Aviation Planning Services

Site Selection for the Relocation of Juan Santamaría International Airport, San José, Costa Rica

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VOLUME III OF IV

SITE SELECTION FOR THE RELOCATION OF JUAN SANTAMARIA INTERNATIONAL AIRPORT, SAN JOSE, COSTA RICA.

FOR

THE MINISTRY OF PUBLIC WORKS AND TRANSPORTATION

REPUBLIC OF COSTA RICA

BY

AVIATION PLANNING SERVICES LTD.

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1. INTRODUCTION

This report presents an evaluation of alternative airport sites for the possible development of a replacement for Juan Santamariá International Airport in San José, Costa Rica. The study was commissioned by the Ministry of Public Works and Transportation (MOPT) in Costa Rica, and was sponsored by the Canadian International Development Agency (CIDA) under the Capital Project Preliminary Study mechanism of the Professional Services section, within CIDA's Industrial Cooperation Program.

It constitutes Volume III of a four volume set of documents presented to the MOPT, which are as follows:

- Volume I Executive Summary;
- Volume II Air Traffic Demand Forecasts;
- **Volume III Site Selection; and**
- Volume IV Economic Feasibility.

The overall objective of the entire study, in compliance with the Terms of Reference of Volume I, was to develop demand forecasts, evaluate alternative airport sites and recommend the most favourable one, carry out a technical and economic feasibility study for the selected site and conduct an environmental impact study.

The objective of the site selection study was to compile all available information from previous studies, and undertake a technical analysis of alternative sites.

The terms of reference state that the Consultants must analyze and compare the advantages and technical/economical limitations of the alternative locations, to satisfy the air traffic demand beyond the year 2010. The study of the sites must include assessment of the following factors: characteristics of the sites; dimensions of the basic components; predominant wind analysis; road accessibility; construction costs; environment; and any other factors deemed necessary.

In view of the number of factors influencing the site decision, a binary decision model was utilized which accepts both qualitative and quantitative information in manner which can be "scored" in order to rank the sites in order of preference.

The reasoning and data requirements, which are incorporated within the decision model, are developed within this volume on essentially a stand-alone basis. However, some information is required from the Forecast or Economic Feasibility volumes and this is so identified.

2. GENERAL METHODOLOGY

As outlined in ICAO Doc. 9184-AN/902 Master Planning, Part I, the major steps involved in the site evaluation and selection of the new airport include:

- broad determination of land area required;
- location of potential sites;
- evaluation of all factors affecting the airport location; and
- ranking of potential sites based on the evaluation factors.

The above steps will be described in the subsequent sections.

The initial choice of potential sites was based primarily upon the following:

- discussions with officials from MOPT and DGAC;
- the general locations studied during a site selection study prepared by R. Dixon Speas Associates (RDSA) in 1977, which were west of San José.
- a study prepared in 1990 by a Costa Rican engineering firm, BEL Ingenieria, which covered much of the same area as the RDSA study.

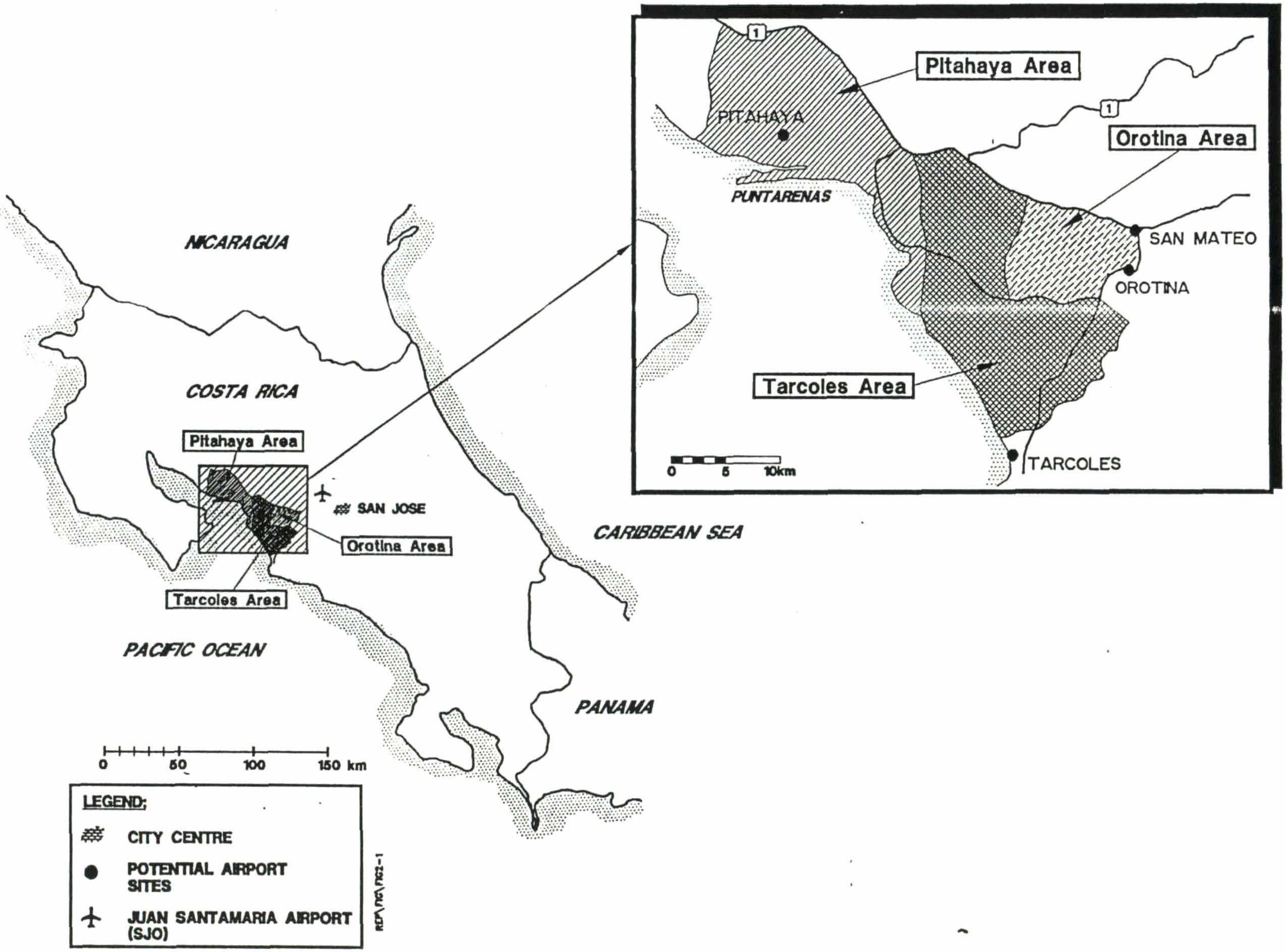
The sites were chosen on the basis that sufficient, reasonably level land was available for the construction of the runway and associated facilities, as well as the ability to accommodate wide-body aircraft, with the potential to expand capacity to accept greater aircraft demands. The prospective sites should not be traversed by major waterways, displace major townships and should not have obvious obstacle clearance problems when landing and departing. Also potential noise or other environmental impact on surrounding areas was assessed.

Due to the mountainous terrain experienced in Costa Rica, each site was initially evaluated on in this report the basis of obstacle clearance considerations, levelness of terrain in order to minimize earthwork, and distance to the demand centres. The general location of the sites being considered are in Figure 2.1, which shows the sites being considered west of San José. The three general areas are defined as follows:

- Orotina;
- Pitahaya;
- Tarcoles.

Those sites that were considered as unsatisfactory in one or more of the foregoing categories were eliminated from succeeding evaluations. A more detailed analysis of all the factors affecting airport location was carried out for the remaining sites, followed by a ranking of the sites, based on the factors.

FIGURE 2.1
GENERAL LOCATION POTENTIAL SITES
SITE SELECTION STUDY - COSTA RICA



3. BROAD DETERMINATION OF LAND AREA REQUIRED

Before searching for potential sites, it was necessary to make a broad assessment of the size and the shape of the parcel of land required. This was achieved by considering the space necessary for runway, taxiway and apron development, which generally forms the major proportion of land required for an airport. Consideration was given to the provision of adequate space required in order to accommodate the demands of Costa Rica for the period 2000 to 2030 and more. The sub-sections which follow provide descriptions of the following:

- runway length;
- meteorological analysis;
- requirement for additional runways;
- preliminary airside and landside requirements;
- preliminary airport layout.

3.1 Runway Length

The new airport should accommodate a runway suitable for the take-off of the critical aircraft on the longest non-stop distance from the new site, preferably at the aerodrome reference temperature. The critical aircraft for this new airport would likely be a long-range, wide-body type such as the B-747-400. The longest non-stop distance in the foreseeable future is the San José to a central European location such as Dusseldorf, which is nearly 5,000 nautical miles over the great circle route but could be greater due to airway routings and airspace restrictions. The runway length required is based on the following general conditions:

- Airport Pressure Altitude:
  100 metres is representative of the elevation of the proposed sites.

- Aerodrome Reference Temperature:
  Based on the reference temperatures of Managua to the north and Panama City to the south, the reference temperature for the proposed site would be in the order of 34°C (or ISA+20°C at 100 metres elevation).

  Both of those airports, being on the western coastal plains and at elevations similar to the proposed sites, were felt to be more representative of temperatures to be expected than those from the Juan Santamariá airport, which is higher and more effected by local topography. It should also be noted that based on Boeing's Airport Temperature Manual, 32°C will only be exceeded 5% of the time at Managua and Panama City.

- Effective Distance:
  The great circle distance for the route San José to Dusseldorf is approximately 5,000 nautical miles and considered typical of European destinations. Assuming a 2% circuity factor to account for variations from great circle routing, the effective distance amounts to 5,100 NM.

- Enroute Winds:
  These winds were taken from Boeing's "Winds on World Air Routes". For performance, wind speeds that will not be exceeded 85% of the time during the year were used. For the route San José to Dusseldorf, equivalent winds would be 1 knot @ 40,000 feet and 0 knots at 53,000 feet. Therefore, the Still Air Range is considered to be 5,100 NM.

- Payload:
  400 passengers and baggage for the B-747-400.
- FAR Part 121 International Reserves.

Based on Boeing's B-747-400 Airplane Characteristics for Airport Planning manual, the brake release gross weight for this mission would be approximately 730,000 lb (331,126 kg), resulting in a FAR takeoff dry runway length requirement of 2,500 metres. This runway length is satisfactory for landing, under wet runway conditions, up to the B-747-400 maximum landing weight of 630,000 lb (285,766 kg).

If the same analysis were carried out for the high gross weight version of the B-777-200, the runway length requirement would be approximately 2,750 metres.

For the B-747-100/-200 aircraft models, the runway length requirements can climb up to 3,500 metres, under worst conditions; however, it is expected that these models will be approaching retirement age, if not already retired, by the time the new airport is commissioned.

As a result, the runway for the new airport was planned using a runway length of 3,000 metres. If a second runway is required (see Section 5.1), a runway length of 2,500 metres would be sufficient for most operations. Examination of the current mix of traffic indicates that more than 90% of the operations are with narrow-body or smaller aircraft, which require less than 2,500 metres of runway with full payload.

3.2 Meteorological Analysis

Runways should be oriented so that aircraft are not directed over populated areas or near obstructions. They should generally be oriented in the direction of the prevailing wind.

The purpose of this analysis is to present a description of the wind patterns over the area, where sites were identified as possibly suitable for the construction of a new international airport. The area under investigation is located mainly in the western part of the Central Valley and in the Puntarenas region, as was shown in Figure 2.1. This section will discuss in general, the wind patterns expected in this area.

The annual precipitation in the rainy season (May to November) reaches 2 to 2.5 metres in the Central Valley, 1.5 to 2 metres in areas north of Puntarenas and up to 3 metres over the southern Pacific Coast. Precipitation tends to increase the closer the location to the mountains.

Temperatures average 26°C along the coastal regions and 20°C in the Central Valley above 1,000 m.

3.2.1 Wind Systems

There are three main synoptic (horizontal scale of 500 to 3,000 km) wind systems: easterly trade winds from the Caribbean Sea, equatorial westerlies from the Pacific Ocean and synoptic winds due to weather perturbations. There are also mesoscale (horizontal scale of 10 to 500 km) winds: sea and mountain breezes, cloud downdrafts and tornadoes.

3.2.1.1 Easterly Trade Winds

The trade winds are easterly winds caused by the subtropical anticyclones and they blow from the ENE over Costa Rica. These are the normal winds which are interrupted for a period of a few days or a few hours by other wind systems.

3.2.1.2 Equatorial Westerly Winds

During the wet season, from May to November, the intertropical convergence zone moves north and crosses Costa Rica, thus allowing equatorial westerly winds to blow over western Costa Rica. These winds are weaker than the trade winds and are helped by mesoscale winds (sea breeze and daytime upslope wind) in order to move inland. Also, because of their shallowness, the westerly winds affect only western Costa Rica and seldom reach over eastern Costa Rica because of the high, central mountains.

3.2.1.3 Synoptic Westerly Winds

From time to time, a synoptic system develops over the Caribbean Sea and produces westerly winds over Costa Rica. This low pressure area drains air towards the Caribbean, and therefore produces these westerly winds. This system may last a few days and is sometimes associated with a hurricane. It occurs mostly during the wet season.

3.2.1.4 **Sea Breeze**

The thermal contrast between the sea and the land creates local winds in the day time, as the land becomes warmer than the surrounding sea and a sea breeze develops as a result of the convection currents rising from the land. This on-shore wind is generally perpendicular to the coast. During night time, the land becomes generally colder than the surrounding sea and an off-shore breeze may develop. Generally, off-shore breezes are much weaker than on-shore sea breezes.

3.1.2.5 **Mountain Breeze**

During daytime, the sun heats up exposed mountain slopes at a faster rate than the ground below and this can create an upslope wind. In a mountainous country like Costa Rica, terrain-induced winds may play an important role in some areas.

3.1.2.6 **Cloud Downdrafts**

Cloud downdrafts are stronger in clouds with extensive vertical development like thunderstorms. The wind direction is variable, there is considerable wind shear and wind speeds may be quite high. A strong thunderstorm may generate a tornado. According to local meteorologists, tornadoes do occur in Costa Rica, but they are short lived.

3.2.2 Wind Measuring Stations

The winds are routinely measured at the following stations: Juan Santamariá, Tobias Bolaños, San José, Puntarenas, Corobici (Cañas), Damas and Taboga.

3.2.2.1 Juan Santamariá Airport

The official anemometer is located 4 metres above the control tower or 28 metres above the ground. This is a poor site, since it is influenced by the turbulence caused by the surrounding buildings and also because it is located too high.

A second anemometer is located near the end of the runway on a 10 metre tower (in a ditch, a few metres below the runway elevation) approximately 20 metres from the runway and not too far from some trees. This anemometer is probably more representative of the true winds at that airport.

Japan International Cooperation Agency (JICA) has used data from the National Meteorological Institute for the period 1986 to 1988 to construct a wind rose which is reproduced as Figure A.1 in Appendix A. Because the anemometer is too high, the wind speed is exaggerated and consequently the strength of the cross wind component is also exaggerated.

The wind rose produced by RDSA is based on data from 1971 and shows a similar behaviour of the wind, for wind speeds above 20 knots (37 km/h) (See Figure A.2 in Appendix A): most strong winds are from the ESE. The RDSA data provided an additional confidence level in the data from the JICA report.

3.2.2.2 **Tobias Bolaños Airport**

The anemometer is located at a 3 metre height, between two runways, and is located too low to provide representative winds. It is not known if reasonable wind data can be extracted from that site. The low height of the anemometer would tend to underestimate the wind speed at 10 metres by a factor of approximately 2. Aircraft pass close to the anemometer and may also influence the readings.

3.2.2.3 **San José**

A meteorological site has been operating in San José for many decades. Its original site was near the city centre but it has moved in the last few years near one of the Universities. The anemometer height is not known. The winds from 1970 to 1977 were analyzed in a report and an hourly and monthly summary is provided in Figure A.3 in Appendix A.

The dominating wind directions are from the E and NE with the NE direction dominating during daytime. Some NW winds occur during the rainy season. The wind directions are strongly influenced by the valley.

Figure A.4 in Appendix A shows the monthly and daily variations of the average wind speed in San José based on data from 1970 to 1977. The average wind speed reaches a maximum of 19 km/h (10.3 knots) at 1300 hours in February and drops to below 6 km/h (3.2 knots) during night-time in September.

3.2.2.4 **Puntarenas Airport**

The airport was officially closed in 1991; however, an observer still continues to take observations 12 hours a day, from 6 am to 6 pm. Charts record continuous temperature and wind data, which have to be extracted manually. The anemometer is located at 6 metres above ground in a slightly sheltered area, due to some trees nearby to the south and to the west of the station.

Figure A.5 in Appendix A presents the hourly and monthly wind roses at Puntarenas based on data of 1970 and 1971. Winds are fairly light all year round. During the night, winds are from the NE, descending from the Central Valley and the mountains to the NE. During the daytime a sea breeze develops and produces southerly winds.

APS has analyzed computer wind data for more recent years, which shows that winds are generally light and follow similar patterns to those depicted in Figure A.5. A visual inspection of raw ceiling data provided by the Meteorological Institute indicates that ceilings below 1,000 feet (305 metres) are not frequent, however observations were only taken during the daylight hours.

3.2.2.5 **Corobici (Cañas) Agrometeorological Station**

The agrometeorological station of Corobici is located 6 km to the NE of Cañas in an area where strong winds are frequent. It measures wind with an anemometer located at 4 metres above the ground. The National Meterological Institute does not keep a complete information file on each station. Unidentified and undated photographs of some of the sites are available, but there is no historical record of the evolution of the areas surrounding these stations. It is therefore very difficult to assess the value of this type of data for planning purposes. This and the two other agrometeorological stations are located on a map in Figure A.6 in Appendix A.

In Table A.1 in Appendix A the monthly average wind speed and dominating wind direction from 1984 to 1987 are presented. The strongest winds are from the NE during the dry season and average 25.7 km/h (13.9 knots) in February, the windiest month. A look at the diurnal variation during February shows that average wind speed is 32 km/h (17.3 knots) in the afternoon and 20 km/h (10.8 knots) during night-time. The maximum recorded wind speed is 55.7 km/h (30.1 knots), again in February. The wind at 10 metres could be twice as strong. Winds are lighter and more variable during the wet season. Southerly winds caused by a sea breeze reach Corobici 10% to 20% of the time in the afternoon during the wet season.

This station is located in a region where the mountains to the NE are lower thus permitting a freer passage to the easterly trade winds. Wind speed is increased because the air from the Atlantic is forced to pass through restricted areas like valleys. This station is located in what is called locally the Valley of the Winds. It is reported that the wind is even stronger a few kilometres to the west of Cañas and it may blow above 80 km/h (43.2 knots) with gusts of more than 100 km/h (54 knots).

3.2.2.6 **Taboga Agrometeorological Station**

The agrometeorological station of Taboga has an anemometer that is located 4 metres above ground. Table A.2 shows the monthly average winds at Taboga. The winds there are fairly similar to the ones measured at Corobici except that they are weaker by 20% to 40%. The station is located in the valley of the Bebedero River which runs from the SW to the NE. Therefore the dominating winds are from the NE all year round. During the wet season, a sea breeze may develop with southerly winds in the morning and south-easterly winds in the afternoon.

3.2.2.7 **Damas Agrometeorological Station**

The agrometeorological station of Damas has an anemometer that is located 3 or 4 metres above ground.

It is located near Quepos approximately 100 km to the SE of Puntarenas. The mountains to the NE are fairly high and do not let the trade winds in easily. There could be high trees in the vicinity that could cause a sheltering of the site. Therefore the winds are very light there, with a yearly average of only 3.4 km/h (1.8 knots) (see Table A.3 in Appendix A). The average wind reaches a maximum of 8 to 10 km/h (4.3 to 5.4 knots) during the daytime and drops to 2 km/h (1.1 knots) during the night. A southerly sea breeze develops by 0900 and ends up by 1600 at which time wind direction becomes variable due in part to downdrafts from convective clouds. This station is located in a wetter tropical climatological regime than localities situated further north. It illustrates that the winds are expected to be lighter at sites near high mountain ranges that prevent the trade winds from blowing.

3.2.3 Availability of Data

All raw meteorological data is available on paper from the National Meteorological Institute in Costa Rica. Some summaries and reports also exist. However, it is difficult to obtain meteorological data on computer diskettes. It appears that only temperature and wind data are routinely archived.

The National Meteorological Institute archive system is based on CLICOM that was produced by the World Meteorological Organization. A recent earthquake has done extensive damage to the National Meteorological Institute building and this has greatly affected their operations.

3.2.4 Wind Analysis at Proposed General Locations

Many factors affect the determination of the orientation, siting and number of runways. One important factor is the usability factor, as determined by the wind distribution. As recommended by ICAO in Annex 14, "the number and orientation of runways at an aerodrome should be such that the usability factor of the aerodrome is not less than 95% for the aeroplanes that the aerodrome is intended to serve".

This section will provide a general analysis of the winds in the area of the proposed sites (recall Figure 2.1). A detailed analysis of the crosswind components, based on the runway orientation, is provided in Section 5.1.

Wind distribution near the proposed site locations would likely be similar to those experienced at the stations of Puntarenas and Juan Santamariá as described in the following sub-sections.

Since the anemometers at Puntarenas and Juan Santamariá are not located at the appropriate 10 metre elevation, the winds at these stations needed to be adjusted. It was felt that the winds depicted for Santamariá were high and those at Puntarenas were low. Therefore, for this study, the wind speeds at Puntarenas were multiplied by 1.3 and those at Juan Santamariá were divided by 1.5. The numbers were based on the experience of professional meteorologists.

3.2.4.1 Tarcoles Area

The winds in the Tarcoles region are expected to be similar to the winds at Puntarenas, except that the sea breeze might be more from the SW in the morning and that the average wind speed should be a little stronger. It should be wetter there, with more thunderstorms and associated downdrafts. The trade winds may reach this site but with much reduced speed as compared to Juan Santamariá.

For the purposes of this study, the winds in the Tarcoles area were considered to be a weighted average of the winds from the Puntarenas Station and the Juan Santamariá Station. A 75% weighting was applied to the windrose occurrences at Puntarenas, and a 25% weight to the occurrences at Juan Santamariá. The Meteorological Institute in Costa Rica agreed with these weights and felt that they were conservative.

3.2.4.2 **Orotina Area**

The winds near Orotina should be a little stronger than the Tarcoles area during the dry season. It is expected that the dominating wind direction is to be from the E to NE at night and during the dry season. During daytime a sea breeze from the SW should develop probably all year round. Some vertical wind shear is to be expected at the boundary between the sea breeze and the trade winds. The shear should be strongest in the morning during the dry season. Just to the east of Orotina there is a sharp rise in terrain: that area may be prone to severe thunderstorms due to the lifting of the moist air.

For the purpose of this study, the winds near Orotina were considered to be a weighted average of the winds from the Puntarenas Station and the Juan Santamariá Station. A 50% weighting was applied to the windrose occurrences at Puntarenas, and a 50% weight to the occurrences at Juan Santamariá. The meteorological Institute in Costa Rica agreed with these weights and felt that they were conservative.

3.2.4.3 Pitahaya Area

The Pitahaya area should experience fairly light winds as is the case at Puntarenas. The area is located fairly close to the Gulf of Nicoya and a southerly sea breeze of 10 km/h (5.4 knots) should develop on most days. A high mountain range exists to the NE: that should reduce significantly the occurrence of easterly trade winds. The meteorologists at the National Meteorological Institute indicated that the winds should be fairly light. An observer at Puntarenas also agrees. However, a pilot from the DGAC indicated that he has experienced north-easterly winds up to 80 knots (148 km/h) over that area. If strong winds do occur near Pitahaya, they must be infrequent. In order to get frequent strong winds one probably has to go at least 10 to 20 kilometres NW of Pitahaya

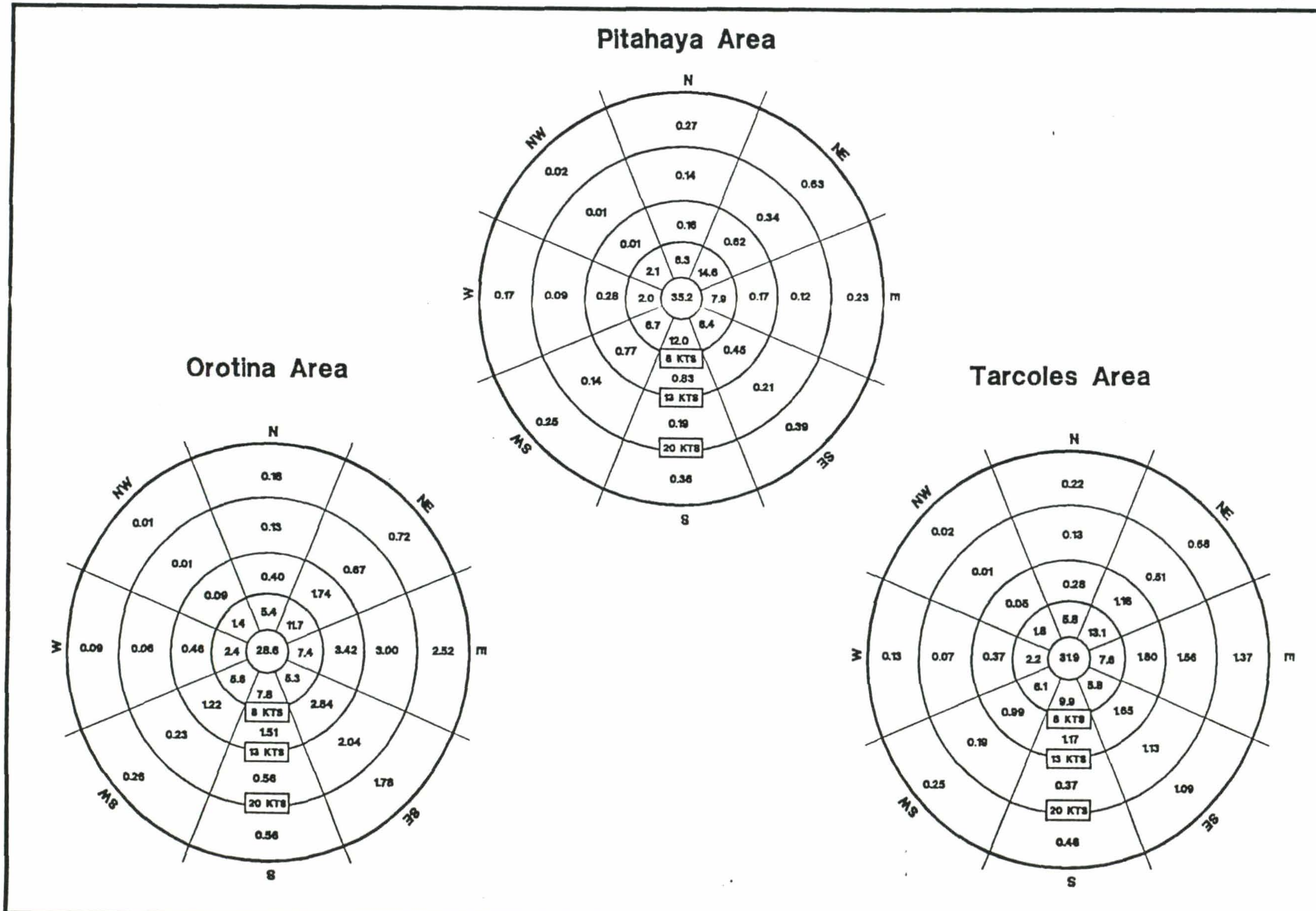
For the purposes of this study, the winds near Pitahaya were considered to be the same as those expected at the Puntarenas station.

3.2.5 Summary

The winds measured at Puntarenas are probably the most representative winds for most of the proposed sites. Based on the above discussions, the resulting windrose at each of the areas is provided in Figure 3.1. A daytime sea breeze of around 10 km/h (5.4 knots) is expected at all sites. North-easterly trade winds are expected to be stronger and more frequent near Orotina. The frequency of nearby thunderstorms is also expected to be higher near Orotina during the wet season.

Because of the uncertainty in wind data, it is recommended to install an anemometer near the selected site. Ideally, a full year of data should be gathered. If this is not possible, six months of data should be collected with three months during the dry season and three months during the wet season.

FIGURE 3.1
WINDROSES NEAR POTENTIAL SITES
SITE SELECTION STUDY - COSTA RICA



3.3 Requirement for Additional Runways

The need for a second runway is normally based on two factors: firstly, the forecasted level of traffic; secondly, the usability of the airport is maintained at a level not less than 95%. Another factor could be the local topography which could preclude a single runway operation (this is discussed in Section 5).

For the level of traffic forecasted in Volume II of this study, a single runway system would be sufficient for operations well into the future. The following sub-section will provide a general description for the requirement of a crosswind runway.

3.3.1 Runway Usability Resulting from Wind Analysis

Based on ICAO Annex 14, landing or take-off of aircraft is precluded when the cross-wind component exceeds:

20 knots (37 km/h)	-	For aircraft whose reference field length is 1,500 m or more.
13 knots (24.1 km/h)	-	For aircraft whose reference field length is 1,200 m or up to 1,500 m.
10 knots (18.5 km/h)	-	For aircraft whose reference field length is less than 1,200 m.

It should be noted that the representative windroses, depicted in Figure 3.1, show generally calm conditions at the proposed sites. Wind conditions less than 8, 10, 13 and 20 knots (14.8, 18.5, 24.1 and 37 km/h) are expected to occur in the following proportions:

	Wind Occurrences (from any Direction) with Speeds Less Than:			
	8 Knots (14.8 km/h)	10 Knots (18.5 km/h)	13 Knots 24.1 km/h)	20 Knots (37 km/h)
Orotina Area	75.5%	80.1%	87.1%	93.8%
Pitahaya Area	93.0%	94.4%	96.3%	97.6%
Tarcoles Area	84.3%	87.3%	91.8%	95.8%

It should be noted that these proportions represent wind occurrences from any direction and are not cross-wind components. Since the runway orientations are provided in Section 5.1, an analysis of cross-wind components is left for this section.

Since a large proportion (more than 80%) of the current scheduled movements at San José are carried out with DC-9 or larger type aircraft, it is expected (based on the above proportions) that one runway would be sufficient at all sites being considered in these three areas.

3.4 Preliminary Airside and Landside Requirements

As the objective of Section 3 is to make a broad assessment of the land area likely to be required, this sub-section will focus on the remaining major airport sub-systems, which will provide for the complete airport development. This will include a discussion[1] of the following:

- minimum parallel runway separations;
- runway and taxiway width;
- parallel taxiway characteristics;
- apron sizing;
- other facilities.

