Under the Southeast Plan, arrival delays add up to 1.50 minutes while departure delays mount to 4.33 minutes per flight, still within acceptable limits.

Table 3-3
SJC Delays-1999

Runs	Arrival Delays (min)				Departure Delays (min)					Total Delays	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
West VFR	218	0.63	.0.00	0.63	255	0.52	0.70	0.80	2.02	473	1.38
West IFR	218	0.52	0.00	0.52	255	0.43	0.63	0.85	1.90	473	1.26
SE IFR	218	1.50	0.00	1.50	255	3.12	0.00	1.21	4.33	473	3.03
All Plans				0.69					2.20		1.50

*Weighted average based on the percentage of time each operating plan is utilized on an annual basis

3.5 MODEL VALIDATION

The model accurately reflects the conditions and delays experienced at the three airports during actual operations in 1999. With the SIMMOD model now tested and validated, it was possible to undertake the modeling of future conditions for 2010 and 2020 as described in Sections 4 and 5.

One approach to accommodating the growing demand at Bay Area airports is to consider modifications of air traffic patterns and volumes. For purposes of this analysis, two alternatives to this strategy are described which are focussed primarily on SFO, the region's most heavily used facility:

- *Demand Management for SFO Traffic* – In this approach, the three-airport system is viewed as a whole and steps are taken to reduce air traffic volumes and redistribute flights between SFO and OAK, thus creating an operating scenario that yields lower delays.
- *New Technology* – In this approach, the introduction of new technology for air traffic control is considered at SFO, and is assumed to increase capacity. This is achieved by reducing in-trail separation minimums and/or by lowering weather restrictions on the use of closely spaced parallel runways.

This section examines how these strategies would affect existing and future aircraft delays for San Francisco, Oakland and San Jose airports, without changing airfield configurations.

In general, introduction of new technology translates into an increase in effective airfield capacity. Benefits from new air traffic technology would apply to existing airfields as well as to airfields with new runways. A scenario combining new technology and new runway configurations is addressed in Section 6.

4.1 PRACTICAL LIMITS OF DEMAND MANAGEMENT

Before presenting the demand management strategies, it should be noted that, while employing these strategies may theoretically reduce delays, there are a number of factors that limit the feasibility of imposing such schedule modifications. These factors include market-based, legal and operational issues.

- From a market-based perspective, increasing flight frequencies is a response to increased demand and artificial limitations that inhibit supply will increase customer inconvenience.
- From a legal perspective, it is illegal under federal airline deregulation laws for airports to artificially limit competition or "move" flights from one airport to another. Attempts at imposing schedule changes may be met by legal challenges from the airlines.
- From an operational perspective, the composition of an airline's fleet may be critical to its operations (such as frequent short-haul flights). For this reason, it is expected that forced alteration of an airline's operations and fleet mix that create scheduling and economic inefficiencies would be challenged.

There may also be other related impacts of regulating aircraft size, such as terminal gate requirements, increased airline operating costs, and effects on airline labor agreements.

4.2 1999 SENSITIVITY ANALYSIS

As a precursor to modeling modified future aircraft schedules and operations, a sensitivity analysis was performed using 1999 schedules and facilities. This sensitivity analysis explores the impact of demand management strategies and shows the potential magnitude of delay reductions resulting from such modifications.

A base case for comparison was established and two cases for analysis developed. These are described below.

- *Base Case* – Actual flight schedule for average day of the peak month (August mid-week) for the Bay Area. Runway configurations for the three airports are the existing layouts. This analysis is presented in Section 3.
- *Sensitivity Case S1* – Uses the existing runway configurations for the three airports. Flight schedules are modified: SFO corporate and general aviation operations are moved to Oakland, and SFO commuter turboprop flights are replaced by half the number of larger regional jets. This does not change the total number of seats offered.
- *Sensitivity Case S2* – Uses the existing runway configurations for the three airports. Flight schedules are modified: SFO corporate and general aviation operations are moved to Oakland, and SFO commuter turboprop flights are replaced by regional jets (as in S1). In addition, flights between SFO and a number of Southern California airports – BUR, LAX, ONT, SBA, SNA, and SAN – are decreased by 26% to reflect larger aircraft (total seats offered are kept constant).

4.2.1 Comparison of Operations

A comparison of the modified traffic volumes for each of the three Bay Area airports under the conditions of the sensitivity cases yielded the following results:

- For San Francisco, the number of operations was reduced from the Base Case total of 1,241 to 1,085 in S1 and 1,028 in S2 (Figure 4-1).
- In Oakland, the absorption of flights from San Francisco resulted in an increase from 548 operations in the Base Case to 614 operations in both S1 and S2 on the South Field (Figure 4-2).
- Operations at San Jose remained unchanged with a total of 473 in all three cases of the sensitivity analysis (Figure 4-3).

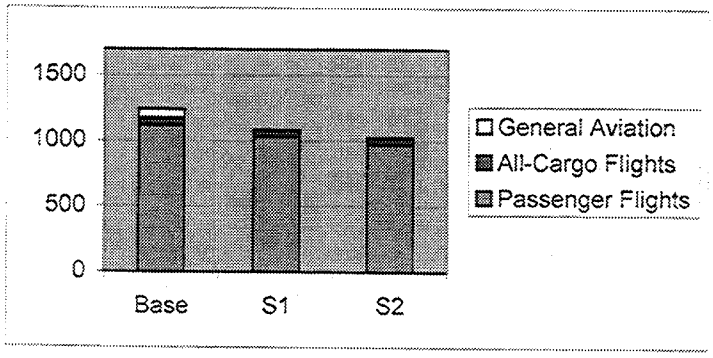


Figure 4-1 Comparison of 1999 SFO Operations

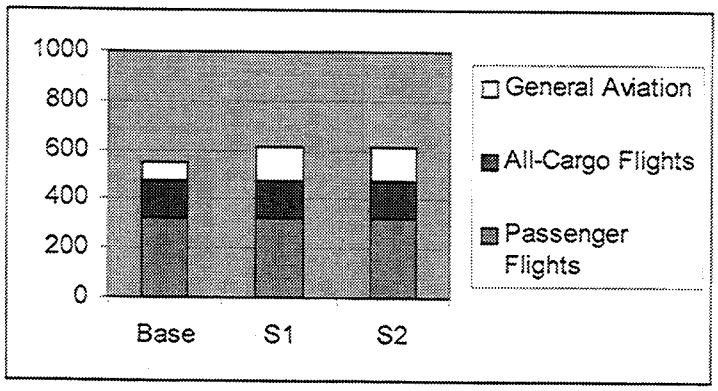


Figure 4-2 Comparison of 1999 Oakland Operations

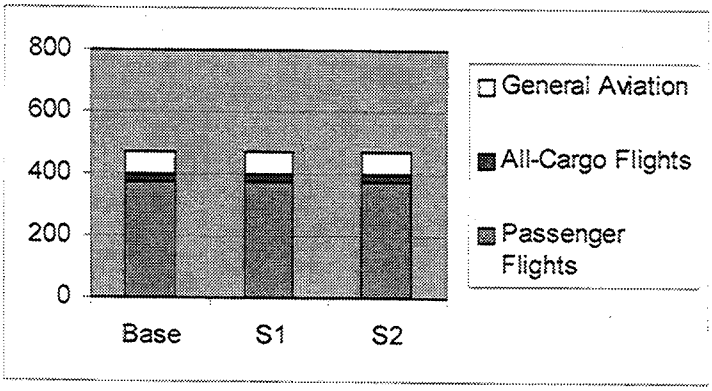


Figure 4-3 Comparison of 1999 San Jose Operations

4.2.2 Delay

Analysis of 1999 delay in the Base Case was discussed in detail in Section 3.4, and 1999 delays are summarized in Tables 3-1, 3-2, and 3-3. As expected when the number of SFO operations is reduced from the Base Case to S1 and then further reduced to S2, delays will be reduced, as discussed below and shown in Tables 4-1 and 4-2.

- *SFO Arrivals* – In general, delays are decreased due to the reduction and diversion of flights from SFO to OAK. Under West VFR operations, delay improved from 2.31 minutes in the Base Case, to 1.94 minutes in both S1 and S2. Under both West IFR and SE IFR operations, delay is reduced by more than 50% from the Base Case, although it is still in the saturated range.
- *SFO Departures* – Delays here are again decreased. Under West VFR operations, delay has improved from 4.74 minutes in the Base Case to 3.63 minutes, well within the acceptable range. For S2, the decrease is from 4.74 minutes to 2.46 minutes, within the free flow range. Under West IFR, delay improved from the congested range in the Base Case (5.78 minutes) to acceptable in S1 (4.08 minutes) and to free-flowing in S2 (2.95 minutes). Under SE IFR operations, delays remain at saturated levels for both S1 and S2.
- *OAK Arrivals* – Because Oakland absorbs some flights from San Francisco, its delays increase in general, but in most cases remain in much the same range. Under West VFR, IFR, and SE IFR operations, delay increases from the Base Case, but still remains in the free flow range in both S1 and S2.
- *OAK Departures* – Similar to arrivals, under West VFR, IFR and SE IFR operations, delay increases from the Base Case, but is still in the free flow and acceptable ranges for S1 and S2.
- *SJC Arrivals* – Delays remain the same in all three scenarios (Base Case, S1 and S2) and for West VFR and IFR. For SE operations, delay increases from the Base Case, but still remains in the free flow range for S1 and S2.
- *SJC Departures* – Under West VFR and IFR operations, delay varies from the Base Case, but still remains in the acceptable range for S1 and S2. Under SE IFR operations, delay decreases and is within the acceptable range.
- *Bay Area Weighted Averages* – When operations at all three airports are considered together and all three weather-related conditions are averaged in proportion to their occurrence, a weighted average for the Bay Area as a whole gives the following delay results:
  - S1 Weighted Averages - Average arrival delays decrease from 17.00 minutes in the Base Case to an average delay of 7.61 minutes per flight. Average departure delays decrease from 3.47 minutes in the Base Case to an average delay of 3.81 minutes per flight, well within the acceptable range.
  - S2 Weighted Averages – Average arrival delays decrease from 17.00 minutes in the Base Case to an average delay of 5.13 minutes per flight, falling near the acceptable range. Average departure delays decrease from 3.47 minutes in the Base Case to 3.25 minutes per flight, well within the acceptable range.

Table 4-1
Sensitivity S1 1999 Delay

Alternatives	1999 Arrival Delays (min)				1999 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	542	1.94	0.01	1.94	543	0.57	0.01	3.05	3.63	1085	2.79
West IFR	542	69.57	0.00	69.57	543	0.04	0.01	4.03	4.08	1085	36.79
SE IFR	542	29.68	0.01	29.70	543	2.66	0.00	25.52	28.18	1085	28.94
Weighted Avg.	542			13.53	543				4.96	1085	9.24
OAK											
West VFR	281	1.28	0.00	1.28	333	1.34	0.00	1.47	2.81	614	2.11
West IFR	281	1.70	0.00	1.70	333	0.10	0.00	0.95	1.05	614	1.35
SE IFR	281	2.55	0.00	2.55	333	3.21	0.00	1.14	4.34	614	3.52
Weighted Avg.	281			1.41	333				2.67	614	2.09
SJC											
West VFR	218	0.88	0.00	0.88	255	1.27	0.63	0.83	2.72	473	1.87
West IFR	218	0.51	0.00	0.51	255	0.49	0.68	0.83	2.00	473	1.31
SE IFR	218	1.50	0.00	1.50	255	3.26	0.00	1.47	4.73	473	3.24
Weighted Avg.	218			0.91	255				2.84	473	1.95
Bay Area											
Weighted Avg.	1041			7.61	1131				3.81	2172	5.63

Table 4-2
Sensitivity S2 1999 Delays

Alternatives	1999 Arrival Delays (min)				1999 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	513	1.93	0.01	1.94	515	0.74	0.01	2.46	3.22	1028	2.58
West IFR	513	46.35	0.00	46.35	515	0.05	0.01	2.88	2.95	1028	24.61
SE IFR	513	8.71	0.02	8.73	515	2.79	0.00	8.97	11.76	1028	10.25
Weighted Avg.	513			8.96	515				3.62	1028	6.29
OAK											
West VFR	281	1.28	0.00	1.28	333	1.37	0.00	1.67	3.04	614	2.23
West IFR	281	1.70	0.00	1.70	333	0.10	0.00	0.97	1.07	614	1.36
SE IFR	281	2.55	0.00	2.55	333	3.34	0.00	1.32	4.66	614	3.69
Weighted Avg.	281			1.41	333				2.87	614	2.20
SJC											
West VFR	218	0.88	0.00	0.88	255	1.44	0.73	0.81	2.98	473	2.01
West IFR	218	0.51	0.00	0.51	255	0.33	0.44	0.77	1.54	473	1.07
SE IFR	218	1.50	0.00	1.50	255	2.99	0.00	1.24	4.24	473	2.98
Weighted Avg.	218			0.91	255				2.99	473	2.03
Bay Area											
Weighted Avg.	1012			5.13	1103				3.25	2115	4.15

4.3 YEAR 2010 AND 2020 FLIGHT SCHEDULES

Design day flight schedules (simulation event files) for 2010 and 2020 for each of the three airports were developed to provide the number of aircraft operations, the time of arrivals and departures, and the types of aircraft. The schedules presented are unconstrained and serve as a basis for comparison to the modified schedules. As with the 1999 schedules, this input data to SIMMOD is developed as a flight schedule over the full 24 hours of airport operations for the average day of the peak traffic month (ADPM), which is a mid-week day in August.

Figures 4-4 through 4-9 show graphically the 2010 and 2020 flight schedules for each of the three airports used in the model simulations.

4.3.1 SFO Flight Schedule

As shown in Figure 4-4, the 2010 ADPM flight schedule includes about 1378 daily arrivals and departures, comprised of commercial passenger, cargo and general aviation flights. The busiest arrival peak occurs from 10PM to 11PM, when 56 flights arrive. The busiest departure peak occurs from 11AM to 12AM when 50 flights depart.

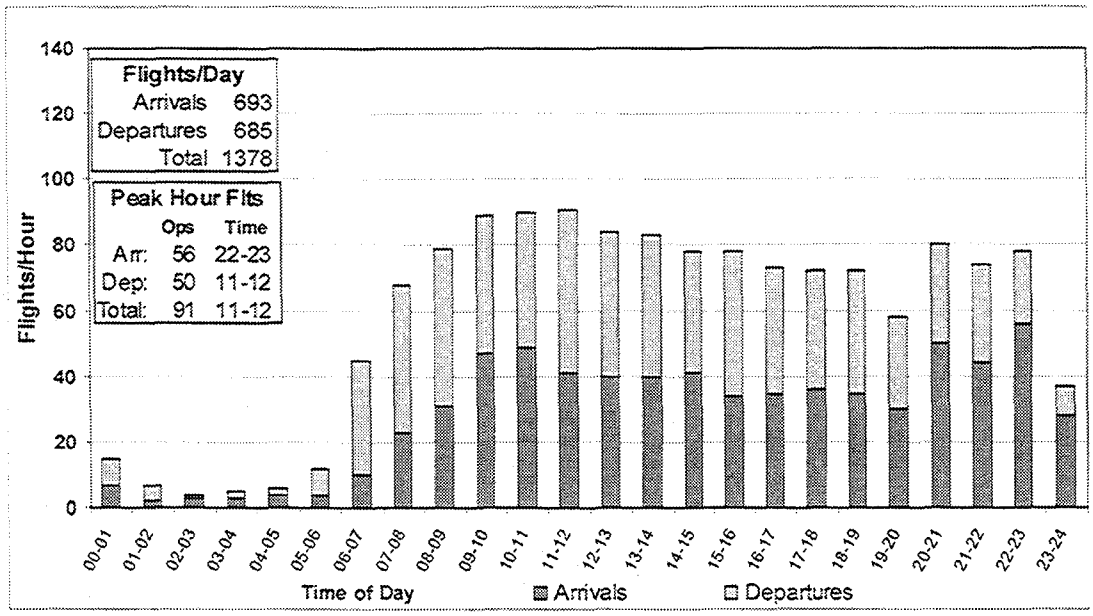


Figure 4-4 2010 Unconstrained Forecast – ADPM SFO Operations

As shown in Figure 4-5, the 2020 ADPM flight schedule includes about 1634 daily arrivals and departures. The busiest arrival peak occurs from 10AM to 11AM, when 62 flights arrive. The busiest departure peak occurs from 11AM to 12AM when 63 flights depart.

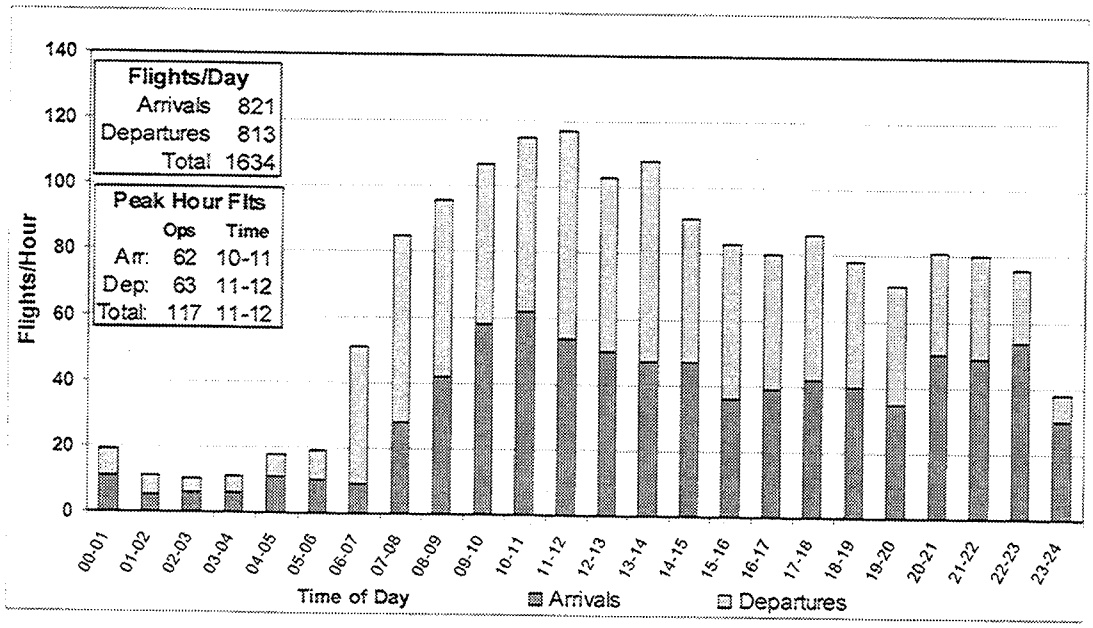


Figure 4-5 2020 Unconstrained Forecast – ADPM SFO Operations

4.3.2 OAK Flight Schedule

The Oakland schedule includes all aircraft arriving and departing the South Field. As shown in Figure 4-6, the 2010 ADPM flight schedule includes about 700 daily arrivals and departures. The busiest arrival peak occurs from 9PM to 10PM, when 30 flights arrive. The busiest departure peak occurs from 7AM to 8AM when 29 flights depart.

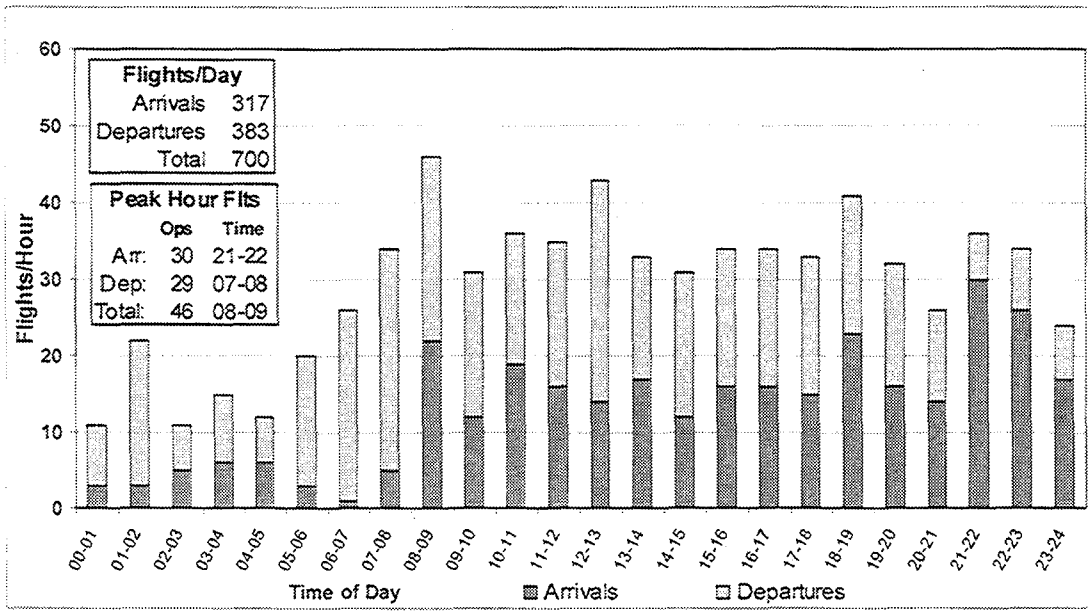


Figure 4-6 – 2010 Unconstrained Forecast – ADPM OAK Operations

As shown in Figure 4-7, the 2020 ADPM flight schedule includes about 893 daily arrivals and departures. The busiest arrival peak occurs from 8AM to 9AM, when 28 flights arrive. The busiest departure peak occurs from 12PM to 1PM when 39 flights depart.

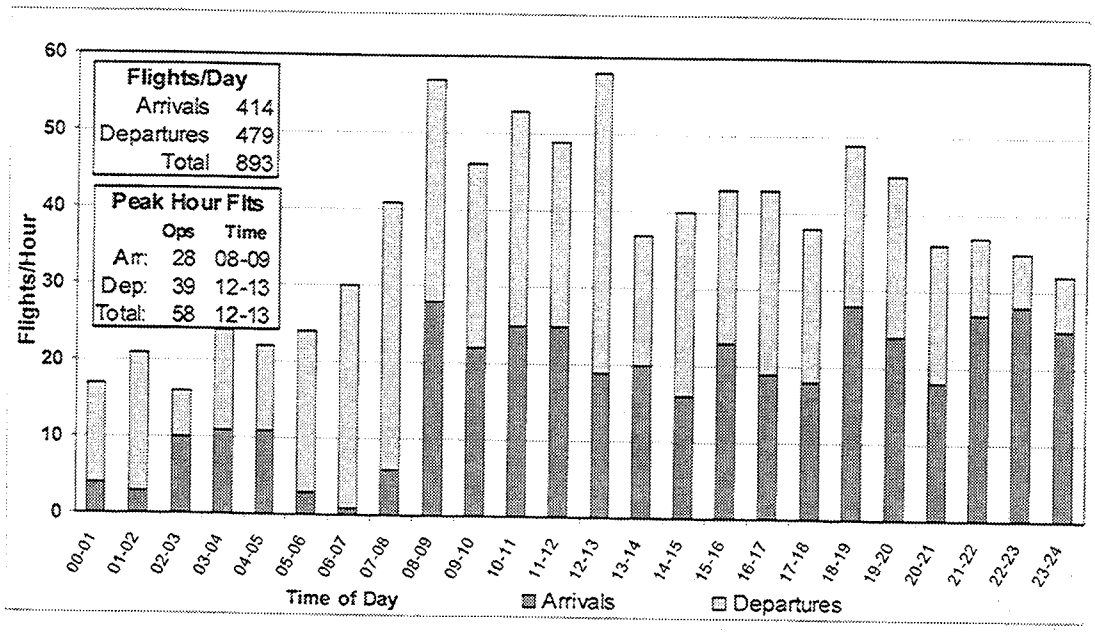


Figure 4-7 2020 Unconstrained Forecast – ADPM OAK Operations

4.3.3 SJC Flight Schedule

The San Jose schedule includes all aircraft using the two air carrier runways (one is currently under construction). As shown in Figure 4-8, the 2010 ADPM flight schedule includes about 539 daily arrivals and departures. The busiest arrival peak occurs from 9PM to 10PM, when 27 flights arrive. The busiest departure peak occurs from 7AM to 8AM when 26 flights depart.

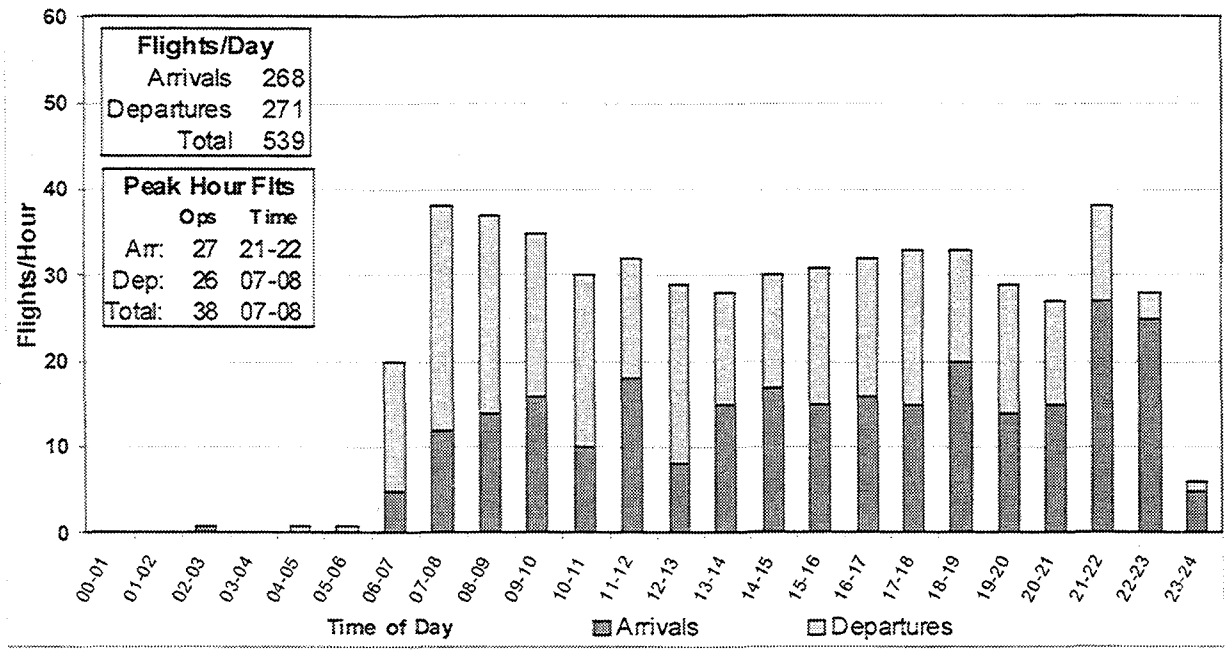


Figure 4-8 2010 Unconstrained Forecast – ADPM SJC Operations

As shown in Figure 4-9, the 2020 ADPM flight schedule includes about 713 daily arrivals and departures. The busiest arrival peak occurs from 9PM to 10PM, when 31 flights arrive. The busiest departure peak occurs from 8AM to 9AM when 34 flights depart.

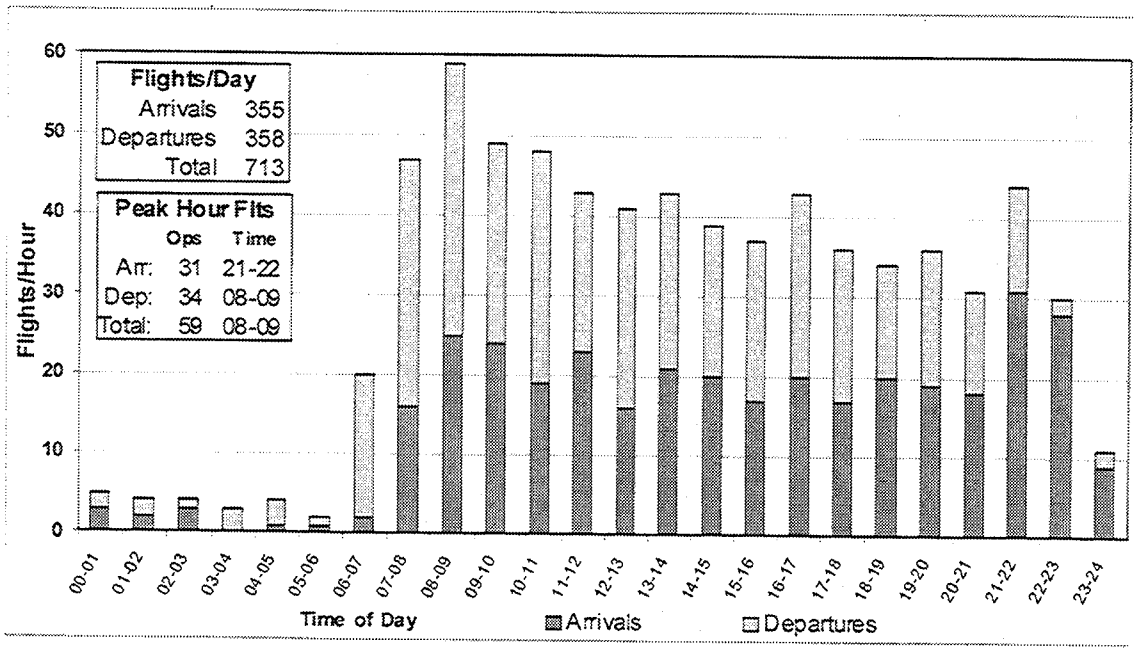


Figure 4-9 2020 Unconstrained Forecast – ADPM SJC Operations

4.4 BASE CASE DELAYS IN 2010 AND 2020

The delays presented in this subsection are for the Base Case for 2010 and 2020 operations. It is assumed that there are no changes to the existing airfield at SFO and at OAK, and that San Jose completes the new runway currently under construction. The flight schedules are assumed to be unconstrained.

At SFO, it is assumed that the simultaneous offset instrument approach/ precision runway monitor (SOIA/PRM) procedures are in use. The effect of this procedure is to allow VFR type operations (two arrival streams) during some of the otherwise IFR type of weather (single stream of arrivals). In practice, this adds 7% to the West VFR plan frequency of occurrence and takes away 7% from the West IFR plan frequency of occurence, thus improving the annual weighted average. The resulting delays given these conditions are shown below.

Table 4-3
Delays for the 2010 Base Case + SOIA/PRM at SFO

Alternatives	2010 Arrival Delays (min)				2010 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	693	4.19	0.01	4.20	685	0.65	0.01	8.07	8.74	1378	6.46
West IFR	693	199.55	0.00	199.55	685	0.03	0.02	4.10	4.15	1378	102.42
SE	693	144.13	0.02	144.15	685	1.43	0.00	52.10	53.54	1378	99.11
Weighted Avg.	693			22.95	685				11.02	1378	17.02
OAK											
West VFR	317	1.13	0.00	1.13	383	1.38	0.00	2.37	3.74	700	2.56
West IFR	317	2.45	0.00	2.45	383	0.07	0.00	1.06	1.13	700	1.73
SE	317	5.11	0.00	5.11	383	2.94	0.00	1.53	4.48	700	4.77
Weighted Avg.	317			1.53	383				3.44	700	2.57
SJC											
West VFR	268	1.24	0.00	1.24	271	0.09	0.76	0.92	1.76	539	1.50
West IFR	268	0.96	0.00	0.96	271	0.02	1.14	0.91	2.08	539	1.52
SE	268	1.78	0.00	1.78	271	0.51	0.00	2.58	3.09	539	2.44
Weighted Avg.	268			1.27	271				1.89	539	1.58
Bay Area											
Weighted Avg.	1278			13.09	1339				7.00	2617	9.97

Table 4-4
Delays for the 2020 Base Case + SOIA/PRM at SFO

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	15.72	0.01	15.73	813	0.81	0.03	97.36	98.20	1634	56.76
West IFR	821	314.55	0.00	314.55	813	0.03	0.02	11.02	11.07	1634	163.55
SE IFR	821	254.90	0.00	251.92	813	1.05	0.00	111.13	112.1	1634	182.39
Weighted Avg.	821			45.66	813				94.15	1634	69.79
OAK											
West VFR	414	1.45	0.00	1.45	479	1.44	0.00	11.83	13.27	893	7.79
West IFR	414	3.78	0.00	3.78	479	0.08	0.00	1.99	2.07	893	2.86
SE IFR	414	27.91	0.00	27.91	479	2.48	0.00	4.01	6.49	893	16.42
Weighted Avg.	414			3.26	479				11.42	893	7.64
SJC											
West VFR	355	2.02	0.26	2.28	358	0.09	3.68	1.13	5.17	713	3.73
West IFR	355	9.19	0.15	9.34	358	0.03	2.81	1.12	4.11	713	6.71
SE IFR	355	3.39	0.00	3.39	358	0.40	0.00	8.95	9.34	713	6.38
Weighted Avg.	355			2.79	358				5.44	713	4.12
Bay Area											
Weighted Avg.	1590			25.05	1650				50.89	3240	38.21

4.5 DEMAND MANAGEMENT CASES

Two sensitivity cases involving demand management strategies were developed for simulation. A description outlining the major characteristics of each is presented below. In both these cases, SOIA procedures are also in use.

4.5.1 Description of Cases

A Base Case for comparison to demand management strategies is defined and discussed above in Section 4.3. Two levels of demand management were developed for analysis and are applied to both years 2010 and 2020. These are defined below.

Sensitivity Case S2 Demand Management includes the following characteristics, which are the same as the 1999 S2 case:

- The event file is the 2010 and 2020 average day peak month (August mid-week) for the Bay Area.

- Runway configurations for the three airport system are: San Francisco with no new runways, Oakland with no new runway, and San Jose with a new parallel runway (currently under construction).
- The SFO corporate and general aviation operations are moved to Oakland.
- All SFO commuter turboprop flights are replaced with regional jets of twice the capacity, reducing their frequency by half.
- Southern California flights between SFO and BUR, LAX, ONT, SBA, SNA, and SAN are decreased by 26% to reflect the future use of larger aircraft.

Sensitivity Case S3 Demand Management:

- The event file is the 2010 and 2020 average day peak month (August mid-week) for the Bay Area.
- Runway configurations for the three airport system are: San Francisco with no new runways, Oakland with no new runway, and San Jose with a new parallel runway (under construction). (Note that the amount of traffic shifted to OAK could exceed the capacity of its single runway as measured by average delay.)
- The SFO corporate and general aviation operations are moved to Oakland.
- All SFO commuter turboprop operations are replaced with regional jets of twice the capacity reducing their frequency by half and also moved to Oakland.
- Flights between SFO and BUR, LAX, ONT, SBA, SNA, and SAN are held at 1999 levels at SFO and additional flights to these Southern California airports above the 1999 level are moved to Oakland.

A comparison of the volume of operations for the Base Case and two demand management sensitivity cases is discussed in the following subsection. The delays incurred as a result of employing the above demand management strategies are presented in Sections 4.4 and 4.5.

4.5.2 Comparison of Operations

Similar to the shift of operations between the airports under the 1999 sensitivity analysis, a comparison is made at each airport in terms of the resulting number of operations with the demand management strategies. In 2010, the operations changed as follows:

- For San Francisco, the number of operations was decreased from the Base Case total of 1378 to 1202 in S2 and 1078 in S3 (Figure 4-10).
- In Oakland, the absorption of flights from San Francisco resulted in an increase from 700 operations in the Base Case to 774 operations in S2 and 926 in S3 (Figure 4-11).
- Operations at San Jose remained unchanged – a total of 539 – in all three cases of the sensitivity analysis (Figure 4-12).

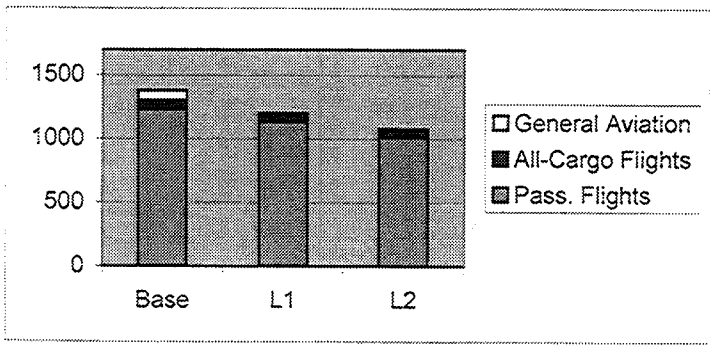


Figure 4-10 Comparison of 2010 SFO Operations

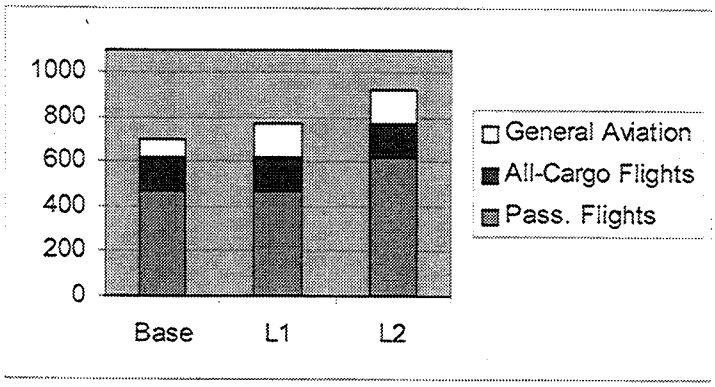


Figure 4-11 Comparison of 2010 OAK Operations

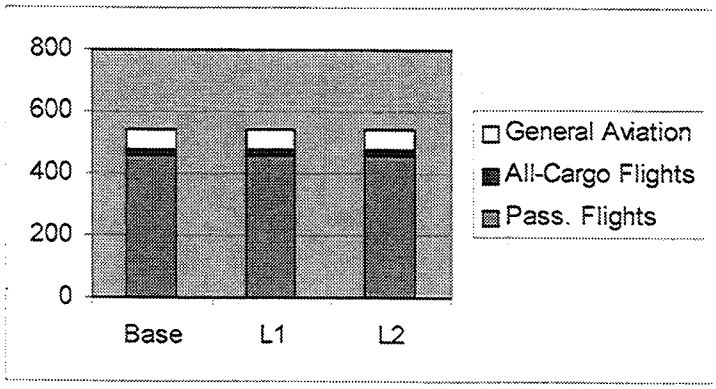


Figure 4-12 Comparison of 2010 SJC Operations

In 2020, the operations changed as follows:

- For San Francisco, the number of operations decreased from the Base Case total of 1634 to 1503 in S2 and 1426 in S3 (Figure 4-13).

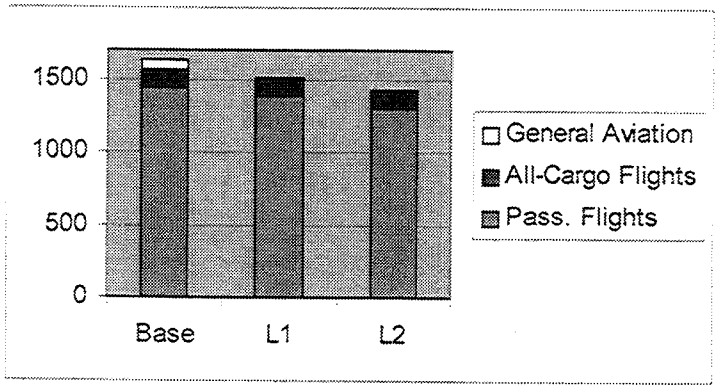


Figure 4-13 Comparison of 2020 SFO Operations

- In Oakland, the absorption of flights from San Francisco resulted in an increase from 893 operations in the Base Case to 969 operations in S2 and 1074 in S3 (Figure 4-14).

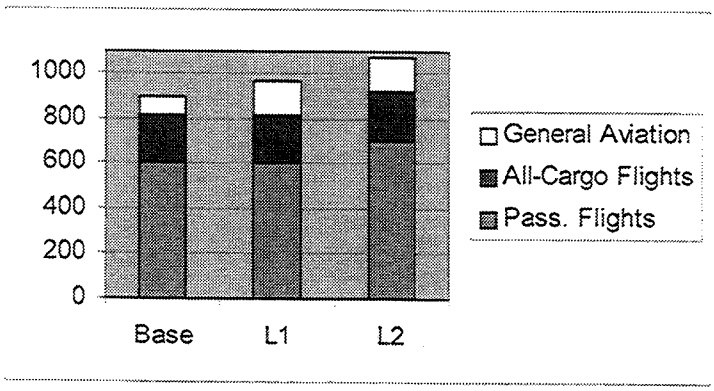


Figure 4-14 Comparison of 2020 OAK Operations

- Operations at San Jose remained unchanged – a total of 713 - in all three cases of the sensitivity analysis (Figure 4-15).

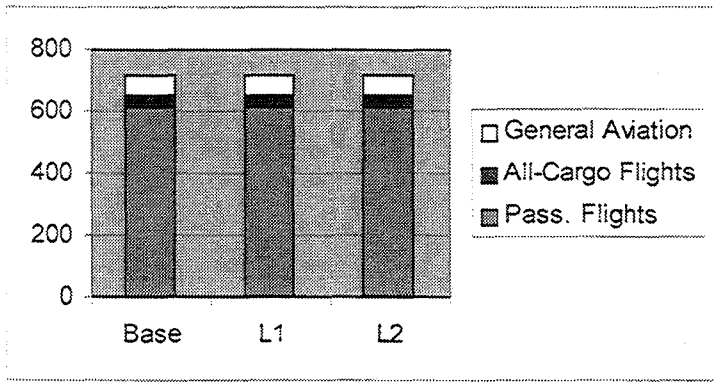


Figure 4-15 Comparison of 2020 SJC Operations

Table 4-5 Resulting Delays for 2010 S2 Demand Reduction + SOIA/PRM at SFO

Alternatives	2010 Arrival Delays (min)				2010 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	601	3.48	0.01	3.49	601	0.54	0.02	7.26	7.83	1202	5.66
West IFR	601	118.86	0.00	118.86	601	0.03	0.01	3.47	3.52	1202	61.19
SE IFR	601	76.22	0.02	76.25	601	1.34	0.00	60.05	61.39	1202	68.82
Weighted Avg.	601			14.00	601				10.62	1202	12.31
OAK											
West VFR	359	1.19	0.00	1.19	415	1.47	0.00	3.06	4.53	774	2.98
West IFR	359	2.88	0.00	2.88	415	0.10	0.00	1.62	1.72	774	2.26
SE IFR	359	2.79	0.00	2.79	415	2.66	0.00	2.16	4.83	774	3.88
Weighted Avg.	359			1.50	415				4.18	774	2.94
SJC											
West VFR	268	1.52	0.00	1.25	271	0.11	0.49	0.88	1.48	539	1.37
West IFR	268	0.97	0.00	0.97	271	0.02	1.00	0.85	1.88	539	1.43
SE IFR	268	1.79	0.00	1.79	271	0.59	0.00	1.89	2.49	539	2.14
Weighted Avg.	268			1.28	271				1.58	539	1.43
Bay Area											
Weighted Avg.	1228			7.57	1287				6.64	2515	7.09

Table 4-6 Resulting Delays for 2010 S3 Demand Reduction + SOIA/PRM at SFO

Alternatives	2010 Arrival Delays (min)				2010 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	539	2.84	0.01	2.85	539	0.68	0.02	2.99	3.69	1078	3.27
West IFR	539	71.18	0.00	71.19	539	0.03	0.02	2.24	2.29	1078	36.74
SE IFR	539	33.08	0.01	33.09	539	1.82	0.00	37.60	39.42	1078	36.26
Weighted Avg.	539			8.35	539				5.63	1078	6.99
OAK											
West VFR	433	1.27	0.00	1.27	491	1.12	0.01	11.49	12.63	924	7.31
West IFR	434	7.07	0.00	7.07	492	0.08	0.00	2.92	3.00	926	4.91
SE IFR	434	4.86	0.00	4.86	492	2.35	0.13	6.43	8.91	926	7.01
Weighted Avg.	434			2.23	492				11.16	925	6.98
SJC											
West VFR	268	1.24	0.00	1.24	271	0.14	0.64	0.83	1.61	539	1.43
West IFR	268	0.97	0.00	0.97	271	0.02	1.23	0.88	2.14	539	1.56
SE IFR	268	1.80	0.00	1.80	271	0.93	0.00	2.02	2.94	539	2.37
Weighted Avg.	268			1.27	271				1.75	539	1.51
Bay Area											
Weighted Avg.	1241			4.68	1302				6.91	2542	5.82

Table 4-7 Resulting Delays for 2020 S2 Demand Reduction + SOIA/PRM at SFO

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	751	11.69	0.01	11.70	752	0.66	0.03	44.75	45.43	1503	28.58
West IFR	751	253.94	0.00	253.94	752	0.04	0.01	6.50	6.55	1503	130.16
SE IFR	751	197.34	0.02	197.36	752	1.23	0.00	105.40	106.6	1503	151.96
Weighted Avg.	751			35.64	752				46.73	1503	41.19
OAK											
West VFR	456	1.48	0.00	1.48	513	1.27	0.00	35.68	36.95	969	20.26
West IFR	456	4.60	0.00	4.60	513	0.09	0.00	2.92	3.01	969	3.76
SE IFR	456	5.94	0.00	5.94	513	2.38	0.00	14.45	16.83	969	11.71
Weighted Avg.	456			2.14	513				31.37	969	17.61
SJC											
West VFR	355	2.04	0.00	2.04	358	0.10	1.90	1.13	3.13	713	2.59
West IFR	355	1.63	0.40	2.04	358	0.04	4.57	1.14	6.16	713	4.11
SE IFR	355	3.31	0.00	3.31	358	0.73	0.00	7.63	8.35	713	5.84
Weighted Avg.	355			2.14	358				3.73	713	2.94
Bay Area											
Weighted Avg.	1562			18.25	1623				32.39	3185	25.45

Table 4-8 Resulting Delays for 2020 S3 Demand Reduction + SOIA/PRM at SFO

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	713	9.05	0.01	9.06	713	0.74	0.02	44.06	44.82	1426	26.94
West IFR	713	217.29	0.00	217.29	713	0.02	0.01	6.94	6.97	1426	112.13
SE IFR	713	162.42	0.02	162.44	713	1.28	0.00	93.10	94.38	1426	128.41
Weighted Avg.	713			29.28	713				45.52	1426	37.40
OAK											
West VFR	508	1.66	0.00	1.66	566	0.90	0.00	114.77	115.6	1074	61.74
West IFR	508	8.97	0.00	8.97	566	0.06	0.55	16.04	16.65	1074	13.02
SE IFR	508	5.45	0.00	5.45	566	2.09	0.00	77.56	79.65	1074	44.55
Weighted Avg.	508			2.83	566				100.6	1074	54.39
SJC											
West VFR	355	2.03	0.00	2.04	358	0.10	1.85	1.13	3.08	713	2.56
West IFR	355	1.63	0.26	1.89	358	0.02	3.82	1.17	5.33	713	3.62
SE IFR	355	3.31	0.00	3.31	358	0.62	0.00	7.53	8.15	713	5.74
Weighted Avg.	355			2.13	358				3.62	713	2.88
Bay Area											
Weighted Avg.	1576			14.64	1637				55.42	3213	35.42

4.6 NEW TECHNOLOGY REDUCED SEPARATION CASE

In the previous strategies, demand (number of flights) is constrained in order to limit the need for facility development. In the technology approach, the unconstrained flight schedules are left intact, but the impact of advanced Air Traffic Control Systems is modeled by reducing in-trail aircraft separation requirements for all airports, resulting in increased runway capacity. These new technologies are:

- Wide Area Augmentation System (WAAS)
- Local Area Augmentation System (LAAS)
- Center TRACON Automation System
- Final Approach Spacing Tool (FAST)
- Automatic Dependent Surveillance (ADS)

Details of the above technology are discussed in a report prepared by the Metropolitan Transportation Commission in August 2000 entitled "Sensitivity Analysis-Factors Affecting Airport Demand and Capacity", Section 6. For model simulation purposes, assumptions have been made to reduce the in-trail separation between aircraft to reflect the effect of improved navigational technology. The results of this analysis for 2010 are presented in Table 4-9 and can be compared to Table 4-3. The case for new technology was not carried out for the 2020 forecast because even with these improvements, the projected 14.75 minute delay at SFO for the 2010 forecast exceeds saturated levels (Figure 2-2).

Table 4-9
Resulting 2010 Delays with Reduced Separation Through New Technology + SOIA/PRM at SFO

Alternatives	2010 Arrival Delays (min)				2010 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	693	4.06	0.01	4.07	685	0.14	0.02	6.00	6.16	1378	5.11
West IFR	693	193.95	0.00	193.96	685	0.02	0.01	4.54	4.57	1378	99.81
SE IFR	693	103.22	0.03	103.25	685	1.45	0.00	60.40	61.85	1378	82.67
Weighted Avg.	693			20.21	685				9.22	1378	14.75
OAK											
West VFR	317	0.78	0.00	0.78	383	0.09	0.00	2.37	2.46	700	1.70
West IFR	317	2.38	0.00	2.38	383	0.07	0.00	1.03	1.10	700	1.68
SE IFR	317	2.86	0.00	2.86	383	2.81	0.00	1.78	4.59	700	3.81
Weighted Avg.	317			1.11	383				2.40	700	1.82
SJC											
West VFR	268	1.22	0.00	1.22	271	0.04	1.05	0.99	2.08	539	1.65
West IFR	268	0.92	0.00	0.92	271	0.02	1.01	0.91	1.94	539	1.43
SE IFR	268	1.78	0.00	1.78	271	0.59	0.00	2.61	3.20	539	2.49
Weighted Avg.	268			1.25	271				2.16	539	1.71
Bay Area											
Weighted Avg.	1278			11.50	1339				5.84	2617	8.60

In Section 5, the major alternatives for increasing runway capacity at SFO and OAK airports are described. Using SIMMOD and the forecasted flight schedules for 2010 and 2020, the impacts on delay resulting from each alternative are quantified and discussed.

5.1 SAN FRANCISCO RUNWAY OPTIONS

In 1999, the SFO-Runway Reconfiguration Study examined a series of alternative runway configurations for SFO that could reduce aircraft delay (and noise impacts) on surrounding residents. The study identified 32 runway options. Following a thorough technical evaluation, three alternatives were determined to be worthy of further study and are the subject of the analysis in this section. These alternatives are designated A3, F2, and BX Refined (BXR).

5.1.1 Alternative A3

As shown in Figure 5-1, alternative A3 includes several changes to the existing runway system at SFO:

- A new runway 28R is added with a length of 9,430 feet and separated from runway 28L (the old 28R), by 4,300 feet. This separation allows simultaneous independent arrivals in IFR conditions, thereby maintaining dual runway capacity in poor weather.
- Existing runway 28L is converted to use as a taxiway. (SFO is also considering intermittent use of 28L as a departure runway under certain weather conditions.)
- Under West Plan flow conditions, dual arrivals do not have to be paired to land on 28R and 28L in both VFR and IFR weather. Arrivals in VFR on 28R will be spaced more closely than those on 28L (since 28R has no intersection, there is no need to leave a gap for departures). In IFR, however, the spacing of arrivals on 28R has to be increased in order to have sufficient protection for missed approaches. Most departures will use 01L and 01R for take-offs with the exception that some heavy long-range flights will still need to use 28L for departure.

As shown in Figure 5-2, under Southeast Plan flow conditions, alternative A3 includes the following operating procedures:

- Arrivals land on Runway 19L
- Departures takeoff from runway 10L and 10R, depending on destination
- For heavy long-haul flights, runway 10R (old runway 10L) is used for departure

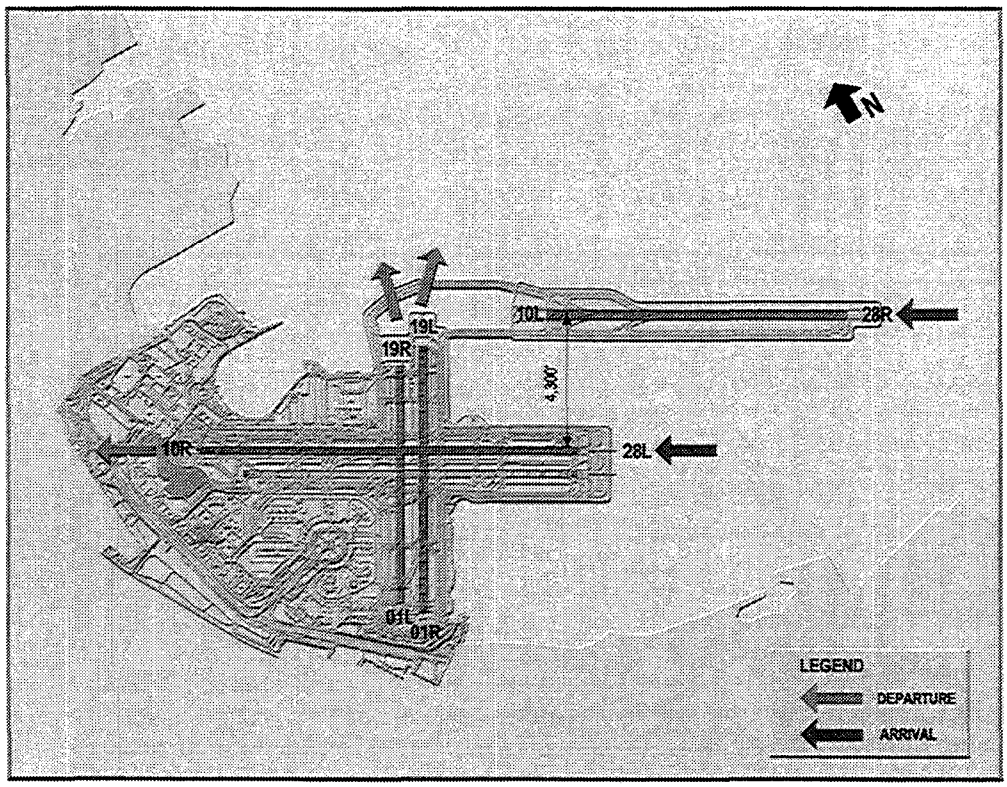


Figure 5-1 Alternative A3 West Plan VFR/IFR

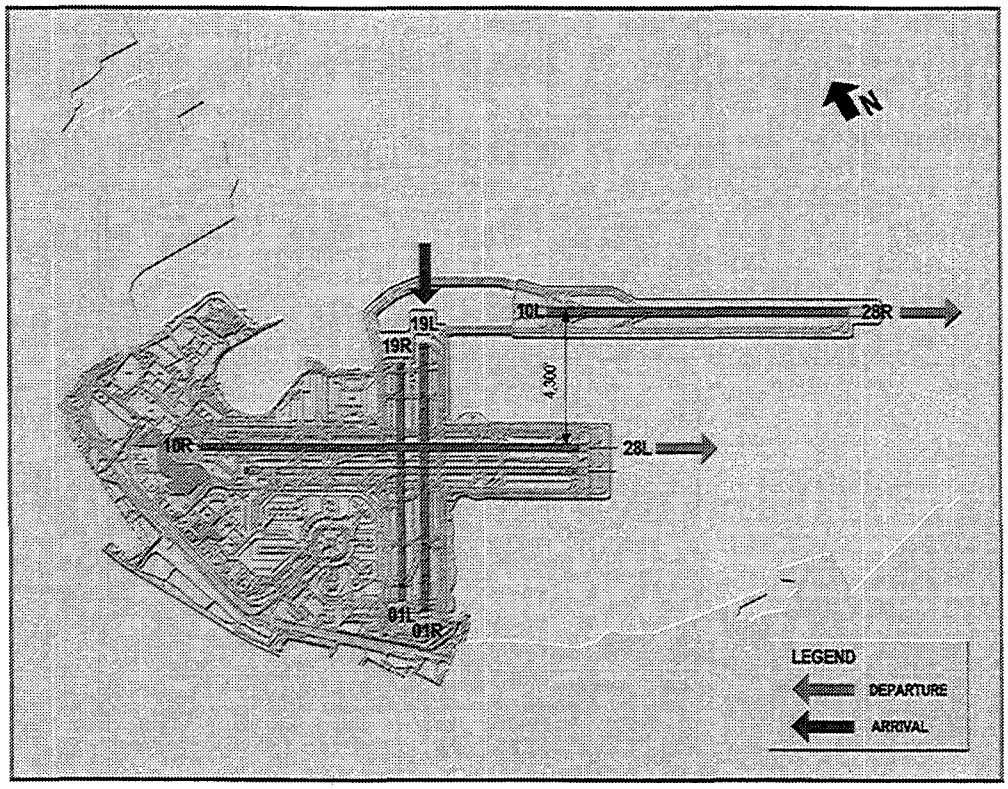


Figure 5-2 Alternative A3 Southeast Plan IFR

5.1.2 Alternative F2

As shown in Figure 5-3, alternative F2 includes several changes to the runway system at SFO:

- A new runway 28R/10L is added with a length of 9,430 feet and separated from runway 28L/10R by 4,300 feet. This separation allows simultaneous independent arrivals in IFR conditions, thereby maintaining dual runway capacity in poor weather.
- A new runway 01L/19R is added 4,300 feet west of existing runway 01R with a length of 11,500 feet.
- Runway 01R is extended north to a total length of 12,350 feet, and the departure threshold is moved 3,350 feet to the north. Extending the runway and displacing the threshold minimizes noise impacts while still maintaining a usable length of 9,400 feet for departures.
- Existing runways 01L and 28L will be converted to use as taxiways.

