Environmental Research and Consultancy Department

R&D REPORT 9823

Assessment of Revised Heathrow Early Mornings Approach Procedures Trial

R E Cadoux
S White
J B Critchley*

* ANRAR Ltd

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Environmental Research and Consultancy Department, Directorate of Airspace Policy, Civil Aviation Authority, CAA House, 45-59 Kingsway, London, WC2B 6TE.

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ASSESSMENT OF REVISED HEATHROW EARLY MORNINGS APPROACH PROCEDURES TRIAL

R E Cadoux
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Prepared on behalf of the Department of the Environment, Transport and the Regions by
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R E Cadoux
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SUMMARY

This report describes a study (using primarily the Heathrow Noise and Track-Keeping (NTK) system) to assess the changes in aircraft operation and noise impact arising from a trial revision of Heathrow early mornings landings procedures, which was initiated in September 1995 for westerly approaches. The study found that there was a high degree of compliance with the trial procedure, and that overall the environmental benefits were positive. Between 0400 and 0600, there was a reduction in noise exposure in the area between 9 nm and 17 nm from touchdown of up to 1.5 dBA SEL, as a direct result of the revised procedure. Some additional noise increases and reductions, of up to about 2 dBA SEL, were caused by ground track changes, resulting from the tendency for aircraft to join the localizer further out under the trial procedure; the increases occurred in small localised areas and from very low base levels.

The opportunity was taken to consider whether the trial might have affected the rate of achievement of Continuous Descent Approaches (CDA), which influences noise at greater distances from the airport. None was observed; moreover there appeared to be little change since CDA was first implemented in the 1970s. Additionally, two quite separate trials of night-time runway alternation took place during the period of the early morning procedures trial: the alternation pattern did not appear to have had a significant impact on vertical profiles, but it produced marked changes of noise exposure due to displacement of some approach paths from runway 27L to 27R.

Prepared on behalf of the Department of the Environment, Transport and the Regions
by National Air Traffic Services Ltd London November 1998

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APPENDICES:

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GLOSSARY

AIP	Aeronautical Information Publication; colloquially known as the 'Air Pilot'.
ARP	Aerodrome Reference Point (a fixed point on the aerodrome, defined in the AIP).
CDA	Continuous Descent Approach.
Chapter 2	Classification of aircraft certification levels as defined in ICAO Annex 16. Chapter 2 types are characterised by the noisier low by-pass turbojet aircraft and early high by-pass turbofan aircraft.
Chapter 3	Classification of aircraft certification levels as defined in ICAO Annex 16. Chapter 3 types are characterised by the more modern, quieter, high by-pass turbofan aircraft.
dB	Decibel, a unit used for quantifying sound level, calculated as 10 times the logarithm (base 10) of a sound energy ratio. It is used in this report to define differences measured on the dBA scale.
dBA	dBA is used to denote levels of noise measured on a decibel scale using a frequency weighting that approximates the characteristics of human hearing. These are referred to as A-weighted sound levels; they are widely used for noise assessment purposes.
ILS	Instrument Landing System.
Initial approach	The segment of an instrument approach procedure between the Terminal holding fix and the 'intermediate fix'. In the initial approach, the aircraft has departed the en-route structure and is manoeuvring to enter the intermediate approach segment.
Intermediate approach	During this segment of the approach, which commences at the 'intermediate fix' (typically the point where the ILS is joined at 3000 or 4000 ft), the aircraft speed and configuration are adjusted to prepare for final approach. For this reason the descent gradient is kept as shallow as possible. Note that the intermediate approach track or radar vector is designed to place the aircraft on the localizer at a height that is below the nominal glidepath.

LATCC	London Area and Terminal Control Centre (located at West Drayton).
L_{eq}	The Equivalent Continuous Sound Level (L_{eq}) is the level of a notional steady sound which at a given position and over a defined period of time would have the same A-weighted acoustic energy as the fluctuating noise. L_{eq} (16-hr) for the 16-hour period 0700 - 2300 hours (Local Time) is used as the UK index of exposure to aircraft noise, but L_{eq} values for other periods of the day can be used. For example L_{eq} (2-hr) is defined for this study for the period 0400-0600, as it was appropriate to assess changes in noise exposure only during the period affected by the early mornings landings trial. However it should be noted that, unlike L_{eq} (16-hr), L_{eq} (2-hr) has not been related to annoyance or disturbance through social survey studies.
Nautical Mile (nm)	6080 ft (i.e. 1.15 statute miles, or 1.85 km).
NTK	Noise and Track Keeping monitoring system; this is a system that integrates noise data from a number of microphones, the airport's Flight Information System, and the NATS SSR and flight identification.
SEL	The single event Sound Exposure Level is the noise level in dBA which, if maintained for a period of one second, would cause the same A-weighted sound energy to be received as is actually received from a given noise event.
SSR	Secondary Surveillance Radar. This system enables aircraft position, altitude and speed to be estimated.
STAR	Standard Arrival Route (defined in the AIP).
TC	Terminal Control (ATC).
Touchdown	In practice, the touchdown position varies from flight to flight. In this report, touchdown is taken to be that point on the runway from where the ILS glideslope signal appears to originate (approximately 1000 ft beyond the runway threshold).

1 INTRODUCTION

1.1 This report describes a study carried out to assess the changes in aircraft operation and noise impact arising from a trial revision of Heathrow early mornings landings procedures, which involved an increase in the minimum altitude to which aircraft are allowed to descend before joining the glideslope on westerly approaches. The source of data for this work was primarily the Heathrow Noise and Track-Keeping monitoring system (NTK).

1.2 Revised procedures for aircraft approaching Heathrow from the east[1] were introduced on a trial basis on 4 September 1995, following discussions between the Department of Transport, now the Department of the Environment, Transport and the Regions (DETR), BAA plc and NATS (Ref 1). The trial procedure applies between 0400 and 0600[2] and the trial, which continues at the time of writing, is known as the 'early mornings landings trial'. The aim of the trial is to help alleviate noise over parts of central London in the early morning. The NATS Environmental Studies Section was asked by the DETR to monitor the trial.

1.3 The trial procedures require aircraft approaching from the east not to descend below 3000 ft before joining the Instrument Landing System (ILS) glideslope at not less than 10 nm from touchdown. At the time of introduction, identical procedures had been in force from 2300 to 0700 for easterly approaches. Previously the minimum altitude for westerly approaches before joining the glideslope was 2500 ft. As this occurred at about 8 nm from touchdown, the expected consequence of the revision was to reduce noise on the ground before that point because of the increased height of aircraft: at the same power setting, noise levels under the flight path are lower for level flight at 3000 ft than for level flight at 2500 ft. DETR have referred to this as a 'benefit in terms of height-keeping'. The main effect of the trial therefore was to replace about 1.6 nm of level flight (at around 8-10 nm from touchdown) by descending flight. For some arrivals (not flying Continuous Descent Approaches and with a level segment at 2500 ft), the revision would be expected to reduce the noise on the ground in this region.

1.4 The benefit of the revision in noise terms would arise only for those aircraft not already intercepting at altitudes of 3000 ft or more. As aircraft affected by the trial procedure would have to be turned on to the ILS earlier (typically 1 nm to 2 nm further from the airport than previously), some areas to the side of the extended runway centreline between 8 and 10 nm from touchdown would experience fewer overflights during the trial periods. Equally, some areas further away from Heathrow might experience a small increase in overflights

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[1] i.e. 'westerly' approaches to runways 27L and 27R.

[2] All times in this report are local, i.e. during summer time they refer to British Summer Time, BST.

although at greater heights (some might occur where previously there had been none).

1.5 Most of the present night-time traffic at Heathrow consists of heavier, long-range aircraft arriving at the airport from about 0430, hence the trial procedures were aimed at mitigating noise between 0400 and 0600, the end of the night quota period. NATS however decided to apply the trial procedures throughout the period 2300 to 0600 for ease of air traffic operations.

1.6 At the outset of the study, the principal area of interest was between about 7 nm and 11 nm from touchdown, as this is where the effects of the revised approach procedure were expected to be most noticeable, and appropriate data were available within NTK at that time. Subsequently, in response to local concerns, the scope of the study was extended by DETR to consider flight paths much further out (as far as 20 nm from touchdown, which includes places such as Blackheath and Greenwich). Use of Continuous Descent Approach (CDA) has long been established as an important means for mitigating approach noise in these more distant areas, by aiming to minimise the use of long level-flight segments during the approach. Although the trial procedure instructions included no variations in the application of CDA, the DETR requested that the opportunity be taken to undertake some monitoring of the achievement of CDA procedures.

1.7 After the commencement of the early mornings landings trial, trials of an unrelated night-time runway alternation scheme were conducted by HAL and ATC. The impact of such a scheme on the trial is briefly discussed in this report.

1.8 The NTK system can only determine the descent profile actually flown by each aircraft. It was beyond the scope of this study to attempt to analyse the instructions or information given to pilots by ATC, although these of course have a profound effect on the ground tracks followed (and to a lesser extent the vertical profiles).

1.9 As changes in the ILS intercept positions led to some changes in the ground tracks followed during the initial approach, an important part of the study was to compare distributions of ground tracks before and after the early mornings landings trial procedure was implemented.

1.10 Because the procedural change affects the height, power settings and positions of arriving aircraft, which in turn affect the levels and numbers of noise events experienced at particular locations, the overall noise impact can be best assessed using noise exposure contours; these account for all such changes.