3.4.1 Parallel Runway Separations

As mentioned previously, although a parallel runway is not required in the short term, adequate provision should be made for such a runway. Based on ICAO Annex 14, the minimum separation distance between centrelines, while at the same time allowing for simultaneous operations under IMC, is 1,525 metres for independent parallel approaches.

3.4.2 Runway and Taxiway Width

The ICAO Aerodrome Reference Code for the runway would be 4E. The recommended runway width would be 45 m, with 7.5 m shoulders to a total width of 60 m.

The straight portion of the taxiways should have a width of 23 m, with

[1] An order of magnitude cost is provided in Section 5, while a more detailed analysis of these facilities will be carried out during the next phase of this project.

10.5 m shoulders to a total width of 44 m.

3.4.3 Parallel Taxiway Characteristics

To minimize up-front construction costs, an airport's taxiway system should be only as complex as needed to support the near-term capacity needs of the runway. Taxiway components can be added to the system in stages to keep pace with the growth in airport demand.

The addition of a parallel taxiway to the runway configuration increases the airport operational efficiency by allowing the runway to realize its maximum capacity potential. The parallel taxiway is justified when the airport's annual operations reach 50,000, or when the normal peak hour itinerant operations total 20. According to the forecast, this level of operations would likely be reached by the year 2010, therefore a parallel taxiway is recommended for construction in the initial airport development.

The recommended width of the taxiway is as described in Section 3.4.2. The separation between the taxiway and runway centreline for a code 4E airport is 182.5 metres.

3.4.4 Apron Sizing

The terminal apron has been sized with sufficient space to allow for peak-hour stand requirements. Preliminary apron sizes of 575 m by 250 m and 225 m by 100 m (for cargo) would be required to accommodate the anticipated aircraft for the year 2010, including jumbo jets, wide-body, narrow-body, cargo and turboprop aircraft. The space from the runway to any aircraft parked on the apron is such that the ICAO 14.3% transitional surface would not be violated.

The proper lateral location of the terminal and apron area should be determined based on the shortest taxiing distances. Additionally, as the operational area required is relatively large, proper care must be taken in order to minimize the earthwork. Since these requirements are site specific, they will be discussed in Section 5.

3.4.5 Other Major Airport Facilities

In order to get a broad determination of land area required, additional area was provided for the following:

a) The preliminary airport terminal building size was determined based on the JICA study.

b) The cargo building size requirement was based on the APS cargo volume forecast.

c) Sufficient space was allocated for a car park and access road.

d) Sufficient space was allocated for a precision approach Category I lighting system at both ends of the runway, if required.

e) Space was made available for a future parallel runway, together with its associated facilities.

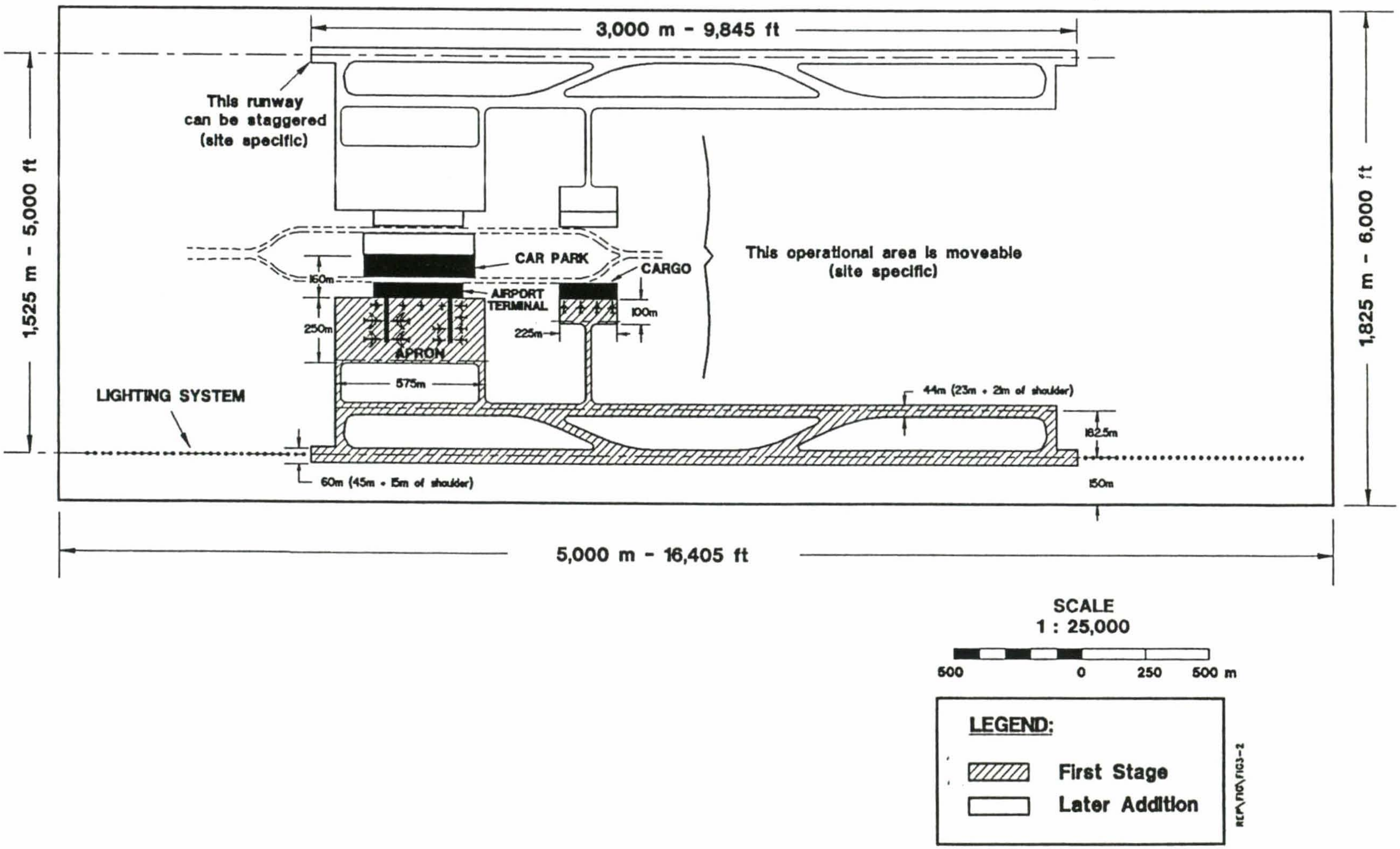
3.5 **Preliminary Airport Layout**

As a result of the analysis in the previous sections, a preliminary airport layout was derived and is shown in Figure 3.2. It should be noted that with improvements in navigational and radar tracking accuracy, the parallel runway separation of 1,525 m may be reduced. Furthermore, an alternative to the system shown in Figure 3.2, would be to stagger the two runways. This allows shorter taxi times when one runway is used for arrivals and the other for departures. This type of configuration will be examined at each of the specific sites.

For instrument runways, an obstacle free strip should be provided, extending laterally to a distance of at least 150 m on each side of the centreline of the runway throughout the length of the strip.

Therefore, in total, a parcel of land should be located at least 1,825 m wide, and 5,000 m long. This area was used for the initial selection of the sites.

FIGURE 3.2
BASIC AIRPORT LAYOUT FOR BROAD DETERMINATION OF LAND AREA REQUIRED
SITE SELECTION STUDY - COSTA RICA



4. LOCATION OF POTENTIAL SITES

Based on the 5,000 m by 1,825 m parcel of land which would be required for the new airport, and was determined in Section 3, the specific location and assessment of the potential sites can now be addressed. This section will provide a brief discussion of the process used in the selection of the potential sites.

During initial meetings with the DGAC and MOPT, discussions regarding the siting of the future international airport led to the following considerations:

- Future plans for development of hotels indicate relatively large developments to the west in the Guanacaste and Puntarenas provinces.
- Preliminary studies by RDSA and BEL considered sites to the west of the city of San José in the Puntarenas province.
- The airport should preferably be located to the west of the city of San José.
- The extension of the major highway from Colon to Orotina would likely be completed in the next few years, and as a result access from San José to the new airport would be via this new road.
- Since Costa Rica is a country with substantial high terrain, with the highest peak at an altitude of 3,189 metres, siting of an airport can be rather difficult. Furthermore, with San José located in the Central Valley and altitudes ranging from 600 to 1,500 metres, siting of an airport close to San José would be not only costly, but would also be operationally unacceptable. The general location considered appropriate for examination was west of the entrance to the Central Valley.

- Operational considerations, earthwork requirements and distance to the city of San José were important criteria in the site selection.

Based on the above considerations, APS selected seven sites for the preliminary analysis. Figure 4.1 shows the general location of each of the sites, as well as their location with respect to San José. The sites are as follows:

a) West of Orotina;
b) West of San Mateo;
c) East of Pitahaya;
d) NW of Pitahaya;
e) NE of Tarcoles;
f) NW of Tarcoles;
g) Caldera.

The potential sites were surveyed from the air as well as on the ground. Following the site inspection and topographic review of each site, four of the seven sites were eliminated from the more detailed analysis.

The site at San Mateo was eliminated for the following reasons:

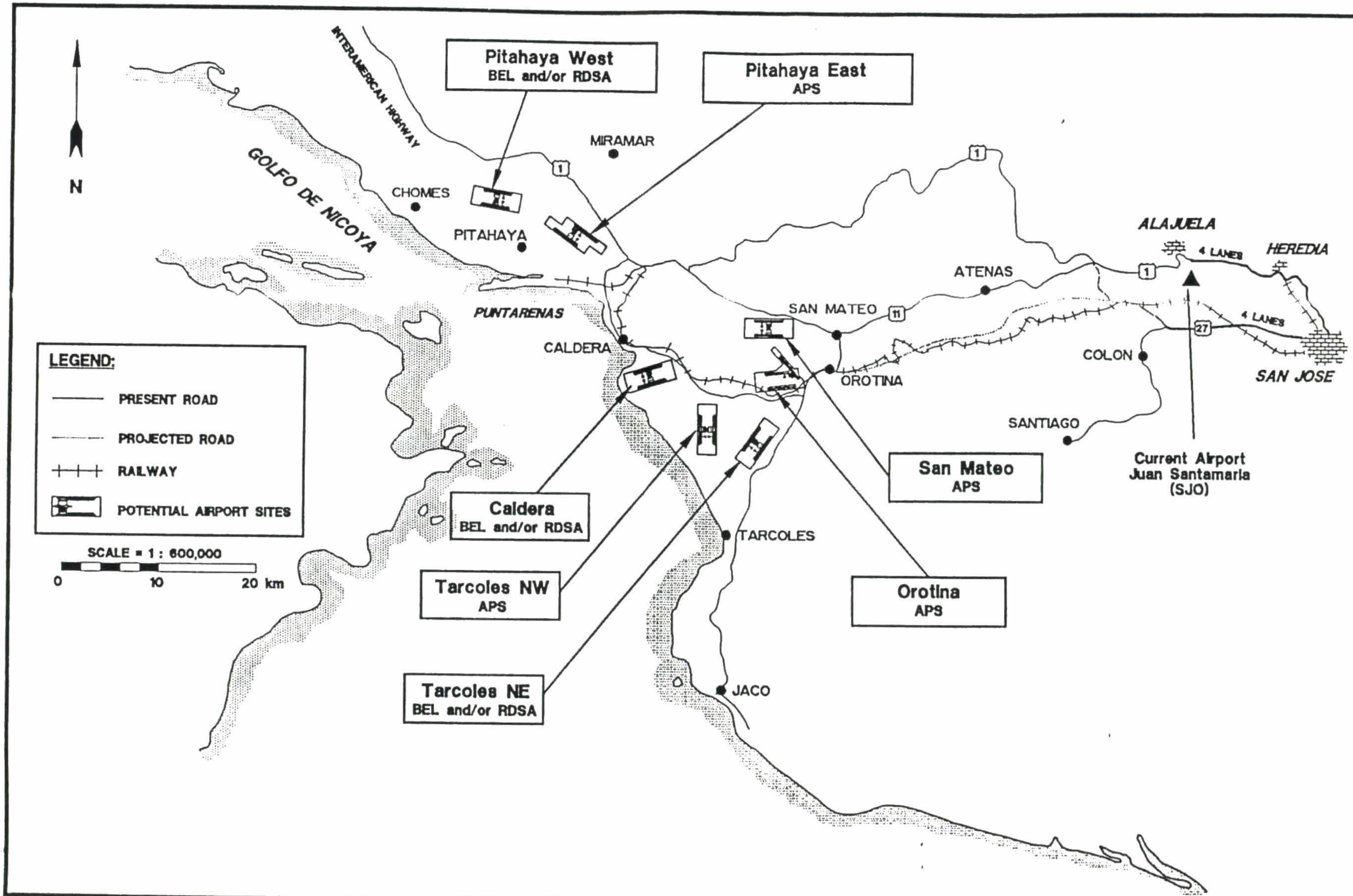
- Operations to the east were considered difficult and operationally unacceptable.
- Expansion of the airport to accommodate a future, parallel runway would be costly due to two rivers (Rio Machuca and Subures).
- The proximity of this site to Orotina resulted in this site being redundant.

The site west of Pitahaya was eliminated based on the following:

- The site east of Pitahaya was closer to San José.
- From an operational point of view, the two sites at Pitahaya were similar.

The site NW of Tarcoles was also removed from subsequent analysis since considerable earthwork would be required, and it is only five kilometres from the other Tarcoles site, with no other significant benefits.

FIGURE 4.1
LOCATION OF POTENTIAL SITES
SITE SELECTION STUDY - COSTA RICA



The site at Caldera was eliminated based on the following:

- Insufficient space for the required runway length and Category I approach lighting systems.
- Insufficient parallel taxiway space.
- Lack of expansion capability for a future, parallel runway.

As a result, the three sites which were considered suitable for further detailed analysis are Orotina, Pitahaya (to the east) and Tarcoles (to the NE), with general locations described below and also shown in Figure 4.2.

Orotina	-	4 km west of Orotina with proposed runway orientations of 08/26 and 14/32 (see Section 5.1); and
Pitahaya	-	4 km east of Pitahaya with a proposed runway orientation of 13/31.
Tarcoles	-	7 km NE of Tarcoles with a proposed runway orientation of 03/21;

The specific location of each of the sites is shown on the topographical maps in Figures 4.3 through 4.5.

A detailed analysis and comparison of each of these sites is contained in Sections 5 and 6.

FIGURE 4.2
SITE CONSIDERED FOR FURTHER ANALYSIS
SITE SELECTION STUDY - COSTA RICA

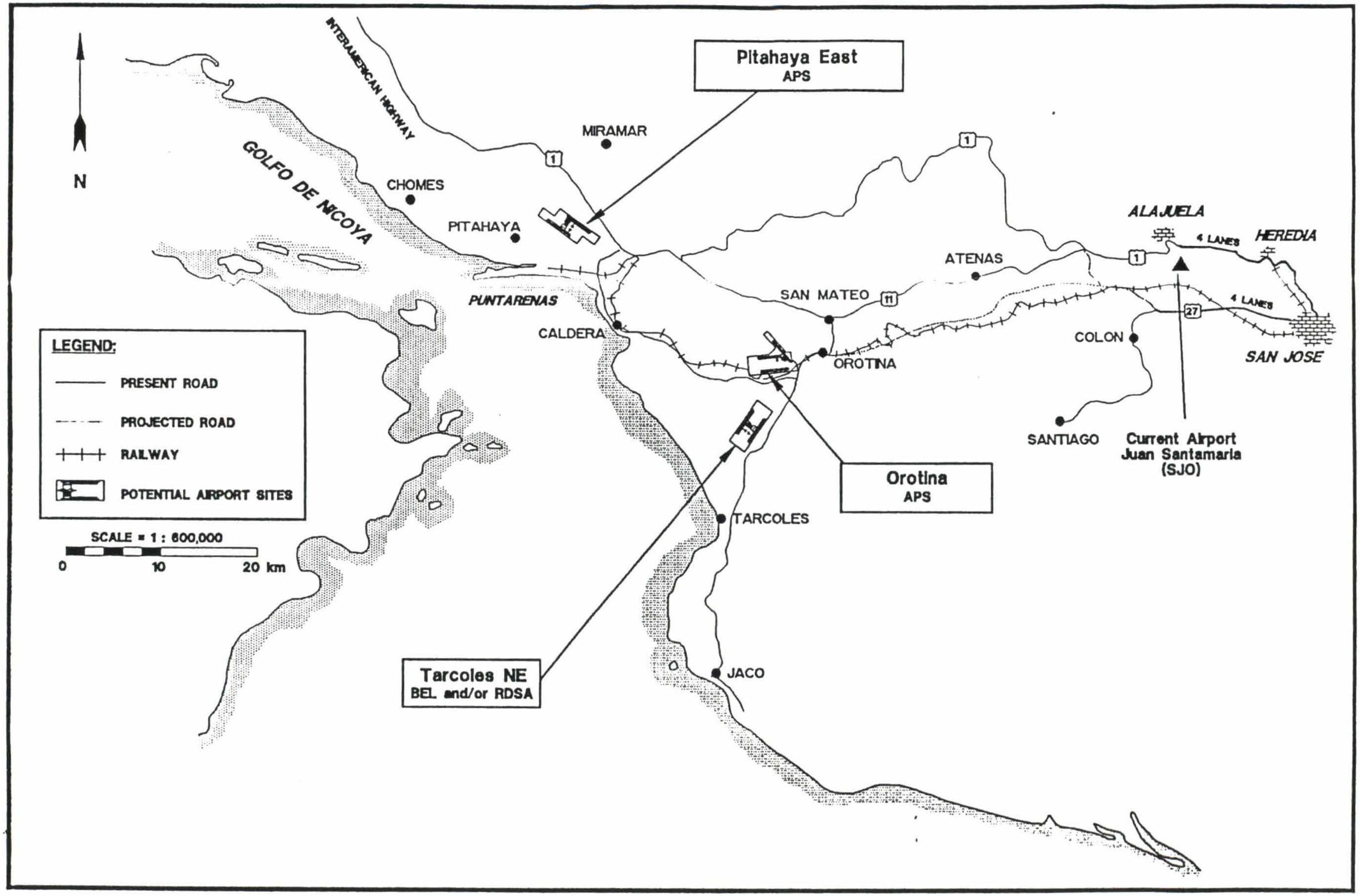


FIGURE 4.3

OROTINA SITE

SITE SELECTION STUDY - COSTA RICA

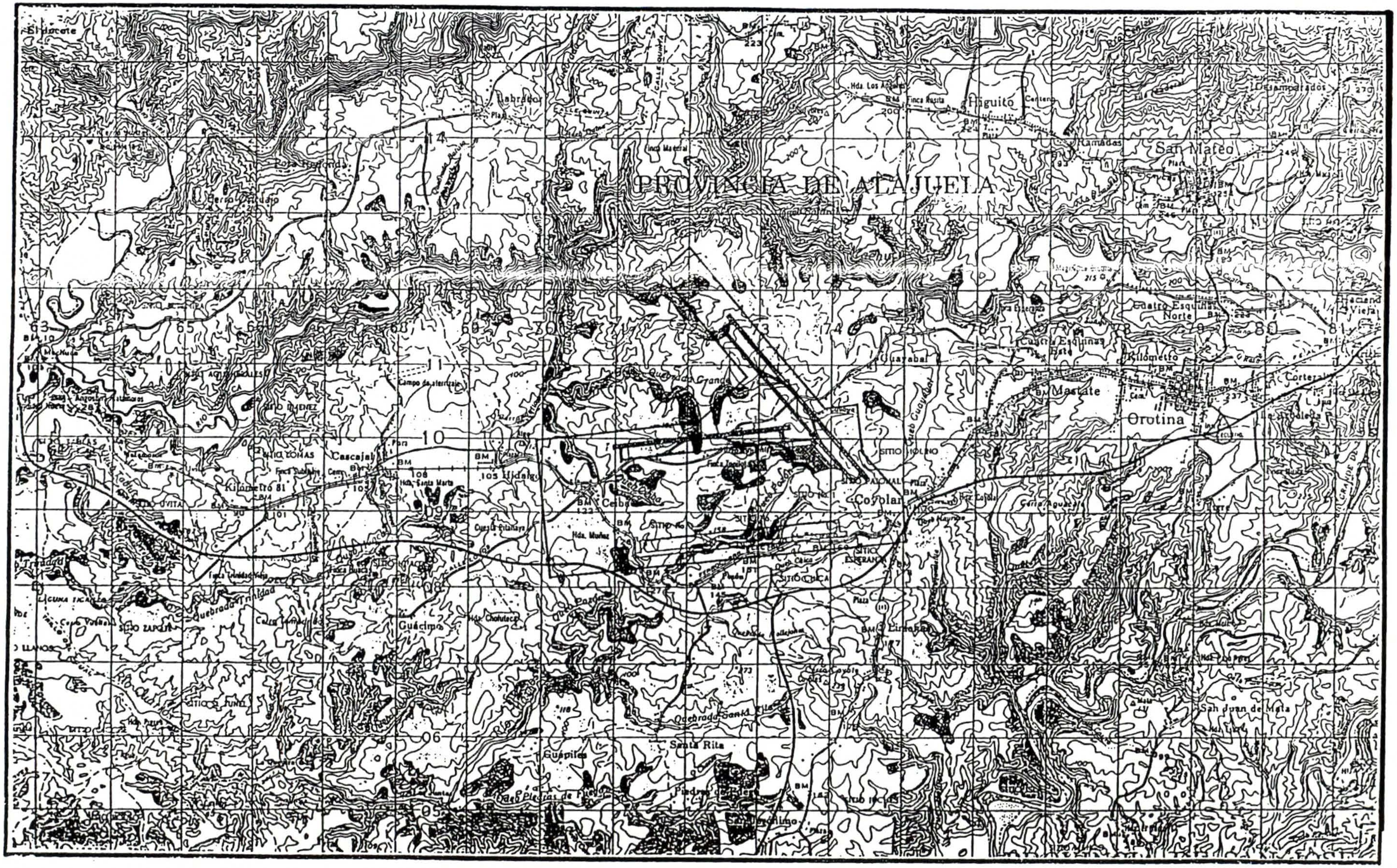


FIGURE 4.4
PITAHAYA SITE
SITE SELECTION STUDY - COSTA RICA

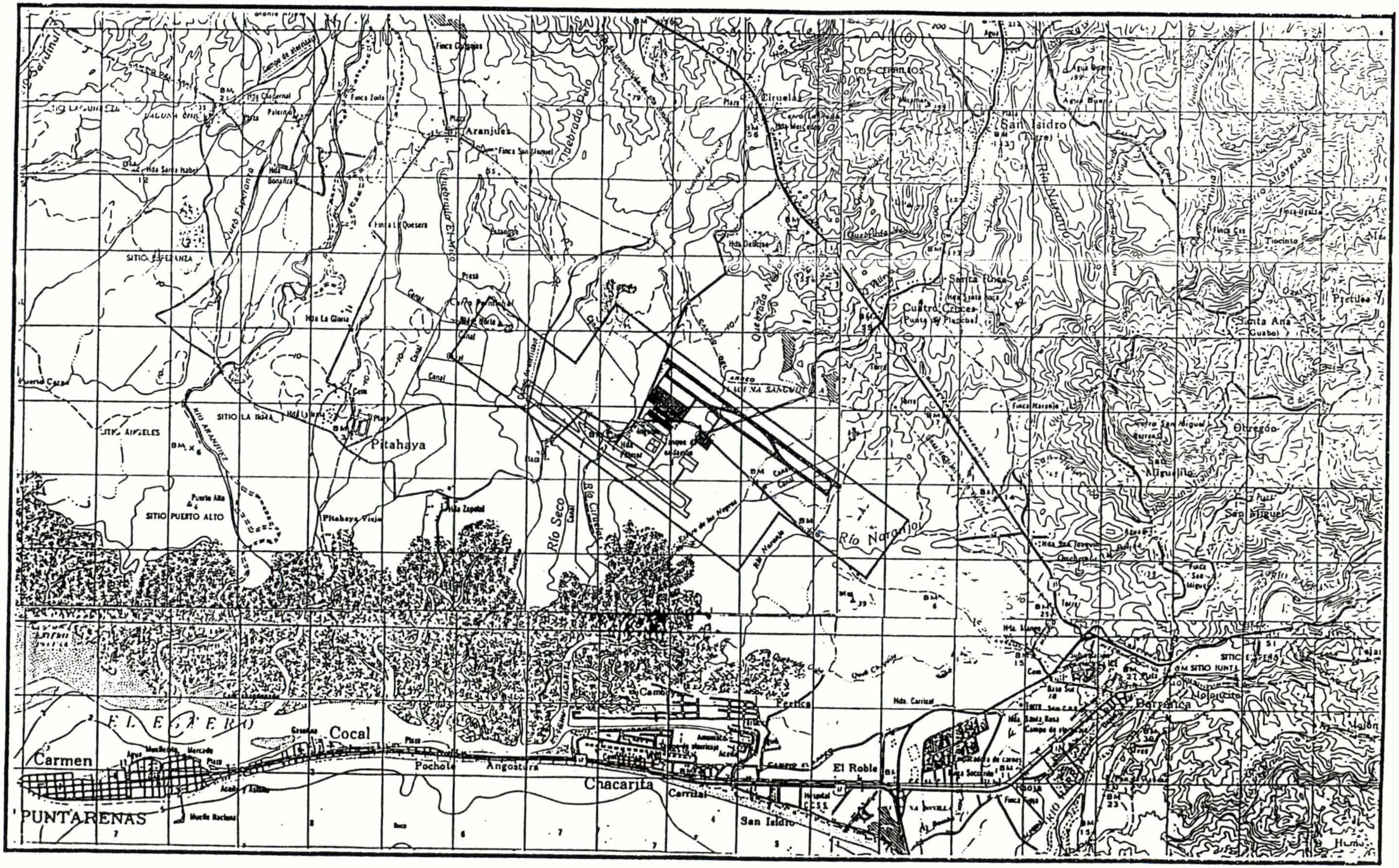


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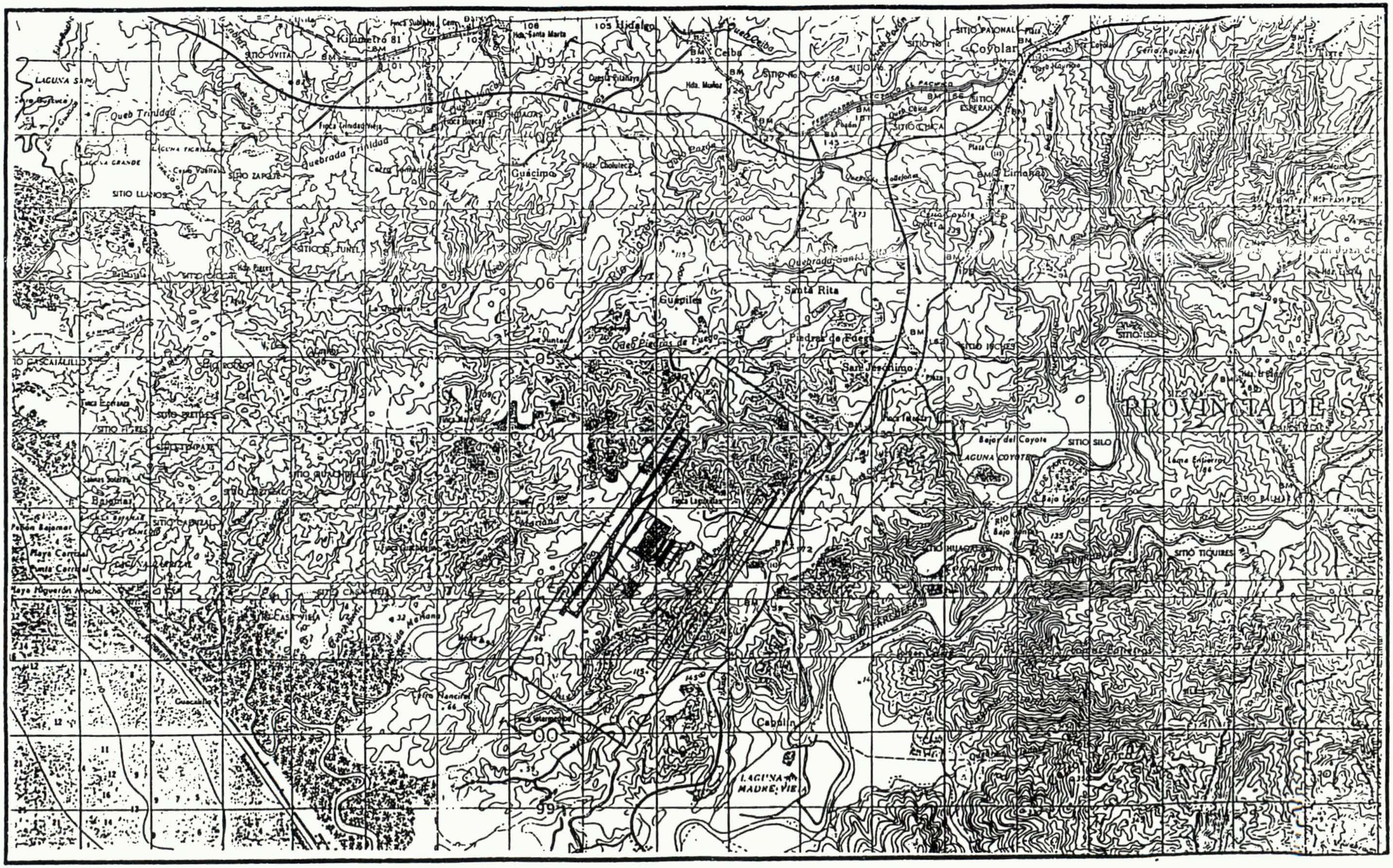
FIGURE 4.5

TARCOLES SITE

SITE SELECTION STUDY - COSTA RICA



5. FACTORS CONSIDERED FOR ANALYSIS AND COMPARISON

With the data developed in Sections 3 and 4, the considerations affecting the location of the airport may be addressed, which are as follows:

- Operational Evaluation;
- Airside Capacity;
- Ground Access from Demand Centres;
  - ground transportation cost comparison
  - access time comparison
- Capital Cost Comparison;
- Environmental Concerns;
- Future Expansion Capability;
- Airspace.

It should be noted that the analysis of each of the above factors will generally include a description of the objective, a discussion of the general methodology used in the analysis, as well as a conclusion of the analysis. These factors are discussed in the subsequent sub-sections.