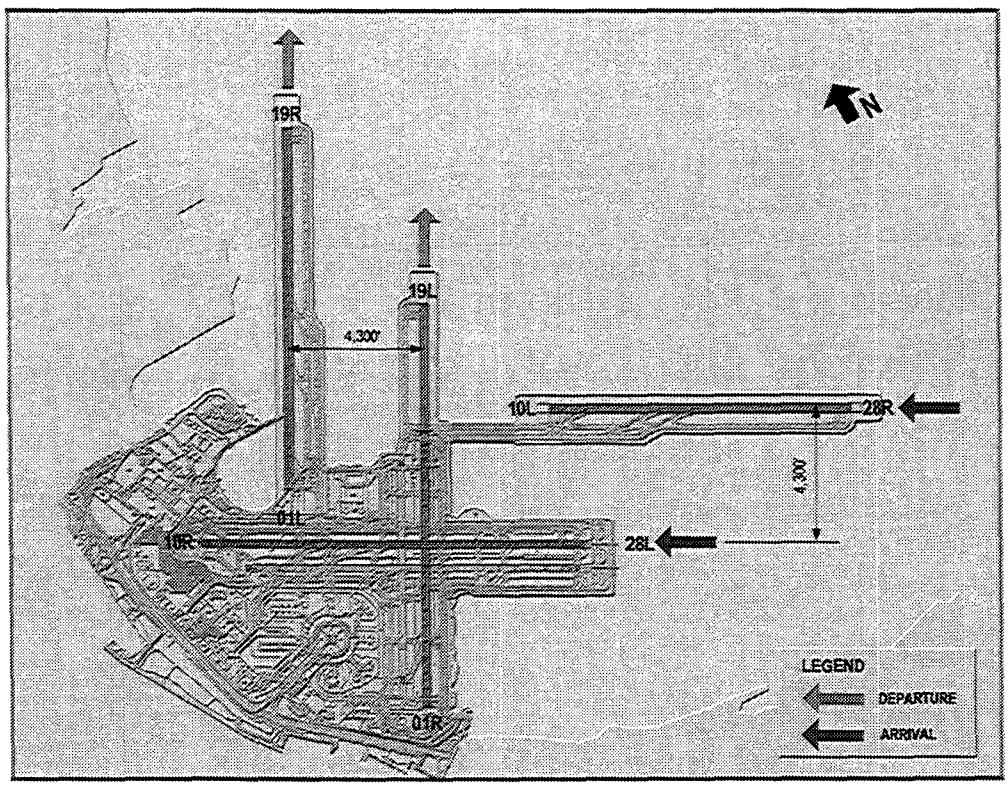


Figure 5-3 Alternative F2 West Plan VFR/IFR

Under West Plan flow conditions, the following procedures would be used:

- Arrivals will use runways 28L and 28R
- Departures will use runway 01L and 01R
- Heavy long-haul departure flights will primarily use the new runway 01L

As shown in Figure 5-4, under the Southeast Plan flow pattern, the following procedures would be used:

- Arrivals land on Runway 19L
- However, due to conflicts with approach to OAK runway 11 during Southeast flow, arrivals cannot use the new runway 19R, thereby losing the ability to use both 19L and 19R for arrivals
- Departing flights use Runways 10L and 10R, depending on destination
- Heavy long-haul flights use 10R for departures

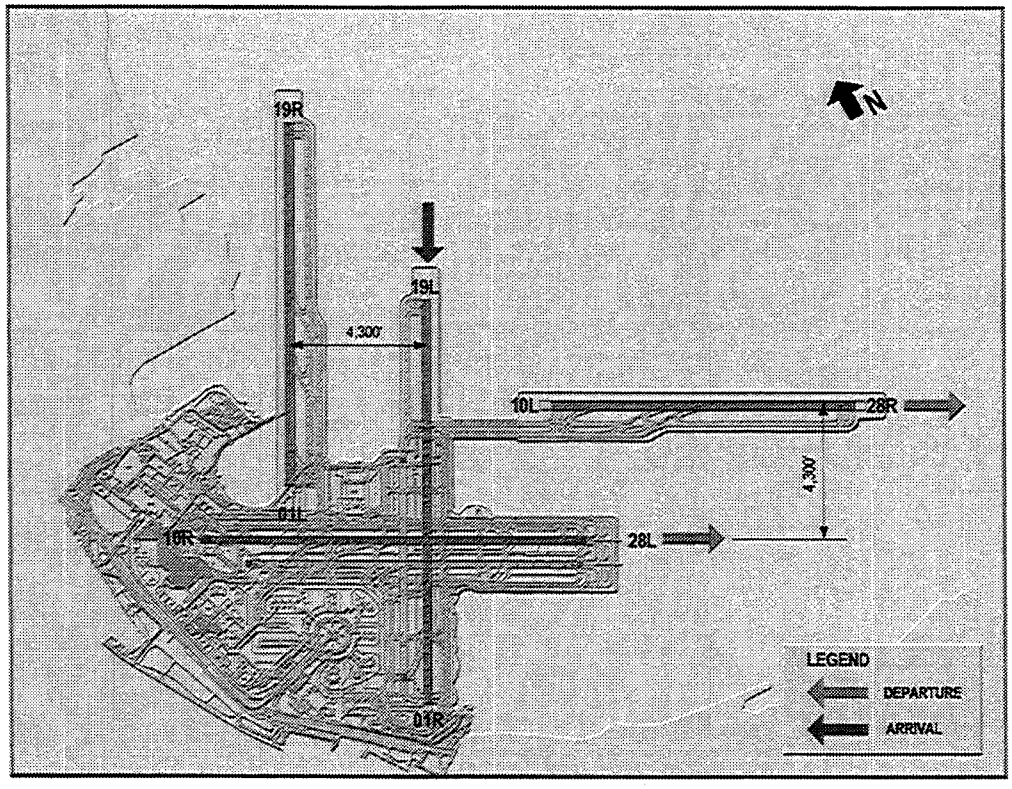


Figure 5-4 Alternative F2 Southeast Plan IFR

5.1.3 Alternative BXR

As shown in Figure 5-5, alternative BXR includes the following changes to the existing runway layout at SFO:

- A new runway 28R/10L is added with a 4,300 feet separation from runway 28L/10R with a length of 9,430 feet, allowing simultaneous independent arrivals.
- A new runway 01R/19L is added 3,400 feet east of existing runway 01R with a length of 9,400 feet.
- Existing runway 01R is re-designated as runway 01L and is extended north to a total length of 14,850 feet. The departure threshold is displaced 3,350 feet north to minimize noise impacts, giving a usable departure length of 11,500 feet.
- Existing runways 01L and 28L are used as taxiways.

As shown in Figure 5-5, under West Plan VFR and IFR procedures:

- Arrivals use runway 28R and 28L
- Departures use runways 01L and 01R
- Departures for heavy long-haul flights use runway 01L

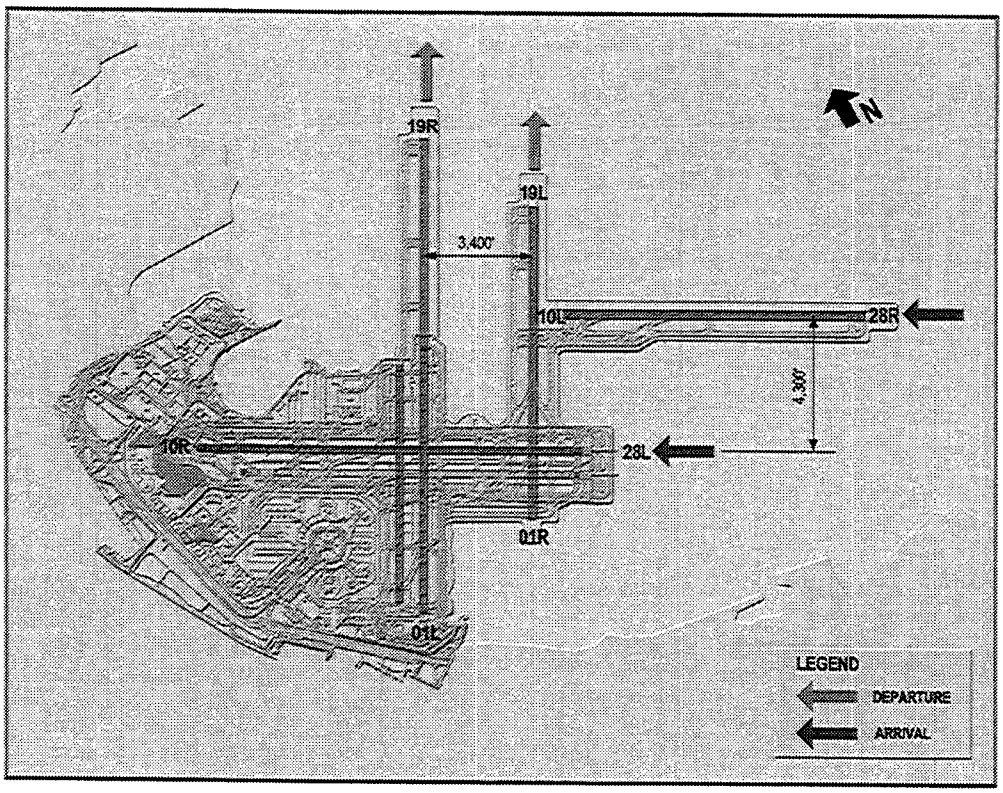


Figure 5-5 Alternative BXR West Plan VFR/IFR

As shown in Figure 5-6, under Southeast Plan procedures:

- Arrivals use runways 19R and 19L
- Departures use 10R and 10L depending on destination
- Departures for heavy long-haul flights use 10R

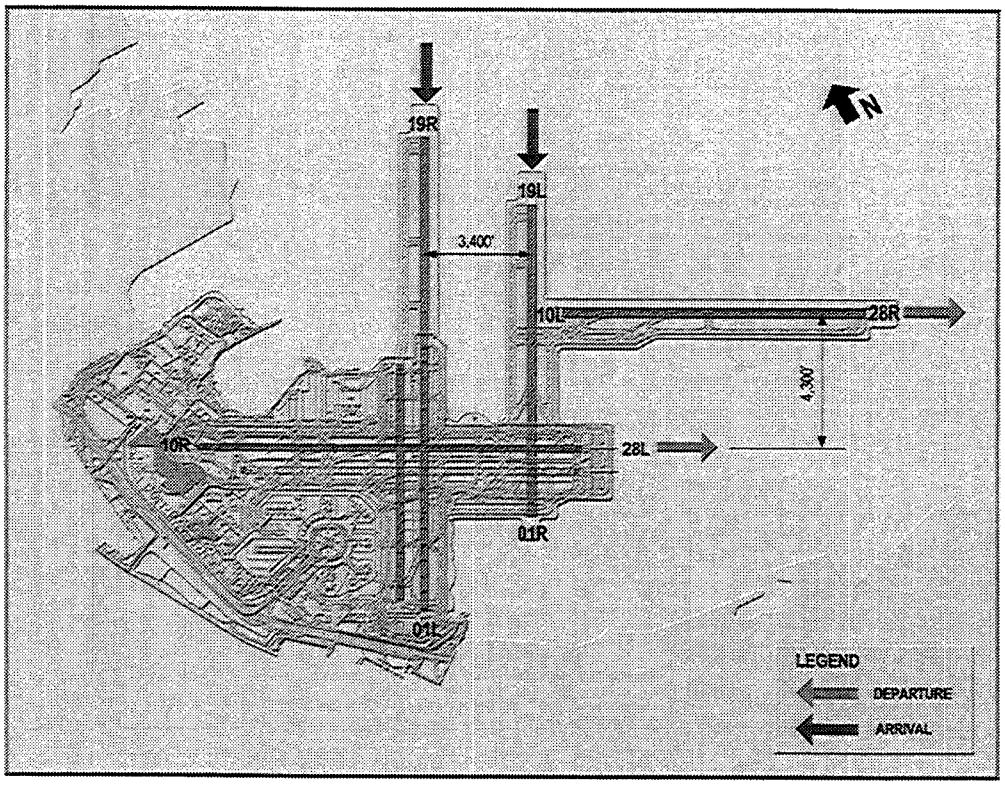


Figure 5-6 Alternative BXR-Southeast Plan

5.2 OAK RUNWAY OPTIONS

As discussed earlier in Section 3 and shown in Figure 5-7 below, the existing runway configuration for OAK consists of a single commercial air carrier runway 11/29 (South Field) and limited use of 9L/27R (North Field) for some air cargo operations. Two alternatives have been modeled for adding runway capacity at OAK, including development of a second commercial air carrier runway approximately 500 feet north of 11/29, called the "inboard" alternative, or development of a new runway 4,300 feet south of 11/29, called the "outboard" alternative.

5.2.1 Inboard Runway Alternative

As shown in Figures 5-7 and 5-8, the inboard alternative would be a closely spaced parallel runway to 11/29. For simplicity in modeling the runways and airspaces it was assumed that these runways are used in a dedicated mode – one for arrivals, one for departures. Operating conditions for the West and Southeast Plans are shown in the following figures indicating arrival and departure use.

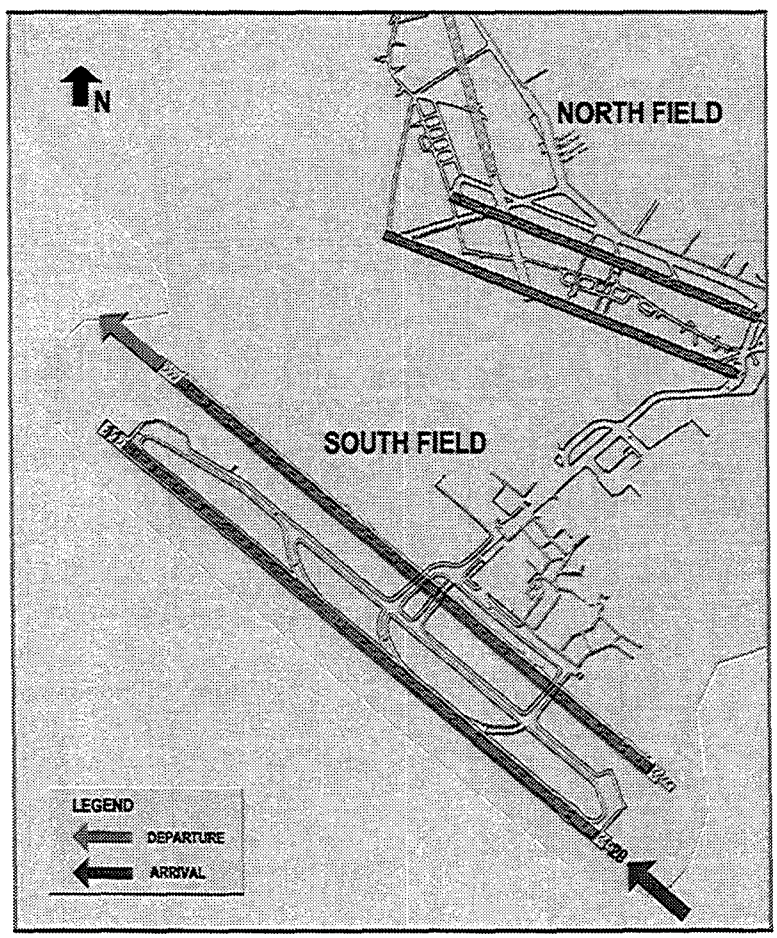


Figure 5-7 OAK Inboard West Plan Alternative

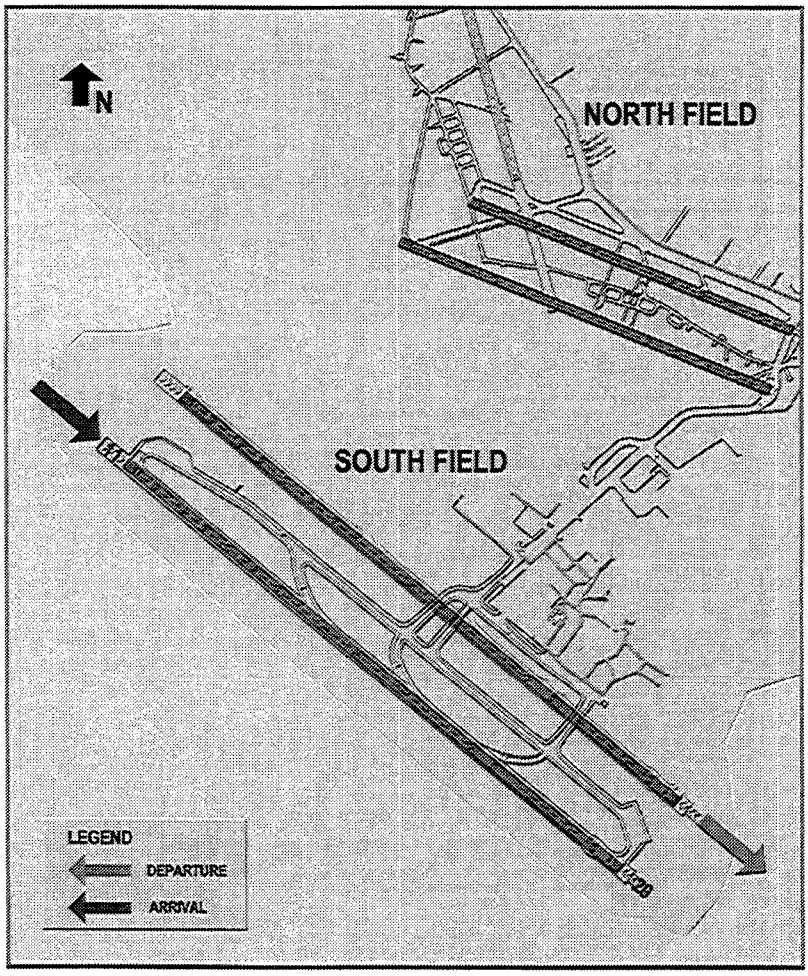


Figure 5-8 OAK Inboard Southeast Plan Alternative

5.2.3 Outboard Runway Alternative

As shown in Figures 5-9 and 5-10, the outboard alternative would allow simultaneous independent runway operations. This alternative would roughly double OAK's runway capacity during both VFR and IFR conditions. Operating conditions for the West and Southeast Plans are shown in the figures indicating arrival and departure use.

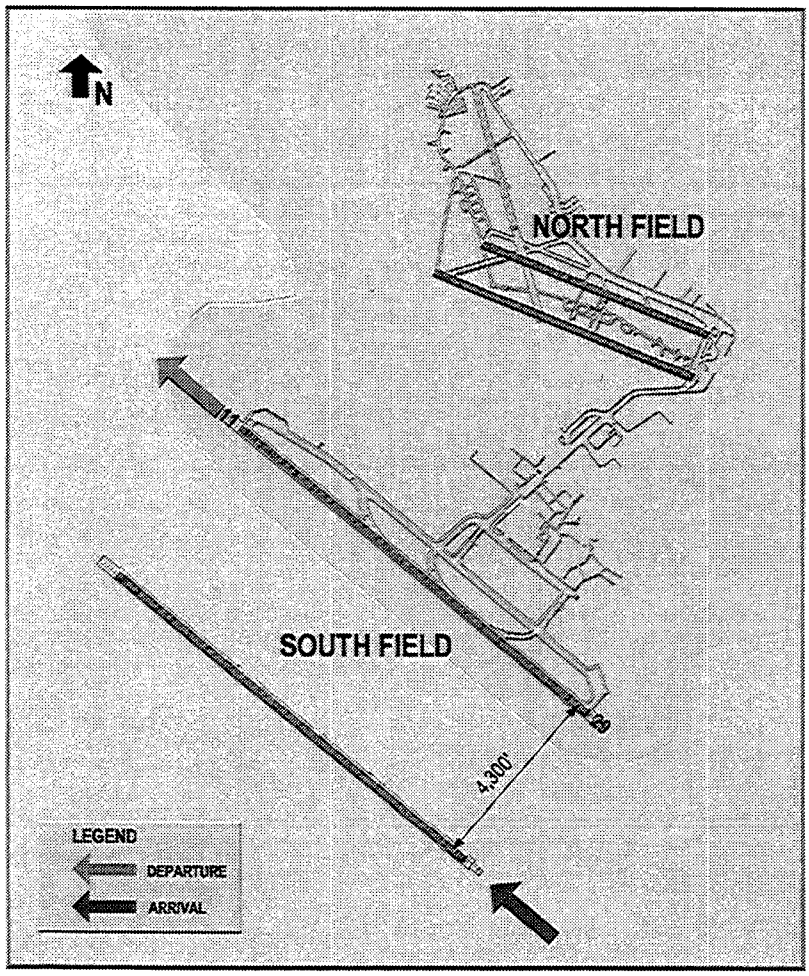


Figure 5-9 OAK Outboard West Plan Alternative

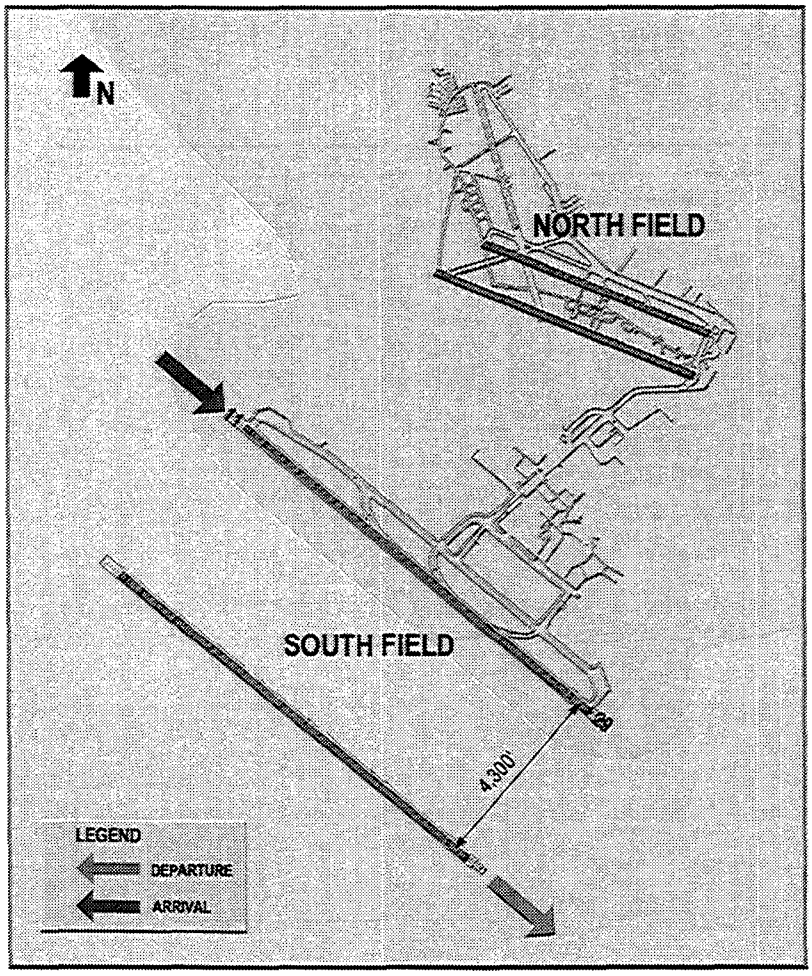


Figure 5-10 OAK Outboard Southeast Plan Alternative

Using the outboard runway for arrivals could impact aircraft landing on SFO's runways 19 due to insufficient vertical separation between the two arrival streams (this applies to aircraft landing on SFO's existing runways as well as the reconfigured runway option). Since it was not the purpose of this modeling effort to solve these types of airspace interactions, the operation of the runways was established to minimize interactions which resulted in assuming arriving aircraft would land on runway 11L (the existing runway) and take off on the new outboard runway 11R. This is different from most airport operations where departures use the runway closet to the terminal, which provides more efficient aircraft circulation.

5.3 SJC RUNWAY OPTIONS

As discussed in Section 3 and shown in Figure 3-8, SJC currently has a single commercial carrier runway, 12R/30L. However, the airport is presently extending the length of runway 12L/30R to enable it to be used for air carrier operations.

With the development of 12L/30R, SJC will have two full-length closely spaced parallel runways. This will moderately increase runway capacity during VFR conditions, but would not increase capacity during IFR conditions. Since construction of the extension will be complete by early 2001, dual runways for SJC are used in the simulation for future years.

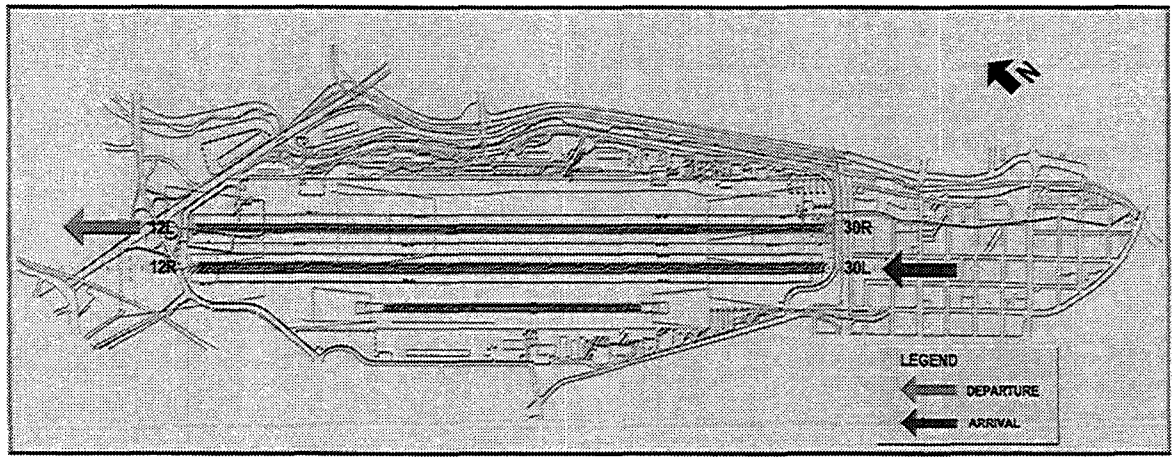


Figure 5-11 SJC Dual Runway West Plan Alternative

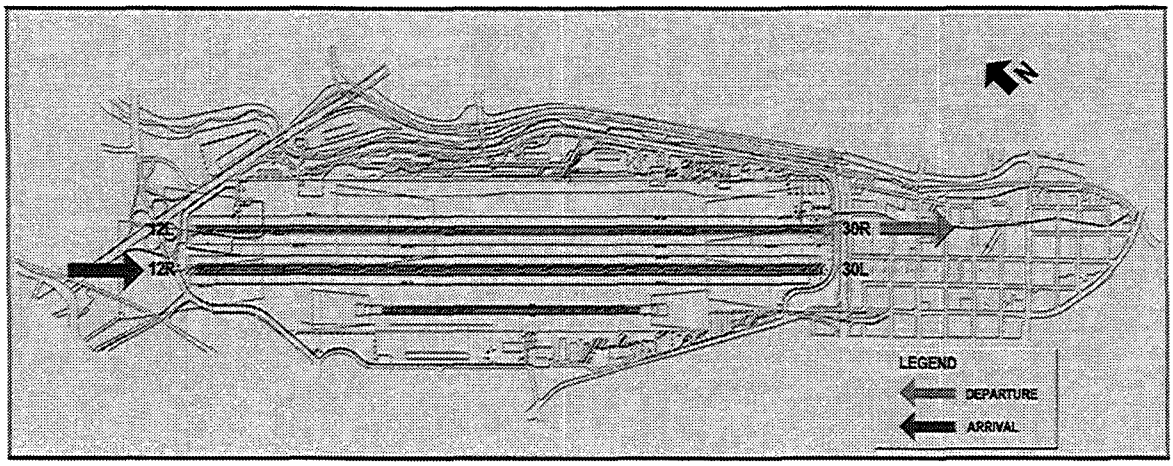


Figure 5-12 SJC Dual Runway Southeast Plan Alternative

5.4 COMBINATIONS OF BAY AREA RUNWAY OPTIONS

The runway alternatives described above have been modeled in different combinations in order to test the impacts on delays and the interaction of airspace routes and procedures between the three airports.

As shown in Table 5-1, a total of 13 simulations of new runway configurations were conducted for the A3, F2 and BXR alternatives at SFO and the different runway options possible at OAK. Three simulations were run against 2010 levels of traffic, 9 against 2020 levels of traffic and, for the BXR alternative, one additional simulation was run which reflects the reduced in-trail separation that future technologies may allow (an in-trail reduction to 3 nm).

Table 5-1
Runway Combinations Simulated

	Runway Configurations			Traffic Demand Level		
Case	SFO	OAK	SJC	1999	2010	2020
1	Existing	Existing	Existing/Master Plan	X	X*	X*
2	A3	Existing	Dual runways		X	X
3	A3	Inboard	Dual runways			X
4	A3	Outboard	Dual runways			X
5	F2	Existing	Dual runways		X	X
6	F2	Inboard	Dual runways			X
7	F2	Outboard	Dual runways			X
8	BXR	Existing	Dual runways		X	X
9	BXR	Inboard	Dual runways			X
10	BXR	Outboard	Dual runways			X
11	BXR + ATC **	Outboard	Dual runways			X

* 2010 and 2020 includes SOIA/PRM at SFO and second new air carrier runway at SJC

** Simulation of BXR with reduced in-trail separation of 3 nm to model the impact of new ATC Technology

5.5 FUTURE AIRSPACE NETWORK AND OPERATING PROCEDURES

The approach/departure procedures shown in Section 3 in Figures 3-8 and 3-9 illustrate the current use of the airspace over the Bay Area for West Plan and Southeast Plan conditions. For VFR conditions, the airspace use was assumed to remain the same as for current VFR operations. In the West Plan IFR, however, all the arriving routes for SFO will merge over San Jose into two separate 20 nm long approach streams feeding runways 28L and 28R. For the Southeast Plan IFR the only SFO alternative with dual arrivals will be the BXR alternative, while the A3 and F2 alternatives will use the same single approach procedure to runway 19L as is used currently.

5.6 PROJECTED DELAYS

As described in Section 4, flight schedules for 2010 and 2020 for each airport have been forecasted and used in the simulations to determine delays for each of the runway alternatives shown in Table 5-1. In order to provide a summary overview of the 13 simulations conducted, the following text will discuss the weighted averages for the three Bay Area airports as a whole. For delay information at each airport under each operating condition, the reader should refer to the detailed results shown in Tables 5-2 through 5-14.

5.6.1 Alternative A3 Delays

With reference to Table 5-2, the weighted average for the three Bay Area airports indicates that, at 2010 levels of traffic without the addition of a new runway at OAK, arrival delays will average 7.49 minutes per flight while departure delays will average 7.63 minutes per flight.

Table 5-3 indicates that the Bay Area average delay, at 2020 levels of traffic without the addition of a new runway at OAK, will rise to 13.11 minutes per arrival and 33.79 minutes per departure.

Table 5-4 indicates that the Bay Area average delay, with the addition of an inboard runway at OAK and 2020 levels of traffic, will be 12.92 minutes per arrival and 22.86 minutes per departure.

Table 5-5 indicates that the Bay Area average delay, with the addition of an outboard runway at OAK and 2020 levels of traffic, will be similar to the inboard runway alternative at 12.92 minutes per arrival and 22.82 minutes per departure.

5.6.2 Alternative F2 Delays

With reference to Table 5-6, the weighted average for the three Bay Area airports indicates that, at 2010 levels of traffic without the addition of a new runway at OAK, arrival delays will average 7.39 minutes per flight while departure delays will average 3.23 minutes per flight.

Table 5-7 indicates that the Bay Area average delay, at 2020 levels of traffic without the addition of a new runway at OAK, will rise to 12.79 minutes per arrival and 16.53 minutes per departure.

Table 5-8 indicates that the Bay Area average delay, with the addition of an inboard runway at OAK and 2020 levels of traffic, will be 12.78 minutes per arrival and 4.55 minutes per departure.

Table 5-9 indicates that the Bay Area average delay, with the addition of an outboard runway at OAK and 2020 levels of traffic, will be 12.82 minutes per arrival and 4.65 minutes per departure.

5.6.3 Alternative BXR Delays

With reference to Table 5-10, the weighted average for the three Bay Area airports indicates that, at 2010 levels of traffic without the addition of a new runway at OAK, arrival delays will average 2.54 minutes per flight while departure delays will average 2.55 minutes per flight.

Table 5-11 indicates that the Bay Area average delay, at 2020 levels of traffic without the addition of a new runway at OAK, will rise to 4.39 minutes per arrival and 16.93 minutes per departure. This large increase in departure delays is due to Oakland departure delays which have jumped to 46 min. This indicates that the capacity of OAK with a single commercial runway has been exceeded.

Table 5-12 indicates that the Bay Area average delay, with the addition of an inboard runway at OAK and 2020 levels of traffic, will be 4.41 minutes per arrival and 4.30 minutes per departure.

Table 5-13 indicates that the Bay Area average delay, with the addition of an outboard runway at OAK and 2020 levels of traffic, will be 4.02 minutes per arrival and 4.35 minutes per departure.

Table 5-14 indicates that the Bay Area average delay, with the addition of an outboard runway at OAK, advanced ATC technology at all three airports, and 2020 levels of traffic, will be 3.27 minutes per arrival and 3.59 minutes per departure.

5.6.4 Oakland Inboard versus Outboard Runway

While the tables show very little difference in the average delays at Oakland International Airport for inboard and outboard runway configurations, this reflects the SIMMOD modeling assumptions, rather than the actual capacity differences. The SIMMOD analysis made the simplifying assumption that all arrivals would use one runway and all departures would use the other runway. However, during peak arrival periods a properly spaced outboard runway would permit simultaneous arrivals during bot VFR and IFR conditions (e.g., low level stratus clouds common in the Bay Area during summer months). This additional capacity was not evaluated, since the projected flight activity in 2020 could be accommodated using one runway for arrivals and the other for departures. Further evaluation would be required to determine the potential for delay reduction associated with an outboard runway compared to an inboard runway.

Table 5-2 Case 2 – SFO A3 and OAK Existing – 2010 Average Delays

Alternatives	2010 Arrival Delays (min)				2010 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	693	4.74	0.13	4.86	685	1.11	0.05	2.93	4.09	1378	4.48
West IFR	693	4.74	0.14	4.88	685	0.63	0.04	50.34	51.01	1378	27.81
SE IFR	693	132.1	0.02	133.14	685	1.62	0.06	1.07	2.75	1378	68.32
Weighted Avg.	693			11.47	685				11.07	1378	11.27
OAK											
West VFR	317	3.25	0.00	3.25	383	2.18	0.01	1.25	3.44	700	3.35
West IFR	317	2.63	0.41	3.04	383	1.34	2.36	10.87	14.64	700	9.39
SE IFR	317	4.90	0.23	4.62	383	2.75	0.00	2.51	5.26	700	4.97
Weighted Avg.	317			3.30	383				5.01	700	4.24
SJC											
West VFR	268	1.94	0.25	2.19	271	0.15	1.49	1.06	2.69	539	2.44
West IFR	268	1.47	0.25	1.72	271	0.09	1.60	1.07	2.77	539	2.25
SE IFR	268	1.85	0.17	2.02	271	0.49	0.27	1.22	1.99	539	2.00
Weighted Avg.	268			2.15	271				2.64	539	2.39
Bay Area											
Weighted Avg.	1278			7.49	1339				7.63	2617	7.56

Table 5-3 Case 2 – SFO A3 and OAK Existing – 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	7.44	0.14	7.57	813	0.75	0.07	21.74	22.55	1634	15.02
West IFR	821	8.61	0.14	8.75	813	0.54	0.05	161.30	161.9	1634	84.95
SE IFR	821	246.80	0.00	246.80	813	1.54	0.05	4.14	5.73	1634	126.86
Weighted Avg.	821			20.08	813				42.62	1634	31.29
OAK											
West VFR	414	4.91	0.22	5.13	479	1.38	1.33	5.77	8.55	893	6.96
West IFR	414	4.12	0.00	4.12	479	1.42	0.00	233.90	235.3	893	128.12
SE IFR	414	28.00	0.25	28.28	479	2.37	0.00	5.69	8.06	893	17.43
Weighted Avg.	414			6.31	479				38.19	893	23.41
SJC											
West VFR	355	3.58	1.74	5.32	358	0.11	5.83	1.49	8.39	713	6.86
West IFR	355	2.55	0.41	2.96	358	0.05	3.65	1.41	5.17	713	4.07
SE IFR	355	2.13	0.22	2.36	358	0.74	1.43	2.13	4.30	713	3.33
Weighted Avg.	355			4.94	358				7.87	713	6.41
Bay Area											
Weighted Avg.	1590			13.11	1650				33.79	3240	23.64

Table 5-4

Case 3 – SFO A3 and OAK Inboard - 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	8.61	0.14	8.75	813	0.68	0.06	21.21	21.95	1634	15.32
West IFR	821	8.61	0.14	8.75	813	0.59	0.05	161.9	162.5	1634	85.25
SE IFR	821	246.6	0.03	246.7	813	1.54	0.04	4.09	5.68	1634	126.7
Weighted Avg.	821			21.01	813				42.22	1634	31.57
OAK											
West VFR	414	4.12	0.00	4.12	479	1.69	0.05	1.23	2.96	893	3.50
West IFR	414	4.08	0.00	4.08	477	1.44	0.04	2.91	4.40	891	4.25
SE IFR	414	27.84	0.25	28.08	479	0.39	0.00	3.66	6.05	893	16.26
Weighted Avg.	414			5.48	478				3.32	892	4.32
SJC											
West VFR	355	2.55	0.35	2.91	358	0.07	3.44	1.45	4.98	713	3.95
West IFR	353	2.54	0.44	2.98	356	0.08	3.69	1.41	5.27	709	4.13
SE IFR	355	2.13	0.22	2.35	358	0.83	1.70	2.08	4.62	713	3.49
Weighted Avg.	354			2.87	357				4.97	712	3.92
Bay Area											
Weighted Avg.	1589			12.92	1649				22.86	3238	17.98

Table 5-5
Case 4 – SFO A3 and OAK Outboard – 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	8.61	0.14	8.75	813	0.68	0.06	21.21	21.95	1634	15.32
West IFR	821	8.61	0.14	8.76	813	0.61	0.05	163.2	162.5	1634	85.25
SE IFR	821	246.7	0.03	246.8	813	1.54	0.05	4.14	5.73	1634	126.8
Weighted Avg.	821			21.02	813				42.23	1634	31.57
OAK											
West VFR	414	4.12	0.00	4.12	479	1.69	0.05	1.23	2.96	893	3.50
West IFR	414	4.12	0.00	4.12	479	1.60	0.04	1.22	2.86	893	3.44
SE IFR	414	28.03	0.25	28.28	479	2.37	0.00	5.69	8.06	893	17.43
Weighted Avg.	414			5.49	479				3.24	893	4.28
SJC											
West VFR	355	2.55	0.35	2.91	358	0.07	3.44	1.45	4.98	713	3.95
West IFR	355	0.55	0.44	2.99	358	0.11	3.70	1.41	5.30	713	4.15
SE IFR	355	2.13	0.22	2.36	358	0.74	1.43	2.13	4.30	713	3.33
Weighted Avg.	355			2.87	358				4.94	713	3.91
Bay Area											
Weighted Avg.	1590			12.92	1650				22.82	3240	17.96

Table 5-6
Case 5 – SFO F2 and OAK Existing – 2010 Average Delays

Alternatives	2010 Arrival Delays (min)				2010 Departure Delays (min)				Total Delays (min)		
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	693	4.59	0.04	4.63	685	0.94	0.14	1.24	2.33	1378	3.49
West IFR	693	4.67	0.04	4.71	685	1.15	0.29	1.17	2.61	1378	3.67
SE IFR	693	132.1	0.01	132.1	685	1.45	0.05	1.28	2.78	1378	67.86
Weighted Avg.	693			11.22	685				2.40	1378	6.83
OAK											
West VFR	317	3.25	0.06	3.31	383	1.99	0.00	1.65	3.64	700	3.49
West IFR	317	3.25	0.07	3.33	383	2.62	0.72	12.79	16.1	700	10.33
SE IFR	317	3.85	2.16	6.01	383	2.38	0.00	1.63	4.01	700	4.92
Weighted Avg.	317			3.47	383				5.30	700	4.47
SJC											
West VFR	268	1.94	0.25	2.19	271	0.15	1.29	1.05	2.48	539	2.34
West IFR	268	1.94	0.24	2.18	271	0.14	1.17	1.01	2.31	539	2.25
SE IFR	268	1.21	0.17	1.38	271	0.74	0.13	1.15	2.03	539	1.71
Weighted Avg.	268			2.12	271				2.43	539	2.28
Bay Area											
Weighted Avg.	1278			7.39	1339				3.23	2617	5.26

Table 5-7
Case 5 – SFO F2 and OAK Existing – 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	6.41	0.05	6.41	813	1.21	0.15	2.35	3.72	1634	5.07
West IFR	821	11.79	0.06	11.85	813	1.07	0.17	2.21	3.44	1634	7.67
SE IFR	821	247.20	0.02	247.20	813	1.44	0.05	4.44	5.94	1634	127.16
Weighted Avg.	821			19.64	813				3.79	1634	11.75
OAK											
West VFR	414	4.91	0.03	4.94	479	1.47	0.13	7.02	8.63	893	6.92
West IFR	414	4.91	0.04	4.95	479	3.90	0.00	286.70	290.6	893	158.17
SE IFR	414	28.46	4.94	33.41	479	2.27	0.00	4.66	6.90	893	19.19
Weighted Avg.	414			6.56	479				45.42	893	27.40
SJC											
West VFR	355	3.58	0.83	4.41	358	0.04	5.12	1.52	7.07	713	5.75
West IFR	355	3.58	0.62	4.20	358	0.06	4.60	1.47	6.33	713	5.27
SE IFR	355	2.13	0.23	2.36	358	0.66	1.43	2.09	4.19	713	3.28
Weighted Avg.	355			4.23	358				6.80	713	5.52
Bay Area											
Weighted Avg.	1590			12.79	1650				16.53	3240	14.70

Table 5-8 Case 6 – SFO F2 and OAK Inboard – 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	6.41	0.05	6.46	813	1.14	0.16	2.14	3.44	1634	4.96
West IFR	821	11.79	0.06	11.85	813	1.23	0.15	2.16	3.54	1634	7.72
SE IFR	821	247.4	0.02	247.4	813	1.40	0.05	4.43	5.88	1634	127.2
Weighted Avg.	821			19.69	813				3.58	1634	11.67
OAK											
West VFR	414	4.91	0.06	4.97	479	3.35	0.00	1.37	4.72	893	4.84
West IFR	414	4.91	0.04	4.96	479	2.46	0.00	3.63	6.09	893	5.57
SE IFR	414	28.61	4.41	33.02	479	2.26	0.00	2.59	4.85	893	17.91
Weighted Avg.	414			6.56	479				4.91	893	5.67
SJC											
West VFR	355	3.58	0.61	4.19	358	0.08	4.62	1.50	6.40	713	5.30
West IFR	355	3.58	0.87	4.45	358	0.08	4.90	1.47	6.85	713	5.66
SE IFR	355	2.13	0.24	2.37	358	0.76	1.44	2.03	4.23	713	3.30
Weighted Avg.	355			4.06	358				6.25	713	5.16
Bay Area											
Weighted Avg.	1590			12.78	1650				4.55	3240	8.59

Table 5-9 Case 7 – SFO F2 and OAK Outboard – 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	6.41	0.05	6.46	813	1.19	0.14	2.32	3.65	1634	5.06
West IFR	821	11.79	0.06	11.85	813	1.21	0.18	2.13	3.53	1634	7.71
SE IFR	821	247.4	0.02	247.4	813	1.40	0.05	4.43	5.88	1634	127.23
Weighted Avg.	821			19.69	813				3.75	1634	11.76
OAK											
West VFR	414	4.91	0.14	5.05	479	3.64	0.00	1.08	4.72	893	4.87
West IFR	414	4.91	0.13	5.04	479	3.72	0.00	1.10	4.82	893	4.92
SE IFR	414	28.61	4.41	33.02	479	2.26	0.00	2.59	4.85	893	17.91
Weighted Avg.	414			6.64	479				4.74	893	5.62
SJC											
West VFR	355	3.58	0.76	4.34	358	0.09	4.86	1.52	6.82	713	5.59
West IFR	355	3.58	0.47	4.05	358	0.09	4.33	1.44	5.97	713	5.01
SE IFR	355	2.13	0.24	2.37	358	0.76	1.44	2.03	4.23	713	3.30
Weighted Avg.	355			4.17	358				6.56	713	5.37
Bay Area											
Weighted Avg.	1590			12.82	1650				4.65	3240	8.66

Table 5-10 Case 8 – SFO BXR and OAK Existing – 2010 Average Delays

Alternatives	2010 Arrival Delays (min)				2010 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	693	3.16	0.07	3.23	685	0.13	0.01	1.76	1.90	1378	2.57
West IFR	693	2.63	0.08	2.71	685	1.31	0.01	1.91	3.24	1378	2.97
SE IFR	693	3.73	0.06	3.79	685	1.69	0.12	3.58	5.39	1378	4.59
Weighted Avg.	693			3.18	685				2.28	1378	2.73
OAK											
West VFR	317	0.27	0.00	2.27	383	0.05	0.00	2.70	2.75	700	2.53
West IFR	317	2.34	0.00	2.34	383	1.71	0.00	0.69	2.40	700	2.37
SE IFR	317	5.53	0.00	5.53	383	2.59	0.00	2.60	5.19	700	5.34
Weighted Avg.	317			2.46	383				2.84	700	2.67
SJC											
West VFR	268	0.91	0.01	0.92	271	0.01	0.00	2.97	2.99	539	1.96
West IFR	268	1.77	0.24	2.00	271	0.01	0.00	2.51	2.52	539	2.26
SE IFR	268	0.55	0.01	0.56	271	0.72	0.00	0.58	1.30	539	0.93
Weighted Avg.	268			0.96	271				2.83	539	1.90
Bay Area											
Weighted Avg.	1278			2.54	1339				2.55	2617	2.54

Table 5-11 Case 8 – SFO BXR and OAK Existing – 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	5.20	0.10	5.30	813	0.22	0.01	2.05	2.27	1634	3.79
West IFR	821	4.29	0.09	4.37	813	1.36	0.01	7.41	8.78	1634	6.56
SE IFR	821	18.68	0.03	18.71	813	2.06	0.16	14.36	16.58	1634	17.65
Weighted Avg.	821			5.85	813				3.99	1634	4.92
OAK											
West VFR	414	3.58	0.00	3.58	479	0.06	0.00	17.21	17.27	893	10.92
West IFR	414	3.65	0.00	3.65	479	2.13	0.00	232.40	234.6	893	127.53
SE IFR	414	8.91	0.00	8.91	479	2.16	0.00	20.10	22.26	893	16.07
Weighted Avg.	414			3.89	479				45.99	893	26.47
SJC											
West VFR	355	1.55	0.01	1.57	358	0.02	0.45	7.48	7.95	713	4.77
West IFR	355	2.85	0.31	3.17	358	0.01	0.41	7.34	7.76	713	5.47
SE IFR	355	0.78	0.02	0.80	358	0.83	0.00	0.81	1.64	713	1.22
Weighted Avg.	355			1.60	358				7.43	713	4.53
Bay Area											
Weighted Avg.	1590			4.39	1650				16.93	3240	10.78

Table 5-12 Case 9 – SFO BXR and OAK Inboard – 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	5.20	0.09	5.29	813	0.22	0.00	2.11	2.33	1634	3.82
West IFR	821	4.13	0.09	4.22	813	1.39	0.01	8.43	9.80	1634	7.00
SE IFR	821	21.33	0.10	21.43	813	1.89	0.12	11.20	13.21	1634	17.34
Weighted Avg.	821			5.96	813				4.01	1634	4.99
OAK											
West VFR	414	3.47	0.00	3.47	479	0.14	0.02	0.94	1.10	893	2.20
West IFR	414	3.58	0.00	3.58	479	1.84	0.00	4.50	6.34	893	5.06
SE IFR	414	4.39	0.04	4.43	479	2.25	0.00	3.65	5.91	893	5.22
Weighted Avg.	414			3.54	479				2.06	893	2.74
SJC											
West VFR	355	1.55	0.10	1.86	358	0.02	0.94	7.71	8.66	713	5.27
West IFR	355	2.85	0.32	3.18	358	0.01	0.10	6.18	6.29	713	4.74
SE IFR	355	0.78	0.02	0.80	358	0.65	0.08	0.71	1.44	713	1.12
Weighted Avg.	355			1.85	358				7.94	713	4.91
Bay Area											
Weighted Avg.	1590			4.41	1650				4.30	3240	4.35

Table 5-13 Case 10 – SFO BXR and OAK Outboard – 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	5.20	0.09	5.29	813	0.22	0.01	2.04	2.27	1634	3.79
West IFR	821	4.13	0.09	4.22	813	1.42	0.01	8.53	9.96	1634	7.08
SE IFR	821	23.34	0.02	23.36	813	1.77	0.15	19.13	21.06	1634	22.22
Weighted Avg.	821			6.06	813				4.39	1634	5.23
OAK											
West VFR	414	1.22	0.00	1.22	479	0.17	0.00	1.03	1.21	893	1.21
West IFR	414	4.04	0.12	4.16	479	2.22	0.00	0.80	3.02	893	3.55
SE IFR	414	8.68	0.13	8.81	479	2.76	0.00	0.89	3.65	893	6.04
Weighted Avg.	414			2.04	479				1.59	893	1.79
SJC											
West VFR	355	1.55	0.01	1.56	358	0.02	0.63	7.70	8.35	713	4.97
West IFR	355	2.85	0.33	3.19	358	0.01	1.90	8.87	10.77	713	7.00
SE IFR	355	0.78	0.03	0.81	358	0.74	0.00	0.87	1.61	713	1.21
Weighted Avg.	355			1.60	358				7.96	713	4.79
Bay Area											
Weighted Avg.	1590			4.02	1650				4.35	3240	4.19

Table 5-14
Case 11 – SFO BXR and OAK Outboard with Advanced ATC – 2020 Average Delays

Alternatives	2020 Arrival Delays (min)				2020 Departure Delays (min)					Total Delays (min)	
	Ops	Air	Ground	Total	Ops	Air	Ground	Queue	Total	Ops	Total
SFO											
West VFR	821	5.18	0.08	5.26	813	0.28	0.01	1.61	1.90	1634	3.59
West IFR	821	2.24	0.09	2.33	813	1.50	0.01	7.25	8.76	1634	5.53
SE IFR	821	1.31	0.06	1.37	813	2.24	0.15	3.15	5.54	1634	3.44
Weighted Avg.	821			4.62	813				3.12	1634	3.87
OAK											
West VFR	414	1.22	0.00	1.22	479	0.14	0.00	0.92	1.06	893	1.13
West IFR	414	4.04	0.11	4.14	479	2.17	0.00	0.84	3.01	893	3.53
SE IFR	414	8.68	0.16	8.84	479	2.86	0.00	0.81	3.67	893	6.07
Weighted Avg.	414			2.03	479				1.46	893	1.73
SJC											
West VFR	355	1.55	0.01	1.56	358	0.02	0.68	7.43	8.14	713	4.86
West IFR	355	2.85	0.34	3.19	358	0.01	0.10	6.40	6.51	713	4.86
SE IFR	355	0.78	0.02	0.81	358	0.81	0.00	0.84	1.65	713	1.23
Weighted Avg.	355			1.60	358				7.52	713	4.57
Bay Area											
Weighted Avg.	1590			3.27	1650				3.59	3240	3.44

5.7 ULTIMATE RUNWAY CAPACITY

Ultimate runway capacity for an airport can be defined as the maximum number of aircraft operations that could be handled in one hour with acceptable levels of delay given a specific runway configuration. The limit of acceptable delays should not be much greater than an average of 5 minutes per aircraft, as discussed in Section 2 above.

By increasing progressively the number of operations until delays exceed 5 minutes, the ultimate capacity of a runway alternative can be established. The ultimate capacities for each airport and runway configuration, as calculated using SIMMOD, are shown in Table 5-15.

These estimates were developed with the SIMMOD Plus version of the airport and airspace simulation model. Calculated capacities may be different with other versions of SIMMOD model, incorporation of more detail for weather conditions (while this analysis evaluated three major weather conditions, there are further variations of each which, when weighted for their frequency of occurrence, could result in different and possibly high hourly capacities), incorporation of alternative taxiway layouts, aircraft gate assignments and gate hold procedures, etc.

Table 5-15
Ultimate Airport Capacity

Alternative	Total Operations per Hour VFR	IFR	Weighted Average
SFO			
Existing	99	71	93
A3	108	99	106
F2	128	110	124
BXR	128	114	125
BXR/ New Tech	129	116	126
OAK			
Existing	49	47	49
Inboard	84*	60	80
Outboard	98*	76**	95
SJC			
Existing	78*	40	72
Dual Runways	78*	43	72

* The numbers in this study are based on single streams for arrivals/departures for simplicity in modeling. In reality, VFR capacity would be higher since dual arrivals are possible.
** IFR capacities would also be higher at OAK with duel arrivals made possible with a properly separated outboard runway.

The results of the SIMMOD model simulations are summarized in this section, both in tabular and in graphic form. The tables give a detailed picture for each demand management and airport runway configuration where arrival, departure and weighted average delays (minutes per flight) are shown for each weather condition. In contrast, the graphs show only the weighted average delays (arrivals and departures combined) to allow a clear visual comparison of the impact of the various alternatives.

6.1 DEMAND MANAGEMENT ALTERNATIVES

The different demand management alternatives were described in Section 4.5 and are briefly summarized below. The delays resulting from these alternatives are shown in Table 6-1 and plotted in Figures 6-1 to 6-4.

- *All Existing – 1999.* Uses the existing layout for all three airports with 1999 traffic levels. This is the validated Base Case.
- *Sensitivity Case S1- 1999.* Uses the existing layout for all airports with 1999 SFO traffic levels reduced by moving corporate GA operations from SFO to OAK, and by replacing turboprop operations at SFO with half the number of regional jet operations.
- *Sensitivity Case S2- 1999.* Uses the existing layout for all airports with 1999 SFO traffic levels reduced by moving corporate GA operations from SFO to OAK, and by replacing turboprop operations at SFO by half the number of regional jets. In addition, flights from Southern California are further reduced by 26% (equivalent to a substitution of B-757 for B-737)

For 2010 and 2020 demand management alternatives, the use of SOIA/PRM procedures are included.

- *All Existing – 2010.* Uses the existing runway layout for all three airports with 2010 traffic forecasts
- *Sensitivity Case S2 Demand - 2010.* Uses the existing runway layout for all airports with 2010 SFO traffic reduced by moving corporate GA operations from SFO to OAK, and by replacing turboprop operations at SFO with half the number of regional jets. In addition, the flights from Southern California are further reduced by 26% (equivalent to a substitution of B-757 for B-737).
- *Sensitivity Case S3 Demand - 2010.* Uses the existing runway layout for all airports with the 2010 SFO traffic reduced by moving corporate GA operations from SFO to OAK, by replacing turboprop operations in SFO by half the number of regional jets, and by reducing the flights from Southern California by 26% (equivalent to a substitution of B-757 for B-737). In addition, a third of the flights to/from Southern California (BUR, LAX, ONT, SAN, SBA, and SNA) are moved from SFO to OAK, resulting in about the same number of flights to these cities as in 1999.

- *All Existing – 2020.* Uses the existing runway layout for all three airports with the 2020 traffic forecast
- *Sensitivity Case S2 Demand - 2020.* Uses the existing runway layout for all airports with the 2020 SFO traffic reduced by moving corporate GA operations from SFO to OAK, and by replacing turboprop operations in SFO with half the number of regional jets. In addition, flights from Southern California are further reduced by 26% (equivalent to a substitution of B-757 for B-737).
- *Sensitivity Case S3 Demand - 2020.* Uses the existing layout for all airports with the 2020 SFO traffic reduced by moving corporate GA operations from SFO to OAK, by replacing turboprop operations in SFO with half the number of regional jets and sending them to OAK, and by reducing flights from Southern California by 26% (equivalent to a substitution of B-757 for B-737). In addition, a third of the flights to/from Southern California (BUR, LAX, ONT, SAN, SBA, and SNA) are moved from SFO to OAK, resulting in about the same number of flights to these cities as in 1999.