1.11 This report is structured as follows:

- Section 2 describes approach procedures in general, as well as (a) the early mornings landings trial and (b) CDA procedures.
- Section 3 briefly describes the sources of data and the analysis tools used in the study.
- Section 4 examines compliance with the trial procedure.
- Section 5 presents the results of specific analyses to compare general aspects of aircraft on approach before and during the trial.
- Section 6 presents the results of the analysis of the achievement of CDA.
- Section 7 is an assessment of the noise impact of the early mornings landings trial, and the noise benefits of CDA procedures.
- Section 8 presents conclusions of the study.
- Section 9 cites the references used in this report.
- Appendix A presents the rationale behind the use of a 200 ft height-keeping tolerance, the ILS glideslope tolerance and the localizer lateral tolerance in assessing compliance with the early mornings landings trial.
- Appendix B contains the definition of the CDA procedure.
- Appendix C describes how approaches have been categorised, in terms of CDA achievement, using the NTK system.
- Appendix D presents tables of the mean heights of aircraft on approach to allow comparison between summer and winter seasons.
- Appendix E presents tables of the mean heights of aircraft on approach to allow comparison between nominal 'daytime' (0600 to 2300) and 'night-time' (2300 to 0600) periods[3].

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[3] Note that these periods are not the same as used in other contexts; a division at 0600 was most appropriate in the context of this study, as the westerly early mornings landings trial procedure ran to 0600. For night restrictions purposes the night quota period is 2330 to 0600, although controls also apply during the night period of 2300-0700. The standard daytime contours cover the period 0700-2300.

2 ATC PROCEDURES BACKGROUND

2.1 This section gives a general overview of the procedures used by ATC for approaches to Heathrow. It includes a description of the early mornings landings trial procedure, and of the separate Continuous Descent Approach procedure which applies throughout the day and night.

General arrival procedures

2.2 Arriving aircraft follow Standard Arrival Routes (STARs) which end at positions termed holding fixes (Ref 2). The holding fixes are usually radio beacons that define a holding facility, frequently termed a 'stack' or 'hold', within which vertically separated aircraft fly standard 'race-track' patterns before being positioned in the sequence of approaches to the airport. It is normal practice for four holds to be used at Heathrow - these are shown schematically in Figure 1, and are known as Bovingdon, Lambourne, Ockham and Biggin. In light traffic, aircraft may not be held.

2.3 After leaving the hold, typically at an altitude of around 7000 ft, aircraft proceed under instructions from Terminal Control (TC, located at LATCC) on a path to intercept the runway extended centreline, which is identified by the localizer signal from the Instrument Landing System (ILS); this stage is termed 'initial approach' (see Glossary). During the initial approach, the aircraft descend to an intermediate altitude, normally 3000 ft or 4000 ft. Figure 2(a) shows a selection of approach ground tracks monitored between 0500 and 0600. The next stage, from the intermediate altitude to the glideslope intercept, is termed the 'intermediate approach'. The direction from which the aircraft approaches the extended runway centreline to pick up the localizer signal is termed the 'closing heading'; this has to be such that the final approach becomes stable well before touchdown. The angle between this heading and the localizer generally does not exceed 30°, but on occasions, especially during busier periods, angles up to 40° were observed for aircraft joining the localizer at furthest points from the runway [4].

2.4 At some point after reaching the extended runway centreline, aircraft intercept the glideslope signal from the ILS which defines a fixed descent angle - in the case of Heathrow nominally 3°, the international norm. This interception is normally made from below by flying level for a short distance; thereafter the aircraft is stabilised on the glidepath. Typically the ILS glideslope intercept is at 8 nm to 10 nm from touchdown, corresponding to altitudes of 2500 ft to 3000 ft. It is during this phase of flight that ATC communication is handed over from TC to Heathrow Approach Control for the 'final approach'.

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[4] There is an ICAO PANS-OPS requirement that the intermediate track shall not differ from the final approach track by more than 30°.

2.5 The noise below the aircraft depends on the engine thrust or power settings; these in turn depend on aircraft speed, rate of descent and flight configuration, i.e. the undercarriage and flap positions. As a general rule, for a given speed and configuration, the noise is less during descent than in level flight, simply because less power is required (in a 'clean' configuration, normal during initial and, sometimes, intermediate approach, descent is effectively a glide at minimal power). But it is important to note that level flight too might be relatively quiet if the aircraft is losing speed; indeed, short segments of level flight are sometimes used deliberately to reduce speed during an approach. There are many factors which affect the precise way in which an aircraft performs its approach; these are being investigated in another study by the Arrivals Working Group of the DETR's Aircraft Noise Monitoring Advisory Committee (ANMAC).

The early mornings landings trial procedure

2.6 The early mornings landings trial procedure is implemented by Terminal Control (TC) through the following instruction in the Manual of Air Traffic Services (Ref 3):

"Between 2300 and 0700 (local) in respect of 09L/09R and between 2300 and 0600 (local) in respect of 27L/27R/23, inbound aircraft, irrespective of weight or type of approach, are to be vectored onto a closing heading which will position aircraft to intercept the extended runway centreline no closer than 10 nm from touchdown. Descent clearance below an altitude of 3000 ft is not to be given until the aircraft is 10 nm from touchdown."

2.7 Ref 3 also states that after 0600 on westerly approaches and 0700 on easterly approaches *"aircraft are not to be cleared for descent below 3000 ft until within 11 nm track distance*[5] *from touchdown, below 2500 ft until within 9 nm or below 2000 ft until 7 nm; except when established on the ILS glideslope".*

2.8 The trial procedure requires that aircraft descend on the ILS glidepath from 3000 ft whilst aligned with the ILS localizer. Previously this altitude was 2500 ft. These altitudes on the glidepath correspond approximately to distances from touchdown of 10 nm and 8 nm respectively. Thus, comparing trial and pre-trial approaches that involve level intercepts - assuming the level segments remain unchanged except for height - noise below the trial aircraft would be lower because of (i) greater height and/or (ii) lower thrust. These benefits would occur under the changed part of the flight path between 8 nm and somewhere beyond 10 nm; differences earlier in the approach would depend on how the intermediate descent was managed - for example, immediately after the

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[5] Unless stated otherwise, all "track distances" hereafter refer to the distance from touchdown measured along the ground track.

start of a 3000 ft level segment, noise would be higher than if the aircraft had continued descending to 2500 ft. The geographic region between 8 nm and 10 nm from touchdown would also be affected by changes to the way in which aircraft close on the localizer. Because some affected aircraft will join the localizer earlier, people close to the extended runway centreline will experience more overflights; those to the side will experience less. Of course, the region beyond 10 nm would also benefit from the greater minimum height of those aircraft which descend unusually early. Below 2500 ft all aircraft should be established on the ILS, and there should be no changes as a result of the trial.

2.9 Although the principal area of interest for this study was between about 7 nm and 11 nm from touchdown, where the effects of the revised procedure were expected to be most noticeable, some consideration has also been given to effects at much greater distances (out to about 20 nm from touchdown). At such distances the use (or non-use) of CDA procedures is a major factor in determining the descent profiles.

CDA procedures

2.10 Following clearance to descend from the hold, a variety of descent profiles is possible for the initial approach. CDA is the optimum profile in noise terms and, for this reason, Heathrow procedures (Ref 2) require that descents are continuous whenever practicable. But, compared with other descent techniques, CDA requires more attention from both ATC and aircrew so its achievement depends on traffic situation and workloads. To achieve full CDA, the aircraft must adhere to a 3° descent over a particular track distance to touchdown. Generally ATC gives initial descent clearances which enable CDA assuming there is sufficient distance to descend at an angle of about 3°. However ATC often have to revise a clearance to maintain safe separation from other aircraft; this changes the track distance to touchdown so that it may not then be possible to maintain a CDA profile. In some situations, aircrews do not always manage their descent to follow a CDA profile.

2.11 Figure 2(b)[6] shows the descent profiles corresponding to the ground tracks in Figure 2(a). The height above airport elevation is plotted against the track distance, measured from touchdown. The flight highlighted in Figures 2(a) and (b) is an example of a flight which did not achieve CDA - there were level segments at 9000 ft (before commencement of the initial approach), 5000 ft and 4000 ft. This may be compared with an example of CDA highlighted in Figures 3(a) and (b).

2.12 Studies of CDA and 'Low Power/Low Drag' noise abatement procedures at

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[6] Note that in Figures 2(b) and 3(b) the vertical scale is not the same as the horizontal scale - i.e. aircraft height is exaggerated.

Heathrow were carried out by DORA[7] in the 1970s (Refs 4 and 5). It was found that 54% of flights analysed used the CDA procedure. Relative to level flight at a constant 3000 ft, the noise benefits of CDA (between 9 nm and 15 nm from touchdown) were estimated to be between 4 dBA and 9 dBA L_{Amax}. However, the noise characteristics of modern aircraft are markedly different and it could not be assumed that such figures would apply today.

Tactical flexibility in arrival procedures

2.13 Heathrow TC has to manage approaches from the four different holds whilst maintaining stringent standards of safety and maximum practicable runway capacity. The sequence of arrivals is subject to a minimum permissible separation distance between aircraft. However, factors such as the speed profile, the times of leaving the different holds and the distances to touchdown vary. TC accommodate these variations chiefly by 'path stretching' - a deliberate introduction of track detours.

2.14 TC aims to keep such detours to a minimum, but tactical flexibility is essential in order to maintain safe traffic flow at the required capacity. Typically these detours take the form of semi-circular loops joining straight track segments of opposite direction, usually parallel to the runway heading. The lengths of the segments can be varied, giving rise to the term 'trombone manoeuvres'. Frequently two such manoeuvres are used - see for example the tracks of the two aircraft arriving from Lambourne shown in Figure 3(a), compared with those arriving via Bovingdon.