5.1 Operational Evaluation

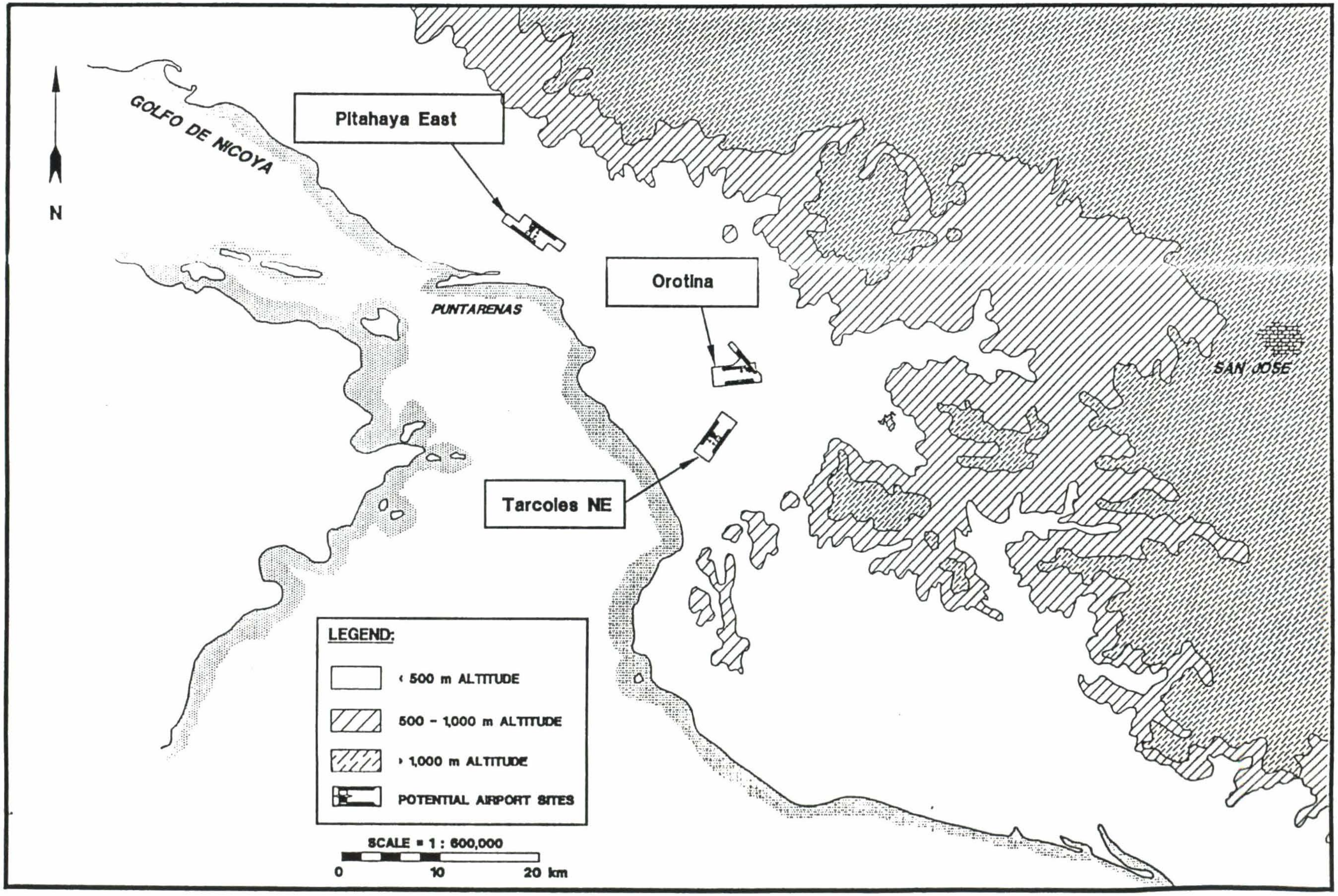
The three sites selected for further analysis in Section 4 were analyzed for "flyability" of departure and arrival procedures considering the adjacent mountainous terrain, weather conditions and surface winds.

Obstacle assessment is a major element in determining airport suitability, runway alignment and runway usability. The shaded area in Figure 5.1 represents mountainous terrain with elevations greater than 500 metres. The white area in the centre, which is where the sites are located, has elevations less than 500 metres. It can be noted that the orientation of the runway at Pitahaya allows for sufficient distance on the flight path, prior to reaching mountainous terrain. At Orotina and Tarcoles, there is much less distance prior to reaching high terrain.

Various obstacle assessment surfaces (slopes) and splays (divergence on either side of the flight path centreline) were used to conform with the requirements of ICAO Annex 6, Annex 14 and PANSOPS.

More specifically, Annex 6, Operation of Aircraft, Part 1 - International Commercial Air Transport, Chapter 5 - Aeroplane Performance Operating Limitations and Attachment C Example 3, Article 3 - Take-off Obstacle Clearance Limitations were used to develop the twin-engine net climb gradient slope of 1.6% as a minimum obstacle floor and corridor from selected runways. This sloping corridor aided the identification of those obstacles requiring reduced take-off weights to clear or alternatively requiring engine-out escape routing. The twin-engine minimum net climb gradient is more conservative than necessary for three and four engine aircraft; however, projecting this airport usage to the year 2000 and beyond will see a preponderance of twin-engine operations, ie. B-767, B-757, B-777, B-737, MD 80, MD 90, A 320, A 310, A 300, A 330 aircraft. The analysis also highlighted

FIGURE 5.1
PROXIMITY OF MOUNTAINOUS TERRAIN
SITE SELECTION STUDY - COSTA RICA



operational considerations and restrictions for the three and four engine aircraft although to a lesser extent than for the twin-engine aircraft fleets.

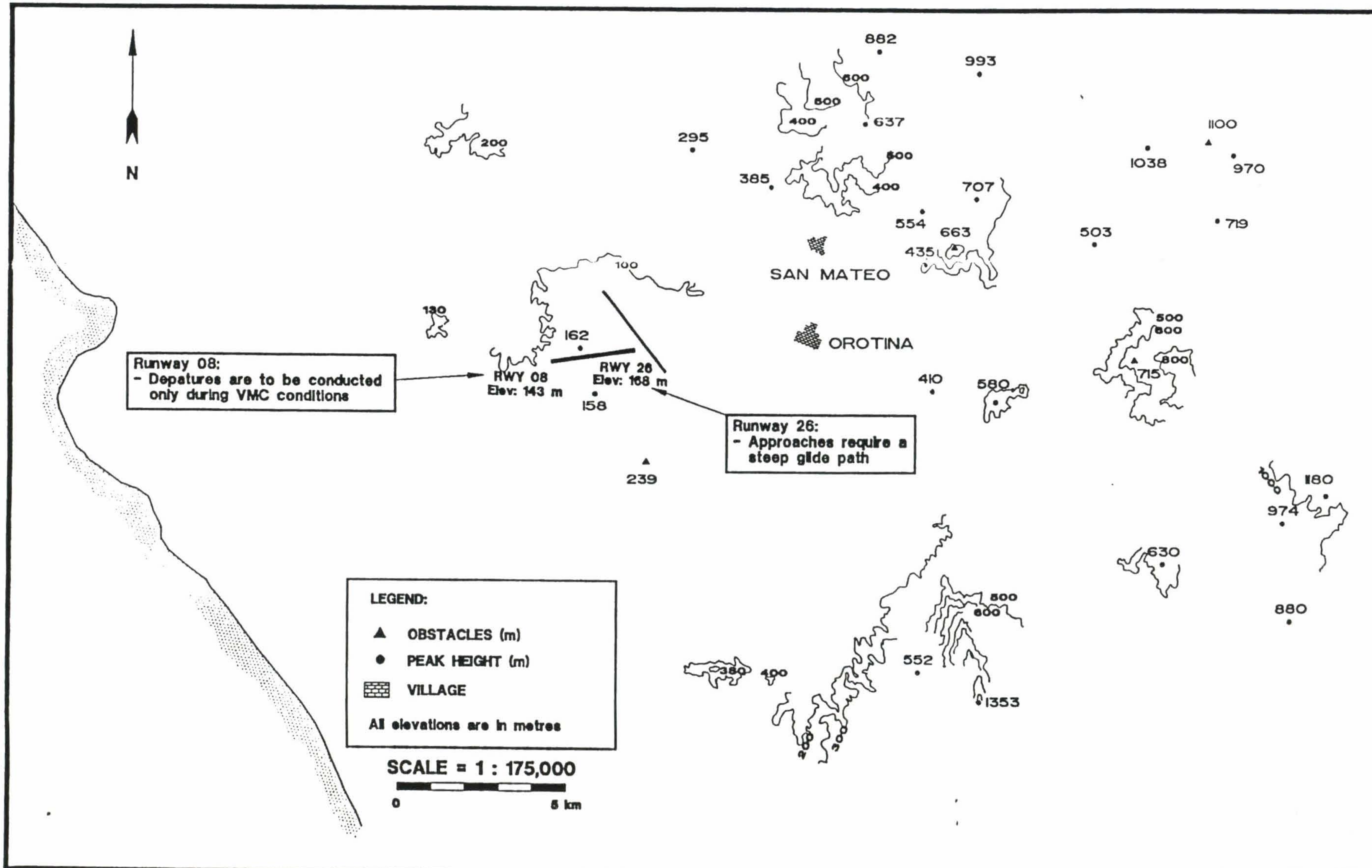
Annex 14, Aerodromes - Volume 1, Chapter 4 - Obstacle Restriction and Removal was used to develop the "airport slopes" for departures, arrivals and manoeuvring operations. These obstacle surfaces are more appropriately used for airport zoning and for local bylaws to prevent growth of man-made obstacles impacting on airport operations - in the mountainous airport sites however, they helped to identify those smaller obstacles that might be removed or levelled and those larger obstacles that will require procedural adjustment and/or additional navigational facilities.

PANSOPS - Procedures for Air Navigation Services - Air Operations, Volume II - Construction of Visual and Instrument Flight Procedures was used to develop obstacle surfaces for departure routes, ILS approaches, and missed approaches (both straight and turning) and to determine minimum obstacle clearance heights and minimum climb gradients for promulgation with the procedures. PANSOPS does not consider engine-out reduced climb performance to clear obstacles that exist - it becomes the operator's responsibility to ensure the aircraft can adequately clear all obstacles in an engine-out configuration (Annex 6) - but since the overall procedures and their practicality impact on the "flyability" of any airport site chosen, preliminary procedural considerations were reviewed.

5.1.1 <u>Orotina Site</u>

- This site poses more operational problems/considerations than any of the other sites reviewed because of the mountains to the NE and SE. Initially only Runway 08/26 orientation was analyzed but the limitations of this 08/26 orientation due to the mountains (see Figure 5.2), their impact on 08 departures and

FIGURE 5.2
CRITICAL TERRAIN AND OBSTACLES FOR OROTINA RUNWAY 08/26
SITE SELECTION STUDY - COSTA RICA



missed approach procedures and the tailwind considerations for departures on Runway 26, prompted a further review of other runway orientations to replace and/or supplement Runway 08/26.

Instrument approaches to Runway 08 can be achieved using either of the following:

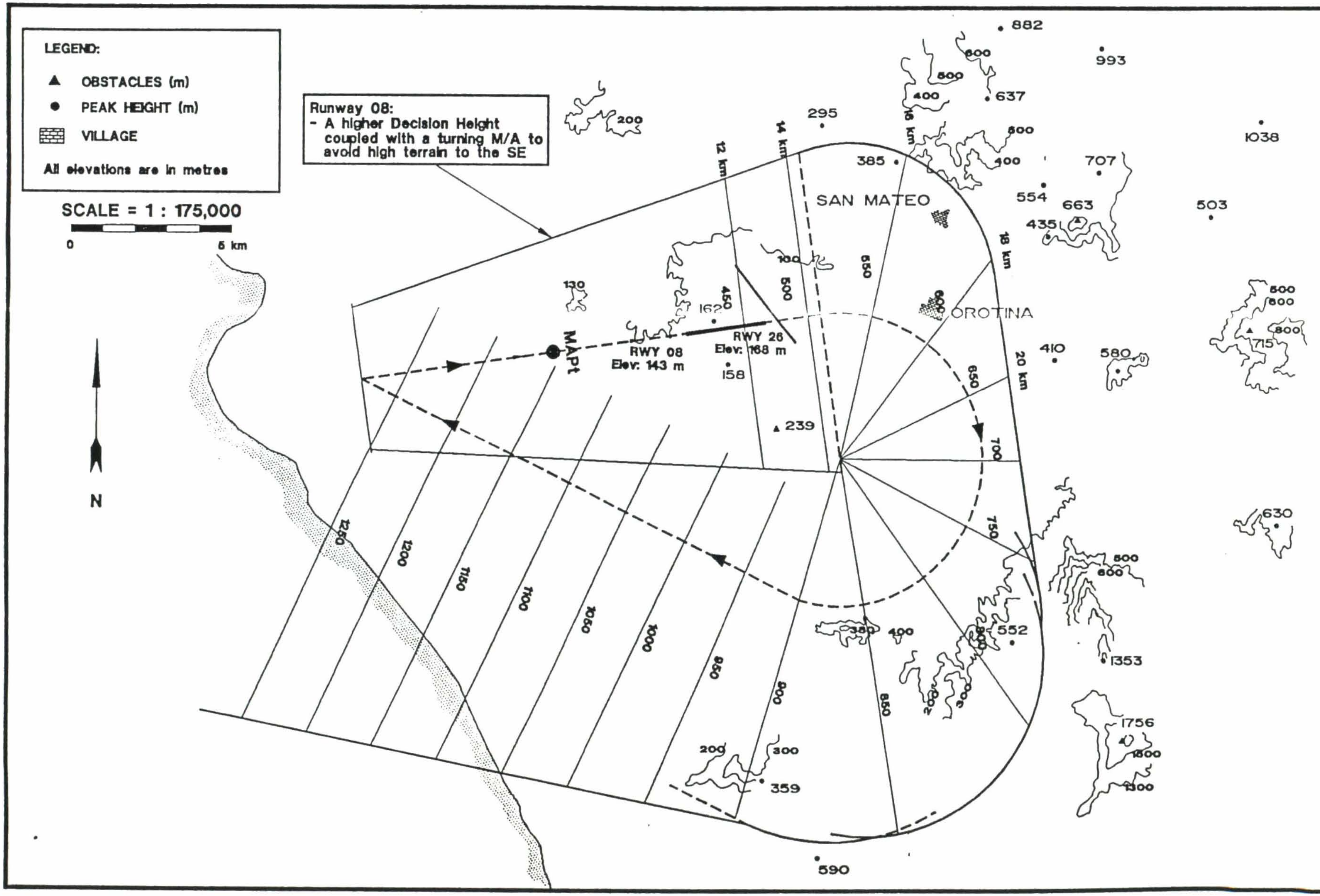
- In the first method, a decision height of 200 feet is achievable; however, a minimum climb gradient must be specified for the turning missed approach in order to clear the high terrain to the east and SE. This minimum climb gradient may be prohibitive for some aircraft or at some landing weights for other aircraft.

- For the second method, which is illustrated in Figure 5.3, a higher decision height accommodating a normal 2.5% climb gradient coupled with a turning missed approach procedure would avoid high terrain to the SE. This higher decision height becomes more like a non-precision approach minima.

Potential Runways 15/33 and 17/35 were reviewed but these too had very restrictive climb gradients so that any departure advantages gained were minimal.

- An orientation of 14/32 was selected because it provided full payload departure capability on Runway 32 with NE winds (down the valley) when Runway 26 might otherwise be operationally unsuitable or suffer too large a performance penalty due to the tail wind. Runway 14/32 is not fully useable for departures and arrivals from both directions due to the

FIGURE 5.3
ARRIVAL AND MISSED APPROACH FOR RUNWAY 08 AT OROTINA
SITE SELECTION STUDY - COSTA RICA



mountains to the SE (see Figure 5.4); however, the combination of Runway 14/32 and Runway 08/26 improve overall operations at Orotina.

The following sub-section provides a description of the requirement for a second runway at Orotina.

5.1.1.1 **Orotina Second Runway Requirement**

The previous section provided a discussion of obstacle limitation surfaces. It was determined that potential runway operations would be as shown in Figure 5.5. Full instrument operations are not possible for all runway directions as a result of the mountainous terrain surrounding the proposed airport.

Based on the potential runway operations from Figure 5.5 and the representative winds at the proposed site, the resulting runway utilization at the airport is as shown in Table 5.1. These utilizations have been determined for each maximum crosswind component and were determined as described below.

Operations with tailwinds were limited to a maximum of 10 knots (18.5 km/h). Figure 5.6 shows a sample of the criteria used to determine permissable operations for a one runway system with 20 knot (37 km/h) cross-winds and 10 knot (18.5 km/h) tailwinds. A wind rose showing the utilizations at Orotina is provided in Figure 5.7. Figure 5.7 was derived using the combined possible usages from Figure 5.5 for IFR conditions and for the 20 knot (37 km/h) maximum crosswind criteria. Similarly, all other percentages were determined resulting in the numbers shown in Table 5.1. The following

FIGURE 5.4
CRITICAL TERRAIN AND OBSTACLES FOR OROTINA - RUNWAY 14/32
SITE SELECTION STUDY - COSTA RICA

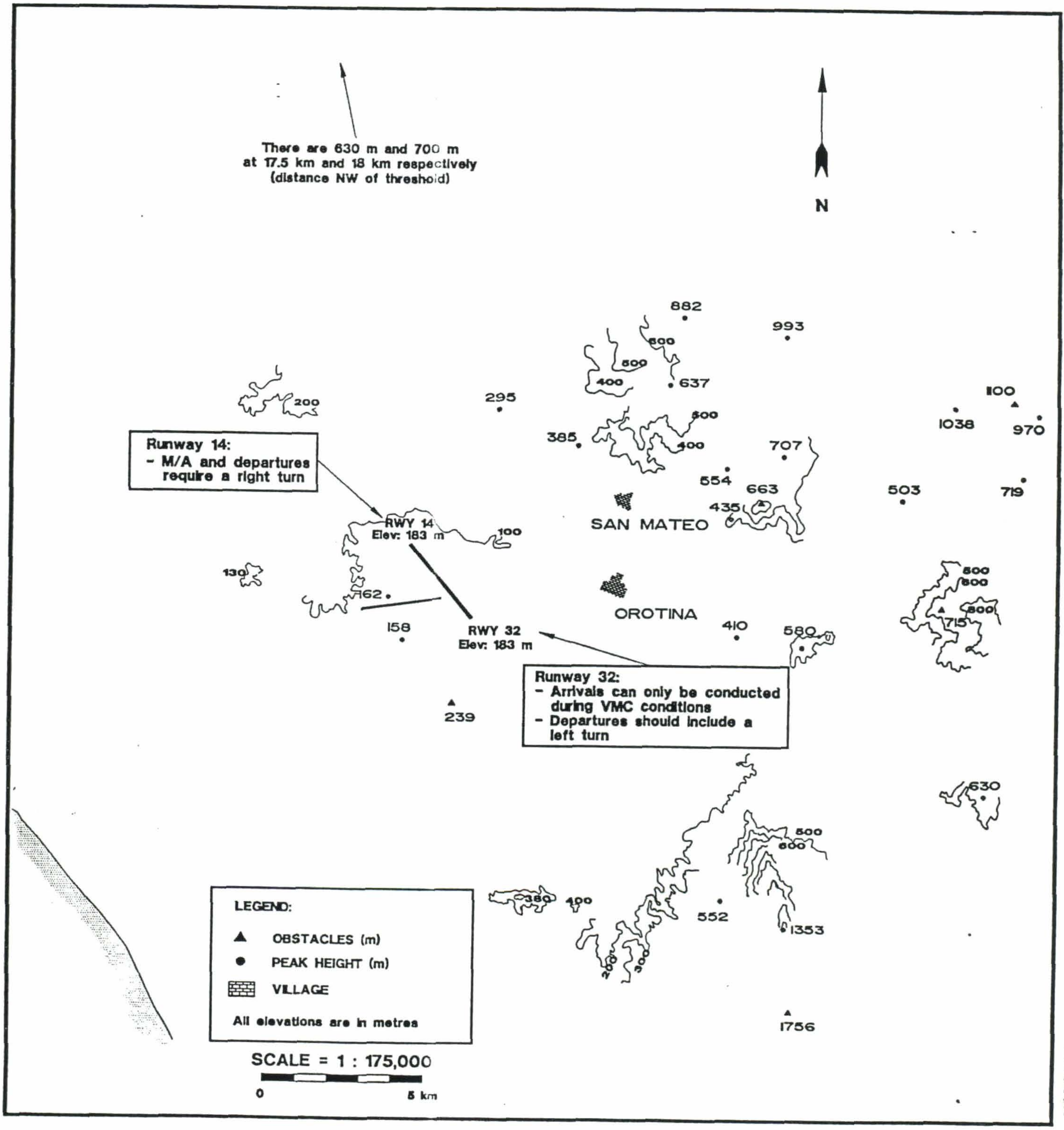


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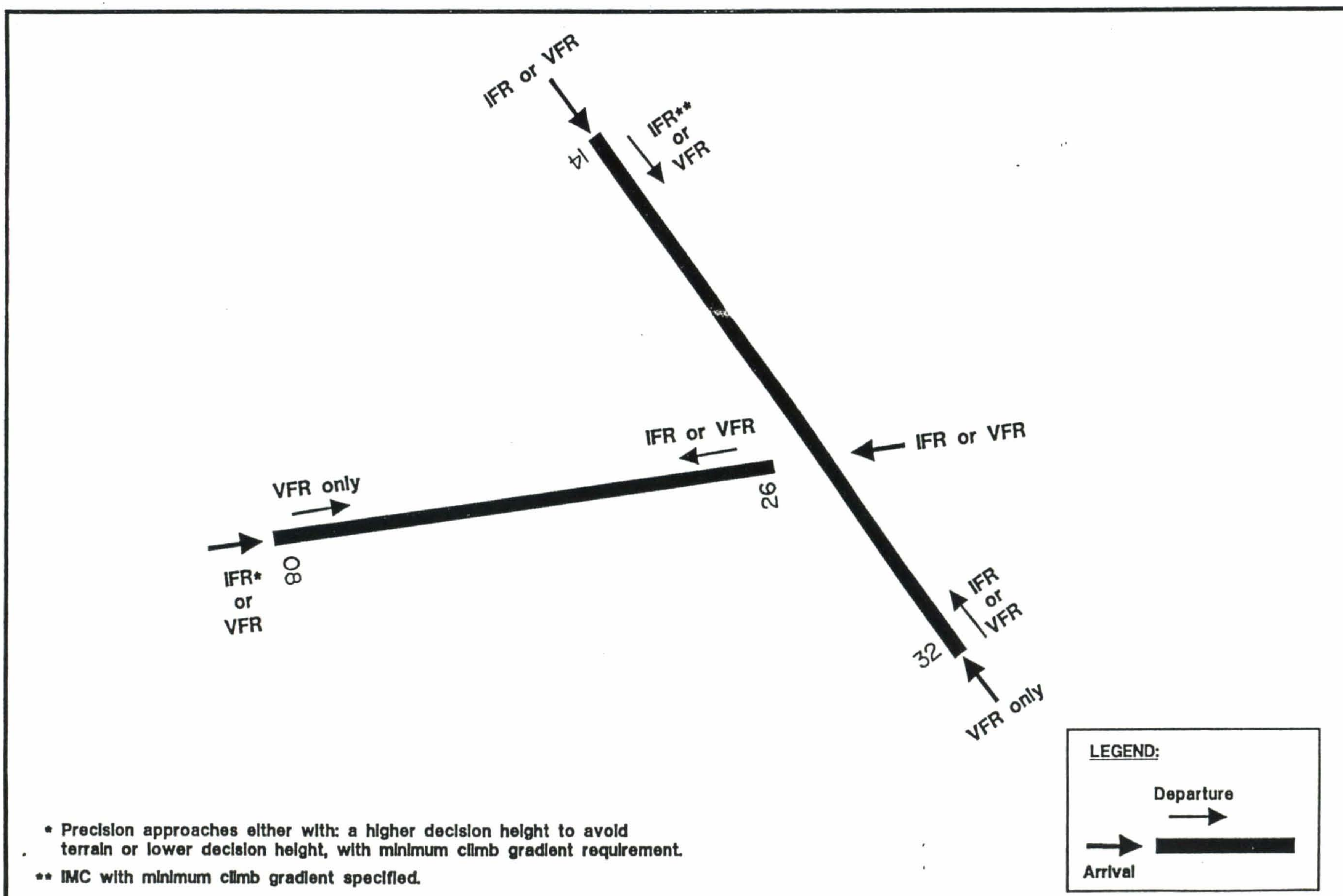
FIGURE 5.5
POTENTIAL RUNWAY OPERATIONS - OROTINA
SITE SELECTION STUDY - COSTA RICA



* Precision approaches either with: a higher decision height to avoid terrain or lower decision height, with minimum climb gradient requirement.

** IMC with minimum climb gradient specified.

TABLE 5.1
RUNWAY USABILITY - OROTINA

	10 knot Cross-Wind					13 knot Cross-Wind					20 knot Cross-Wind				
	Departure/Arrival	Departure/No Arrival	No Departure/Arrival	No Departure/No Arrival	**Total**	Departure/Arrival	Departure/No Arrival	No Departure/Arrival	No Departure/No Arrival	**Total**	Departure/Arrival	Departure/No Arrival	No Departure/Arrival	No Departure/No Arrival	**Total**
IFR															
Both Runways	93.1	0.1	2.2	4.6	100 %	96.9	0.2	1.5	1.4	100 %	98.5	0.1	0.9	0.5	100 %
Single Rwy 08/26	81.3		8.9	9.8	100 %	83.2		13.1	3.3	100 %	85.2		13.9	0.9	100 %
Single Rwy 14/32	91.7	0.3		8.0	100 %	95.0	0.2		4.8	100 %	98.3	0.3		1.4	100 %
VFR															
Both Runways	97.3			2.7	100 %	98.5			1.5	100 %	99.5			0.5	100 %
Single Rwy 08/26	92.3			7.7	100 %	95.8			4.2	100 %	98.7			1.3	100 %
Single Rwy 14/32	92.0			8.0	100 %	95.2			4.8	100 %	98.6			1.4	100 %

FIGURE 5.6
EXAMPLE OF PERMISSABLE OPERATIONS BASED ON WIND CRITERIA
MAXIMUM 20 KNOT CROSS-WIND AND 10 KNOT TAILWIND COMPONENT

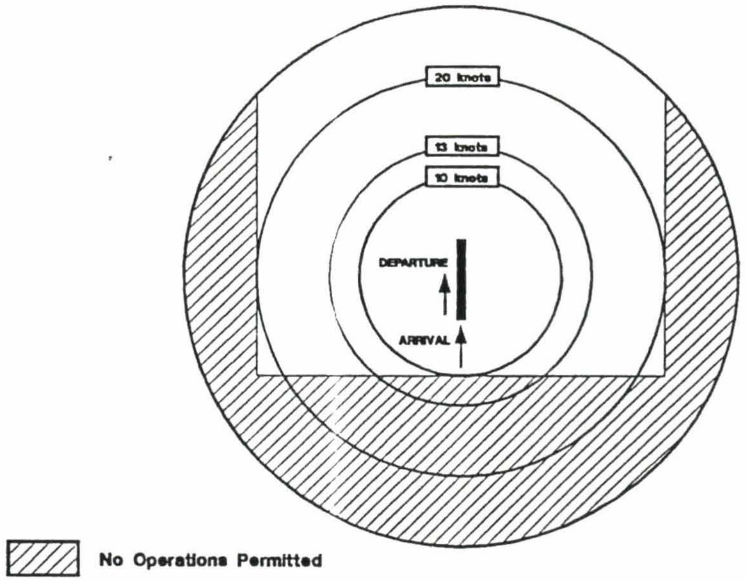
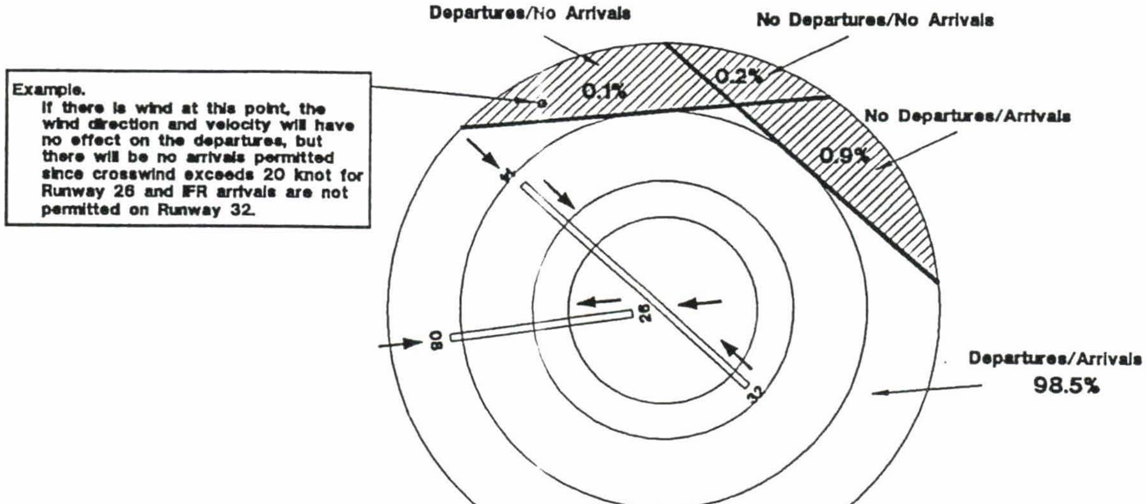


FIGURE 5.7
WINDROSE DEPICTING ALLOWABLE RUNWAY OPERATIONS AT OROTINA
MAXIMUM 20 KNOT CROSS-WIND AND 10 KNOT TAILWIND COMPONENT

IFR CONDITIONS



conclusions can be derived from Table 5.1:

- under VFR conditions, one runway would be sufficient for most of the operations;
- under IFR conditions, a shorter second runway is recommended in order to provide improved operations and more reliability (usability);
- it is recommended that the primary, longer runway be oriented in the 14/32 direction, and the secondary, shorter runway oriented in the 08/26 direction;
- more detailed and representative meteorological information should be acquired, if this site is selected.