Table 6-1
Summary of Demand Management Alternatives – Average Delays in Minutes

Al ernatives	San Francisco			Oakland			San Jose			Bay Area Airports		
	Arr.	Dep.	Total	Arr.	Dep.	Total	Arr.	Dep.	Total	Arr.	Dep.	Total
1999 Ex sting												
West-\ FR	2.31	4.74	3.51	0.51	1.13	0.86	0.63	2.02	1.38	1.57	3.21	2.42
West-I FR	148.	5.78	77.8	1.14	0.88	0.99	0.52	1.90	1.26	86.02	3.66	43.20
SE-IFF	93.7	8.61	51.5	1.58	3.80	2.82	1.50	4.33	3.03	54.66	6.43	29.59
Average	29.0	5.10	17.1	0.65	1.25	0.99	0.69	2.20	1.50	17.00	3.47	9.96
1999 S												
West-\ FR	1.94	3.63	2.79	1.28	2.81	2.11	0.88	2.72	1.87	1.54	3.18	2.40
West-I FR	69.5	4.08	36.7	1.70	1.05	1.35	0.51	2.00	1.31	36.79	2.72	19.05
SE-IFF	29.7	28.18	28.9	2.55	4.34	3.52	1.50	4.73	3.24	16.47	15.87	16.16
Average	13.5	4.96	9.24	1.41	2.67	2.09	0.91	2.84	1.95	7.61	3.81	5.63
1999 S												
West-\ FR	1.94	3.22	2.58	1.28	3.04	2.23	0.88	2.98	2.01	1.53	3.11	2.35
West-I FR	46.3	3.0	24.6	1.70	1.07	1.36	0.51	1.54	1.07	24.08	2.06	12.59
SE-IFF	8.7	11.76	10.2	2.55	4.66	3.69	1.50	4.24	2.98	5.46	7.88	6.72
Average	8.96	3.62	6.29	1.41	2.87	2.20	0.91	2.99	2.03	5.13	3.25	4.15
2010 Ex st. + SOIA												
West-\ FR	4.20	8.74	6.46	1.13	3.74	2.56	1.24	1.76	1.50	2.82	5.90	4.39
West-I FR	199.	4.2	102.	2.45	1.13	1.73	0.96	2.08	1.52	109.0	2.87	54.70
SE-IFF	144.	53.54	99.1	5.11	4.48	4.77	1.78	3.09	2.44	79.81	29.30	53.96
Average	22.9	11.02	17.0	1.53	3.44	2.57	1.27	1.89	1.58	13.09	7.00	9.97
2010 S2 + SOIA												
West-\ FR	3.49	7.83	5.66	1.19	4.53	2.98	1.25	1.48	1.37	2.33	5.43	3.92
West-I FR	118.	3.5	61.1	2.88	1.72	2.26	0.97	1.88	1.43	59.23	2.59	30.25
SE-IFF	76.3	61.39	68.8	2.79	4.83	3.88	1.79	2.49	2.14	38.52	30.75	34.55
Average	14.0	10.62	12.3	1.50	4.18	2.94	1.28	1.58	1.43	7.57	6.64	7.09
2010 S3 + SOIA												
West-\ FR	2.85	3.69	3.27	1.27	12.63	7.31	1.24	1.61	1.43	1.95	6.63	4.35
West-I FR	71.1	2.29	36.7	7.07	3.00	4.91	0.97	2.14	1.56	33.60	2.53	17.69
SE-IFF	33.1	39.42	36.2	4.86	8.91	7.01	1.80	2.94	2.37	16.46	20.30	18.43
Average	8.35	5.63	6.99	2.23	11.16	6.98	1.27	1.75	1.51	4.68	6.91	5.82
2010 Ex ist. + Tech												
West-\ FR	4.07	6.16	5.11	0.78	2.46	1.70	1.22	2.08	1.65	2.66	4.28	3.48
West-I FR	193.	4.57	99.8	2.38	1.10	1.68	0.92	1.94	1.43	105.9	3.05	53.30
SE-IFF	103.	61.85	82.6	2.86	4.59	3.81	1.78	3.20	2.49	57.07	33.60	45.06

Table 6-1
Summary of Demand Management Alternatives – Average Delays in Minutes (Cont'd)

Alternatives	San Francisco			Oakland			San Jose			Bay Area Airports		
	Arr.	Dep.	Total	Arr.	Dep.	Total	Arr.	Dep.	Total	Arr.	Dep.	Total
Average	20.2	9.22	14.7	1.11	2.40	1.82	1.25	2.16	1.71	11.50	5.84	8.60
2020 Exist. + SOIA												
West-VFR	15.7	98.20	56.7	1.45	13.27	7.79	2.28	5.17	3.73	9.01	53.36	31.60
West-IFR	314.	11.07	163.	3.78	2.07	2.86	9.34	4.11	6.71	165.4	6.95	84.75
SE-IFR	251.	112.1	182.	27.9	6.49	16.4	3.39	9.34	6.38	138.1	59.18	97.91
Average	45.6	94.15	69.7	3.26	11.42	7.64	2.79	5.44	4.12	25.05	50.89	38.21
2020 S2 + SOIA												
West-VFR	11.7	45.43	28.5	1.48	36.95	20.2	2.04	3.13	2.59	6.52	33.42	20.23
West-IFR	253.	6.55	130.	4.60	3.01	3.76	2.04	6.16	4.11	123.9	5.35	63.49
SE-IFR	197.	106.6	151.	5.94	16.83	11.7	3.31	8.35	5.84	97.38	56.57	76.58
Average	35.6	46.73	41.1	2.14	31.37	17.6	2.14	3.73	2.94	18.25	32.39	25.45
2020 S3 + SOIA												
West-VFR	9.06	44.82	26.9	1.66	115.6	61.7	2.04	3.08	2.56	5.09	60.19	33.16
West-IFR	217.	6.97	112.	8.97	16.65	13.0	1.89	5.33	3.62	101.6	9.96	54.92
SE-IFR	162.	94.38	128.	5.45	79.65	44.5	3.31	8.15	5.74	75.99	70.43	73.16
Average	29.2	45.52	37.4	2.83	100.6	54.3	2.13	3.62	2.88	14.64	55.42	35.42

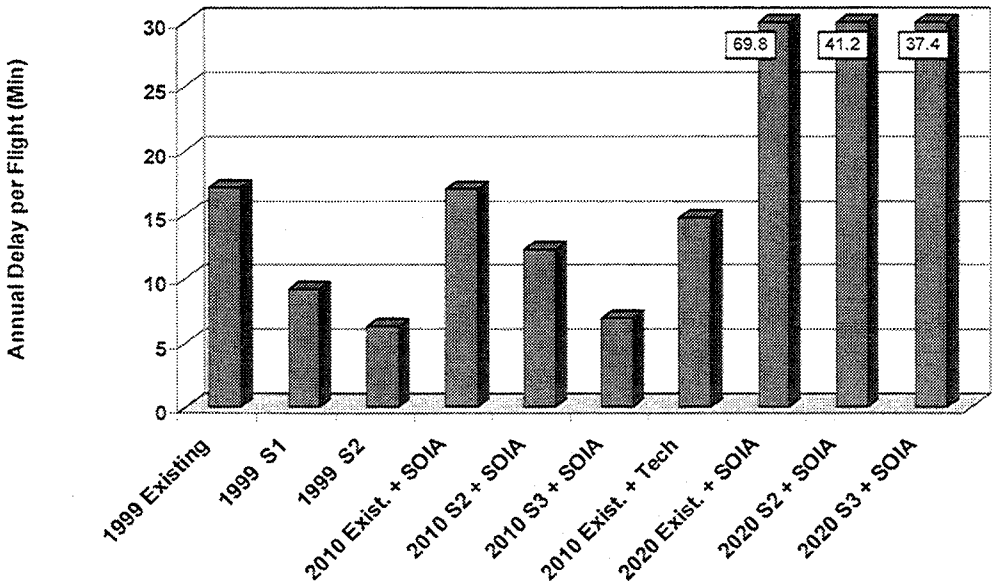


Figure 6-1 San Francisco Airport – Average Delay By Demand Management Alternative

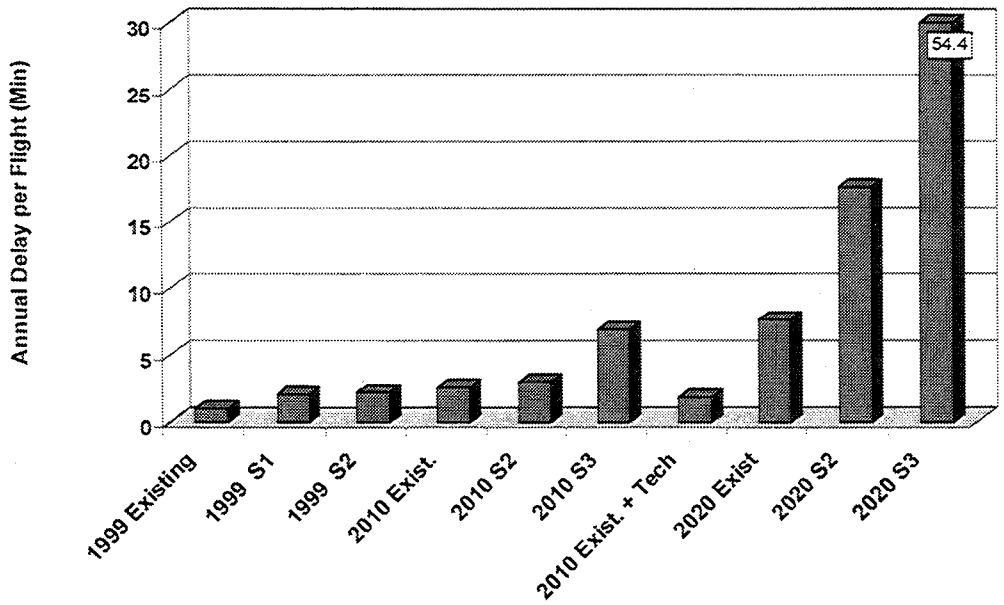


Figure 6-2 Oakland Airport – Average Delay By Demand Management Alternative

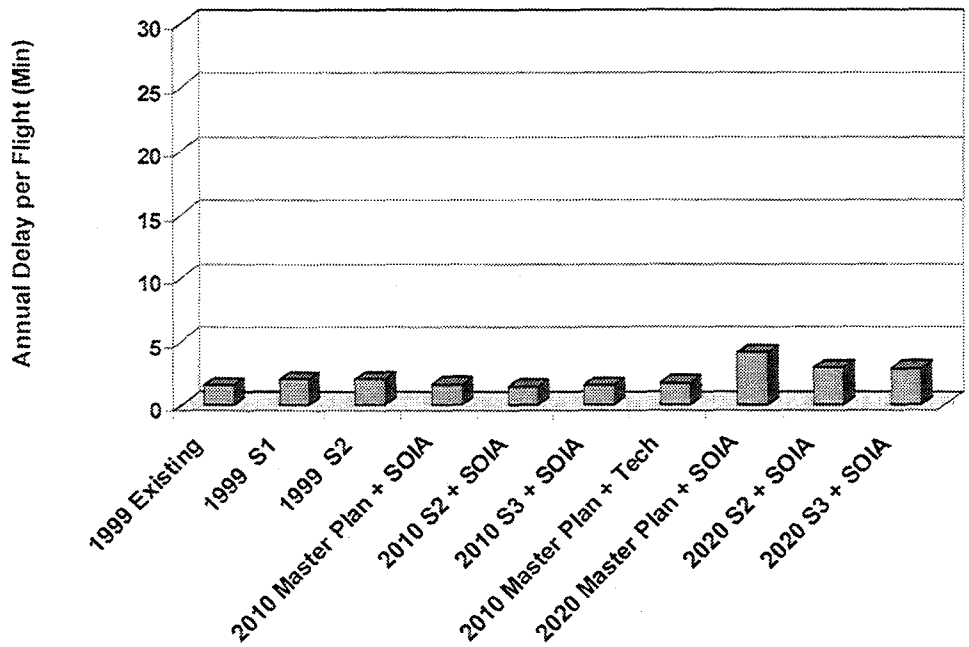
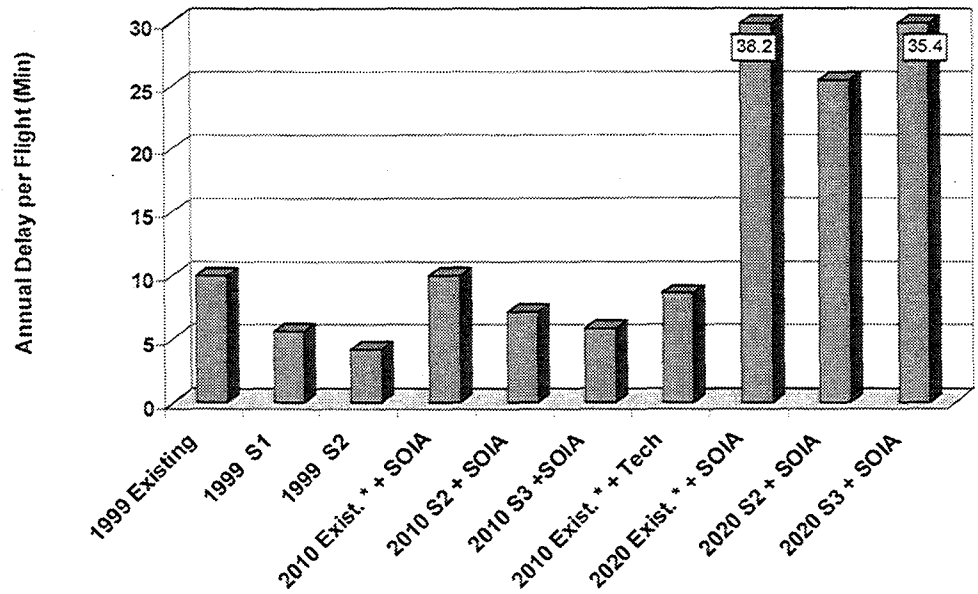


Figure 6-3 San Jose Airport – Average Delay By Demand Management Alternative



*Existing includes the San Jose Master Plan

Figure 6-4 Bay Area Airports – Average Delay By Demand Management Alternative

6.2 RUNWAY CONFIGURATION ALTERNATIVES

The different runway configuration alternatives were described in Section 5 and are briefly summarized below. The delays resulting from these alternatives are shown in Table 6-2 and plotted in Figures 6-5 to 6-8. In SFO, the situation is somewhat worse in SE IFR than in West IFR because the former uses two runways for departures (10L and 10R), whereas the latter can use three runways (1L, 1R, and 28R).

- *All Existing – 1999.* Uses the existing runway layout for all three airports with 1999 traffic levels. This is the validated Base Case.
- *SFO A3 and OAK Existing - 2010.* Uses the A3 Alternative for SFO, existing OAK airport layout, and second parallel runway for SJC with traffic level per 2010 forecast demand.
- *SFO A3 and OAK Existing - 2020.* Uses the A3 Alternative for SFO, existing OAK airport layout, and second parallel runway for SJC with traffic level per 2020 forecast demand.
- *SFO A3 and OAK Inboard - 2020.* Uses the A3 Alternative for SFO, OAK airport layout with inboard parallel runway, and second parallel runway for SJC with traffic level per 2020 forecast demand.
- *SFO A3 and OAK Outboard - 2020.* Uses the A3 Alternative for SFO, OAK airport layout with outboard parallel runway, and second parallel runway for SJC with traffic level per 2020 forecast demand.
- *SFO F2 and OAK Existing - 2010.* Uses the F2 Alternative for SFO, existing OAK airport layout, and second parallel runway for SJC with traffic level per 2010 forecast demand.
- *SFO F2 and OAK Existing - 2020.* Uses the F2 Alternative for SFO, existing OAK airport layout, and second parallel runway for SJC with traffic level per 2020 forecast demand.
- *SFO F2 and OAK Inboard - 2020.* Uses the F2 Alternative for SFO, OAK airport layout with inboard parallel runway, and second parallel runway for SJC with traffic level per 2020 forecast demand.
- *SFO F2 and OAK Outboard - 2020.* Uses the F2 Alternative for SFO, OAK airport layout with outboard parallel runway, and second parallel runway for SJC with traffic level per 2020 forecast demand.
- *SFO BXR and OAK Existing - 2010.* Uses the BXR Alternative for SFO, existing OAK airport layout, and second parallel runway for SJC with traffic level per 2010 forecast demand.
- *SFO BXR and OAK Existing - 2020.* Uses the BXR Alternative for SFO, existing OAK airport layout, and second parallel runway for SJC with traffic level per 2020 forecast demand.

- *SFO BXR and OAK Inboard - 2020.* Uses the BXR Alternative for SFO, OAK airport layout with inboard parallel runway, and second parallel runway for SJC with traffic level per 2020 forecast demand.
- *SFO BXR and OAK Outboard - 2020.* Uses the BXR Alternative for SFO, OAK airport layout with outboard parallel runway, and second parallel runway for SJC with traffic level per 2020 forecast demand.
- *SFO BXR and OAK Outboard + ATC – 2020.* Uses the BXR Alternative for SFO, OAK airport layout with outboard parallel runway, and second parallel runway for SJC with traffic level per 2020 forecast demand. Impact of new ATC technology modeled for SFO to allow closer spacing of aircraft on final approach and expedited releases of departures. Separation rules for intersection clearing are still respected

Table 6-2
Summary of New Runway Alternatives – Average Delays in Minutes

Alt rnatives	San Francisco			Oakland			San Jose			Bay Area Airports		
	Arr.	Dep.	Total	Arr.	Dep.	Total	Arr.	Dep.	Total	Arr.	Dep.	Total
All Exist ng – 1999												
West-VF R	2.31	4.74	3.51	0.51	1.13	0.86	0.63	2.02	1.38	1.57	3.21	2.42
West-IFF	148.	5.78	77.82	1.14	0.88	0.99	0.52	1.90	1.26	86.02	3.66	43.20
SE-IFR	93.7	8.61	51.53	1.58	3.80	2.82	1.50	4.33	3.03	54.66	6.43	29.59
Average	29.0	5.10	17.15	0.65	1.25	0.99	0.69	2.20	1.50	17.00	3.47	9.96
2010 A3 + OAK Existing												
West-VF R	4.86	4.09	4.48	3.25	3.44	3.35	2.19	2.69	2.44	3.90	3.62	3.76
West-IFF	4.88	51.01	27.81	3.04	14.64	9.39	1.72	2.77	2.25	3.76	30.84	17.62
SE-IFR	133.	2.75	68.32	4.62	5.26	4.97	2.02	1.99	2.00	73.77	3.31	37.72
Average	11.4	11.07	11.27	3.30	5.01	4.24	2.15	2.64	2.39	7.49	7.63	7.56
2020 A3 + OAK Existing												
West-VF R	7.57	22.55	15.02	5.13	8.55	6.96	5.32	8.39	6.86	6.43	15.41	11.01
West-IFF	8.75	161.9	84.95	4.12	235.3	128.1	2.96	5.17	4.07	6.25	149.2	79.05
SE-IFR	246.	5.73	126.8	28.28	8.06	17.43	2.36	4.30	3.33	135.3 3	6.10	69.51
Average	20.0	42.62	31.29	6.31	38.19	23.41	4.94	7.87	6.41	13.11	33.79	23.64
2020 A3 + OAK Inboard												
West-VF R	8.75	21.95	15.32	4.12	2.96	3.50	2.91	4.98	3.95	6.24	12.76	9.56
West-IFF	8.75	162.5	85.25	4.08	4.40	4.25	2.98	5.27	4.13	6.25	82.68	45.15
SE-IFR	246. 7	5.68	126.7 8	28.08	6.05	16.26	2.35	4.62	3.49	135.2 2	5.56	69.19
Average	21.0	42.22	31.57	5.48	3.32	4.32	2.87	4.97	3.92	12.92	22.86	17.98
2020 A3 + OAK Outboard												
West-VF R	8.75	21.95	15.32	4.12	2.96	3.50	2.91	4.98	3.95	6.24	12.76	9.56
West-IFF	8.76	162.5	85.25	4.12	2.86	3.44	2.99	5.30	4.15	6.26	82.05	44.86
SE-IFR	246.	5.73	126.8	28.28	8.06	17.43	2.36	4.30	3.33	135.3	6.10	69.51
Average	21.0	42.23	31.57	5.49	3.24	4.28	2.87	4.94	3.91	12.92	22.82	17.96
2010 F2 + OAK Existing												
West-VF R	4.63	2.33	3.49	3.31	3.64	3.49	2.19	2.48	2.34	3.79	2.74	3.25
West-IFI	4.71	2.61	3.67	3.33	16.13	10.33	2.18	2.31	2.25	3.84	6.42	5.16
SE-IFR	132.	2.78	67.86	6.01	4.01	4.92	1.38	2.03	1.71	73.46	2.98	37.40
Average	11.2	2.40	6.83	3.47	5.30	4.47	2.12	2.43	2.28	7.39	3.23	5.26
2020 F2 + OAK Existing												
West-VF R	6.41	3.72	5.07	4.94	8.63	6.92	4.41	7.07	5.75	5.58	5.87	5.73
West-IFI	11.8	3.44	7.67	4.95	290.6	158.1	4.20	6.33	5.27	8.35	87.43	48.62
SE-IFR	247.	5.94	127.1	33.41	6.90	19.19	2.36	4.19	3.28	136.8	5.84	70.14
Average	19.6	3.79	11.75	6.56	45.42	27.40	4.23	6.80	5.52	12.79	16.53	14.70
2020 F2 + OAK Inboard												
West-VF R	6.46	3.44	4.96	4.97	4.72	4.84	4.19	6.40	5.30	5.57	4.45	5.00
West-IFI	11.8	3.54	7.72	4.96	6.09	5.57	4.45	6.85	5.66	8.40	5.00	6.67
SE-IFR	247.	5.88	127.2	33.02	4.85	17.91	2.37	4.23	3.30	136.8	5.22	69.83

Table 6-2
Summary of New Runway Alternatives – Average Delays in Minutes (Cont'd)

Alternatives	San Francisco			Oakland			San Jose			Bay Area Airports		
	Arr.	Dep.	Total	Arr.	Dep.	Total	Arr.	Dep.	Total	Arr.	Dep.	Total
Average	19.6	3.58	11.67	6.56	4.91	5.67	4.06	6.25	5.16	12.78	4.55	8.59
2020 F2 + OAK Outboard												
West-VFR	6.46	3.65	5.06	5.05	4.72	4.87	4.34	6.82	5.59	5.62	4.65	5.12
West-IFR	11.8	3.53	7.71	5.04	4.82	4.92	4.05	5.97	5.01	8.34	4.43	6.35
SE-IFR	247.	5.88	127.2	33.02	4.85	17.91	2.37	4.23	3.30	136.8	5.22	69.83
Average	19.6	3.75	11.76	6.64	4.74	5.62	4.17	6.56	5.37	12.82	4.65	8.66
2010 BXR + OAK Existing												
West-VFR	3.23	1.90	2.57	2.27	2.75	2.53	0.92	2.99	1.96	2.51	2.36	2.43
West-IFR	2.71	3.24	2.97	2.34	2.40	2.37	2.00	2.52	2.26	2.47	2.85	2.67
SE-IFR	3.79	5.39	4.59	5.53	5.19	5.34	0.56	1.30	0.93	3.54	4.51	4.04
Average	3.18	2.28	2.73	2.46	2.84	2.67	0.96	2.83	1.90	2.54	2.55	2.54
2020 BXR + OAK Existing												
West-VFR	5.30	2.27	3.79	3.58	17.27	10.92	1.57	7.95	4.77	4.02	7.86	5.97
West-IFR	4.37	8.78	6.56	3.65	234.6	127.5	3.17	7.76	5.47	3.91	74.11	39.66
SE-IFR	18.7	16.58	17.65	8.91	22.26	16.07	0.80	1.64	1.22	12.16	14.99	13.60
Average	5.85	3.99	4.92	3.89	45.99	26.47	1.60	7.43	4.53	4.39	16.93	10.78
2020 BXR + OAK Inboard												
West-VFR	5.29	2.33	3.82	3.47	1.10	2.20	1.86	8.66	5.27	4.05	3.35	3.69
West-IFR	4.22	9.80	7.00	3.58	6.34	5.06	3.18	6.29	4.74	3.82	8.03	5.97
SE-IFR	21.4	13.21	17.34	4.43	5.91	5.22	0.80	1.44	1.12	12.40	8.54	10.43
Average	5.96	4.01	4.99	3.54	2.06	2.74	1.85	7.94	4.91	4.41	4.30	4.35
2020 BXR + OAK Outboard												
West-VFR	5.29	2.27	3.79	1.22	1.21	1.21	1.56	8.35	4.97	3.40	3.28	3.34
West-IFR	4.22	9.96	7.08	4.16	3.02	3.55	3.19	10.77	7.00	3.97	8.12	6.09
SE-IFR	23.3	21.06	22.22	8.81	3.65	6.04	0.81	1.61	1.21	14.54	11.79	13.14
Average	6.06	4.39	5.23	2.04	1.59	1.79	1.60	7.96	4.79	4.02	4.35	4.19
2020 BXR + OAK Out/Tech												
West-VFR	5.26	1.90	3.59	1.22	1.06	1.13	1.56	8.14	4.86	3.38	3.01	3.19
West-IFR	2.33	8.76	5.53	4.14	3.01	3.53	3.19	6.51	4.86	2.99	6.60	4.83
SE-IFR	1.37	5.54	3.44	8.84	3.67	6.07	0.81	1.65	1.23	3.19	4.15	3.68
Average	4.62	3.12	3.87	2.03	1.46	1.73	1.60	7.52	4.57	3.27	3.59	3.44

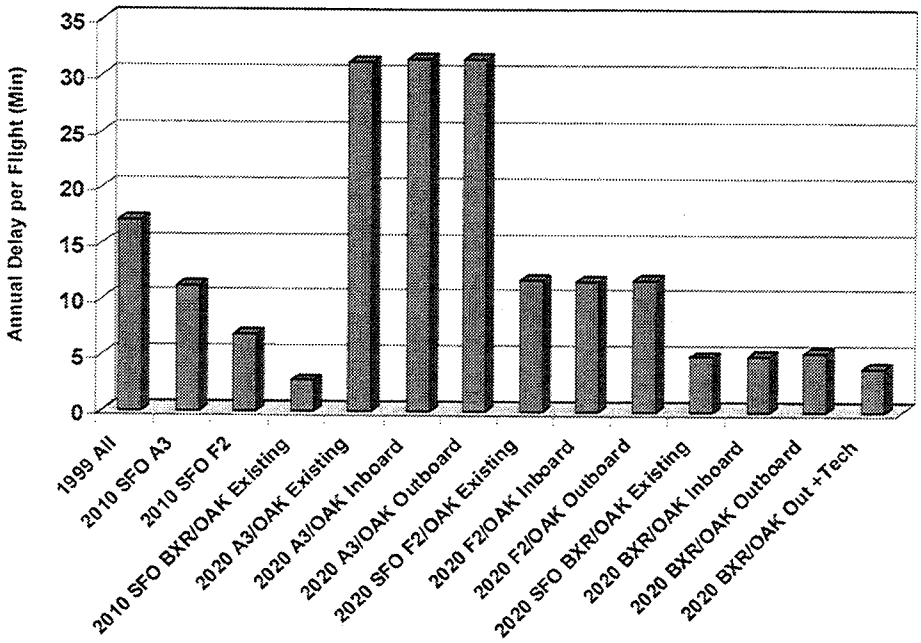


Figure 6-5 San Francisco Airport – Average Delay By Runway Configuration Alternative

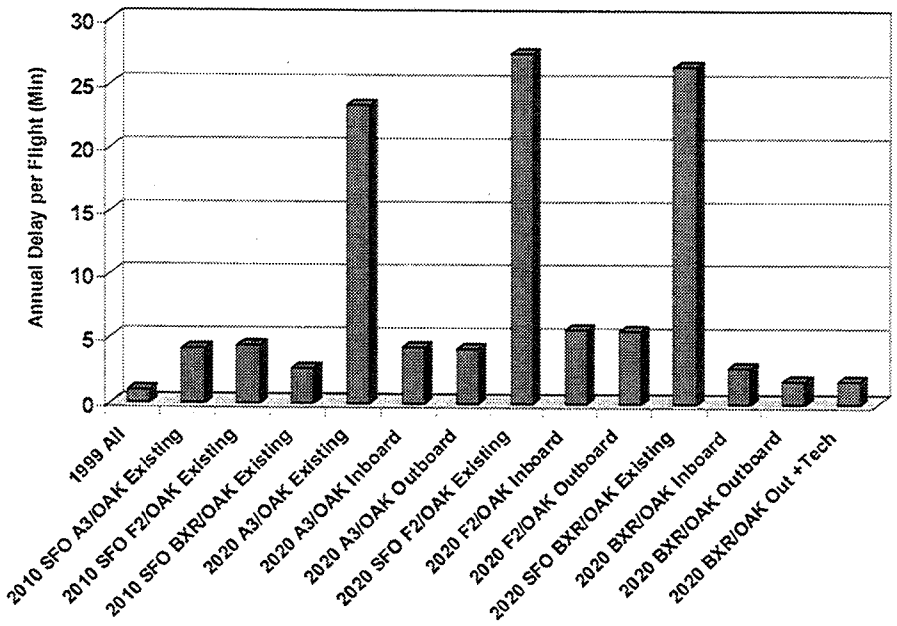


Figure 6-6 Oakland Airport – Average Delay By Runway Configuration Alternative

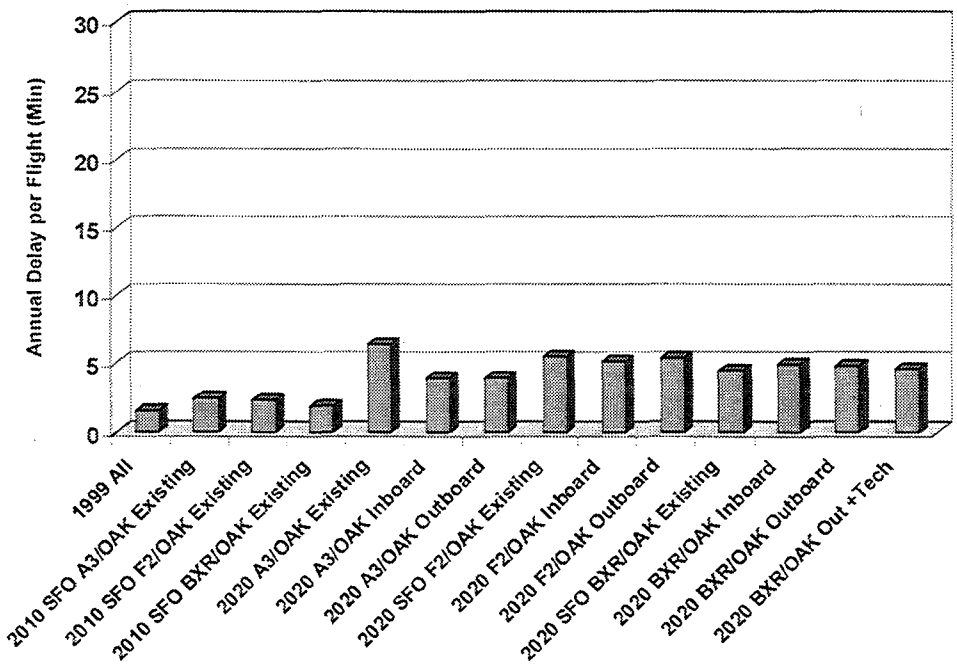


Figure 6-7 San Jose Airport – Average Delay By Runway Configuration Alternative

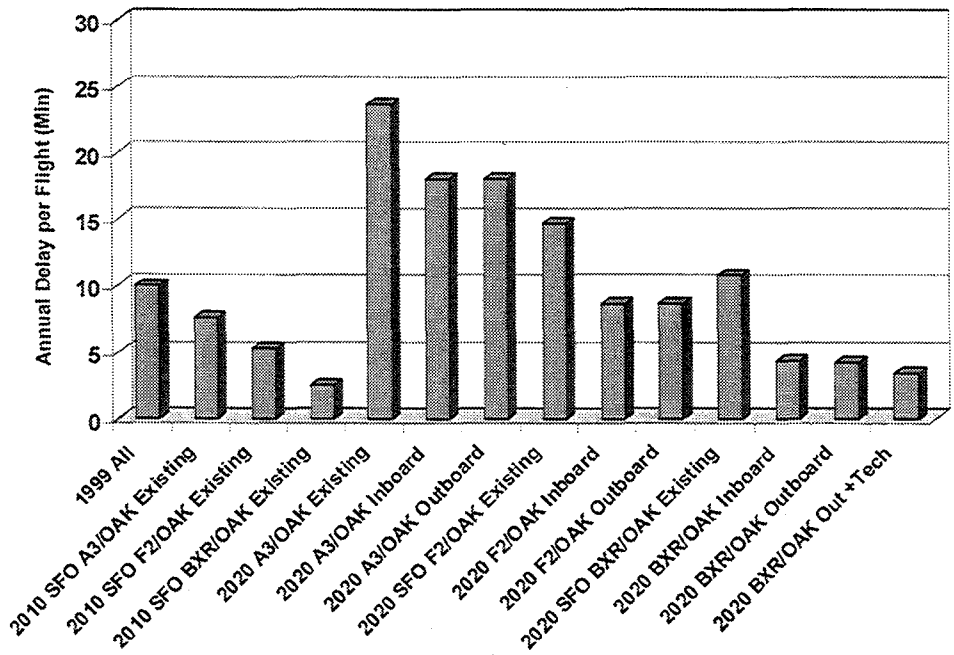


Figure 6-8 Bay Area Airports – Average Delay By Runway Configuration Alternative

7.1 FAA DELAY DATA FOR 1997 AND 1998

Nationally, the FAA reports that around 70 percent of recorded delays are due to bad weather and the resulting degradation in airport system capacity. Another 20 percent of delays are related to high traffic volumes at and around airports[1]. Some delays are caused by conditions at a specific airport while other delays are caused by systemwide Air Traffic Control conditions or by the airlines themselves (e.g., late crew, baggage, or other carrier-related activity). Any discussion of delay statistics is hampered by the acknowledged fact that there is currently no system in place that accurately tracks both the causes and amount of delay in a uniform manner. Thus, the simple question of what causes delay does not have a simple answer.

The FAA's Consolidated Operations and Delay Analysis System (CODAS) provides the most detailed information. It counts delays on every flight, no matter how small and includes the difference between an aircraft's actual arrival time and the arrival time listed in the airlines' computer reservation system. It also divides delays into "where caused" and "where taken", meaning which airport caused the delay and at which airport the delay was taken, usually in the form of an ATC imposed groundhold. CODAS was used to estimate various statistics for arrival delay, departure delay, and average flow control (ground hold) delay per flight[2].

Delay data was developed for 1997 and 1998. California was hard hit by El Niño storms in 1998, and SFO experienced extremely high delays, reflecting the airport's reduced runway capacity when aircraft are required to operate under instrument flight rules. The year 1997 was a relatively good weather year and is also included in the CODAS database. As would be expected, the incidence of delay and the measures showing delay performance were significantly better in 1997. While SFO did experience less delay in 1997, the high average (mean) delay of 14 minutes was still significant and close to the worst in the country, exceeded only by Newark at 16 minutes of average delay and Atlanta with an average of 15 minutes. From the CODAS data, it is also apparent that neither OAK nor SJC currently experience significant delay problems.

[1] Based on flights delayed 15 minutes or more.

[2] Flow control is an FAA procedure to restrict departures at the origin airport until there is an assured arrival slot at the destination airport.

Table 7-1
Delays at Bay Area Airports

	SFO		OAK		SJC	
	1997	1998	1997	1998	1997	1998
Arrivals						
Mean	14 min. (5th worst)	21 min. (worst)		11 min.		11 min.
Median	10 min.	15 min.		9 min.		10 min.
Mode	7 min. (14 days)	8 min. (29 days)		8 min.		8 min.
No. of Days Average Delay >40 min.	11 days	64 days				
Flow Control Delay[4]	112 days (worst)	182 days (worst)				
Departures						
Mean	13 min.	19 min.		12 min.		10 min.
Median	12 min.	15 min.		10 min.		9 min.
Mode	10 min.	12 min.		9 min.		8-9 min.

Source: FAA CODAS database

Mean: Average delay

Median: Half of delays greater than value shown and half less

Mode: Amount of delay most frequently occurring and number of days (in parentheses) this delay occurred

(worst, 2nd worst): Refers to rank among other major US airports

Notes: Arrival delay includes delay caused by the destination airport (e.g., SFO), plus any delays due to problems at the origin airport.

Flow control delay is the number of days SFO caused delays in flights leaving other airports for SFO.

[4] Number of days flow control imposed on aircraft arriving at SFO.

ARTC C	Air Route Traffic Control Center.
DME	Distance Measuring Equipment (DME) is another electronic NAVAID. It provides distance information to pilots.
NDB	Nondirectional Radio Beacons (NDB). NDB are simply radio transmitters that indicate a particular location in space. Unlike VORs, they do not provide heading information. NDBs assist in navigation and are sometimes used for instrument approaches.
Radia	Radials are lines with specific headings extending from a VOR or VORTAC. Two such lines from two nearby navaids can define an intersection point.
TRAC ON	Terminal Radar Approach Control
VOR	Very High Frequency Omni Directional Range (VOR) is an electronic NAVAID that provides directional information to pilots.
VORT AC	A VORTAC is a combination of a VOR and a Tactical Air Navigation system (TACAN). It also provides distance information to pilots.

Regional Airport System Plan

Update 2000

Regional Overflight Noise Trends

Regional Airport System Plan
Update 2000

Regional Overflight Noise Trends

Prepared for the
Regional Airport Planning Committee

Prepared by the
Metropolitan Transportation Commission

June 2000
Revised, August 2000

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Glossary

Chapter 1 – Introduction

Noise is unwanted sound that can disturb daily activity both indoors and outdoors. Aircraft noise is loudest near airport runways but also can be noticeable at higher altitudes as aircraft enter and leave the Bay Area airspace. Aircraft noise has been addressed both through technological advances in aircraft engines and through development of aircraft routes and flight procedures that minimize, to the extent possible, impacts on communities surrounding the airports.

As of January 1, 2000 all aircraft in the airline fleet now meet the most stringent "Stage 3" noise criteria or have received an exemption from FAA for special circumstances. This is a significant milestone for the nation and local communities (for comparison, in 1991, 93% of the SFO airline fleet met Stage 3 requirements). The International Civil Aviation Organization (ICAO) is taking the lead in developing a new aircraft noise standard for future aircraft fleets.

Since any new aircraft designs are several years away, policy makers began to discuss the idea of phasing out the loudest of the Stage 3 aircraft (mainly "hush kitted" aircraft), and thereby creating a "Stage 3 ½" noise standard. "Stage 4," on the other hand, refers to a future phase-in of new aircraft with increased noise reduction stemming from new aircraft design and/or technology. More recently the term "Stage 3 ½" has disappeared, and the phase-out of hush kitted aircraft is now being included in the discussion of the Stage 4 noise standard.

ICAO's Committee on Aviation Environmental Protection (CAEP) is responsible for developing a Stage 4 noise standard. The CAEP will convene in January 2001, at which time working groups within the Committee will develop final recommendations for the Stage 4 noise standard, as well as a Stage 3 phase-out schedule. Stage 4 noise levels could become effective with applications for new type certificates filed starting in 2003. Stage 3 aircraft would probably not be phased out until 2020. Additionally, the quietest Stage 3 aircraft would probably meet any new Stage 4 standards.

<u>Local Airport Noise</u>

Aircraft noise in communities near airports is regulated by California State Noise Standards (Code of Regulations, Title 21). These standards are administered by the State Division of Aeronautics, and airports that cannot meet the standards operate under a "variance". Airport noise is measured in terms of Community Noise Equivalent Levels, and the permissible level is 65 CNEL based on a number of noise studies around airports.

New runways have the potential to lower noise in communities by providing additional distance between homes and aircraft landing and taking off and/or by increasing the availability of runways for take offs and landings over water. At SFO, one of the benefits associated with lengthening Runway 1/19 would be the ability for some of the heavier, long haul flights to takeoff over the Bay instead of through the San Bruno Gap to the Pacific Ocean. Lengthening Runway 1/19 would increase the distance between aircraft starting their takeoff roll and homes behind Runway 1, which experience low frequency

"back blast" noise. A new parallel Runway 28R located 0 .7 miles to the north would provide some noise relief for Peninsula communities along the immediate edge of the Bay.

At OAK, a new outboard runway in the Bay would also shift some flight operations further from the shore. Conversely, a new "inboard" runway would bring aircraft arrivals or departures further inland, increasing noise for some communities. Expanded use of the North Field for general aviation and airline operations, a configuration currently under study as well, could significantly increase noise over homes on either end of the runway (a 1976 Settlement Agreement between the Port of Oakland and the city of Alameda limits commercial and general aviation aircraft takeoffs on the North Field).

Both SFO and OAK will need to prepare detailed noise studies of the different runway options before such projects could advance. The RASP noise assessment focuses more attention on the issue of overflight noise as discussed below.

Overflight Noise

Overflight noise is a different type of noise, generated by aircraft at higher altitudes, and farther away from the main airport runways. Communities receiving over flight noise are under established arrival and departure tracks designed a number of years ago for the safe and efficient routing of aircraft into and out of the Bay Area airspace. Overflight noise, like the issue of Bay fill, has arrived at the center of public discussion concerning existing and future impacts of air traffic growth in the Bay Area.

Air routes are currently defined by navigational aids located on the ground that direct aircraft to certain points in space for final sequencing to and from the airport runways. At the present time, these navigational aids are fixed, but in the future aircraft routes may be defined in reference to coordinates established by global positioning satellites. Such a "redesign" of the airspace could address both airspace efficiency and noise issues, but because it is based on the introduction of new technology, it could also take a number of years to implement.

Unlike close in airport noise, which is measured by acceptable CNEL levels, there is no metric for overflight noise provided in law. The FAA analyzes a level of 60 CNEL when it proposes revisions to flight procedures, but often complaints are not correlated to this criterion. A single loud, low altitude aircraft or multiple higher altitude aircraft events may trigger noise complaints. It is also clear that individuals react differently to overflight noise levels, and that more people are expressing concerns than in the past.

Chapter 2 – Methodology

The RASP noise analysis involves a review of projected aircraft activity on various flight trac :s used for aircraft arrivals and departures at all three Bay Area airports. The location of tl e flight tracks on the ground can be generally correlated with the potential for noise in d fferent Bay Area communities, recognizing that the aircraft do not precisely fly these trac :s and that they are at different altitudes depending on distance from the airport. We hav(not attempted to translate the forecasted changes in flight track activity into con(lusions about the acceptability of these changes to persons on the ground.

The efore, the methodology used is one of translating our earlier forecasts of aircraft take)ffs and landings at each airport into operations on individual flight tracks.

- \ircraft operations (takeoffs and landings) have been forecasted from each Bay Area ıirport to each domestic and international city served from that airport. The forecasts ılso contain our assumptions about the type of aircraft that will be used on these 'outes.
- ;uture aircraft flights have also been "scheduled", meaning aircraft arrival and leparture times are based on passenger preferences to different time zones, as well as he need for certain airlines to meet "banks" of connecting flights at their major hubs. Thus, the flight schedules are intended to be as realistic as possible.
- Jse of airport arrival and departure routes is largely determined by the)rigin/destination of the flight. Projected changes in flight track activity are a product)f the overall growth in air traffic at an airport to existing destinations already served ıt the airport as well as the effect of flights to new cities which are assumed to eceive service in the future (see Appendix A for new cities assumed to be served by :ach airport).
- 'light track activity is projected for on an average day in August, the peak month in erms of commercial aircraft operations in the Bay Area (This activity level is also ısed for the airport runway and airspace capacity analysis). August aircraft)perations therefore represent a higher level of operations than would be experienced)n a more typical "average day" of the year, and than would be used in airport noise stimation models which are used to prepare sound contours (lines on a map showing he level of noise in communities around airports).
- 'light track use projections were prepared for two weather patterns, called "West 'lan" (winds from the west) and "Southeast Plan "(winds from the Southeast). The lirection of aircraft takeoffs and landings shifts significantly for these different wind onditions. Southeast plan operations are experienced much less frequently than Vest Plan operations (only 5% of the time at SFO).

This analysis provides an estimate of future conditions based on a plausible set of assu nptions about air service and traffic growth at each airport. It is important to reme mber that forecasting aircraft use of specific flight tracks over extended periods of time (e.g. 10 or 20 years into the future) has a considerable amount of uncertainty

attached to such a forecast because of the multiple assumptions that enter into such a calculation.

Chapter 3 – Results

The forecasts results are summarized for three factors that would affect overflight noise:

1) Mix of aircraft types in the future at each airport,
2) Time of day of flights, and
3) Distribution of flights by flight track at each airport.

Aircraft Fleet Mix at Each Airport

The term "fleet mix" refers to the mixture of types of aircraft using an airport or a specific flight track. This mix in turn is based on the flight destinations (passenger and cargo) from each airport and the types of aircraft airlines would likely use to serve these destinations. Different aircraft types can have markedly different noise "footprints" (area exposed to specific levels of noise) around airports based on their weight, engine design, and flight profile. These differences are most noticeable close to the airport and less noticeable at higher altitudes because of lower engine power settings (compared to take off and landing) and greater noise attenuation due to the height of the aircraft above the ground. The recent transition to all Stage 3 aircraft would have some effect on jet noise at higher altitudes (typically 4,000 to 15,000 feet for overflight areas), but air temperature, cloud level (which can reflect sound back to the ground), and height of terrain (which changes the distance between people and aircraft) would also be significant factors in the amount of noise received on the ground. Aircraft that are descending to land and are operating at lower altitudes with wing flaps down and engine power up are generally the most noticeable of the overflight events.

Assuming there is a connection, although somewhat weak and imprecise, between aircraft size/weight and overflight noise, we can provide the projected aircraft fleet mix both by airport and by flight track (see Figure 1). As can be seen, both OAK and SJC aircraft mixes are dominated by smaller aircraft in the B737/MD-80 category, whereas, SFO has a significant proportion of larger aircraft, including the B747-B777 series and the older, wide body DC10's and L1011s. OAK's larger aircraft are used almost exclusively in air cargo service and fly primarily at night or early mornings.

Fleet mix can also be disaggregated by flight track as shown in the example tables in Appendix B-2.

Aircraft Operations by Time of Day

California state noise standards recognize that noise is more intrusive in certain hours of the day compared to others. Noise in the evenings (defined as 7 p.m. to 10 p.m.) and late night (defined as 10 p.m. to 7a.m.) is "weighted" more heavily in analyzing community noise. The same can be said of overflight noise; therefore, we have identified projected changes in the distribution of flights among the three different time periods (the third is the daytime, defined as 7 a.m. to 7 p.m.). Overall, we do not forecast significant shifts in the share of activity between these three time periods as shown by Figure 2. In terms of

absolute numbers, SFO had the largest projected increase in daily flights in the late night period (85) and SJC has the lowest (35).

It is also possible to forecast the use of individual flight tracks by time of day as illustrated in Appendix B-1.

Projected Flight Track Activity by Airport

Due to the complexity of the Bay Area's airspace, the traffic routes have been designed and refined over the years to accommodate all the required flows into and out of the Bay Area airports which need to occur in a relatively confined (by aircraft flight standards) airspace. For each airport, there are assigned flight tracks for aircraft arriving and departing to the north, east, south, and west. For example, eastbound departures from SFO's Runway 1 fly over the Bay and directly over the Oakland Airport. Arrivals from the east come in over San Jose and turn right onto final to Runways 28 L and 28R.

We have also estimated flight track use for West Plan and Southeast Plan traffic flows for each airport and for arrivals and departures (Again, readers are cautioned to take these detailed estimates with a "grain of salt" based on our comments above).

- Figures 3 to 6 show projected West Plan flight track activity for departures
- Figures 7 to 10 show projected West Plan flight track activity for arrivals
- Appendix C contains a summary of Southeast Plan activity

The flight track forecasts for each airport are discussed in more detail below for the West Plan, since this is the predominant weather/runway system used. Figures 4 to 10 show the general location of the flight tracks. Figures 11 and 12 provide the forecasted change in number of operations on each major flight track as well as the forecasted percentage change. The communities over flown by aircraft on the various flight tracks are referenced in the notes to Figures 3 and 7.

- Metropolitan Oakland International. Jet departures from OAK are metered to intermix with SFO departures on key routes. Currently, the majority of the departures (54%) are to the South and turn left over San Francisco. Because of the assumed addition of new point-to-point airline service over the planning horizon (Appendix A), the largest growth in departures is projected be to the east. These flights would climb out and turn right over the East Bay hills before splitting into two eastbound routes – over Sacramento and Lindin. Southbound departures will not grow as fast as flights to the east, due to the maturing California corridor market. Thus, the projected increase in number of flights to the east between 1999 and 2020 (91) will exceed the projected increase in flights to the south and north (82) for this same time period. Aircraft arrivals from the south (over Fremont/Newark) and east (over Sunol) will continue to be the dominant arrival pattern with a share that is similar to today (80% of flights). Arrivals from the north come in over Sausalito and Richmond and will continue to account for about 20%, of the flights as they do today.

- San Francisco International. The most heavily used departure flight tracks today will continue to be the most heavily used in the future. The departure track with the highest number of flights in 2020 would be to south with departures from Runway 1 climbing out with a left turn over San Francisco (265 daily flights in 2020). A similar number of departures (264) would take place to the east over Oakland (which later splits into two routes--Sacramento and Linden routes). Long haul flights through the San Bruno Gap would just about double between 1999 and 2020, from 38 to 72. Departures to the Pacific Northwest and Canada would result in a 50% increase in flights headed north over the Bay and towards Red Bluff. The biggest increase in arriving flights between 1999 and 2020 is projected to be from the north (88) arriving over Marin County, followed by flights from the south arriving over the South Bay (58).

- San Jose International. SJC departures in 2020 will be split just about equally between departures to the south (right turn towards Gilroy after departure) and east (full clockwise turn over the airport then north over the Pleasanton/Danville). SJC will also have a small number of oceanic flights that continue west after departure over Palo Alto. The share of arriving flights from the north will increase from 14% to 24% between 1999 and 2020, but the number of flights from the south and east will far exceed those from the north in 2020 (269 versus 86).

Potential Flight Track Changes with SFO Runway Reconfiguration.

The SFO flight track projections assume that the runway system is operated in the same manner as today. Other changes are being considered which could affect usage of SFO runways and flight tracks (no decisions have been made about these possible changes).

- There could be fewer international and domestic long haul flights taking off through the San Bruno Gap (Oceanic departures), as these aircraft could use the lengthened Runway 1. There could be increased use of the flight track up the Bay towards Red Bluff by flights to Asia and the east.
- There could be fewer aircraft arriving SFO from the north over Point Reyes as these aircraft could be assigned to the CEDES route from the east which would be split into two parallel tracks.
- Aircraft arriving from the north over the Peninsula could be at higher altitudes than today and the left turn onto the final approach course to Runway 28 may be shifted further towards the South Bay.
- Aircraft arriving from the north directed over the mid-Bay could be turned on to final approach to Runways 28 further to the south over the East Bay.

These changes would be developed after further consultation and airspace review by the airports, FAA, and public.

Figure 1
AIRCRAFT FLEET MIX BY AIRPORT
(Average Daily Takeoffs and Landings for Peak Month)

SAN JOSE AIRPORT

	1999		2010		2020	
Regional Jet/Commuter	22	5%	14	3%	64	9%
727's	16	3%	12	2%	8	1%
737's/MD 80	312	66%	354	66%	414	58%
747's	0	0%	6	1%	6	1%
757's	32	7%	14	3%	18	3%
767's	0	0%	18	3%	28	4%
777's	1	0%	4	1%	16	2%
Airbus	17	4%	52	10%	92	13%
DC-8's	6	1%	2	0%	0	0%
Wide Body	0	0%	2	0%	6	1%
GA Piston/Turboprop	36	8%	0	0%	0	0%
GA/Bus Jet	31	7%	61	11%	61	9%
TOTAL	**473**	**100%**	**539**	**100%**	**713**	**100%**

OAKLAND INTERNATIONAL AIRPORT

	1999		2010		2020	
Regional Jet/Commuter	12	2%	14	2%	12	1%
727's	37	7%	8	1%	0	0%
737's/MD 80	319	58%	430	61%	537	60%
747's	5	1%	10	1%	17	2%
757's	13	2%	22	3%	13	1%
767's	15	3%	16	2%	26	3%
777's	0	0%	4	1%	6	1%
Airbus	20	4%	76	11%	134	15%
DC-8's	11	2%	0	0%	0	0%
Wide Body	26	5%	20	3%	44	5%
GA Piston/Turboprop	49	9%	57	8%	61	7%
GA/Bus Jet	41	7%	43	6%	43	5%
TOTAL	**548**	**100%**	**700**	**100%**	**893**	**100%**

SAN FRANCISCO INTERNATIONAL AIRPORT

	1999		2010		2020	
Regional Jet/Commuter	208	17%	252	18%	292	18%
727's	32	3%	12	1%	2	0%
737's/MD 80	461	37%	320	23%	254	16%
747's	86	7%	83	6%	101	6%
757's	163	13%	38	3%	42	3%
767's	68	5%	94	7%	88	5%
777's	11	1%	70	5%	122	7%
Airbus	95	8%	428	31%	630	39%
DC-8's	3	0%	0	0%	0	0%
Wide Body	53	4%	8	1%	20	1%
New Large Aircraft	0	0%	0	0%	10	1%
GA Piston/Turboprop	14	1%	0	0%	0	0%
GA/Bus Jet	47	4%	73	5%	73	4%
TOTAL	**1,241**	**100%**	**1,378**	**100%**	**1,634**	**100%**
GRAND TOTAL	**2,262**		**2,617**		**3,240**	

Figure 2
AIRCRAFT OPERATIONS BY TIME OF DAY
(Average Day of Peak Month)

San Francisco International Airport

Total Operations (Takeoffs and Landings)

	1999		2010		2020	
	Totals	Percent	Totals	Percent	Totals	Percent
Day (7 AM to 7 PM)	879	71%	957	69%	1,149	70%
Evening (7 PM to 10 PM)	194	16%	212	15%	232	14%
Night (10 PM to 7 AM)	168	14%	209	15%	253	15%
	1,241	100%	1,378	100%	1,634	100%

Oakland International Airport

Total Operations (Takeoffs and Landings)

	1999		2010		2020	
	Totals	Percent	Totals	Percent	Totals	Percent
Day (7 AM to 7 PM)	326	59%	431	62%	554	62%
Evening (7 PM to 10 PM)	77	14%	94	13%	118	13%
Night (10 PM to 7 AM)	145	26%	175	25%	221	25%
	548	100%	700	100%	893	100%

San Jose Airport

Total Operations (Takeoffs and Landings)

	1999		2010		2020	
	Totals	Percent	Totals	Percent	Totals	Percent
Day (7 AM to 7 PM)	337	71%	388	72%	519	73%
Evening (7 PM to 10 PM)	88	19%	94	17%	111	16%
Night (10 PM to 7 AM)	48	10%	57	11%	83	12%
	473	100%	539	100%	713	100%

Figure 3

WEST PLAN

Departing Flights by Ground Tracks
(Percentage Use by Flight Track)

OAKLAND – South Field

	1999		2010		2020	
South (1)	164	54%	184	48%	220	46%
East (2)	108	35%	153	40%	199	41%
North (3)	34	11%	46	12%	60	13%
All Departing Flights	306	100%	383	100%	479	100%

1) Climb from 29, left turn over San Francisco, then SKY 3 Standard Instrument Departure (SID)
2) Climb from 29, right turn over Richmond, OAK 5 SID. Later track splits towards SAC and LIN
3) Climb from 29, straight towards Skaggs Island, then towards RBL (Red Bluff) or ILA (Williams)

SAN FRANCISCO

	1999		2010		2020	
East from Rwy 1 (1)	229	37%	220	32%	264	32%
East from Rwy 28 (2)	37	6%	49	7%	61	7%
Oceanic (3)	38	6%	50	7%	72	9%
South (4)	211	35%	239	35%	265	33%
Pacific and NW (5)	100	16%	127	19%	151	19%
All Departing Flights	615	100%	685	100%	813	100%

1) Climb straight from 1L/1R over Oakland, then SFO 8 SID. Later track splits towards SAC and LIN
2) Climb from 28R, right turn over the Bay and Richmond. SFO 8 SID. Later splits towards SAC and LIN
3) Climb from 28R, left turn over South San Francisco towards Oceanic routes. GAP 3 SID.
4) Climb from 1L/1R, left turn over San Francisco, the head south along coast. PORTE 3 SID.
5) Climb from 1L/1R, left over the Bay towards RBL. SFO 8 SID

SAN JOSE

	1999		2010		2020	
East (1)	143	56%	127	47%	172	48%
South (2)	111	43%	140	52%	175	49%
Oceanic (3)	1	1%	4	1%	11	3%
All Departing Flights	255	100%	271	100%	358	100%

1) Full clockwise 360 over San Jose from 30L, north over Pleasanton and Danville. Loupe 9 LIN / SAC SID.
2) Climb from 30L, right turn towards Gilroy and south. SJC 8 MOONY SID.
3) Right turn over San Jose from 30L then west over OSI and Palo Alto towards Oceanic routes.

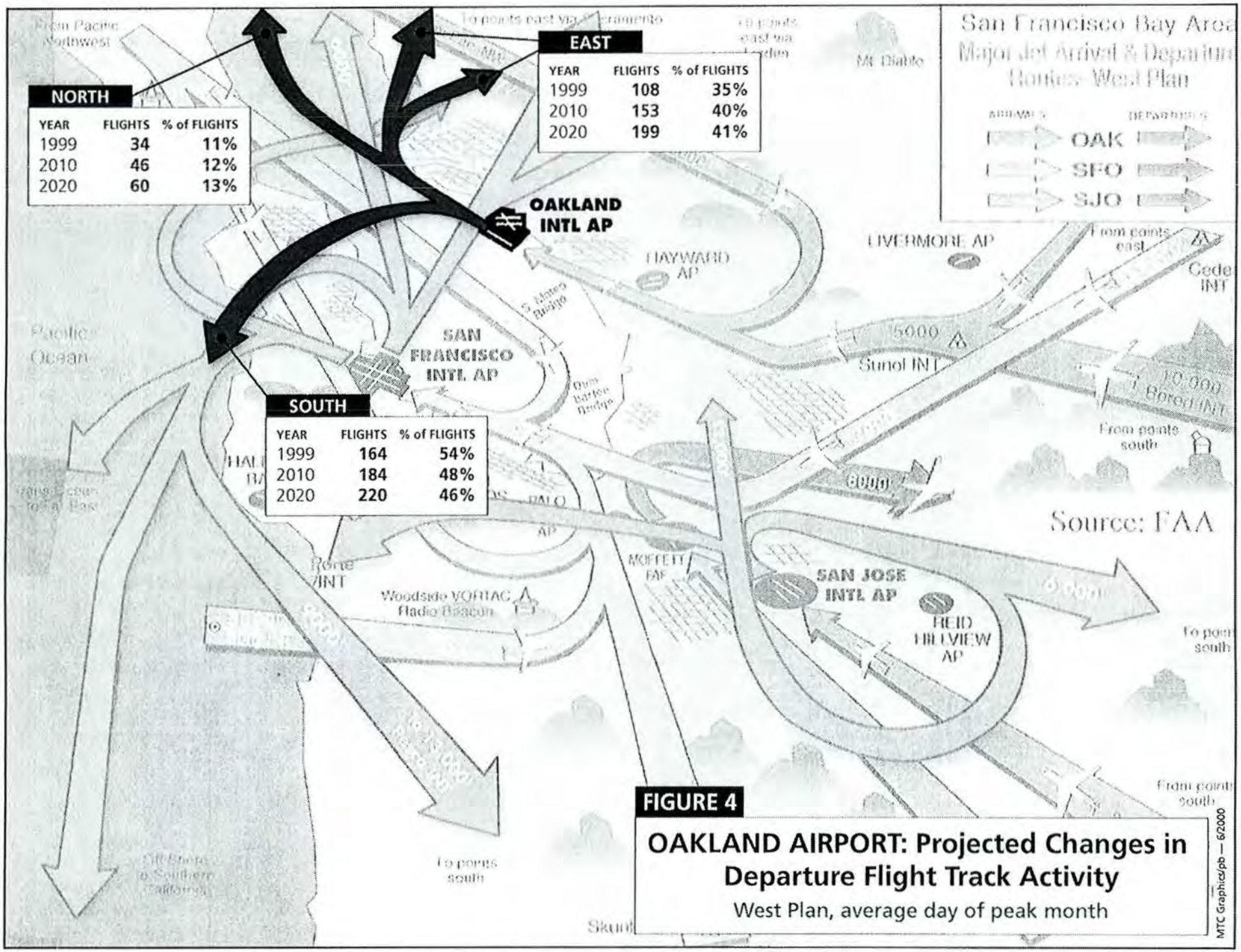


FIGURE 4

OAKLAND AIRPORT: Projected Changes in Departure Flight Track Activity

West Plan, average day of peak month

MTC Graphics/pb — 6/2000

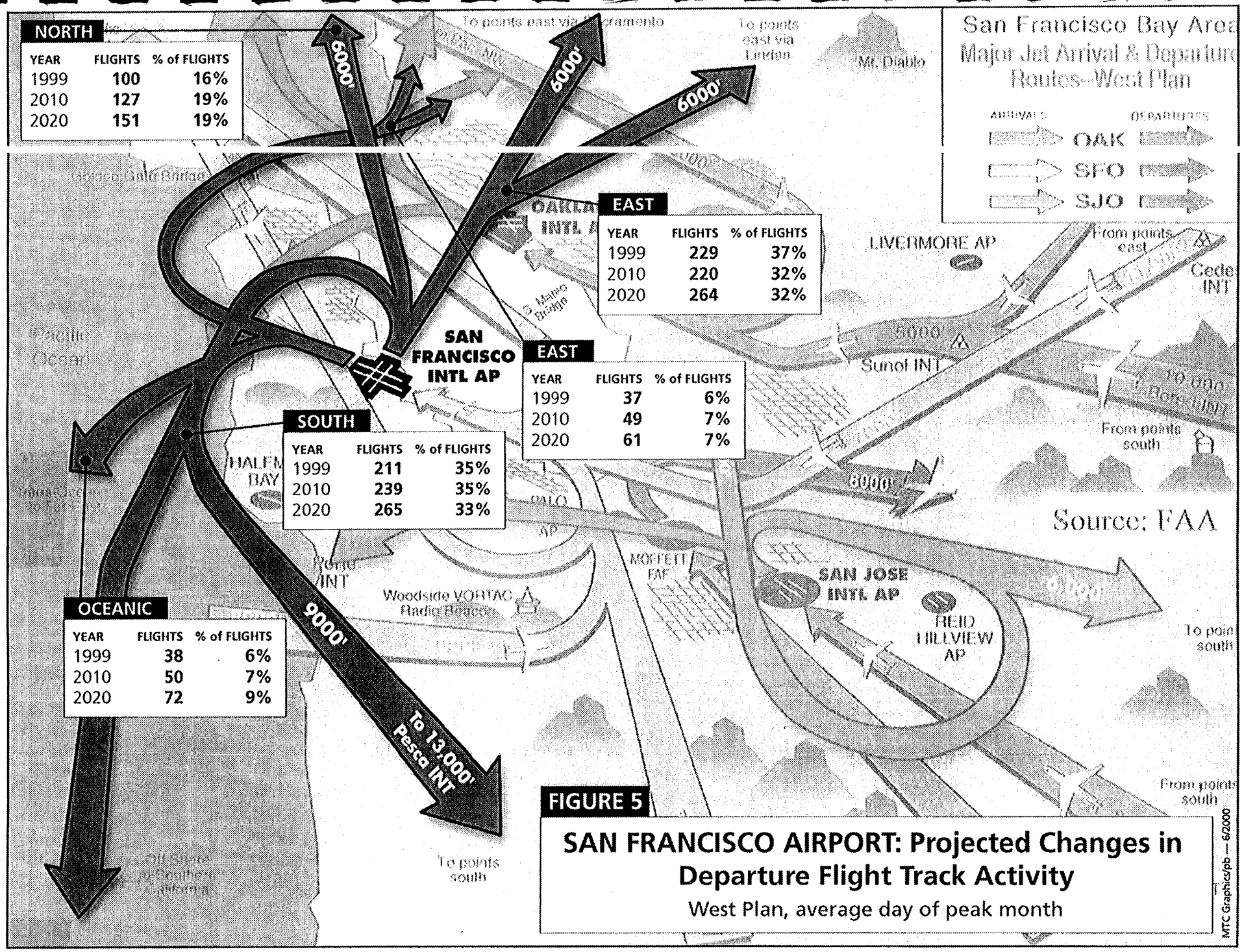


FIGURE 5

SAN FRANCISCO AIRPORT: Projected Changes in Departure Flight Track Activity

West Plan, average day of peak month

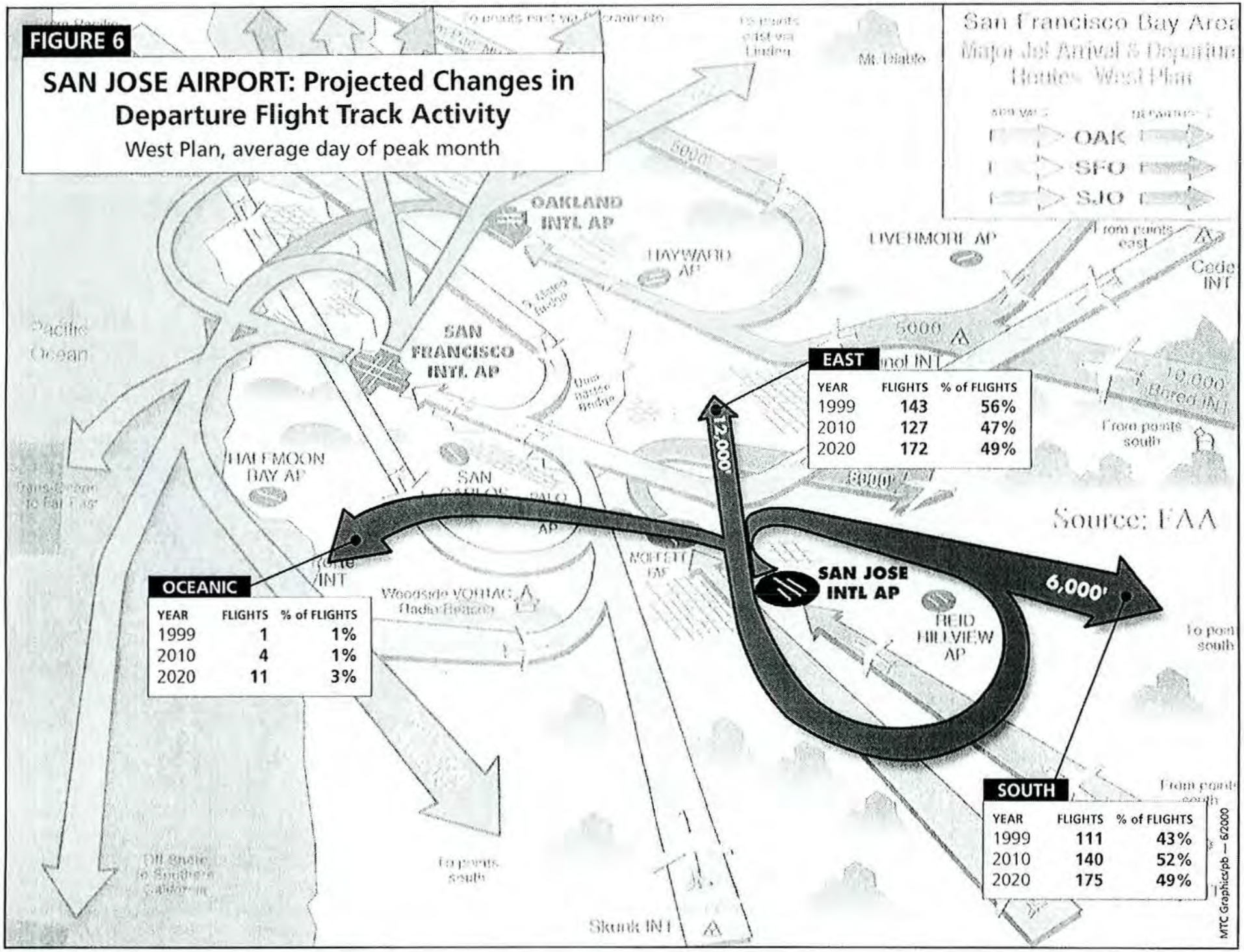


FIGURE 6
SAN JOSE AIRPORT: Projected Changes in Departure Flight Track Activity
West Plan, average day of peak month
San Francisco Bay Area
OAK
SFO
SJO
OAKLAND INTL AP
HAYWARD AP
LIVERMORE AP
SAN FRANCISCO INTL AP
HALFMOON BAY AP
SAN JOSE INTL AP
REID HILLVIEW AP
Pacific Ocean
Mt. Diablo
Source: FAA
EAST
YEAR FLIGHTS % of FLIGHTS
1999 143 56%
2010 127 47%
2020 172 49%
OCEANIC
YEAR FLIGHTS % of FLIGHTS
1999 1 1%
2010 4 1%
2020 11 3%
SOUTH
YEAR FLIGHTS % of FLIGHTS
1999 111 43%
2010 140 52%
2020 175 49%
12,000'
6,000'
MTC Graphics/pb — 6/2000

Figure 7

WEST PLAN

Arriving Flights by Ground Tracks

OAKLAND – South Field

	1999		2010		2020	
North (1)	45	19%	60	19%	81	20%
South/East (2)	197	81%	257	81%	333	80%
All Arriving Flights	242	100%	317	100%	414	100%

(1) Descend over Richmond, follow ContraCosta Range down wind and left turn over Hayward on to 29
(2) Descend over SUNOL and Fremont, right turn over Hayward on to final for 29

SAN FRANCISCO

	1999		2010		2020	
East (1)	247	39%	216	31%	260	31%
South (2)	212	34%	244	35%	270	33%
Oceanic (3)	34	5%	45	7%	70	9%
North (4)	133	22%	188	27%	221	27%
All Arriving Flights	626	100%	693	100%	821	100%

(1) Descend over CEDES, then right turn over SJC on to final for 28L and 28R.
(2) Descend over SKUNK, left turn over Palo Alto on to final for 28L and 28R.
(3) Descend over BRINY, left turn over Woodside VOR on to final for 28L and 28R.
(4) Descend over Point Reyes to Sausalito, down wind along mid-Bay, right on to final for 28L and 28R.