2.15 Sometimes, after issuing the original clearance, adjustments to the speed, heading or cleared altitude are necessary, which may result in an aircraft flying level instead of continuing with a CDA, depending on the type of adjustment and on the capabilities of the aircraft. The need for adjustments increases with traffic intensity. Typical approach tracks during a busy period, 0800-0900, are shown in Figure 4, which may be compared with those of a less busy period, 0500-0600, shown in Figure 3(a). Figure 5 shows the positions of several aircraft at a particular time (0814 hours), together with their tracks for a short time earlier. This figure illustrates how path variations have to be used to achieve a uniformly spaced stream of arrivals to the runway.

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[7] Department of Operational Research and Analysis, NATS.

3 DATA SOURCES

3.1 Data were obtained principally from the Heathrow Noise and Track Keeping monitoring system (NTK). The NTK integrates data from several sources:

- ten fixed noise monitors;
- mobile noise monitors;
- SSR and flight identification data via LATCC;
- the airport Flight Information System;
- BUCHair registry database to determine full aircraft type information;
- weather sensors at some of the fixed monitor locations.

3.2 Initial processing of the above data is carried out by the airport Noise Unit; it is then transferred to NATS' NTK workstation for detailed analysis by DORAstaff. It should be noted that all radar positional data are subject to tolerances; limits on the accuracy of the NTK height and track data are discussed in Appendix A.

3.3 For this study, each aircraft movement was allocated a time marker. For the purposes of conforming with the trial requirements, ATC identify the time of leaving the hold. This cannot be obtained from NTK directly, so for this study each aircraft movement was timed as it first entered the NTK radar coverage area (a rectangular area extending 42 nm east to west, and 30 nm north to south, centred on the Aerodrome Reference Point (ARP)). This differs slightly from the time of leaving the hold, but this did not affect the findings of the study. (Aircraft landing times are typically about ten minutes after leaving the hold.)

3.4 This study has used NTK data covering time periods between June 1995 and July 1997. Before December 1995, the NTK system was set to obtain radar data over a 24 nm square area only (centred on the ARP). In December 1995 this was increased to the full area specified in para 3.3. The pre-trial approach NTK data, i.e. before September 1995, included heights below about 3600 ft only; later data extend to heights of up to 10,000 ft.

3.5 Comparisons of 'before/after'[8] trial conditions at the further out distances (to 20 nm from touchdown) are therefore not possible using NTK data, because prior to the trial no NTK coverage was available beyond about 11 nm. However, some pre-trial data, for January 1995, was obtained from DERA[9]. Because of the significant additional effort which was required to process and analyse this data[10], the use of such data is not suitable for routine analyses of

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[8] "after" is used in this report in this context to mean "after the commencement of the trial".

[9] The Defence Evaluation and Research Agency, who provide some radar analysis and data storage facilities for NATS.

this type.

3.6 NTK approach profiles were categorised as 'CDA' or 'non-CDA'. CDA is defined in Appendix B. The categorisation process is explained in Appendix C.

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[10] The DERA data was in a different form to the NTK data, and the altitude data was given in the form of Mode C Flight Level information. An approximate adjustment was applied to give the height above airfield, to be consistent with the NTK data. Speed and height values contained no smoothing, unlike NTK data, and the data supplied only extended to a time of about 0730. The radar data had to be matched to flight details using LATCC flight database records, runway logs and the BUCHair database.

4 COMPLIANCE WITH THE EARLY MORNINGS LANDINGS TRIAL PROCEDURE

4.1 This section examines to what extent aircraft have complied with the trial procedure. Section 5 presents the results of analyses, which were mostly specifically requested by the DETR, in order to compare general aspects of aircraft on approach before and during the trial. Section 6 considers the achievement of Continuous Descent Approach (CDA) procedures. The effects of the trial procedure and of CDA on noise exposure are examined in Section 7.

4.2 Radar data for aircraft arrivals during June 1995[11], January 1996[12], June 1996, January 1997, and July 1997 were extracted from the NTK system, and additional data for January 1995 were obtained from DERA as described in para 3.5. The data were divided into the following time periods:

- 0400 to 0600;
- 0600 to 0700;
- 0700 to 0800;
- 0600 to 0800.

4.3 Table 1 shows the numbers of westerly arrivals analysed. The proportion of approaches on runway 27R before 0700 in June 1995 was unusually low due to night-time runway maintenance work. The sample numbers in January 1996 were small due to the preponderance of easterly operations in that month.

Table 1: Numbers of arrivals on runways 27L and 27R

Time period	Jan. 1995		June 1995		Jan. 1996		June 1996		Jan. 1997		July 1997	
	27L	27R	27L	27R	27L	27R	27L	27R	27L	27R	27L	27R
0400-0600	237	83	298	32	136	37	281	111	115	74	304	174
0600-0700	178	139	408	173	76	53	496	295	158	83	507	334
0700-0800	133*	113*	341	352	70	84	472	527	202	112	606	382
Total	548	335	1047	557	282	174	1249	933	475	269	1417	890

* These samples are small because the DERA data extended to about 0730 only; they are nevertheless considered to be representative of the 0700-0800 hour.

Height-keeping of approaching aircraft

4.4 The 'height-keeping' of aircraft at different distances from touchdown is illustrated by histograms which classify heights into 200 ft bands; see Table 2a

[11] For June 1995, arrivals data only for the period 0400-0600 were extracted.

[12] There were no NTK radar data for 26 January 1996.

for the figure numbers relevant to the different months. Corresponding 'track keeping' between 0400 and 0600 during the same months is illustrated by the ground tracks in the area between about 5 and 11 nm from touchdown: Table 2b gives the figure numbers.

Table 2a: Figure references of histograms showing height-keeping performance of aircraft on approach

	Runway 27L				Runway 27R			
Distance from touchdown nm	**June 1995**	**Jan. 1996**	**Jan. 1997**	**July 1997**	**June 1995**	**Jan. 1996**	**Jan. 1997**	**July 1997**
7	6a	7a	8a	9a	6f	7g	8g	9g
8	6b	7b	8b	9b	6g	7h	8h	9h
9	6c	7c	8c	9c	6h	7i	8i	9i
10	6d	7d	8d	9d	6i	7j	8j	9j
11	6e	7e	8e	9e	6j	7k	8k	9k
12	n/a*	7f	8f	9f	n/a*	7l	8l	9l

* Data were not available beyond 11 nm from touchdown in June 1995 due to the limited coverage of the NTK system at that time.

Table 2b: Figure references of track-keeping figures (tracks of approaching aircraft with respect to the localizer tolerance at 10 nm from touchdown)

Runway 27L				Runway 27R			
June 1995	**Jan. 1996**	**Jan. 1997**	**July 1997**	**June 1995**	**Jan. 1996**	**Jan. 1997**	**July 1997**
6k	7m	8m	9m	6l	7n	8n	9n

4.5 Each bar of the histograms is labelled to show the actual number of aircraft within each 200 ft band[13]. To show the position of the nominal[14] 3° glideslope, the class interval which encompasses it is underlined.

4.6 The histograms showing heights of aircraft at 10 nm from touchdown (Figures 6d, 6i, 7d, 7j, 8d, 8j, 9d and 9j) give an indication of whether aircraft descended below 3000 ft before 10 nm from touchdown. However, for reasons explained in Appendix A, the SSR data from which these diagrams have been derived are subject to measurement tolerances. Thus, to make a fair assessment of compliance with the trial procedure a tolerance must be allowed; the rationale

[13] The value shown on the x-axis is that at the centre of the class interval. For example, in Figure 6a the class interval labelled '2300' shows that there were 229 aircraft at heights between 2200 ft and 2400 ft.

[14] i.e. ignoring tolerances of the ILS beam (see Appendix A).

for fixing this at 200 ft is given in Appendix A. Aircraft have been classed as "non-compliant" in respect of height-keeping only if their height at 10 nm is below 2800 ft. Table 3 summarises the incidence of non-compliance found according to this criterion. A marked improvement during the trial is evident.

4.7 Further analysis of the data confirmed the expectation that no aircraft which was above 2800 ft at 10 nm was below 2800 ft at greater distances from touchdown. Thus aircraft, shown in Figures 7e, 7f, 7k, 7l and 9e to be below 2800 ft at distances greater than 10 nm from touchdown, are automatically included in the Table 3 counts.

Table 3: Arrivals below 2800 ft at 10 nm from touchdown between 0400 and 0600

Runway	Period	Total number of aircraft	Number of aircraft below 2800 ft at 10 nm from touchdown	Percentage of aircraft below 2800 ft at 10 nm from touchdown
27L	Jan. 1995	237	11	4.6%
	June 1995	298	20	6.7%
	Jan. 1996	136	2	1.5%
	Jan. 1997	115	0	0.0%
	July 1997	304	5	1.6%
27R	Jan. 1995	83	3	3.6%
	June 1995	32	0	0.0%
	Jan. 1996	37	1	2.7%
	Jan. 1997	74	1	1.4%
	July 1997	174	1	0.6%

4.8 To assess the effect of the trial procedure on the number of aircraft intercepting the glideslope relatively close in, i.e. at heights such as 2500 ft or less, the distribution of heights at a distance of 9 nm from touchdown has also been examined. At this distance, aircraft on the glideslope would be at a height of approximately 2900 ft. In June 1995, before the trial, 6.4% of aircraft were in the 2500 ft band or lower at this distance (Figures 6c and 6h). After the trial started the equivalent rates were 1.7%, 0.5% and 0.6% for January 1996 (Figures 7c and 7i), January 1997 (Figures 8c and 8i) and July 1997 (Figures 9c and 9i) respectively. These results, derived directly from the height histograms, are not compatible with the 'compliance' criterion used in paras 4.6 and 4.7 above, because they make no allowance for the 200 ft tolerance allowed there. Nevertheless the results confirm that the numbers of early morning approaches with aircraft intercepting at a nominal height of 2500 ft or less were markedly reduced as a result of the trial, and that the trial did have a major effect in eliminating level segments at 2500 ft or lower before joining the glidepath.