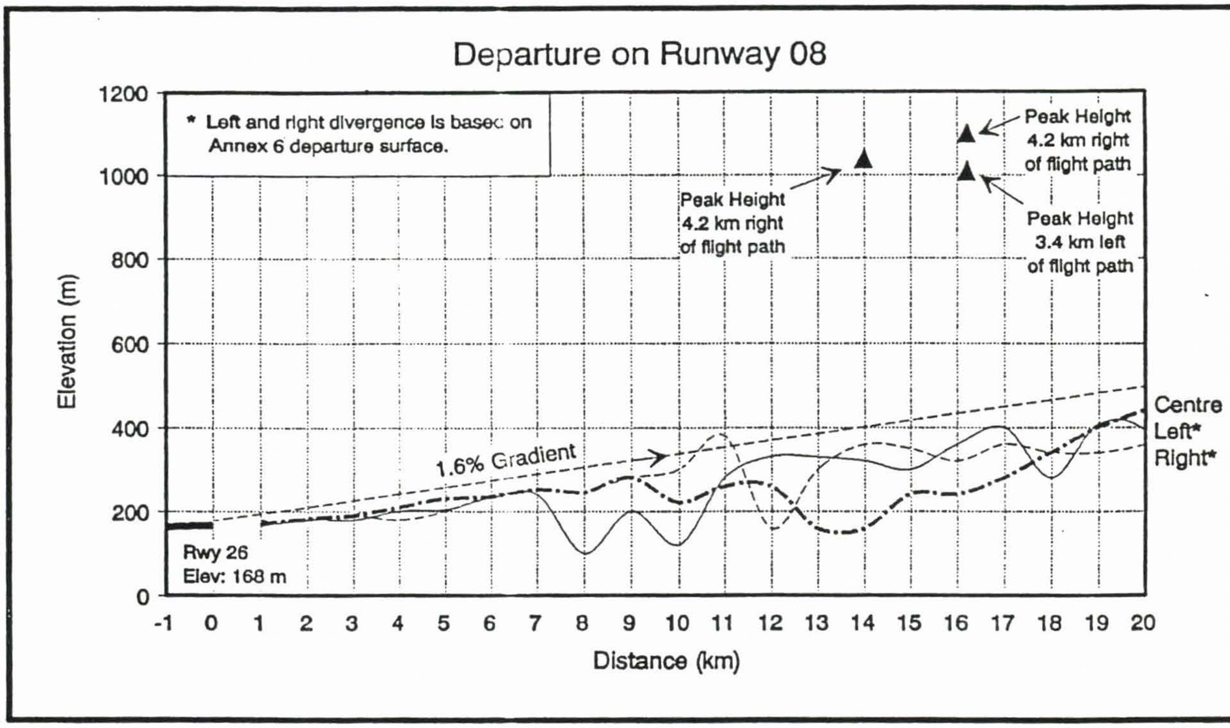
5.1.1.2 **Other Considerations at Orotina**

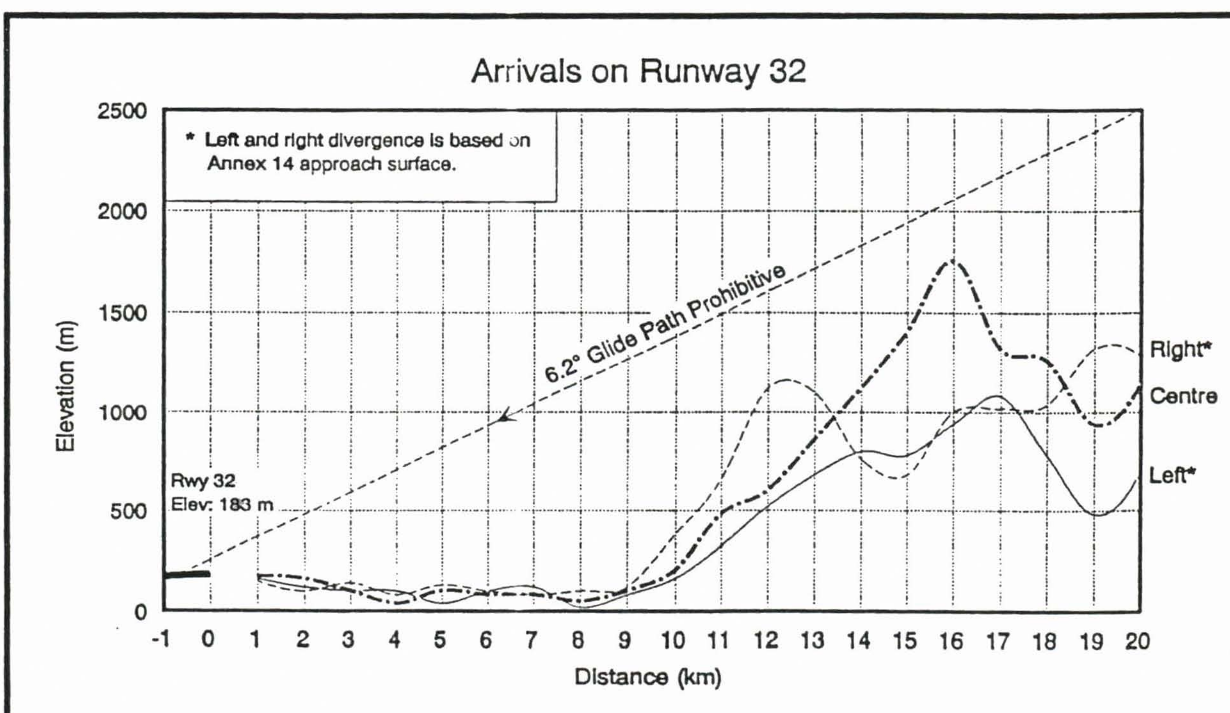
- Figure 5.8 provides a profile view of an aircraft operating out from Runway 08 based on the minimum 1.6% climb gradient requirement of Annex 6. In addition, a profile of an approach to Runway 32 is shown.

- From the data available, winds tend to be from the NE during darkness, likely funnelling down the valley, and from the south or SW during daylight hours. Runway alignment, with two Runways 08/26 and 14/32, was selected because it provided a full payload departure capability even with the NE winds.

- Rainshowers in the Orotina area may be more prevalent than at Pitahaya as annual precipitation is expected at approximately 2.5 m, and occurrence of fog may be frequent, therefore, Category I ILS installations are

FIGURE 5.8
AIRCRAFT PROFILE AT OROTINA
SITE SELECTION STUDY - COSTA RICA





REPFIG1VFIG5_8

recommended for Runways 08, 26 and 14. An approach to Runway 26 in showery conditions will likely encounter moderate mechanical turbulence and wind shears adding to the operational complexity of this approach. Airport DME or ILS/DME is also recommended to assist the pilot in positional confirmation for high terrain awareness and avoidance.

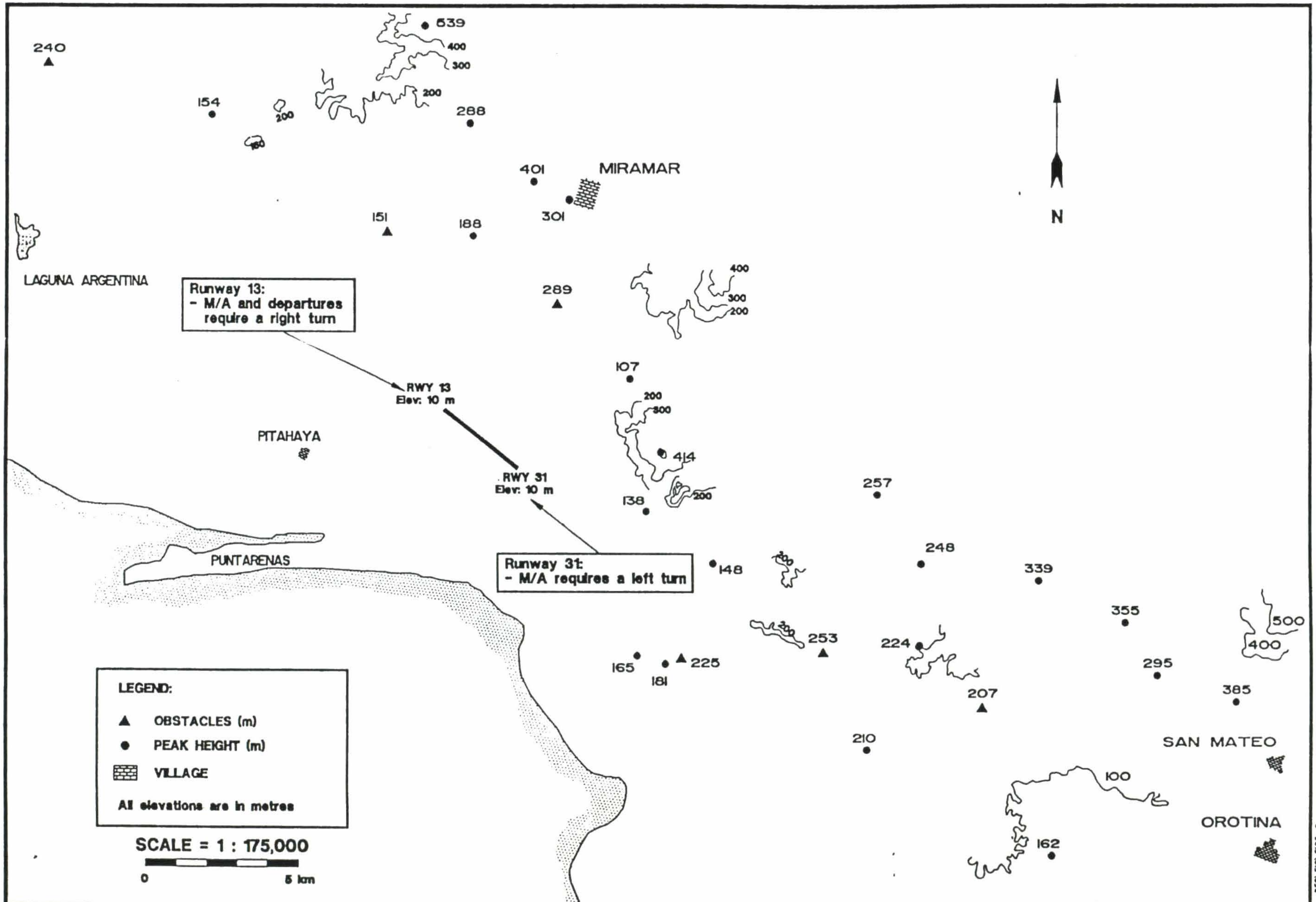
- The town of Orotina is under the flight path of 08/26 just 4 km east of the airport site. Noise abatement will be a consideration for use of this runway but more over-flights are expected to be arrivals than departures which will diminish noise exposure.

5.1.2 **Pitahaya Site**

- IFR and VFR operations are feasible using both Runway 13 and 31 (see Figure 5.9). From the data available, the winds in the area tend to be from the NE from between 0100 and 0800 hours and 1800 and 2400 hours, and from the south between 1100 and 0700 hours which will result in frequent cross-wind operations, but fortunately with fairly light velocity so no operational problems are foreseen. It is anticipated that most arrivals and departures will use Runway 13 as the most "into the wind runway" throughout the day, except for wind gusts in showery conditions.

- The heavy rain showers in the Pitahaya region are reported as less severe than at the other sites; however, Pitahaya still receives 1.5 to 2 metres of rain per annum. A Category I ILS installation for Runway 13 is considered mandatory and a

FIGURE 5.9
CRITICAL TERRAIN AND OBSTACLES FOR PITAHAYA - RWY 13/31
SITE SELECTION STUDY - COSTA RICA



Category I ILS installation for Runway 31 is considered beneficial because ceilings and visibilities below VFR may occur primarily in convective cloud activity and winds will shift as the showers move about or pass overhead.

- Based on the runway orientation of 13/31 and the expected windrose from Figure 3.1, the following runway utilization would be achievable at Pitahaya.

Cross-wind Component Less Than:	Pitahaya
20 knots (37.0 km/h)	98.8%
13 knots (24.1 km/h)	97.5%
10 knots (18.5 km/h)	96.2%

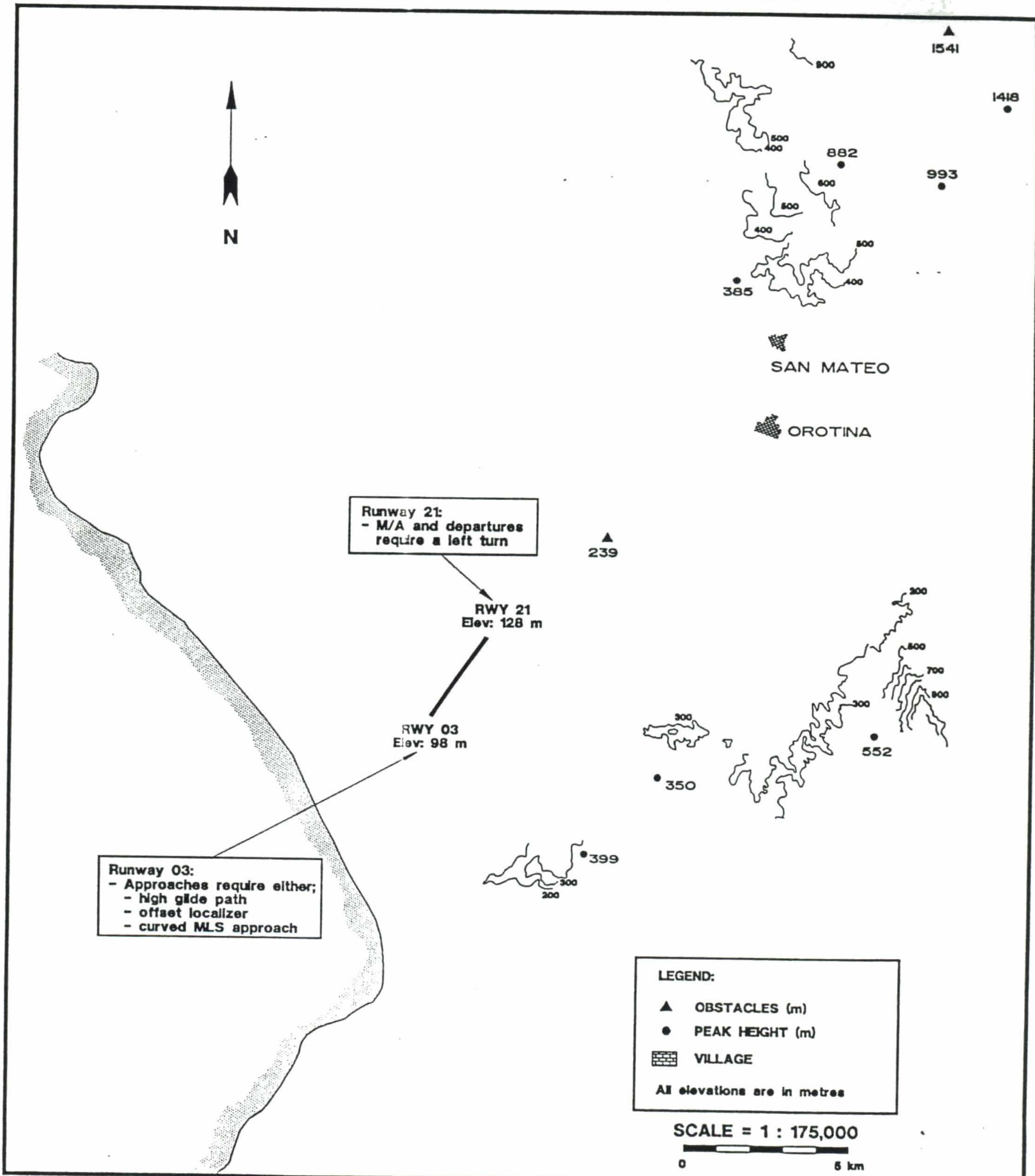
As a result, it is expected that a second cross-wind runway would not be required for Pitahaya.

5.1.3 Tarcoles Site

- The obstacle assessment shows that landings on Runway 03 and departures on Runway 21 are without problems, but the high terrain (see Figure 5.10) to the NE would impact straight-out/straight-in operations with some operational penalties. Radar vectoring or curved track guidance (MLS) for turns to or from the NW, west of the rapidly rising terrain, will permit essentially unrestricted operations from both Runway 03 and Runway 21.

- Rain showers in the Tarcoles area may be more prevalent than at the Pitahaya site as annual precipitation is expected at approximately 2.5 metres, and occurrence of fog may be

FIGURE 5.10
CRITICAL TERRAIN AND OBSTACLES FOR TARCOLES - RWY 03/21
SITE SELECTION STUDY - COSTA RICA



frequent. Therefore, a Category I ILS or MLS installation at both ends of the runway is recommended.

- A long, straight-in approach to Runway 21 over the mountains in showery conditions will likely encounter moderate mechanical turbulence and wind shears over the mountains adding to the operational degree of difficulty to safely conduct this approach.

- No communities are presently under the flight paths although San Mateo is just South of the Runway 03 take-off path. A turning departure to the NW will further minimize the noise footprint over San Mateo.

- Based on the runway orientation of 03/21 and the expected windrose from Figure 3.1, the following runway utilization would be achievable at Tarcoles.

Cross-wind Component Less Than:	Tarcoles
20 knots (37.0 km/h)	97.6%
13 knots (24.1 km/h)	94.8%
10 knots (18.5 km/h)	91.9%

As a result, it is expected that a second cross-wind runway would not be required for Tarcoles.

5.1.4 Summary - Operational Evaluation

From an operational point of view, the major factor of differentiation between the three sites is the proximity of the mountainous terrain, the resulting procedural complexity of departure or arrival procedures and the environmental aircraft handling considerations. A summary of the operational analysis is provided in Table 5.2, Parts 1 and 2.

The Pitahaya site is essentially free of obstacle considerations permitting precision approaches to both runways with routine aircraft handling to typical decision heights and light crosswinds.

The Tarcoles site is less free from obstacle considerations, but with procedural turns to avoid the high terrain to the NE, precision approaches to typical decision heights can be flown to both runways with routine aircraft handling. Both Pitahaya and Tarcoles sites show that they will be able to handle anticipated traffic using both ends of a single runway layout.

Orotina, with the mountains to the NE and SE, adds procedural restrictions for visual take-offs on 08 or visual arrivals on 32. Precision approaches to Runway 08 are feasible, either with a higher decision height or with a standard decision height, coupled with a minimum climb gradient for the missed approach. Depending on the wind, a combination of runways - one for departures and another for arrivals - will likely be required. Aircraft handling is more complex to avoid obstacles, whether or not engine-out or all-engine operation, and environmental factors of mechanical turbulence, subsidence, wind shear

TABLE 5.2, Part 1 of 2

OPERATIONAL EVALUATIONS FOR DEPARTURE, APPROACH AND MISSED APPROACH SURFACES

SITE	TARCOLES		OROTINA				PITAHAYA	
SURFACES	RUNWAY 03	RUNWAY 21	RUNWAY 08	RUNWAY 26	RUNWAY 14	RUNWAY 32	RUNWAY 13	RUNWAY 31
INNER HORIZONTAL	Good		Hill - S Exceeded by 34 m (cut) or Higher Limits		Hill - SW Exceed by 34 m (cut) Hills - NE Exceed by 38 m (cut) or Higher Limits		Hills - N Higer Limits or Manoeuvre - SW	
CONICAL	Hill - SSE Manoeuvre W		Hills - NE Manoeuvre S		Hills - NE Manoeuvre SW		Hills - NE Manoeuvre SW	
DEPARTURE Annex 6	Straight Reduced TOW or Escape Route Left Turn Good	Good	Straight=Canyon > 5 min Reduced TOW Hazardous no turns	Good	Straight = Prohibitive	Good but Left Turn Recommended Due to Hills	Straight = Reduced TOW or Escape Route RT turn good	Good
Annex 14	Hills Left Turn Required	Good	Canyon Hills above both sides No Turns	Good	Mountain Right Turn Required	Good but Left Turn Recommended Due to Hills	Good but Right Turn Recommended Due to Hills	Good
PANSOPS	Left Turn or Minimum Climb Gradient	Good	VMC and Minimum Climb Gradient 390 Feet/NM	Good	Right Turn and Minimum Climb Gradient or Right Turn and VMC	Left Turn or Minimum Climb Gradient	Minimum Climb Gradient and Right Turn	Good
IMC/VMC	Both	Both	VMC Only	Both	Both	Both	Both	Both

TABLE 5.2, Part 2 of 2

OPERATIONAL EVALUATIONS FOR DEPARTURE, APPROACH AND MISSED APPROACH SURFACES

SITE	TARCOLES		OROTINA				PITAHAYA E	
SURFACES	RUNWAY 03	RUNWAY 21	RUNWAY 08	RUNWAY 26	RUNWAY 14	RUNWAY 32	RUNWAY 13	RUNWAY 31
APPROACH	Good	Straight = Steep G/P or Offset LOC or Curved MLS	Good But High Limits due to M/A	Straight=Over Mountains & Canyon Steep G/P Subject to Operational Factors	Hills 3° GP Good	Mountain ST=Prohibitive Visual from SW only	Good	Hills - SE 3° GP Good
IMC/VMC	Both	Both	High Limits During IMC or Normal Limits With Minimum Climb Gradient or VMC	Both	Both	VMC Only	Both	Both
MISSED APPROACH	Left Turn to W or Back to FAF	Good	Right Turn Back to FAF and Minimum Climb Gradient	Good	RT Turn to SW or Back to FAF	VMC Approach Only	Good RT Turn to SW	Good LT Turn to SW
NAVAIDS APPROACH	ILS + NDB or ILS + DME	ILS + DME	ILS + DME	ILS+DME+NDB	ILS + NDB		ILS + NDB	ILS+DME+NDB or ILS + NDB
AIRPORT	VOR/DME		VOR/DME				VOR/DME	
NOISE SENSITIVITY	San Mateo S of Flight Path	Good	Orotina under Flight Path 4 km East		Good	Good	Good	Good

will need to be flown through and adjusted to while attempting to fly an ILS localizer and glidepath with precision. Additionally, the proximity of the hills to the Orotina site, in comparison to the other two sites, should result in more convective cloud and rain showers there with lower visibilities, wind gusts and turbulence.

Operational preference then is for the Pitahaya site with Orotina being last. The two runway configuration at Orotina is an effort to still allow both departures and arrivals in anticipated meteorological conditions and with practical payloads; however, the complexity, degree of difficulty and need for additional navigational aids increases.

5.2 Demand Versus Capacity Analysis

As a result of the two runway system at Orotina, additional capacity would be available. This section will provide a preliminary comparative analysis of capacity for each of the three sites.

The maximum capacity for each of the proposed sites was determined from the FAA Airport Capacity and Delay AC 150/5060-5 and are as follows:

	Max VFR Capacity	Max IFR Capacity
Orotina	73	59
Tarcoles	50	49
Pitahaya	50	49

These figures are based on the following assumptions:

- runway configurations described in Section 4;
- 50% arrivals, 50% departures;
- mix index of 80 based on 10% heavy aircraft (over 136,000 kg MTOW), 50% large (5670 kg to 136,000 kg MTOW), and 40% small (less than 5,670 kg MTOW) aircraft;
- no touch-and-go traffic;
- two exits from runway are available.

Based on the above analysis, the two runway system at Orotina would provide up to 40% additional capacity as compared to the single runway systems at Tarcoles and Pitahaya. Based on the long term projected traffic growth rates, the second runway at Orotina would defer investment for an additional parallel runway by about 10 to 20 years.

For the level of traffic forecast for the year 2010 (25 aircraft movements in the peak hour), a single runway system would be sufficient. It is prudent, however, to look further into the future at a time where the traffic could well grow to such extent as to require an extra, parallel runway for independent, simultaneous operations. The provision for this additional runway will be discussed in Section 5.6.

5.3 Ground Access Costs and Time From Demand Centres

Each passenger using the international airport and any accompanying well-wishers or greeters will incur a cost of transport to and from the airport. This cost to access the airport is comprised of two parts:

- the actual ground transportation cost, such as bus fare, gasoline, and the like; and
- a cost that represents the time required to travel to and from the airport.

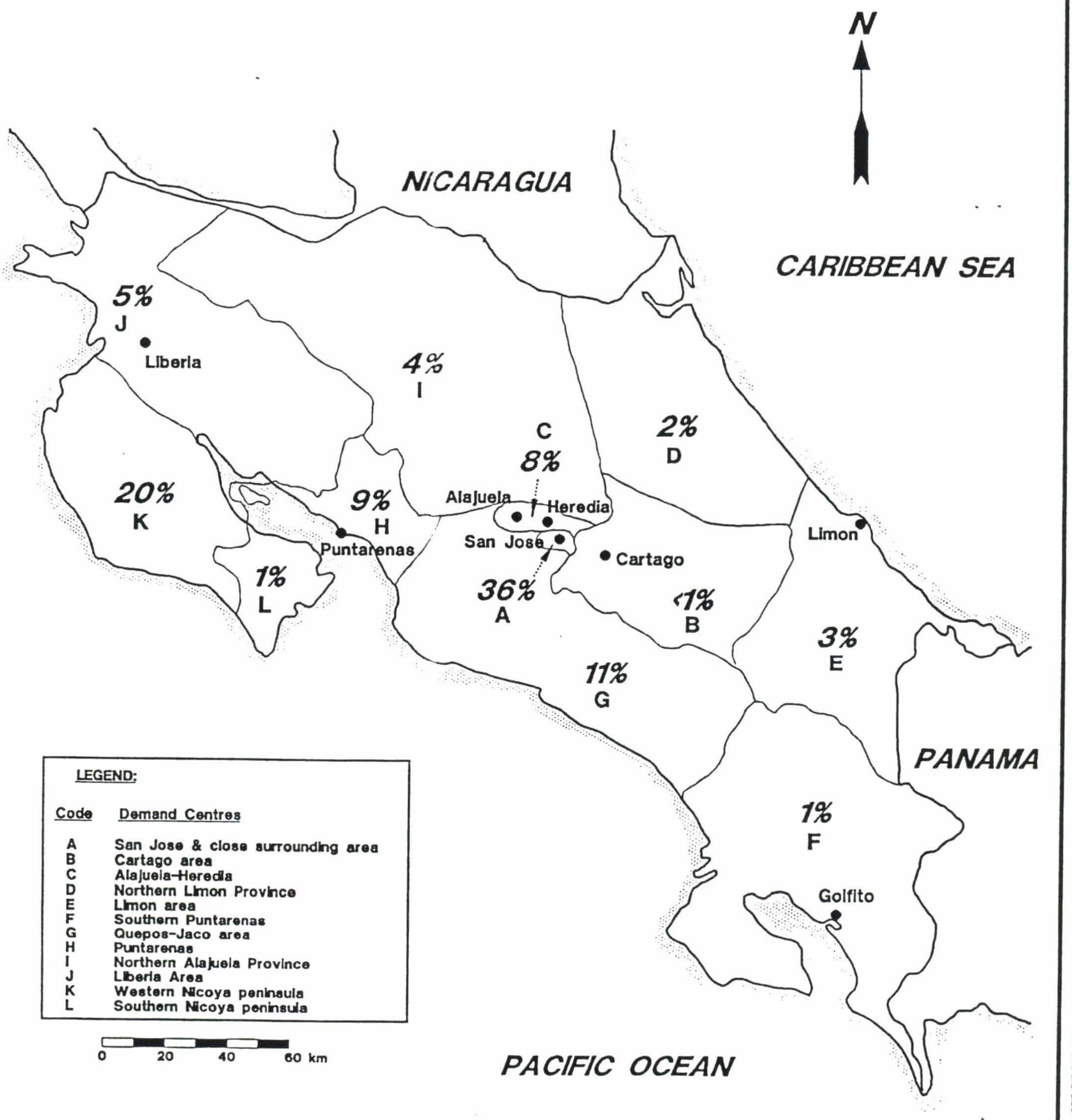
Each potential airport site will, therefore, have an associated access cost. The general methodology used, as well as the computation of ground transportation access costs and access time, is provided in the following sub-sections.

5.3.1 General Methodology

Costs and time incurred accessing the various sites from the centres of air passenger demand were estimated according to the following general methodology.

- The country was segmented into twelve demand centres based on the distributions of population, tourist accommodation, business centres and natural boundaries. These centres are depicted in Figure 5.11, which also shows the percentage of ICT-registered accommodation rooms in each centre.
- For each of the above demand centres, travel distances and probable travel times were established to each of the three

FIGURE 5.11
DEMAND CENTRES
SITE SELECTION STUDY - COSTA RICA



Note: Percentages (rounded) represent the distribution of hotel room accommodation (ICT-registered) based on existing and approved rooms to 1998 as at Sept. 1992.

airport sites. For the larger geographic demand centres, a central point (approximation based on centres of population and hotels and major road access) was chosen for these calculations. Distances and times were derived from 1990 and 1991 maps, 1988 MOPT data, and 1992 brochures providing such information.

- The completion of the four-lane divided highway between Colon and Orotina was assumed.

- Actual international air passenger demand to and from each demand centre was ascertained in the manner outlined below. Domestic demand, which constitutes approximately 10% of total air passenger demand was not considered for this preliminary evaluation, since it is assumed that the current airport may handle a large part of this traffic.

  - The demand source, international air traffic, is based on projected air traffic from APS' international passenger demand forecast, 1991-2030.
  - Pleasure travel accounts for approximately 70% of international traffic (1991 ICT survey).
  - Business and pleasure travellers who stay in San José for their entire trip were allocated to the San José area. This accounts for 17% of pleasure travellers and 66% of business travellers (1991 ICT survey). Any travellers spending some nights outside of San José were not included in this total.
  - The remaining 83% of pleasure travellers and 34% of business travellers were allocated to the remaining demand centres based on the relative weights of the

number of ICT-registered hotel rooms in each area.

- The travellers were distributed among the three modes of transportation - car (private or rental), taxi, or bus (public or tour) - based on data provided by ICT surveys. The data did not specifically deal with access to or from the airport but rather dealt with any modes of transportation used during the passenger's stay in Costa Rica. Thus, the distribution among transportation modes is an approximation.

- Passengers per vehicle and well-wishers/greeters per passenger were estimated based on information contained within the RDSA report. The data used was such that no differentiation could be made between business and pleasure passengers.

- It was assumed that all well-wishers/greeters would also incur access costs and that each well-wisher/greeter would travel to and from the airport.

The assumptions of the costs for each transportation mode were assumed as follows:

- Car transportation costs were estimated at 25 colones per kilometre based on fuel charge of 47.5 colones per litre.

- Taxi transportation costs were estimated at 65 colones per kilometre. Taxi costs are somewhat random as taxi drivers do not use meters.

- Bus transportation costs were set to range between 100 and 700 colones based on a comment in a travel guidebook. The costs were broken down by distance ranges as follows:

COST (Colones)	DISTANCE RANGE (km)
100	0 to 20
200	21 to 45
300	46 to 60
400	61 to 100
500	101 to 160
600	161 to 350
700	350 +

This general methodology is depicted in Figure 5.12, while the next two sub-sections will provide the computations of ground access costs and access time.