SAN JOSE

	1999		2010		2020	
North (1)	30	14%	61	23%	86	24%
South and East (2)	188	86%	207	77%	269	76%
All Arriving Flights	218	100%	268	100%	355	100%

(1) Descend over PYE and SFO, over JDOWNS and turn left on to final for 30L.
(2) Descend over GILRO from East and South, over San Jose, straight on final for 30L

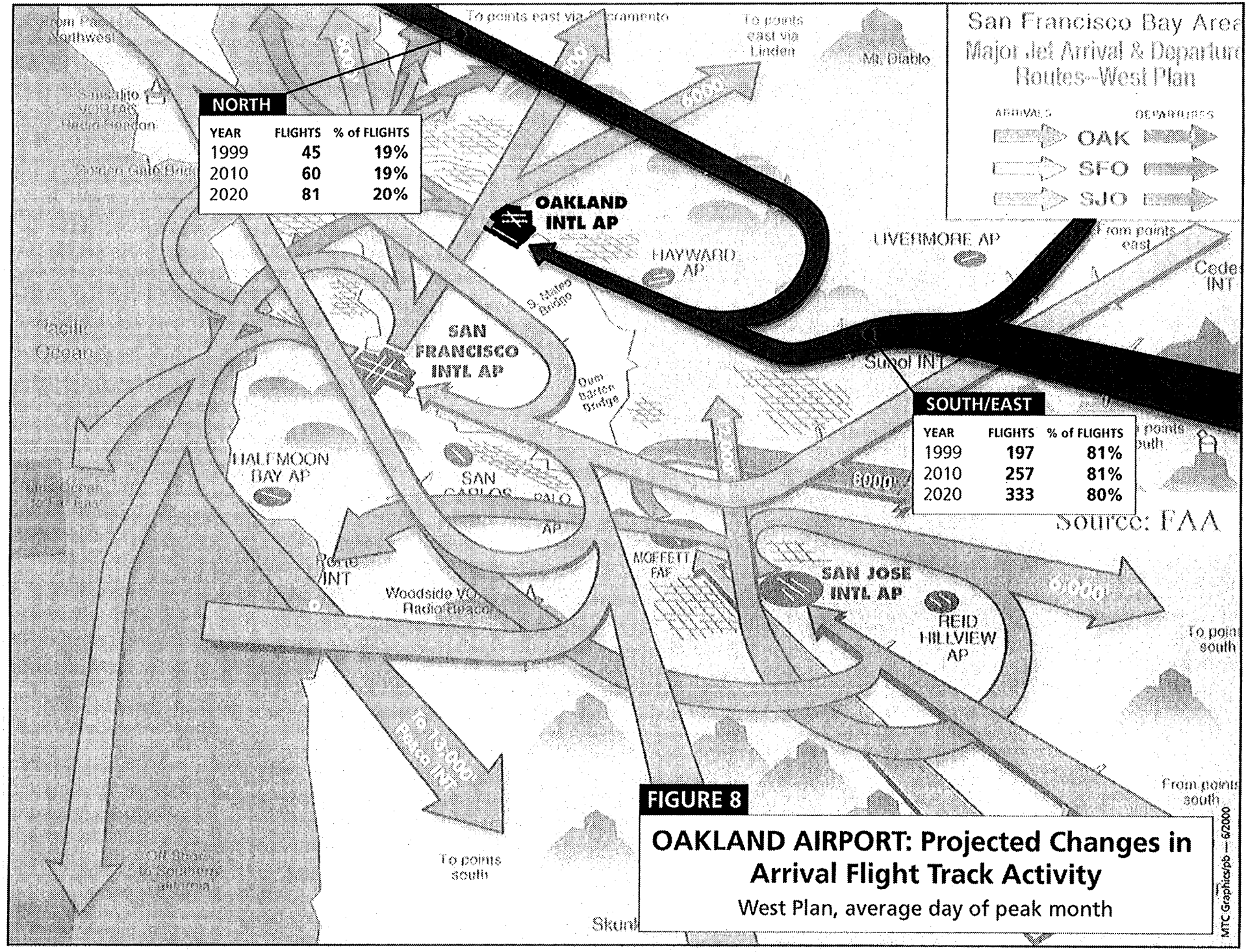


FIGURE 8

OAKLAND AIRPORT: Projected Changes in Arrival Flight Track Activity

West Plan, average day of peak month

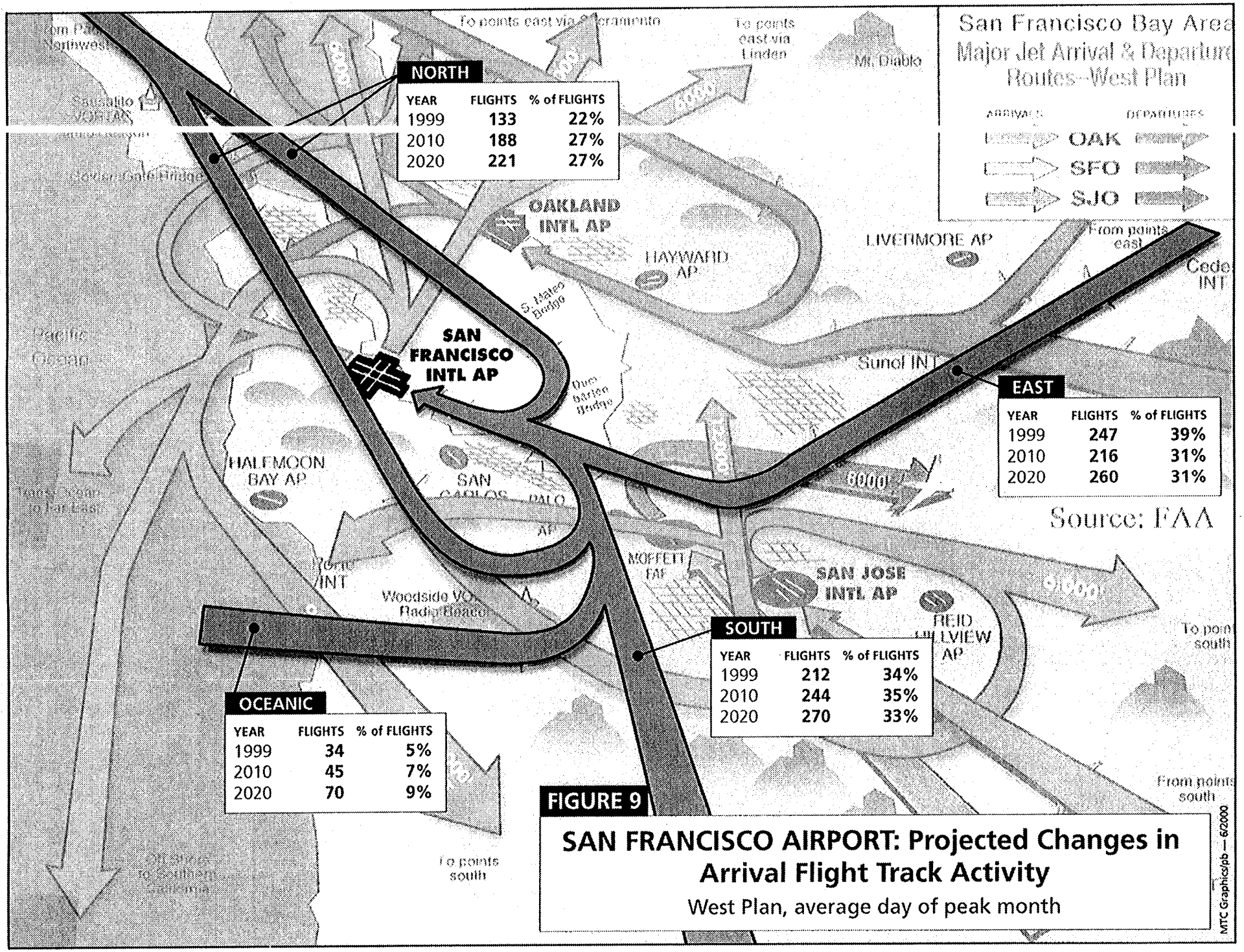


FIGURE 9

SAN FRANCISCO AIRPORT: Projected Changes in Arrival Flight Track Activity

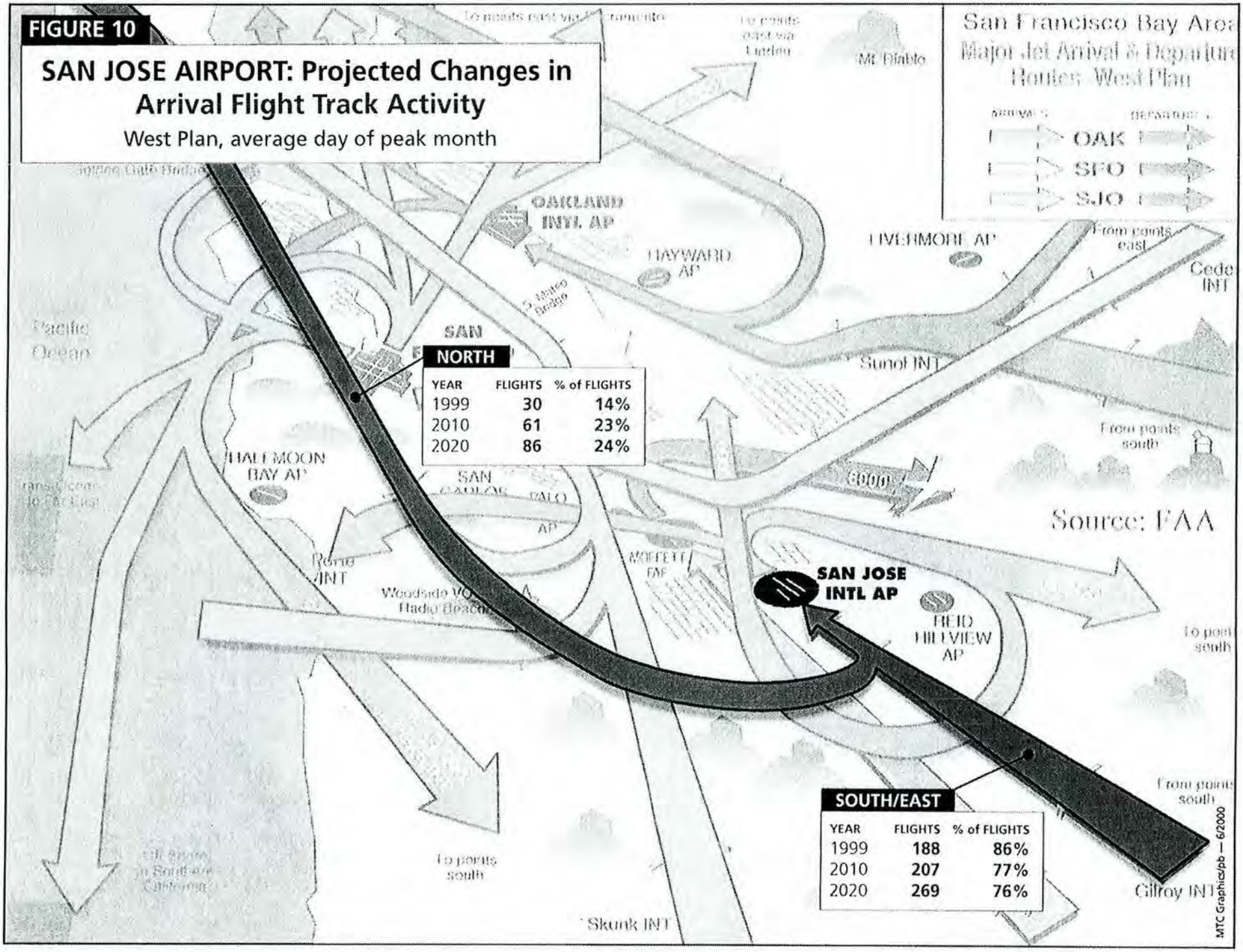
West Plan, average day of peak month

MTC Graphics/pb — 6/2000

FIGURE 10

SAN JOSE AIRPORT: Projected Changes in Arrival Flight Track Activity

West Plan, average day of peak month



NORTH

YEAR	FLIGHTS	% of FLIGHTS
1999	30	14%
2010	61	23%
2020	86	24%

SOUTH/EAST

YEAR	FLIGHTS	% of FLIGHTS
1999	188	86%
2010	207	77%
2020	269	76%

Figure 11
PERCENTAGE INCREASE IN FLIGHT TRACK USE
West Plan Departures

OAKLANI) - South Field

	1999	2010	2020	Change: 1999-2010		Change: 1999-2020	
South (1)	164	184	220	20	(12%)	56	(34%)
East (2)	108	153	199	45	(42%)	91	(84%)
North (3)	34	46	60	12	(35%)	26	(76%)
All Departir g Flights	306	383	479	77	(25%)	173	(57%)

(1) Climb fron 29, left turn over San Francisco, then SKY 3 Standard Instrument Departure (SID)

(2) Climb fron 29, right turn over Richmond, OAK 5 SID. Later track splits towards SAC and LIN

(3) Climb fron 29, straight towards Skaggs Island, then towards RBL (Red Bluff) or ILA (Williams)

SAN FRA NCISCO

	1999	2010	2020	Change: 1999-2010		Change: 1999-2020	
East from F wy 1 (1)	229	220	264	-9	-(4%)	35	(15%)
East from F wy 28 (2)	37	49	61	12	(32%)	24	(65%)
Oceanic (3)	38	50	72	12	(32%)	34	(89%)
South (4)	211	239	265	28	(13%)	54	(26%)
Pacific and NW (5)	100	127	151	27	(27%)	51	(51%)
All Departi g Flights	615	685	813	70	(11%)	198	(32%)

(1) Climb str ight from 1L/1R over Oakland, then SFO 8 SID. Later track splits towards SAC and LIN

(2) Climb fro 28R, right turn over the Bay and Richmond. SFO 8 SID. Later splits towards SAC and LIN

(3) Climb fro 28R, left turn over South San Francisco towards Oceanic routes. GAP 3 SID.

(4) Climb fro 1L/1R, left turn over San Francisco, then head south along coast. PORTE 3 SID.

(5) Climb fro 1L/1R, left over the Bay towards RBL (Red Bluff). SFO 8 SID.

SAN JOS E

	1999	2010	2020	Change: 1999-2010		Change: 1999-2020	
East (1)	143	127	172	-16	-(11%)	29	(20%)
South (2)	111	140	175	29	(26%)	64	(58%)
Oceanic (3	1	4	11	3	(300%)	10	(1000%)
All Departi ng Flights	255	271	358	16	(6%)	103	(40%)

(1) Full cloc wise 360 turn over San Jose from 30L, north over Pleasanton and Danville. Loupe 9 LIN/SAC SID.

(2) Climb fro n 30L, right turn towards Gilroy and south. SJC 8 MOONY SID.

(3) Left turn over San Jose from 30L then west over OSI and Palo Alto towards Oceanic routes.

Figure 12
PERCENTAGE INCREASE IN FLIGHT TRACK USE
West Plan Arrivals

OAKLAND - South Field

	1999	2010	2020	Change: 1999-2010		Change: 1999-2020	
North (1)	45	60	81	15	(33%)	36	(80%)
South/East (2)	197	257	333	60	(30%)	136	(69%)
All Arriving Flights	242	317	414	75	(31%)	172	(71%)

(1) Descend over Richmond, follow Contra Costa Range down wind and right turn over Hayward onto 29

(2) Descend over SUNOL and Fremont, right turn over Hayward onto final for 29

SAN FRANCISCO

	1999	2010	2020	Change: 1999-2010		Change: 1999-2020	
East (1)	247	216	260	-31	-(13%)	13	(5%)
South (2)	212	244	270	32	(15%)	58	(27%)
Oceanic (3)	34	45	70	11	(32%)	36	(106%)
North Bay (4)	133	188	221	55	(41%)	88	(66%)
All Arriving Flights	626	693	821	67	(11%)	195	(31%)

(1) Descend over CEDES, then right turn over SJC onto final for 28L and 28R.

(2) Descend over SKUNK, left turn over Palo Alto onto final for 28L and 28R.

(3) Descend over BRINY, left turn over Woodside VOR onto final for 28L and 28R.

(4) Descend over Point Reyes to Sausalito, down wind along mid-Bay turn right onto final for 28L and 28R.

SAN JOSE

	1999	2010	2020	Change: 1999-2010		Change: 1999-2020	
North (1)	30	61	86	31	(103%)	56	(187%)
South and East (2)	188	207	269	19	(10%)	81	(43%)
All Arriving Flights	218	268	355	50	(23%)	137	(63%)

(1) Descend over PYE and SFO, over JDOWNS and turn left on to final for 30L.

(2) Descend over GILRO from East and South, over San Jose, straight on final for 30L.

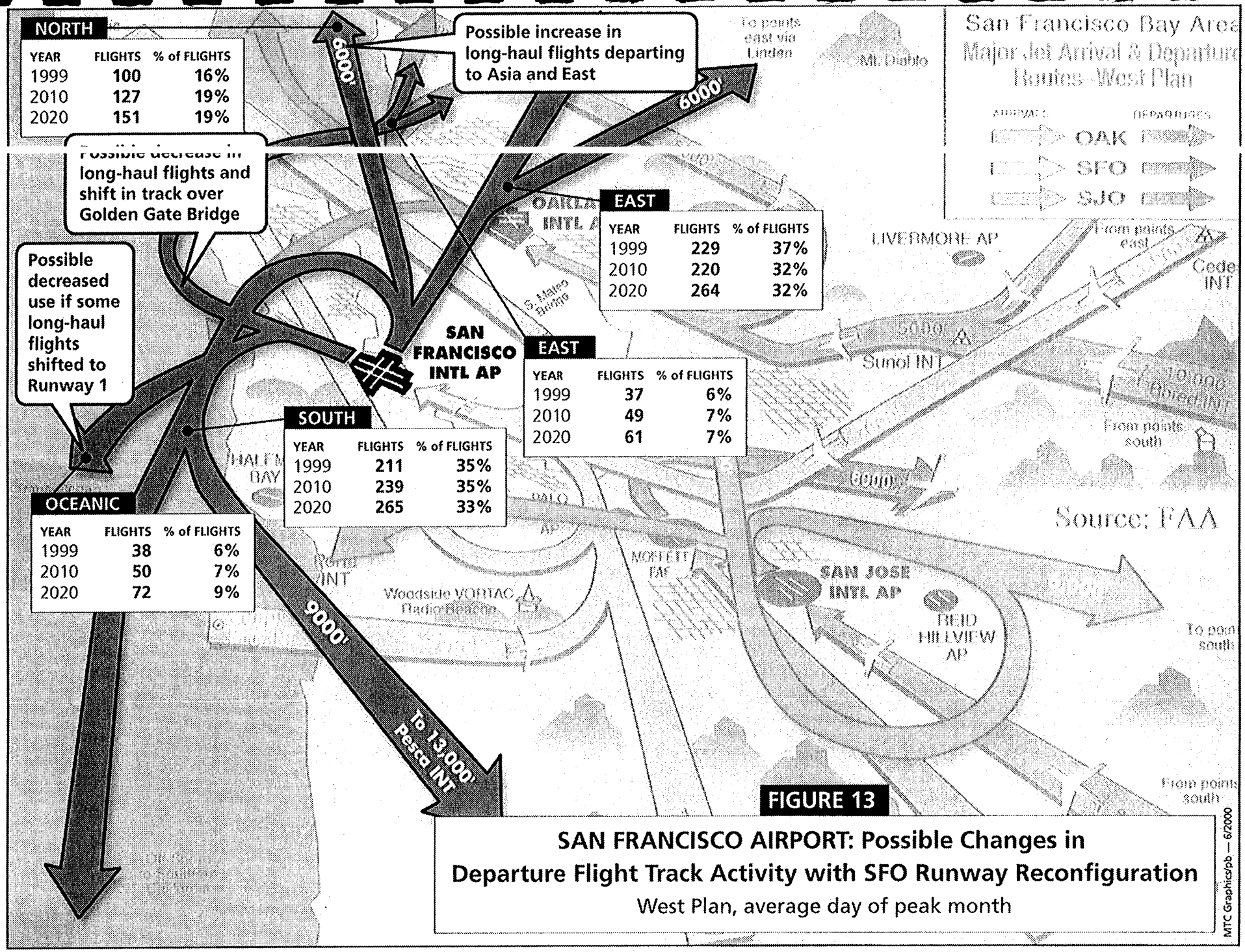


FIGURE 13

SAN FRANCISCO AIRPORT: Possible Changes in Departure Flight Track Activity with SFO Runway Reconfiguration

West Plan, average day of peak month

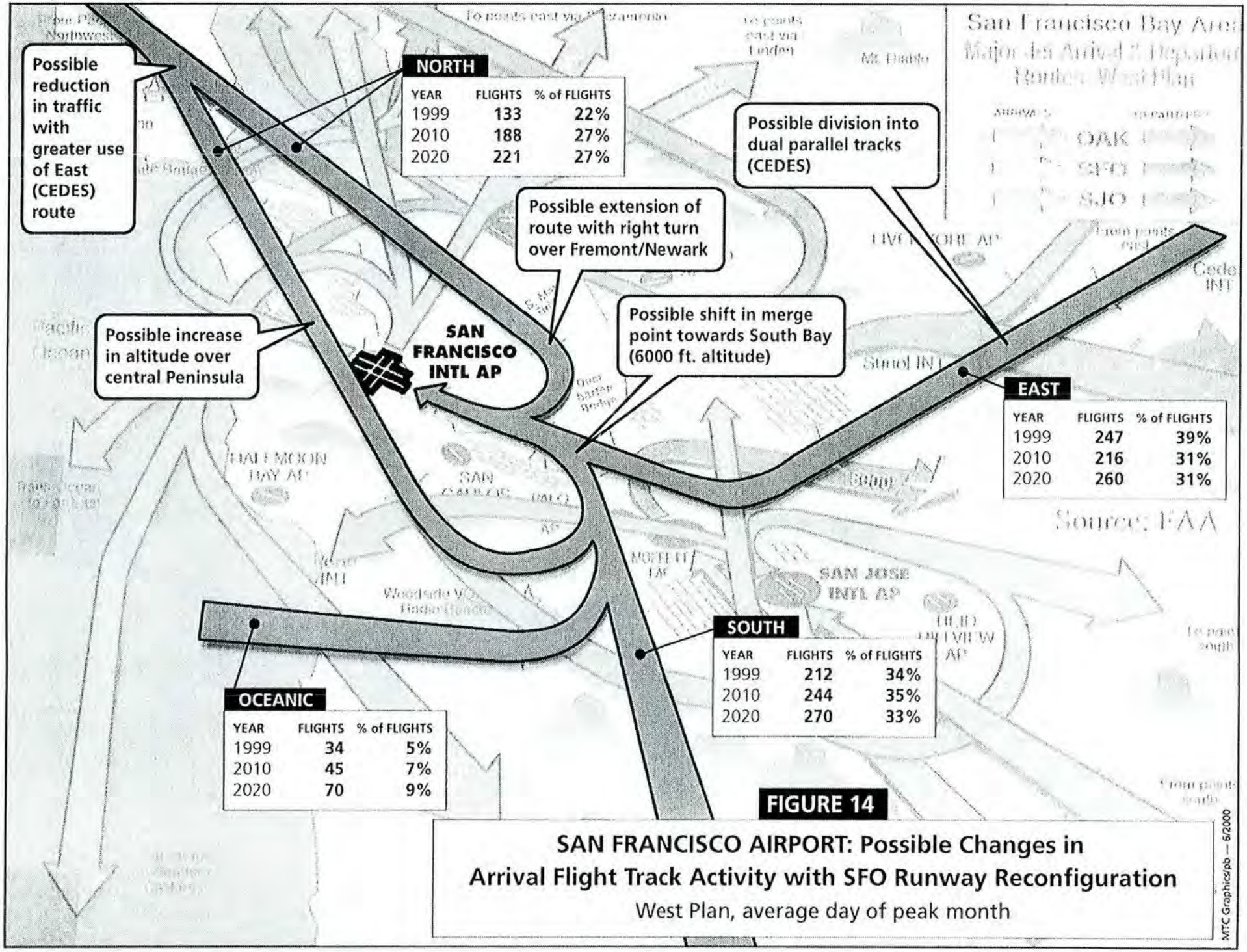


FIGURE 14

SAN FRANCISCO AIRPORT: Possible Changes in Arrival Flight Track Activity with SFO Runway Reconfiguration

West Plan, average day of peak month

Appendices

APPENDIX A
POTENTIAL NEW NONSTOP SERVICE IN 2020

DOMESTIC		INTERNATIONAL	
SAI I FR/ .NCISCO			
Milw ıukee		Nagoya	Monterey
Indiz ıapolis		Melbourne	Cancun
Tam ›a		Auckland	Montreal
Ancl orage		Singapore	Manchester
Colu nbus		Bangkok	Madrid
		Guatemala	Dublin
			Brussels
OA! ‹LAND			
Albu ¡uerque			
St. L ›uis	Fort Lauderdale	London	
Birm ngham	Indianapolis	Amsterdam	
San ∧ntonio	Houston	Paris	
Okla ıoma City	Boston	Cancun	
Bois ı	Eugene	Puerto Vallarta	
Balti nore	Detroit	Cabo San Lucas	
Orla do	Jacksonville	Vancouver	
New Orleans	New York		
Minr ɜapolis	Atlanta		
	Raleigh-Durham		
	Buffalo		
SAI I JOSE			
Sacı ımento			
Fres ıo		London	
Was ıington		Paris	
New York City		Cancun	
Detr it		Puerto Vallarta	
Rale gh		Cabo San Lucas	
Pitts ›urgh		Vancouver	
Phil: delphia		Mexico City	
Orla do		Frankfurt	
Hon lulu		Osaka	
Eug ne		Seoul	
Spol ane		Taipei	

Note New services represent a plausible set of routes based on known carrier strategies. Actual future city pairs could vary, but specific city identities aside, the number of new routes is indicative of the growing mar et potential for each airport.

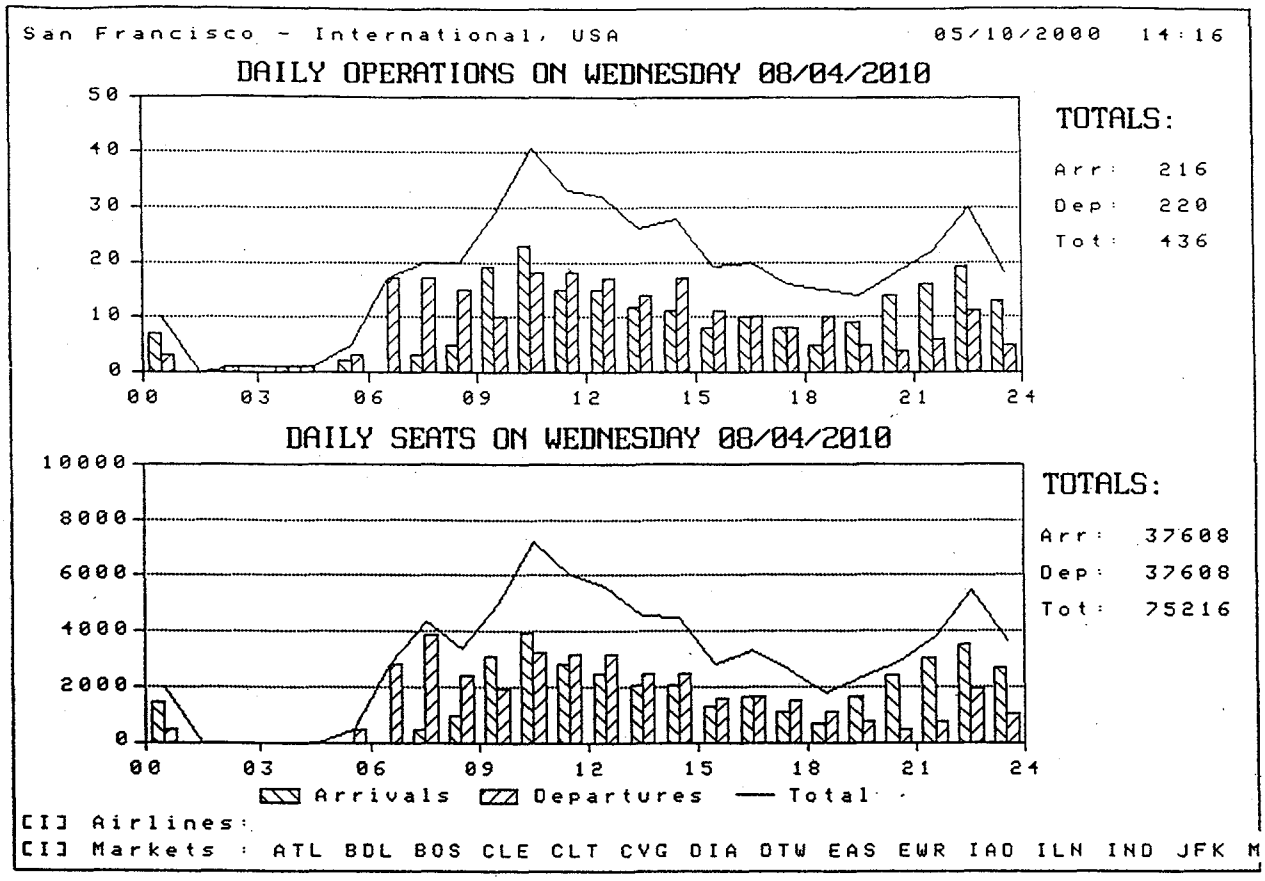
Appendix B

Example of Data for One Flight Track
San Francisco 2010 West Plan

Departures on
Oakland Track
(Straight Over Oakland from 1L/1R)

SFO 8 SAC
SFO 8 LIN

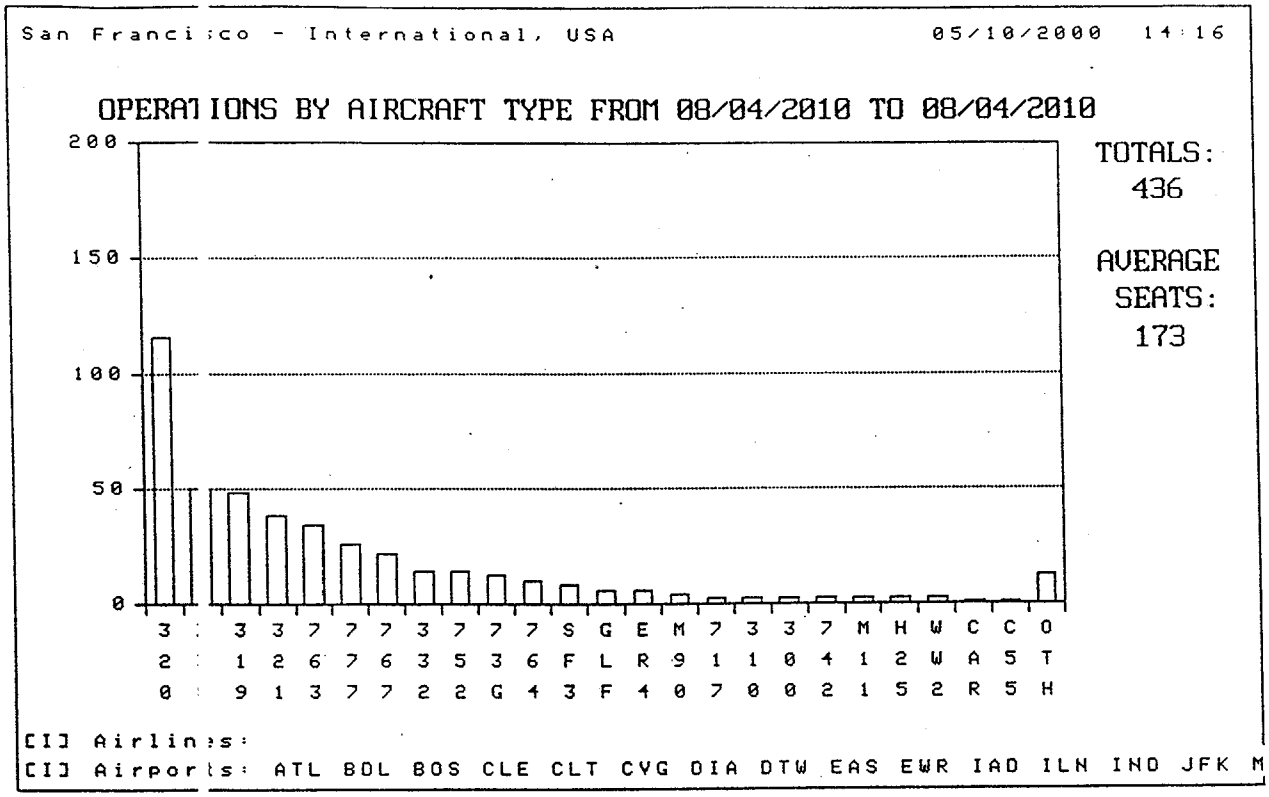
Appendix B-1
Flight Track Use by Hour of One Day



HOURLY SUMMARY OF SEATS/PASSENGERS AND OPERATIONS

Time	Operations and percentages Departures		Seats and percentages Departures	
00-01	3	1.4%	516	1.4%
01-02	0	0.0%	0	0.0%
02-03	0	0.0%	0	0.0%
03-04	1	0.5%	0	0.0%
04-05	0	0.0%	0	0.0%
05-06	3	1.4%	500	1.3%
06-07	17	7.7%	2811	7.5%
07-08	17	7.7%	3913	10.4%
08-09	15	6.8%	2431	6.5%
09-10	10	4.5%	1923	5.1%
10-11	18	8.2%	3272	8.7%
11-12	18	8.2%	3181	8.5%
12-13	17	7.7%	3167	8.4%
13-14	14	6.4%	2520	6.7%
14-15	17	7.7%	2505	6.7%
15-16	11	5.0%	1568	4.2%
16-17	10	4.5%	1647	4.4%
17-18	8	3.6%	1525	4.1%
18-19	10	4.5%	1077	2.9%
19-20	5	2.3%	747	2.0%
20-21	4	1.8%	500	1.3%
21-22	6	2.7%	784	2.1%
22-23	11	5.0%	1964	5.2%
23-24	5	2.3%	1057	2.8%

Appendix B-2
Fleet Mix on Flight Track

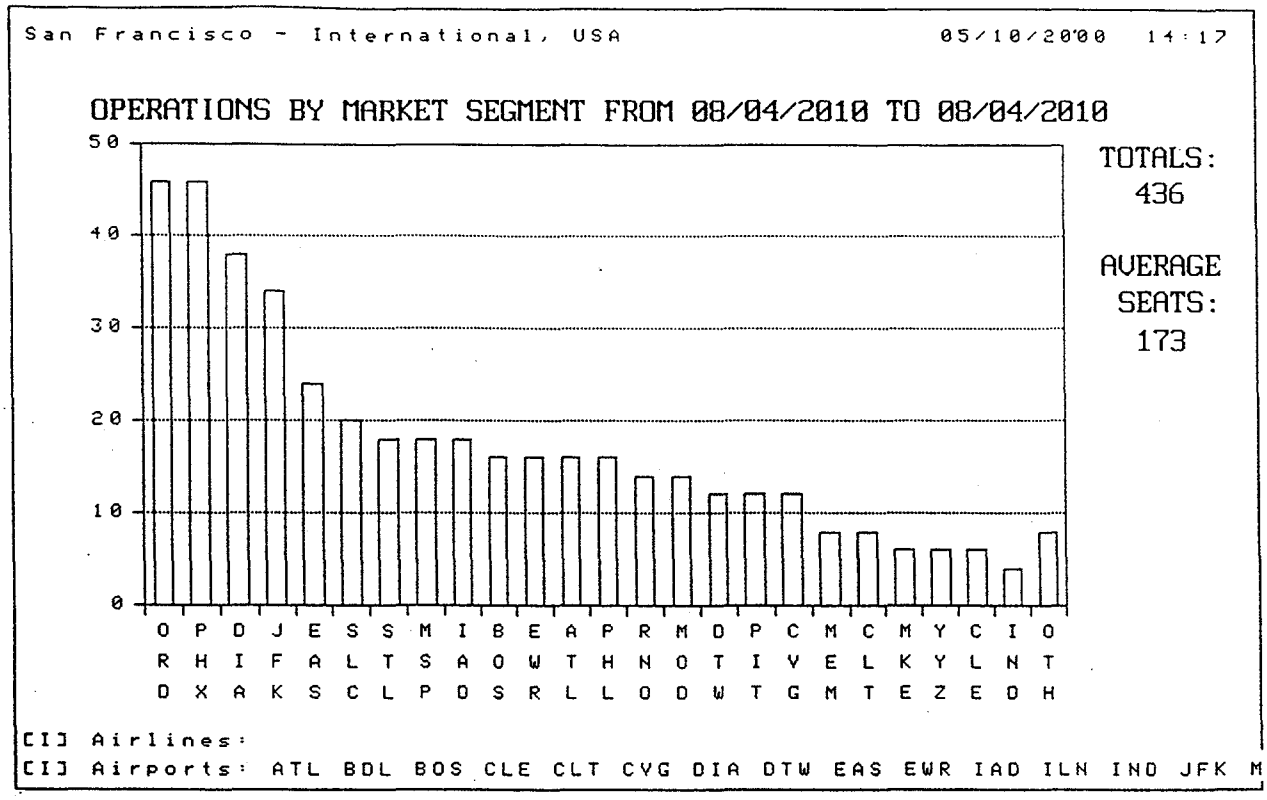


OPERATIONS BY AIRCRAFT TYPE FROM 08/04/2010 TO 08/04/2010

Type	Seats	Pa	Pct	Ops	Pct	Type	Seats	Pax	Pct	Ops	Pct	Type	Seats	Pax	Pct	Ops	Pct
300	0			2	0.5%	764	280			10	2.3%	GLF	0			6	1.4%
310	0			2	0.5%	767	250			22	5.0%	H25	0			2	0.5%
319	150			48	11.0%	777	350			26	6.0%	L29	0			1	0.2%
320	157			116	26.6%	AST	0			1	0.2%	LJ2	0			1	0.2%
321	159			38	8.7%	B74	0			1	0.2%	LJ5	0			1	0.2%
332	330			14	3.2%	BE4	0			1	0.2%	LJ6	0			1	0.2%
717	106			2	0.5%	C55	0			1	0.2%	LR3	0			1	0.2%
738	162			50	11.5%	C65	0			1	0.2%	M11	0			2	0.5%
73G	126			12	2.8%	CAR	0			1	0.2%	M90	152			4	0.9%
742	0			2	0.5%	ER4	45			6	1.4%	MU3	0			1	0.2%
752	200			14	3.2%	F90	0			1	0.2%	SF3	30			8	1.8%
763	235			34	7.8%	FA5	0			1	0.2%	WW2	0			2	0.5%

Total Ops: 43(Total Seats: 75216 Total Pax: 0

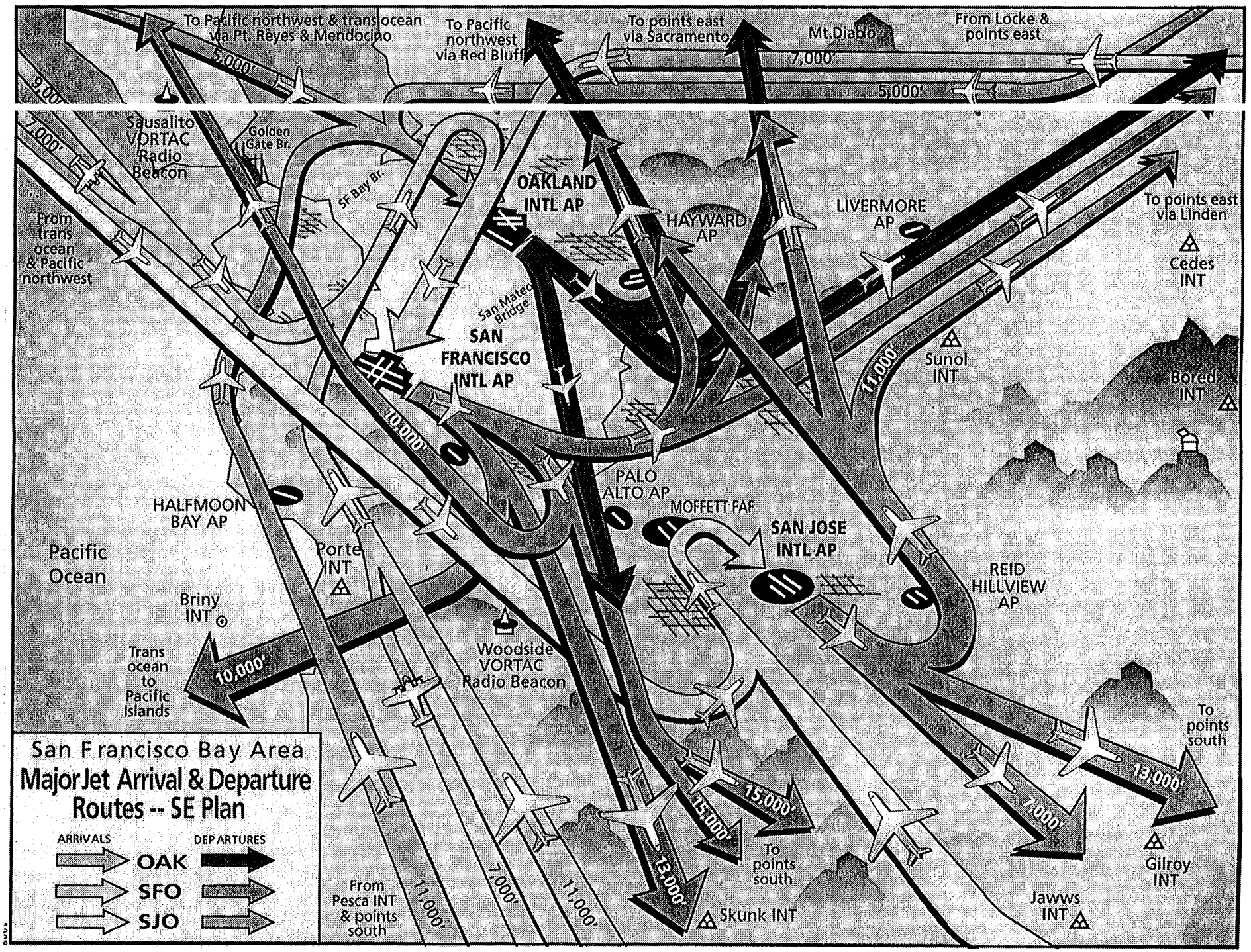
Appendix B-3
City Destinations on Flight Track



OPERATIONS BY MARKET SEGMENT FROM 08/04/2010 TO 08/04/2010

City	Ops	Pct	City	Ops	Pct	City	Ops	Pct	City	Ops	Pct	City	Ops	Pct
ATL	16	3.7%	DIA	38	8.7%	IND	4	0.9%	MSY	2	0.5%	SLC	20	4.6%
BDL	2	0.5%	DTW	12	2.8%	JFK	34	7.8%	ORD	46	10.6%	STL	18	4.1%
BOS	16	3.7%	EAS	24	5.5%	MEM	8	1.8%	PHL	16	3.7%	TPA	2	0.5%
CLE	6	1.4%	EWR	16	3.7%	MKE	6	1.4%	PHX	46	10.6%	YYZ	6	1.4%
CLT	8	1.8%	IAD	18	4.1%	MOD	14	3.2%	PIT	12	2.8%			
CVG	12	2.8%	ILN	2	0.5%	MSP	18	4.1%	RNO	14	3.2%			

Total Ops: 436 Total Seats: 75216 Total Pax: 0


San Francisco Bay Area
MajorJet Arrival & Departure Routes -- SE Plan
ARRIVALS
DEPARTURES
OAK
SFO
SJO
To Pacific northwest & trans ocean via Pt. Reyes & Mendocino
To Pacific northwest via Red Bluff
To points east via Sacramento
Mt.Diablo
From Locke & points east
5,000'
7,000'
5,000'
9,000'
7,000'
Sausalito VORTAC Radio Beacon
Golden Gate Br.
SF Bay Br.
OAKLAND INTL AP
HAYWARD AP
LIVERMORE AP
To points east via Linden
Cedes INT
From trans ocean & Pacific northwest
San Mateo Bridge
SAN FRANCISCO INTL AP
11,000'
Sunol INT
Bored INT
10,000'
PALO ALTO AP
MOFFETT FAF
SAN JOSE INTL AP
HALFMOON BAY AP
Pacific Ocean
Porte INT
REID HILLVIEW AP
Briny INT
Woodside VORTAC Radio Beacon
Trans ocean to Pacific Islands
10,000'
To points south
13,000'
15,000'
15,000'
7,000'
13,000'
To points south
Gilroy INT
Jawws INT
Skunk INT
From Pesca INT & points south
11,000'
7,000'
11,000'

Appendix C - 1
SOUTHEAST PLAN

Departing Flights by Ground Tracks
(Percentage Use by Flight Track)

OAKLAND – South Field

	1999		2010		2020	
South (1)	145	47%	176	46%	213	45%
East via Linden(2)	95	31%	126	33%	164	34%
East via Sacramento (3)	15	5%	13	3%	14	3%
North (4)	51	17%	68	18%	88	18%
All Departing Flights	306	100%	383	100%	479	100%

(1) Climb from 11, left turn over San Jose, then SKYLINE 3 Standard Instrument Departure (SID)
(2) Climb from 11, left turn over Fremont, then over Livermore and Marina Four SID over LIN
(3) Climb from 11, left towards Mt Diablo and Sacramento. Marina Four over FMG SID
(4) Climb from 11, left towards Concord and Pacific NW. SCD SID

SAN FRANCISCO

	1999		2010		2020	
West-Oceanic (1)	15	2%	17	3%	19	2%
North-Transocean (2)	121	20%	151	22%	193	24%
North (3)	19	3%	31	5%	44	5%
South (4)	238	39%	229	33%	257	32%
East via Linden (5)	194	31%	229	33%	272	34%
East and NW (6)	28	5%	28	4%	28	3%
All Departing Flights	615	100%	685	100%	813	100%

(1) Climb from 10L/10R, right over Palo Alto, then Gap 3 towards Oceanic tracks
(2) Climb from 10L/10R, right over Palo Alto and then over Golden Gate to Pacific NW and transocean.
(3) Climb from 10L/10R, left turn over Fremont, then Dumbarton Six ILA SID.
(4) Climb from 10L/10R, straight over San Jose, and then head south along coast. Luvve Two SID.
(5) Climb from 10L/10R, left over Livermore, then east. Dumbarton Six LIN SID
(6) Climb from 10L/10R, left over Fremont towards SAC. Dumbarton Sic SID

SAN JOSE

	1999		2010		2020	
South (1)	110	43%	137	51%	169	47%
East via Linden (2)	104	41%	65	24%	84	23%
East via Sacramento (3)	12	5%	12	4%	16	5%
Pacific NW, Europe (4)	29	11%	57	21%	89	25%
All Departing Flights	255	100%	271	100%	358	100%

(1) Climb from 12R, straight over Gilroy and South. Moony One SID to AVE.
(2) Climb from 12R, left turn then, right turn over SUNOL and east. Sunol Five SID.
(3) Climb from 12R, left turn then, right turn over Mt Diablo towards SAC. Danville One SID
(4) Climb from 12R, left turn then, straight over Oakland Hills towards North Bay. Danville One SID

APPENDIX C - 2
SOUTHEAST PLAN

Arriving Flights by Ground Tracks
(Percentage Use by Flight Track)

OAKLAND – South Field

	1999		2010		2020	
South (1)	125	52%	155	49%	194	47%
East (2)	73	30%	103	33%	141	34%
North (3)	44	18%	59	18%	79	19%
All Arriving Flights	242	100%	317	100%	414	100%

1) Descend over San Francisco, turn right over Alcatraz to final for 11. Hadly Two STAR
2) Descend over Berkeley, left turn over Bay Bridge to final for 11. Locke One STAR.
3) Descend over Marin and Sausalito, straight in to final for 11.

SAN FRANCISCO

	1999		2010		2020	
East (1)	277	44%	250	36%	297	36%
South (2)	216	35%	254	37%	281	34%
North (3)	133	21%	189	27%	243	30%
All Arriving Flights	626	100%	693	100%	821	100%

(1) Descend over Mt Diablo, then left turn over OAK on to final for 19L and 19R. Locke One STAR
(2) Descend over Porte, right turn over Daly City and OAK on to final for 19L and 19R. Hadly Two STAR
(3) Descend over Stins, left turn over Daly City, right turn over OAK on to final for 19L/19R.

SAN JOSE

	1999		2010		2020	
South and East (1)	180	83%	196	73%	247	70%
North (2)	38	17%	72	27%	108	30%
All Arriving Flights	218	100%	268	100%	355	100%

( ) Descend over GILRO from East and South, over San Jose, right turn on final for 12R. Jawws One STAR
(2) Descend over PYE and SFO, over JDOWNS and turn left on Boldr and right over Moffett to final for 12R.

GLOSSARY

Ba ckblast: Noise generated by jet exhaust or takeoff whose characteristic signature is high acoustic energy and low frequency. Also, high velocity air behind the aircraft engine.

CN EL (Community Noise Equivalent Level): A noise metric required by the California Airport Noise Standards for use by airport proprietors to measure aircraft noise levels. It describes average aircraft noise impacts at an airport and incorporates penalties for operations during the more sensitive evening and night-time hours. This metric is only used in California; the other 49 states use Day/Night noise level (DNL).

dB A: A unit for expressing the relative intensity of sounds (decibels) measured on the 'A' weighted scale; the 'A' weighted scale approximates human hearing.

DN L (Day-night Noise Level): The daily average noise metric in which that noise occurring between 10:00 p.m. and 7:00 a.m. is penalized by 10 times.

Ga p Departure: An aircraft departure via Runways 28 at San Francisco International Airport to the west over San Bruno, South San Francisco, Daly City and Pacifica.

Gr ound Track: The seeming path an aircraft would follow on the ground if its airborne flight path were plotted on the terrain.

Nc ise Contour: A computer-generated line representing a line of equal noise level drawn on a base map.

Si gle Event: Noise generated by a single aircraft overflight.

Regional Airport System Plan

Update 2000

Airport Access Report
August 25, 2000

Regional Airport System Plan
Update 2000

Airport Access Report

Prepared for the
Regional Airport Planning Committee

Prepared by the
Metropolitan Transportation Commission

June 28, 2000
Revised, August 2000

San Francisco Bay Area Airport Access Report

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San Francisco Bay Area
Airport Access Report

1. Introduction

This report focuses on the implications of increasing air passenger and air cargo for the regional ground transportation system (highways and public transit) serving the airports. The aviation forecasts prepared in earlier tasks provide the basic input into the ground transportation analysis. Because the airports are located in heavily traveled transportation corridors, there will be competition on freeways and roads between airport trips and other work and non-work related travel in these corridors. This report addresses a number of the questions regarding airport access. Specifically, it:

- Identifies transportation improvements that are planned or have been proposed that would contribute to improved airport access
- Estimates travel times to the airports in 2010 and 2020 by road and public transit
- Estimates the number of trips by mode of transportation to each airport in the future
- Assesses where the trips are coming from and the timing of these trips by hour of the day
- Estimates the number of airport employee trips to each airport by mode
- Reviews information collected on air cargo truck trips to the airports

To set the stage for this analysis, we begin by describing the various transportation projects that would improve regional and local access to airports and their status. We next outline the connection between the airport demand forecasts and the airport access analysis. Then, we provide our assessment of how air passengers and airport employees will get to the airports in the future, the number of airport access vehicle trips that will be generated, and the implications of these forecasts for the regional transportation network.

2. Planned and Proposed Airport Access Improvements

Airport access improvements include both improvements made on the airport (including public and rental car parking, circulation around the terminal and other areas of the airport, transit facilities, airport people movers, etc.) as well as local and regional transportation improvements (such as to adjacent highways, interchanges, connecting roads and transit). Airport projects can be pursued with airport generated revenues, while local and regional access projects essentially compete with other transportation projects for available funds from federal, state, and local sources. These projects must be coordinated with the county transportation agencies and included in MTC's *Regional Transportation Plan* (RTP) to advance. MTC's plan currently assigns a significant share of the resources for maintenance of the existing transportation system, but MTC has also actively advocated for new funding to expand the transportation system in the face of projected regional growth. This recent planning effort, termed the *Bay Area Transportation Blueprint for the 21st Century*, or "Blueprint" for short, identifies a number of projects that would improve access to OAK, SFO, and SJC from different parts of the region if new funding could be secured.

The projects with the most significant potential to effect future airport access conditions are shown in Figure 1 and described in Table 1. The BART extension to SFO, which will open in 2002, represents a major financial commitment of regional and federal funds to airport access in the Bay Area. New transit connections between the airports and nearby transit systems are in the planning stage at OAK and SJC, and both airports are also pursuing a range of highway and local road access projects. Longer term concepts that have received some attention but have not been fully developed include new ferry services (both passenger and cargo) and off airport terminals for check in and transit service to the airports.

3. Airport Accessibility

Airport accessibility is the proximity of an airport (distance and time) to different parts of the Bay Area where the air passengers are located. Accessibility enters into the airport access discussion in two ways: 1) as a determinant of each airport's passenger "catchment" area (the potential passenger market each airport could serve), and 2) as a factor in the choice of ground transportation modes by air passengers and employees.

As explained in our earlier aviation forecasts report,[1] the airport passenger forecasts were based on three principals:

1) An airport has a natural catchment area which, given equivalent airline service at each airport, will determine the passenger levels that each airport will develop.

2) The share of Bay Area air travel captured by each airport is strongly influenced by the quality/quantity/price of the air service it receives compared to the other airports.

3) The specific services provided at each airport are to a substantial extent functions of the individual carrier route strategies.

Appendix B compares distances and travel times from different cities in the Bay Area to each airport in 2010 and 2020. Forecasted travel times are derived from the MTC travel demand forecast model (which is the basis for most all regional and corridor level transportation studies in the Bay Area). The estimated highway travel times reflect the traffic conditions on the ground transportation network in place for these future years. Travel times to airports on public transit also reflect the transportation system in place in 2010 and 2020 as defined in the RTP. As shown in the tables, there is a significant variation in travel time depending on whether the airport trip is made in the peak commute period or off peak.

4. Origins of Air Passengers to the Airports

As part of the initial forecasting effort, we projected the number of air passengers in each Bay Area county, considering factors such as the trip purpose and city destinations of air passengers in each county and the population and employment growth projected by the Association of Bay Area Governments (ABAG). Air passenger trip information, including the origin of passengers using each airport, has been periodically collected through air passenger surveys conducted at the

[1] San Francisco Bay Area Aviation Demand Forecasts (1998-2020), Roberts Roach and Associates, February 2000

three airports (see below). We also defined likely new city destinations that would be served from each Bay Area airport in the future. Combining the air passenger origin forecasts for each county, the accessibility information, and the projected flight schedules, we arrived at the forecasts shown in Table 2. Table 2 shows the percentage of air passengers from each county that would use each of the three Bay Area airports.

By 2020, Oakland and San Jose airports are projected to claim about 50% of the domestic air passenger market and about 24% of the international air market, which is considerably higher than today. As a result, both OAK and SJC will serve a larger percentage of air passengers in their catchment areas (primarily Alameda and Contra Costa counties and portions of the North Bay for OAK and Santa Clara County and out of region passengers for SJC). For example, the forecasts indicate that only 18% of Alameda and Contra Costa counties' air passengers will need to make a trip across the Bay to SFO. Those that do make this trip will do so because certain air markets will only be served from SFO in the future, which is a reasonable assumption given the fuller menu of services available there.

SJC will primarily serve Santa Clara County air passengers, with over 87% of the local passengers using this airport in 2020, up from 70% today.

SFO's air passenger market will continue be strongly based on passengers from San Francisco and San Mateo counties (about 70% of the airports "local", i.e. non-connecting passengers), but passengers from all over the region will continue to use SFO because there will be some flights that are only available at SFO.

In terms of overall ground access conditions, the projected redistribution of passengers among the three airports due to new airline services will mean more rapidly growing ground access demand at OAK and SJC and proportionately fewer longer distance trips from the East and South Bay to SFO. In fact, both the East Bay and South Bay would show an absolute decrease in vehicle trips to SFO compared to 1998. (For the East Bay, this is also partially due to the effect of the BART extension to SFO.)