Track-keeping of approaching aircraft

4.9 To determine compliance with the trial requirement for all aircraft before 0600 to intercept the extended runway centreline no closer than 10 nm from touchdown, the ground tracks of approaches have been analysed. Table 2b references the figures which show plan views of the arrivals radar tracks between 0400 and 0600.

4.10 When interpreting the track diagrams to estimate the point of joining the extended runway centreline, allowance has to be made for the limited horizontal precision of radar data. For reasons explained in Appendix A, a 0.5 nm wide 'gate' centred on the extended runway centreline at a distance of 10 nm has been used to define the appropriate tolerance.

4.11 The number of approach tracks outside the gates for runways 27L and 27R are summarised in Table 4. Again a marked improvement is evident under the post-1995 trial procedures.

Table 4: Arrivals not established on the runway centreline at 10 nm from touchdown between 0400 and 0600

Runway	Period	Total number of aircraft	No. of aircraft not established on localizer	Percentage not established on localizer
27L	Jan. 1995	237	28	11.8%
	June 1995	298	47	15.8%
	Jan. 1996	136	10	7.4%
	Jan. 1997	115	4	3.5%
	July 1997	304	12	3.9%
27R	Jan. 1995	83	14	16.9%
	June 1995	32	3	9.4%
	Jan. 1996	37	0	0.0%
	Jan. 1997	74	2	2.7%
	July 1997	174	4	2.3%

4.12 The difficulties for ATC in vectoring an aircraft to any precise point need to be appreciated. In strong cross winds, for example, it can be very difficult to select the heading which will take an aircraft to the required turn-on point. The actual points of closing on the localizer will therefore vary significantly about the designated point, depending on the angle of drift or on the variation in wind speed and direction with altitude. It should also be noted that the radar display used by ATC has a less precise resolution than can be obtained by NTK computer analysis.

Overall compliance with trial procedure

4.13 Table 5 shows overall compliance with the trial procedure, for the periods under investigation, for approaches to both westerly runways between 0400 and 0600. This combines the results shown in Table 3 (compliance with the height requirement) and Table 4 (compliance with the requirement to be established on the runway centreline by 10 nm from touchdown). Table 5 accounts for the fact that some flights are non-compliant in both respects, i.e. are included in both Tables 3 and 4. It should be noted that in order to assess the effect of the trial, 'compliance' has been calculated for the January and June 1995 data, even though the trial procedures were not in effect in those periods. The results in Table 5 show a good level of compliance with the trial procedure, and a clear improvement over the pre-trial situation.

Table 5: Overall compliance with trial procedure

	Period	Total number of aircraft	Number of non compliant aircraft	Percentage of compliant aircraft
BEFORE TRIAL	Jan. 1995	320	48	85%
	June 1995	330	54	84%
DURING TRIAL PERIOD	Jan. 1996	173	13	92%
	Jan. 1997	189	7	96%
	July 1997	478	21	96%

5 GENERAL ASPECTS OF THE EARLY MORNINGS LANDINGS TRIAL

5.1 This section presents further analyses of the study results, mostly specifically requested by the DETR, to compare more general aspects of approaches to Heathrow before and during the trial. These concern:

- mean heights on approach;
- variation in compliance rates between holding stacks;
- time of day effects;
- the use of path stretching manoeuvres;
- localizer and glide path intercept points;
- day - night effects;
- comparison of easterly and westerly approaches;
- seasonal effects.

These topics are considered in turn.

Comparison of mean heights on approach

5.2 Tables 6a and 6b list the mean heights for approaches to Heathrow runways 27L and 27R during January and June 1995 (pre-trial) and June 1996 (during trial), for the period 0400 to 0600, between 7 and 16 nm from touchdown. Figures 10 and 11 plot the mean heights for these periods, and also for January 1996, January 1997 and July 1997, the full results for which are tabulated in Appendix D. These figures show vertical profiles of aircraft flight paths converging on the ILS glideslope, in terms of 'height above touchdown', which is based on the altitude relayed from the aircraft altimeter via SSR radar returns. As the flight profiles at this stage of flight are governed by the ILS, they actually identify the position of the ILS beam, regardless of any effects of misalignment, earth curvature or other factors which affect the height of the beam above the ground. Therefore, the nominal glideslopes in these diagrams have simply been drawn as straight lines with a slope of 3° and in alignment with the final descent paths (relative to the ground, the beam actually has a slight upward curve). The glideslope tolerances described in Appendix A (just over ±0.1°), indicated by dashed lines above and below the approximate glideslope, give an indication of its variability. This variability is believed to explain (a) why the position of the glideslope differs slightly in the diagrams, and (b) some of the differences between the mean descent paths.

Table 6a: Comparison of mean heights of aircraft approaching runway 27L

	January 1995		June 1995		June 1996	
Distance from touchdown nm	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2355	76	2366	154	2344	122
8	2679	107	2676	211	2649	143
9	2973	152	2969	266	2942	181
10	3200	261	3222	347	3156	262
11	3425	384	3471	453	3364	381
12	3632	476	-	-	3549	471
13	3833	529	-	-	3730	536
14	4038	584	-	-	3933	596
15	4233	616	-	-	4136	649
16	4419	679	-	-	4329	704

Table 6b: Comparison of mean heights of aircraft approaching runway 27R

	January 1995		June 1995		June 1996	
Distance from touchdown nm	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2313	112	2333	69	2337	208
8	2643	129	2674	107	2660	242
9	2925	167	2994	125	2982	273
10	3110	261	3291	200	3237	349
11	3291	384	3566	280	3478	458
12	3489	486	-	-	3698	545
13	3704	534	-	-	3916	608
14	3937	564	-	-	4150	661
15	4176	624	-	-	4398	728
16	4389	691	-	-	4639	780

5.3 It can be seen from Figures 10 and 11 that, within 10 nm of touchdown, mean heights during the different time periods differ less than the ILS glideslope tolerance. From 10 nm out to a distance of 16 nm the differences are mostly smaller than the height-keeping tolerance of 200 ft, except in June 1996 at 14 nm and beyond, where sample mean heights for runway 27R approaches were generally higher than during the other periods. The diagrams (and the tabulated values in Appendix D) also illustrate mean height changes between

1995, 1996 and 1997. All mean heights out to 10 nm differ by less than the glideslope tolerance. Note that during part of the 1997 study period a separate trial of night westerly runway alternation was undertaken by HAL - this is discussed in paras 5.26 to 5.29.

Variation in compliance rates between holding stacks

5.4 Analysis was undertaken to identify if there was any relationship between compliance with the trial procedure and the particular holding stack used by an aircraft. The periods chosen for this analysis were June 1995 and January 1996, between 0400 and 0600. (Although the trial was not in effect in June 1995, 'non-compliance' has been calculated on the same basis as for January 1996 to highlight the effect of the trial.) Table 7 compares non-compliance rates - according to either the vertical (glideslope joining point) or the lateral (localizer joining point) criteria - for arrivals from the four stacks.

5.5 The table gives the percentage distribution of the 'non-compliant' arrivals by hold before (June 1995) and after (January 1996) the trial commenced. The 'straight-in' category has been used to denote those flights which were flying on or close to the extended runway centreline when entering the NTK radar coverage area[15]. There was no marked difference in the compliance rates of aircraft arriving via different holds.

Table 7: Effect of holding stack on overall non-compliance

Hold	Percentage of total sample 'non-compliant' with MATS	
	June 1995	Jan. 1996
Bovingdon	4.8%	0.6%
Lambourne	3.6%	2.9%
Ockham	0.6%	1.7%
Biggin	3.6%	0.6%
'Straight-In'	3.6%	1.7%
All westerly arrivals	16.4%	7.5%

Time of day effects: early morning

5.6 An alternative method of illustrating the effect of the trial is to plot aircraft heights at different positions (10 nm to 12 nm from touchdown) against time of arrival (Figures 12 to 15). Separate figures show data for runways 27L and 27R and for January 1995, January 1996, January 1997 and July 1997. Many of these graphs show two distinct clusters of data, one at around 3000 ft and the

[15] i.e. aligned with the localizer at a distance of at least 20 nm from touchdown.

other corresponding approximately to the height of the ILS glideslope at that distance. Figure 12a (before the trial) shows a number of flights below 3000 ft at 10 nm; this can be compared with Figures 14a and 15a, which show that after commencement of the trial such flights tended to occur only after 0600. However there is no abrupt change in height distribution at around 0600 as might be expected to occur in changing from the early morning to the daytime procedures.