5.3.2 Ground Transportation Access Costs

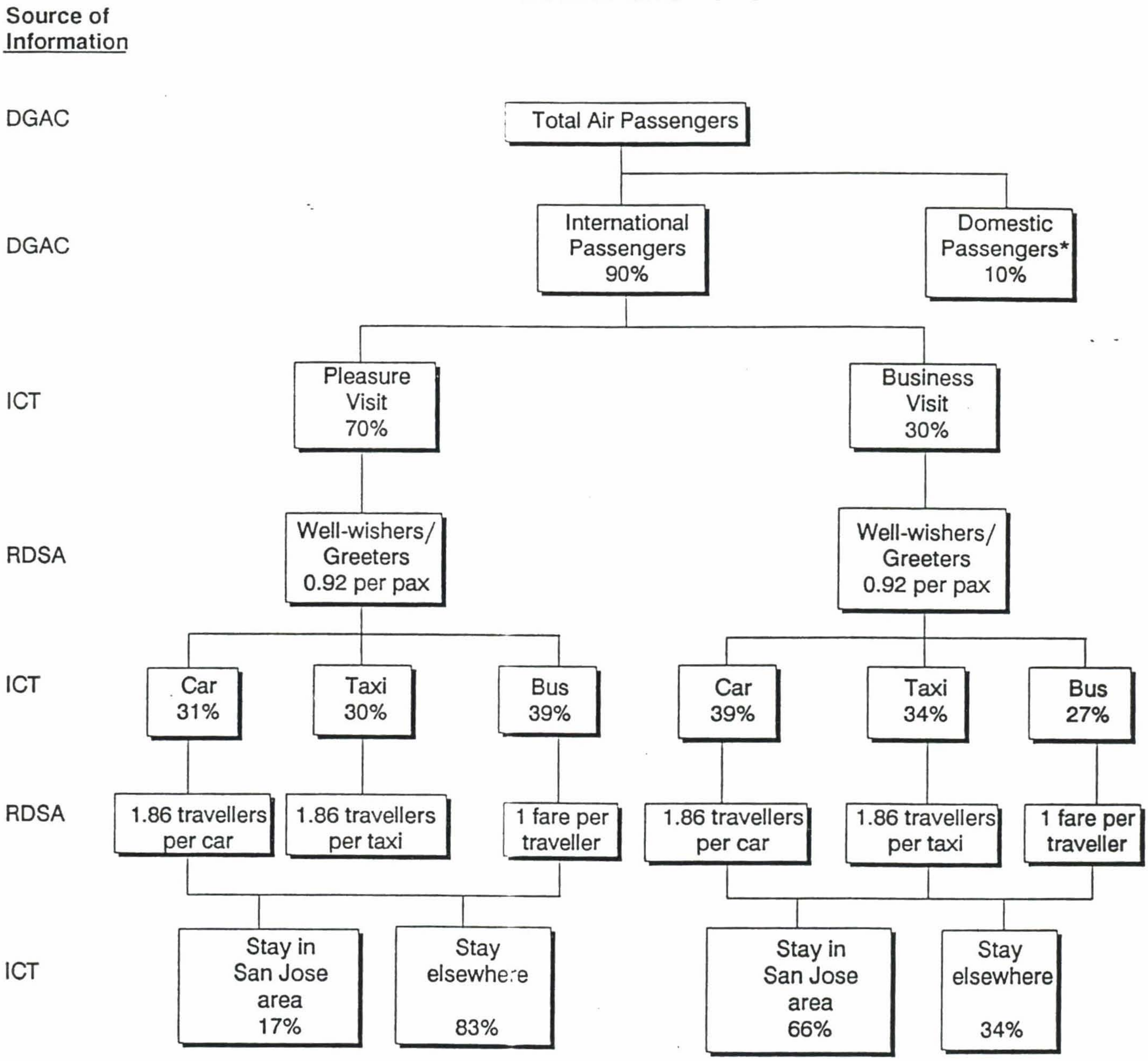
The transportation access costs were calculated using the formula listed below.

$$COST_{access} = TOTALPAX \sum_{type=1}^{2} PAX_{type} \sum_{centre=1}^{12} DEMAND_{centre} \cdot (2WWPP+1) \sum_{mode=1}^{3} USE_{mode} \cdot (COST_{transport_{mode}} / PAX_{vehicle_{mode}})$$

Where

- TOTAL PAX = total passengers
- PAX_{type} = percentage of travellers that are Business (1) or Pleasure (2)
- $DEMAND_{centre}$ = percentage of passengers originating at each of the 11 defined demand centres.
- WWPP = Well Wishers, greeters per Passenger (Average Value Applied to all passengers based on RDSA research.)

FIGURE 5.12
CALCULATION OF ACCESS COSTS FROM DEMAND CENTRES
GENERAL METHODOLOGY



*Domestic traffic not considered in this analysis.

Note: ICT and RDSA sources cited here did not necessarily provide these figures but they supplied background information, which APS in turn used to form these assumptions.

Source: APS Analysis

- USE_{mode} = percentage of travellers using each of the three modes of transport (1=car; 2=taxi; 3=bus)

- $COST_{transport\ mode}$ = the cost associated with a single trip for the particular mode of transport

- $PAX_{vehicle\ mode}$ = the passengers per vehicle for the particular mode of transport.

Before examining the specific results of the analysis, it is useful, for purposes of orientation, to examine the distance of the sites from San José as compared to the current airport. These are shown in Table 5.3. However, it should be noted that the majority of air traffic demand does not, in fact, originate in San José, despite the fact that San José is the metropolitan centre.

TABLE 5.3
TRAVEL DISTANCE AND TIME FROM SAN JOSE
Bus and Car Only

	Orotina	Pitahaya	Tarcoles	SJO
Approximate Distance (km) (San José to...)	71	105	81	18
Approximate Time (minutes) (San José to...)	53	79	61	25

Source: Road maps, Rental car guides.

The centres of business demand and pleasure demand are generally the San José area and the Guanacaste/Puntarenas coastal areas, respectively. The business and pleasure groups have different access costs due to their differing distances from the sites and were, therefore, examined separately. The business and pleasure travellers' access costs were then weighted based on the relative proportions of air traffic produced by each of the two groups to determine a total access cost.

Table 5.4 provides the average distances that both business and pleasure passengers would have to travel in order to reach each of the sites. In both cases, the Orotina site is the closest followed by Tarcoles and Pitahaya for business travellers, and Pitahaya then Tarcoles for the pleasure traveller. On a total weighted average basis, Orotina is the closest site to the demand centres followed by Tarcoles and then Pitahaya. This table also shows that the average distance travelled to SJO is less than all of the sites for business travellers, while it is the furthest for the pleasure passenger. This would indicate that any site chosen would benefit pleasure passengers while business passengers will always be required to travel further. On a weighted average basis SJO ranks a close second behind Orotina, while Tarcoles ranks third and Pitahaya is fourth.

TABLE 5.4
AVERAGE DISTANCE FROM DEMAND CENTRES TO SITES

Purpose of Travel	Average Distance to Sites (km)			Average Distance
	Orotina	**Pitahaya**	**Tarcoles**	**to San José**
Business	95	116	103	70
Pleasure	130	132	135	146
Weighted Total	120	127	125	123

Source: APS Analysis

Figure 5.13 depicts the average weighted differential distance to each of the sites from the demand centres for the total passenger demand.

Translating these distances into the cost of transportation yielded the same weighted results in terms of ranking of the sites, Orotina, Tarcoles and Pitahaya. Table 5.5 presents the calculated cost of transportation incurred by the average business and pleasure traveller and the weighted average total cost to access each of the sites. As with the distances, SJO represents the least access cost in terms of transportation for business travellers, while for pleasure travellers it is the most expensive. On a weighted average basis, SJO ranks a very close second behind Orotina.

TABLE 5.5
AVERAGE TRANSPORTATION COST FROM DEMAND CENTRES TO SITES

Purpose of Travel	Average Transportation Cost to Site (¢)			(¢)
	Orotina	Pitahaya	Tarcoles	SJO
Business	1741	2112	1875	1263
Pleasure	2093	2121	2163	2307
Weighted Total	1987	2119	2076	1994
Absolute Differential	Base[1]	+132¢	+89¢	+7¢
Differential in Percent	Base	+7%	+4%	+0%

Source: APS Analysis

Figure 5.14 graphs these costs and shows the differential transportation cost to each of the sites. Once again, Orotina represents the least cost transportation solution followed by Tarcoles and Pitahaya.

1. In this table, and others following, the site noted as "Base" is the site with the most favourable results for the criterion being discussed.

FIGURE 5.13

TRANSPORTATION DISTANCE COMPARISON

SITE SELECTION STUDY - COSTA RICA

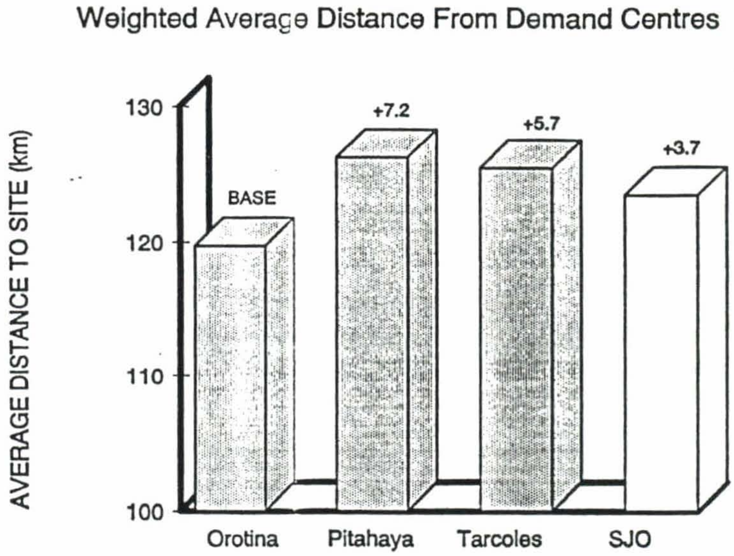
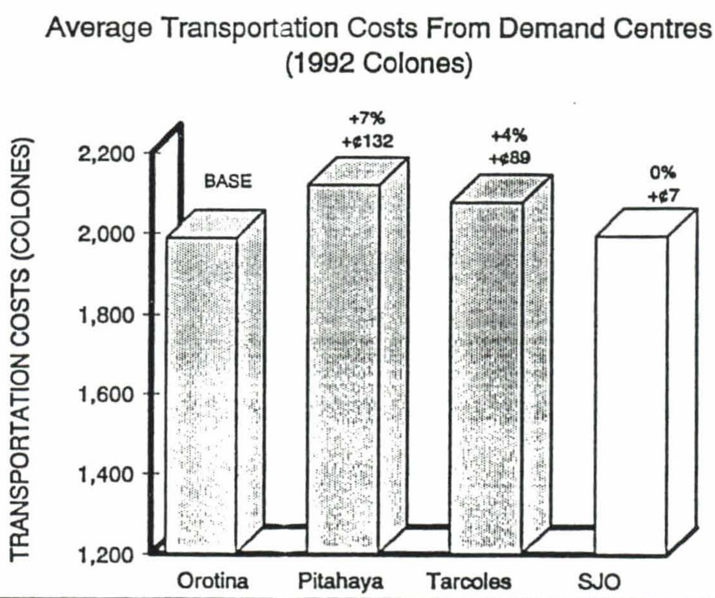


FIGURE 5.14

TRANSPORTATION COST COMPARISON

SITE SELECTION STUDY - COSTA RICA



SOURCE: AVIATION PLANNING SERVICES ANALYSIS

It should be noted that these costs are incurred by each air passenger, well-wisher and greeter. The transportation costs incurred by the forecasted flow of international passengers and the associated well-wishers/greeters from the opening of the airport, assumed to be year 2000, to year 2030 were calculated, and the results are shown below.

DIFFERENTIAL TRANSPORTATION ACCESS COSTS, 2000 - 2030
(Mil. Colones)

	Orotina	Pitahaya	Tarcoles	SJO
NPV Year 2000*	BASE	23,342	16,053	971
Percentage	BASE	+7%	+5%	+0%

(*Escalation rate applied to 1992 costs at 9.9% p.a. Discount rate applied to yield value in year 2000, 11.9% p.a.)

As would be expected, with no change in the underlying assumptions, the Orotina site is the least transportation cost solution, followed by the Tarcoles and Pitahaya sites. The purpose of this calculation is to show that, despite the low cost of transportation for one traveller, the sum of the costs to all travellers over the typical life of an airport is significant. The difference in costs between the sites also becomes substantial over a long period of time.

5.3.3 Access Time

The second element of the demand centre analysis is the time required to travel to the airport. This value is calculated with the following formula.

$$TOTALTIME_{access} = TOTALPAX \sum_{type=1}^{2} PAX_{type} \sum_{centre=1}^{12} DEMAND_{centre} \cdot (2WWPP+1) \sum_{mode=1}^{3} USE_{mode} \cdot TIME_{access}$$

- $TIME_{access}$ = the access time for the particular demand centre and access mode.

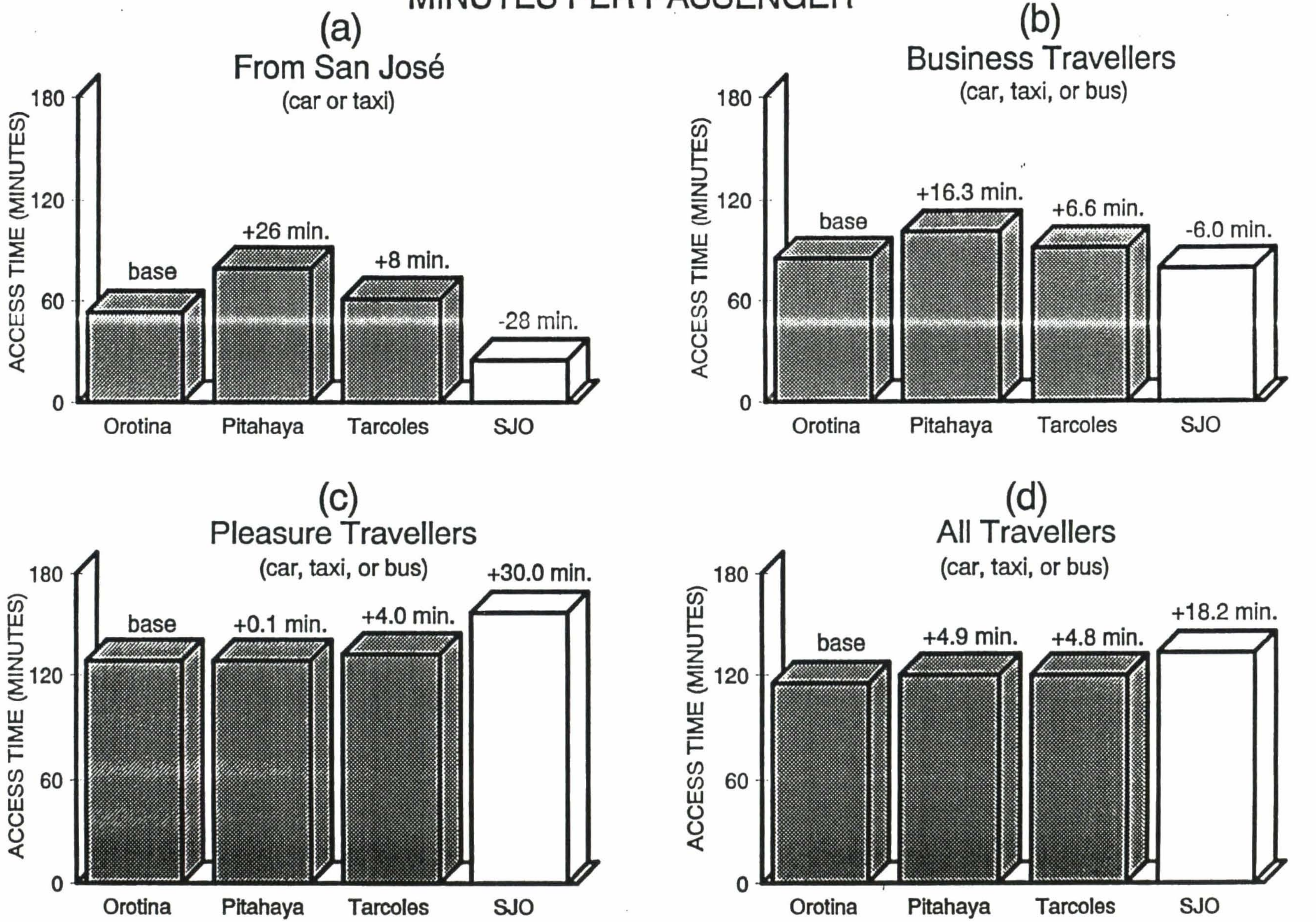
Due to the lack of an industry accepted methodology for the valuation of time and subjective nature of any value chosen, it was decided to omit the value of time and examine the travel time data alone.

Figure 5.15 provides the results of the access time analysis. Frame (a) shows the differential time required to access each of the sites, and the current airport, from San José.

The access cost analysis was again broken down in terms of the purpose of visit to Costa Rica and then examined in total. It can be seen in Frame (b) of Figure 5.15 that for the average business traveller, Orotina requires the least amount of time to access (84 minutes) followed by Tarcoles (91 minutes) and Pitahaya (101 minutes). In a comparison of the three sites to SJO, it was found that SJO is a closer alternative than any of the sites for business travellers at 6 minutes less average access time than Orotina.

The average access time for pleasure travellers shows a much smaller differential between the sites with Orotina and Pitahaya being the closest (128 minutes), followed by Tarcoles (132 minutes). The time differential between sites is much smaller for pleasure travellers than for business travellers due to the large demand centres in the Guanacaste/Puntarenas regions. It is important to realize that, when considering SJO, the current airport is found to require 30 minutes longer travel time than would Orotina for the pleasure travellers. In

FIGURE 5.15
ACCESS TIME COMPARISON
MINUTES PER PASSENGER



SOURCE: AVIATION PLANNING SERVICES ANALYSIS

AVIATION PLANNING SERVICES LTD.

fact, each site improves the travel time for the pleasure travellers.

Examining a weighted average of all travellers from all demand centres shown in Frame (d), it was found that Orotina had the lowest average access time (115 minutes) followed by Tarcoles (120 minutes), and Pitahaya (120 minutes) and a distant SJO (133 minutes).

5.4 Capital Cost Comparison

In order to achieve suitable returns from the investment necessary for their construction, airports should be located so that the cost of development work is minimized. Therefore, topography, soil condition, construction materials availability, as well as services and land values, are of particular importance.

Preliminary airport capital costs were computed at each of the three sites. Where a currency conversion was required, an exchange rate of 1 US$ = 135 Colones was used. For the comparative analysis of the sites, only the difference in capital costs would be significant. This section will focus on the cost comparison of the following elements for the airport:

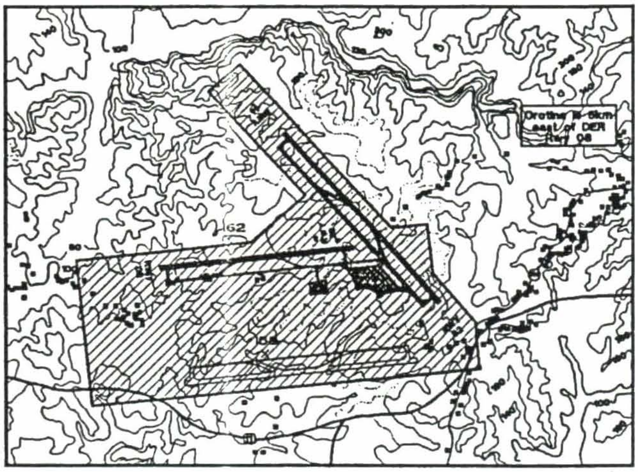
- Land Acquisition
- Runway, Taxiway and Apron
- Earth Moving
- Access Roads
- Lighting Systems
- Navigational Aids

It should be noted that the estimates in this section are order of magnitude costs and would only be significant if there were a substantial difference between the three sites. Furthermore, for this comparative analysis, Pitahaya was assumed to be the "base". The detailed cost estimates will be left for the preliminary design phase.

5.4.1 Land Acquisition

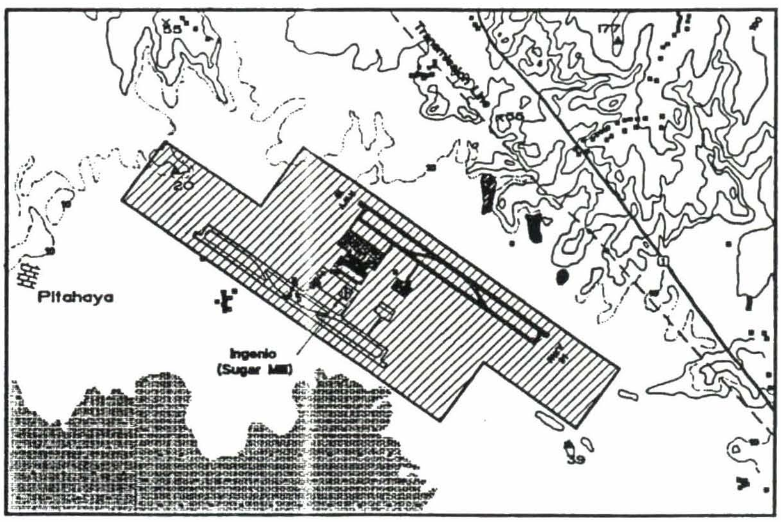
As noted earlier, airports require adequate space for present and future development and the value of land is a factor to be considered. Figure 5.16 shows the proposed airport locations, together with the

FIGURE 5.16
LAND AREA REQUIRED
SITE SELECTION STUDY - COSTA RICA



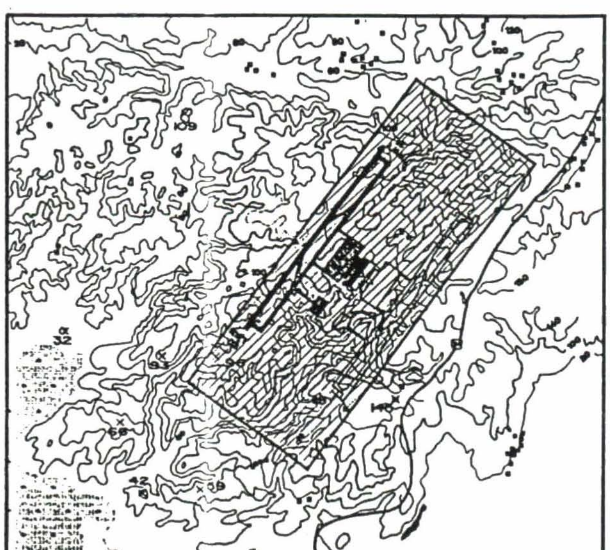
OROTINA SITE

Initial Land Area Required (ha):	677
Future Land Area Required (ha):	383
Total Land Area Required (ha):	1060



PITAHAYA SITE

Initial Land Area Required (ha):	457
Future Land Area Required (ha):	457
Total Land Area Required (ha):	914



TARCOLES SITE

Initial Land Area Required (ha):	457
Future Land Area Required (ha):	457
Total Land Area Required (ha):	914

LEGEND:
- ■ Village (housing)
- × Peak Heights
- Initial Runway
- Future Runway
- Land Area Required

All contours are in metres

SCALE 1 : 100 000

0 2,000 m

REP.\FIG.\FIGS-16

area of land required, both for the present and future facilities.

Based on the areas in Figure 5.16, and an expropriation cost of 400,000 colones per hectare at Pitahaya (provided by the DGAC), land acquisition costs can be estimated. It should be noted that this land value is based on rural lots in the 100 to 200 hectare range, and for land values in the Pitahaya area. It was indicated that the value at Orotina would be higher and prices in the Tarcoles area would be equivalent. For this study, the land values at Orotina and Tarcoles were considered to be 500,000 and 400,000 colones per hectare, respectively.

As a result, anticipated expropriation costs (in 1992 colones) are as computed below:

	Orotina	Pitahaya	Tarcoles
Initial land area required (ha)	677	457	457
Future land area required (ha)	383	457	457
Total land area required (ha)	1,060	914	914
Land acquisition cost (M Col)	530	366	366

When the suitability of a site is being considered, the land required for future development must be controlled. Initial acquisition of this land safeguards the possibility of future expansion and may also prove to be the cheapest course of action. For this study, land for future expansion was considered to be acquired initially.

In addition, it is expected that compensation for the homes (See Section 5.5.4), where the airports would be located, is required. Based on a visual inspection of the maps and aerial photographs of the three sites, it is expected that compensation would amount to approximately 170 M. Colones at Orotina, 70 M. Colones at Pitahaya and 35 M. Colones at Tarcoles.

Therefore, the anticipated land acquisition costs are summarized below:

	Orotina	Pitahaya	Tarcoles
Total (M Col)	700	436	401
Difference (M Col)	+264	Base	-35

5.4.2 Runway, Taxiway and Apron System

The apron area required for the three potential sites was considered to be equal and is not included for the comparative analysis. Geometric standards for airport runways and taxiways depend upon the characteristics of the design aircraft. The reference code of a runway is identified by the combination of a code number and letter. Based on a Code 4E airport for a precision runway, costs were provided by Transport Canada as follows:

Runway - flexible pavement: 412,000 Col. per lineal metre;

Taxiway - flexible pavement: 157,000 Col. per lineal metre;

The resulting quantities for the pavement design structure of the runway and taxiway are shown below, which are based on the pavement areas from Section 3.5.

	Orotina	Pitahaya	Tarcoles
Runway (lineal m)	5,500	3,000	3,000
Taxiways (lineal m)	8,200	4,150	4,150

Based on the above, the cost estimate for the runway and taxiway pavement system at each of the airports is as follows:

	Orotina	Pitahaya	Tarcoles
Runways (M. Col.)	2,267	1,236	1,236
Difference (M. Col.)	+1,031	Base	+0
Taxiways (M. Col.)	1,283	649	649
Difference (M. Col.)	+634	Base	+0

5.4.3 Earth Moving and Drainage Costs

An estimate of the earth moving requirements was made using maps with a scale of 1:50,000 and contour intervals of 20 metres, in the absence of more accurate and detailed topographic data. In view of the level of accuracy of this map, the simplifying assumption was made that runway and taxiway (and strips) would not have transverse slopes. The runway and taxiway longitudinal profile is based on maximum slopes according to Annex 14.

Although aerial photographs are available for this area, which can provide more detailed contour intervals, the cost for this more detailed analysis was prohibitive at this stage of the analysis.

Requirements for cut in the terrain adjacent to the runway strip (ie. 14.3% transitional surface slope and inner horizontal surface) were considered in this analysis. Similarly, requirements for fill on the terrain adjacent to the airside surfaces were also considered. This requirement is to have an approximate maximum downward slope of 1 to 1.5 in order to provide for adequate soil stability.

It should be noted that the level of the taxiway and runway (at a typical cross-section) is not necessarily the same, but a function of the slope of crossing taxiways. Furthermore, the lateral position of the apron was such that earthwork was minimized. On an aircraft stand, the maximum slope should not exceed 1%.

A cost of 280 colones/cubic metre was provided by the DGAC for earth moving. Visual inspection of the sites has indicated that dynamite blasting, at approximately 20 times the earth moving cost, would not likely be required.

Orientation, slope, elevation and position of the surfaces have been taken so as to yield a 10 per cent greater cut than fill. More precise positioning would be possible with more detailed topographic data.

Drainage costs for each of the sites was estimated using a cost of 6000 colones/lineal metre, provided by DGAC.

The following sub-sections provide a description of the earthwork and drainage computations for each of the three sites.

5.4.3.1 **Orotina**

The location of the airside surfaces assumed for the computations are shown in Figure 5.17. This figure shows the land area considered for earthwork computations.

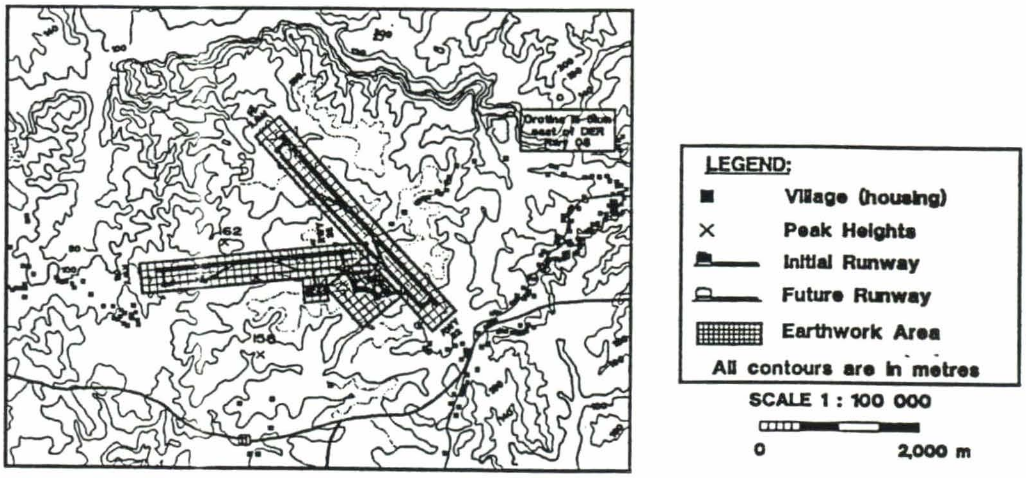
Runway 08/26 at Orotina would slope upwards towards the east with an overall slope of 1.0%, while Runway 14/32 would slope downwards and then upwards with an overall slope of 0%. These runway profiles are also shown in Figure 5.17.

The results of the preliminary optimized computations show that at the Orotina site, the earth moving would amount to the following quantities and costs.