5. Air Passenger Trips by Mode of Transportation

We next take a look at the methodology used to forecast the number of trips to each airport by mode of ground transportation. The data underlying this analysis is derived from a survey of air passengers conducted by MTC every five years at San Francisco, Oakland and San Jose International Airports. The most recent survey was conducted in 1995, and the data has been adjusted for 1998 levels of activity at each airport (our base year). Air passengers leaving the Bay Area were asked questions regarding their air trip, including where they left from and how they got to the airport. (The survey response applied to the entire air party if the passenger interviewed was traveling as part of a group. Knowing the number of people in each party, we were able to determine the number of air passengers represented in the survey results).

For the airport access analysis, we divided the county air passengers into a finer zone system, called "super districts" used by MTC for other transportation modeling purposes. We next developed spreadsheets for each airport which combined the number of air passengers projected

by super district with the observed data on ground transportation modes used by passengers from each super district to each airport. Our primary categories for ground transportation modes are:

1. Private car and rental car
2. Door-to door shuttle, taxi or limousine
3. Public transit
4. Private bus (operating on a fixed schedule, like public transit)
5. Hotel shuttle, charter bus and other

We made some adjustments to these existing observed mode choice patterns for future years based primarily on the likely effect of the BART extension to SFO on mode choice. (We previously analyzed this project as part of a federally required study and applied these results to our current forecasts.)

Table 3 presents the summary results of our projections by airport. We have also grouped the results geographically by subregion (Table 4), of which there are five (North Bay, East Bay, Peninsula, South Bay and out of region).

Among the three major airports, there are significant differences in the modes of ground transportation used to get to the airports. For SFO today, about 60% of air passengers drive a personal vehicle or a rental car to the airport, with this percentage decreasing slightly over time. Around a quarter of the passengers take door-to-door shuttles, taxis or limousines. Use of public transit is expected to increase significantly from 2% in 1998 to 6% and 8% in 2010 and 2020 respectively, with the BART extension to SFO opening in 2002.

At Oakland and San Jose airports, most passengers drive their own vehicle or a rental car to the airport now and are projected to continue to do so in the future (between 84% and 88%). This leaves a small percentage taking other modes, such as a door-to-door shuttle, taxi, limousine, public transit, private scheduled bus, hotel shuttle, chartered bus or other forms of transportation. The use of public transit to get to Oakland International Airport would be expected to increase significantly if an improved transit connection between Oakland airport and the BART system is provided in the future (as is now being studied).

Table 4 displays the difference in travel behavior by subregion of the Bay Area. An obvious observation is that air passenger use of public and private transit is directly related to the quantity and quality (cost, need for transfers, baggage accommodation) of service provided to an airport. Good transit service currently exists from downtown San Francisco to SFO and from the North Bay (due to three private operators providing frequent service) to SFO. East Bay travelers to SFO also have some good transit options, as do San Francisco passengers using OAK.

6. Forecasted Air Passenger Vehicle Trips to the Airports

We next convert the mode of transportation used to actual vehicle trips. This requires that we know the occupancy factors for various modes (number of air passenger parties in a mode and average party size). We have used the 1995 air passenger survey again to derive this information. For example, private vehicles and rental cars typically carry one party, which may

include one or more air passengers. Certain modes, such door-to-door or airport shuttle vans typically carry more than one party. In addition, a significant number of air passengers in private vehicles are dropped off at the airport. A drop off results in two vehicle trips for each air passenger party, one to the airport and one returning to the home or other place of origin.

Table 5 shows the estimated number of daily air passenger vehicle trips and vehicle miles of travel to each of the three airports. (For every vehicle traveling a mile, we call that a "vehicle mile traveled.") The projected increase in regional passenger shares at OAK and SJC coupled with the observed dependency on auto access, means that traffic at these airports could increase by large amounts, in the range of 128% to 150%. Between 1998 and 2020 this would mean that daily vehicle trips at OAK would grow by 32,000 (151%), daily vehicle trips at SJC would grow by 33,000 (128%), and vehicle trips to and from SFO would increase by about 24,000 (40%). These figures include vehicle trips by out of region air passengers.

Overall the number of vehicle trips per local air passenger at the three airports in 2020 would be:

OAK: .86
SFO: .70
SJC: .92

Figure 2 displays the growth in vehicle trips by subregion. This information indicates the directional patterns of airport access trips to each airport and the freeway facilities that would be affected to the greatest extent. A comparison of growth rates between 1998 to 2020 for air passengers, passenger flights and air passenger vehicle trips is shown in Figure 3.

7. Timing of Airport Access Trips

Another critical question concerning the impact of airport traffic on regional facilities is the timing of the trips made to the airports and whether the trips occur during the peak commute period or outside of this period. To analyze this question in greater detail, we again rely on our earlier forecast work where we have estimated the number of aircraft operations by hour of the day based on the cities served by each airport. The hourly schedules reflect the preferred flight times to destination cities as well as likely airline decisions to meet banks of flights at their major hubs across the nation. We also know the number of seats on these flights from our forecasts, thus the scheduled number of seats becomes a good indicator of the number of air passengers arriving and leaving the airports by hour of the day. This information is shown in Table 6.

For SFO, the flight schedule is projected to continue to be fairly uniform through out the day, such that only about 34% of the air passengers will arrive and depart during the peak commute period. On the other hand this percentage increases to about 40% at both OAK and SJC with the evening peak being higher than the morning peak.

8. Airport Employee Trips

Like air passengers, the number of employees working at the three airports is expected to increase, but at a lower rate of 25% between 1998 and 2020. (Airport employment is derived

from *Projections '98* census tract level estimates prepared by the Association of Bay Area Governments.) The travel behavior of these employees is projected using the MTC travel demand forecast model described above.

Currently, the majority of airport employees drive alone to work (71%). The remaining employees share rides (14%), take public transit (11%) or bike or walk to work (4%). By 2020, the percentages of employees taking these transportation modes are projected to look essentially the same as today.

We then estimated the number of vehicle trips generated as shown in Table 7 and the vehicle miles of travel in the region associated with employee travel. The forecasted ratio of air passenger to airport employee vehicle trips at each airport is shown below:

SFO: 2.26: 1
OAK: 2.57:1
SJC: 2.70: 1

9. Air Cargo Truck Trips

In addition to air passengers and airport employees, trucks carrying air cargo to and from the airport must also be considered in evaluating future traffic conditions. To better understand current air cargo truck activity, the Metropolitan Transportation Commission retained a consultant to collect air cargo truck data at the three Bay area airports in 1998. The consultant collected data during randomly selected blocks of time through the day and week. On an average work week (Monday through Friday) the three airports generate 33,456 air cargo related truck trips to and from the airport (see Table 8). Daily truck trips were highest at SFO (17,348), followed by OAK (11,765) and SJC (4,344).

Of the five weekdays, Friday is the busiest day for air cargo truck trips. Regionally, truck traffic is heaviest between the hours of 6:00 p.m. and midnight, and is lightest between midnight and 6:00 a.m., with each airport having slightly different hourly patterns. The survey also recorded vehicle ownership for each observed truck trip. The ownership data are shown in Table 9.

Given that our air cargo forecasts indicate a tripling of air cargo volumes over the 20-year time frame, we expect that truck volumes would also increase. However, we have not developed a methodology in this study that would be reliable enough to forecast future truck traffic at each airport. There are several complicating factors, such as the fact that some trucks counted in our survey may have been carrying goods other than air cargo (although we did attempt to limit the survey to cargo). Also, the changing air cargo patterns in the industry mean that a growing number of trucks are carrying 2 and 3 day delivery cargo that is consolidated at the airport but leaves the airport on the ground instead of by air (our forecasts address only the cargo leaving by air). Finally, the pattern of truck activity by freight forwarders at SFO needs to be better understood. We had hoped to follow up the truck counts with driver interviews, but were not able to work out a satisfactory survey approach with the freight industry and thus were not able to collect this type of information.

10. Implications

The long term traffic implications of increased ground traffic to airports are indeed significant, particularly for facilities close to the airports where the airport bound traffic is most concentrated. In addition, most existing freeways serving the airports already are near their peak capacities for extended periods of the day (see Table 10). What then can be expected in the future?

First, as discussed earlier, there are a number of transportation projects that could provide improved regional access to the airports as shown in Table 1. Projects that are not financially feasible now could become so in the future with new funding sources. Or new airport access concepts such as remote terminals that allow passengers to purchase tickets, check in bags and board airport transit services may be developed.

Second we have essentially analyzed the worst-case airport access scenario, largely reflecting current air passenger and airport employee mode choice patterns. We have not explicitly considered how air passengers and airport employees will adapt to increasing congestion on regional freeways and airport access roads to minimize their travel time and inconvenience. This adaptive behavior could include choice of private higher occupancy shuttles instead of private cars, increased use of public and private transit, or shifting these trips to less congested routes to reach the airports.

Finally, passengers may decide to shift their flight times or flight day to avoid surface congestion. Airport employers may also further stagger airport shifts to allow their employees to avoid the most congested times of the day.

Appendix A

Tables and Figures

Table 1a
Airport Ground Access Improvements -- SFO

Project or Program	Description	Status/Sponsor	Cost/Funding	Comments
BART extension	8 miles extension to SFO terminal from Colma	Under construction (BART)	$1.5 billion	
Caltrain upgrades				
• "Baby bullets"	Track improvements and signals to significantly reduce travel times	Funded	$127 m	Will improve access times up and down Peninsula
• Electrification	Convert Caltrain from diesel to electric power, improving acceleration and reducing travel time	Planning phase (Peninsula JPB)	$403 m	Not funded
• Airport Light Rail Connections	Would provide a direct transfer between Caltrain and the SFO on airport light rail	Planning phase (Peninsula JPB)	$124 m	Not funded
Route 101 interchanges and auxiliary lanes • San Bruno Ave. • Airport • Millbrae Ave.	Improve freeway interchanges serving airport and add auxiliary lanes near airport on US 101	Construction nearing completion	$97.7 m	
Route 101 auxiliary lanes	Add auxiliary lanes in various locations between Santa Clara Co. and the San Francisco Co. lines	Partially funded (Caltrans)	$75 m to $188 m depending on number provided	
Ferry connections				
• Moffett-SFO	Access from South Bay	Proposed operator for new services not identified	$21 m	Not funded
• Ferry Terminal-SFO	Access from Downtown SF		$28 m	
• Other (Vallejo/Larkspur)	New service from existing terminals		–	Moffett service may affect sensitive Bay areas
• SFO-OAK (freight)	Airport-to-airport connection		–	
Other				
• Off-airport terminals	Off airport terminal for transit and baggage check in	Has been studied, but no follow up	–	Not funded

Table 1b
Airport Ground Access Improvements -- OAK

Project or Program	Description	Status/Sponsor	Cost/Funding	Other Issues
I-880/Hegenberger interchange	Widen overcrossing and improve ramps to I-880	Recently completed (Caltrans)		
Airport Roadway Project	Arterial roadway extending from I-880 at 98th Ave. through the airport to Bay Farm Island	98th Ave. work under construction; Cross-airport roadway in design phase; (City of Oakland/Port of Oakland)	$104 m	Funded
BART Connector	Exclusive guideway transit system between Coliseum BART station and OAK terminal	BART preparing EIR/EIS	$134 m	Not fully funded
Capitol Corridor intercity rail/ new Coliseum Station	Increase service between Solano Co. and Santa Clara Co. with new stop at BART Coliseum Station to connect to airport transit	Service would be increased incrementally as funding is available (Capitol Corridor JPB)	$187 m	Not fully funded
Ferry connections				
• OAK to SF Ferry Terminal	Access from Downtown San Francisco	Proposed in Bay Area Council Ferry Plan	$21 million (capital)	Not funded
• OAK to Moffett Field (freight)	Ferries could avoid highway congestion in bringing South Bay air cargo to OAK	Being studied	Unknown	Not funded
Other				
• OAK to SFO connection	Proposed to integrate SFO/OAK operations; could be rail or water (ferry) connection	Sponsor unknown; high cost would make it difficult for airports to fund (ferries would be less)	$3.5 to $4 b	Not funded
• Hegenberger Road extension to I-580	Widen and extend Hegenberger to I-580	City of Oakland	$40+ m	Would impact neighborhoods along Edwards Ave.

Table 1c
Airport Ground Access Improvements -- SJC

Project or Program	Description	Status/Sponsor	Cost/Funding	Other Issues
Route 87 freeway widening and new airport interchange	Route 87 widened to six lanes with interchange into airport at Skyport Dr.	Funded (Caltrans)	$225 million	New overpasses with Skyport Blvd will make it easier to access Terminal from Route 87
Improved I-880/Coleman Ave. interchange	Reconstruct interchange to improve airport access	Design by Caltrans	$36 m	Not fully funded
Transit connection to Caltrain and VTA light rail	Provide a people mover-type connection linking airport terminals to Caltrain and VTA light rail	Under study by SJC	$200-$300 m	Not funded
Other • Direct bus service from Fremont BART station	More frequent bused service could be considered as an interim measure	Existing VTA line 180 serves airport, but not express	Unknown	Not funded
Upgrade Caltrain Service on Peninsula and to South County	More frequent service would improve access from South County; connect to airport via transit bus or people mover	Funded	$52 m	Airport connection could be bus or people mover

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Table 2
Distribution of Air Passengers to Airports
(2010 and 2020)

Year 2010	Bay Area Airports		SFO		OAK		SJC	
County	MTC Estimated Annual Passengers	Percent of Air Passengers	Annual Air Passengers	Percent of Air Passengers	Annual Air Passengers	Percent of Air Passengers	Annual Air Passengers	Percent of Air Passengers
Alameda	8,716,319	11%	1,732,137	20%	6,113,287	70%	870,895	10%
Contra Costa	4,884,011	6%	1,123,322	23%	3,614,168	74%	146,520	3%
Marin	1,960,616	2%	1,372,431	70%	588,185	30%	-	0%
Napa	1,052,443	1%	578,844	55%	473,599	45%	-	0%
San Francisco	18,777,271	23%	15,585,135	83%	3,192,136	17%	-	0%
San Mateo	9,217,757	11%	7,558,561	82%	276,533	3%	1,382,664	15%
Santa Clara	14,674,810	18%	1,667,652	11%	293,496	2%	12,713,662	83%
Solano	1,766,458	2%	794,906	45%	971,552	55%	-	0%
Sonoma	1,925,749	2%	1,444,312	75%	481,437	25%	-	0%
Out of Region	4,521,427	5%	1,944,213	43%	768,643	17%	1,808,571	40%
Subtotal (Local)	**67,496,862**	**82%**	**33,801,514**	**51%**	**16,773,036**	**25%**	**16,922,311**	**25%**
Connecting Passengers	14,811,017	18%	12,743,716	86%	698,877	5%	1,372,079	9%
TOTAL AIR PASSENGERS	**82,307,879**	**100%**	**46,545,230**	**57%**	**17,471,913**	**21%**	**18,294,390**	**22%**

Year 2020	Total All Airports		SFO		OAK		SJC	
County	MTC Estimated Annual Passengers	Percent of Air Passengers	Annual Air Passengers	Percent of Air Passengers	Annual Air Passengers	Percent of Air Passengers	Annual Air Passengers	Percent of Air Passengers
Alameda	11,473,671	10%	1,967,607	17%	8,358,697	73%	1,147,367	10%
Contra Costa	6,688,481	6%	1,301,242	20%	5,131,216	77%	256,024	4%
Marin	2,552,715	2%	1,786,901	70%	765,815	30%	-	0%
Napa	1,435,908	1%	646,159	45%	789,749	55%	-	0%
San Francisco	24,623,432	22%	20,437,449	83%	4,185,983	17%	-	0%
San Mateo	12,269,514	11%	10,061,002	82%	368,085	3%	1,840,427	15%
Santa Clara	19,085,727	17%	2,072,386	11%	381,715	2%	16,631,626	87%
Solano	2,793,168	3%	837,950	30%	1,955,218	70%	-	0%
Sonoma	2,644,965	2%	1,851,476	70%	793,490	30%	-	0%
Out of Region	6,375,681	6%	1,848,947	29%	1,020,109	16%	3,506,624	55%
Subtotal (Local)	**89,943,263**	**81%**	**42,811,118**	**48%**	**23,750,076**	**27%**	**23,382,068**	**26%**
Connecting Passengers	21,184,101	19%	18,304,731	86%	989,586	5%	1,895,843	9%
TOTAL AIR PASSENGERS	**111,127,364**	**100%**	**61,115,849**	**55%**	**24,739,662**	**22%**	**25,277,912**	**23%**

Table 3

Form of Transportation Used to Get to the Airports for Air Passengers for Years 1998, 2010 and 2020

1998	Annual Passengers							
Form of Transportation Used to Get to the Airport	SFO		OAK		SJC		TOTAL	
Private car or rental car	17,359,818	62%	7,843,898	85%	9,049,839	88%	34,253,556	72%
Door-to-door shuttle, taxi or limousine	6,535,340	23%	643,308	7%	711,801	7%	7,890,449	17%
Public transit	434,477	2%	471,566	5%	65,940	1%	971,982	2%
Private scheduled bus	2,079,202	7%	145,770	2%	104,065	1%	2,329,038	5%
Hotel shuttle, chartered bus or other	1,658,162	6%	111,458	1%	306,356	3%	2,075,976	4%
TOTAL	**28,067,000**	**100%**	**9,216,000**	**100%**	**10,238,000**	**100%**	**47,521,000**	**100%**

2010	Annual Passengers							
Form of Transportation Used to Get to the Airport	SFO		OAK		SJC		TOTAL	
Private car or rental car	19,150,045	57%	14,100,213	84%	14,912,435	88%	48,162,693	71%
Door-to-door shuttle, taxi or limousine	7,845,910	23%	1,185,070	7%	1,177,294	7%	10,208,273	15%
Public transit	2,053,910	6%	1,028,142	6%	151,130	1%	3,233,182	5%
Private scheduled bus	2,728,009	8%	255,973	2%	151,363	1%	3,135,345	5%
Hotel shuttle, chartered bus or other	2,023,639	6%	203,638	1%	530,091	3%	2,757,368	4%
TOTAL	**33,801,513**	**100%**	**16,773,036**	**100%**	**16,922,312**	**100%**	**67,496,861**	**100%**

2020	Annual Passengers							
Form of Transportation Just to Get to the Airport	SFO		OAK		SJC		TOTAL	
Private car or rental car	23,541,301	55%	20,015,349	84%	20,626,757	88%	64,183,407	71%
Door-to-door shuttle, taxi or limousine	9,951,457	23%	1,622,628	7%	1,593,104	7%	13,167,190	15%
Public transit	3,239,182	8%	1,454,727	6%	234,820	1%	4,928,729	5%
Private scheduled bus	3,438,914	8%	367,801	2%	231,944	1%	4,038,658	4%
Hotel shuttle, chartered bus or other	2,640,265	6%	289,571	1%	695,443	3%	3,625,280	4%
TOTAL	**42,811,119**	**100%**	**23,750,077**	**100%**	**23,382,068**	**100%**	**89,943,264**	**100%**

Table 4a

Form of Transportation Used to Get to the Airports for Air Passengers by Subregion in 1998

1998 Mode Split (using mode split from the MTC Air Passenger Survey)

San Francisco International Airport	Annual Passengers											
Form of Transportation Used to Get to the Airport	North Bay		East Bay		South Bay		Peninsula		Out of Region		TOTAL	
Private car or rental car	1,683,818	59%	2,684,492	80%	2,583,976	83%	9,074,860	52%	1,332,672	91%	17,359,818	62%
Door-to-door shuttle, taxi or limousine	269,075	9%	522,406	16%	421,992	14%	5,248,644	30%	73,224	5%	6,535,340	23%
Public transit	26,608	1%	54,934	2%	46,246	1%	292,045	2%	14,645	1%	434,477	2%
Private scheduled bus	845,122	30%	63,656	2%	26,013	1%	1,100,477	6%	43,934	3%	2,079,202	7%
Hotel shuttle, chartered bus or other	32,168	1%	33,783	1%	17,342	1%	1,574,869	9%	-	0%	1,658,162	6%
TOTAL	**2,856,792**	**100%**	**3,359,271**	**100%**	**3,095,569**	**100%**	**17,290,895**	**100%**	**1,464,474**	**100%**	**28,067,000**	**100%**

Oakland International Airport	Annual Passengers											
Form of Transportation Used to Get to the Airport	North Bay		East Bay		South Bay		Peninsula		Out of Region		TOTAL	
Private car or rental car	1,049,247	88%	5,088,860	88%	172,185	95%	1,054,763	70%	478,844	91%	7,843,898	85%
Door-to-door shuttle, taxi or limousine	54,143	5%	376,464	6%	6,377	4%	180,013	12%	26,310	5%	643,308	7%
Public transit	8,530	1%	212,633	4%	3,189	2%	241,952	16%	5,262	1%	471,566	5%
Private scheduled bus	66,658	6%	46,012	1%	-	0%	17,314	1%	15,786	3%	145,770	2%
Hotel shuttle, chartered bus or other	11,575	1%	82,792	1%	-	0%	17,091	1%	-	0%	111,458	1%
TOTAL	**1,190,152**	**100%**	**5,806,761**	**100%**	**181,751**	**100%**	**1,511,134**	**100%**	**526,202**	**100%**	**9,216,000**	**100%**

San Jose International Airport	Annual Passengers											
Form of Transportation Used to Get to the Airport	North Bay		East Bay		South Bay		Peninsula		Out of Region		TOTAL	
Private car or rental car	38,038	100%	646,613	94%	6,514,003	87%	558,181	91%	1,293,003	91%	9,049,839	88%
Door-to-door shuttle, taxi or limousine	-	0%	27,608	4%	577,660	8%	35,489	6%	71,044	5%	711,801	7%
Public transit	-	0%	2,906	0%	44,216	1%	4,609	1%	14,209	1%	65,940	1%
Private scheduled bus	-	0%	2,906	0%	52,774	1%	5,759	1%	42,626	3%	104,065	1%
Hotel shuttle, chartered bus or other	-	0%	10,171	1%	288,117	4%	8,068	1%	-	0%	306,356	3%
TOTAL	**38,038**	**100%**	**690,205**	**100%**	**7,476,769**	**100%**	**612,105**	**100%**	**1,420,882**	**100%**	**10,238,000**	**100%**

Table 4b

Form of Transportation Used to Get to the Airports for Air Passengers by Subregion in 2010

2010 R2A Forecast (using 2010 mode split with BART to SFO)

San Francisco International Airport	Annual Passengers											
Form of Transportation Used to Get to the Airport	North Bay		East Bay		South Bay		Peninsula		Out of Region		TOTAL	
Private car or rental car	2,496,633	60%	2,128,566	75%	1,394,144	84%	11,361,468	49%	1,769,234	91%	19,150,045	57%
Door-to-door shuttle, taxi or limousine	417,354	10%	406,360	14%	226,192	14%	6,698,794	29%	97,211	5%	7,845,910	23%
Public transit	39,778	1%	242,997	9%	24,206	1%	1,727,486	7%	19,442	1%	2,053,910	6%
Private scheduled bus	1,189,374	28%	50,613	2%	14,014	1%	1,415,682	6%	58,326	3%	2,728,009	8%
Hotel shuttle, chartered bus or other	47,353	1%	26,924	1%	9,096	1%	1,940,266	8%	-	0%	2,023,639	6%
TOTAL	**4,190,493**	**100%**	**2,855,459**	**100%**	**1,667,652**	**100%**	**23,143,696**	**100%**	**1,944,213**	**100%**	**33,801,513**	**100%**

Oakland International Airport	Annual Passengers											
Form of Transportation Used to Get to the Airport	North Bay		East Bay		South Bay		Peninsula		Out of Region		TOTAL	
Private car or rental car	2,253,714	90%	8,471,227	87%	278,374	95%	2,397,433	69%	699,465	91%	14,100,213	84%
Door-to-door shuttle, taxi or limousine	100,766	4%	621,093	6%	10,348	4%	414,431	12%	38,432	5%	1,185,070	7%
Public transit	16,324	1%	422,922	4%	4,774	2%	576,435	17%	7,686	1%	1,028,142	6%
Private scheduled bus	113,604	5%	77,623	1%	-	0%	41,686	1%	23,059	3%	255,973	2%
Hotel shuttle, chartered bus or other	30,365	1%	134,589	1%	-	0%	38,685	1%	-	0%	203,638	1%
TOTAL	**2,514,773**	**100%**	**9,727,455**	**100%**	**293,496**	**100%**	**3,468,669**	**100%**	**768,643**	**100%**	**16,773,036**	**100%**

San Jose International Airport	Annual Passengers											
Form of Transportation Used to Get to the Airport	North Bay		East Bay		South Bay		Peninsula		Out of Region		TOTAL	
Private car or rental car	-		953,728	94%	11,039,529	87%	1,273,378	92%	1,645,800	91%	14,912,435	88%
Door-to-door shuttle, taxi or limousine	-		40,119	4%	973,838	8%	72,908	5%	90,429	5%	1,177,294	7%
Public transit	-		4,148	0%	119,807	1%	9,089	1%	18,086	1%	151,130	1%
Private scheduled bus	-		4,148	0%	88,437	1%	4,520	0%	54,257	3%	151,363	1%
Hotel shuttle, chartered bus or other	-		15,271	2%	492,051	4%	22,769	2%	-	0%	530,091	3%
TOTAL	**-**		**1,017,415**	**100%**	**12,713,662**	**100%**	**1,382,664**	**100%**	**1,808,571**	**100%**	**16,922,312**	**100%**

Table 4c

Form of Transportation Used to Get to the Airports for Air Passengers by Subregion in 2020

2020 R2A Forecast (using 2020 mode split with BART to SFO)

San Francisco International Airport	Annual Passengers											
Form of Transportation Used to Get to the Airport	North Bay		East Bay		South Bay		Peninsula		Out of Region		TOTAL	
Private car or rental car	3,022,835	59%	2,362,921	72%	1,734,090	84%	14,738,913	48%	1,682,542	91%	23,541,301	55%
Door-to-door shuttle, taxi or limousine	505,322	10%	443,890	14%	280,386	14%	8,629,412	28%	92,447	5%	9,951,457	23%
Public transit	48,293	1%	376,012	12%	29,482	1%	2,766,905	9%	18,489	1%	3,239,182	8%
Private scheduled bus	1,488,618	29%	56,028	2%	17,337	1%	1,821,462	6%	55,468	3%	3,438,914	8%
Hotel shuttle, chartered bus or other	57,418	1%	29,998	1%	11,091	1%	2,541,759	8%	-	0%	2,640,265	6%
TOTAL	**5,122,486**	**100%**	**3,268,849**	**100%**	**2,072,386**	**100%**	**30,498,451**	**100%**	**1,848,947**	**100%**	**42,811,119**	**100%**

Oakland International Airport	Annual Passengers											
Form of Transportation Used to Get to the Airport	North Bay		East Bay		South Bay		Peninsula		Out of Region		TOTAL	
Private car or rental car	3,878,230	90%	11,698,198	87%	362,159	95%	3,148,463	69%	928,299	91%	20,015,349	84%
Door-to-door shuttle, taxi or limousine	166,864	4%	846,423	6%	13,577	4%	544,759	12%	51,005	5%	1,622,628	7%
Public transit	26,009	1%	657,251	5%	5,979	2%	755,287	17%	10,201	1%	1,454,727	6%
Private scheduled bus	174,803	4%	107,650	1%	-	0%	54,745	1%	30,603	3%	367,801	2%
Hotel shuttle, chartered bus or other	58,366	1%	180,391	1%	-	0%	50,814	1%	-	0%	289,571	1%
TOTAL	**4,304,272**	**100%**	**13,489,913**	**100%**	**381,715**	**100%**	**4,554,068**	**100%**	**1,020,109**	**100%**	**23,750,077**	**100%**

San Jose International Airport	Annual Passengers											
Form of Transportation Used to Get to the Airport	North Bay		East Bay		South Bay		Peninsula		Out of Region		TOTAL	
Private car or rental car	-		1,317,569	94%	14,423,176	87%	1,694,985	92%	3,191,028	91%	20,626,757	88%
Door-to-door shuttle, taxi or limousine	-		53,816	4%	1,266,934	8%	97,023	5%	175,331	5%	1,593,104	7%
Public transit	-		5,369	0%	182,271	1%	12,114	1%	35,066	1%	234,820	1%
Private scheduled bus	-		5,369	0%	115,333	1%	6,043	0%	105,199	3%	231,944	1%
Hotel shuttle, chartered bus or other	-		21,269	2%	643,912	4%	30,262	2%	-	0%	695,443	3%
TOTAL	**-**		**1,403,391**	**100%**	**16,631,626**	**100%**	**1,840,427**	**100%**	**3,506,624**	**100%**	**23,382,068**	**100%**

Table 5
Daily Air Passenger Vehicle Trips and Vehicle Miles Traveled (VMT) to the Airports

	Daily Vehicle Trips in Region				
Airport	1998	2010	2020	% Change from 1998 to 2010	% Change from 1998 to 2020
SFO	55,047	61,577	77,731	12%	41%
OAK	20,892	37,573	53,218	80%	155%
SJC	22,237	38,040	49,966	71%	125%
TOTAL	**98,176**	**137,190**	**180,914**	**40%**	**84%**

	Daily Vehicle Trips Out of Region				
Airport	1998	2010	2020	% Change from 1998 to 2010	% Change from 1998 to 2020
SFO	3,678	4,883	4,644	33%	26%
OAK	1,289	1,883	2,499	46%	94%
SJC	3,537	4,502	8,729	27%	147%
TOTAL	**8,504**	**11,268**	**15,871**	**33%**	**87%**

	Total Daily Vehicle Trips				
Airport	1998	2010	2020	% Change from 1998 to 2010	% Change from 1998 to 2020
SFO	58,725	66,461	82,375	13%	40%
OAK	22,181	39,456	55,717	78%	151%
SJC	25,774	42,542	58,694	65%	128%
TOTAL	**106,680**	**148,458**	**196,786**	**39%**	**84%**

	Total Daily VMT*				
Airport	1998	2010	2020	% Change from 1998 to 2010	% Change from 1998 to 2020
SFO	1,236,688	1,390,846	1,695,163	12%	37%
OAK	497,136	909,087	1,319,832	83%	165%
SJC	330,061	529,327	775,933	60%	135%
TOTAL	**2,063,886**	**2,829,260**	**3,790,927**	**37%**	**84%**

* Includes travel within the Bay Area counties by people traveling from counties outside the Bay Area to the airport.

Table 6

Percentage of Air Passengers Arriving and Departing Bay Area Airports By Time Period

San Francisco International Airport

	Number of Scheduled Seats (Passengers)					
	1999		2010		2020	
Time Period	**Totals**	**Percent**	**Totals**	**Percent**	**Totals**	**Percent**
AM Peak (6 AM to 9 AM)	24,822	14%	30,195	15%	34,101	14%
PM Peak (4 PM to 7 PM)	37,056	20%	39,055	19%	46,975	19%
All Other Times	120,311	66%	134,466	66%	166,534	67%
TOTAL	182,189	100%	203,716	100%	247,610	100%

Oakland International Airport

	Number of Scheduled Seats (Passengers)					
	1999		2010		2020	
Time Period	**Totals**	**Percent**	**Totals**	**Percent**	**Totals**	**Percent**
AM Peak (6 AM to 9 AM)	7,412	16%	13,088	19%	14,966	17%
PM Peak (4 PM to 7 PM)	11,485	25%	15,334	23%	19,059	22%
All Other Times	27,158	59%	39,377	58%	52,714	61%
TOTAL	46,055	100%	67,799	100%	86,739	100%

San Jose Airport

	Number of Scheduled Seats (Passengers)					
	1999		2010		2020	
Time Period	**Totals**	**Percent**	**Totals**	**Percent**	**Totals**	**Percent**
AM Peak (6 AM to 9 AM)	8,852	17%	13,597	18%	16,447	18%
PM Peak (4 PM to 7 PM)	12,650	24%	17,423	23%	19,453	21%
All Other Times	31,118	59%	43,654	58%	57,094	61%
TOTAL	52,620	100%	74,674	100%	92,994	100%

Table 7
Daily Airport Employee Trips to the Airports

Total Employment (ABAG Projections '98)

Year	SFO	OAK	SJC	Total
1998	29,900	18,600	13,600	62,100
2010	33,100	21,600	18,300	73,000
2020	35,800	23,000	19,100	77,900

Daily Vehicle Trips (Average Weekday Daily)

Year	SFO	OAK	SJC	Total
1998	30,900	19,800	15,500	66,200
2010	33,900	21,700	20,700	76,300
2020	36,300	22,400	21,700	80,400

Vehicle Miles of Travel (Average Weekday Daily)

Year	SFO	OAK	SJC	Total
1998	465,000	263,800	167,800	896,600
2010	528,400	298,500	240,200	1,067,100
2020	588,300	309,000	253,000	1,150,300

Table 8
Cargo Truck Volumes to the Airports

			SFO			
Time of Day	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Total**
6 a.m. to 12 p.m.	752	774	803	755	851	3,935
12 p.m. to 6 a.m.	690	534	655	655	743	3,277
6 p.m. to 12 a.m.	1,469	1,584	1,354	1,469	1,469	7,345
12 a.m. to 6 a.m.	534	550	569	569	569	2,791
TOTAL	3,445	3,442	3,381	3,448	3,632	17,348

			OAK			
Time of Day	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Total**
6 a.m. to 12 p.m.	544	496	496	572	372	2,480
12 p.m. to 6 a.m.	811	442	739	739	965	3,696
6 p.m. to 12 a.m.	708	634	864	708	628	3,542
12 a.m. to 6 a.m.	409	245	455	486	452	2,047
TOTAL	2,472	1,817	2,554	2,505	2,417	11,765

			SJC			
Time of Day	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Total**
6 a.m. to 12 p.m.	210	272	272	140	468	1,362
12 p.m. to 6 a.m.	370	222	326	326	388	1,632
6 p.m. to 12 a.m.	198	214	182	198	198	990
12 a.m. to 6 a.m.	72	72	104	40	72	360
TOTAL	850	780	884	704	1,126	4,344

			All Airport - Total Counts			
Time of Day	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Total**
6 a.m. to 12 p.m.	1,506	1,542	1,571	1,467	1,691	7,777
12 p.m. to 6 a.m.	1,871	1,198	1,720	1,720	2,096	8,605
6 p.m. to 12 a.m.	2,375	2,432	2,400	2,375	2,295	11,877
12 a.m. to 6 a.m.	1,015	867	1,128	1,095	1,093	5,198
TOTAL	6,767	6,039	6,819	6,657	7,175	33,457

Table 9

Vehicle Ownership for Truck Trips to the Airports

	Airport			
Company	**SFO**	**OAK**	**SJC**	**Total**
Federal Express	3%	22%	17%	13%
United States Post Service	6%	10%	8%	8%
United Parcel Service	3%	11%	7%	6%
No Marking	25%	17%	19%	21%
Other	63%	40%	49%	52%
Total	100%	100%	100%	100%

Table 10
Existing Freeway Conditions Near Airports

Loc. Num.	Location	Direction	# of Lanes	HOV Lane	Percent Capacity Used and Traffic Conditions[1] a.m. (6-9 am)		p.m. (4-7 pm)	
San Mateo County near SFO								
1	US 101 South of Millbrae Ave.	NB	4	None	99.20%	Unstable conditions	103.75%	Congestion
	South of SFO	SB	4	None	96.73%	Congestion	97.42%	Congestion
2	US 101 at San Bruno Ave.	NB	4	None	75.52%	No congestion	72.54%	No congestion
	North of SFO	SB	4	None	71.44%	Congestion	70.89%	No congestion
Santa Clara County near SJC								
3	I-880 North of US 101	NB	3	None	78.17%	Congestion	73.81%	Congestion
		SB	2	None	87.61%	No congestion	106.56%	Congestion
4	US 101 North of Guadalupe Parkway	SB	5	Yes	41.66%	No congestion	74.40%	Congestion
Alameda County near OAK								
5	I-880 North of 66th Ave.	NB	5	None	68.75%	Unstable conditions	81.20%	No speed data available
		SB	4	None	88.16%	No speed data available	92.66%	Unstable conditions

Note: (1) Shaded numbers reflect percent capacity used greater than 80%

FIGURE 1: Proposed Regional Transportation Projects Which Would Improve Airport Access

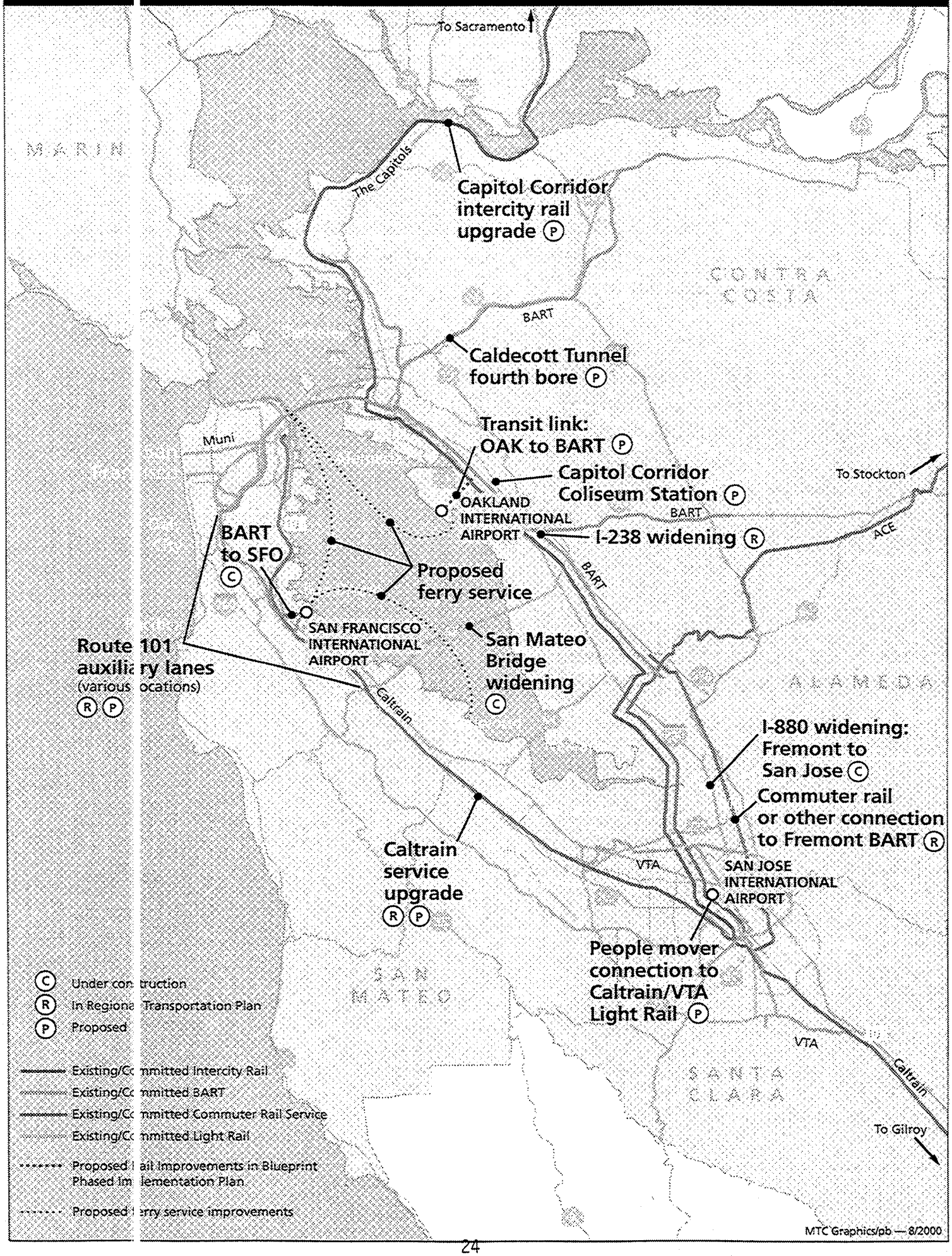


FIGURE 2A

Daily Vehicle Trips by Air Passengers to SFO by Subregion (1998-2020)

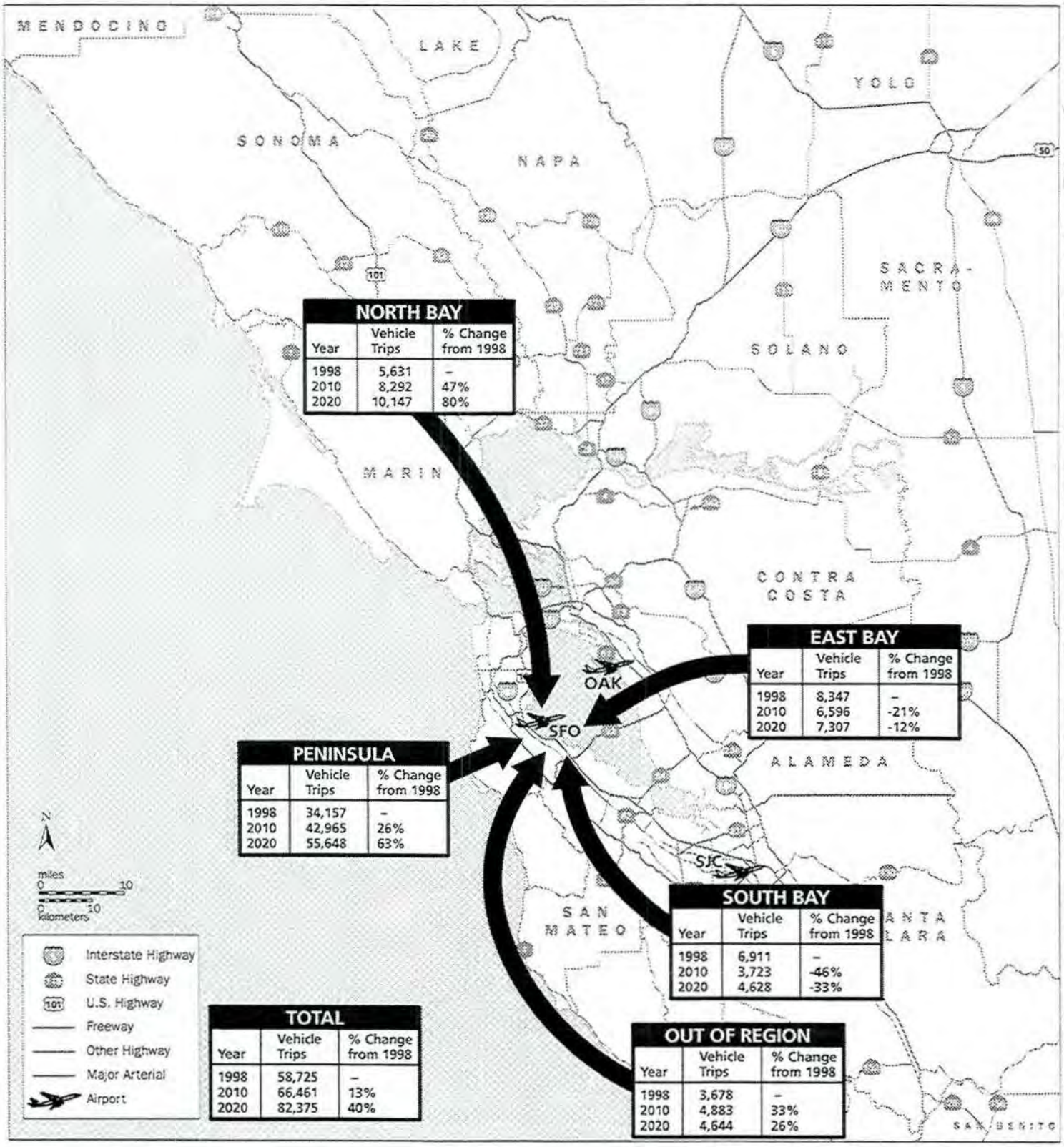


FIGURE 2B

Daily Vehicle Trips by Air Passengers to OAK by Subregion (1998-2020)

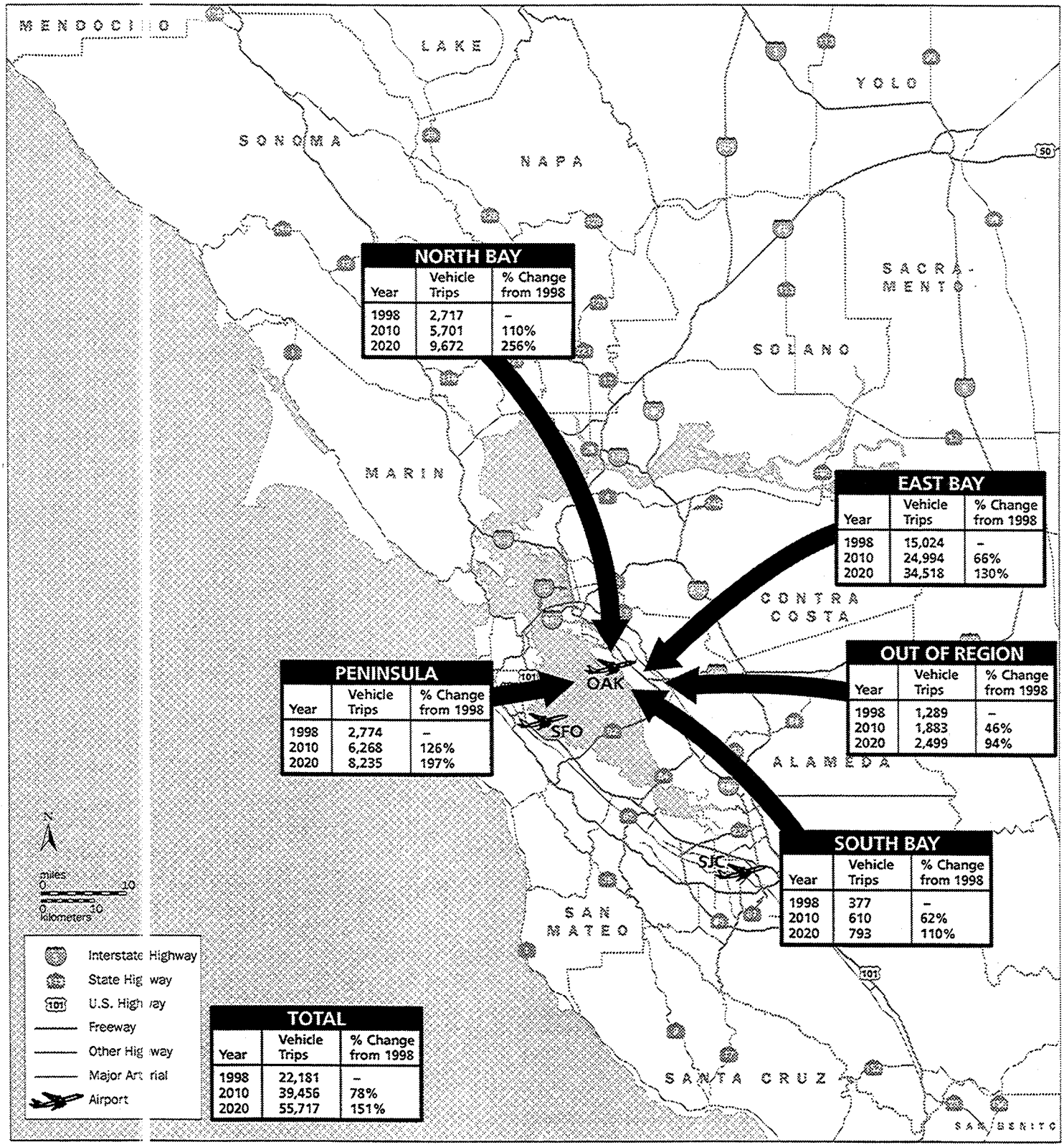
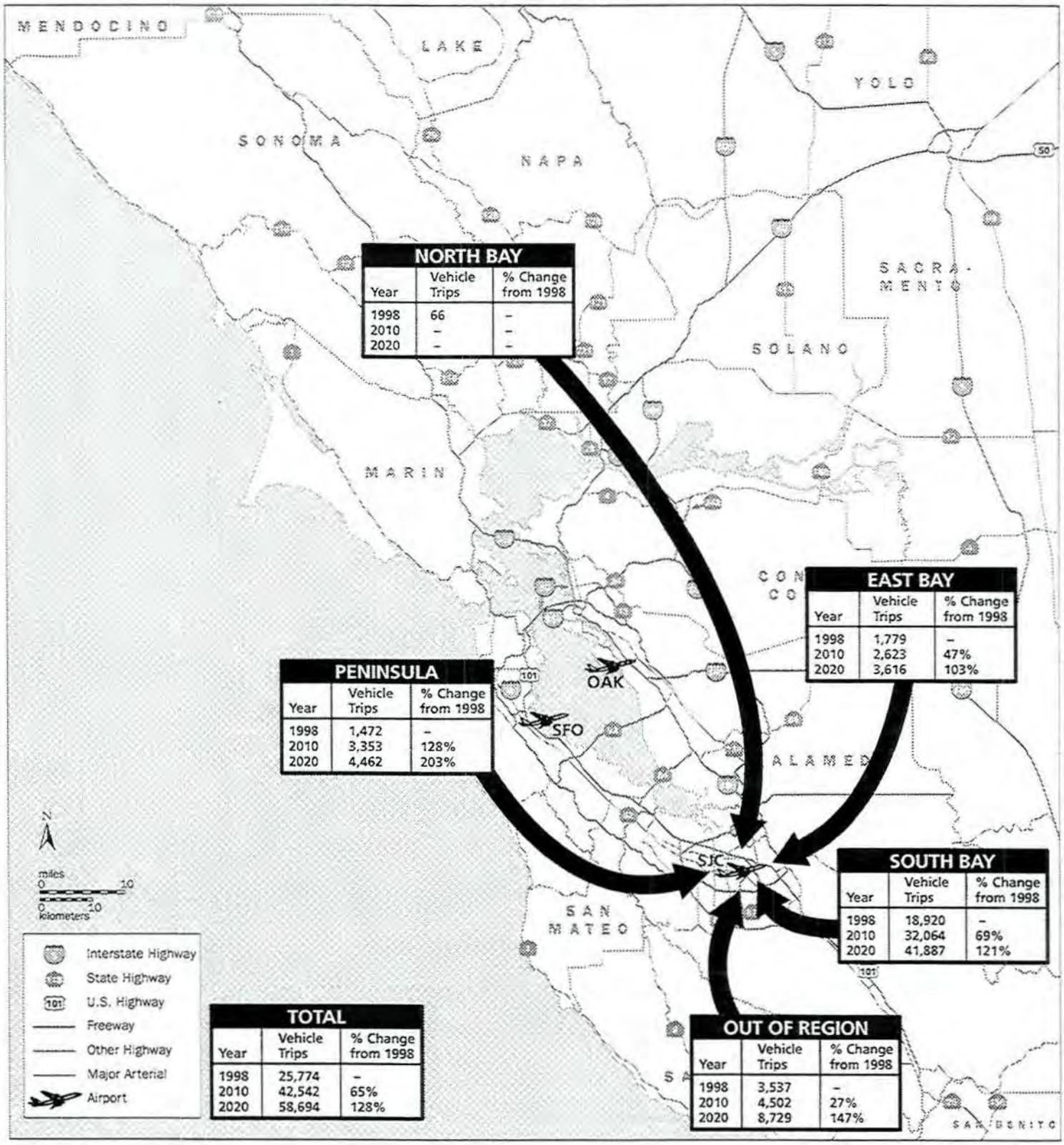


FIGURE 2C

Daily Vehicle Trips by Air Passengers to SJC by Subregion (1998-2020)



NORTH BAY

Year	Vehicle Trips	% Change from 1998
1998	66	–
2010	–	–
2020	–	–

EAST BAY

Year	Vehicle Trips	% Change from 1998
1998	1,779	–
2010	2,623	47%
2020	3,616	103%

PENINSULA

Year	Vehicle Trips	% Change from 1998
1998	1,472	–
2010	3,353	128%
2020	4,462	203%

SOUTH BAY

Year	Vehicle Trips	% Change from 1998
1998	18,920	–
2010	32,064	69%
2020	41,887	121%

TOTAL

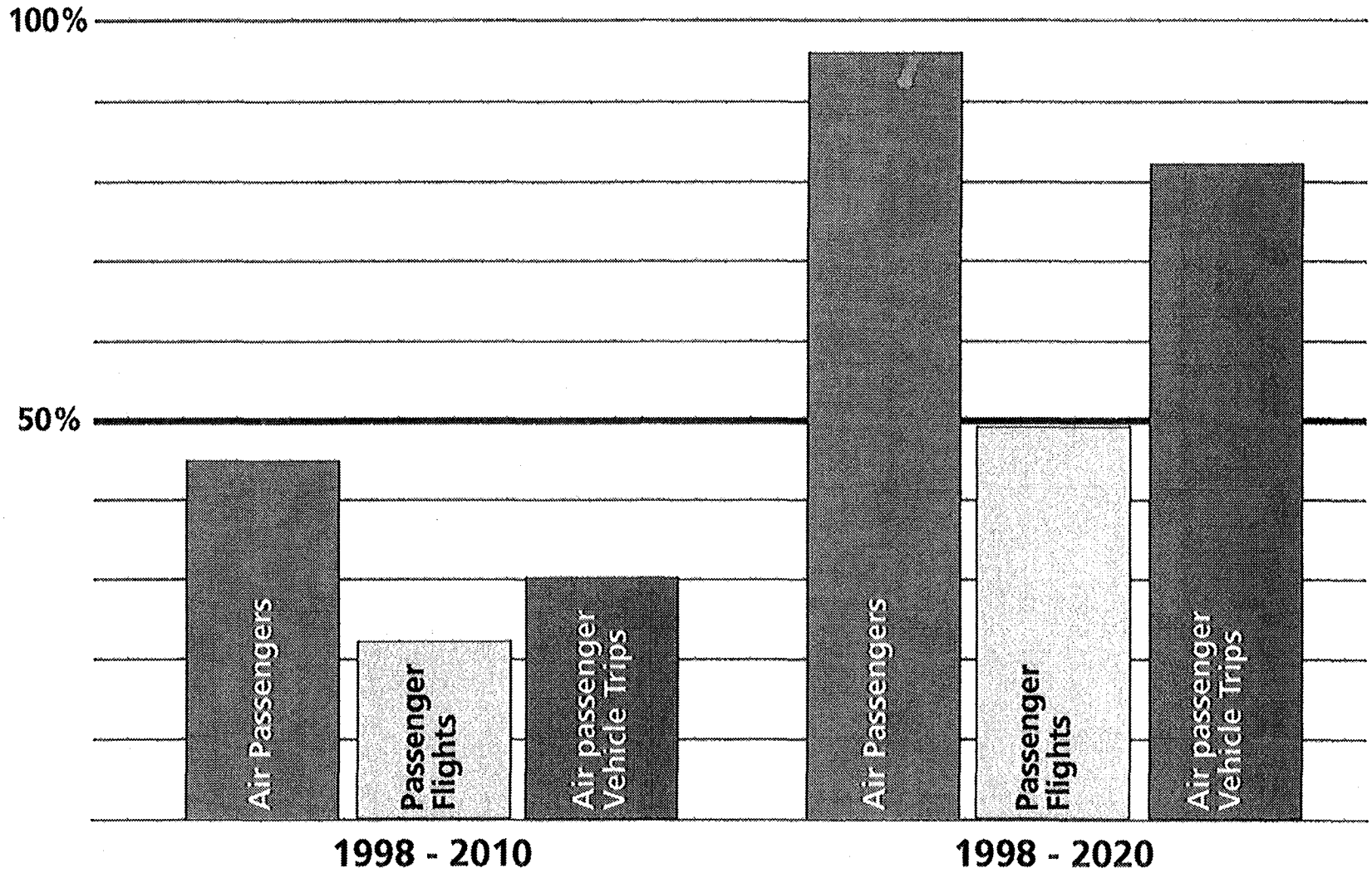
Year	Vehicle Trips	% Change from 1998
1998	25,774	–
2010	42,542	65%
2020	58,694	128%

OUT OF REGION

Year	Vehicle Trips	% Change from 1998
1998	3,537	–
2010	4,502	27%
2020	8,729	147%

Figure 3

Growth Rate Comparisons



Appendix B

Distance and Travel Times to Bay Area Airports (2010 and 2020)

Table 11
Driving Distances to Bay Area Airports (in miles)

zone	Neighborhood/Community	SFO	SJC	OAK
From the Peninsula				
1	San Francisco - Financial District	16	49	19
47	San Francisco - Richmond District	18	56	23
132	Daly City	8	50	27
184	San Mateo	7	28	25
219	Redwood City	15	21	29
From the South Bay				
245	Palo Alto	21	16	28
273	Mountain View	26	11	40
285	Sunnyvale	29	9	38
350	Cupertino	33	10	43
402	San Jose - Downtown	37	4	36
465	Milpitas	36	8	29
503	Morgan Hill	59	26	59
From the East Bay				
516	Livermore	42	32	27
552	Fremont	31	16	21
612	Hayward	24	27	9
699	Oakland - Downtown	23	40	9
733	Berkeley - Downtown	24	45	15
759	Richmond	30	52	21
810	Concord	42	50	31
847	Walnut Creek	37	44	26
858	Danville	42	38	27
891	Antioch	57	65	46
From the North Bay				
917	Vallejo	44	66	36
942	Fairfield	59	74	55
963	Vacaville	66	82	58
977	Napa	60	80	52
992	Sonoma	61	88	59
1003	Petaluma	56	85	55
1024	Santa Rosa	72	101	71
1052	Novato	45	74	44
1077	San Rafael	34	63	33
1097	Sausalito	25	69	38

Table 12
AM Peak Drive Times to Bay Area Airports, 2010 and 2020

zone	Neighborhood/Community	SFO 2010	SFO 2020	SJC 2010	SJC 2020	OAK 2010	OAK 2020
From the Peninsula							
1	San Francisco - Financial District	25	27	71	73	34	34
47	San Francisco - Richmond District	31	32	75	78	41	42
132	Daly City	20	20	63	65	43	43
184	San Mateo	17	17	46	48	37	38
219	Redwood City	25	24	36	37	42	43
From the South Bay							
245	Palo Alto	31	31	28	29	37	38
273	Mountain View	35	35	18	19	48	49
285	Sunnyvale	37	37	15	16	46	47
350	Cupertino	44	44	18	19	52	53
402	San Jose - Downtown	51	51	11	12	46	46
465	Milpitas	50	50	15	16	35	36
503	Morgan Hill	75	76	37	39	69	71
From the East Bay							
516	Livermore	74	79	53	55	39	42
552	Fremont	56	41	29	31	28	29
612	Hayward	47	49	44	47	15	15
699	Oakland - Downtown	58	61	58	61	17	17
733	Berkeley - Downtown	61	64	67	69	26	26
759	Richmond	65	70	72	77	31	33
810	Concord	82	88	73	79	45	47
847	Walnut Creek	77	81	67	73	39	41
858	Danville	75	77	57	60	40	41
891	Antioch	105	112	95	103	67	71
From the North Bay							
917	Vallejo	95	103	94	103	60	66
942	Fairfield	114	125	108	122	80	89
963	Vacaville	123	135	117	132	89	99
977	Napa	117	123	117	123	83	86
992	Sonoma	115	116	127	132	93	96
1003	Petaluma	112	107	137	133	96	90
1024	Santa Rosa	132	128	157	153	116	110
1052	Novato	85	89	110	115	69	72
1077	San Rafael	66	70	91	96	50	52
1097	Sausalito	55	58	96	101	56	58

Table 13
Off-Peak Drive Times to Bay Area Airports, 2010 and 2020

zone	Neighborhood/Community	SFO 2010	SFO 2020	SJC 2010	SJC 2020	OAK 2010	OAK 2020
From the Peninsula							
1	San Francisco - Financial District	16	17	46	48	21	21
47	San Francisco - Richmond District	19	19	50	50	27	28
132	Daly City	11	11	42	42	30	30
184	San Mateo	8	8	27	28	25	26
219	Redwood City	15	15	21	21	30	30
From the South Bay							
245	Palo Alto	21	21	17	17	30	30
273	Mountain View	26	26	12	12	35	35
285	Sunnyvale	28	28	10	10	37	37
350	Cupertino	32	32	11	12	41	41
402	San Jose - Downtown	36	36	5	5	37	37
465	Milpitas	34	34	8	9	30	31
503	Morgan Hill	56	56	26	26	57	57
From the East Bay							
516	Livermore	43	44	33	34	28	28
552	Fremont	32	32	21	21	24	24
612	Hayward	24	25	28	29	10	10
699	Oakland - Downtown	25	25	39	38	11	11
733	Berkeley - Downtown	26	26	47	47	19	19
759	Richmond	29	29	50	49	22	22
810	Concord	43	43	51	51	33	33
847	Walnut Creek	36	36	44	45	26	26
858	Danville	42	42	37	38	28	28
891	Antioch	56	56	64	65	46	46
From the North Bay							
917	Vallejo	43	43	64	64	36	36
942	Fairfield	56	56	72	72	49	49
963	Vacaville	63	63	78	79	56	56
977	Napa	60	60	81	80	53	53
992	Sonoma	66	66	92	91	64	64
1003	Petaluma	56	56	81	80	53	53
1024	Santa Rosa	71	71	96	96	69	68
1052	Novato	45	45	70	70	43	43
1077	San Rafael	35	35	60	60	33	33
1097	Sausalito	28	28	58	58	36	36

Table 14
Transit Times to Bay Area Airports, 2010 and 2020

zone	Neighborhood/Community	SFO 2010	SFO 2020	SJC 2010	SJC 2020	OAK 2010	OAK 2020
From the Peninsula							
1	San Francisco - Financial District	50	50	139	n/a	59	59
47	San Francisco - Richmond District	61	62	n/a	n/a	79	80
132	Daly City	35	35	139	n/a	78	78
184	San Mateo	33	32	101	90	103	104
219	Redwood City	41	40	90	78	112	111
From the South Bay							
245	Palo Alto	73	73	80	70	109	109
273	Mountain View	83	84	61	57	n/a	n/a
285	Sunnyvale	86	86	51	61	n/a	n/a
350	Cupertino	131	131	70	79	n/a	n/a
402	San Jose - Downtown	101	101	32	42	106	106
465	Milpitas	116	116	51	52	79	79
503	Morgan Hill	134	134	78	79	n/a	n/a
From the East Bay							
516	Livermore	108	109	n/a	n/a	77	78
552	Fremont	104	104	89	103	67	67
612	Hayward	86	86	101	111	51	51
699	Oakland - Downtown	61	61	117	127	52	52
733	Berkeley - Downtown	79	79	129	139	63	63
759	Richmond	98	98	137	147	82	82
810	Concord	98	98	n/a	n/a	108	108
847	Walnut Creek	93	93	n/a	n/a	103	103
858	Danville	108	109	n/a	n/a	77	77
891	Antioch	123	121	n/a	n/a	133	131
From the North Bay							
917	Vallejo	113	112	n/a	n/a	97	96
942	Fairfield	n/a	146	n/a	n/a	132	132
963	Vacaville	n/a	n/a	n/a	n/a	146	144
977	Napa	n/a	n/a	n/a	n/a	n/a	n/a
992	Sonoma	n/a	n/a	n/a	n/a	n/a	n/a
1003	Petaluma	n/a	149	n/a	n/a	n/a	n/a
1024	Santa Rosa	n/a	178	n/a	n/a	n/a	n/a
1052	Novato	149	147	n/a	n/a	n/a	n/a
1077	San Rafael	112	113	n/a	n/a	130	131
1097	Sausalito	113	114	n/a	n/a	120	121

Ground Access to Bay Area Airports
Data Summary

Prepared by the
Metropolitan Transportation Commission

December 1999

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2 Total Population and Total Employment to Closest Bay Area Airport, Based on AM Peak Public Transit Travel Time

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6 Total Population and Total Employment to Closest Bay Area Airport, Based on Off-Peak (Free-Flow) Drive Alone Travel Time

7 Total Population and Total Employment to Closest Bay Area Airport, Based on Off-Peak Public Transit Travel Time

8 Total Population and Total Employment Within 60 Minutes of Bay Area Airports, by Off-Peak (Free-Flow) Drive Alone Time, 1990 - 2020

9 Total Population and Total Employment Within 60 Minutes of Bay Area Airports, by Off-Peak Public Transit Travel Time

SUMMARY

1. This technical summary is intended as an overview of accessibility patterns to San Francisco Bay Area airports. The database for these tables are MTC's regional travel demand modeling system, including the ABAG's "Projections '98" databases, and MTC's model-simulated transit and highway travel times. Both weekday AM peak period and off-peak (mid-day) travel times are used in this analysis. The AM peak period travel times are based on a two-hour peak period definition, and does not include travel time delays associated with accidents and traffic incidents.