Use of path stretching manoeuvres

5.7 A major influence on individual ground tracks is the extent to which path stretching manoeuvres are used by ATC. Figure 16 shows pre-trial westerly approach ground tracks in January 1995[16], and Figures 17 and 18 show the ground track patterns after the trial commenced, in January 1996 and June 1996 respectively; each figure is split by runway and by time period. Figures 17 and 18 indicate that before 0600 there was comparatively little use of 'trombone manoeuvres' to extend ground tracks; more tracks were flying in a straight line before joining the localizer. After 0600 most arrivals from the Lambourne and Biggin holds (which are to the east - see Figure 1) were subject to trombone manoeuvres, as the traffic from those holds is fitted in at the correct spacing with approaches from Bovingdon and Ockham respectively. The Biggin hold was rather more heavily used after 0700 than before that time.

5.8 Figures 19 and 20 show similar ground tracks for approaches in January 1997 and July 1997 respectively, split by runway and by time period. Again, during the period 0400-0600 a large proportion of approaches from the east did not approach via a holding point, but flew directly to intercept the runway centreline at some distance east of central London. An inspection of a number of individual height profiles for these 'straight-in' approaches showed that they were not noticeably different from the profiles of the other arrivals during the 0400-0600 period.

Localizer and glide path intercept points

(a) Localizer joining position

5.9 Variations in the position where the ILS localizer and glide path were intersected were analysed for January 1995 (pre-trial), and January 1996, January 1997 and July 1997 (during trial) and for the periods 0400-0600, 0600-0700 and 0700-0800.

5.10 Figures 21 to 24 show localizer intercept distances from touchdown in 1 nm

[16] derived from DERA radar data.

intervals[17] for westerly approaches. In the period 0400-0600, a considerable proportion of aircraft were already aligned with the localizer before entering the NTK radar coverage area (approximately 21 nm east of touchdown for runways 27L and 27R). During the period 0600-0700 there were fewer flights coming 'straight in' from beyond the radar coverage limit. The distribution of the point of joining the localizer during this period peaks at around 12 nm for both runways. After 0700 there were no aircraft flying along the extended runway centrelines prior to entering the radar coverage area, but there appears to be no prominent distance at which aircraft become established - most join at between 11 nm and 16 nm.

5.11 An inspection of track plots such as Figure 4 has shown no marked trend for the closing heading of tracks, prior to joining the localizer, to increase with increasing distance from touchdown above an angle of 30° relative to the localizer, either before 0600 or in the busier period 0600-0800.

(b) Glideslope joining position

5.12 Figures 25 to 28 show the distributions, in each time period, of the position where the glideslope was joined. During the period 0400-0600, the majority of approaches on both runways intersected the glideslope in the region of either 9 nm or 12 nm from touchdown; these distances correspond to altitudes of approximately 3000 ft and 4000 ft for aircraft on the glideslope. After 0600, however, a smaller percentage of approaches on 27L intersect the glideslope at 12 nm; most aircraft joined at 9 nm from touchdown. In the hour 0700-0800 in January 1996 (Figures 26a and 26b), nearly 40% of 27R approaches joined at 12 nm (approximately 4000 ft), compared with only 5% of 27L approaches. In the other months considered, however (Figures 23 and 24), the proportion was around 30% for both runways; the apparent marked effect in January 1996 does not therefore appear to be typical[18]. After 0600, on both runways, a smaller proportion of aircraft joined the glideslope beyond 12 nm from touchdown than in the period 0400-0600. However, it has not been possible within the scope of this study to identify reasons for differences between approaches to the two runways.

5.13 During 0400-0600 in January 1997, most flights intersected the glideslope at 9 nm from touchdown; this was also true during the hour 0600-0700. After 0700, a greater proportion of approaches joined the glideslope at 12 nm from touchdown. In July 1997 the numbers of aircraft joining the glideslope (during all time periods considered) at 9 nm and 12 nm was approximately equal. After 0600, fewer approaches joined the glideslope beyond 12 nm than in the period

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[17] rounded to the nearest integer nautical mile.

[18] The January 1996 result was probably distorted by the small sample sizes for that month - only three days of data was available for each of the westerly runways.

0400-0600.

5.14 Figure 29 shows, for a sample of June 1996 westerly approaches, the cumulative distributions of the position where the glideslope was joined (derived by inspection of the NTK height profiles), comparing the three time periods 0400-0600, 0600-0700 and 0700-0800. The median distance is between 8 nm and 10 nm, with a clear tendency in the early part of the morning (0400-0600) for approaches to join the glideslope further out, typically by between 1 nm and 2 nm.

(c) AIP minimum altitude requirement

5.15 A requirement of the UK AIP (Ref 2) is that aircraft "shall not descend below an altitude of 2500 ft before intercepting the glidepath, nor thereafter fly below the glidepath". Compliance with this requirement was investigated by analysing January 1996 data, taking into account the 200 ft height keeping tolerance applicable at this altitude (see Appendix A).

5.16 Aircraft following a 3° glideslope are at a height of 2500 ft at approximately 7.9 nm from touchdown. An NTK 'gate' analysis for this distance was performed on aircraft approaching runways 27L and 27R during the period 0400 to 0800[19].

5.17 Figure 30[20] shows the results for the January 1996 data. Of the 456 flight tracks which passed through the gate, there were three below a height of 2300 ft, i.e. 0.7%. Figure 31 gives the height profiles of those particular three aircraft, showing that two of them did not join the glideslope until approximately 1900 ft above the runway, and the third (an exceptional case) joined at about 1100 ft. The results clearly indicate that the great majority of aircraft are complying with the AIP requirement.

Day-night effects

5.18 The mean heights on approach between the nominal 'daytime' (0600 to 2300) and 'night-time' (2300 to 0600) periods were compared for January 1996, January 1997 and July 1997. The numbers of arrivals analysed in each period is shown in Table 8.

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[19] This period, embracing all the four hours analysed in this report, was used to assess compliance with the AIP '2500 ft' requirement because the AIP requirement applies throughout the day and night, irrespective of the early mornings trial.

[20] Note that the scales of the horizontal axes of Figures 30 and 31 are in kilometres.

Table 8: Number of arrivals analysed for day/night comparisons

Period	January 1996		January 1997		July 1997	
	27L	27R	27L	27R	27L	27R
0600 - 2300	1380	1513	2445	2657	7100	7016
2300 - 0600	144	67	128	95	345	194
Total	1524	1580	2573	2752	7445	7210

5.19 Figures 32a and 32b show the mean aircraft height profiles for 27L and 27R approaches respectively. From these figures it can be seen that the differences between daytime and night-time are less than the ILS glideslope tolerance out to 9 nm, and less than the height-keeping tolerance (see Appendix A) beyond 9 nm. There is thus no evidence of any significant difference between the two periods.

5.20 The mean values plotted in Figures 32a and 32b are given in Appendix E, Tables E1 to E6, along with the associated standard deviations and mean difference in heights between the two time periods each month.

Comparison of approaches to runways 09L and 27L

5.21 The DETR also requested comparisons between easterly and westerly approaches; a procedure similar to the early mornings trial procedure has applied to easterly approaches for many years. When operations are in an easterly direction, most landings are on the northern runway (09L), and hence this analysis concentrated on approaches to that runway. The periods analysed were 0400 to 0600 during January 1996, January 1997 and July 1997. Table 9 shows the numbers of samples analysed for 09L and 27L[21] approaches during each study period, and Tables 10a, 10b, and 10c show the mean aircraft heights. These values are also plotted in Figures 33a, b, and c.

Table 9: Number of arrivals on runways 09L and 27L, 0400-0600

Period	Jan 1996		Jan 1997		July 1997	
	09L	27L	09L	27L	09L	27L
0400-0600	117	136	243	115	80	304

[21] Runway 27L was used to represent westerly approaches as this had more operations than 27R in the periods under study.

Table 10a: Comparison of mean heights of aircraft on westerly (27L) and easterly (09L) approaches during January 1996

Distance from touchdown nm	Runway 27L		Runway 09L	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2376	56	2450	96
8	2696	69	2743	158
9	2999	117	2922	209
10	3225	240	3007	262
11	3461	375	3119	368
12	3671	478	3244	473

Table 10b: Comparison of mean heights of aircraft on westerly (27L) and easterly (09L) approaches during January 1997

Distance from touchdown nm	Runway 27L		Runway 09L	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2401	83	2509	78
8	2742	93	2837	88
9	3026	146	2977	130
10	3235	274	3056	235
11	3440	408	3150	342
12	3638	520	3266	431

Table 10c: Comparison of mean heights of aircraft on westerly (27L) and easterly (09L) approaches during July 1997

Distance from touchdown nm	Runway 27L		Runway 09L	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2373	118	2282	72
8	2704	138	2607	75
9	2992	168	2893	53
10	3224	265	3050	149
11	3457	386	3183	285
12	3661	472	3327	402

5.22 From Figure 33 and Table 10 it appears that although heights beyond a distance of 9 nm from touchdown are lower on runway 09L approaches than on 27L, the differences between the runways are small compared with the ILS glideslope tolerance out to 9 nm, and can be regarded as unimportant.

Seasonal effects: Comparison of summer and winter results

5.23 DETR requested comparisons of heights between summer and winter to assess any possible seasonal effects (such as temperature, visibility and wind). Comparisons were made between:

- January 1996 (winter) and June 1996 (summer);
- January 1997 (winter) and July 1997 (summer).

5.24 The comparisons were made of the mean heights of arrivals during the periods 0400 to 0600, 0600 to 0700, and 0700 to 0800. These are plotted in Figures 34a to 34c for runway 27L, and Figures 34d to 34f for runway 27R. The heights are also listed in Appendix D, Tables D1 to D12.

5.25 Figure 34 shows that the differences in mean height out as far as 12 nm are less than the glideslope or height-keeping tolerances, and there is no evidence of any difference between the winter and summer samples.