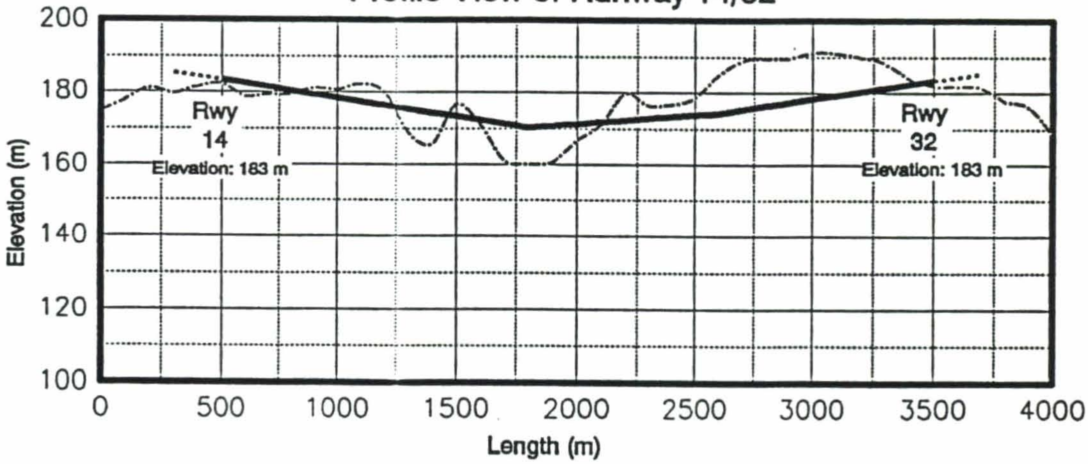
	Cut (Million m^3)	Fill (Million m^3)	Cost (Million Col)
Apron	2.5	0.2	728
Runway 14-32/Taxiway	6.3	3.7	2,787
Runway 08-26/Taxiway	3.9	7.1	3,056
Additional Earth Moving	---------	0.6	176
Total	12.6	11.5	6,748

FIGURE 5.17
EARTHWORK REQUIREMENTS - OROTINA
SITE SELECTION STUDY - COSTA RICA

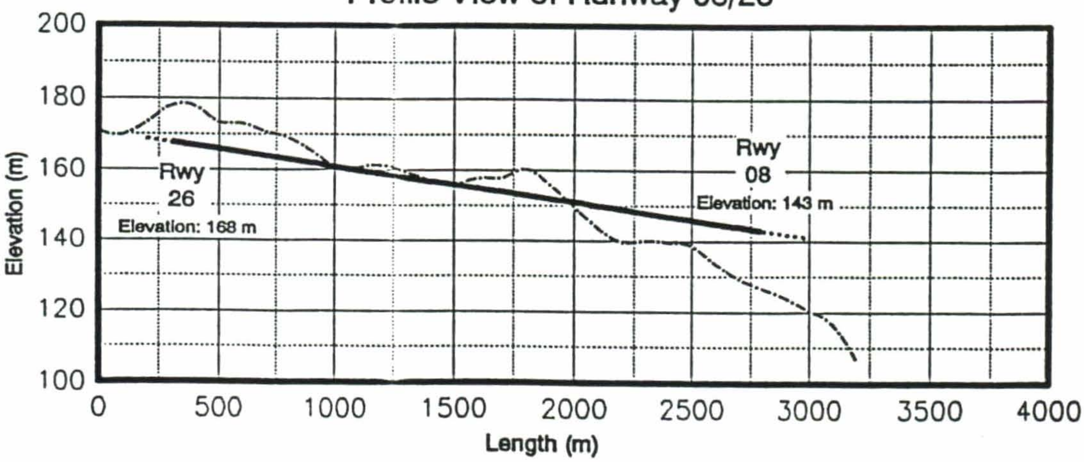
Plan View of Orotina Site



Profile View of Runway 14/32



Profile View of Runway 08/26



Drainage cost totalling 134 million colones is estimated based on a requirement of 22,300 lineal metres.

5.4.3.2 **Pitahaya**

The location of the airside surfaces assumed for the computations are shown in Figure 5.18.

The terrain in the Pitahaya area is relatively level, between sea level and the 20 metre contour. As a result the runway was considered to be level, with a nominal amount of earthwork required. It was established that approximately 4.5 million cubic metres of cut and fill (including embankment) would be required at a total cost of 1,260 million colones.

Drainage costs of 78 million Colones was estimated, based on a requirement of 13,000 lineal metres.

5.4.3.3 **Tarcoles**

The location of the airside surfaces assumed for the computations are shown in Figure 5.19.

Runway 03-21 at Tarcoles would slope upwards towards the NE with an overall slope of 1%. The runway profile is shown in Figure 5.11, together with a typical cross-section along the runway.

The results of the preliminary optimized computations show that at the Tarcoles site, the earth moving would

FIGURE 5.18
EARTHWORK REQUIREMENTS - PITAHAYA
SITE SELECTION STUDY - COSTA RICA

Plan View of Pitahaya Site

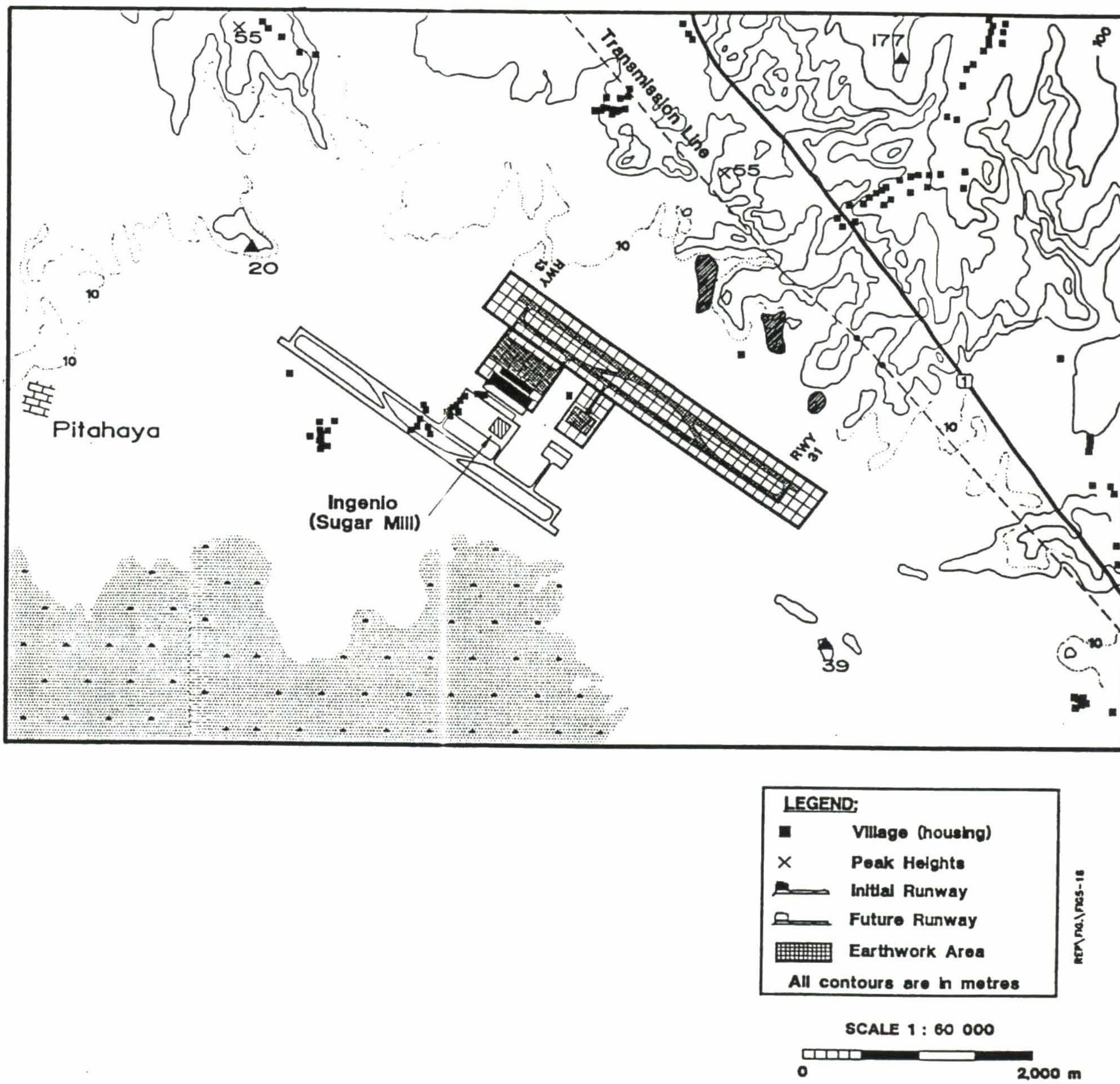
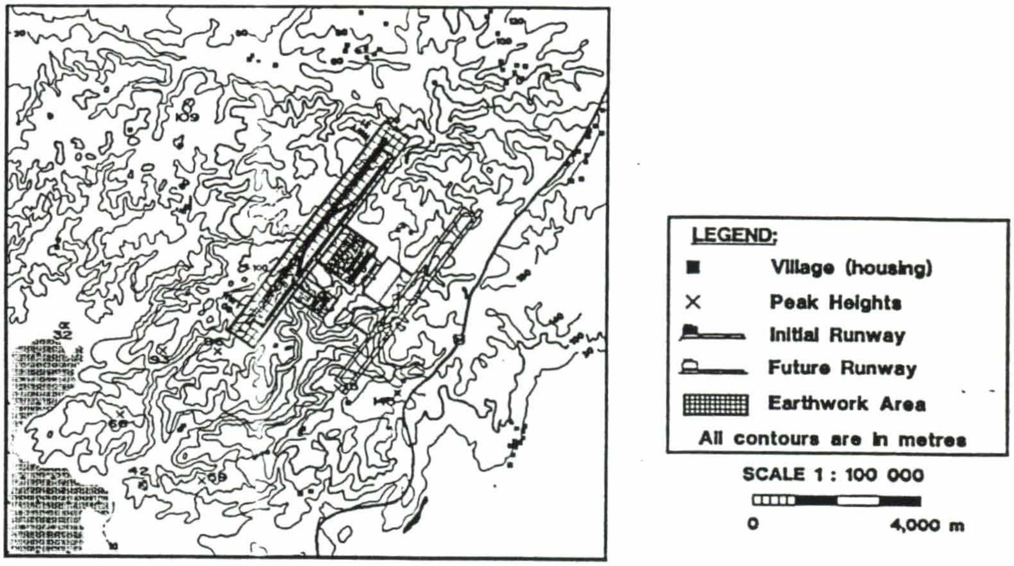
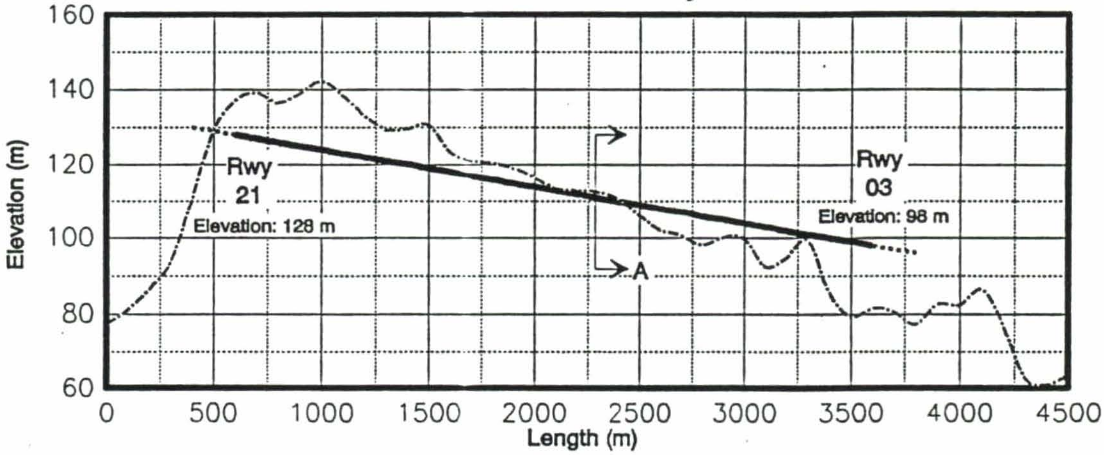


FIGURE 5.19
EARTHWORK REQUIREMENTS - TARCOLES
SITE SELECTION STUDY - COSTA RICA

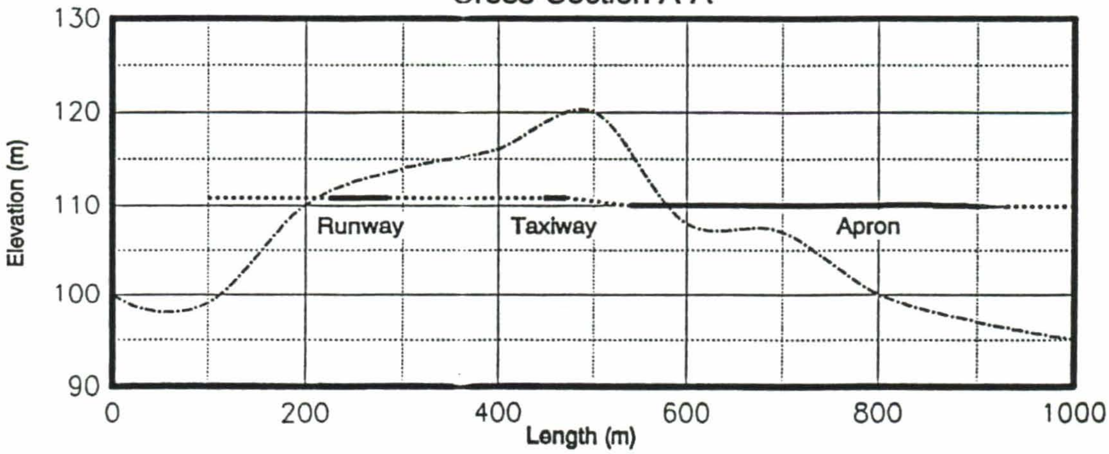
Plan View of Tarcoles Site



Profile View of Runway 03/21



Cross-Section A-A



amount to the following quantities and costs.

	Cut (Million m³)	Fill (Million m³)	Cost (Million Col)
Apron	2.1	1.7	1,055
Runway 03-21/Taxiway	8.2	7.8	4,465
Additional Earth Moving	---------	0.3	93
Total	10.3	9.7	5,613

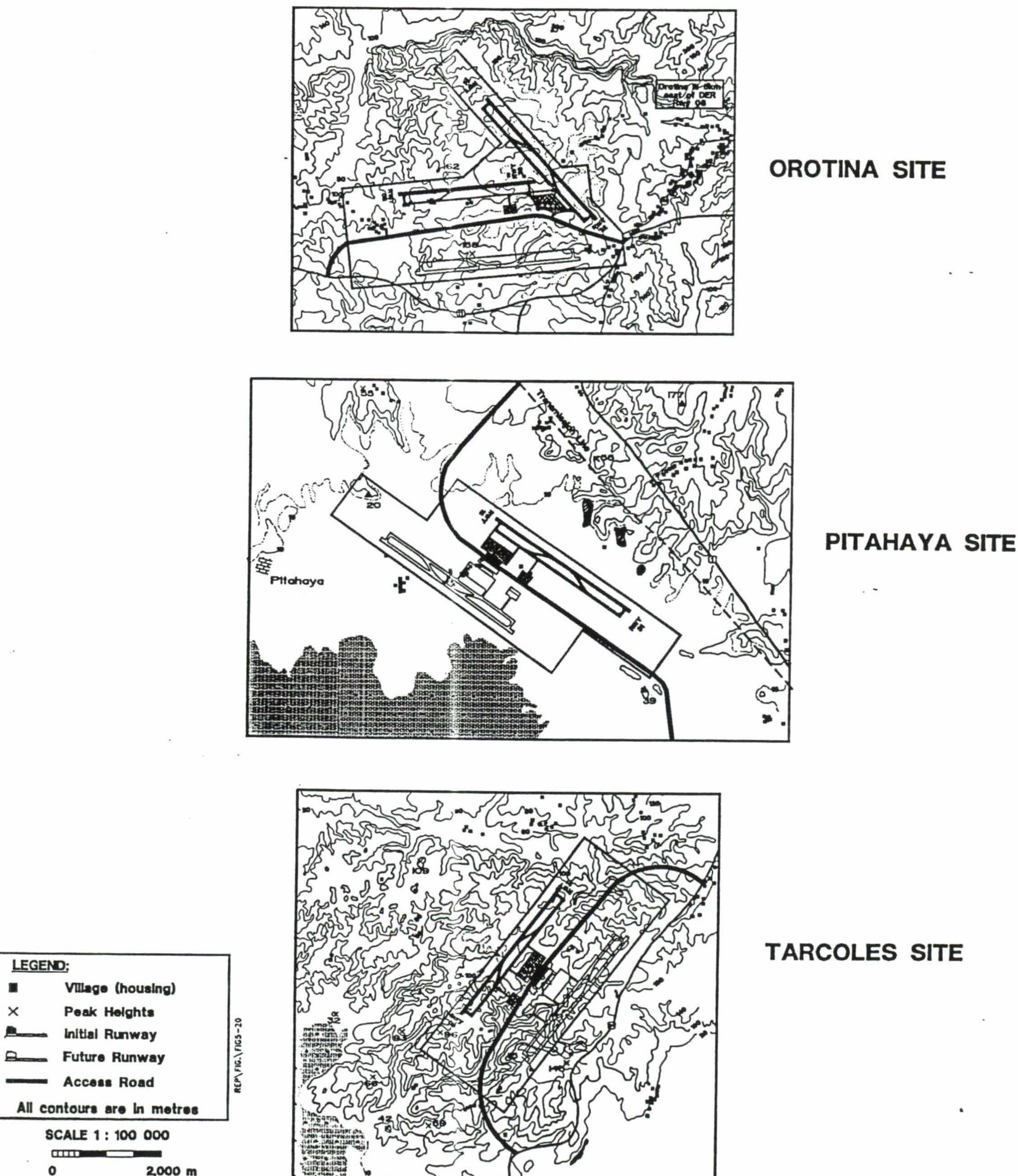
Drainage cost of 78 million colones was estimated, based on a requirement of 13,000 lineal metres.

5.4.4 Access Roads

Fast and convenient access facilities for passengers and freight are essential for an airport to provide efficient service. Of extreme importance for the sites being considered is the completion of the road from Colon to Orotina. It was assumed for this study that this road will be completed prior to construction of the airport.

The access roads (from the present roadway system to the terminal) at each of the sites are shown in Figure 5.20, and the approximate road distances are given below. These distances include an additional 5 km allowance for internal airport roads and circulation (curbside) roads around the terminal complex.

FIGURE 5.20
ACCESS ROADS
SITE SELECTION STUDY - COSTA RICA



	Distance (km)
Orotina	12
Pitahaya	17
Tarcoles	13

To determine the required width of the roads, the number of vehicles expected in the critical direction in the peak hour was estimated. From the passenger movement forecast, the numbers of arriving and departing passengers were taken to determine the number of people on a busy day for the years 2010 and 2030. The average number of well-wishers and greeters was as described in Section 5.3.

The peak hour flow was obtained from summing the flows of passengers and greeter/well-wishers for both arrivals and departures. Using the breakdown in mode of ground transportation and the average vehicle occupancy as provided in Section 5.3, the number of vehicles on the road can be estimated.

The number of lanes required is based on a lane capacity of 2,000 vehicles per hour. The unit cost to build a 7.5 metre wide two lane road (one lane each way), obtained from MOPT, is 20 million colones per kilometre.

Based on the peak hour traffic, the greeters/well-wishers and the mode of transport, it is expected that a two lane road (one lane each way) would be sufficient until the year 2020. However, this does not include any allowance for airport personnel or local traffic, and as a result, it is recommended that a four lane road be built during the initial construction of the airport. Therefore, the cost of access road construction is as follows:

	COST (M. COL.)	DIFFERENCE (M. COL.)
Orotina	480	-200
Pitahaya	680	BASE
Tarcoles	520	-160

These costs do not include excavation or earthwork for the access roads. Routing of roads is more flexible than for runways, so that more opportunity exists to select the most favourable route. For this exercise, the costs are assumed to be the same at each of the sites.

5.4.5 Lighting Systems and Visual Aids

While lighting systems and visual aid requirements for a new airport normally include indicators, pavement markings, lighting and signs, this section will focus only on lighting systems.

Requirements for lighting systems are determined from the recommendations set forth in ICAO Annex 14 and the Aerodrome Design Manual, Part 4.

The airport lighting systems would include runway edge, ideally runway centreline, runway threshold/end, stopway, approach, VASI/PAPI, taxiway and apron flood lights.

Cost estimates for visual aids at all three sites are provided below, and these include allowances for packing, shipping, insurance, installation, contractor costs, custom fees and design.

	ABSOLUTE	DIFFERENCE
Orotina	$US 3.7 million (500 M. Col.)	+ 176 M. Col.
Pitahaya	$US 2.4 million (324 M. Col.)	Base
Tarcoles	$US 2.4 million (324 M. Col.)	+ 0

It should be noted that lighting required for a Category I precision approach has been used on three of the four runways at Orotina, as indicated in Section 5.1.

5.4.6 Navigational Aids

The rough order of magnitude costs for navaids are provided below:

- ILS (CAT I) $600,000 US
- VOR $480,000 US
- DME $160,000 US
- MLS $400,000 US
- NDB $120,000 US

Therefore, based on the requirements for navaids from Table 5.2, a cost estimate for the three sites, including $500,000 US for additional site preparation for each localizer and glide path installation, is provided below:

	ABSOLUTE	DIFFERENCE
Orotina	$5.0 M US (675 M. Colones)	+ 243 M. Col.
Pitahaya	$3.2 M US (432 M. Colones)	Base
Tarcoles	$3.2 M US (432 M. Colones)	+ 0

5.4.7 Summary of Capital Cost Comparison

The total cost differences for construction of the new airport is arrived at by summing the above differences and adding 7% for design and construction supervision, and an additional 10% for contingency. These estimates are provided in Table 5.6, which shows that Orotina is the most costly of the three sites.

TABLE 5.6
PRELIMINARY AIRPORT CAPITAL COST COMPARISON

	OROTINA	PITAHAYA	TARCOLES
	Estimated Cost 1992 currency (Million Colones)	Estimated Cost 1992 currency (Million Colones)	Estimated Cost 1992 currency (Million Colones)
1 Land Acquisition	+264	BASE	-35
2 Site Preparation	+5,488		+4,353
3 Drainage	+56		+0
4 Runway System	+1,031		+0
5 Taxiway System	+634		+0
6 Lighting	+176		+0
7 Navigational Aids	+243		+0
8 Road Access	-200		-160
9 Engineering Services & Contingency	+1,308		+707

Difference (in Million Colones)	+8,999	BASE	+4,865
Difference (in Million USD)	+67	BASE	+36

Note: Pitahaya was used as the base since it was the least expensive.

5.5 Environmental Concerns

The construction of a new airport will always evoke environmental concerns to some degree. The areas of concern may be generally broken down to include noise, air and water pollution, ecological processes and the demographic development of the area. This section briefly discusses the particular concerns at each of the potential airport sites, for comparative purposes, to be followed by a more detailed environmental impact analysis in the next phase of the study. The assessment would indicate how these environmental concerns might be alleviated or reduced.

5.5.1 Noise

The noise exposure of the population due to aircraft operations can be estimated by the Noise Exposure Forecast (NEF) index, developed in the USA. The ICAO index referred to as Weighted Continuous Perceived Noise Level (WECPNL) differs only by a constant from the NEF index. For this analysis, a qualitative assessment of the noise was carried out at each of the sites in Section 5.1 and 5.5.4. The results of this analysis are directly attributable to the size of the surrounding population, hence Pitahaya is the most favourable site followed by Tarcoles and then Orotina. The airport site at Orotina is surrounded by a large, residential, noise-sensitive area in comparison to the other sites. Departures to the east and arrivals from the east will cause unwanted sound to the community of Orotina.

5.5.2 Air and Water Pollution

Air and water pollution is a concern at each of the sites but to varying degrees. In terms of air pollution, world aviation actually accounts for less than 5% of all industrial emissions and only an estimated 2% of the nitrogen oxide which makes its way to above 30,000 feet. New airport design has many pollution-reducing and environmentally friendly technologies available to it, which could alleviate the negative impact of airport construction and operation. With this in mind, the potential for air and water pollution will have the greatest effect on the Tarcoles site due to its very close proximity to the Carara Biological Reserve on the opposite side of the Tarcoles River.

5.5.3 Ecological Processes

The impact on ecological processes is not properly evaluated without a detailed study of the local habitat at each site. At this point in the analysis, it is evident that the wildlife habitats at the Carara Biological Reserve could be disrupted. The Tarcoles site is also located near bird migratory areas, which could present a potentially dangerous situation to aircraft. The Orotina and Pitahaya sites are not situated relatively close to any wildlife reserves; thus, the potential for a severe impact on natural, ecological processes is significantly reduced at these sites.

5.5.4 Demographic Development of the Area

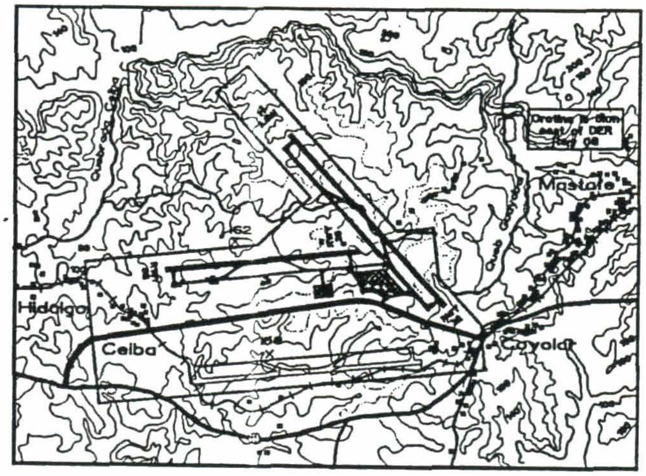
The most significant and potentially negative aspect of the impact of new airport on demographic development, is the relocation of some residents and businesses. Preliminary indications suggest that the largest number of relocations would occur if the Orotina site were selected for development. The Tarcoles site would require substantially fewer relocations, followed by Pitahaya with the smallest number. The selection of the Pitahaya site may, however, cause the loss of productive farm land.

Each site also crosses a few rivers and streams, which require further study regarding possible rerouting. Infrastructure elements, such as railway operations, in the case of Orotina, and minor roadways, appear to be within the sites' boundaries. The rerouting of these items should not present any long-term impact on the demographic development of the individual areas. Figure 5.21 shows the location of the airport at each of the sites, highlighting the populated areas and infrastructure elements that could be adversely effected by the airport.

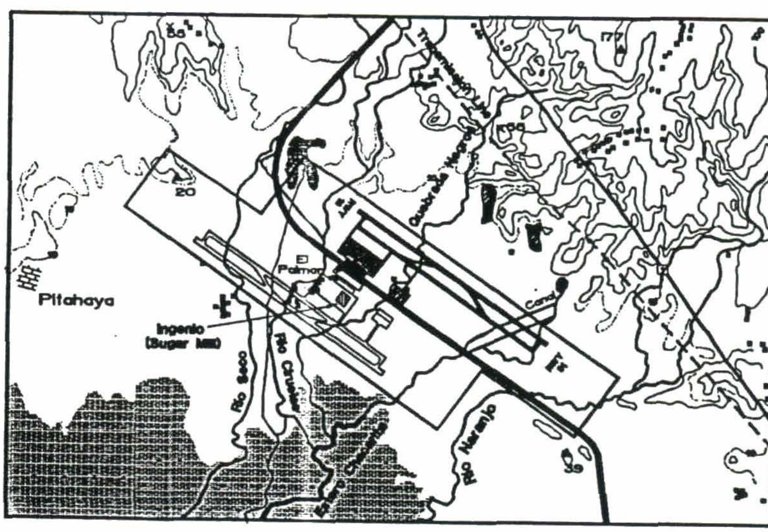
5.5.5 Summary

Following this very preliminary look at the impact of a new airport on the environment at each of the sites, it appears that the Tarcoles site, due to its close proximity to the Carara Reserve, presents the greatest potential for a negative impact. Orotina is likely the second worst, due both to the large number of residents that would require relocation and to the noise impact on the surrounding towns. Pitahaya is probably the least likely to suffer any lasting negative environmental impact due to the small surrounding size of population and to the distant location of airport operations from protected areas.

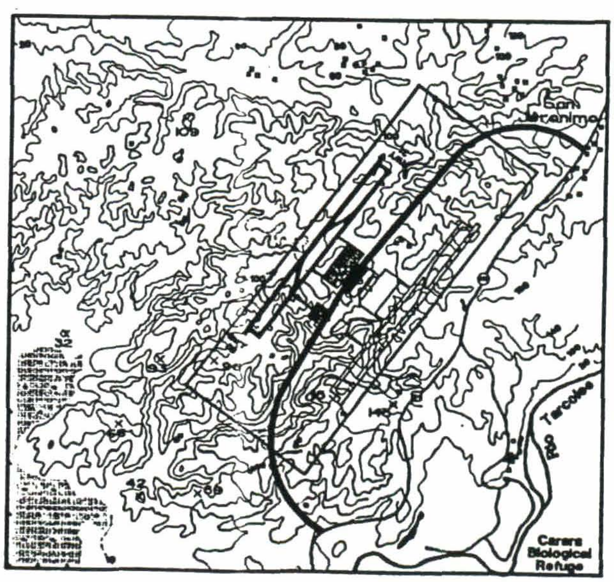
FIGURE 5.21
PHYSICAL INFRASTRUCTURE AFFECTING DEVELOPMENT OF AIRPORT
SITE SELECTION STUDY - COSTA RICA



OROTINA SITE



PITAHAYA SITE



TARCOLES SITE

LEGEND:
- ■ Village (housing)
- × Peak Heights
- Initial Runway
- Future Runway
- Access Road

All contours are in metres

SCALE 1 : 100 000

0 2,000 m

REF\FIG\FIGS-21

5.6 Future Expansion Capability

The objective of this section is to determine whether sufficient land is available at each of the sites for the construction of a future parallel runway, which would provide additional capacity well into the future. Furthermore, a subjective analysis of the impact this future runway would have, particularly on capital cost and flight operations, will be addressed.

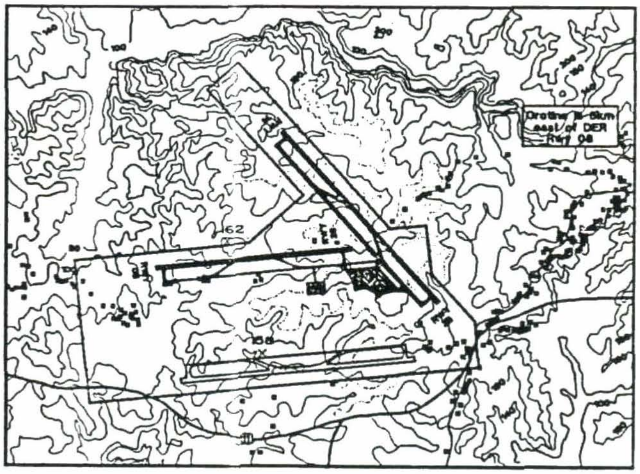
5.6.1 Orotina Site

It can be seen from Figure 5.22 that the future runway is planned parallel to Runway 08/26 and south of the present runway, such that the present terminal can be easily accessed from the three runways. If this site is selected, a more detailed analysis of the cost (particularly earthwork) and operations would be undertaken.