2. This report includes nine tables. The tabular data reports on the total population and total employment to the closest Bay Area airport, based on highway or transit door-to-door travel times. In addition to this "closest airport" analysis, the report includes information on population and employment within 60 minutes travel time of the three airports. The 60-minute cut-off value is a fairly arbitrary, but intuitive measure to describe the market area of the three airports.

Public Transit Issues

3. It is important to note that the term "public transportation" in this report excludes private scheduled operators, door-to-door services and taxis (e.g., airporter services, SuperShuttle). Public transportation in the context of this report includes regularly scheduled, fixed route service (e.g., BART, Caltrain, Oakland's AirBART service; AC Transit).

4. The 1995 MTC Airline Passenger Survey indicates that only 5.0 percent of Oakland Airport, 1.6 percent of San Francisco Airport, and 0.7 percent of San Jose Airport users took public transportation to or from the airport. The automobile – private plus rental cars – dominates airport access to Bay Area airports (85.3 percent of Oakland; 61.1 percent of San Francisco; 88.4 percent of San Jose) (1995 Metropolitan Transportation Commission Airline Passenger Survey: Final Report MTC, February 1996, Figure 7).

5. These fairly low levels of transit use to Bay Area airports is not surprising given the higher accessibility and speed of drive access to the airports as compared to transit access. In 1990, for example, only 11 percent of the Bay Area population were within 60 minutes transit travel time of Oakland International Airport. In comparison, 80 percent of the Bay Area population were within 60 minutes drive time of Oakland International (Tables 3 and 4).

Public Transit Improvements

6. Public transit accessibility to Bay Area airports is expected to improve over the next few years. With the completion of the BART to San Francisco International Airport extension (in 2001/02), the share of the Bay Area population within 60 minutes travel time of SFO is expected to increase from 4.1 percent of the region in 2000 to 15.5 percent of the region by the year 2010 (Table 4).

7. As a further examination of public transit accessibility to Bay Area airports, this analysis compares the MTC Regional Transportation Plan (RTP) to the MTC Blueprint for the 21st Century "Rail Alternative." This Blueprint Rail alternative includes, in addition to the BART extension to SFO, the Oakland Airport fixed guideway connection to BART, the BART extension to Warm Springs, a Santa Clara light rail extension to Warm Springs, and the electrification and upgrade of Peninsula (Caltrain) commuter rail service. This has the effect of doubling the transit accessibility to Oakland airport, and a 15 percent increase in the market area within 60 minutes transit travel time to San Jose International airport (Table 5).

Comparative Transit Accessibility to Bay Area Airports

8. The midday transit accessibility is less than the AM peak period due to less frequent transit service, and the restriction of midday transit access to walk-access only (compared to walk or auto access to transit in the AM peak period.) What is notable in this analysis is the impact of the BART extension to SFO on transit accessibility: central Contra Costa County is more accessible to SFO than to Oakland Airport, both for the peak and midday periods. This is due to a direct BART line from the Pittsburg/Concord line to SFO, comparing to a two-transfer journey from central Contra Costa to the Oakland Airport.

9. When comparing the RTP to the Blueprint Rail alternative the total transit travel times from central Contra Costa to Oakland are less than central Contra Costa to SFO. The Blueprint Rail alternative includes the Oakland Airport fixed guideway connection to BART; the RTP project alternative does not.

Comparative Highway Accessibility to Bay Area Airports

10. Oakland Airport is the closest Bay Area airport via highways for most of the East Bay and North Bay. For the year 2020 analysis, the highway travel times from Marin and Sonoma County are modestly shorter to Oakland than to SFO by about two to three minutes. The highway travel times from Marin and Sonoma Counties to SFO are slower due to travel time needed to cross over the Golden Gate and through the City of San Francisco.

11. San Francisco International Airport is the closest Bay Area airport to residents of San Francisco and San Mateo County. San Jose Airport is the closest airport to all residents of Santa Clara County, and to residents of Menlo Park, East Palo Alto, and the southern neighborhoods of Fremont.

Pro luction Notes / For More Information

12. The travel time databases were extracted from MTC's regional travel model system usir g the transportation planning software packages MINUTP and TP+. The statistical pacl age SAS was used to summarize the population and employment data, and to prepare the lata for use in MTC's Geographic Information System (GIS).

13. For more information on this data summary, please contact Mr. Chuck Purvis, MTC seni or transportation planner/analyst, at (510) 464-7731, or e-mail: cpurvis@mtc.ca.gov.

Table 1
Total Population and Total Employment to Closest Bay Area Airport
Based on AM Peak Drive Alone Travel Time

Total Population (in thousands)

	Total Population				Percent of Region			
Closest Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	1,336	1,476	1,548	1,559	22.2%	21.6%	20.9%	20.1%
San Jose (SJC)	1,707	1,977	1,982	2,053	28.3%	29.0%	26.8%	26.4%
Oakland (OAK)	2,978	3,371	3,867	4,162	49.5%	49.4%	52.3%	53.5%
Bay Area	6,021	6,824	7,397	7,774	100.0%	100.0%	100.0%	100.0%

Total Employment(in thousands)

	Total Employment				Percent of Region			
Closest Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	861	931	1,030	1,105	28.0%	26.9%	25.9%	25.1%
San Jose (SJC)	957	1,133	1,215	1,314	31.2%	32.7%	30.6%	29.9%
Oakland (OAK)	1,253	1,395	1,724	1,979	40.8%	40.3%	43.4%	45.0%
Bay Area	3,070	3,459	3,969	4,398	100.0%	100.0%	100.0%	100.0%

Total Population and Total Employment is from ABAG's Projections '98.

Table 2
Total Population and Total Employment to Closest Bay Area Airport
Based on AM Peak Public Transit Travel Time (excludes taxis, shuttles, airporters)

Total Population (in thousands)

	Total Population				Percent of Region			
Closest Airport	1990	2000	2010	2020	1990	2000	2010	2020
No Transit Access	837	1,006	631	723	13.9%	14.7%	8.5%	9.3%
San Francisco (SFO)	1,311	1,445	2,604	2,682	21.8%	21.2%	35.2%	34.5%
San Jose (SJC)	1,453	1,687	1,908	1,978	24.1%	24.7%	25.8%	25.4%
Oakland (OAK)	2,421	2,686	2,254	2,392	40.2%	39.4%	30.5%	30.8%
Bay Area	6,021	6,824	7,397	7,774	100.0%	100.0%	100.0%	100.0%

Total Employment(in thousands)

	Total Employment				Percent of Region			
Closest Airport	1990	2000	2010	2020	1990	2000	2010	2020
No Transit Access	299	373	242	291	5.0%	5.5%	3.3%	3.7%
San Francisco (SFO)	726	803	1,526	1,670	23.7%	23.2%	38.4%	38.0%
San Jose (SJC)	835	993	1,166	1,260	27.2%	28.7%	29.4%	28.6%
Oakland (OAK)	1,210	1,289	1,036	1,178	39.4%	37.3%	26.1%	26.8%
Bay Area	3,070	3,459	3,969	4,398	100.0%	100.0%	100.0%	100.0%

Total Population and Total Employment is from ABAG's Projections '98.

Note: BART to SFO service included in forecasts for years 2010 and 2020.

Table 3
Total Population and Total Employment Within 60 Minutes of Bay Area Airports by AM Peak Drive Alone Time, 1990 - 2020

Total Population within 60 Minutes Drive Time (in thousands)

	Total Population				Percent of Region			
Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	4,048	*4,055*	*4,060*	4,067	67.2%	59.4%	54.9%	52.3%
San Jose (SJC)	3,672	*3,700*	*3,750*	3,807	61.0%	54.2%	50.7%	49.0%
Oakland (OAK)	4,818	5,377	5,681	5,848	80.0%	78.8%	76.8%	75.2%
Bay Area	6,021	6,824	7,397	7,774	100.0%	100.0%	100.0%	100.0%

Total Employment within 60 Minutes Drive Time (in thousands)

	Total Employment				Percent of Region			
Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	2,378	*2,450*	*2,575*	2,689	77.4%	70.8%	64.9%	61.1%
San Jose (SJC)	1,869	*2,000*	*2,100*	2,254	60.9%	57.8%	52.9%	51.3%
Oakland (OAK)	2,666	2,954	3,248	3,562	86.8%	85.4%	81.8%	81.0%
Bay Area	3,070	3,459	3,969	4,398	100.0%	100.0%	100.0%	100.0%

Note: Values in italics are interpolated values and are not model simulations.

Table 4
Total Population and Total Employment Within 60 Minutes of Bay Area Airports by AM Peak Door-to-Door Public Transit Time, 1990 - 2020

Total Population within 60 Minutes Public Transit Travel Time (in thousands)

	Total Population				Percent of Region			
Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	253	282	1,146	1,154	4.2%	4.1%	15.5%	14.8%
San Jose (SJC)	592	691	863	891	9.8%	10.1%	11.7%	11.5%
Oakland (OAK)	642	693	731	742	10.7%	10.1%	9.9%	9.5%
Bay Area	6,021	6,824	7,397	7,774	100.0%	100.0%	100.0%	100.0%

Total Employment within 60 Minutes Public Transit Travel Time (in thousands)

	Total Employment				Percent of Region			
Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	306	338	830	892	10.0%	9.8%	20.9%	20.3%
San Jose (SJC)	436	508	727	780	14.2%	14.7%	18.3%	17.7%
Oakland (OAK)	462	468	538	572	15.1%	13.5%	13.5%	13.0%
Bay Area	3,070	3,459	3,969	4,398	100.0%	100.0%	100.0%	100.0%

Table 5
Total Population and Total Employment Within 60 Minutes of Bay Area Airports by AM Peak Door-to-Door Public Transit Time, 1990 - 2020
Compare MTC 1998 RTP Project Alternative to Blueprint Rail Alternative

Total Population within 60 Minutes Public Transit Travel Time (in thousands)

	RTP	Blueprint Rail	Percent of Region	
Airport	2020	2020	RTP	Blueprint Rail
San Francisco (SFO)	1,154	1,147	14.8%	14.8%
San Jose (SJC)	891	1,024	11.5%	13.2%
Oakland (OAK)	742	1,444	9.5%	18.6%
Bay Area	7,774	7,774	100.0%	100.0%

Total Employment within 60 Minutes Public Transit Travel Time (in thousands)

	RTP	Blueprint Rail	Percent of Region	
Airport	2020	2020	RTP	Blueprint Rail
San Francisco (SFO)	892	883	20.3%	20.1%
San Jose (SJC)	780	775	17.7%	17.6%
Oakland (OAK)	572	1,121	13.0%	25.5%
Bay Area	4,398	4,398	100.0%	100.0%

The 1998 RTP (Regional Transportation Plan) includes the BART extension to SFO.

The Blueprint Rail Alternative includes, in addition to the BART extension to SFO, the Oakland Airport people-mover, the BART extension to Warm Springs, the Santa Clara light rail extension to Warm Springs, and electrification/upgrade of Peninsula (Caltrain) commuter rail service.

Table 6
Total Population and Total Employment to Closest Bay Area Airport
Based on Off-Peak (Free-Flow) Drive Alone Travel Time

Total Population (in thousands)

	Total Population				Percent of Region			
Closest Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	1,384	1,523	1,578	1,589	23.0%	22.3%	21.3%	20.4%
San Jose (SJC)	1,725	2,000	2,129	2,208	28.6%	29.3%	28.8%	28.4%
Oakland (OAK)	2,912	3,301	3,690	3,978	48.4%	48.4%	49.9%	51.2%
Bay Area	6,021	6,824	7,397	7,774	100.0%	100.0%	100.0%	100.0%

Total Employment(in thousands)

	Total Employment				Percent of Region			
Closest Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	885	956	1,031	1,107	28.8%	27.6%	26.0%	25.2%
San Jose (SJC)	979	1,158	1,313	1,420	31.9%	33.5%	33.1%	32.3%
Oakland (OAK)	1,206	1,345	1,626	1,872	39.3%	38.9%	41.0%	42.6%
Bay Area	3,070	3,459	3,969	4,398	100.0%	100.0%	100.0%	100.0%

Total Population and Total Employment is from ABAG's Projections '98.

Table 7
Total Population and Total Employment to Closest Bay Area Airport
Based on Off-Peak Public Transit Travel Time (excludes taxis, shuttles, airporters)

Total Population (in thousands)

	Total Population				Percent of Region			
Closest Airport	1990	2000	2010	2020	1990	2000	2010	2020
No Transit Access	1,979	2,319	1,961	2,193	32.9%	34.0%	26.5%	28.2%
San Francisco (SFO)	1,495	1,644	2,244	2,292	24.8%	24.1%	30.3%	29.5%
San Jose (SJC)	1,326	1,535	1,674	1,728	22.0%	22.5%	22.6%	22.2%
Oakland (OAK)	1,221	1,326	1,518	1,562	20.3%	19.4%	20.5%	20.1%
Bay Area	6,021	6,824	7,397	7,774	100.0%	100.0%	100.0%	100.0%

Total Employment (in thousands)

	Total Employment				Percent of Region			
Closest Airport	1990	2000	2010	2020	1990	2000	2010	2020
No Transit Access	780	932	798	945	13.0%	13.7%	10.8%	12.2%
San Francisco (SFO)	1,021	1,090	1,467	1,593	33.3%	31.5%	37.0%	36.2%
San Jose (SJC)	734	882	1,018	1,104	23.9%	25.5%	25.7%	25.1%
Oakland (OAK)	535	555	685	757	17.4%	16.0%	17.3%	17.2%
Bay Area	3,070	3,459	3,969	4,398	100.0%	100.0%	100.0%	100.0%

Total Population and Total Employment is from ABAG's Projections '98.

Note: BART to SFO service included in forecasts for years 2010 and 2020.

Table 8
Total Population and Total Employment Within 60 Minutes of Bay Area Airports by Off-Peak (Free-Flow) Drive Alone Time, 1990 - 2020

Total Population within 60 Minutes Off-Peak Drive Time (in thousands)

	Total Population				Percent of Region			
Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	5,366	6,029	6,548	6,792	89.1%	88.3%	88.5%	87.4%
San Jose (SJC)	4,820	5,424	5,849	6,046	80.1%	79.5%	79.1%	77.8%
Oakland (OAK)	5,536	6,252	6,809	7,104	91.9%	91.6%	92.0%	91.4%
Bay Area	6,021	6,824	7,397	7,774	100.0%	100.0%	100.0%	100.0%

Total Employment within 60 Minutes Off-Peak Drive Time (in thousands)

	Total Employment				Percent of Region			
Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	2,824	3,158	3,610	3,971	92.0%	91.3%	90.9%	90.3%
San Jose (SJC)	2,631	2,934	3,334	3,636	85.7%	84.8%	84.0%	82.7%
Oakland (OAK)	2,888	3,233	3,702	4,079	94.1%	93.5%	93.3%	92.7%
Bay Area	3,070	3,459	3,969	4,398	100.0%	100.0%	100.0%	100.0%

Note: Values in italics are interpolated values and are not model simulations.

Table 9
Total Population and Total Employment Within 60 Minutes of Bay Area Airports by Off-Peak (Midday) Door-to-Door Public Transit Time, 1990 - 2020

Total Population within 60 Minutes Off-Peak Public Transit Travel Time (in thousands)

	Total Population				Percent of Region			
Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	243	272	754	755	4.0%	4.0%	10.2%	9.7%
San Jose (SJC)	143	173	306	321	2.4%	2.5%	4.1%	4.1%
Oakland (OAK)	200	215	308	308	3.3%	3.1%	4.2%	4.0%
Bay Area	6,021	6,824	7,397	7,774	100.0%	100.0%	100.0%	100.0%

Total Employment within 60 Minutes Off-Peak Public Transit Travel Time (in thousands)

	Total Employment				Percent of Region			
Airport	1990	2000	2010	2020	1990	2000	2010	2020
San Francisco (SFO)	336	371	651	695	11.0%	10.7%	16.4%	15.8%
San Jose (SJC)	170	207	360	388	5.5%	6.0%	9.1%	8.8%
Oakland (OAK)	138	142	318	329	4.5%	4.1%	8.0%	7.5%
Bay Area	3,070	3,459	3,969	4,398	100.0%	100.0%	100.0%	100.0%

Regional Airport System Plan

Update 2000

Airport Emissions in the San Francisco Bay Area

2000 Regional Airport System Plan Update

Airport Emissions in the San Francisco Bay Area

for
San Francisco International Airport
Oakland International Airport
San Jose International Airport

Prepared for the
Regional Airport Planning Committee

Prepared by the
Bay Area Air Quality Management District and the
Metropolitan Transportation Commission

October 31, 2000
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Airport Emissions in the San Francisco Bay Area

Introduction

Compared to traditional stationary sources of air pollution such as power plants and oil refineries, airports are among the largest sources of air pollution in large urban areas such as the Bay Area. Known to regulators as "indirect sources," airports are also one of the most difficult sources to represent in an emissions inventory, given the wide variety of activity taking place at airports. Accurate emissions inventories are very important for air quality planning, as they are the starting point for determining which sources could yield emission reductions that would contribute to achieving clean air.

The current inventory produced by the Bay Area Air Quality Management District (BAAQMD) for 1995 includes all the activities at the commercial, general aviation and military airports, but does not separately identify car, shuttle, bus and truck travel to and from each airport (see Table 1 and Figure 1). In addition, the latest federal ozone attainment plan includes emission estimates for the year 2000. Emission inventories are typically prepared for shorter range "attainment" years, (however, the BAAQMD has the ability to forecast an emissions inventory for any year through 2020).

Table 1 -- 1995 Emissions Inventory (in Tons per Day)

Emissions Source	Volatile Organic Compounds (VOC)	Oxides of Nitrogen (NOx)
Commercial Aircraft	3.6	17.0
On-Road Motor Vehicles	273.7	326.3
Total Emissions Inventory	562.0	626.0

Environmental impact reports prepared for airport expansion projects have quantified total airport emissions, including vehicle trips to and from the airports. Finally, as part of this update, the Regional Airport Systems Plan independently had projected future activity at the large commercial airports – San Francisco, Oakland and San Jose –and provided emissions projections both for aircraft and air passenger and airport employee trips. **While emissions calculations were made, the numbers have been removed, pending further review by the airports.**

Airports "generate" emissions from a variety of different activities that occur both on- and off-site – aircraft in flight, taxiing and idling; fueling and servicing of the aircraft; on- and off-site shuttle vehicles and buses; motor vehicle trips to and from the airport, etc. No one entity is responsible for this wide array of activity; thus reducing emissions at airports poses a tremendous challenge.

In contrast to many stationary and mobile sources, similar strides have not been made in reducing emissions from aircraft engines. (Engine retooling has focused more on noise reduction due to concern of those living near airports.) Recent efforts to reduce emissions from shuttles and aircraft service vehicles are beginning to yield small reductions in emissions. However, over the next twenty years, commercial aircraft emissions at the region's three commercial airports will grow substantially. In contrast to other sources for which reduced emissions are projected, airports will represent a larger share of the Bay Area's emissions in the future. Therefore, the regulatory agencies, airports and aircraft manufacturers are interested in taking steps to reduce airport emissions.

Recent reports have raised concern over airports being large emitters of toxic air contaminants. To determine potential health risks for Bay Area airports, monitoring data would be needed over some reasonable time period to assess concentrations of pollutants (health studies at one airport are not directly transferable to other airports due to different terrain and meteorology which affect concentrations). There is no information available to this study on the Bay Area airports.

Pollutants of Concern

The Bay Area is a nonattainment area for both the state and national ozone standards and the state particulate standard, and is either attainment or unclassified for all other air pollution standards. Thus, the main pollutants of concern for airports are oxides of nitrogen (NOx) and reactive organic gases (ROG), which are ozone precursors, and fine particulate matter. Aircraft produce significantly more NOx than ROG, motor vehicles coming to the airport produce the two pollutants in roughly equal amounts, and buses and trucks produce more NOx than ROG. Thus, from the perspective of airports' contribution to regional emissions that lead to the formation of ozone, NOx is the pollutant deserving greatest attention.

From a more local perspective, the many diesel vehicles at airports emit fine and very fine particulate matter, PM_{10} and $PM_{2.5}$, respectively. Recent research has documented a significant public health effect from even modest particulate levels, with the effect being progressively greater as levels rise. The new federal PM standards (promulgated in 1997) are under review by the Supreme Court. If the standards are upheld, the emphasis on reducing particulate emissions will be increased, and airports would be a potential source of emission reductions.

Toxic emissions are also of concern, given the sheer volume of fuel burned in a limited and, in some cases, confined area (e.g., parking structures) or for employees who have a long duration of exposure (e.g., baggage handlers). Fortunately, Bay Area airports benefit from good ventilation due to their proximity to the high average wind speeds of San Francisco Bay. Efforts to reduce reactive organic gases will also reduce toxic emissions.

Au hority to Regulate

Gi en that aircraft and motor vehicles contribute the bulk of airport emissions, there is ver little that can be done at the regional level to achieve *significant* emission red ictions. The U.S. Environmental Protection Agency (EPA) regulates aircraft engine sta dards, and the Air Resources Board (ARB) regulates motor vehicle emissions in Cal fornia.

In 1997, EPA adopted the voluntary NOx and carbon monoxide aircraft engine standards of t e United Nations International Civil Aviation Organization, bringing U.S. standards int alignment with international standards. (Prior to 1997, EPA had only regulated eng ne smoke and fuel venting from aircraft.) Manufacturers are already meeting these sta dards due to technology changes to jet engines made for the purpose of noise red ction around airports. Thus overall aircraft emissions will increase in the future due to i creased aircraft operations.

Mo or vehicle engine emissions have been reduced greatly over the past 20 years due to tec nology-forcing standards of ARB. ARB has adopted a low emission vehicle program tha will continue to result in large emissions reductions over the next 10 to 20 years.

AR 3 also has a role in approving the airport expansion projects through the U.S. Airport Im rovement Act. Where future increases in airport emissions have not been included in fed ral air quality plans, ARB may condition the airport to include mitigation measures tha reduce the unplanned increase in emissions.

Lo al air agencies do not have a key role in regulating airports. In 1997, the Bay Area Air Quality Management District included two control measures in its State Clean Air Pla – the conversion of ground support equipment to alternative fuels, and ground power sys ems at airport terminals. However, adoption of regulations to mandate these me sures may not be needed since airports already plan to implement these as part of thei expansion projects.

The Air District has funded several projects to reduce emissions at Bay Area airports over the ast five years: replacement of gasoline- and diesel-powered vehicles with clean air veh cles, and subsidies for the operation of buses to nearby rail stations to increase the nun ber of people using mass transit.

Em ssion Projections

As nentioned above, the update proposed new emission estimates, which were intended pri arily to indicate trends in motor vehicle and aircraft emissions. These estimates are the subject of further revisions by the airports and federal and state air agencies and will be i cluded in this report after further review. These are not the same estimates that wo ld be used in preparing updated federal and state air quality plans, as these plans

typically designed to achieve the applicable federal and state standards in a shorter timeframe (e.g. 3 to 5 years). Additionally, the Air District uses an average day in their planning inventory whereas we have based this trend analysis on our design day to be consistent with the airport and airspace capacity analysis (the August design day is consistent with the peak ozone season from May to October). Nevertheless, the trends would be the same for the aircraft and auto emissions.

When completed, the resulting inventory will be estimated for aircraft and automobiles by source (see Table 2).

Table 2 -- Bay Area Mobile Source Emissions, 1999-2020

Reactive Organic Gases (ROG) (Tons per Day)

Year	**1999**	**2010**	**2020**
Aircraft	TBD	TBD	TBD
Air Passengers	TBD	TBD	TBD
Airport Employees	TBD	TBD	TBD
TOTAL	TBD	TBD	TBD

Oxides of Nitrogen (NOX) (Tons per Day)

Year	**1999**	**2010**	**2020**
Aircraft	TBD	TBD	TBD
Air Passengers	TBD	TBD	TBD
Airport Employees	TBD	TBD	TBD
TOTAL	TBD	TBD	TBD

Note: Emissions for aircraft and air passengers have been calculated for the average day of the peak month. The aircraft category includes commercial and general aviation aircraft using air carrier runways only.

Potential Emission Reduction Strategies

At this time, the best and most direct approach is to advocate and obtain support for tighter international aircraft engine standards, which would reduce emissions as airlines replace their fleets. This is a longer-term strategy given the research and development requirements and the negotiations with the international government and airline organizations. NASA has a research goal of reducing engine emissions by a factor of 3 in 10 years and 5 in 20 years, but at this point these reductions are merely goals.

The most promising near-term emission reduction strategies that can be implemented through local efforts are (1) to encourage the use of public and private transit service to San Francisco, Oakland and San Jose airports, and (2) to facilitate the conversion of

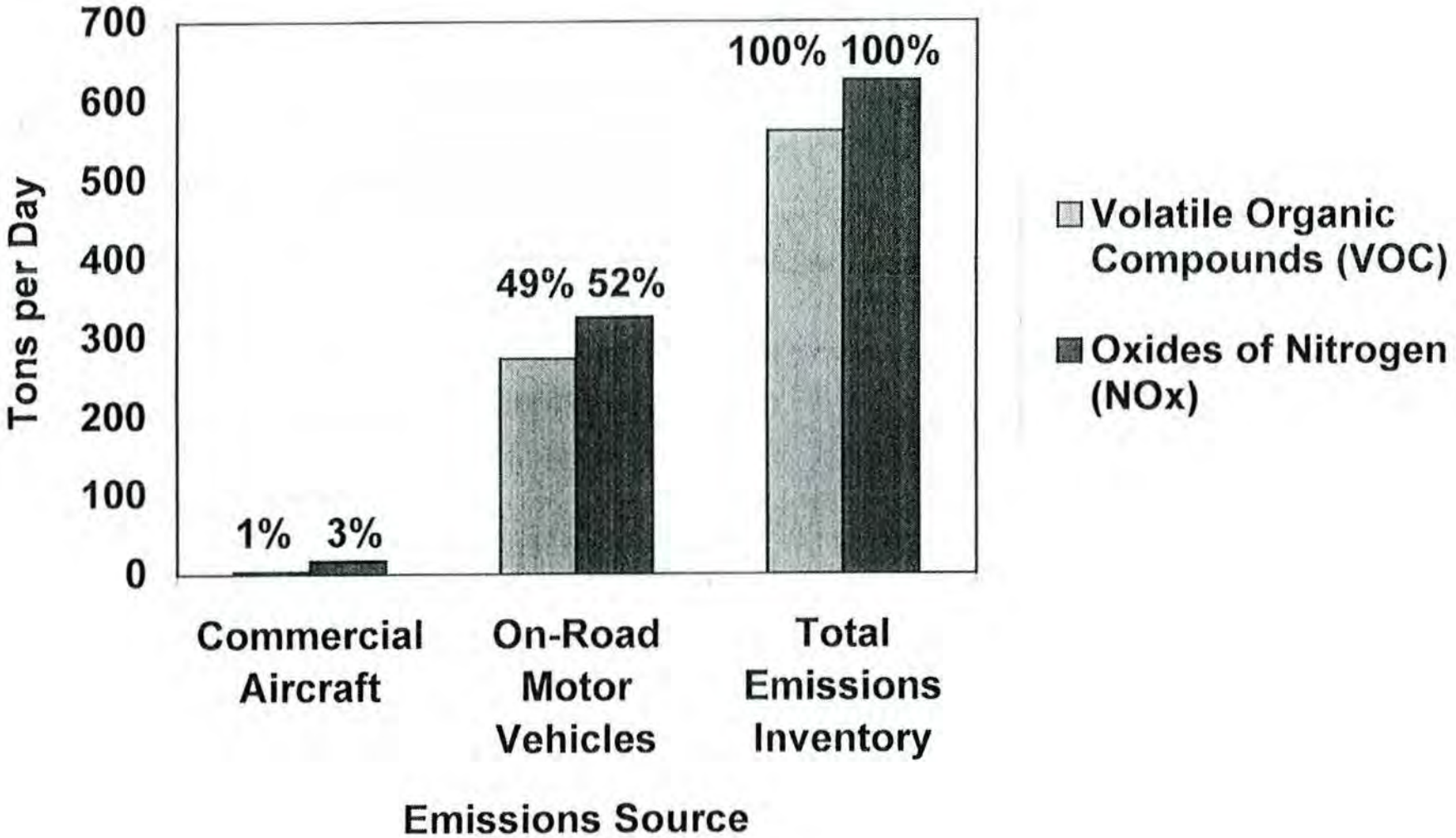
shu tles, buses and ground support equipment to clean fuels. To a large degree, better trar sit is a key element of all the airports' expansion plans, and both employees and pas engers are increasingly expected to take advantage of improved transit options. Fur hermore, airports could provide additional transit subsidies for their employees to low er fares to and from airports.

Co version of vehicles and equipment to clean fuels has only recently begun, and much mo e could be achieved in this area. Incentives are probably the best mechanism to enc urage the shift to cleaner equipment. As an example, San Francisco airport is allo wing taxis to occasionally bypass queues if they are clean-fueled to give operators a visi le incentive to purchase a clean air vehicle. Airports could adjust their trip fees for shu tles, buses and taxis to encourage clean air equipment, and could provide the nec ssary refueling/recharging infrastructure to support the new vehicles. Airport-owned equ pment could all be converted to the lowest emission vehicle available to provide a visi le example to tenants and operators.

Air orts plan to reduce the need for aircraft to run auxiliary power units at the gates by inst lling ground power systems at new, and when feasible, existing gates. This will red ce power unit emissions when pilots know they will be parked at the gate for exte nded periods of time. Airports could retrofit existing gates with this capability as soo as possible.

Las ly, changes to the equipment used in aircraft refueling may provide additional emi sion reductions. Smaller planes use uncontrolled, over-the-wing, refueling, which doe not prevent any fuel vapor from escaping to the atmosphere. A booted nozzle would be c f some benefit. Larger craft use a single point pressure system with a closed con ection, with vapors vented to the atmosphere through vents on the wings. Opp ortunities may exist to modify the system to recover these vapors.

Figure 1 - 1995 Emissions Inventory



Regional Airport System Plan

Update 2000

Airports and Bay Area Earthquakes

Regional Airport System Plan
Update 2000

Airports and Bay Area Earthquakes Report

Prepared for the
Regional Airport Planning Committee

Prepared by the
Association of Bay Area Governments

September 2000

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MTC METROPOLITAN TRANSPORTATION COMMISSION

ABAG ASSOCIATION OF BAY AREA GOVERNMENTS

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FINDINGS – EARTHQUAKES AND AIRPORTS

What Are the Threats to Airport Operations Following Future Earthquakes in the Bay Area?

Based on past experience in California and other recent earthquakes, the threats to Bay Area airport operations following future earthquakes fall into four general categories:

- liquefaction damage to airport runways, particularly at San Jose (until the new runways are completed), Oakland, San Francisco, and, perhaps, Moffett Federal Airfield;
- shaking damage to air control and terminal facilities, particularly older facilities that may be present at Oakland, Moffett, Hayward, San Francisco, Half Moon Bay, Buchanan, and Livermore airports;
- power and communications disruptions; and
- disruptions to the transportation systems serving the airports.

Our Airport Systems Can and Should Be Made More Earthquake-Ready!

1. **We need to better understand and mitigate the liquefaction hazard to runways.** Thus, we need to expand on the liquefaction analysis conducted for the runways at the three major airports (OAK, SFO, and SJC) to:
   - gain further information on the vulnerability of other major airports, particularly Moffett Federal Airfield on the Peninsula and Travis Air Force Base in Solano County, and, if feasible, Buchanan, Hayward, and Livermore in the East Bay; and
   - incorporate more recent geotechnical information becoming available for OAK, SJC and SFO.

   We need to ensure that the design of new runways also mitigates liquefaction hazards associated with the connections to the existing runway system. Any runway expansions at SFO and OAK that tie into sections of existing runways which are vulnerable to liquefaction will make the expansions vulnerable as well. Current runway work at SJC is designed to minimize the liquefaction hazard.

2. **We need to improve emergency planning at individual airports and to better coordinate emergency planning among airports and with other forms of transportation.** Some ideas focusing on employees and operations at individual airports are listed at the end of this report. However, airport participation in coordinated emergency planning is also essential. MTC is starting this planning as part of the integrated Trans Response Plan (TRP) for earthquakes.

3. **We need to identify alternate locations capable of handling large commercial and cargo jets after an earthquake should Bay Area commercial airports loose capacity due to road transportation system disruptions, runway damage, or structural damage.** Travis AFB will have increased air and vehicle traffic during the post-earthquake emergency response phase because the federal government plans on using Travis AFB as the primary mobilization center for their response to the disaster. With the normal operations that Travis has in addition to this major role, emergency planners should not believe that Travis has additional capacity for other commercial or cargo needs. Options include neighboring commercial airports (Sacramento, Stockton, Monterey, etc.), as well as larger general aviation airports.

THE ISSUE – WHY WORRY ABOUT AIRPORT DISRUPTIONS FOLLOWING FUTURE EARTHQUAKES IN THE BAY AREA?

Airports Are Part of Our Transportation System

We need our transportation systems to be functional after earthquakes for two principal reasons:

1. Emergency responders need to use transportation systems, including airports, after earthquakes.
2. Transportation system disruptions, including disruptions to airports, can have a severe impact on a region's economy for months, if not years (Brady and Perkins, 1998).

Airports as Intersections

Airports are critical points in our transportation system because they function as intersections, not between two freeways, but between our air space and our land-side transportation. Yet, just as damage to a major interchange or bridge in an earthquake can have impacts far beyond the local area, so can damage to an airport, particularly one of the principal international airports in the Bay Area.

Focus on Major Airports

Although the focus of this report is on the three major airports, other airports are also discussed in the context of the potential problems at these facilities in comparison to the three international airports.

Other Emergency Planning Efforts

ABAG held a series of five subregional workshops discussing hypothetical road and rail closures resulting from selected scenario earthquakes in October and November 1998. "Tabletop" disaster drills and extensive discussion led to identification of the major issues, interagency dependencies, and areas of potential conflict likely to face transportation providers, governments, utilities and businesses as they struggle to address the transportation impacts after a large earthquake. The ***Riding Out Future Quakes – Ideas for Action*** report (Perkins and others, 1999) is both the proceedings of those workshops, as well as a tool to inspire innovative planning for minimizing transportation disruption following future earthquakes. One conclusion of these workshops was that airports are critically important in the region's response and recovery to earthquakes.

At the same time, MTC is continuing to test and refine the Trans Response Plan (TRP) which integrates response and recovery efforts among all modes of transportation. The TRP coordinates the activities of MTC, Caltrans, State and local Offices of Emergency Services, and other transportation providers, including transit agencies and airports.

Objectives of ABAG Report for Fall 2000

In the fall of 2000, ABAG expects to produce a report on airports and Bay Area earthquakes. The objectives of that effort are:

1. To develop a long-term partnership among air transportation providers, users, the earthquake research community, and earthquake responders to foster cooperation for response and recovery.
2. To assess the vulnerability of our air transportation system to land-side access issues given the scenario earthquakes considered likely for the San Francisco Bay Area.
3. To assist in collaborative planning for emergency response among the airports, and together with emergency responders and cargo carriers. Emergency responders are depending on our airports for delivering disaster cargo and disaster relief workers.
4. To identify methods for minimizing the impact of reduced land-side access following future earthquakes, thereby minimizing the potential impacts on airport business, the cargo industry, and the regional economy.
5. To provide increased public awareness and support of emergency planning activities at and among airports.

Questions to Be Addressed in ABAG Report for Fall 2000

The report will address the following questions:

1. What are the options for bringing in relief aircraft if all runways at one or more major airports are damaged beyond immediate repair?
2. What concerns should airport safety managers be addressing? What specific Bay Area earthquake issues should be included in airport earthquake and disaster plans?
3. What are the potential problems and possible solutions related to land-side access?
4. How should airport and other agency emergency plans be improved to deal with damage to and access related to airports following an earthquake?
5. If an airport lifeline network is established, what are the critical land-side components of that network (control towers, runways, key access routes, etc.)?
6. What are the opportunities in design and construction available for new runways and runway segments constructed to comply with new FAA safety regulations?

Thus, the findings that follow should be considered preliminary and will be refined during the remainder of 2000.

THE PROBLEM – WHAT HAPPENED LAST TIME?

1989 Loma Prieta Earthquake

The magnitude 6.9 Loma Prieta earthquake occurred in the Santa Cruz mountains near the border of Santa Cruz and Santa Clara counties. Because the earthquake source fault was far south of the main urban center of the Bay Area, it only serves as a wake-up call for what might happen in a closer or larger magnitude earthquake. Thus, it is inappropriate to assume that since a problem did not occur in this earthquake, it will not occur in the future.

San Francisco International Airport (SFO) was over 35 miles from the fault source for the Loma Prieta earthquake. Although operations at SFO officially halted for one night, this was not due to any significant damage to the facilities or the runways. The control tower sustained window and non-structural damage, and some unanchored equipment was broken, but this did not prevent the tower from operating. ***The primary reason for the shutting down of flights during that night was that not enough controllers were available to operate the tower safely.*** The runways (built on fill), navigational equipment, runway lights, fuel tanks, and piping were mostly unaffected. However, liquefaction (a process where loose water-saturated sands temporarily behave like a liquid when shaken) shifted some small support structures. Lost power was restored within 3 hours, well before the time the airport was reopened. Non-structural damage occurred in the terminals, but did not cause the airport to be shut down. Damage to an air cargo building was significant, and problems transpired with a power transformer, but these were remedied over time without air operations being affected. ***There were no problems with access road failures or freeway closures within the immediate vicinity of this airport that contributed to closure. However the ability of the controllers to travel to work safely and quickly was an issue*** (EERI, 1990).

Oakland International Airport (OAK) was also affected by the Loma Prieta earthquake, in spite of its location over 40 miles from the fault source for the earthquake. These problems affected airport operations. Its main 10,000-foot runway, built on hydraulic fill over Bay mud, was severely damaged by liquefaction; 3,000 feet of the runway sustained cracks, some of them were a foot wide and a foot deep. Spreading of the adjacent unpaved ground resulted in cracks up to 3 feet wide. Large sand boils appeared on the runway and adjacent taxiway, a few as wide as 40 feet (EERI, 1990). As a result, OAK was immediately shut down to evaluate runway damage. A shorter 6,212-foot general aviation runway was used to accommodate diverted air traffic for a couple of hours before the main runway was reopened with a usable length of only 7,000 feet. This shorter runway length impacted cargo loads during takeoff. Over the next 30 days, 1,500 feet of the 3,000 foot damaged section of the runway was repaired using an emergency repair order for resurfacing and crews already present during the earthquake. An adjacent taxiway was also damaged by liquefaction. Repairs of this taxiway segment and the final 1,500 feet of the main runway were completed six months later, after a competitive bidding process (T. LaBasco, S. Kopacz, and J. Serventi, Port of Oakland, personal comm., September, 2000). Post-earthquake communications were difficult

at OAK, as both telephone service and the usable radio frequency became quickly overloaded, affecting both cleanup crews and the public on-site at the time of the earthquake. Other damage was limited – for example, the control tower lost three windows, a walkway between terminals was damaged, and a water main ruptured causing a service road to collapse (EERI, 1990).

San Jose International Airport (SJC) was located approximately 15 miles from the fault source of the Loma Prieta earthquake. The control tower lost a window and had non-structural problems; other cosmetic damage occurred at the terminal. Commercial power was lost for over 5 hours, but backup generators worked well. No problems affected operations, which were shut down only briefly to assess damage. The airport was considered as an alternative airfield if flights needed to be diverted from San Francisco or Oakland. The main reason this did not occur was the lack of refueling capabilities at San Jose (rendering takeoff of most of those planes impossible) rather than damage due to the earthquake. No road failures at or near the airport were reported (EERI, 1990).

No damage was reported at smaller airports in the Bay Area (EERI, 1990). Smaller amounts of damage would be expected because these airfields generally have fewer facilities.

1994 Northridge Earthquake

The magnitude 6.7 Northridge earthquake occurred on a fault buried beneath the San Fernando Valley of Los Angeles.

The three airports in the area with most severe shaking in the Northridge earthquake were closed for runway and taxiway inspections. However, all three were reopened quickly when the inspections were completed and showed no significant damage.

Van Nuys Airport, a general aviation airport close to the area with the highest shaking intensity, had some window glass breakage in the control tower (EERI, 1995).

Burbank Airport, a commercial airport located just east of the fault source, was closed for approximately five minutes while the runways and taxiways were inspected. The terminal building was closed for approximately two hours for inspection and to allow cleanup of fallen ceiling tiles (EERI, 1995).

The Los Angeles International Airport (LAX), located almost 20 miles south of the fault source, was closed for several hours for inspection. Due to a power loss of approximately one hour, the emergency generator power backup was used and functioned. Some ceiling tiles fell, and there were some water leaks at pipe joints (EERI, 1995).

1995 Kobe, Japan Earthquake

The Kansai International Airport serving the Kobe and Osaka region was less than a year old at the time of the earthquake, completed in 1994. It lies approximately 20 miles from the most heavily shaken area on a man-made island. The Itami Airport, the former international airport for the region, now handles domestic flights. It lies approximately 6 miles from the most heavily damaged area. Neither airport sustained significant structural damage.

The Vulnerabilities – What Problems Do We Expect?

Based on the past experiences described in the previous section, the principal problems that can disrupt airport operations after a future earthquake are:

1. liquefaction damage to airport runways;
2. damage to air control and terminal facilities;
3. power and communications disruptions; and
4. disruptions to the transportation system serving the airports.

These problems can result from any of a number of earthquake scenarios on faults shown on Figure 1.

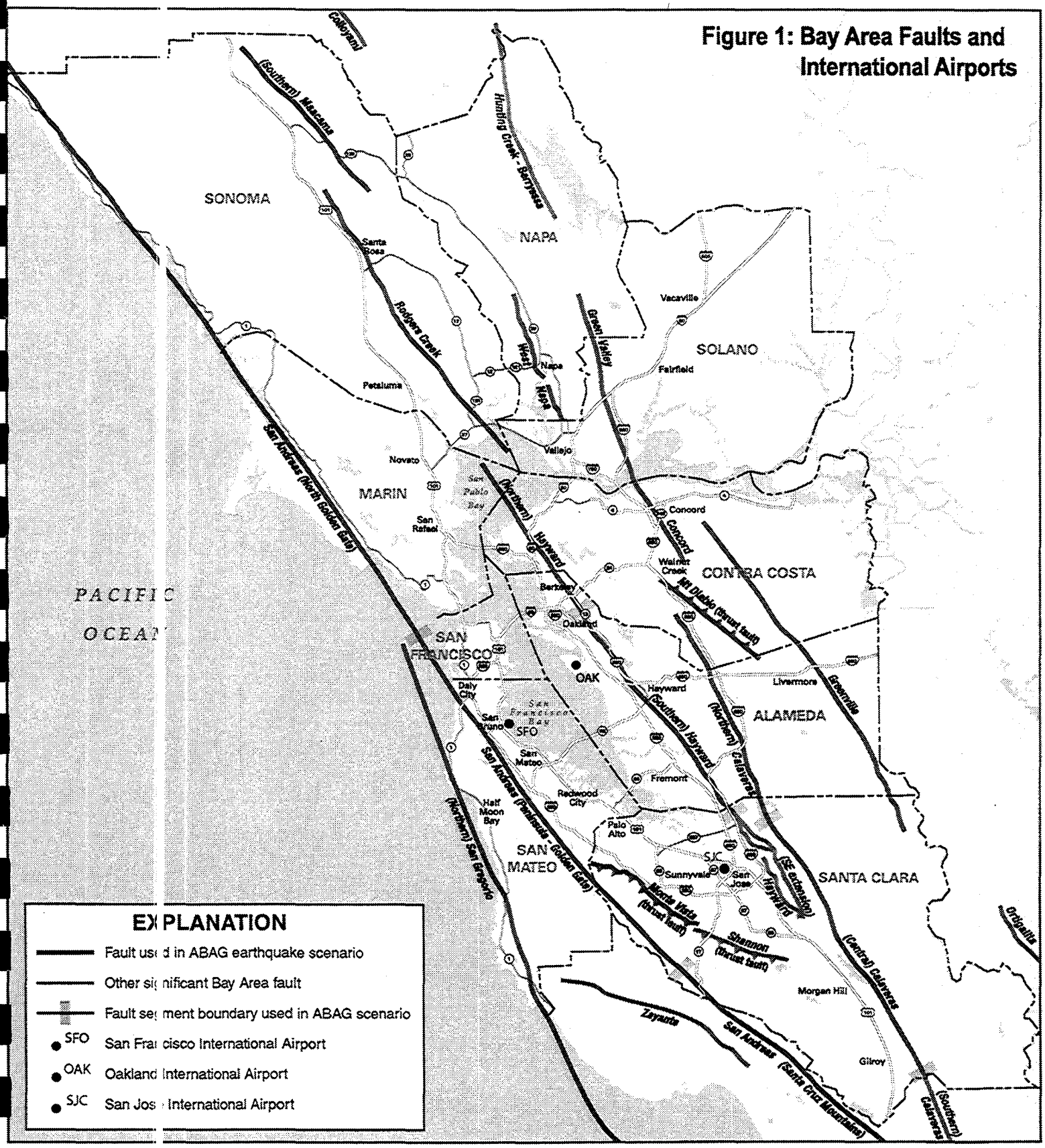
ISSUE 1 – Liquefaction Damage to Airport Runways

When the ground liquefies, sandy materials saturated with water can behave like a liquid, instead of like solid ground. The ground appears to sink or pull apart. Sand boils, or sand "volcanoes," can appear. When this ground "failure" occurs, it can cause damage to paved areas, pipelines, and building foundations. These failures take the form of:

- flows and lateral spreads (essentially landslides on flat or nearly flat ground next to rivers, harbors, or drainage channels);
- ground oscillations (or movement of the liquefied layer of ground separately from the surrounding layers);
- loss of bearing strength (to hold up buildings or hold tanks underground); and
- settlement and differential (uneven) settlement.

ABAG earthquake hazard maps show portions of all three commercial airports in areas with very high liquefaction susceptibility. Thus, ABAG contracted with William Lettis & Associates (WLA) to prepare a preliminary assessment of the susceptibility of runways at the three major Bay Area airports to earthquake-induced liquefaction – ***Evaluation of Earthquake-Induced Liquefaction Hazards at the San Francisco Bay Area Commercial Airports*** (WLA, 1999). The distribution and magnitude of liquefaction-induced settlement and differential settlement estimated by WLA varies from facility to facility, and across each facility. ABAG staff have assumed that the size of these estimated differential settlements are sufficient to close runways in at least one likely earthquake. These analyses have been supplied to the three commercial airports to aid them when they conduct further studies to characterize the limits and amount of liquefaction-related deformation and to plan for disruptions.

WLA developed preliminary liquefaction hazard maps for each airport (Figures 2 – 4). These maps show areas susceptible to liquefaction and the amount of potential liquefaction-induced settlement (in feet). The hazard maps are based on a separate maximum likely earthquake event for each individual airport, and incorporate conservative assumptions regarding liquefaction susceptibility and subsurface conditions. Therefore, the estimated settlement values likely represent a maximum for any realistic earthquake event in the San Francisco Bay Area based on our current knowledge of how Bay Area faults behave. Additional subsurface information would allow refined estimates of settlement extent and magnitude that incorporate less conservative assumptions.



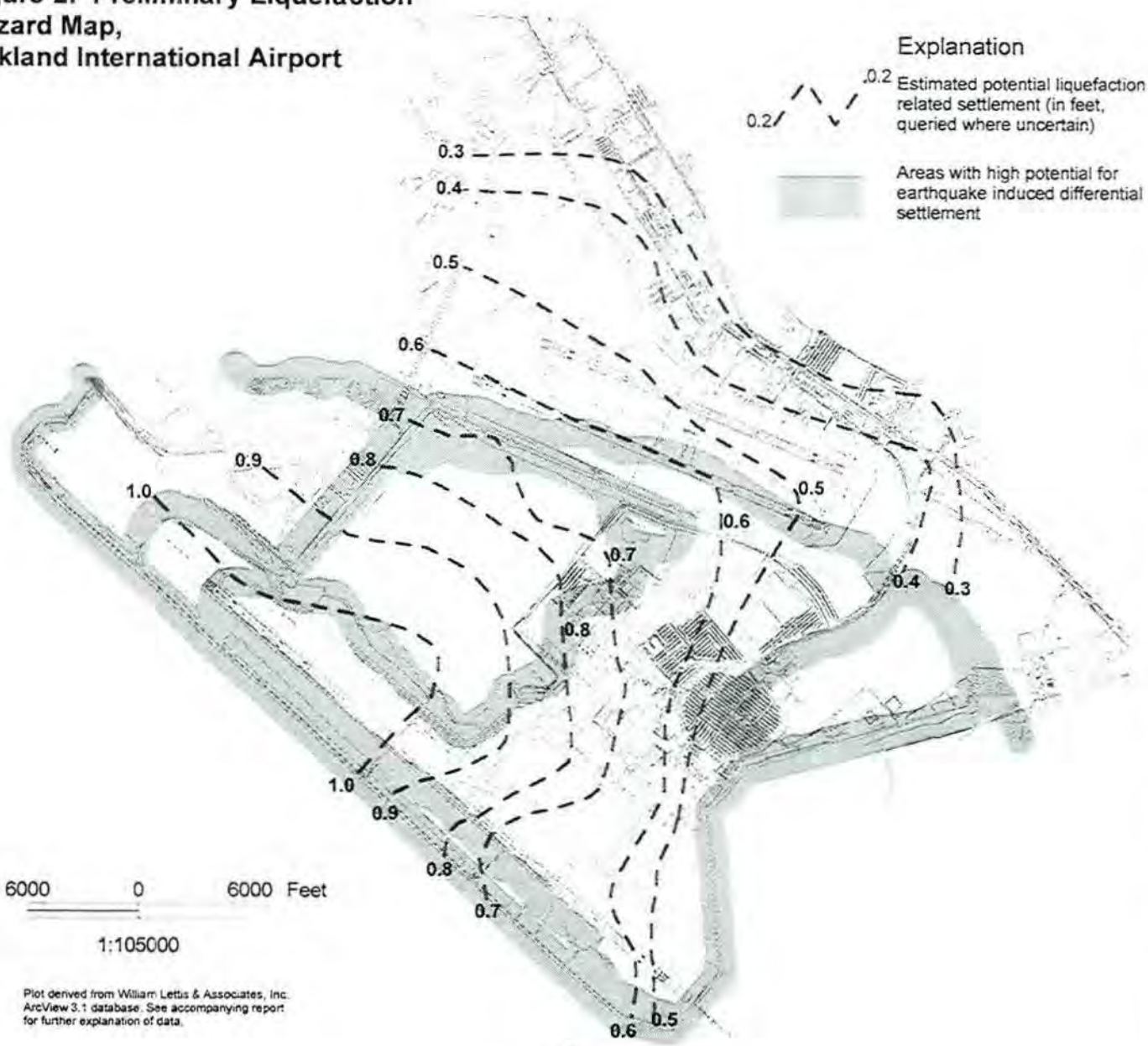
ABAG

Source: Association of Bay Area Governments- 2000

Oakland International Airport Liquefaction Susceptibility Due to Particularly Sandy Fill on Bay Mud

The Oakland International Airport (OAK) is susceptible to liquefaction due to its particularly sandy artificial fill overlying Bay mud. In the event of a large earthquake on the Hayward fault, liquefaction-related settlement is estimated to be at least 0.5 ft. across runways, and potential settlement could exceed 1 foot over the northernmost 30-40% of the main runways. Significant differential settlement at OAK is expected along the south and north margins of the runways. Differential settlement likely will be most severe at fill boundaries and along Bay margin levees. This assessment is partly supported by the liquefaction-related damage documented at OAK following the Loma Prieta earthquake.