Night runway alternation trials

5.26 At Heathrow there is a well-established daytime runway alternation scheme, which applies to westerly operations during the period 0700 to 2300. At any time the normal practice is to designate one of the westerly runways (27L and 27R) for landings and the other for take-offs. The runway use is switched at 1500 each day; the overall pattern of runway use is also alternated on a weekly basis so that morning relief one week is followed by afternoon relief the following week and so on. The principal effect of alternation - substantial periods during which overflying aircraft are either present or absent - is noticeable to the east of the airport beneath final approach at distances up to about 12 nm from the runway, but not at larger distances or on initial approach.

5.27 When the airport is on easterly operations, aircraft normally take off from runway 09R because the Cranford Agreement effectively prevents departures from 09L, which is therefore used for most landings.

5.28 Whilst runway alternation has no effect on the long-term L_{eq}(16-hr) (provided the overall split of landings between runways is unchanged), it provides for periods of lower and higher noise exposure, and is highly valued by local residents. Suggestions to extend the period of alternation to the night-time period were made and this led HAL and ATC to undertake trials of two slightly different schemes for night-time runway alternation. These trials were conducted after the commencement of the early mornings landings trial, as follows:

(a) 28 October 1996 to 16 March 1997: weekly alternation of designated landing and departure runways between 2300 and 0700. During each 24-hour period, the designated runway was changed at 1500 and 0700. During the period of this trial, the 0700 end time was changed to 0630 to provide some ATC flexibility during the most intense period of landings.

(b) 15 June to 25 October 1997: the existing daytime weekly alternation scheme was extended into the night period, thereby covering the full 24 hours, by changing the designated runways at 1500 and again at 2300.

5.29 In view of the small differences in heights and ILS joining points found in comparisons between runways 27L and 27R (see Section 4), it would not be expected that night runway alternation would have any particular impact on the parameters considered in this study. A limited inspection of NTK height profiles revealed no consistent differences between periods when night alternation was or was not in force. Assessment of the noise effects is considered in para 7.37.

6 CONTINUOUS DESCENT APPROACH

Previous studies

6.1 Monitoring in the mid/late 1970s (Refs 4 and 5) established that the incidence of CDA was 54%, based on analysis of a large sample of daytime data. Until this present study, no further monitoring had been carried out. The 1970s work indicated that CDA produced substantial noise benefits, estimated at between 4 and 9 dBA (L_{Amax}) under the appropriate parts of the approach path, relative to 3000 ft level segments. Analyses of present day noise effects are discussed in Section 7. This section describes analyses carried out to estimate the current rates of achievement of CDA for westerly approaches to Heathrow during the early morning.

Definition of CDA

6.2 In order to monitor the achievement of CDA, an achievement criterion is required. For the present purpose an approach was classified as CDA if its radar profile contained no level segments of 2 nm or more below a height of 6000 ft.[22] This definition is discussed in Appendix B. The corollary is that an approach is classed as 'non-CDA' if it contains a level segment greater than 2 nm in length below 6000 ft. The 6000 ft 'ceiling' ensures that any level flying in a hold is excluded from assessment of CDAs. Note that one result of using this criterion is that approaches which started as CDAs but during which ATC intervention proved necessary for tactical reasons (typically to ensure vertical separation from other aircraft) could be classed here as 'non-CDA'.

6.3 The reason for the 2 nm criterion is that short level segments, e.g. those less than 2 nm, are often used to reduce airspeed during the descent; there is usually therefore no additional thrust and concomitant noise increase in such segments compared with descending flight.

Analysis and Results

6.4 NTK track data were analysed for seven nights from each of the months June 1995, January 1996 and June 1996, to cover periods before and after the revised procedure had been introduced. The radar coverage limitations of the NTK system discussed in Section 3 meant that the analysis of CDA using the NTK June 1995 data (before the revision of procedures in September 1995) was limited, being confined to an assessment of level segments at 3500 ft and below. Additional data for 11 nights of westerly approaches during January 1995 were obtained from DERA to use as a pre-trial 'baseline' case.

6.5 Figure 35 shows as an illustration the height profiles and ground tracks for

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[22] The same criterion was used in Refs 4 and 5.

approaches during 0700-0800 on one day. By applying the criterion described in para 6.2, each profile was categorised as 'CDA', 'non-CDA' or 'indeterminate'. The top half of the figure shows all approaches classified as CDA; the lower half all those that were non-CDA. Some approaches were defined as indeterminate because of the absence of radar data up to a sufficient height (i.e. 6000 ft). Further details of the categorisation are given in Appendix C.

6.6 The distributions of approach categorisations are shown in Table 11. Because of the indeterminate data, CDA achievement has been expressed as a range between 'minimum' and 'maximum' percentage values. The 'minimum' includes all flights which comply fully with the CDA definition in para 6.2, and the 'maximum' also includes any indeterminate flights. As it was not possible to assess reliably the frequency of level segments at 4000 ft or above for June 1995, there is a very large uncertainty in the range for this particular period.

Table 11: Summary of CDA achievement by time period

Level segments:	non-CDA	Indeterminate	Minimum CDA achievement	Maximum CDA achievement
0000-0400				
June 95	59%	23%	18%	41%
Jan. 96	43%	14%	43%	57%
June 96	62%	0%	38%	38%
Jan. 97	67%	0%	33%	33%
0400-0600				
Jan. 95	57%	15%	27%	43%
June 95	15%	78%	7%	85%
Jan. 96	55%	12%	33%	45%
June 96	45%	11%	44%	55%
Jan. 97	47%	6%	47%	53%
0600-0700				
Jan. 95	51%	2%	47%	49%
June 95	24%	63%	14%	76%
Jan. 96	51%	3%	46%	49%
June 96	53%	2%	45%	47%
Jan. 97	65%	1%	34%	35%
0700-0800				
Jan. 95	41%	3%	56%	59%
June 95	9%	80%	11%	91%
Jan. 96	51%	1%	48%	49%
June 96	41%	0%	58%	59%
Jan. 97	39%	0%	61%	61%

6.7 The results show that CDA achievement in 1996 between 0400 and 0800 ranged from a minimum of 33% (if allowance is made for uncertainties) to a maximum of 59%. Similar achievement rates are also indicated in January 1997. ATC almost invariably offer CDA to each approaching aircraft provided there is no conflicting traffic, by indicating the distance to run at an appropriate point. The results show little systematic variation in CDA achievement with time of day; the higher achievement actually occurred during the busier period 0700-0800. Figure 36 shows the data plotted against the average hourly landing traffic level. The achievement of CDA during the busiest period analysed, around 60%, compares with the average of 54% reported in 1978 for morning and afternoon arrivals (Ref 4 and 5).

Impact of the Revised Procedure on CDA

6.8 The revised early mornings landings trial procedure does not involve any change to CDA procedures. Comparisons between the 1995 (pre-trial) data and 1996 and 1997 (during trial) data do not indicate any appreciable change in CDA achievement after 0600 but, for the 0400-0600 period, Figure 36 indicates that achievement appears to have increased by about 10% to around 50%. There is certainly no evidence that the early mornings landings trial had any adverse impact on the achievement of CDA. From the perspective of the trial it is important to note that changing the point of glidepath intercept, e.g. from 8 nm to 10 nm, should not affect the achievement of CDA.

Dependence on hold

6.9 Previous studies have shown that achievement of CDA could depend on a number of factors, including whether a hold was used, and if so, which hold. The numbers of CDAs were analysed by hold for all time periods (0400-0800) in January and June 1996, representing winter and summer. The results are shown in Table 12(a) and Figure 37. There is a spread in CDA achievement between holds, and although the ranking of the holds by achievement rate changes slightly from summer to winter, Biggin has the highest rates in both cases.

6.10 Examination of Figure 1 shows that the holds may be grouped by their relative positions:

- the West holds are defined as Bovingdon and Ockham;
- the East holds are defined as Lambourne and Biggin;
- the North holds are defined as Bovingdon and Lambourne;
- the South holds are defined as Ockham and Biggin.

6.11 The above groupings have been used to analyse the pattern of CDA achievement and the results are shown in Table 12(b). The differences in rates of achievement of CDA are small, but the more marked difference arose between the East and West groups, with the East group achieving higher achievement of CDA. This probably arises from the different ways in which ATC handle the traffic from the West and East holds in order to integrate traffic flows and to generate the correct spacing between aircraft on final approach.

Because of the shorter track distances in the initial approach phase, approaches from Lambourne and Biggin tend to achieve CDA of necessity. Moreover, CDA is facilitated because the glideslope signal can be used over more of the descent, compared with the curved tracks from Bovingdon and Ockham.

Table 12: CDA achievement by hold

(a) Comparison of Winter and Summer 1996 CDA

January 1996 0400-0800	Total number	non-CDA	CDA	Indeterminate	CDA achievement (min.)	CDA achievement (max.)	Ranking order
Bovingdon	57	39	18	0	32%	32%	5
Lambourne	151	81	66	3	44%	46%	2
Ockham	82	47	35	0	43%	43%	4
Biggin	101	38	62	1	61%	62%	1
Straight	62	31	16	11	26%	44%	3
All	453	236	197	15	43%	47%	

June 1996 0400-0800	Total number	non-CDA	CDA	Indeterminate	CDA achievement (min.)	CDA achievement (max.)	Ranking order
Bovingdon	108	49	59	0	55%	55%	2
Lambourne	226	104	116	1	51%	52%	3
Ockham	87	45	41	0	47%	47%	4
Biggin	136	61	75	0	55%	55%	1
Straight	57	23	23	3	40%	46%	5
All	614	282	314	4	51%	52%	

(b) Combined 1996 data: Comparison of 'East'/'West' and 'North'/'South' Holds

January + June 1996 0400-0800	Total number	non-CDA	CDA	Indeterminate	CDA achievement (min.)	CDA achievement (max.)
'West'	334	180	153	0	46%	46%
'East'	614	284	319	5	52%	53%
Straight	119	54	39	14	33%	45%
'North'	542	273	259	4	48%	49%
'South'	406	191	213	1	52%	53%
All	2015	982	983	24	49%	50%

'West' = Bovingdon + Ockham
'East' = Biggin + Lambourne
'North' = Bovingdon + Lambourne
'South' = Ockham + Biggin

6.12 The difference in CDA achievement rates between the North and South holds is even smaller than between the East-West grouping, and is not considered important.