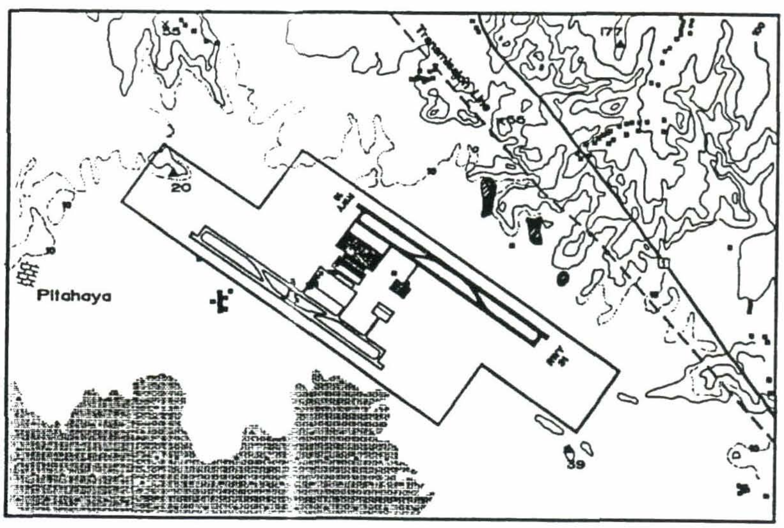
One other possibility for the future runway would be to locate it parallel and west of Runway 14/32. This configuration would also allow easy access to the terminal from the three runways. The location of the future parallel runway will, however be dependant on the winds experienced at the site and should only be finalized once representative wind data can be acquired. In addition, a detailed operational analysis, as provided in Section 5.1, should be carried out for the future parallel runway.

Further examination of Figure 5.22 shows that the terrain where the new runway would be located is not very mountainous and large rivers are not present. It is expected that the earthwork for the future runway would be similar to that of the present runways, and flight operations would present additional difficulties at Orotina.

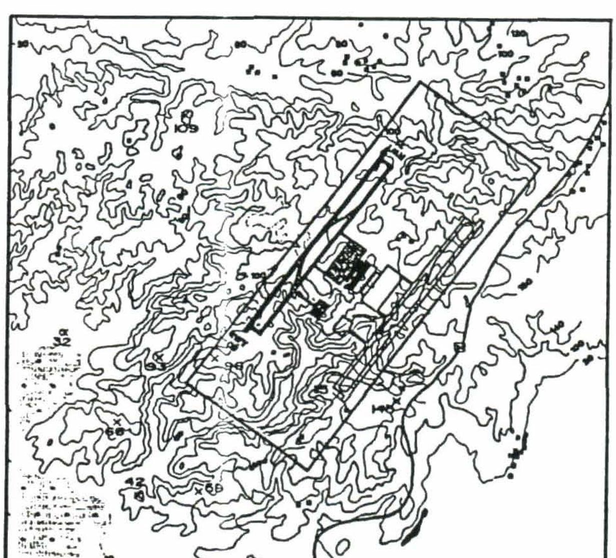
FIGURE 5.22
FUTURE EXPANSION CAPABILITY
SITE SELECTION STUDY - COSTA RICA



OROTINA SITE



PITAHAYA SITE



TARCOLES SITE

LEGEND:

- ■ Village (housing)
- × Peak Heights
- Initial Runway
- Future Runway

All contours are in metres

SCALE 1 : 100 000

0 2,000 m

REP\FIG\FIG5-22

5.6.2 Pitahaya Site

It can be seen from Figure 5.22 that the future parallel runway at Pitahaya has been planned SW of the current runway, with the two runways staggered. The stagger will allow shorter taxi times, in the future, when one runway is used for arrivals and the other for departures. Based on the wind data at Puntarenas, it is likely that Runway 13 would be the predominant runway used for operations at Pitahaya. As a result, the operational area would be optimally located closer to the threshold of Runway 13. This would minimize the taxi times for departures from Runway 13.

From an earthwork and operational standpoint, the future runway would not likely show many differences from the current runway.

5.6.3 Tarcoles Site

Figure 5.22 shows that the future parallel runway at Tarcoles has been planned to the east of the current runway.

It should be noted that the placement of the operational area for the current runway at Tarcoles was dictated primarily by the earthwork. It is likely that the placement of the future runway will also be located such that earthwork is minimized. This will be determined in the next phase if Tarcoles is the selected site. Consideration may also be given to placement of the future runway to the NW of the current runway.

It would appear that the earthwork required for the future runway would be similar to that of the current runway. From an operational standpoint, departures from Runway 03R may require left turns to avoid hills, while approaches to Runway 21L would likely require steeper approaches as compared to 21R. Furthermore, additional operations at Tarcoles would further disrupt the Carara Reserve. In any case, further analysis of operations would be required if Tarcoles is the selected site.

5.6.4 Summary

Based on the previous sub-sections it is evident that the most suitable site for future expansion would be Pitahaya. When comparing Orotina and Tarcoles, it appears that the two would be equivalent; Orotina would likely be less expensive to build, while Tarcoles would likely provide for more reliable and safe operations.

5.7 Airspace

The topography of the areas examined, in several cases, indicated potential airspace management problems. These were discussed individually in the site-specific comments in Section 5.1. This section will focus on the discussion of problem's, if any, encountered in the interfacing between the current airways structure and the operations in close proximity to the proposed sites.

5.7.1 Airway Structure

All the potential sites examined are within normal radar vectoring, or Standard Instrument Departure (SID) routings to the current airway structure. When a final site has been determined, a general flight pattern projection for both arrival and departure aircraft can be assessed. At that point, a re-evaluation of the routing patterns and associated airway preferential utilizations will be required to ensure a maximum effectiveness of both the airport and the airspace management procedures.

5.7.2 Control Methodology

The topography of the entire area, with the possible exception of a coastal plains location, appears to dictate an almost mandatory radar controlled environment for a safe and effective airport/airspace operation. In point of the fact, the delays encountered with a non-radar environment probably would be unacceptable. Costing for this radar was provided in Section 5.6.4.

5.7.3 Summary

Since this factor would likely have the same impact at all three sites, it was not evaluated any further during this phase of the analysis.

6. SITE COMPARISONS AND EVALUATION

In the previous sections, the Consultants defined and described a number of criteria which would form the basis of selection of one of the candidate sites. Qualitative and quantitative data were acquired on all of the sites to allow justifiable comparisons. In addition, discussions of these factors and sites were held with various Government officials in Costa Rica. This section provides a summary of the results of the discussions held in Costa Rica and is followed by a description of a decision model used for evaluating the sites.

6.1 Discussions of Factors and Sites with Government of Costa Rica

The objective of this section is to provide an overview of the results of discussions held with various Government of Costa Rica officials, particulary in MOPT and ITC. The meetings entailed discussions pertaining to the three sites discussed in Section 4 and the seven criteria discussed in Section 5.

The results of the analysis of Orotina were presented to the Government of Costa Rica officials. The Consultants and Costa Rica officials agreed that flight operations at Orotina would be too complex and costly. Therefore, this site was removed from further consideration based on the following:

- The analysis in Section 5.1 showed that operational considerations were a major concern at Orotina, due to mountainous terrain to the North, East and South. As a result, a two runway system was recommended in order to permit IFR operations in more directions. Furthermore, due to close proximity of the mountainous terrain to the site, operation would will likely encounter mechanical turbulence precipitation and wind shear adding to the complexity of this site. In the final analysis, it was considered that operations at this site would impose to great a work-load on the flight crews.

- It is known that there is pressure to relocate SJO airport because of two important factors, namely the aircraft operational difficulties at SJO and lack of terminal space for future expansion. It is therefore not realistic to consider Orotina, with a two runway system, which would inherit one of the main operational problems of the current airport.

Since the site near Tarcoles is less than 10 km from the site proposed at Orotina, and further from residential, noise-sensitive areas, the Costa Rican officials agreed to remove Orotina from further analysis. Therefore, the analysis of each factor for Orotina, carried out in Section 5, will not be used in the Binary Analysis discussed below.

6.2 Binary Decision Model Overview

The model used for the analysis is the Binary Decision Model (BDM). It integrates relative criteria and site preference data in a simple process so that the decision maker is not confronted with vast amounts of data at one time. Details of the application of the model using an example are shown in Appendix B, while this section presents the application of the model to the current project. The objective of this exercise is to obtain a relative score for each of the sites, while accounting for all of the criteria.

BDM was developed by Westinghouse and modified by Aviation Planning Services. It is essentially a systematic process for subdividing a complex array of decisions into decisions involving only two choices at a time. These individual decisions are then aggregated to give overall results.

The important aspect of the binary decision analysis technique is the weighting of the individual criteria and then positioning of the sites along each criteria. The general methodology essentially involves four steps.

The first step in the analysis involves selection of criteria relevant to the decision. It should be stressed that the selection criteria must be mutually exclusive and collectively exhaustive. The second step involves developing a weight for each site, for all the criteria. The third step is to develop a weighting of the criteria in order of importance. In step four, based on the criteria weight and the weighting of each site, composite scores are computed.

6.2.1 Criteria Selection (Step 1)

A number of criteria were described and analyzed in the previous sections, and are as follows:

- Operational Evaluation
- Ground Transportation Cost Comparison
- Access Time Comparison
- Capital Cost Comparison
- Environmental Concerns
- Future Expansion Capability

It should be noted that airspace was removed from further analysis since this would not have any adverse effect on the site comparisons. Furthermore, capacity was removed from further analysis since Orotina is no longer being considered.

6.2.2 Site Weighting for Each Criterion (Step 2)

The two sites were compared in pairs along each criterion. Sections 6.3.1 through 6.3.7 present the rationale behind the scoring of the sites along the individual criteria.

6.2.2.1 Operational Evaluation

This criterion is based on the operational analysis from Section 5.1. Based on this analysis, the results indicate that Pitahaya is the preferred site, followed by Tarcoles.

6.2.2.2 Ground Transportation Cost Comparison

It is recalled from Section 5.3.2 that a comparison of the average distances from the demand centres to the various sites resulted in a ranking of sites beginning with Tarcoles (125 km) followed by Pitahaya (127 km). Applying the cost of transportation to these distances resulted in the same ranking of the sites. The weighted average transportation cost to Tarcoles is calculated at ¢2076 and to Pitahaya at ¢2119.

The pleasure passengers will have a smaller transportation cost at each of the sites than is currently experienced with SJO, whereas the business passengers will experience an increase.

6.2.2.3 **Access Time Comparison**

Section 5.3.3 examined the weighted average time required to reach the various sites from the demand centres. The weighted average resulted in Tarcoles and Pitahaya being equal at 120 minutes each. In the weighted analysis, the differential times were too small to be considered significant.

In the analysis of pleasure passengers alone it was found that each of the sites provided a shorter travel time from the demand centres than the current airport. To reach the sites from the demand centres, Pitahaya required 128 minutes and Tarcoles required 132 minutes. Thus, no matter which of the sites is chosen, pleasure passengers are better off than the current situation (SJO 158 minutes). Also, the time differential between the sites was not significant.

In an examination of the business passengers and public officials alone, the following was found:

- Each of the sites presented an increase in travel time as compared with the 78 minutes average transportation time to the current airport. These access times are provided below:

	Pitahaya	Tarcoles
Average Access Time (minutes)	110	91

- The time differential between alternative sites is significant.

The time of a business person is likely more critical, more valuable and more important to Costa Rican development. Therefore, for access time comparison the site rankings recognize the importance and the more valuable time of the business traveller. The sites ranked in order of business traveller preference are: Tarcoles and Pitahaya. This is not to say that the pleasure travellers are not important, indeed, they are the second largest source of foreign exchange earnings in Costa Rica. However, because the new sites represent only a positive impact on pleasure travellers by decreasing their transportation cost and time, the negative impact on business travellers is deemed more important for this issue.

6.2.2.4 **Capital Cost Comparison**

The total cost comparison includes all the capital cost differences computed in Section 5.4 and summarized in Table 5.6. The cost difference, in 1992 currency, was estimated to be an additional $36M US for Tarcoles.

6.2.2.5 **Environmental Concerns**

Environmental factors must be carefully considered in the development of the new airport. While some effort was given to consideration of the environment in Section 5.5, a more detailed environmental impact study will be carried out in Volume IV of this study for the selected site. Based on the discussion in Section 5.5, Pitahaya is the most favourable site, followed by Tarcoles.

6.2.2.6 Future Expansion Capability

This criterion considers the degree of difficulty to expand the airport in the future. It compares, for example, future earthwork requirements at the sites, flight operations with the new runway, etc. This criterion is described in Section 5.6, and the conclusions show that Pitahaya is the most favourable site, followed by Tarcoles.

6.2.3 Individual Site Scores (Step 2 continued)

The various factors described in the previous sections are summarized in Table 6.1. The table provides an overall summary of the comparisons of the sites for each criterion.

The cumulative scores of each of the two sites for each of the six criteria are presented in Table 6.2. The table shows both the results of the individual comparisons as well as the relative scores in percentage terms for the two sites, along each criterion.

TABLE 6.1
RELATIVE COMPARISON OF SITES

		PITAHAYA	TARCOLES
Operational Analysis		Most Favourable	Less Favourable
Transportation Costs (1992 Colones)	Absolute	2119	2076
	Relative	+43 +2%	Base Base
Access Time	Absolute Overall Absolute Pleasure Absolute Business	120 minutes 128 minutes 110 minutes	120 minutes 132 minutes 91 minutes
	Relative Overall Relative Pleasure Relative Business	Equal Base +19 minutes	Equal + 4 minutes Base
Capital Cost Differential in year 1992 $US Million	Relative	Base	+36
Environment		Most Favourable	Less Favourable
Expansion Capability		Most Favourable	Less Favourable

Source: Aviation Planning Services Ltd.

TABLE 6.2
DEVELOPMENT OF INDIVIDUAL SITE SCORES

	INDIVIDUAL SITE RAW SCORES FOR EACH CRITERION					
SITE	OPER. ANALYSIS	TRANSPORT COST	ACCESS TIME	CAPITAL COST	ENVIRONMENT	EXPANSION
PITAHAYA	1	0	0	1	1	1
TARCOLES	0	1	1	0	0	0

	NORMALIZED SCORE					
SITE	OPER. ANALYSIS	TRANSPORT COST	ACCESS TIME	CAPITAL COST	ENVIRONMENT	EXPANSION
PITAHAYA	67	33	33	67	67	67
TARCOLES	33	67	67	33	33	33
TOTAL	100	100	100	100	100	100

Source: Aviation Planning Services Ltd.

For example, when comparing capital costs at each of the sites, Pitahaya's capital costs were less than Tarcoles', resulting in a score of "1" for Pitahaya and "0" for Tarcoles.

As a result, a normalized weight was computed for each of the sites for capital cost. Pitahaya received a normalized weight of 67%, followed by Tarcoles with 33%.

This entire process was also carried out for the other five criteria.

6.2.4 Weighting of the Six Criteria (Step 3)

The six criteria identified were compared in pairs to determine their relative importance. The comparisons are summarized in Table 6.3, where a comparison between two criteria is displayed as a "1" for the more favourable criterion and "0" for the other. Therefore, each column of data represents an independent comparison of two different criteria. The frequency count of favourable outcomes for each criterion is taken as a measure of its relative importance.

The "scoring" of the criteria was based on the judgement of APS professionals. The combined results, shown in Table 6.3, indicate that "access time" was considered the most important criterion with a relative weight of 29%, followed by:

- transportation costs with 24%;
- flight operations with 19%;
- capital costs with a weight of 14%;
- environment with 10%; and
- expansion capability with 5%.

TABLE 6.3
RESULTS OF CRITERIA WEIGHTING EXERCISE

CRITERION	RAW SCORE	TOTAL SCORE	TRANSFORMED SCORE	CRITERIA WEIGHT
OPERATIONAL ANALYSIS	0 0 1 1 1	3	4	19%
TRANSPORTATION COST	1 0 1 1 1	4	5	24%
ACCESS TIME	1 1 1 1 1	5	6	29%
CAPITAL COST	0 0 0 1 1	2	3	14%
ENVIRONMENT	0 0 0 0 1	1	2	10%
FUTURE EXPANSION	0 0 0 0 0	0	1	5%
TOTAL		15	21	100%

Notes:
Transformed Score = Total Raw Score + 1
Criterion Weight = (Transformed Score)/(Total of Transformed Score)

Source: Aviation Planning Services Ltd.

6.2.5 Composite Site Scores (Step 4)

The final step in the BDM analysis was the combination of all the relative scores with the criterion weights. This determined an overall relative ranking of the two sites. Based on the criteria weight, and the weighting of the sites, which were shown in the previous sections, composite scores were computed for each site. These composite scores were computed by multiplying the individual site scores for each criterion by the criterion weight and dividing by 100. The results, weighted by criterion scores and combined into a single value, are presented in Table 6.4.

From the results of the binary analysis it is seen that, although each site has its own merits, Tarcoles would be the most suitable site, followed by Pitahaya.

TABLE 6.4
COMPOSITE SITE SCORES AND RELATIVE RANKING

	AIRPORT SITES		
	PITAHAYA	TARCOLES	TOTAL
OPERATIONAL ANALYSIS	12.7	6.3	19
TRANSPORTATION COST	7.9	15.9	24
ACCESS TIME	9.5	19.0	29
CAPITAL COST	9.5	4.8	14
ENVIRONMENT	6.3	3.2	10
FUTURE EXPANSION	3.2	1.6	5
TOTAL SCORE	**49.1**	**50.8**	**100**

Note: Composite site score per criterion = Individual Site Score per Criterion x Criterion Weight / 100

Source: Aviation Planning Services Ltd.

6.3 Sensitivity Analysis

A sensitivity analysis of the Binary Decision Model was conducted in order to test the results from Table 6.4. There are a number of unknown factors in this study, which require a more detailed analysis, and could affect the overall results. In addition, because the criterion weighting will vary according to what one individual may consider important, a number of different tests were developed, which are described below.

6.3.1 Additional Costs at Pitahaya (Sensitivity Test #1)

During the detailed design phase, the costs of the airport will be fine tuned and it may very well be that the capital cost of Pitahaya would increase for the following reasons:

- During the last visit to the site at Pitahaya, it was discovered that the soil is composed of clay and the water table may be close to ground level. More detailed studies would likely reveal that the costs of the airport pavements would be higher.

- Furthermore, some research and/or measures would be required to study the potential of tidal waves and its effects on the proposed airport.

- During the last visit, it was indicated that removal of the sugar mill near the Pitahaya site would cost in the order of $10 Million US.

- If Pitahaya were the selected site, a four lane highway to the airport would be required. The cost of the expansion from two to four lanes would have to be determined in a more detailed study and must include the cost of land reclamation, earthwork and pavement construction.

Based on the above, if one performs a sensitivity analysis to test if Pitahaya was as expensive to build as Tarcoles, the results under column 1 of Table 6.5 would be obtained. It can be seen from the results that the ranking remains unchanged, however the margin in the scoring of Tarcoles over Pitahaya has increased.

6.3.2 Potential Future Economic Impact (Sensitivity Test # 2)

One very important factor which has not been discussed thus far is the relative impact that the selection of either site could have on the current airport in San José. In the case that the airport was constructed at Pitahaya, there would undoubtedly be much more pressure from the local business community to maintain the current airport open, particularly for domestic services and perhaps for intra-regional (Central American) services. In addition, there would also be pressures to maintain cargo operations at SJO. It is obvious that this scenario would not be beneficial to the development of Costa Rica, and particularly the development of the new airport. The overall costs to maintain and operate the two airport systems would be large.

If the new airport were constructed at Tarcoles, then the pressures to maintain the current airport open would not be as strong and perhaps SJO would be reduced in size but be maintained open for General Aviation (GA) and local commuter traffic only. In this case, operations from Tobias Bolaños airport, which is currently a GA airport, and considered a more operationally complex airport, can be transferred to SJO. This scenario would provide for sale of the land at Tobias Bolaños, and SJO, which could be used to draw down the

TABLE 6.5
SENSITIVITY ANALYSIS

	ORIGINAL RANKING		SENSITIVITY TEST NUMBER**											
			1		2		3		4		5		6	
CRITERIA WEIGHTS	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Operational Evaluation	19	3	19	3	18	3	18	3	11	5	21	2	14	4
Future Economic Impact					14	4	14	4	18	3	14	4	7	6
Transportation Cost	24	2	24	2	21	2	21	2	7	6	18	3	21	2
Access Time	29	1	29	1	25	1	25	1	25	1	25	1	25	1
Capital Cost	14	4	14	4	11	5	11	5	21	2	11	5	18	3
Environment	10	5	10	5	7	6	7	6	14	4	7	6	11	5
Expansion Capability	5	6	5	6	4	7	4	7	4	7	4	7	4	7
TOTAL	100		100		100		100		100		100		100	

FINAL SCORES & RANKING	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Pitahaya	49.2	2	46.8	2	46.4	2	44.6	2	46.4	2	45.8	2	45.8	2
Tarcoles	50.8	1	53.2	1	53.6	1	55.4	1	53.6	1	54.2	1	54.2	1
TOTAL	100		100		100		100		100		100		100	

Note: Lowest Rank is most Important or Best.
Source: Aviation Planning Services Ltd.

*Test #1: Considering capital costs equal resulting from possible increase in costs due to soil conditions, sugar mill and roads at Pitahaya.
*Test #2: Additional criteria "Future Economic Impact".
*Test #3: Combination of Test #2 and Test #3.
*Test #4: From an investor's perspective.
*Test #5: From the government's perspective.
*Test #6: From a passenger's perspective.

capital cost of the new airport. If only GA and perhaps domestic traffic is maintained at SJO, then almost half of the land at SJO could be sold, (since the runway length required for GA is considerably less).

Furthermore, it was indicated to the Consultants that Liberia Airport would have a role for future charter operations. As a result, a small portion of the passenger tourist traffic would not be arriving at the new airport. This would have the effect of increasing the importance of time for the business travellers, resulting in increased importance of Tarcoles in relation to Pitahaya.

Based on the above discussion, if an additional criterion, future economic impact, were input to the BDM, then the results under column 2 would be obtained. The results show that, once again, Tarcoles is the more favourable site, but by a greater margin than the base case.

6.3.3 Combination of Sensitivity Test 1 & 2 (Sensitivity Test #3)

A third test was developed by combining the tests produced in the first two scenarios. With the capital costs considered to be equal and the additional criterion included, the results in column 3 of Table 6.5 show that Tarcoles is the more favourable site, by a greater margin than the three other scenarios.

6.3.4 Variation of Criteria Weighting (Sensitivity Test # 4, #5 and #6)

A fourth test was developed from an "investor's perspective". The test was developed using potential future economic impact as a criterion and capital costs considered equal at Pitahaya and Tarcoles. If access time is considered to be the most important criterion, followed by capital cost, future economic impact, environment, operational analysis, transportation cost and expansion capability as the least important, then the results shown in column 4 of Table 6.5 show that Tarcoles is still the preferred site.

Similarly, two additional tests were performed from a government (the MOPT or DGAC may prefer this order of importance) and a passenger perspective. The results of the criterion weighting and final scores are depicted in columns 5 and 6 of Table 6.5, which again shows that Tarcoles is the preferred site.

Assuming that access time is always considered as most important and expansion capability is always least important, then a total of 120 (or 5 factorial) combinations of criterion rankings would be possible with the seven criteria. The results of this analysis show that Tarcoles is the preferred site in 116 of the 120 cases, and Tarcoles is tied with Pitahaya in the remaining four cases. It should be noted, however, that three of the 120 cases were discussed above and presented in columns 4, 5 and 6 of Table 6.5.

6.3.5 Summary

It can be seen, from the above sensitivity tests, that Tarcoles is the most favourable site. To summarize, it can be concluded that reasonable variations in the criteria weighting will not significantly change the overall ranking.

One noteworthy point is that, as access time and ground transportation costs become less important, the standard deviation from the mean overall score becomes smaller and smaller. Pitahaya would be the more favourable site if, for example, access time and ground transportation costs were not considered to be important criteria. Similarly, if environment and operational analysis were considered to be the most important criteria, then Pitahaya would be the preferred site.

7. SITE RECOMMENDATION

Based on the detailed examination and evaluation of each of the potential sites, and the decision analysis from Section 6, the final ranking of the sites in order of merit is as follows:

1) Tarcoles
2) Pitahaya

In summary, Tarcoles is considered the most favourable site since:

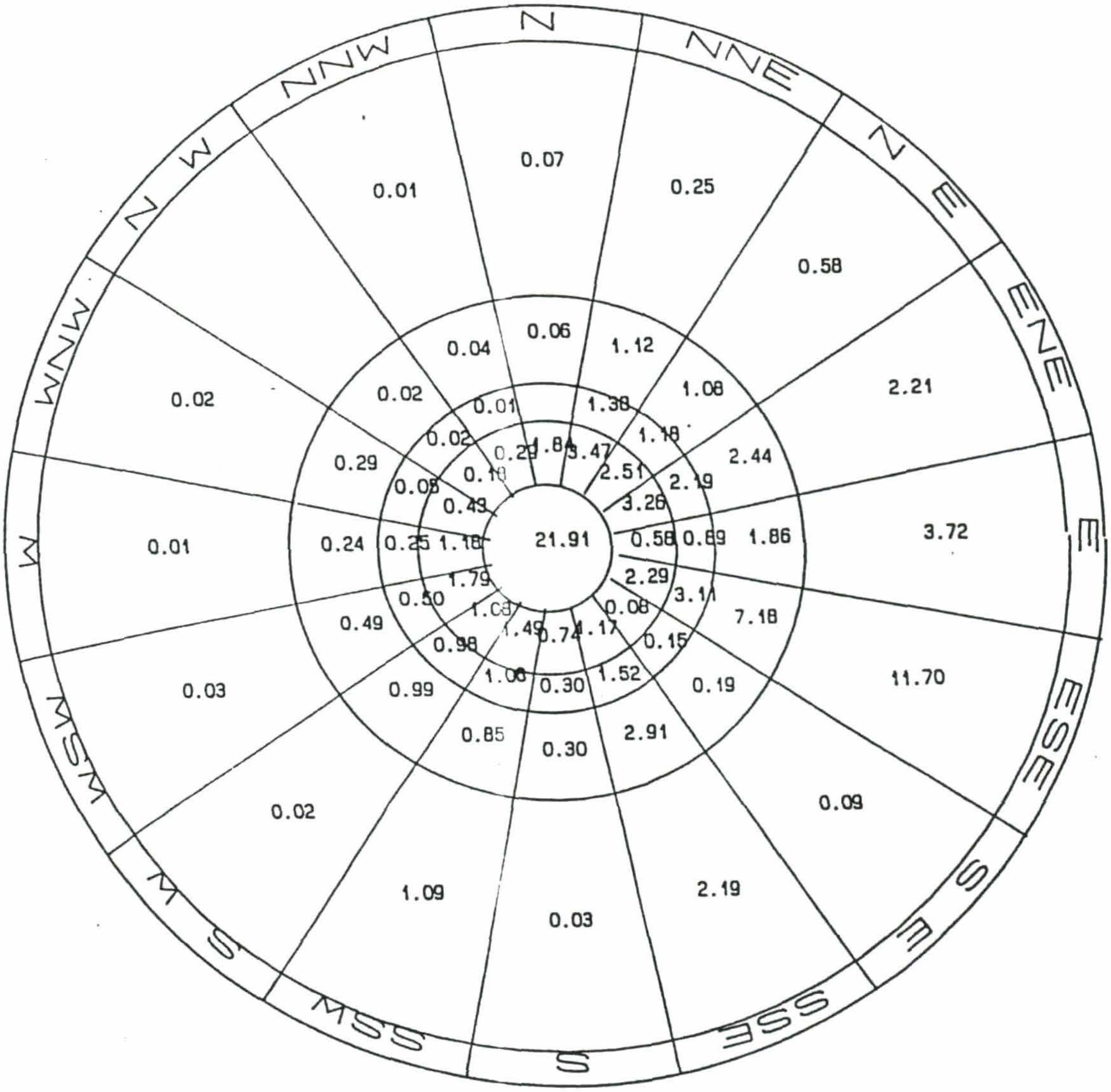
- access time is the shortest; and
- transportation cost is the least.

In addition, more negative impacts to the overall economic community in Costa Rica would result from selection of Pitahaya over Tarcoles.

While Pitahaya has its own merits such as better operational safety and more favourable environmental impact, on an overall basis Tarcoles is the most favourable site.