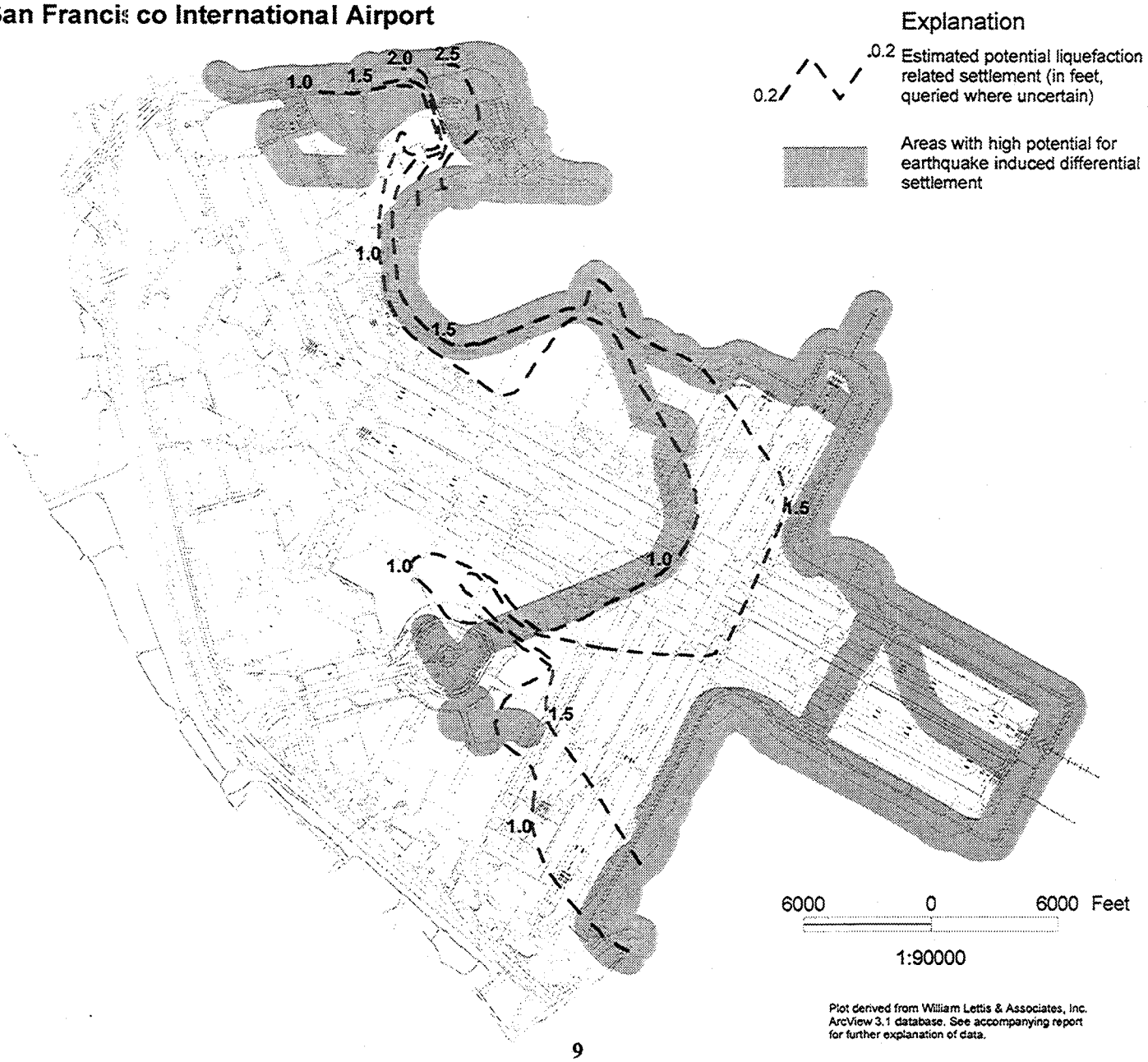
Figure 2: Preliminary Liquefaction Hazard Map, Oakland International Airport



San Francisco International Airport Liquefaction Susceptibility Due to Particularly Thick Fill on Bay Mud

The San Francisco International Airport (SFO) is built on artificial fill that is potentially susceptible to liquefaction. In the event of a repeat of the 1906 San Francisco earthquake, settlement of 0.5 ft. may occur across the entire runway field, and settlements of between 1 and 1.5 ft. may occur under the southeast part of the field. Thickness changes in liquefiable fill are relatively broad at SFO, suggesting that settlement may be spread out, and that the runway field may undergo a general southeastward tilt. The areas that likely present the greatest hazard to the operation of the runways are the fill boundaries crossing the central and southeastern part of the runways, where differential settlement is most likely to occur. ***The SFO liquefaction hazard map (Figure 3) is based on more limited borehole data than the maps for OAK and SJC.***

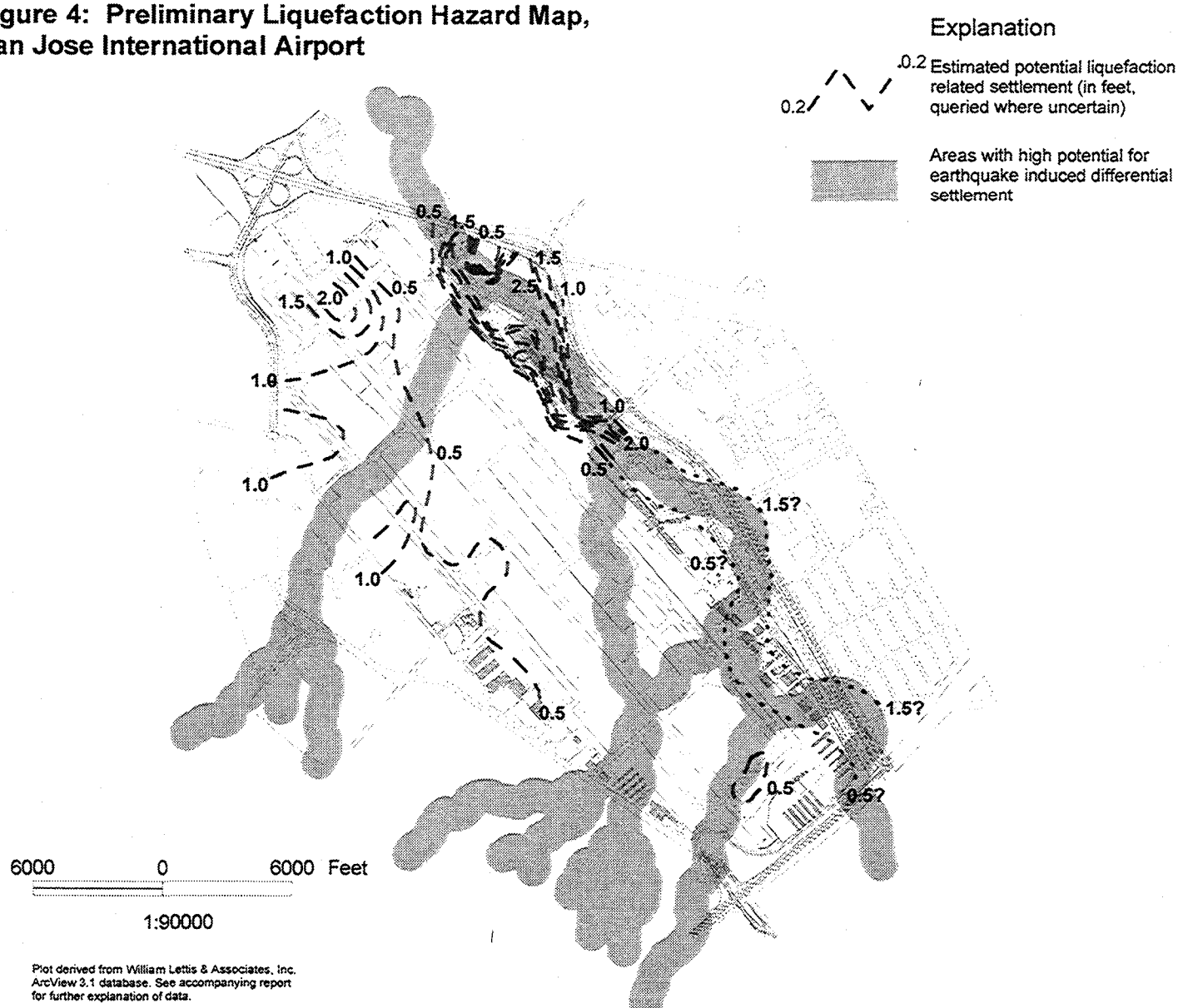
Figure 3: Preliminary Liquefaction Hazard Map, San Francisco International Airport



San Jose International Airport Liquefaction Susceptibility Due to Buried Stream Channels

The liquefaction hazards at San Jose International Airport (SJC) are related primarily to naturally occurring ancient stream channel deposits and localized fills, unlike OAK and SFO that are underlain by broad artificial fills susceptible to liquefaction. A large earthquake on either the San Andreas (such as a repeat of the 1906 San Francisco earthquake) or the Hayward faults could cause total settlements of at least 0.5 feet under the northwestern 20-25% of the runways, with possible localized settlement between 1 and 2 feet under the extreme northern end of the field. The northwesternmost parts of the airport and runways may experience up to 2 ft. of settlement related to liquefaction, and the westernmost runway may settle as much as 1 ft. Extensive differential settlement is expected in the extreme northernmost part of the runways. Lesser amounts of differential settlement may occur over buried creek channels in the north-central and southern parts of the runways.

Figure 4: Preliminary Liquefaction Hazard Map, San Jose International Airport



Plot derived from William Lettis & Associates, Inc. ArcView 3.1 database. See accompanying report for further explanation of data.

Likelihood of Liquefaction Damage to Airport Runways

In October 1999, the U.S. Geological Survey (USGS) released revised estimates of the overall probability of a magnitude 6.7 earthquake in the region. They also released information on the probabilities of earthquakes on each fault system, but not on each fault segment. This information is not sufficient to perform a probability-based assessment of the likelihood of airport closure due to runway liquefaction. However, based on preliminary USGS information on the probability of earthquakes occurring on each fault segment(s), ABAG staff have estimated the closure probabilities for each airport in the next 30 years as shown in Table 1. Note that these probabilities of closure are approximate. In addition, for comparison purposes, ABAG examined the probabilities in the context of liquefaction probabilities at the other airports in the San Francisco Bay Area able to accommodate moderate-sized aircraft. With the exception of the Oakland Airport's North Field, the liquefaction analysis is based on regional, rather than site-specific information, however. This information for those Bay Area airports is also included in Table 1. The values in this table should be considered as preliminary and will be modified during the next 4 months as ABAG finalizes its report on improving the post-earthquake reliability of our air-based transportation system. However, the general conclusion that the three major airports are among the most vulnerable to liquefaction will probably not change.

Table 1: Liquefaction Disruption Information

Airport Name	**PRELIMINARY Approximate Probability of at Least One Airport Closure Due to Liquefaction in the Next 30 Years**
OAK – Oakland	**60 %** (Main runways ***and*** longest North Field runway; somewhat less for other North Field runways)
SFO – San Francisco	**20 %**
SJC – San Jose	**30 %** (due to buried stream channels)
Travis Air Force Base	Negligible
Moffett Fed. Airfield	From negligible (S end) to **50 %** (N end of longer runway)
Hayward	Negligible
Livermore	**4 %**
Buchanan	**6 %**
Napa Co	Negligible
Half Moon Bay	Negligible
Rio Vista – Solano	Negligible
Nut Tree – Solano	Negligible
Santa Rosa – Sonoma	Negligible

TABLE NOTE – The variation in liquefaction hazard at individual airports can be quite large. The liquefaction hazard associated with runways at Moffett Field may be particularly large.

What About Making Runways More Liquefaction Resistant?

The engineering measures usually used to mitigate potential problems due to liquefaction typically require closing runways to perform major ground improvement work. Such efforts are usually not cost effective or feasible unless undertaken as part of a larger runway construction or reconstruction project, such as that underway at San Jose International Airport.

Runway Program at the San Jose International Airport	SJC is currently extending a shorter runway to create a new full-length (11,000 ft) runway (30R/12L) that should be far less vulnerable to damage because the new pavement section is sufficient to "bridge" the stream channels. Upon completion of this project, the existing full-length runway (30L/12R) will be taken out of service and reconfigured in a similar fashion. Both projects should be completed by 2004.

ISSUE 2 – Potential Damage to Air Traffic Control and Terminal Facilities

A second major potential source of airport disruption is damage to air traffic control and terminal facilities. A structural analysis of these facilities is beyond the scope of this plan. In general, prior to constructing control and terminal facilities, seismic factors are investigated and new facilities are designed to resist shaking damage.

However, structural damage in past earthquakes is clearly correlated with the measured intensity of shaking. Thus, for emergency planning purposes, it is useful to know the probability that Bay Area airports may be subject to very violent or violent ground shaking (modified Mercalli intensity (MMI) IX or greater) in the next 30 years. The shaking intensity information is based on the latest version of ABAG's ground shaking maps (Perkins and Boatwright, 1995; Perkins, 1998; Perkins and others, 1999). As mentioned in the discussion of liquefaction issues, the scenario-specific USGS probability information is preliminary at this time. However, future changes are unlikely to change the overall conclusion that facility managers at Oakland, Moffett, Hayward, San Francisco, Half Moon Bay, Buchanan and Livermore all need to be particularly concerned about the potential for violent ground shaking when designing new facilities. In addition, a structural assessment of older existing facilities may be warranted.

In addition, even if the airport itself is not damaged, damage to buildings in the surrounding area may make the functioning of the airport particularly useful immediately after earthquakes, such as for airlifting in critical medical supplies or search and rescue teams. This makes conservative design of facilities at these seven airports particularly important.

Table 2: Shaking Exposure Information

Airport Name	PRELIMINARY Approximate Probability of Airport Structures Being Exposed to Violent or Very Violent Shaking (MMI IX or Greater) in the Next 30 Years
OAK – Oakland	**24 %**
SFO – San Francisco	**12 %**
SJC – San Jose	Negligible
Travis Air Force Base	Negligible
Moffett Fed. Airfield	From negligible (S end) to **23 %** (N end of longer runway)
Hayward	**13 %**
Livermore	**4 %**
Buchanan	**6 %**
Napa Co	Negligible
Half Moon Bay	**7 %**
Rio Vista – Solano	Negligible
Nut Tree – Solano	Negligible
Santa Rosa – Sonoma	Negligible

ISSUE 3 – Power and Communications Disruptions

The third potential threat to airport operations is disruptions to power and communications systems. Problems with these "operating" systems are particularly disruptive, but can also be easily mitigated, using many of the techniques listed in Part IV on page 15. More extensive information on how airports are currently dealing with this threat will be available when the ABAG report on airports and Bay Area earthquakes is completed in the fall of 2000.

ISSUE 4 – Disruptions to the Transportation Systems Serving the Airports

The final major potential source of airport disruption is damage to the road and highway transportation system that serves the airports. Critical staff (including air traffic controllers) needed to operate the airport may not be able to get to work. Crews and materials (such as gravel and concrete) necessary for airport runway and other repairs may be prevented from or delayed in reaching the airport. After the emergency, airport customers (including travelers and shipping companies) may not be able to get to and from the airport.

Transportation disruptions that may impact airport operations include:

- The Oakland and San Francisco International Airports are expected to be affected by numerous road closures servicing their facilities in a number of different earthquake scenarios.
- Hayward Airport and Moffett Field, while not experiencing quite as many closures as Oakland and San Francisco, will probably still be affected by several road closures.
- Livermore, Buchanan, and Half Moon Bay airports are only affected by major numbers of road closures should faults immediately adjacent to these facilities rupture.
- Roads in the vicinity of San Jose International are also potentially affected, particularly from larger earthquakes on the Hayward and San Andreas faults.

We need to identify alternate locations capable of handling large commercial and cargo jets after an earthquake should road transportation system disruptions make access to some airports difficult. Travis AFB will have increased air and vehicle traffic during the post-earthquake emergency response phase because the federal government plans on using Travis AFB as the primary mobilization center for their response to the disaster. With the normal operations that Travis has in addition to this major role, emergency planners should not believe that Travis has additional capacity for other commercial or cargo needs. Options include neighboring commercial airports (Sacramento, Stockton, Monterey, etc.), as well as larger general aviation airports.

More specific information on routes most likely to be impacted will be provided in the ABAG report being compiled at this time and to be produced in late fall, 2000.

IDEAS FOR ACTION – HOW CAN WE BETTER PLAN?

The following checklist is derived from recommendations contained in ABAG's report, ***Riding Out Future Quakes – Ideas for Action*** (Perkins and others, 1998). It focuses on ways to keep providing transportation services following earthquakes, as well as how to plan around expected transportation interruptions. As such, they are useful in airport operations. Additional and more specific recommendations will be developed during the next few months as ABAG finalizes the planning project discussed earlier.

Airport Checklist

Employees

- ☐ work with employees to set up alternative routes from their homes to key facilities and offices in an emergency
- ☐ plan alternative shifts and/or crews since maintenance workers can be overworked
- ☐ cross-train employees to allow for some workers being unable to reach your facilities in a timely manner
- ☐ make efforts to ensure safety to crews working on repairs, for they may be close to other damage

Operations

- ☐ *general* - evaluate the extent to which general aviation and military airports could accommodate commercial aircraft in an emergency
- ☐ *roads* - work to keep open surface roads in and out of your facility routinely maintained by your agency
- ☐ *supplies* - ensure that you have stocked your operations center with food, water and sanitation systems to allow for disruptions
- ☐ *fuel* - connect fuel pumps at vehicle yards to a backup power system
- ☐ *fuel* - ensure adequate fuel supplies should restocking of fuel supplies be delayed
- ☐ *power* - provide, anchor and test back-up power equipment, such as batteries
- ☐ *power* - size fuel supply tanks for emergency generators; power outages may be longer than expected
- ☐ *communications* - provide, anchor and test back-up equipment, such as portable radios and relay towers
- ☐ *water* - install back-up supplies on-site and anchor tanks
- ☐ *equipment* – work to ensure that all equipment and non-structural items are appropriately anchored, particularly in control towers
- ☐ *pipelines* - design on-site utility lines to minimize risk of pipeline breaks
- ☐ *pipelines* - create and isolate shorter segments of pipelines to facilitate repairs by installing additional valves; maintain those pipelines and valves

Location

Examine the location of your facilities relative to exposure to various earthquake hazards described in this plan, including:

- ☐ liquefaction and/or differential settlement (in particular, work to minimize the likelihood of closed runways due to pavement buckling) earthquake-induced landsliding
- ☐ violent shaking and associated structural deficiencies
- ☐ land-side access transportation disruption

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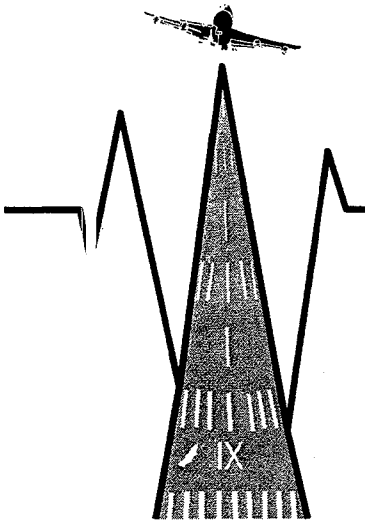

Don't Wing It

Airports and Bay Area Earthquakes

Using Airport Vulnerability Data and Response Capability to Improve Planning for Post-Earthquake Transportation Disruptions in the San Francisco Bay Region

DECEMBER 2000

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MTC METROPOLITAN TRANSPORTATION COMMISSION

ABAG ASSOCIATION OF BAY AREA GOVERNMENTS

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BACKGROUND AND OBJECTIVES ...

These materials build on two reports on the vulnerability of the region's transportation system to earthquakes published by ABAG –

- ***Riding Out Future Quakes*** – October 1997
- ***Riding Out Future Quakes – Ideas for Action*** – March 1999

The ***Riding Out Future Quakes*** project was initiated by ABAG and Caltrans following the Northridge and Loma Prieta earthquakes. We learned that we need our transportation systems to be functional after earthquakes for two principal reasons:

- Emergency responders need to use transportation systems, including airports, after earthquakes.
- Transportation system disruptions, including disruptions to airports, can have a severe impact on a region's economy for months, if not years.

As a second step in the planning process, ABAG held a series of five subregional workshops discussing hypothetical road and rail closures resulting from selected scenario earthquakes in October and November 1998. "Tabletop" disaster drills and extensive discussion led to identification of the major issues, interagency dependencies, and areas of potential conflict likely to face transportation providers, governments, utilities and businesses as they struggle to address the transportation impacts after a large earthquake. The ***Riding Out Future Quakes – Ideas for Action*** report is both the proceedings of those workshops, as well as a tool to inspire innovative planning for minimizing transportation disruption following future earthquakes. One conclusion of these workshops was the importance of airports in the region's response and recovery to earthquakes.

At the same time, MTC is continuing to test and refine the Trans Response Plan (TRP) which integrates response and recovery efforts among all modes of transportation. The TRP coordinates the activities of MTC, Caltrans, State and local Offices of Emergency Services, and other transportation providers, including transit agencies and airports.

Our work on airports and earthquakes has five principal overall ***objectives***:

- To develop a ***long-term partnership*** among air transportation providers, users, the earthquake research community, and earthquake responders to foster cooperation for response and recovery.
- To assess the ***vulnerability of our air transportation system*** to liquefaction and land-side access issues given the scenario earthquakes considered likely Bay Area.
- To assist in ***collaborative planning for emergency response*** among the airports, emergency responders, and cargo and passenger carriers. Emergency responders are depending on our airports for delivering disaster cargo and disaster relief workers.
- To identify methods for ***minimizing long-term impacts*** of reduced land-side access and airport damage following future earthquakes, thereby minimizing impacts on airport business, the cargo industry, and our regional economy.
- To ***increase public awareness*** and support of emergency planning activities at and among airports.

As a first step in this process, ABAG has been actively involved in the discussion of earthquake issues as part of the Regional Airport System Plan (RASP) Update 2000 process. In addition, ABAG held a workshop on October 10, 2000, to discuss the potential problems outlined in this report and to begin the process of developing strategies to cope to earthquake-related disruptions to airports.

- What are the options for bringing relief aircraft into the region if all runways at one or more major airports are damaged beyond immediate repair?
- What kinds of concerns should airport safety managers be addressing? What specific Bay Area earthquake issues should be included in their earthquake plans?
- What are the potential problems and solutions related to land-side access?
- How should emergency plans be improved to deal with areas likely to be damaged in an earthquake?
- If an airport lifeline network is established, what are the critical land-side components of that network (control towers, runways, key access routes, etc.)?

FINDINGS – EARTHQUAKES AND AIRPORTS

What Are the Threats to Airport Operations Following Future Earthquakes in the Bay Area?

Based on past experience in California and other recent earthquakes, the threats to Bay Area airport operations following future earthquakes fall into four general categories:

- liquefaction damage to airport runways, particularly at San Jose (until the new runways are completed), Oakland, San Francisco, and, perhaps, Moffett Federal Airfield;
- shaking damage to air control and terminal facilities, particularly older facilities that may be present at Oakland, Moffett, Hayward, San Francisco, Half Moon Bay, Buchanan, and Livermore airports;
- power and communications disruptions; and
- disruptions to the transportation systems serving the airports.

Our Airport Systems Can and Should Be Made More Earthquake-Ready!

1. **We need to better understand and mitigate the liquefaction hazard to runways.** Thus, we need to expand on the liquefaction analysis conducted for the runways at the three major airports (OAK, SFO, and SJC) to:
   - gain further information on the vulnerability of other major airports, particularly Moffett Federal Airfield on the Peninsula and Travis Air Force Base in Solano County, and, if feasible, Buchanan, Hayward, and Livermore in the East Bay; and
   - incorporate more recent geotechnical information becoming available for OAK, SJC and SFO.

   We need to ensure that the design of new runways also mitigates liquefaction hazards associated with the connections to the existing runway system. Any runway expansions at SFO and OAK that tie into sections of existing runways which are vulnerable to liquefaction will make the expansions vulnerable as well. Current runway work at SJC is designed to minimize the liquefaction hazard.

2. **We need to improve emergency planning at individual airports and to better coordinate emergency planning among airports and with other forms of transportation.** Some ideas focusing on employees and operations at individual airports are listed at the end of this report. However, airport participation in coordinated emergency planning is also essential. MTC is starting this planning as part of the integrated Trans Response Plan (TRP) for earthquakes.

3. **We need to identify alternate locations capable of handling large commercial and cargo jets after an earthquake should Bay Area commercial airports loose capacity due to road transportation system disruptions, runway damage, or structural damage.** Travis AFB will have increased air and vehicle traffic during the post-earthquake emergency response phase because the federal government plans on using Travis AFB as the primary mobilization center for their response to the disaster. With the normal operations that Travis has in addition to this major role, emergency planners should not believe that Travis has additional capacity for other commercial or cargo needs. Options include neighboring commercial airports (Sacramento, Stockton, Monterey, etc.), as well as larger general aviation airports.

THE ISSUE – WHY WORRY ABOUT AIRPORT DISRUPTIONS FOLLOWING FUTURE EARTHQUAKES IN THE BAY AREA?

Airports Are Part of Our Transportation System

We need our transportation systems to be functional after earthquakes for two principal reasons:

1. Emergency responders need to use transportation systems, including airports, after earthquakes.
2. Transportation system disruptions, including disruptions to airports, can have a severe impact on a region's economy for months, if not years (Brady and Perkins, 1998).

Airports as Intersections

Airports are critical points in our transportation system because they function as intersections, not between two freeways, but between our air space and our land-side transportation. Yet, just as damage to a major interchange or bridge in an earthquake can have impacts far beyond the local area, so can damage to an airport, particularly one of the principal international airports in the Bay Area.

Focus on Major Airports

Although the focus of this report is on the three major airports, other airports are also discussed in the context of the potential problems at these facilities in comparison to the three international airports.

Other Emergency Planning Efforts

ABAG held a series of five subregional workshops discussing hypothetical road and rail closures resulting from selected scenario earthquakes in October and November 1998. "Tabletop" disaster drills and extensive discussion led to identification of the major issues, interagency dependencies, and areas of potential conflict likely to face transportation providers, governments, utilities and businesses as they struggle to address the transportation impacts after a large earthquake. The ***Riding Out Future Quakes – Ideas for Action*** report (Perkins and others, 1999b) is both the proceedings of those workshops, as well as a tool to inspire innovative planning for minimizing transportation disruption following future earthquakes. One conclusion of these workshops was that airports are critically important in the region's response and recovery to earthquakes.

At the same time, MTC is continuing to test and refine the Trans Response Plan (TRP) which integrates response and recovery efforts among all modes of transportation. The TRP coordinates the activities of MTC, Caltrans, State and local Offices of Emergency Services, and other transportation providers, including transit agencies and airports.

The information in this report will hopefully serve to improve earthquake emergency planning at and among airports.

PAS" ' EARTHQUAKES – WHAT HAPPENED LAST TIME?

1989 Loma Prieta Earthquake

The magnitude 6.9 Loma Prieta earthquake occurred in the Santa Cruz mountains near the border of Santa Cruz and Santa Clara counties on October 17, 1989. Because the earthquake source fault was far south of the main urban center of the Bay Area, it only serves as a wake-up call for what might happen in a closer or larger magnitude earthquake. Thus, it is inappropriate to assume that since a problem did not occur in this earthquake, it will not occur in the future.

San Francisco International Airport (SFO) was over 35 miles from the fault source for the Loma Prieta earthquake. Although operations at SFO officially halted for one night, this was not due to any significant damage to the facilities or the runways. The control tower sustained window and non-structural damage, and some unanchored equipment was broken, but this did not prevent the tower from operating. ***The primary reason for the shutting down of flights during that night was that not enough controllers were available to operate the tower safely.*** The runways (built on fill), navigational equipment, runway lights, fuel tanks, and piping were mostly unaffected. However, liquefaction (a process where loose water-saturated sands temporarily behave like a liquid when shaken) shifted some small support structures. Lost power was restored within 3 hours, well before the time the airport was reopened. Non-structural damage occurred in the terminals, but did not cause the airport to be shut down. Damage to an air cargo building was significant, and problems transpired with a power transformer, but these were remedied over time without air operations being affected. ***There were no problems with access road failures or freeway closures within the immediate vicinity of this airport that contributed to closure. However the ability of the controllers to travel to work safely and quickly was an issue*** (EERI, 1990).

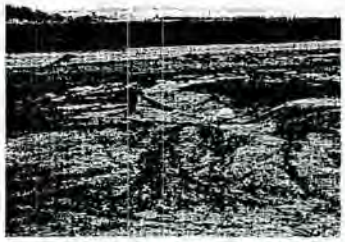
source –
SFO – R. Wiggins

Oakland International Airport (OAK) was also affected by the Loma Prieta earthquake, in spite of its location over 40 miles from the fault source for the earthquake. OAK and adjacent Port of Oakland lands, however, experienced peak ground accelerations of almost 0.3 g. These problems affected airport operations. Its main 10,000-foot runway, built on hydraulic fill over Bay mud, was severely damaged by liquefaction; 3,000 feet of the runway sustained cracks, some of them were a foot wide and a foot deep. Spreading of the adjacent unpaved ground resulted in cracks up to 3 feet wide. Large sand boils appeared on the runway and adjacent taxiway, a few as wide as 40 feet (EERI, 1990). As a result, OAK was immediately shut down to evaluate runway damage. A shorter 6,212-foot general aviation runway was used to accommodate diverted air traffic for a couple of hours before the main runway was reopened with a usable length of only 7,000 feet. This shorter runway length impacted cargo loads during takeoff. Over the next 30 days, 1,500 feet of the 3,000 foot damaged section of the runway was repaired using an emergency repair order for resurfacing and crews already present during the earthquake. An adjacent taxiway was also damaged by liquefaction. Repairs of this taxiway segment and the final 1,500 feet of the main

source –
Geomatrix Consultants

runway were completed six months later, after a competitive bidding process (T. LaBasco, S. Kopacz, and J. Serventi, Port of Oakland, personal communications, Sept. 2000). Post-earthquake communications were difficult at OAK, as both telephone service and the usable radio frequency became quickly overloaded, affecting both cleanup crews and the public on-site at the time of the earthquake. Other damage was limited – for example, the control tower lost three windows, a walkway between terminals was damaged, and a water main ruptured causing a service road to collapse (EERI, 1990). Repair costs totaled approximately $6.8 million, including $3.5 million for runway repairs, $2.2 million for taxiway repairs, and $1.1 million for repair of other damage. FAA funded approximately $5.5 million of the repairs, with the remainder funded by OAK (T. LaBasco and I. Osantowski, Port of Oakland, and J. Rodriguez, FAA, personal communications, Sept. 2000).

San Jose International Airport (SJC) was located approximately 15 miles from the fault source of the Loma Prieta earthquake. The airport immediately closed for inspection of runways, taxiways, associated lighting systems, and aircraft parking ramps. The operational status of the Air Traffic Control (ATC) tower, other ATC facilities, and aircraft navigational aids were verified. Both terminals, automobile parking garages, and lots were also inspected. The inspection showed that there was no damage that might affect operations, so the airport reopened and was fully operational 40 minutes after the earthquake. The airport also determined the status of the three principal access routes, as well as of SFO and OAK. The status of the airport was then communicated to the City Emergency Response Center (C. Herrera, SJC, in Perkins and others, 1999b). The control tower lost a window and had non-structural problems; other cosmetic damage occurred at the terminal. Commercial power was lost for over 5 hours, but backup generators worked well. The airport was considered as an alternative airfield if flights needed to be diverted from San Francisco or Oakland. The main reason this did not occur was the lack of refueling capabilities at San Jose (rendering takeoff of most of those planes impossible) rather than damage due to the earthquake. No road failures at or near the airport were reported (EERI, 1990). The emergency plan for natural disasters, in place at the time of the earthquake, clearly spelled out procedures relating to duties, communications and inspection procedures. The airport staff feel that the plan worked well, although the minimal damage did not give the plan a thorough test. The staff, therefore, are continuing to use this plan and procedures (D. Chubbic, SJC, personal communication, Sept. 2000).



source –
J. Bray – University of California, Berkeley and U.S. Geological Survey

Significant damage also occurred to the Alameda Naval Air Station. Substantial liquefaction led to the closure of both the 8,000-ft. and 7,200-ft. runways. The terminal building had structural damage and was closed. Other damage occurred to piers, railroad tracts on piers, and the water- and gas-distribution system. The power was not disrupted. The helicopter pads were not damaged and were used during the emergency operation. The two runways were repaired and reopened (one in December 1989 and the second expected in January 1990) (EERI, 1990). However, the facility was closed in 1995 and is now scheduled for non-airport reuse.

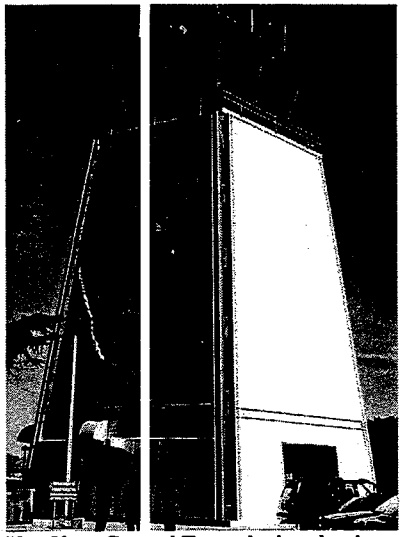
source –
J. Villarin,
for California Pilots Association

The Watsonville airport, with two 4,000-ft. runways, had a loss of power and no emergency generators. Thus, flights could not depart at night due to lack of runway lights. Some hanger doors fell from their support rails. However, this airport became a key player in the emergency relief effort. For example, there was an average of 25 military flights per day. In addition, approximately 300 flights were made by light planes on the weekend of October 28-29 (EERI, 1990). A total of about 300,000 pounds of emergency supplies were flown to Watsonville and Hollister during the week following the earthquake utilizing over a hundred small aircraft (J. White, California Pilots Association, personal communication, 2000).

Because of problems at the three commercial airports, flights were diverted to outside of the Bay Area. Sacramento Airport was notified to expect diversions from the Bay Area. It had 256,000 gallons of jet fuel on hand. An emergency recall of fueling staff was ordered to help facilitate fueling aircraft, escorting of vehicles and handling of paperwork (flight plans and fueling paperwork). The second runway and some taxiways were used to park incoming aircraft. No domestic flights at Sacramento were cancelled. Some international flights landed and fueled, these had to keep people onboard the aircraft due to no international facilities available. The airport accepted a total of 40 diversions in the first five hours, at which time Chevron topped off the jet fuel tank farm. There were later occasional fuel diversions during the following week.(S. Soto, Sacramento County Airport System, personal communication, 2000).

No significant damage was reported at smaller airports in the region. Smaller amounts of damage would be expected because these airfields generally have fewer facilities.

1994 Northridge Earthquake



Van Nuys Control Tower had gashes in its siding caused when ¾" thick windows fell.
source –
A. Schiff, 1995

The magnitude 6.7 Northridge earthquake occurred on a fault buried beneath the San Fernando Valley of Los Angeles on January 17, 1994. The three airports in the area with most severe shaking in the Northridge earthquake were closed for runway and taxiway inspections. However, all three were reopened quickly when the inspections were completed and showed no significant damage.

Van Nuys Airport, the general aviation airport closest to the area of highest shaking intensity, had window glass breakage in the control tower (EERI, 1995a). Equipment in that tower slid up to 4 inches. Damage to FAA facilities at the airport control tower totaled about $160,000 (Schiff, 1995).

Burbank Airport, a commercial airport located just east of the fault source zone, was closed for approximately five minutes while the runways and taxiways were inspected. The terminal building was closed for approximately two hours for inspection and to allow cleanup of fallen ceiling tiles (EERI, 1995a).

The Los Angeles International Airport (LAX), located almost 20 miles south of the fault source zone, was closed down for several hours for inspection. Due to a power loss of approximately one hour, the emergency generator power backup was used and functioned. Some ceiling tiles fell, and there were some water leaks at pipe joints (EERI, 1995a).

1995 Kobe, Japan Earthquake

The magnitude 6.9 Hanshin-Awaji (Kobe) earthquake occurred on January 17, 1995 on a 30 – 50 km segment of the Nojima and associated faults (EERI, 1995b). There were three airports in the region affected by the earthquake: the Osaka International Airport, the Kansai International Airport, and the Yao Airport. The Yao Airport is a small general aviation airport and was undamaged in the earthquake. Both the Osaka and Kansai International Airports were slightly damaged. More importantly, they had a large role in the rescue and emergency response phase of the earthquake, particularly due to damage to the main bullet train connecting eastern and western Japan. The following description is summarized from a report prepared by the Editorial Committee on the Hanshin-Awaji Earthquake Disaster (2000). This Committee consisted of the Architectural Institute of Japan, the Japanese Geotechnical Society, the Japan Society of Civil Engineers, the Japan Society of Mechanical Engineers, and the Seismological Society of Japan.

source – Kansai International Airport Web Site

The Kansai International Airport, completed in 1994, serves the Kobe and Osaka region. It was less than a year old at the time of the earthquake. It lies approximately 19 miles (30 km) from the epicenter on a man-made island. Although there was no damage on the outside levees, some cracks were observed on the apron of the water access base. Runways, access ways, and asphalt maintenance aprons had minor cracks approximately 1/8" (2-3 mm) wide. At the time of the earthquake (5:46 am) there was a plane preparing to land. Immediately, the runway was inspected and determined to be safe in spite of the cracking, so that plane was allowed to land at 6:15 am. The cracks were sealed the following night to prevent rainwater from seeping into them. The fuel supply system is equipped for automatic shutoff when shaking exceeds 80 gal (0.08 g). After inspection confirmed the system was safe, it was restarted. Airport buildings had damage to ceilings, hallways and water lines. The rail of the shuttle in the passenger terminal was slightly bent, but service was quickly restored. Minor damage occurred to terminal walkways, expansion joints, escalators, water tanks and light fixtures.

The Itami (Osaka) Airport, the former international airport for the region, now handles domestic flights. It is approximately 6 miles from the most heavily damaged area. Immediately after the earthquake, runways were inspected and many cracks of less then an inch (a few mm) wide were observed. The airport was not closed; the cracks were sealed the following night to prevent rainwater seepage. The control tower and the fire department and power generation buildings had cracks in glass, as well as other areas. The passenger terminal had fallen concrete panels, broken wall panels, damaged roof and ceiling sections, and broken glass. Water lines, toilets, sprinklers, air conditioners, and boarding bridges were damaged. There was some damage to the runway lighting system, but this system was quickly restored.

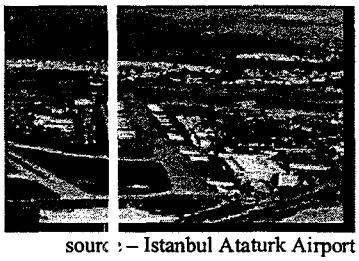
Due to damage to the rail lines and roads, the number of flights increased significantly between January 17th and April 14th. Additional flights were added at the Itami Airport until 10 p.m. during this period. (Airport service had stopped at 8 p.m. prior to the earthquake.) Helicopters

transported emergency relief goods. Those goods were mainly food and drinking water during the first 4-5 days, followed by tents, portable toilets, blankets and heaters for the next 6-10 days, and then clothes and goods for infants. The Itami Osaka Airport accepted domestic relief goods and distributed them via trucks and helicopters to the disaster area. The Kansai Airport accepted both domestic and international relief goods, which were then distributed via trucks, helicopters and ships to the disaster area. Between January 19th and May 10th, about 1,722 tons of goods were transported. The sky over the disaster area was crowded with airplanes from the Japanese self-defense forces, police, fire fighters, and media groups. NATM was provided to control them. The process of obtaining permits to land in non-equipped areas was simplified in order to speed up the transportation of relief goods by helicopter.

The Kobe report notes that the role of air transportation is to provide emergency and alternate transportation, and to contribute to the recovery of the disaster area. Recommendations included:

- seismic reinforcement of current facilities;
- alternate or redundancy for aircraft control facilities;
- establishment of air emergency response and recovery systems; and
- research on earthquake investigation methods.

1999 Turkey Earthquake



source – Istanbul Ataturk Airport Web Site

The magnitude 7.4 Kocaeli earthquake occurred in northwest Turkey, rupturing an approximately 70 mile (110 km) length of the North Anatolian fault system on August 17, 1999. The epicenter was approximately 60 miles (95 km) from Istanbul and 70 miles (110 km) from the Istanbul Ataturk International Airport (IST). The closest extension of the source fault rupture was approximately 50 miles (80 km) from the city center and 60 miles (95 km) from the airport. The peak ground acceleration at the strong motion station nearest the airport was only 0.09 g (USGS, 2000). Because the earthquake source fault was relatively far away and because IST likely experienced low shaking levels, there was minimal damage. Stronger shaking would have damaged the emergency power system (J. Eidinger, personal commications, Sept. 2000). Thus, one should not assume that since a problem did not occur in this earthquake, problems will not occur in the future.

Airport personnel conducted inspections of all runways and aprons following the earthquake prior to allowing any planes to land. When no damage was found, airport operations continued without major delays (A. Tang, personal communication, Sept. 2000). Although more damage to runways might have occurred with higher shaking levels, the runways are ***not*** located in a general area of high liquefaction susceptibility (unlike the Oakland and San Francisco airports on the margins of San Francisco Bay) (J. Bachhuber, personal communication, Nov. 2000).

IST handled over 14 million passengers in 1998 on over 184 thousand flights. In August 1999, international flights were highest on the 19th and 20th with a smaller rise on the 26th and 27th, probably due to international rescue and relief efforts. Cargo operations were also

increased due to the increase in foreign aid (A. Tang, personal communication, Sept. 2000). In addition, during the month following the earthquake, there was a significant drop in inbound passenger arrivals over historical seasonal trends, reflecting the 30% to 50% reduction in tourism for the month following the post-earthquake. Outbound departures may have increased after the earthquake, reflecting the shortened vacation plans of tourists and the departure of displaced people (J. Eidinger, personal communication, Sept. 2000).

A new $305 million terminal was under construction when the earthquake occurred. As a result of the earthquake, the decision was made to review the design for the terminal, although construction was 90% complete at the time of the earthquake. Needed changes were made and it was opened in January 2000 (Eng. News Record, 1-17- 2000).

Much less information is available on the performance of the Cengiz Topel Military Airport in Izmit. It appears that there was significant damage to the control tower rendering it unusable. It was further reported that airport operations were reduced as a result of the damage (A. Tang, personal communication, Sept. 2000).

1999 Taiwan Earthquake

The magnitude 7.6 Chi-Chi earthquake occurred in central Taiwan on September 21, 1999. The international airport is located approximately 75 miles (120 km) from the earthquake epicenter and approximately 50 miles (90 km) from the fault source. It was undamaged and functional following the earthquake, enabling it to serve a critical role in the earthquake response and recovery effort.

THE AIRPORT SYSTEM – HOW DOES IT OPERATE?

The Airports

The airport system in the Bay Area consists of three commercial international airports –

- San Francisco International Airport (SFO),
- Oakland International Airport (OAK), and
- San Jose International Airport (SJC).

There are also two military/federal airfields –

- Travis Air Force Base, and
- Moffett (NASA).

In addition, there are several general aviation airports that vary greatly in size. The principal general aviation airports include –

- Hayward (in Alameda County)
- Livermore (in Alameda County)
- Oakland – North Field (in Alameda County)
- Buchanan – Concord (in Contra Costa County)
- Napa County
- Half Moon Bay (in San Mateo County)
- Rio Vista (in Solano County)
- Nut Tree (in Vacaville in Solano County)
- Sonoma County – Santa Rosa

Other significant general aviation airports include –

- Byron (in Contra Costa County)
- Marin County (Gnoss Field)
- San Carlos (in San Mateo County)
- Reid Hillview (in San Jose in Santa Clara County)
- South County (in Gilroy in Santa Clara County)
- Palo Alto (in Santa Clara County)

Airport Usage Statistics

The three major commercial airports serviced 56.6 million passengers on 639,000 total flights in 1999, for an average of 1,750 flights per day. In addition, there were 71,000 cargo flights, or 195 flights per day. SFO handled 66% of the passengers, while OAK handled 76% of the cargo flights (MTC, 2000a). The current airport usage statistics and projections for that usage in the future are shown on Figure 1.

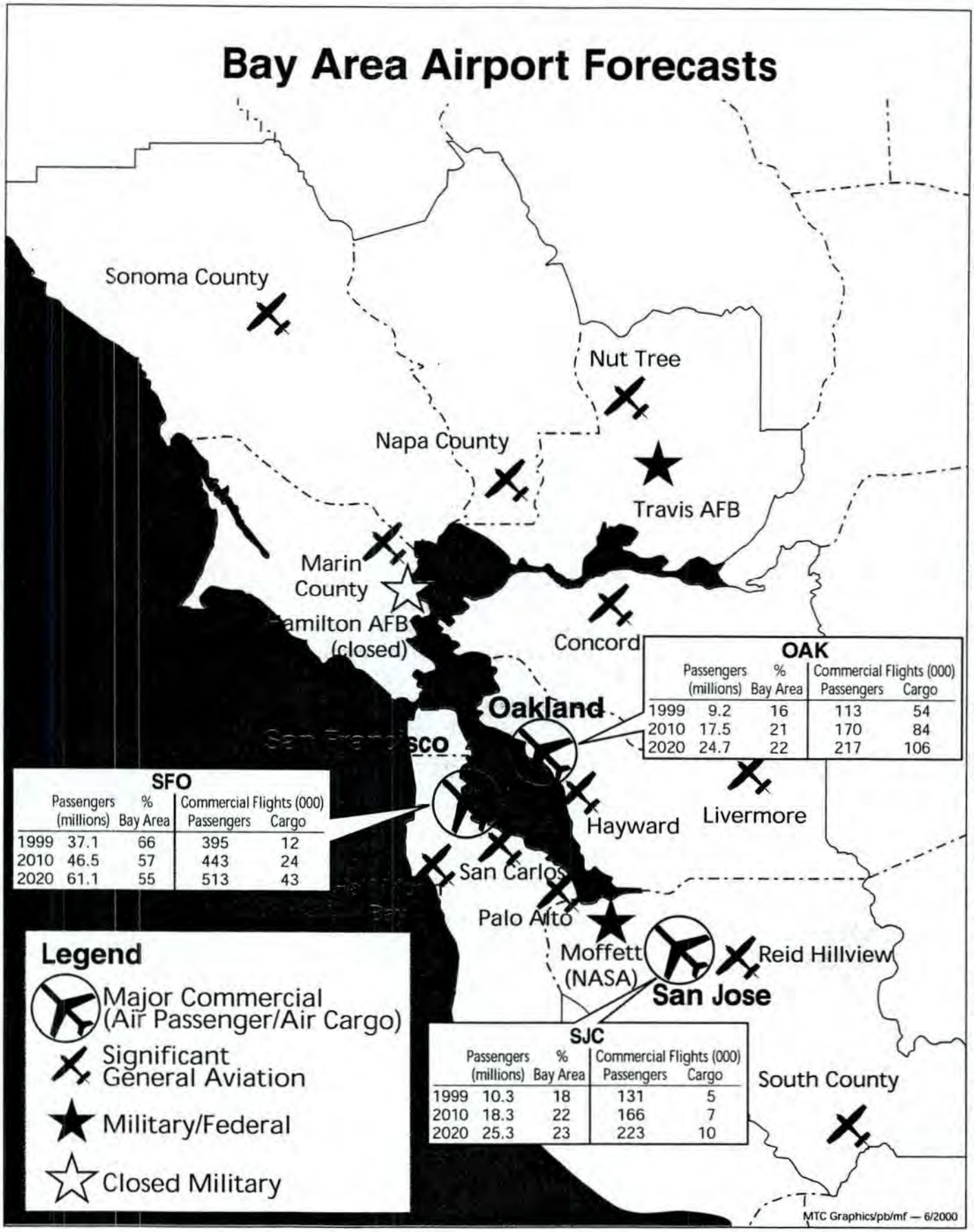
Airport Area Employee Access

Thousands of people work at the region's airports. Table 1, below, provides estimates of airport employees for 1998 – 2020 (MTC, 2000b).

Table 1: Bay Area Airport Employees

	Year		
Airport Name	**1998**	**2010**	**2020**
OAK – Oakland	18,600	21,600	23,000
SFO – San Francisco	29,900	33,100	35,800
SJC – San Jose	13,600	18,300	19,100

Figure 1



OAK

	Passengers (millions)	% Bay Area	Commercial Flights (000) Passengers	Cargo
1999	9.2	16	113	54
2010	17.5	21	170	84
2020	24.7	22	217	106

SFO

	Passengers (millions)	% Bay Area	Commercial Flights (000) Passengers	Cargo
1999	37.1	66	395	12
2010	46.5	57	443	24
2020	61.1	55	513	43

SJC

	Passengers (millions)	% Bay Area	Commercial Flights (000) Passengers	Cargo
1999	10.3	18	131	5
2010	18.3	22	166	7
2020	25.3	23	223	10

According to the ***Regional Airport System Plan – Update 2000 Airport Access Report*** (MTC, 2000b):

> Currently, the majority of airport employees drive alone to work (71%). The remaining employees either share rides (14%), take public transit (11%) or bike or walk to work (4%). By 2020, the percentages of employees taking these transportation modes are projected to look essentially the same as today.

Thus, any disruption of the road transportation system could seriously impact the commute patterns of airport employees, as well as their availability after an earthquake.

Airline Passenger Access

Similarly, the majority of air passengers get to the three major commercial airports by private car (72%). The vast majority of the remainder take a door-to-door shuttle or taxi (17%), or a private bus, chartered bus, or hotel shuttle (9%). Only 2% ride public transit (MTC, 2000b). The completion of BART to SFO in approximately 2002 may change this pattern. Disruptions of the road transportation system or of BART could seriously impact the ability of these passengers to get to the airport.

Cargo Access Patterns

The third source of airport-related traffic is air cargo trucking. According to the ***Regional Airport System Plan – Update 2000 Airport Access Report*** (MTC, 2000b):

> On an average work week (Monday through Friday) the three airports generate 33,456 air cargo related truck trips to and from the airport… . Daily truck trips were highest at SFO (17,348), followed by OAK (11,765) and SJC (4,344).

Thus, any disruption of the road transportation system also could be expected to seriously impacts air cargo truck traffic and associated flights.

See Appendix A for More Information

A table listing runway facilities for the various airports within the nine Bay Area counties is included as Appendix A. In addition, because of the focus of this project on emergency planning, the table also includes the larger airport facilities in adjacent counties.

THE VULNERABILITIES – WHAT PROBLEMS DO WE EXPECT?

Based on the past experiences described in the previous section, the principal problems that can disrupt airport operations after a future earthquake are:

1. liquefaction damage to airport runways;
2. damage to air control and terminal facilities;
3. power and communications disruptions; and
4. disruptions to the transportation and fuel systems serving the airports.

These problems can result from any of a number of earthquake scenarios on faults shown on Figure 2.

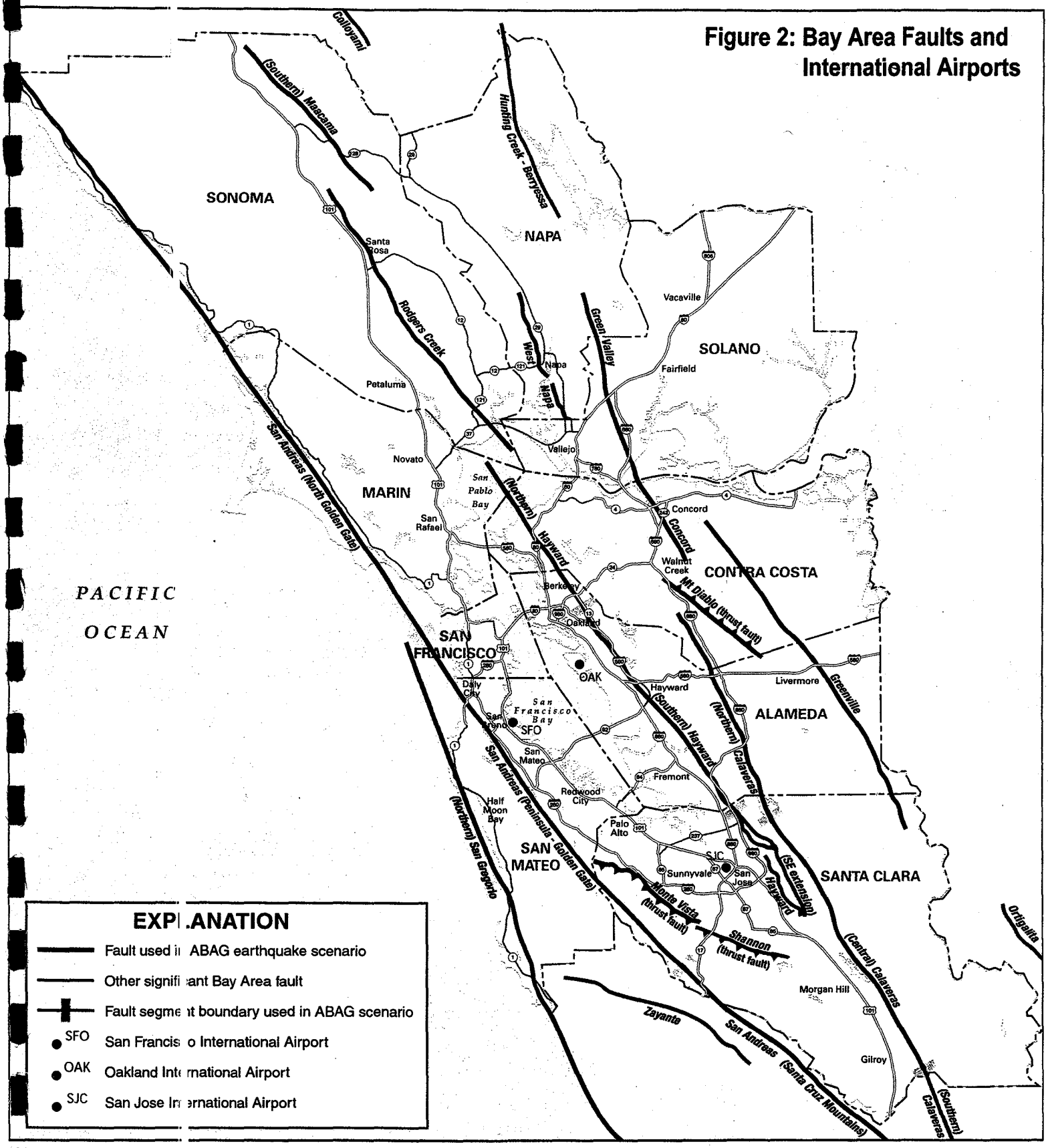
ISSUE 1 – Liquefaction Damage to Airport Runways

When the ground liquefies, sandy materials saturated with water can behave like a liquid, instead of like solid ground. The ground appears to sink or pull apart. Sand boils, or sand "volcanoes," can appear. When this ground "failure" occurs, it can cause damage to paved areas, pipelines, and building foundations. These failures take the form of:

- flows and lateral spreads (essentially landslides on flat or nearly flat ground next to rivers, harbors, or drainage channels);
- ground oscillations (or movement of the liquefied layer of ground separately from the surrounding layers);
- loss of bearing strength (to hold up buildings or hold tanks underground); and
- settlement and differential (uneven) settlement.

ABAG earthquake hazard maps show portions of all three commercial airports in areas with very high liquefaction susceptibility. Thus, ABAG contracted with William Lettis & Associates (WLA) to prepare a preliminary assessment of the susceptibility of runways at the three major Bay Area airports to earthquake-induced liquefaction – ***Evaluation of Earthquake-Induced Liquefaction Hazards at the San Francisco Bay Area Commercial Airports*** (WLA, 1999). The distribution and magnitude of liquefaction-induced settlement and differential settlement estimated by WLA varies from facility to facility, and across each facility. ABAG staff have assumed that the size of these estimated differential settlements are sufficient to close runways in at least one likely earthquake. These analyses have been supplied to the three commercial airports to aid them when they conduct further studies to characterize the limits and amount of liquefaction-related deformation and to plan for disruptions.

WLA developed preliminary liquefaction hazard maps for each airport (Figures 3 – 5). These maps show areas susceptible to liquefaction and the amount of potential liquefaction-induced settlement (in feet). The hazard maps are based on a separate maximum likely earthquake event for each individual airport, and incorporate conservative assumptions regarding liquefaction susceptibility and subsurface conditions. Therefore, the estimated settlement values likely represent a maximum for any realistic earthquake event in the San Francisco Bay Area based on our current knowledge of how Bay Area faults behave. Additional subsurface information would allow refined estimates of settlement extent and magnitude that incorporate less conservative assumptions.



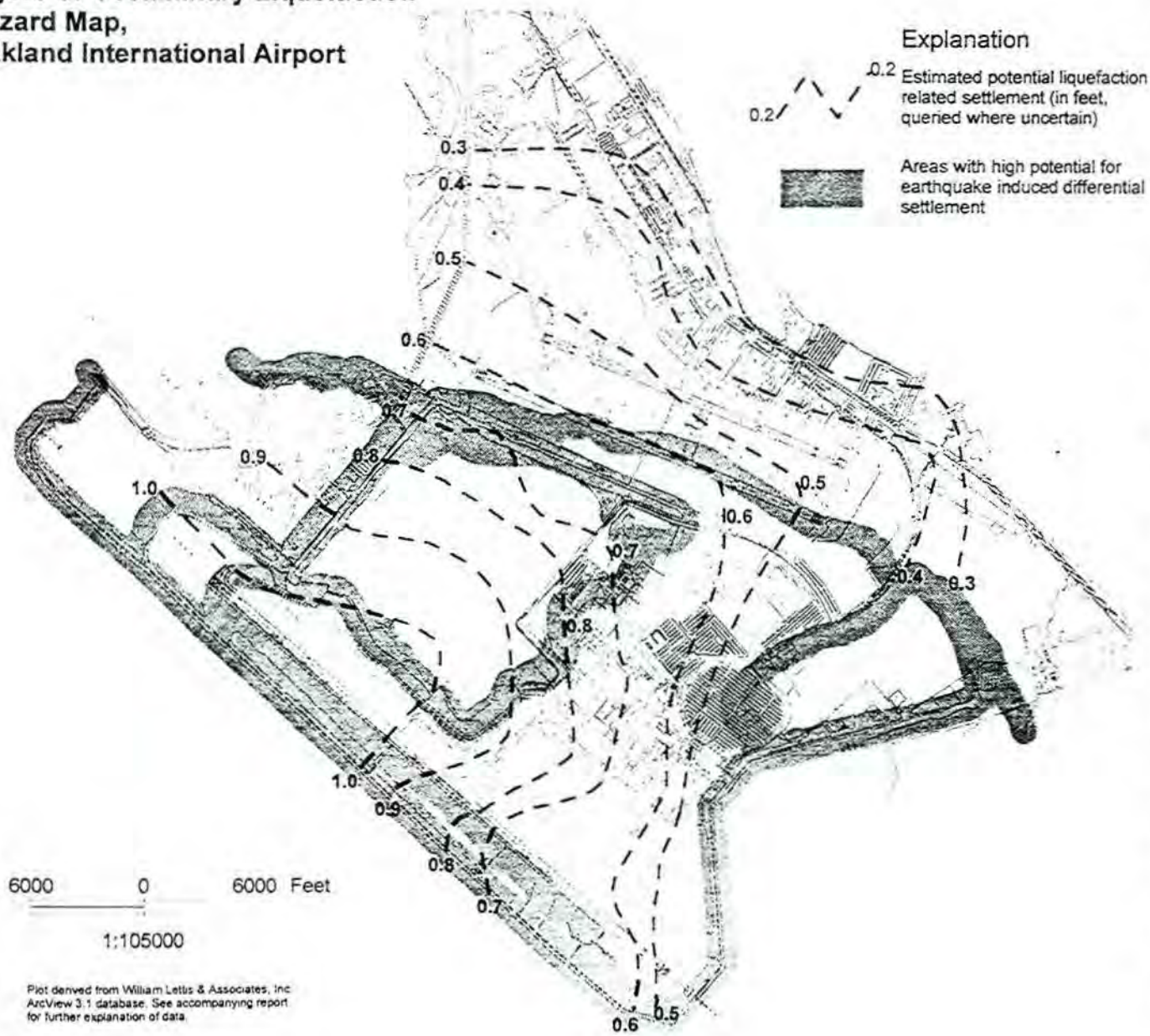
ABAG

Source: Association of Bay Area Governments- 2000

Oakland International Airport Liquefaction Susceptibility Due to Particularly Sandy Fill on Bay Mud

The Oakland International Airport (OAK) is susceptible to liquefaction due to its particularly sandy artificial fill overlying Bay mud. In the event of a large earthquake on the Hayward fault, liquefaction-related settlement is estimated to be at least 0.5 ft. across runways, and potential settlement could exceed 1 foot over the northernmost 30-40% of the main runways. Significant differential settlement at OAK is expected along the south and north margins of the runways. Differential settlement likely will be most severe at fill boundaries and along Bay margin levees. This assessment is partly supported by the liquefaction-related damage documented at OAK following the Loma Prieta earthquake.