Dependence on season

6.13 Table 12(a) shows slightly higher achievement of CDA in summer (51%-52%) than in winter (43% to 47%). A number of factors may be responsible for variations in CDA achievement between the summer and winter seasons, for example:

- higher wind speeds in winter than summer;
- more complex patterns of wind speed/direction variations and turbulence;
- lower visibility, either due to increased cloud or the greater duration of darkness in the winter months.

Assessment of such factors was beyond the scope of this study.

Discussion

6.14 Apart from any weather-related effects, maximum achievement of CDA depends on the following:

(a) The necessary CDA advice (i.e. accurate information on the track distance to touchdown) being issued to an aircraft by ATC at the appropriate time. This is normal LATCC practice when the descent clearance is given, and in effect offers appropriate conditions to the aircrew to fly a CDA[23].

(b) Pilot action.

(c) Minimising the need for ATC subsequently to modify the descent clearance they had provided (in order to maintain safe separation between aircraft, or to expedite traffic flow), unless the aircraft could still achieve a CDA with the revised clearance.

6.15 It might be expected that the frequency of occurrence of some of these factors would vary with traffic volume, particularly so in the case of (c). The passive observation of radar tracks and profiles however cannot establish the relative contributions of the factors. Previous work in 1978 (Ref 4) found that a dominant factor governing achievement of CDA was the distance from

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[23] ATC normally provide pilots with an estimate of the track distance to run, from the point where descent clearance is given. There is an AIP requirement for pilots to inform ATC if they are unable to descend (once a clearance has been given) at a rate of at least 500 ft/min, or if they are in fact descending at a rate of less than 500 ft/min. A 3° glideslope at a 'still air' speed of 210 kt gives a descent rate of 1113 ft/min, and at 160 kt the rate is 850 ft/min. In some situations however it may be necessary to descend less rapidly than at 3° to achieve CDA. If in such situations pilots do maintain 500 ft/min, or if for separation reasons ATC require a greater descent rate than that requested by a pilot, this could have an effect on achievement of CDA. For example, at a speed of 210 kt and a descent rate of 500 ft/min, a complete CDA is not possible if an aircraft is instructed to descend from 6000 ft at a point earlier than about 32 nm from touchdown to join the ILS at 3000 ft at a point 10 nm from touchdown. At lower speeds the critical distance for commencing CDA is closer to touchdown.

touchdown when descent clearance was given; it was beyond the scope of this study however to analyse ATC messages[24].

[24] The possibility of further study of such topics is to be considered by DETR. An investigation of the effects of various factors on approach noise is currently being undertaken by the Arrivals Working Group of the Aircraft Noise Monitoring Advisory Committee (ANMAC).

7 ASSESSMENT OF NOISE IMPACT

Methods for noise impact assessment

7.1 Sound Exposure Level (SEL) and the Equivalent Continuous Sound Level, L_{eq}(2-hr) (see Glossary), both measured in dBA, have been used in this study to quantify noise. SEL is a measure used to define the level of a particular noise event and accounts for its duration as well as its intensity. L_{eq} is a measure of long-term average noise exposure - obtained in practice through summation of the SELs of all aircraft over a given period.

7.2 The published annual daytime contours for the London airports use the average (summer) daily L_{eq}(16-hr) covering the period 0700-2300. In this study of early morning noise, SEL contours are used to illustrate the noise of a single aircraft type and the average daily L_{eq}(2-hr) covering the period 0400-0600 has been used to illustrate overall average exposure. These are special applications of contour methodology, and such contours would not be appropriate for any form of 'routine' noise assessment. Unlike L_{eq}(16-hr), there are no known studies, either in the UK or internationally, relating L_{eq}(2-hr) to annoyance or disturbance through social survey studies.

7.3 These noise contours are determined by noise modelling which is dependent on detailed specification of:

- the height and speed profile of each aircraft;
- the ground track of each aircraft;
- how much thrust each aircraft is using at different points in its flight; this depends on its configuration, particularly undercarriage and flap settings;
- the relationship between noise and thrust for each aircraft;
- how that noise is propagated to the ground;
- the mix of aircraft types; and
- the average number of flights during the period of interest.

7.4 The noise contours were estimated using DORA's ANCON noise model which is considered reliable for the purpose. To accurately model approach noise it is necessary to take account of different approach power settings (e.g. comparing level flight and descent on the glideslope). This is done using 'noise-power-distance' (NPD) curves, which for specific aircraft types define noise levels against distance for a range of engine power settings. The principal source of NPD information is a standardised database maintained by the US Federal Aviation Administration (Ref 6); this is used by DORA, but only after validation and adjustment through comparison with airport-measured data.

7.5 For this analysis, the standard NPD curves have been used without modification. They are considered satisfactory for application to final approach conditions as the data were derived under such conditions, i.e. from measurements made at approach speed with final approach flap setting and undercarriage down. Their reliability for 'cleaner' descent conditions is less certain; this is being investigated in other DORA work but, as yet, no validation tests have been completed[25]. It is known, for example, that for any approaching aircraft there is a marked difference in thrust and noise between uniform level flight and 3° descent. However, NPD curves do not always reflect these differences: it is possible that the noise levels are over- and under-estimated during different portions of initial and intermediate approaches. This is not normally a problem in the production of 'conventional' 16-hr average day contours; it arises here because interest is extended to low noise exposures well beyond the extremities of standard contours.

Early mornings landings trial

7.6 To indicate the effect on noise impact of the early mornings landings trial procedure, aircraft noise contours are compared. These have been prepared in three ways:

a) using the actual movements, ground tracks and profiles flown during representative periods before and after the commencement of the trial;

b) using a representative ground track and a single aircraft type, to show just the effect of any differences in the height/speed profiles (i.e. excluding all other confounding differences between the 'before' and 'after' cases in (a) above; the factors might include different aircraft types and numbers, and different ground tracks);

c) for a single aircraft type, showing the combined effects of differences in the height/speed profiles and of differences in ground tracks.

7.7 Contours have also been produced to illustrate the noise benefits, compared to the actual summer 1996 situation, of two hypothetical cases: (i) all approaches using CDA, and (ii) all aircraft lined up on the localizer at 20 nm from touchdown.

7.8 These contours have been produced only for comparison with each other. It is not appropriate to compare these contours and the L_{eq} values with the annual L_{eq}(16-hr) contours published for Heathrow. The published annual contours are for all movements on an average summer day (0700-2300), while the contours presented in this report cover only westerly approaches, and just the

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[25] It was not possible to undertake field measurements to confirm approach NPD data as part of this study; adequate measurements would involve a major programme of work, requiring significant input from aircraft manufacturers and/or operators as well as extensive noise measurements at a range of locations. Despite uncertainty concerning the absolute values predicted, use of the standard NPD data is considered adequate for assessing noise differences, e.g. between pre-trial and trial conditions.

two hours from 0400-0600, averaged over a number of days.

7.9 The outermost L_{eq}(2-hr) contours also represent very different noise levels from those in the published annual 16-hour contours. The annual contours are given down to a L_{eq}(16-hr) value of 57 dBA. For this study the L_{eq}(2-hr) contours are shown down to a much lower level, 45 dBA. The SEL contours for a single aircraft type, the B747-400, are shown here down to 70 dBA (equivalent to L_{Amax} levels of around 60 dBA, too low to be measured reliably by the airport's NTK monitors). Such low level events might be noticeable outdoors if background noise levels in the relevant period are also low, but in urban areas such events would often be masked by any local road traffic noise. Many sounds with levels of 60 dBA L_{Amax} and above, both natural and man-made, are commonplace in suburban environments. Indoors, such events would be attenuated to the range 30-50 dBA. It must be added that there are technical difficulties in estimating low levels of aircraft noise. However, although the absolute accuracy of low noise level contours is limited, estimates of <u>differences</u>, used for comparative purposes, are considered more reliable.

7.10 Table 13 shows the number of days' data analysed for the contours, and the average number of approaches per day of each aircraft type in the period 0400-0600, for January 1995 (pre-trial) and July/August 1996 (during trial). For comparison, the average daily traffic in July/August 1995 (pre-trial) is also shown.