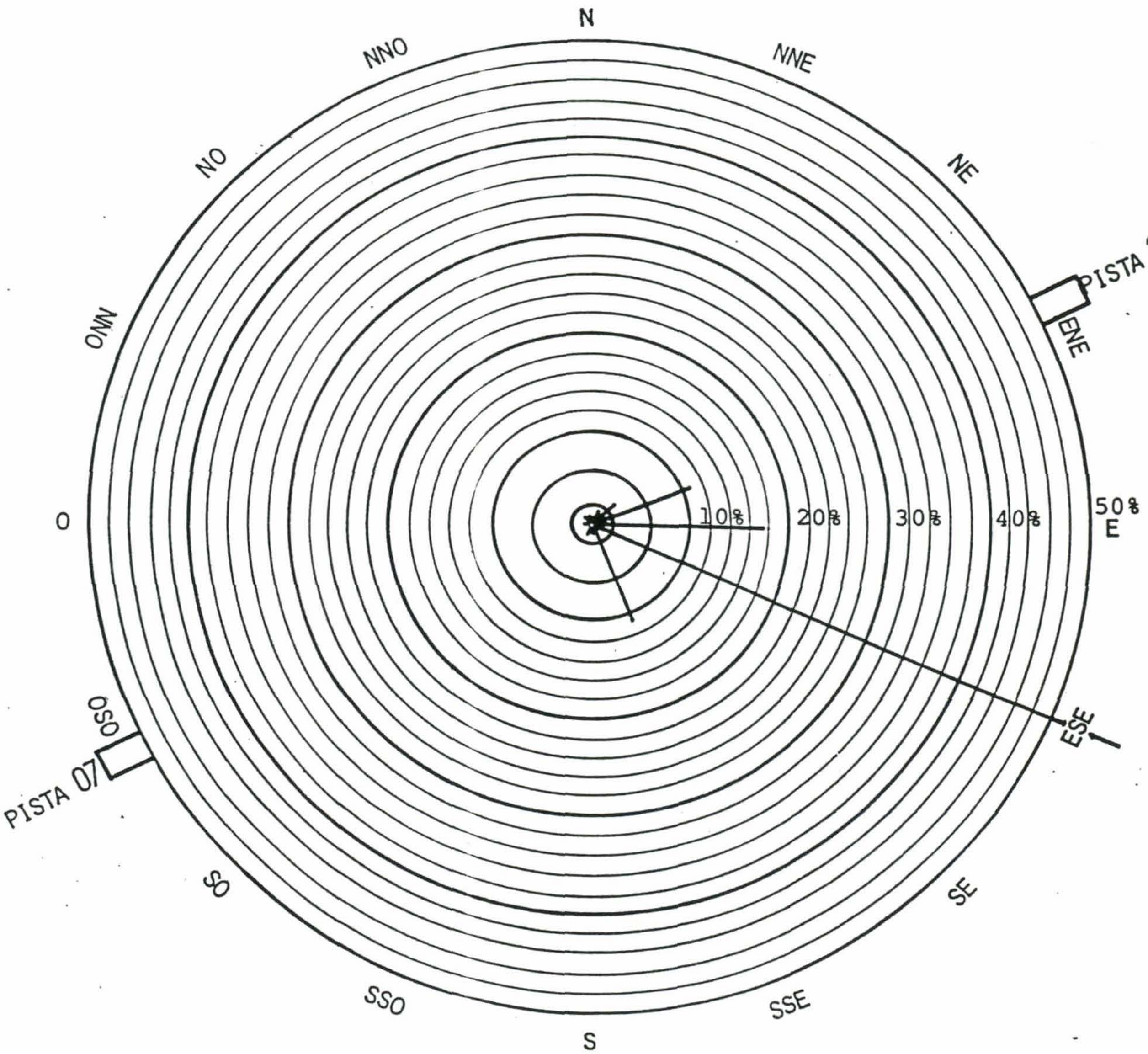
APPENDIX A
METEOROLOGICAL CHARTS

FIGURE A.1



SOURCE	:	Costarica Metorological Bureau
LOCATION	:	Juan Santamaria
PERIOD	:	1986～ 1988
RUNWAY ORIENTATION	:	N 70° E
WIND COVERAGE	:	78.01% (CROSS WIND 13kt)
		90.12% (CROSS WIND 20kt)

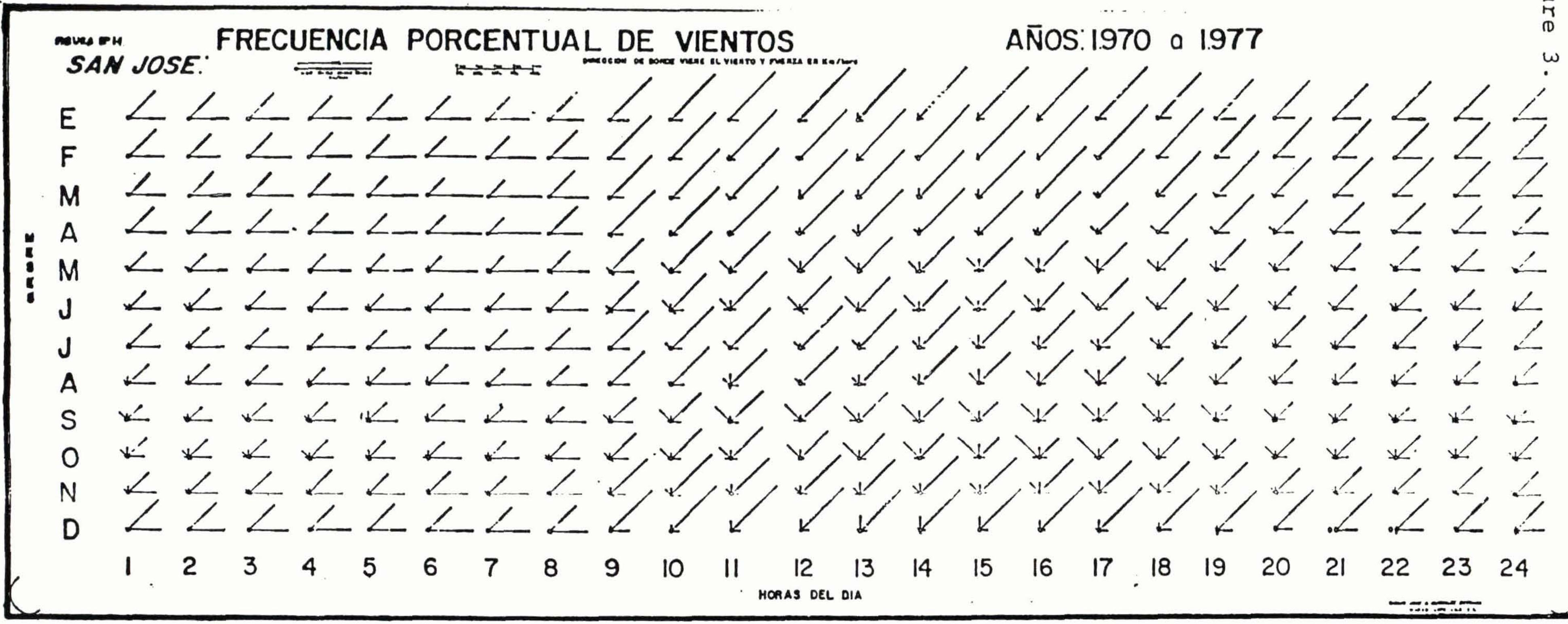
FIGURE A.2



(FRECUENCIAS RELATIVAS)

DISTRIBUCION RELATIVA DE VIENTOS MAYORES DE 37 KM/H (20 NUDOS) DURANTE EL AÑO

Figure 3.



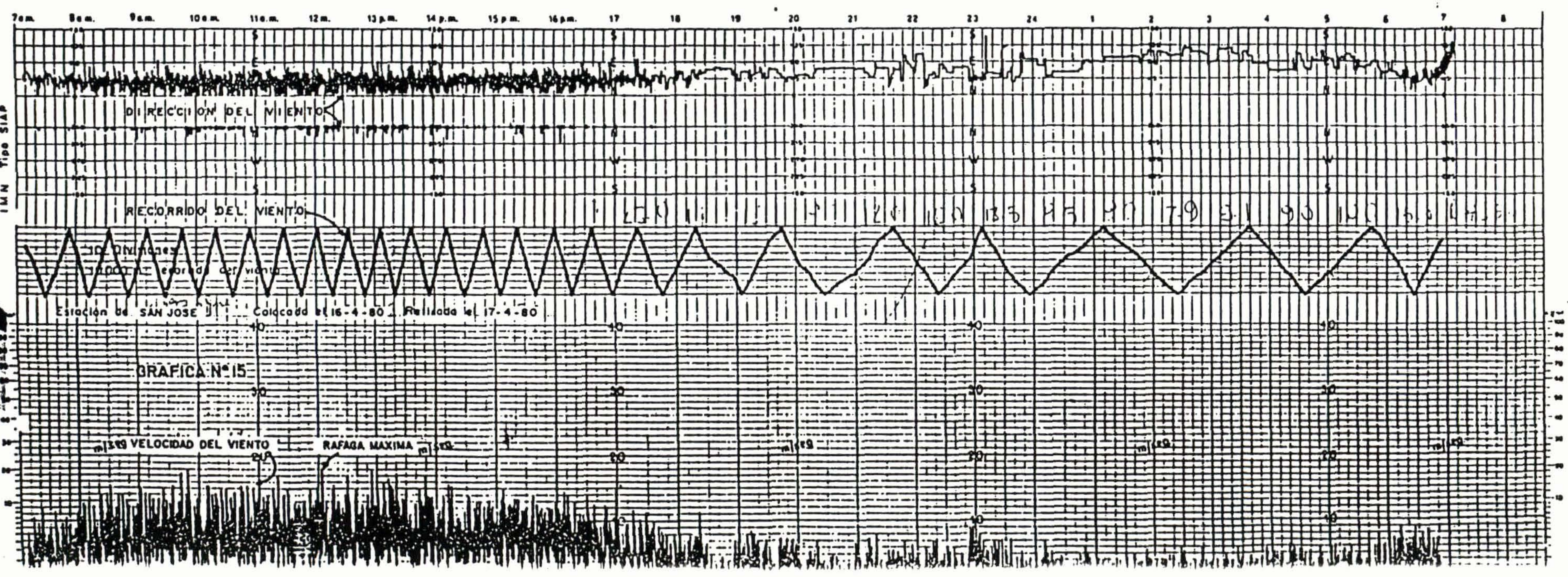


FIGURE A.3

AVIATION PLANNING SERVICES LTD.

Figure 4.

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GRAFICA N° 13

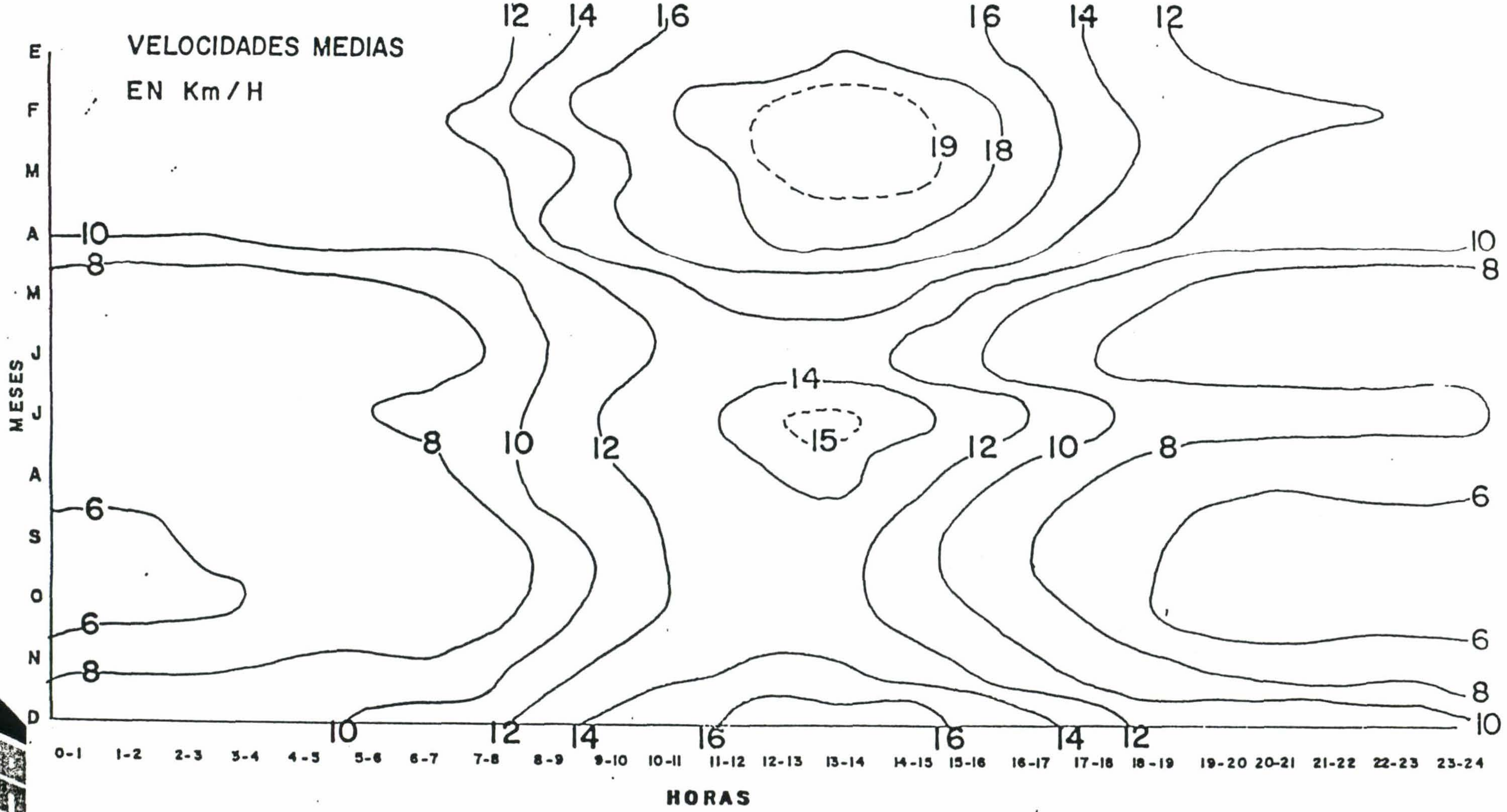

FIGURE A.4

J.A. González E, 1979

FIGURE A.5

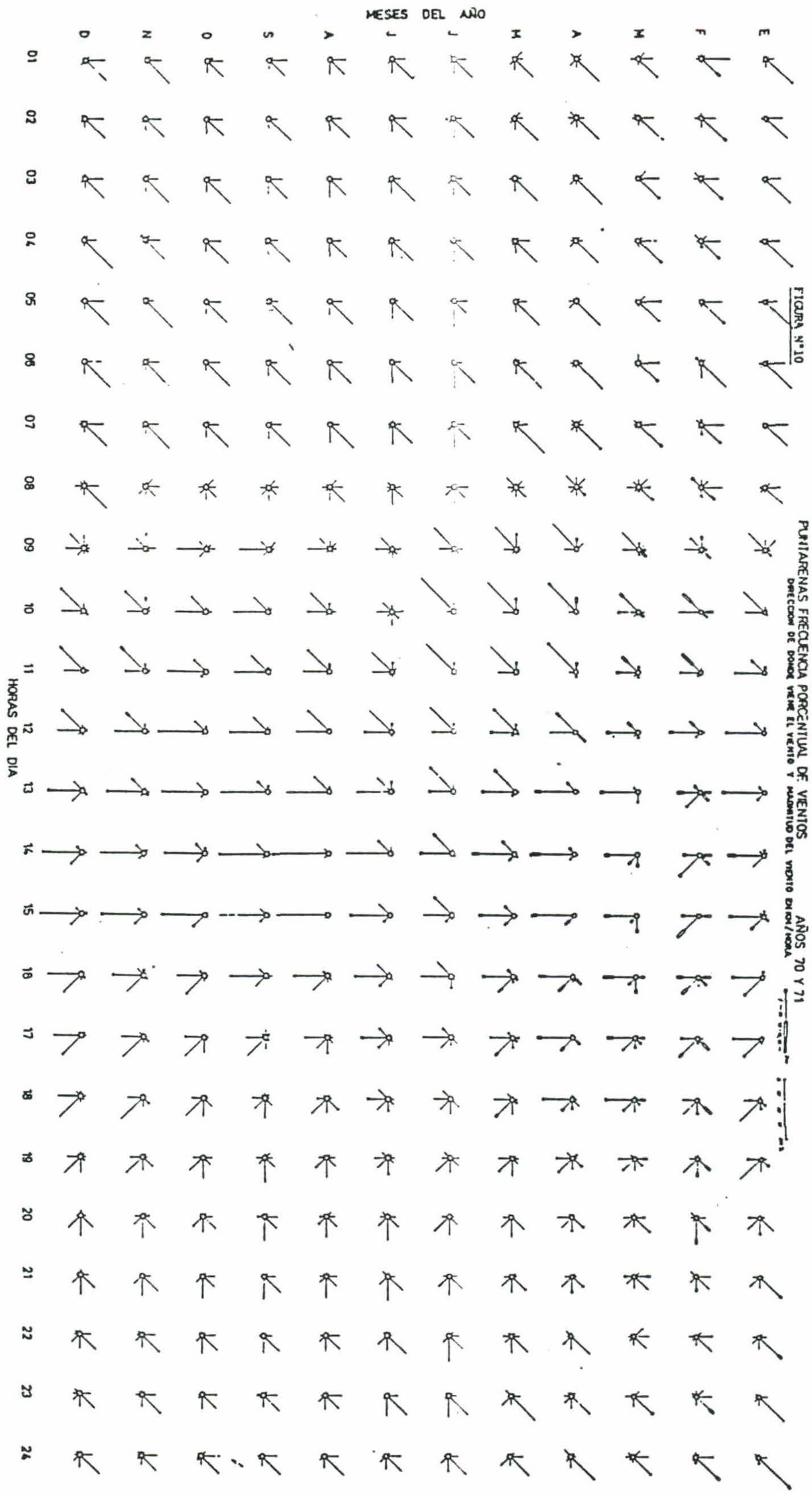
MESES DEL AÑO
D N O S A J J M A M F E
FIGURA N°10
PUNTARENAS FRECUENCIA PORCENTUAL DE VIENTOS
DIRECCION DE DONDE VIENE EL VIENTO Y MAGNITUD DEL VIENTO EN KM/HORA
AÑOS 70 Y 71
HORAS DEL DIA
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

FIGURE A.6

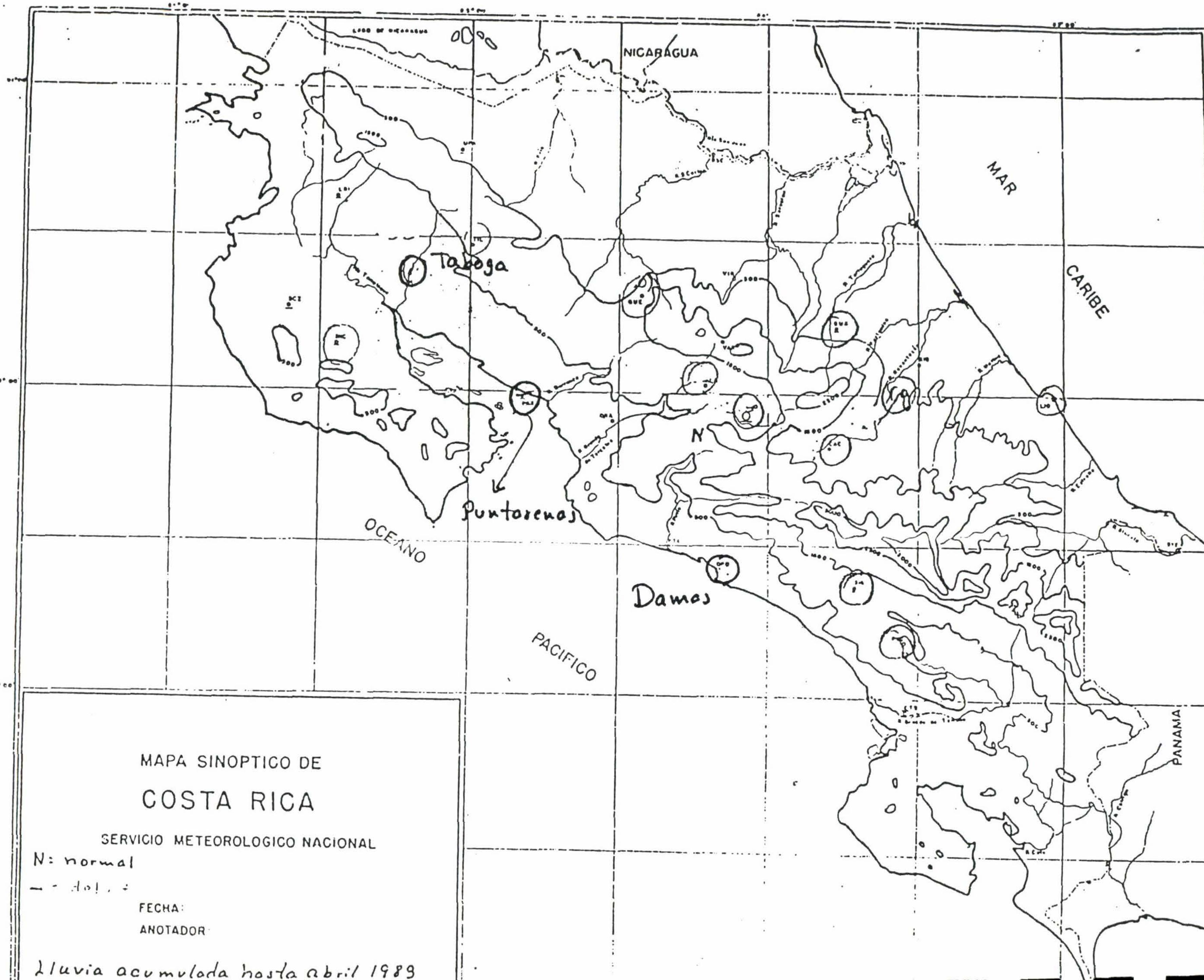

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TABLE A.1

INSTITUTO METEOROLOGICO NACIONAL

VELOCIDAD MEDIA DEL VIENTO (KMS/HORA) Y DIRECCION PREDOMINANTE
INSTRUMENTO A 4 METROS DE ALTURA

ESTACION: COROBICI, CAÑAS　　　No.　　　LAT. 10°26'N.　　　LONG. 85°09' W　ELEV. 128 MTS

AÑO	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC	ANUAL
1983			21.1	21.1	23.4		17.7	16.2	10.5	9.6	10.9	17.2	16.4
			NE	NE	NE		NE	NE	NE	E	E	E	
1984	21.1	22.4	22.7	17.5	14.6	11.1	10.7	10.9	6.6	9.7	10.8	22.3	15.0
	E	E	E	E	E	E	E	E	S	E	NE	NE	
1985	22.7	31.6	31.0	25.0	15.5	12.7	11.5	10.4	9.0	9.0	12.6	16.5	17.5
	NE	NE	E	E	E	E	E	E	E	E	E	E	
1986	26.8	21.1	26.3	26.6	16.6	14.1	20.3	15.0	11.8	8.8	13.7	18.1	18.3
	NE	NE	NE	E	NE	NE	NE	NE	E	E	E	E	
1987	25.3	27.6											
	NE	E											
MEDIA	24.0	25.7	25.3	22.6	17.5	12.6	15.1	13.1	9.5	9.3	12.0	19.0	17.1
D.S.	2.6	4.8	4.4	4.1	4.0	1.5	4.7	2.9	2.2	0.4	1.4	2.3	1.4
D.P.	NE	E,NE	E,NE	E	E,NE	E	E,NE	E,NE	E	E	E	E	E

ESPACIOS EN BLANCO: NO HAY DATOS
D.S. : DESVIACION ESTANDAR
D.P. : DIRECCION PREDOMINANTE

N : NORTE
NE : NORESTE
E : ESTE
SE : SURESTE

S : SUR
SO : SUROESTE
O : OESTE
NO : NOROESTE

TABLE A.2

INSTITUTO METEOROLOGICO NACIONAL

VELOCIDAD MEDIA DEL VIENTO(KMS/HORA) Y DIRECCION PREDOMINANTE

ION: TABOGA   No. 076008   LAT.10°21' N.   LONG.85°09' O.   ELEV. 40 MTS   VELOCIDAD EN KM/H

AÑO	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC	ANUAL
83			14.2	14.3	15.7	7.6	11.9	11.0	7.4	7.7	7.4	12.5	11.0
			NE	NE	NE	VRB	N	N	VRB	VRB	VRB	N	VRB
984	17.8	17.4	15.6	11.4	9.9	8.6	7.8	8.3		7.6	10.1	19.6	12.2
	NE	NE	NE	NE	NE	SE	N	N		N	NE	NE	NE
85	18.8	22.3	20.8	16.4	9.7	8.3	8.6	7.6	6.6	7.1	10.0	14.8	12.6
	NE	NE	NE	NE	N	N	N	N	SE	N	N	NE	N
86	22.1	13.7	20.2	18.5	11.5	9.4		10.0	9.3	7.8	8.2	15.2	13.3
	N	N	NE	N	N	N		N	N	N	N	NE	N
987	19.9	21.8	13.6										18.4
	NE	NE	NE										
88													
MA	78.6	75.2	84.4	60.6	46.8	33.9	28.3	36.9	23.3	30.2	35.7	62.1	67.4
IA	19.7	18.8	16.9	15.2	11.7	8.5	9.4	9.2	7.8	7.6	8.9	15.5	12.4
S.	1.8	4.1	3.4	3.0	2.8	0.7	2.2	1.6	1.4	0.3	1.3	3.0	2.9
P.	NE	NE	NE	NE	N,NE	N	N	N	VRB	N	N	NE	N

S EN BLANCO : NO HAY DATO
: DESVIACION ESTANDAR
: DIRECCION PREDOMINANTE

N : NORTE
NE: NORESTE
E : ESTE
SE: SURESTE
S : SUR

SO: SUROESTE
O : OESTE
NO: NOROESTE
VRB:VARIABLE

TABLE A.3

INSTITUTO METEOROLOGICO NACIONAL

VELOCIDAD MEDIA DEL VIENTO(KMS/HORA) Y DIRECCION PREDOMINANTE

CION: DAMAS No. 090009 LAT.09°30' N. LONG.84°13' O. ELEV. 6 MTS VELOCIDAD EN KM/H

AÑO	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC	ANUAL
1983							3.7	3.9	4.0	3.8	3.6	3.0	3.7
							E	E	E	E	E	E	E
1984	4.2	4.7	4.7	4.8	2.8	2.8	2.9	2.9	2.7	2.9	2.6	2.7	3.4
	S	E	S	S	S	S	S	S	S	S	S	S	S
1985	2.7	3.0	3.3	3.5	3.3	3.0	3.0	3.1	3.0	3.2	3.1	2.6	3.1
	S	S	S	SO	S	S	S	S	S	S	S	S	S
1986	2.7	2.8	3.1	3.4	3.4	3.0	2.7	2.6	4.7	4.9	4.6	4.5	3.5
	E	E	E	E	S	E		E		S	E	NE	E
SUMA	9.6	10.5	11.1	11.7	9.5	8.8	12.3	12.5	14.4	14.8	13.9	12.8	13.7
EDIA	3.2	3.5	3.7	3.9	3.2	2.9	3.1	3.1	3.6	3.7	3.5	3.2	3.4
D.S.	0.9	1.0	0.9	0.8	0.3	0.1	0.4	0.6	0.9	0.9	0.9	0.9	0.3
D.P.	S	E	S	VRB	S	S	S	VRB	S	S	VRB	S	S

IOS EN BLANCO : NO HAY DATO
. : DESVIACION ESTANDAR
. : DIRECCION PREDOMINANTE

N : NORTE
NE: NORESTE
E : ESTE
SE: SURESTE
S : SUR

SO: SUROESTE
O : OESTE
NO: NOROESTE
VRB:VARIABLE

Un alto porcentaje de los casos de esta Serie el viento es calmo.

APPENDIX B
BINARY DECISION MODEL ANALYSIS

BINARY DECISION MODEL

The application of the model involves the following steps:

Step 1: Identify the Important "Decision Criteria" or "Decision Variables"

This involves simply enumerating the factors, both quantitative and qualitative, which should be considered in selecting a site from the perspective of a decision maker faced with a major capital expenditure. An effort is made to keep this list as short as possible without excluding any important variables, and to minimize the "double-counting" or duplication of variables. In other words, the criteria selected must be mutually exclusive and collectively exhaustive.

Step 2: Weighting the Decision Criteria

Having identified the major decision criteria, it is necessary to attach relative weights to each criterion, as they are not all equally important to the selection process. APS' binary decision analysis technique was used to establish the relative weights of the decision criteria.

The technique requires examining every possible pair of criteria, deciding which of the two criteria is the most important, and then assigning a 1 to the most important and 0 to the less important criterion. After every pair is evaluated the number of 1's received by each criterion is calculated to produce a "raw" total score. The highest scoring criterion is the most important. A simple mathematical transformation[2] is then performed to convert the raw scores into percentage weights or scores. A relative ranking can be assigned based on the percentage scores.

---

[2] Unity is first added to every raw score to ensure no zero scores are present and then each score is converted into a percentage figure.

Step 3: Evaluating Sites Using the Decision Criteria

This step involves an assessment of each site, to establish a ranking on the basis of ability to satisfy the criterion being considered. Again a binary decision analysis process is used. It involves examining the sites in pairs, deciding which of the two sites best meets the criterion being considered, and then assigning a 1 to the preferred site, and 0 to the less desirable site. After every pair of sites has been systematically analyzed in this manner, a total is computed. The site with the highest score on a particular criterion is considered the best in fulfilling the demands of that criterion.

Step 4: Applying the Criterion Weights to the Evaluation Scores to Produce a Final Weighted Score for each Site

In the previous step each site was evaluated on the basis of its ability to satisfy the criterion being considered without regard for the relative importance or weight of the criterion. In the unweighted form, each criterion has equal value. Therefore, it is now necessary to weigh each site's score by the applicable criterion weight, so that the relative importance of each criterion can be incorporated. This is accomplished by multiplying the relative weights assigned to each of the criterion, by the scores assigned to the sites for each criterion. This process produces a weighted score of each site for each criterion considered. The total weighted score for each site is calculated by adding up the criteria weighted scores associated with a particular site, and normalizing to unity.

It should be noted that the use of the binary decision analysis technique in this application requires such a large number of individual decisions to be made that any subjective biasing of the results by the analysis is highly improbable.

	criteria	weight	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total
	0	0	1	3	2	6	17	50	33	100	0.0	0.0	0.0	0
cost	4	40	3	1	2	6	50	17	33	100	20.0	6.7	13.3	40
safety	3	30	1	3	2	6	17	50	33	100	5.0	15.0	10.0	30
environ	2	20	2	3	1	6	33	50	17	100	6.7	10.0	3.3	20
	0	0	1	3	2	6	17	50	33	100	0.0	0.0	0.0	0
expansion	1	10	2	3	1	6	33	50	17	100	3.3	5.0	1.7	10
	10	100									35.0	36.7	28.3	100

	criteria	weight	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total
cap cst	5	24	1	3	2	6	17	50	33	100	4.0	11.9	7.9	24
access cst	6	29	3	1	2	6	50	17	33	100	14.3	4.8	9.5	29
safety	4	19	1	3	2	6	17	50	33	100	3.2	9.5	6.3	19
environ	3	14	2	3	1	6	33	50	17	100	4.8	7.1	2.4	14
displace	1	5	1	3	2	6	17	50	33	100	0.8	2.4	1.6	5
expansion	2	10	2	3	1	6	33	50	17	100	3.2	4.8	1.6	10
	21	100									30.2	40.5	29.4	100

	criteria	weight	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total
cap cst	5	24	1	3	2	6	17	50	33	100	4.0	11.9	7.9	24
access cst	6	29	3	1	2	6	50	17	33	100	14.3	4.8	9.5	29
safety	4	19	1	3	2	6	17	50	33	100	3.2	9.5	6.3	19
environ	3	14	2	3	1	6	33	50	17	100	4.8	7.1	2.4	14
capacity	1	5	3	1.5	1.5	6	50	25	25	100	2.4	1.2	1.2	5
expansion	2	10	2	3	1	6	33	50	17	100	3.2	4.8	1.6	10
	21	100									31.7	39.3	29.0	100

	criteria	weight	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total
	0	0	1	3	2	6	17	50	33	100	0.0	0.0	0.0	0
cost	5	33	3	1	2	6	50	17	33	100	16.7	5.6	11.1	33
safety	4	27	1	3	2	6	17	50	33	100	4.4	13.3	8.9	27
environ	3	20	2	3	1	6	33	50	17	100	6.7	10.0	3.3	20
capacity	1	7	3	1.5	1.5	6	50	25	25	100	3.3	1.7	1.7	7
expansion	2	13	2	3	1	6	33	50	17	100	4.4	6.7	2.2	13
	15	100									35.6	37.2	27.2	100

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	criteria	weight	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total	orotina	pitahaya	tarcoles	total
time value	4	19	3	1	2	6	50	17	33	100	9.5	3.2	6.3	19
cost	6	29	3	1	2	6	50	17	33	100	14.3	4.8	9.5	29
safety	5	24	1	3	2	6	17	50	33	100	4.0	11.9	7.9	24
environ	3	14	2	3	1	6	33	50	17	100	4.8	7.1	2.4	14
capacity	1	5	3	1.5	1.5	6	50	25	25	100	2.4	1.2	1.2	5
expansion	2	10	2	3	1	6	33	50	17	100	3.2	4.8	1.6	10
	21	100									38.1	32.9	29.0	100