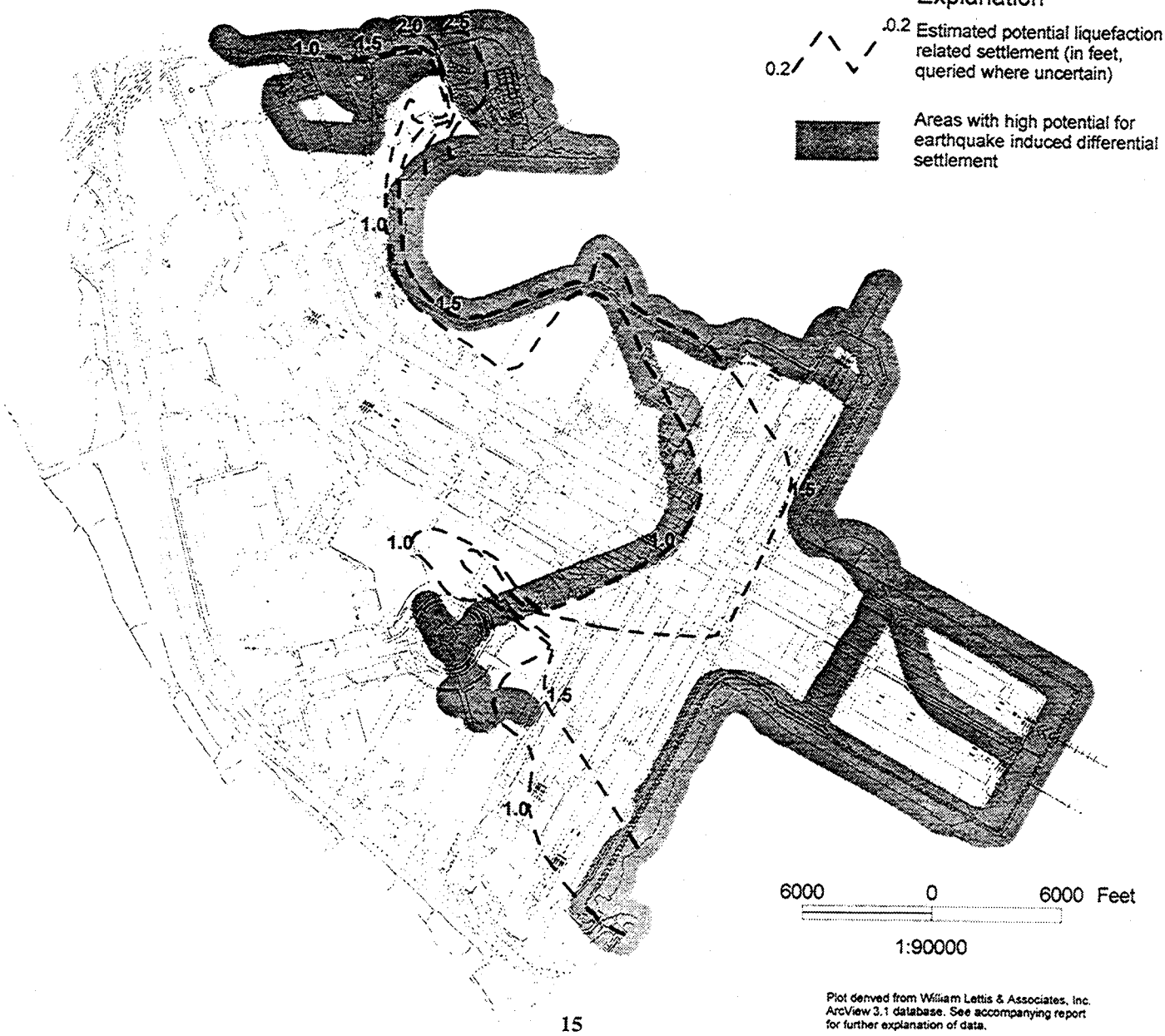
Figure 3: Preliminary Liquefaction Hazard Map, Oakland International Airport



San Francisco International Airport Liquefaction Susceptibility Due to Particularly Thick Fill on Bay Mud

The San Francisco International Airport (SFO) is built on artificial fill that is potentially susceptible to liquefaction. In the event of a repeat of the 1906 San Francisco earthquake, settlement of 0.5 ft. may occur across the entire runway field, and settlements of between 1 and 1.5 ft. may occur under the southeast part of the field. Thickness changes in liquefiable fill are relatively broad at SFO, suggesting that settlement may be spread out, and that the runway field may undergo a general southeastward tilt. The areas that likely present the greatest hazard to the operation of the runways are the fill boundaries crossing the central and southeastern part of the runways, where differential settlement is most likely to occur. ***The SFO liquefaction hazard map (Figure 4) is based on more limited borehole data than the maps for OAK and SJC.***

Figure 4: Preliminary Liquefaction Hazard Map, San Francisco International Airport

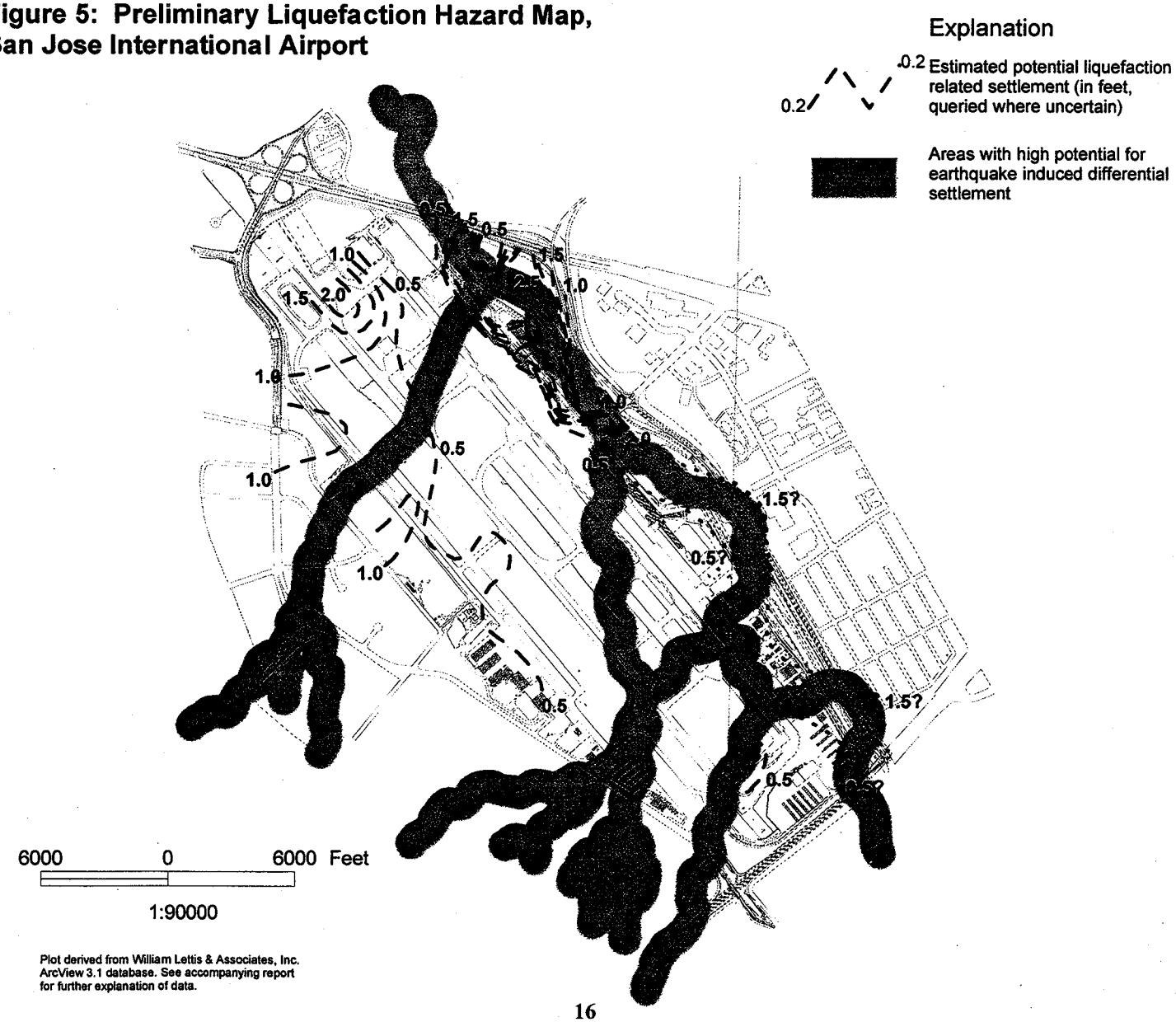


Plot derived from William Lettis & Associates, Inc. ArcView 3.1 database. See accompanying report for further explanation of data.

San Jose International Airport Liquefaction Susceptibility Due to Buried Stream Channels

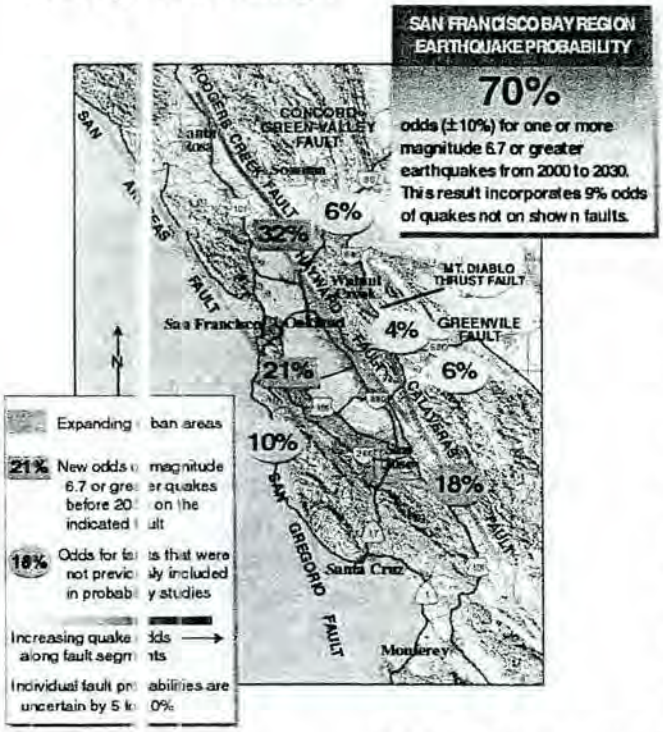
The liquefaction hazards at San Jose International Airport (SJC) are related primarily to naturally occurring ancient stream channel deposits and localized fills, unlike OAK and SFO that are underlain by broad artificial fills susceptible to liquefaction. A large earthquake on either the San Andreas (such as a repeat of the 1906 San Francisco earthquake) or the Hayward faults could cause total settlements of at least 0.5 feet under the northwestern 20-25% of the runways, with possible localized settlement between 1 and 2 feet under the extreme northern end of the field. The northwesternmost parts of the airport and runways may experience up to 2 ft. of settlement related to liquefaction, and the westernmost runway may settle as much as 1 ft. Extensive differential settlement is expected in the extreme northernmost part of the runways. Lesser amounts of differential settlement may occur over buried creek channels in the north-central and southern parts of the runways.

Figure 5: Preliminary Liquefaction Hazard Map, San Jose International Airport



Plot derived from William Lettis & Associates, Inc. ArcView 3.1 database. See accompanying report for further explanation of data.

Likelih ood of Liquefaction Damage to Airp rt Runways



Even airport runways in areas with very high susceptibility to liquefaction will not have a problem unless shaken long and hard enough in an earthquake to trigger liquefaction. Thus, when evaluating the liquefaction hazard, it is extremely important to understand the likelihood of a major earthquake on a fault that is close enough to trigger liquefaction. Using published and unpublished USGS data, ABAG staff estimated the closure probabilities for each commercial airport in the next 30 years as shown in Table 2. Note that these probabilities of closure are approximate.

In addition, for comparison, ABAG estimated the probabilities of closure due to liquefaction for the other airports in the region. The information for the other airports able to accommodate moderate-sized aircraft is also shown in Table 2. With the exception of the three international airports and Oakland Airport's North Field, the liquefaction analysis is based on regional, rather than site-specific information, however. ***The three major airports are among the most vulnerable to liquefaction of any airports in the Bay Area.***

Table 2: Liquefaction Disruption Information

Airport Name	Liquefaction Susceptibility of Runway Area	Approximate Probability of at Least One Airport Closure Due to Liquefaction in the Next 30 Years
O K – Oakland	**Very High**, somewhat less for shorter North Field runway	**61 %** (Main runways ***and*** longest North Field runway; somewhat less for other North Field runways)
SFO – San Francisco	**Very High**	**18 %**
S C – San Jose	**Very High**	**33 %** (due to buried stream channels)
Trav s Air Force Base	**Low**	Less than **2 %**
Moff t Federal Airfield	**Very High**, somewhat less for inland portion a south end	From less than **2%** (S end) to **50 %** (N end of longer runway)
Hayward	**Moderate**	Less than **2 %**
Livermore	**High**	**4 %**
Buchanan	**High**	**6 %**
Napa Co	**Low**	Less than **2 %**
alf Moon Bay	**Low**	Less than **2 %**
Ri Vista – Solano	**Very High**	Less than **2 %**
N t Tree – Solano	**Moderate**	Less than **2 %**
San Rosa – Sonoma	**Very Low**	Less than **2 %**

TABLE NOTES – See Appendix B for data on other Bay Area airports. **Liquefaction information** – Variations in liquef ction susceptibility at individual airports can be quite large, particularly at Moffett Field. **Probability informa ion** – In 1999, the U.S. Geological Survey (USGS) released revised estimates of the overall probability of a magni de 6.7 earthquake in the region, as well as the probabilities of earthquakes on each fault system, but not on each fa t segment. ABAG used additional preliminary USGS information on the probability of earthquakes occurrin on each fault segment(s) to perform this analysis (personal communication, David Schwartz, USGS).

Can Runways Be Made More Liquefaction Resistant?

The engineering measures usually used to mitigate potential problems due to liquefaction typically require closing runways to perform major ground improvement work. Such efforts are usually not cost effective or feasible unless undertaken as part of a larger runway construction or reconstruction project, such as that underway at San Jose International Airport.

Runway Program at the San Jose International Airport

SJC is currently extending a shorter runway to create a new full-length (11,000 ft) runway (30R/12L) that should be far less vulnerable to damage because the new pavement section is sufficient to "bridge" the stream channels. Upon completion of this project, the existing full-length runway (30L/12R) will be taken out of service and reconfigured in a similar fashion. Both projects should be completed by 2004.

Is Funding Available for Making Runways More Liquefaction Resistant?

The FAA has funding for assisting airports in various capital improvements. Airport Capital Improvement Plan (AIP) funding is described in U.S. Department of Transportation Federal Aviation Administration Order 5100.38A. Additional information on how priorities are established for distribution of these funds is provided in Order 5100.39A. Although there are no special funds set aside for making runways more liquefaction resistant, FAA will evaluate improvements critical for pavement service life and continued operation of the runways, particularly for SFO, OAK, and SJC. Federal AIP funds pay for 75% of eligible expenses at SFO, and 80.56% of eligible expenses at OAK and SJC. Improvements at the commercial service airports of Buchanan and Santa Rosa/Sonoma are of a lower priority, while funding improvements at general aviation airports are the lowest priority. The FAA will fund 90% of eligible expenses at these other airports, however, if the improvements are deemed a high priority in competing for the limited funds. AIP funds cover 90% of the eligible cost, with emphasis placed on runway rehabilitation projects at general aviation reliever airports. The FAA would review all funding requested following a major earthquake, or at sites suffering from major storm damage due to heavy rains that resulted n subsurface damage or erosion.

For more information, contact Fernando Yanez of the FAA San Francisco Airports District Office at 650/876-2803 or see **http://www.faa.gov/arp/app500/acip/fedfinal.htm**.

See Appendix B for More Information

A table listing general liquefaction hazard information for the runway facilities at the various airports within the nine Bay Area counties is included as Appendix B.

The types of liquefaction hazard information for airport runways provided in this report are more useful for planning purposes than for design of specific mitigation programs. The information is also useful to provide a comparative analysis of hazards among airports, rather than specific to an individual airport.

ISSUE 2 – Potential Damage to Air Traffic Control and Terminal Facilities

source – Control tower at Anchorage International Airport collapsed in 1964 earthquake – Steinbrugge Collection, Earthquake Engineering Research Center, University of California, Berkeley

source – SFO terminal damage due to Loma Prieta earthquake – R. Wiggins

A second major potential source of airport disruption is damage to air traffic control and terminal facilities. ***A structural analysis of these facilities is beyond the scope of this plan. In general, prior to constructing control and terminal facilities, seismic factors are investigated and new facilities are designed to resist shaking damage.***

However, structural damage in past earthquakes is clearly correlated with the measured intensity of shaking. Thus, for emergency planning purposes, it is useful to know the probability that Bay Area airports may be subject to very violent or violent ground shaking (modified Mercalli intensity (MMI) IX or greater) in the next 30 years. The shaking intensity information is based on the latest version of ABAG's ground shaking maps (Perkins and Boatwright, 1995; Perkins, 1998; Perkins and others, 1999a). As mentioned in the discussion of liquefaction issues, the scenario-specific USGS probability information is preliminary at this time. ***Facility managers at Oakland, Moffett, Hayward, San Francisco, Half Moon Bay, Buchanan and Livermore all need to be particularly concerned about the potential for violent ground shaking when designing new facilities. In addition, a structural assessment of older existing facilities may be warranted.***

In addition, even if the airport itself is not damaged, damage to buildings in the surrounding area may make the functioning of the airport particularly useful immediately after earthquakes, such as for airlifting in critical medical supplies or search and rescue teams. This makes conservative design of facilities at these seven airports particularly important.

Table 3: Shaking Exposure Information

Airport Name	Approximate Probability of Airports Being Exposed to Violent or Very Violent Shaking in the Next 30 Years
OAK – Oakland	**24 %**
SFO – San Francisco	**12 %**
SJC – San Jose	Less than **2 %**
Travis Air Force Base	Less than **2 %**
Moffett Federal Airfield	**23 %**
Hayward	**13 %**
Livermore	**4 %**
Buchanan	**6 %**
Napa Co	Less than **2 %**
Half Moon Bay	**7 %**
Rio Vista – Solano	Less than **2 %**
Nut Tree – Solano	Less than **2 %**
Santa Rosa – Sonoma	Less than **2 %**

TABLE NOTES – See Appendix B for data on other Bay Area airports. **Probability information** – As stated on page 17, ABAG used a combination of published and unpublished probability information as a basis for these estimates.

ISSUE 3 – Power and Communications Disruptions

Another potential threat to airport operations is disruptions to power and communications systems. ***An analysis of the vulnerability of these facilities is beyond the scope of this plan.*** However, as noted earlier, problems with these systems were among the most common in past earthquakes.

One of the reasons for these problems is the complexity of the systems, particularly at large airports. Another is that airports are constantly changing, with various buildings, maintenance facilities, passenger terminals, and operational structures being expanded, moved, and torn down. Thus, the nonstructural and lifeline components of airports, though originally designed to function after an earthquake, may be vulnerable today. A third problem is that these complex systems may have remnants of systems that were designed to standards in effect at the time they were installed, but that would not meet current standards. The system is as vulnerable as its weakest link.

Problems with power and communications systems are particularly disruptive, but can also be easily mitigated, using many of the techniques on page 27.

ISSUE 4 – Disruptions to the Transportation and Fuel Systems Serving the Airports

The final major potential source of airport disruption is damage to the road and highway transportation system that serves the airports. Critical staff (including air traffic controllers) needed to operate the airport may not be able to get to work. Crews and materials (such as gravel and concrete) necessary for airport runway and other repairs may be prevented from or delayed in reaching the airport. After the emergency, airport customers (including travelers and shipping companies) may not be able to get to and from the airport. Transportation disruptions that may impact airport operations are varied.

- The Oakland International Airport (OAK) is expected to be affected by numerous road closures servicing its facilities in a number of different earthquake scenarios. These scenarios include earthquakes on various segments of the Hayward fault system in the east Bay, as well as on more distant faults. As the highway interchanges in the vicinity of the airport are retrofitted, access problems are being reduced. Remaining critical structures in the vicinity of the airport that are still being retrofitted or waiting for replacement include the I-980 East Connector Viaduct, the Hwy. 24 West Connector Viaduct, the I-880 Distribution Structure, and the I-880/Rte.77/High St./SP Railroad Structure (personal communication, Rebecca Franti, Caltrans, Office of Earthquake Engineering). However, access routes to OAK will continue to be subject to disruption even after all structural retrofits are completed. For example, pipelines are more likely to rupture in areas subjected to liquefaction, and these pipeline ruptures can cause roads to be closed. In addition, OAK access roads are subjected to the threat of increased road closures indirectly due to the effects of amplified ground shaking on buildings, sites containing hazardous materials, and other problems which will continue to affect access to the airport.
- Similarly, the San Francisco International Airport (SFO) is expected to be affected by numerous road closures servicing its facilities in a

number of different earthquake scenarios. Since the highway interchanges in the vicinity of the airport have been retrofitted, access problems are reduced. In addition, since most of the faults in the Bay Area are closer to OAK than SFO, the access problems in the immediate vicinity of the airport are less. On the other hand, many of those traveling to SFO cross one or more toll bridges in route to the airport. Thus, to the extent that retrofits on those bridges have not been completed, access problems will remain. Potential road disruptions due to amplified ground shaking will affect access to SFO, but probably not to the extent that OAK is impacted. As with OAK, those problems may include road closures due to building damage, hazardous materials spills, broken pipelines, and other reasons.

- Hayward Airport and Moffett Field, while not experiencing quite as many closures as OAK and SFO, will probably still be affected by several road closures.
- Livermore, Buchanan, and Half Moon Bay airports are only affected by major numbers of road closures should faults immediately adjacent to these facilities rupture. Thus, problems are most severe when the potential role of these airports for emergency response is most critical.
- Roads in the vicinity of San Jose International are also potentially affected, particularly from larger earthquakes on the Hayward and San Andreas faults. However, the extent of these problems is much less severe, and the nature of the road network in the vicinity of the airport makes using alternate routes more practical. Thus, particularly after the completion of the runway improvements discussed on page 18, SJC should be considered a more likely to be functional than either SFO or OAK after a major Bay Area earthquake.

We need to identify alternate locations capable of handling large commercial and cargo jets after an earthquake should road transportation system disruptions make access to some airports difficult. Travis AFB will have increased air and vehicle traffic during the post-earthquake emergency response phase because the federal government plans on using Travis AFB as the primary mobilization center for their response to the disaster. With the normal operations that Travis has in addition to this major role, emergency planners should not believe that Travis has additional capacity for other commercial or cargo needs. Options include neighboring commercial airports (Sacramento, Stockton, Monterey, etc.), as well as larger general aviation airports.

source –
J. Villarin
for California Pilots Association

One major problem may be fuel. Both SFO and OAK have jet fuel delivered to their facilities via the ***same*** jet fuel pipeline. SJC, however, depends on fuel being trucked to the facility over roads which may be damaged. General aviation airports also have fuel trucked to their facilities. Disruptions in truck-based refueling over damaged roads, as well as with disruptions to fuel pipelines, should be considered in emergency planning. These plans should also discuss jet fuel supply issues should refinery sources be disrupted. Again, implementing many of the mitigation strategies on page 27 may be useful.

THE AIRPORT SYSTEM IN AN EMERGENCY – WHAT ARE OUR CURRENT PROCEDURES?

By definition, an earthquake, like any disaster, disrupts the normal way in which business is conducted. There are, however, plans by various airports and airport users on how airports will and should be used after an earthquake. The current system contains plans, both formal and informal, of:

- the Federal Aviation Administration;
- the three major international airports;
- other airports (including general aviation, out-of-region, and military/federal airports); and
- airport users (including passenger carriers, air cargo carriers, disaster services providers, and businesses).

This section summarizes the extent of those activities in 2000.

Federal Aviation Administration (FAA)

The Federal Aviation Administration (FAA) has responsibility for the management of the nation's air traffic system. The Airports Division of FAA works with the Air Traffic, Flight Standards, Airways Facilities and Logistics Divisions to provide for the installation and maintenance of federal navigational equipment and Air Traffic Control facilities. FAA works with City and county governments to construct airport runways, taxiways, and airport terminal facilities, and provides for the management of airport transportation on a daily basis (J. Rodriguez, FAA, personal communication, 2000).

The Airports Division of the FAA keeps a record of airport facilities and emergency services contacts. In the event of a serious earthquake, the San Francisco Airports District Office will conduct a survey of the airport facilities to assess damages and the need for federal funding for repairs for runways/taxiways, airport access roads, and terminal/cargo facilities. The public agencies that own and operate airports will be requested to submit grant applications for reconstruction projects. Funding priority will be given to runway/taxiway repairs and terminal areas needed to move passengers, airfreight, and the U.S. mail (J. Rodriguez, FAA, personal communication, 2000).

Bay Area International Airports

The three international airports are required by the Federal Aviation Administration to prepare emergency plans. These three plans include earthquake procedures. The specificity of those procedures, and the exact nature of those procedures, varies from airport to airport. In one case, the plan contains extensive checklists for use by airport personnel. The checklists streamline the decisions of personnel as they confirm the operational status of the FAA air traffic control tower, fire station, runway surfaces and lighting, taxiway surfaces and lighting, signage, utilities (power, gas, propane, communications, water, generators, and fuel farm), access routes, and medical support resources. In another case, the plan focuses on coordination with other agencies, administrative procedures, procedures for the care and sheltering of passengers and employees, and medical issues. In the third case, the emphasis of the earthquake portion of

the plan is on duck-cover-hold procedures, as well as on evacuation procedures.

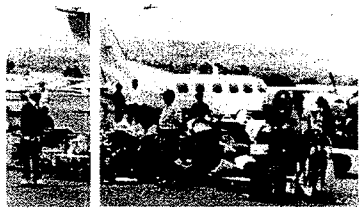
The difficulty in writing an emergency plan results, in part, from the four roles of that planning in an earthquake disaster:

- to protect employee and public safety during an earthquake (such as by the use of duck-cover-hold emergency procedures);
- to provide for employee and public safety in the immediate aftermath of the earthquake (such as plans for the medical care, feeding and sheltering on site of airport employees and passengers);
- to ensure the most rapid return of the airport to a status where the airport can be used for the dispatch and delivery of emergency personnel and materials; and
- to ensure the most rapid return to full operational status by the airport.

The existing plans could all be improved and expanded with more extensive coordination among the three Bay Area airports, as well as with airport users, general aviation airports, military and federal airports, and airports outside the Bay Area.

General Aviation Airports

General aviation airports are not subject to the same requirements for emergency plans that FAA requires of the commercial airports. However, as facilities owned and operated by local governments, they are, or should be, involved in emergency planning with the local government that owns them. There is typically not a separate emergency plan prepared for the airport facility. These airports, however, have a longer history of collaborative planning with other general aviation airports than the larger airports. Thus, they understand the benefits of working together to define creative solutions for mutual problems.



source – J. McCloud for California Pilots Association

These airports have nighttime staffing issues that are more significant than with larger commercial airports (G. Petersen, San Mateo County Airports Manager, personal communication, 2000).

In addition, several Bay Area general aviation airports have been involved in airlift operations in past earthquakes and are familiar with the process. For example, after the 1989 Loma Prieta earthquake, approximately 300,000 pounds of emergency supplies were flown to the Watsonville and Hollister airports from the Hamilton Field, Buchanan, and Reid Hillview airports (J. White, California Pilots Association, personal communication, 2000).

Out-of-Region Airports

Out-of-region commercial airports include Sacramento International Airport (SMF), Mather Field (MHR), Stockton, and Monterey. Sacramento County handles both SMF and Mather Field MHR. SMF is commercial airport with limited customs and immigration services. MHR, however, is not certified to handle passenger aircraft. Five major cargo companies use it. These two airfields, even when combined with Stockton Airport, do not have the capability of handling the 80 – 100 flights per hour currently handled by the three major Bay Area airports (OAK, SFO, and SJC). Depending on the time of day, these out-of-region airports could expect to be saturated within the first two hours of a major earthquake in the Bay

Area. Thus, major airport closures could expect to cause flight changes throughout the western portions of the country (S. Soto, Airport Firefighting and Airports Operations, Sacramento County, personal communication, 2000).

In an emergency, the first actions of these airports will be to ensure that they can be safely operated. Thus, they plan to move emergency equipment into open areas, dispatch units to survey damage, and prepare for aftershocks. If damage occurs, priority will be given to lifesaving efforts, call for medical help as needed, and fire suppression action. As victims are searched for, they anticipate that they may be involved in light rescue operations and may need to call for heavy equipment to rescue trapped victims. The airports will use mutual aid as needed, and use the airport paging systems for self-help instructions. Finally, the airports plan to establish access controls, organize multi-purpose staging areas, and set up for cargo aircraft relief operations.

Travis Air Force Base

At Travis Air Force Base, the priority is their wartime mission to support military operations. However, a commercial aircraft declaring an in-flight emergency may land at Travis AFB. In addition, civil authorities may designate Travis AFB as a base support installation and FEMA Mobilization Center. The rail lines servicing the base enhance the usefulness of the facility. In these instances, the facility will respond to a top-down request for support from FEMA. The AFB has begun to participate in disaster exercises. This has been a change in directive from the top air force command at the base (Lt. Col. R. Sandico, Travis Air Force Base, personal communication, 2000).

Air Cargo Carriers

The cargo carriers are challenged even on a normal business day to get goods delivered in the Bay Area due to the overstressed transportation network. An earthquake would make many transit corridors unavailable. Given the "just-in-time" nature of business, companies now count on their cargo carriers to be a "mobile warehouse" for them. The package is not in the back room, but in the back of a truck coming to them. Thus, it is that much more important for cargo carriers to be in business after a disaster. Cargo carriers use the full transportation network, including airports, roads, and rail lines.

UPS has been a leader in developing a plan for earthquake response and recovery. Their first priority is to protect employees and their families through drills, communications networks, meeting and evacuation points, and training for safety. The communications system includes radios for communications with employees at airports in and outside the region. Their second priority is to protect business assets, including securing computers to desktops, retrofitting hazardous older buildings, and working with customers to minimize their business disruption. Their third priority is to help the community they serve. In northern California, UPS plans to assist the Red Cross in logistics and with emergency support vehicles for the first 7 – 10 days after a major earthquake. An unprepared business may join the list of victims of the disaster. UPS plans to be a prepared business and to be a resource for the community in time of need (D. Bullert, UPS, personal communication, 2000).

The principal concern of a cargo carrier should an airport be shut down is how that carrier can get to their equipment so that they can go to an alternate airport. A secondary concern is setting up an alternate service network using a combination of alternate airports (such as Mather), alternative rail yards (such as Stockton rather than Richmond), and ground transportation.

Airline Passenger Carriers

The passenger carriers have goals similar to the cargo carriers, for they want to protect their employees and their assets, as well as to serve the community. However, they have the additional concern that their "cargo" is people. The disaster created by an earthquake may be one of the most stressful, emotionally challenging, and physically exhausting events we will ever experience. The stresses on carrier employees are particularly intense as they struggle to meet the needs of the passengers. Thus, carriers such as Southwest Airlines have developed guidelines for making the necessary decisions in an emergency. These guidelines have been provided to all carrier employees (C. Enriquez, Southwest Airlines, personal communication, 2000).

Some airlines view their responsibility to deliver passengers to an airport, not to care for and feed those passengers if they are stranded. This issue needs to be addressed with collaborative planning among airports, passenger carriers, and disaster relief agencies.

To the extent that passenger flights are diverted to other airports, these carriers may be dependent on road-based transit to deliver passengers to their destination.

Bay Area Red Cross and Other Disaster Service Providers

source – American Red Cross, Bay Area Chapter

The disaster service providers currently expect the airports and airlines to service the needs of stranded passengers and employees, particularly for the first few days. For a Hayward scenario event, they will need to move about 10,000 people into the affected area for logistics, mass care, mental health, family services, public affairs, and health services support in the first 7 – 10 days. In addition, they plan to move medical supplies, communications equipment, computer equipment, and mass care support supplies into the area (J. Cahill, American Red Cross – Bay Area, personal communication, 2000).

Major airport and road closures are also assumed. Therefore, initially, local logistics workers inside the Bay Area will support the Red Cross effort to the best of their ability and operate autonomously. Marshalling is planned to occur in Reno next to the airport, with a closer material mobilization center and staging area in the Sacramento area. A staff mobilization center is planned for the Stockton area. The Red Cross plans to open a staff reception area in the vicinity of Los Angeles area airports, and then people would be bused to Stockton if airports at Stockton and Sacramento were unavailable. East Bay activities might be supported with a mobilization center in the Stockton-Tracy area, for this area has both port and airport facilities which might be used. At the present time, West Bay activities might be supported by opening a logistics center at Moffett Federal Airfield. In past disasters, the Red Cross has brought in supplies by air to

Moffett and stored them there until they can be separated and redistributed. However, as the air museum at Moffett expands, this space may not be readily available. In addition, potential problems with runways discussed earlier may make use of this facility impractical. Travis AFB is being looked at as an alternate. The Red Cross is dependent on commercial shipping; food and other materials are typically trucked. The Red Cross hopes to continue to develop planning relationships with the airports, developing a liaison network which is useful to both the airports and the Red Cross, and integration of the American Red Cross needs into airport priorities (J. Cahill, American Red Cross – Bay Area, personal communication, 2000).

Business Users

As stated earlier when describing the role of cargo carriers, businesses have concerns about building and shipping and products. A typical manufacturing business relies on supplies from multiple companies that are trucked to the manufacturing facility. In the high-tech business environment of the San Francisco Bay Area, many of those parts are delivered as airfreight. That facility then adds value by creating a more complex and complete product. Those products are then sent throughout the world for distribution. Thus, there is a highly complex "supply chain" network system just to build and distribute one product. Typical disruptions in this network include:

- problems with information (such as data inconsistencies);
- operational delays (such as a delay in delivery of parts similar to the world-wide impact of the 1999 Taiwan earthquake on computer circuits); and
- strategic issues (such as how to set up a design system to meet customer demands).

Information technology businesses in the Bay Area get supplies from all over the world, and distribute product throughout the world. Airport cargo is an integral part of the logistical system. Companies such as Agilent Technologies have a plan for what to do after a disaster, such as an earthquake, but realize that the success of that plan is highly dependent on the particular affects of any earthquake (M. Ronstadt, Agilent Technologies, personal communication, 2000). Back-up shipping systems include use of barges to get product to and from airports, use of helicopters, and use of alternate airports outside of the region, such as Sacramento. Smaller businesses are typically not as sophisticated with their emergency planning as larger companies. They may easily experience disruptions in communications that cause them to be unable to contact airports, their suppliers, and their distributors.

Businesses have several concerns after an earthquake related to product being shipped. Where is the product in the distribution channel? Can the product be expected to reach the customer? What kind of shape is the product in? If it is damaged, can you get it back to the manufacturer? Where will the product be held? Although there will be some delay that is expected in the distribution system, it will not be long before cargo customers will expect service to return to normal to allow the economy to return to normal.

IDEAS FOR ACTION – HOW CAN WE BETTER PLAN?

The following checklist is expanded from recommendations contained in ABAG's report, ***Riding Out Future Quakes – Ideas for Action*** (Perkins and others, 1998). The recommendations focus on ways to keep providing transportation services following earthquakes, as well as how to plan around expected transportation interruptions. As such, they are useful in airport operations.

Airport Checklist

Employees

- ☐ work with employees to set up alternative routes from their homes to key facilities and offices in an emergency
- ☐ plan alternative shifts and/or crews since maintenance workers can be overworked
- ☐ cross-train employees to allow for some workers being unable to reach your facilities in a timely manner due to transportation disruptions
- ☐ make efforts to ensure safety to crews working on repairs, for they may be close to other damage

Operations

- ☐ *general* - evaluate the extent to which general aviation and military airports could accommodate commercial aircraft in an emergency
- ☐ *roads* - work to keep open surface roads in and out of your facility routinely maintained by your agency
- ☐ *supplies* - ensure that you have stocked your operations center with food, water and sanitation systems to allow for disruptions
- ☐ *fuel* - connect fuel pumps at vehicle yards to a backup power system
- ☐ *fuel* - ensure adequate fuel supplies should restocking of fuel supplies be delayed due to transportation disruptions, breaks in fuel pipelines, or refinery source disruptions (including fuel for ground-based vehicles)
- ☐ *power* - provide, anchor and test back-up power equipment, such as batteries
- ☐ *power* - size fuel supply tanks for emergency generators; power outages may be longer than expected
- ☐ *communications* - provide, anchor and test back-up equipment, such as portable radios and relay towers
- ☐ *water* - install back-up supplies on-site and anchor tanks
- ☐ *equipment* – work to ensure that all equipment and non-structural items are appropriately anchored, particularly in control towers
- ☐ *pipelines* - design on-site utility lines to minimize risk of pipeline breaks
- ☐ *pipelines* - create and isolate shorter segments of pipelines to facilitate repairs by installing additional valves; maintain those pipelines and valves

Site Hazards

Mitigate the exposure of your facilities to various earthquake hazards described in this plan, including:

- ☐ *liquefaction and/or differential settlement* – in particular, work to minimize the likelihood of closed runways due to pavement buckling by undertaking ground improvement mitigation as part of larger runway construction or reconstruction projects
- ☐ *violent shaking* – assess and mitigate structural deficiencies, particularly in older facilities designed and constructed using less stringent building codes

Emergency Plans

Ensure that the emergency plan for your facility covers the four roles of that planning process in an earthquake disaster:

- ☐ to protect employee and public safety during an earthquake (such as by the use of duck-cover-hold emergency procedures);
- ☐ to provide for employee and public safety in the immediate aftermath of the earthquake (such as plans for the medical care, feeding and sheltering on site of airport employees and passengers);
- ☐ to ensure the most rapid return of the airport to a status where the airport can be used for the dispatch and delivery of emergency personnel and materials; and
- ☐ to ensure the most rapid return to full operational status by the airport.

Existing airport emergency plans could be improved and expanded with more extensive coordination among the three Bay Area international airports, as well as with airport users, general aviation airports, military and federal airports, and airports outside the Bay Area.

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APPENDIX A – RUNWAY INFORMATION FOR AIRPORTS

The following table lists runway facilities for the various airports within the nine Bay Area counties. In addition, because of the focus of this project on emergency planning, the table also includes the larger airport facilities in adjacent counties. Data were collected in 2000 from AirNav (at **www.airnav.com**) on runways. The airports were then grouped by runway capacity based on a combination of runway length and weight restrictions. Finally, the list was forwarded to several airport managers to confirm that the categories were useful for planning purposes.

Airports are dynamic. Facilities change. Therefore, this table has been developed for planning purposes only and is not suitable for use in runway landing or takeoff decisions.

APPENDIX A - Airport and Runway Information Categorized by Capacity

Runway Able to Accommodate Large Aircraft
Length Over 7,500 ft; Can Accommodate Single Wheel Aircraft Over 50,000 lbs

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Oakland	Oakland Intl Arprt, South Field	OAK	Public	11/29	10,000	200,000	200,000	400,000	900,000
Monterey	Monterey	Monterey Peninsula Airport	MRY	Public	10R/28L	7,598	100,000	160,000	300,000	
Sacramento	Sacramento	Sacramento International Airport	SMF	Public	16L/34R	8,600	100,000	209,000	407,000	850,000
Sacramento	Sacramento	Sacramento International Airport	SMF	Public	16R/34L	8,600	100,000	209,000	407,000	850,000
Sacramento	Sacramento	Sacramento Mather Airport	MHR	Public	04R/22L	11,301	160,000	280,000	500,000	
San Mateo	San Bruno	San Francisco International Airport	SFO	Public	01R/19L	8,901	60,000	195,000	325,000	710,000
San Mateo	San Bruno	San Francisco International Airport	SFO	Public	10L/28R	11,870	60,000	200,000	355,000	710,000
San Mateo	San Bruno	San Francisco International Airport	SFO	Public	10R/28L	10,600	60,000	200,000	355,000	710,000
Santa Clara	San Jose	San Jose International Airport	SJC	Public	12R/30L	10,200	60,000	200,000	350,000	
Santa Clara	Mountain View	Moffett Federal Airfield	NUQ	Federal	14L/32R	9,200	64,000	144,000	253,000	528,000
Santa Clara	Mountain View	Moffett Federal Airfield	NUQ	Federal	14R/32L	8,120	82,000	239,000	300,000	814,000
Solano	Fairfield	Travis Air Force Base	SUU	Military	03L/21R	11,000	155,000	260,000	470,000	720,000
Solano	Fairfield	Travis Air Force Base	SUU	Military	03R/21L	10,995	155,000	260,000	470,000	720,000

Runway Able to Accommodate Moderately Large Aircraft
Length Over 5,400 ft; Can Accommodate Single Wheel Aircraft Over 25,000 lbs

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	Public	09L/27R	5,453	75,000	115,000	180,000	
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	Public	09R/27L	6,212	75,000	200,000	400,000	800,000
Napa	Napa	Napa County Airport	APC	Public	18R/36L	5,931	30,000	50,000	120,000	
Sacramento	Sacramento	Sacramento Executive Airport	SAC	Public	02/20	5,503	60,000	130,000	210,000	
Sacramento	Sacramento	Sacramento Mather Airport	MHR	Public	04L/22R	6,040	90,000	105,000	190,000	
San Benito	Hollister	Hollister Municipal Airport	3O7	Public	13/31	6,350	30,000	45,000		
San Joaquin	Stockton	Stockton Metropolitan Airport	SCK	Public	11L/29R	8,650	40,000	150,000		
San Mateo	San Bruno	San Francisco International Airport	SFO	Public	01L/19R	7,001	60,000	170,000	270,000	710,000
Stanislaus	Modesto	Modesto Cty-CO-Harry Sham Fld Arprt	MOD	Public	10L/28R	5,911	60,000	200,000	350,000	
Yolo	Davis	Yolo CO - Davis/Wdlnd/Winters Arprt	2Q3	Public	16/34	6,000	30,000	36,000		

Runway Able to Accommodate Medium-Sized Aircraft
Length Over 3,300 ft; Can Accommodate Single Wheel Aircraft Over 20,000 lbs

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Hayward	Hayward Executive Airport	HWD	Public	10R/28L	5,024	30,000	75,000		
Alameda	Livermore	Livermore Municipal Airport	LVK	Public	07L/25R	5,255	45,000	60,000		
Contra Costa	Byron	Byron Airport	C83	Public	12/30	4,500	29,500			
Contra Costa	Concord	Buchanan Field [1]	CCR	Public	01L/19R	5,010	60,000	90,000	140,000	
Contra Costa	Concord	Buchanan Field [1]	CCR	Public	14L/32R	4,601	60,000	90,000	140,000	
Mendocino	Ukiah	Ukiah Municipal Airport	UKI	Public	15/33	4,415	28,000			
Monterey	Salinas	Salinas Municipal Airport	SNS	Public	08/26	5,005	25,000	32,000	62,000	
Monterey	Salinas	Salinas Municipal Airport	SNS	Public	13/31	4,825	65,000	100,000	170,000	
Napa	Napa	Napa County Airport	APC	Public	06/24	5,007	30,000	50,000	120,000	
Sacramento	Sacramento	Sacramento Executive Airport	SAC	Public	12/30	3,836	30,000	43,000	67,000	
Sacramento	Sacramento	Sacramento Executive Airport	SAC	Public	12/30	3,485	60,000	85,000	90,000	
San Joaquin	Lodi	Kingdon Airpark Airport	O20	Public	12/30	4,000	30,000			
San Joaquin	Tracy	Tracy Municipal Airport	TCY	Public	07/25	3,438	50,000	70,000	120,000	
San Joaquin	Tracy	Tracy Municipal Airport	TCY	Public	07/25	3,680	50,000	70,000	120,000	
San Mateo	Half Moon Bay	Half Moon Bay Airport	HAF	Public	12/30	5,000	30,000	200,000	360,000	
Santa Clara	San Jose	San Jose International Airport	SJC	Public	11/29	4,599	60,000			
Santa Clara	San Jose	San Jose International Airport	SJC	Public	12L/30R	4,419	60,000			
Santa Cruz	Watsonville	Watsonville Municipal Airport	WVI	Public	02/20	4,501	81,000	96,000	167,000	
Santa Cruz	Watsonville	Watsonville Municipal Airport	WVI	Public	08/26	3,999	45,000	65,000		
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	Public	07/25	4,200	30,000			
Solano	Vacaville	Nut Tree - Solano County Airport	VCB	Public	02/20	3,800	30,000			
Sonoma	Santa Rosa	Sonoma County Airport [2]	STS	Public	01/19	5,002	52,000	75,000	117,000	
Sonoma	Santa Rosa	Sonoma County Airport [2]	STS	Public	14/32	5,115	35,000	53,000	85,000	
Stanislaus	Modesto	Modesto Cty-CO-Harry Sham Fld Arprt	MOD	Public	10R/28L	3,459	30,000			

[1] These runways have Declared Distances that are listed in the Airport Facilities Directory.

[2] During the summer of 2000, Sonoma County Airport is resurfacing both runways. This project will add runway strength and as a result will be able to accommodate larger aircraft.

Runway Able to Accommodate Small Aircraft

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Hayward	Hayward Executive Airport	HWD	Public	10L/28R	3,107	13,000			
Alameda	Livermore	Livermore Municipal Airport	LVK	Public	07R/25L	2,699	12,500			
Alameda	Livermore	Meadowlark Field Airport	23Q	Private	07/25	1,860				
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	Public	15/33	3,366	12,500			
Colusa	Colusa	Colusa County Airport	O08	Public	13/31	3,000	10,000			
Contra Costa	Brentwood	Funny Farm Airport (Brentwood Arprt)	4CA2	Private	17/35	1,880				
Contra Costa	Byron	Byron Airport	C83	Public	12/30	3,000	29,500			
Contra Costa	Concord	Buchanan Field	CCR	Public	01R/19L	2,768	17,000			
Contra Costa	Concord	Buchanan Field	CCR	Public	14R/32L	2,800	12,500			
Marin	Novato	Marin County Airport (Gnoss Field)	DVO	Public	13/31	3,300	26,000			
Marin	San Rafael	San Rafael (Smith Ranch Airport)	CA35	Private	04/22	2,140	7,000			
Mendocino	Gualala	Ocean Ridge Airport	Q69	Public	13/31	2,500	8,000			
Merced	Gustine	Gustine Airport	3O1	Public	18/36	3,200	12,000			
Merced	Los Banos	Los Banos Municipal Airport	LSN	Public	14/32	3,005	23,000			
Monterey	Monterey	Monterey Peninsula Airport	MRY	Public	10L/28R	3,501	12,500			
Monterey	Salinas	Salinas Municipal Airport	SNS	Public	14/32	1,899	30,000	45,000	75,000	
Napa	Angwin	Angwin-Parrett Field Airport	2O3	Public	16/34	3,217				
Napa	Napa	Moskowite Airport	41Q	Private	03/21	2,200				
Napa	Napa	Napa County Airport	APC	Public	18L/36R	2,500	12,500			
Napa	Pope Valley	Mysterious Valley Airport	69Q	Private	14/32	3,500				
Napa	Pope Valley	Pope Valley Airport	Q91	Private	10/28	3,700	6,000			
Sacramento	Sacramento	Natomas Field Airport	Q96	Public	16/34	2,700	12,000			
San Benito	Hollister	Frazier Lake Airpark Airport	1C9	Public	05/23	2,500	6,700			
San Benito	Hollister	Frazier Lake Airpark Airport	1C9	Public	05W/23W	3,000				
San Benito	Hollister	Hollister Municipal Airport	3O7	Public	06/24	3,150	30,000	45,000		
San Joaquin	Lodi	Lodi Airport	1O3	Public	08/26	3,085	30,000			
San Joaquin	Lodi	Lodi Airport	1O3	Public	12/30	2,070	30,000			
San Joaquin	Lodi	Lodi Airpark Airport	Q80	Public	07/25	2,705				
San Joaquin	Stockton	Stockton Metropolitan Airport	SCK	Public	11R/29L	3,050	12,500			
San Joaquin	Tracy	New Jerusalem Airport	1Q4	Public	12/30	4,000	12,500			
San Mateo	San Carlos	San Carlos Airport	SQL	Public	12/30	2,600	12,500			
Santa Clara	Palo Alto	Palo Alto Airport of Santa Clara CO	PAO	Public	12/30	2,500	12,500			
Santa Clara	San Jose	Reid-Hillview Airport	RHV	Public	13L/31R	3,101	17,000			

Runway Able to Accommodate Small Aircraft (continued)

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Santa Clara	San Jose	Reid-Hillview Airport	RHV	Public	13R/31L	3,099	17,000			
Santa Clara	San Martin	South County Airport	Q99	Public	14/32	3,100	12,500			
Solano	Cordelia	Garibaldi Brothers Airport	6Q2	Private	06/24	2,000				
Solano	Dixon	Maine Prairie Airport	Q33	Private	16/34	1,950				
Solano	Fairfield	Travis AFB Aero Club	8Q0	Military	04/22	2,000				
Solano	Fairfield	Travis AFB Aero Club	8Q0	Military	16/34	1,800				
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	Public	14/32	2,200	12,500			
Solano	Vacaville	Blake Sky Park Airport	CA57	Private	17/35	1,600				
Sonoma	Cloverdale	Cloverdale Municipal Airport	O60	Public	14/32	3,155	12,000			
Sonoma	Healdsburg	Healdsburg Municipal Airport	O31	Public	13/31	2,707	12,500			
Sonoma	Petaluma	Petaluma Municipal Arprt (Skyranch)	O69	Public	11/29	3,600	12,500			
Sonoma	Santa Rosa	Graywood Ranch Airport	CA39	Private	E/W	2,500				
Sonoma	Santa Rosa	Graywood Ranch Airport	CA39	Private	N/S	1,500				
Sonoma	Sonoma	Sonoma Skypark	0Q9	Public	08/26	2,480	8,000			
Sonoma	Schellville	Sonoma Valley Airport	0Q3	Public	07/25	2,700	12,500			
Sonoma	Schellville	Sonoma Valley Airport	0Q3	Public	17/35	1,500	12,500			
Sonoma	The Sea Ranch	The Sea Ranch Airport	CA51	Private	12/30	2,600	12,500			
Yolo	Davis	University Airport	0O5	Public	16/34	3,185	12,500			

Seaplane Base

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Marin	Sausalito	Commodore Center Seaplane Base	OQ2	Private	11/29	10,000				
Merced	Los Banos	San Luis Reservoir Seaplane Base	0O0	Public	ALL/WAY	15,840				
Napa	Napa	Lake Berryessa Seaplane Base	Q86	Public	13/31	7,000				
Napa	Napa	Lake Berryessa Seaplane Base	Q86	Public	14/32	13,000				
Napa	Napa	Lake Berryessa Seaplane Base	Q86	Public	15/33	10,500				
San Joaquin	Stockton	Lost Isle Seaplane Base	Q87	Public	NW/SE	4,000				

Helipads

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Hayward	Hayward Executive Airport [3]	HWD	Public	Helipad	50				
Napa	Rutherford	River Mdw Frm Hlprt/Inglenook Rnch	7CA9	Private	Helipad H1	65				
Sacramento	Sacramento	Sacramento Mather Airport	MHR	Public	Helipad 1	100				
Sacramento	Sacramento	Sacramento Mather Airport	MHR	Public	Helipad 2	100				
San Joaquin	Stockton	Stockton Metropolitan Airport	SCK	Public	Helipad H1	70	45,000	55,000		
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	Public	Helipad H1	180				
Sonoma	Santa Rosa	Sonoma County Airport [4]	STS	Public	Helipad					
Stanislaus	Modesto	Modesto Cty-CO-Harry Sham Fld Arprt	MOD	Public	Helipad H1	50	20,000			

[3] Hayward Executive Airport helipad has three parking spots.

[4] Sonoma County Airport helipad has parking for four helicopters.

Airports, Gliderports That Are Closed

County	City	Facility Name	Airport Code	Public/ Private Airfield	Runway Name	Runway Length (ft)	Single Wheel (lbs)	Double Wheel (lbs)	Double Tandem (lbs)	Dual Double Tandem
Alameda	Alameda	Alameda Naval Air Station		Military						
Contra Costa	Antioch	Antioch Airport		Public						
Marin	Novato	Hamilton Air Force Base		Military						
Napa	Calistoga	Calistoga Gliderport	O58	Private	10L/28R	2,000				
Napa	Calistoga	Calistoga Gliderport	O58	Private	10R/28L	2,600				
San Francisco	San Francisco	Crissy Field		Public						

APPENDIX B –AIRPORT LIQUEFACTION HAZARD AND ACCESS VULNERABILITY

The following table lists liquefaction hazard and access vulnerability information for runway facilities for the various airports within the nine Bay Area counties. Note that those facilities outside the region are not included in this table because no information on liquefaction hazard or access disruption potential is currently available for those areas.

Table Explanation

Liquefaction Susceptibility Information – The information in this column was obtained by examining the general location of the airport facility relative to the ***Map Showing Quaternary Geology and Liquefaction Susceptibility - San Francisco Bay Area, California*** (Knudsen and others, 2000). The map indicates five levels of susceptibility:

- Very high
- High
- Moderate
- Low
- Very Low

30-Year Probability of Closure Due to Liquefaction – The information in this column is derived by combining:

- the liquefaction susceptibility information with information on the intensity of shaking anticipated at the airport for various earthquake scenarios from the 1999 modeling described in the report ***The San Francisco Bay Area – On Shaky Ground*** (Perkins and Boatwright, 1995); as well as
- the probability of that earthquake occurring in the next 30 years based on published U.S. Geological Survey information (Working Group on California Earthquake Probabilities, 1999) and preliminary data from the U.S. Geological Survey (D. Schwartz, USGS, personal communication, 2000).

Two sites with the same liquefaction susceptibility can have very different probabilities of closure. For example, the probability of closure of OAK is far greater than SFO because the airport is closer to many more faults in the east Bay.

30-Year Probability of Disruption Due to Violent Shaking – The information in this column is derived from:

- the intensity of shaking anticipated at the airport for various earthquake scenarios from the 1999 modeling described in the report ***The San Francisco Bay Area – On Shaky Ground*** (Perkins and Boatwright, 1995); as well as
- the probability of that earthquake occurring in the next 30 years based on published U.S. Geological Survey information (Working Group on California Earthquake Probabilities, 1999) and preliminary data from the U.S. Geological Survey (D. Schwartz, USGS, personal communication, 2000).

APPENDIX B - Airport Liquefaction Hazard and Access Vulnerability

Runway Able to Accommodate Large Aircraft
Length Over 7,500 ft; Can Accommodate Single Wheel Aircraft Over 50,000 lbs

County	City	Facility Name	Airport Code	Runway Name	Liquefaction Susceptibility	30-Year Probability of Closure Due to Liquefaction	30-Year Probability of Disruption Due to Violent Shaking
Alameda	Oakland	Oakland Intl Arprt, South Field	OAK	11/29	Very High	61%	24%
San Mateo	San Bruno	San Francisco International Airport	SFO	01R/19L	Very High	18%	12%
San Mateo	San Bruno	San Francisco International Airport	SFO	10L/28R	Very High	18%	12%
San Mateo	San Bruno	San Francisco International Airport	SFO	10R/28L	Very High	18%	12%
Santa Clara	San Jose	San Jose International Airport	SJC	12R/30L	Very High	33%	less than 2%
Santa Clara	Mountain View	Moffett Federal Airfield	NUQ	14L/32R	Very High	50% at Bay end	23%
Santa Clara	Mountain View	Moffett Federal Airfield	NUQ	14R/32L	Very High	50% at Bay end	23%
Solano	Fairfield	Travis Air Force Base	SUU	03L/21R	Low	less than 2%	less than 2%
Solano	Fairfield	Travis Air Force Base	SUU	03R/21L	Low	less than 2%	less than 2%

Runway Able to Accommodate Moderately Large Aircraft
Length Over 5,400 ft; Can Accommodate Single Wheel Aircraft Over 25,000 lbs

County	City	Facility Name	Airport Code	Runway Name	Liquefaction Susceptibility	30-Year Probability of Closure Due to Liquefaction	30-Year Probability of Disruption Due to Violent Shaking
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	09L/27R	Very High	61%	24%
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	09R/27L	Very High	61%	24%
Napa	Napa	Napa County Airport	APC	18R/36L	Low	less than 2%	less than 2%
San Mateo	San Bruno	San Francisco International Airport	SFO	01L/19R	Very High	18%	12%

Runway Able to Accommodate Medium-Sized Aircraft
Length Over 3,300 ft; Can Accommodate Single Wheel Aircraft Over 20,000 lbs

County	City	Facility Name	Airport Code	Runway Name	Liquefaction Susceptibility	30-Year Probability of Closure Due to Liquefaction	30-Year Probability of Disruption Due to Violent Shaking
Alameda	Hayward	Hayward Executive Airport	HWD	10R/28L	Moderate	less than 2%	13%
Alameda	Livermore	Livermore Municipal Airport	LVK	07L/25R	High	4%	4%
Contra Costa	Byron	Byron Airport	C83	12/30	Low	less than 2%	less than 2%
Contra Costa	Concord	Buchanan Field	CCR	01L/19R	High	6%	6%

Runway Able to Accommodate Medium-Sized Aircraft (continued)
Length Over 3,300 ft; Can Accommodate Single Wheel Aircraft Over 20,000 lbs

County	*City*	*Facility Name*	*Airport Code*	*Runway Name*	*Liquefaction Susceptibility*	*30-Year Probability of Closure Due to Liquefaction*	*30-Year Probability of Disruption Due to Violent Shaking*
Contra Costa	Concord	Buchanan Field	CCR	14L/32R	High	6%	6%
Napa	Napa	Napa County Airport	APC	06/24	Low	less than 2%	less than 2%
San Mateo	Half Moon Bay	Half Moon Bay Airport	HAF	12/30	Low	less than 2%	7%
Santa Clara	San Jose	San Jose International Airport	SJC	11/29	Very High	33%	less than 2%
Santa Clara	San Jose	San Jose International Airport	SJC	12L/30R	Very High	33%	less than 2%
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	07/25	Very High	less than 2%	less than 2%
Solano	Vacaville	Nut Tree - Solano County Airport	VCB	02/20	Moderate	less than 2%	less than 2%
Sonoma	Santa Rosa	Sonoma County Airport	STS	01/19	Very Low	less than 2%	less than 2%
Sonoma	Santa Rosa	Sonoma County Airport	STS	14/32	Very Low	less than 2%	less than 2%

Runway Able to Accommodate Small Aircraft

County	*City*	*Facility Name*	*Airport Code*	*Runway Name*	*Liquefaction Susceptibility*	*30-Year Probability of Closure Due to Liquefaction*	*30-Year Probability of Disruption Due to Violent Shaking*
Alameda	Hayward	Hayward Executive Airport	HWD	10L/28R	Moderate	less than 2%	13%
Alameda	Livermore	Livermore Municipal Airport	LVK	07R/25L	High	4%	4%
Alameda	Livermore	Meadowlark Field Airport	23Q	07/25	Low	less than 2%	6%
Alameda	Oakland	Oakland Intl Arprt, North Field	OAK	15/33	High	61%	24%
Contra Costa	Brentwood	Funny Farm Airport (Brentwood Arprt)	4CA2	17/35	High	less than 2%	less than 2%
Contra Costa	Byron	Byron Airport	C83	12/30	Low	less than 2%	less than 2%
Contra Costa	Concord	Buchanan Field	CCR	01R/19L	High	6%	6%
Contra Costa	Concord	Buchanan Field	CCR	14R/32L	High	6%	6%
Marin	Novato	Marin County Airport (Gnoss Field)	DVO	13/31	High	33%	33%
Marin	San Rafael	San Rafael (Smith Ranch Airport)	CA35	04/22	Very High	47%	23%
Napa	Angwin	Angwin-Parrett Field Airport	2O3	16/34	Very Low	less than 2%	less than 2%
Napa	Napa	Moskowite Airport	41Q	03/21	Very Low	less than 2%	less than 2%
Napa	Napa	Napa County Airport	APC	18L/36R	Low	less than 2%	less than 2%
Napa	Pope Valley	Mysterious Valley Airport	69Q	14/32	Low	less than 2%	less than 2%
Napa	Pope Valley	Pope Valley Airport	Q91	10/28	Low	less than 2%	less than 2%
San Mateo	San Carlos	San Carlos Airport	SQL	12/30	Very High	37%	12%
Santa Clara	Palo Alto	Palo Alto Airport of Santa Clara CO	PAO	12/30	Very High	50%	12%

Runway Able to Accommodate Small Aircraft (continued)

County	City	Facility Name	Airport Code	Runway Name	Liquefaction Susceptibility	30-Year Probability of Closure Due to Liquefaction	30-Year Probability of Disruption Due to Violent Shaking
Santa Clara	San Jose	Reid-Hillview Airport	RHV	13L/31R	Moderate	less than 2%	less than 2%
Santa Clara	San Jose	Reid-Hillview Airport	RHV	13R/31L	Moderate	less than 2%	less than 2%
Santa Clara	San Martin	South County Airport	Q99	14/32	Low	less than 2%	less than 2%
Solano	Cordelia	Garibaldi Brothers Airport	6Q2	06/24	Low	less than 2%	6%
Solano	Dixon	Maine Prairie Airport	Q33	16/34	HIgh	less than 2%	less than 2%
Solano	Fairfield	Travis AFB Aero Club	8Q0	04/22	Low	less than 2%	less than 2%
Solano	Fairfield	Travis AFB Aero Club	8Q0	16/34	Low	less than 2%	less than 2%
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	14/32	Very High	less than 2%	less than 2%
Solano	Vacaville	Blake Sky Park Airport	CA57	17/35	Low	less than 2%	less than 2%
Sonoma	Cloverdale	Cloverdale Municipal Airport	O60	14/32	High	less than 2%	less than 2%
Sonoma	Healdsburg	Healdsburg Municipal Airport	O31	13/31	Very Low	less than 2%	less than 2%
Sonoma	Petaluma	Petaluma Municipal Arprt (Skyranch)	O69	11/29	Moderate	less than 2%	20%
Sonoma	Santa Rosa	Graywood Ranch Airport	CA39	E/W	Very Low	less than 2%	less than 2%
Sonoma	Santa Rosa	Graywood Ranch Airport	CA39	N/S	Very Low	less than 2%	less than 2%
Sonoma	Sonoma	Sonoma Skypark	0Q9	08/26	Very Low	less than 2%	less than 2%
Sonoma	Schellville	Sonoma Valley Airport	0Q3	07/25	Low	less than 2%	less than 2%
Sonoma	Schellville	Sonoma Valley Airport	0Q3	17/35	Low	less than 2%	less than 2%
Sonoma	The Sea Ranch	The Sea Ranch Airport	CA51	12/30	Very Low	less than 2%	less than 2%

Helipads

County	City	Facility Name	Airport Code	Runway Name	Liquefaction Susceptibility	30-Year Probability of Closure Due to Liquefaction	30-Year Probability of Disruption Due to Violent Shaking
Alameda	Hayward	Hayward Executive Airport	HWD	Helipad	Moderate	less than 2%	13%
Napa	Rutherford	River Mdw Frm Hlprt/Inglenook Rnch	7CA9	Helipad H1	Moderate	less than 2%	less than 2%
Solano	Rio Vista	Rio Vista Airport/Jack Baumann Field	O88	Helipad H1	Very High	less than 2%	less than 2%
Sonoma	Santa Rosa	Sonoma County Airport	STS	Helipad	Low	less than 2%	less than 2%