Table 13: Westerly arrivals 0400-0600: Average numbers of arrivals per day

Type	January 1995	July/August 1995	July/August 1996[26]
No. of Days	12	35	51
B747-400	5.93	8.46	7.90
B747-200	0.78	2.43	0.98
A340	0.58	1.26	0.88
B767	4.57	0.54	0.27
B737-300	0.00	0.23	0.04
B747-300	0.25	0.06	0.00
B747-100	1.15	0.06	0.00
B747SP	0.00	0.06	0.00
LR35	0.00	0.03	0.08
CJ1	0.00	0.03	0.04
BE20	0.00	0.03	0.00
B737-400	0.00	0.00	0.06
MD83	0.00	0.00	0.02
MD11	0.33	0.00	0.02
B757	0.00	0.00	0.02
B737-500	0.00	0.00	0.04
Others	0.00	0.00	0.00
Total	13.58	13.09	10.20

Before/After trial comparison: (a) actual traffic and tracks for each period, 0400-0600

7.11 Figure 38 shows average L_{eq}(2-hr) contours for the actual traffic and tracks in January 1995 and July/August 1996, for the daily period 0400-0600, based on all the actual approaches in that period in the number of days specified in Table 13. The innermost contours are for 63 dBA, and the contours are in 3 dBA steps down to 45 dBA. The bold contours are for the 1996 traffic mix as shown in Table 13, and the fine ones for the January 1995 mix. (Contours were also computed for July/August 1995 out to a distance of about 11 nm, the limit of the NTK radar data in that year, but they are not shown here as they were very similar to the January 1995 contours.) The 45 dBA L_{eq}(2-hr) contours are 'open-ended' because the available radar data did not extend far enough to be able to compute the contours beyond the end-points shown.

7.12 Generally all the 1996 contours are smaller than those for 1995 (i.e. the bold contours are inside the corresponding fine ones). The differences principally reflect the different runway utilisations and the lower early morning traffic in summer 1996 - although this was counteracted by the increase in use of B747-

[26] The noticeable drop in numbers of arrivals between 0400 and 0600 between July/August 1995 and July/August 1996 reflects the actual traffic in those months, and the figures are valid for use in this study, although the 1996 traffic increased from mid-August onwards, reverting more closely to 1995 levels.

400s (see Table 13). At the extremity of the 45 dBA L_{eq}(2-hr) contours (in the area beyond Greenwich), the results indicate an increase in noise exposure in 1996. However, levels of noise exposure this low are subject to uncertainties regarding the accuracy of the modelling methodology.

Before/After trial comparison: (b) effect of profile changes only

7.13 To make a more meaningful 'before/after' comparison illustrating the effect of the trial procedure on the vertical profiles, it is necessary to remove the confounding effects of the different runway utilisations, ground tracks, traffic mixes and numbers of flights. This is best done by considering a single aircraft type; the Boeing 747-400 has been used as this was the dominant type among both 1995 and 1996 arrivals in the 0400-0600 time period. For selected flights of a single aircraft type, it is more appropriate to provide contours showing average SEL rather than L_{eq}.

7.14 Figure 39 gives (in bold) the average SEL contours (between 75 dBA and 90 dBA in 3 dBA steps) for those B747-400 approaches from the total sample in July/August 1996 that flew straight-in from 20 nm during the period 0400-0600. Superimposed on these (the fine contours) are the corresponding contours for the straight-in January 1995 approaches, adjusted to have the same numbers of landings on each runway as the 1996 operations. In each case, the actual profiles of the relevant approaches in each period have been used to model the noise exposure. Any small differences that are observable in the close-in contours (87 and 90 dBA SEL) are simply the result of normal data scatter between two different samples of data, and are within the typical resolution of the modelling methodology. The 75 dBA SEL contours are 'open-ended' because the available radar data did not extend far enough to be able to compute the contours beyond the end-points shown. Note that 75 dBA SEL corresponds to approximately 65 dBA L_{Amax}.

7.15 The biggest difference between the 1995 and 1996 contours is seen at around 9 nm from touchdown and beyond; the 81 dBA SEL contour for 1996 is shorter than in 1995 (representing an average noise level reduction of about 1 dBA SEL). The area 9 nm to 11 nm from touchdown[27] is where before the trial some approaches were flying level at 2500 ft, but after the commencement of the trial any level segments should be at 3000 ft or above. The effectiveness of the trial here was described in para 4.8, where the results indicated that the incidence of approaches at or below 2500 ft at 9 nm was reduced from 6.4% before the trial to 1.7% or less. Beyond 11 nm, out to a distance of about 17 nm, noise exposure in 1996 was also lower than in 1995.

7.16 Illustrating typical 'event' noise changes, Figure 40 shows the average SEL under the flight path along the extended runway centreline for straight-in

[27] This area includes parts of Putney, Fulham, Chelsea, Battersea and Clapham.

approaches of the B747-400. The figure compares the pre-trial and during-trial noise levels estimated from the actual profiles flown in the two periods. The 1996 levels are very similar to the pre-trial 1995 levels out to a distance of 9 nm from touchdown, but are up to 1.5 dBA SEL quieter at 10 nm and beyond[28]. These SEL reductions would equate to reductions of similar magnitude in L_{eq}(2-hr) if other aircraft types were affected similarly and if the traffic mix were unchanged before and after the trial, although it should be noted that the B747-400 was the dominant aircraft type in both the 'before' and 'after' trial samples (see Table 13).

7.17 This comparison shows that the trial did result directly in less noise at distances of 8 nm and more from touchdown, the benefit being up to 1.5 dBA. This confirms that a practical approach noise abatement procedure such as this can be effective. As shown later (paras 7.26 - 7.31), part of the improvement is attributable to a small increase in CDA achievement (even though CDA instructions were not changed for the trial). CDA might have the potential to deliver greater improvements at a distance of 9 nm from threshold and beyond if achievement rates could be further increased, within the scope of ATC and pilot constraints.

Before/After trial comparison: (c) effect of track and profile changes

7.18 Raising the minimum intercept height by 500 ft moves the latest glideslope join point outwards by 1.6 nm. This means that some aircraft will join the ILS localizer at greater distances from touchdown. A likely consequence is that, in order to maintain fully stabilized ILS approaches, ground track patterns of aircraft approaching the localizer will also tend to be displaced outwards to a similar extent. Figure 41(a) shows the overall effect of the trial on the B747-400 noise footprint, i.e. showing the combined effect of the changes in height profile and the changes in ground tracks. This figure has been produced by averaging the SEL noise contributions of all B747-400 approaches during the period 0400-0600, again comparing the January 1995 sample (pre-trial) against July/August 1996 (trial). The proportion of approaches on each runway in January 1995 has been scaled to be equal to the number in July/August 1996. The 75 dBA SEL contours are 'open-ended' because the available radar data did not extend far enough to be able to compute the contours beyond the end-points shown.

7.19 Because the contours are based on a relatively small number of actual tracks, it is important to be aware of the limitations of the modelling technique used here. If a single aircraft flew over a particular area in 1996, which no aircraft in the 1995 sample overflew, there would be a predicted increase in aircraft noise in that area of many decibels - though starting from a very low baseline noise level. The results are therefore very sensitive to the actual tracks included in the

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[28] covering locations such as Clapham, Battersea, Vauxhall, Westminster and Camberwell.

samples representing before and after the trial. Nevertheless, the results indicate that almost everywhere except the area around Lewisham and Blackheath (beyond the extremity of the 1995 75 dBA SEL contour - see Figure 41(a)), the noise exposure in 1996 was lower than before commencement of the trial in 1995. This is illustrated more clearly in Figure 41(b), which shows the areas where the noise exposure in 1996 was higher than in 1995 [29]. In all unhatched areas (the dotted area) there was a reduction or no change in noise levels in 1996 compared with the pre-trial base case. Close to the airport, all aircraft are on the glideslope so there is no difference in average noise levels. Any small differences close-in are the result of normal data scatter between two different samples of data, and are within the typical resolution of the modelling methodology. Because of this, it is not possible to indicate precisely where the transition from 'no change' to 'noise reduction' occurs, but Figure 40 indicates that under the flight path it is at a point approximately 8 nm from touchdown.

7.20 It is important to place changes in noise level in context with 'absolute' levels. In order to show differences within an area where aircraft noise can be represented reasonably reliably by contour modelling, the 'difference contours' for the B747-400 in Figure 41(b) are only shown within the envelope of a 1995 'baseline' 70 dBA SEL contour. The contour is truncated at the right-hand-side of the map, where noise levels cannot be calculated because available radar data did not extend further out. The 70 dBA SEL envelope in Figure 41(b) indicates that noise increased only in areas where the noise level is low; in contrast, in areas of higher noise level, noise levels fell during the trial.

7.21 As with many other practical noise abatement operating procedures, negative side-effects could also be observed. Because more aircraft were joining the ILS further from touchdown, there was an area near the join-points around Deptford, Lewisham and Blackheath where average aircraft noise levels increased. This is principally because more aircraft passed close by; previously there had been very few. The largest increase of average SEL within this area (which for the B747-400 was 77 dBA SEL or less) was just over 2 dB compared with the 1995 base. There was also a smaller area where noise levels increased, to the south-east of Clapham, although the maximum increase in this area was only 0.5 dBA SEL. Close in to the airport (out to approximately the region marked Brentford and Richmond), where all aircraft are established on the ILS, the trial causes no difference in noise levels. Everywhere else the noise level decreased, by more than 2 dBA SEL in some places.

7.22 The changes are shown in greater detail in Figures 41(c) and 41(d), for the areas between Richmond and Clapham, and between Clapham and Blackheath, respectively. These show the SEL difference contours for July-August 1996

[29] Within the 1995 B747-400 70 dBA SEL footprint, the lines which contain the hatched areas show the "contour of zero difference", i.e. where the B747-400 SEL noise levels computed for Figure 41(a) are equal in the 1995 and 1996 cases. Closer in to the airport, the 1996 levels were equal to or lower than those in the 1995 base case.

relative to January 1995 for the B747-400 approaches. But as well as showing the 0 dBA difference contour as in Figure 41(b), they also show other changes, ranging between 1 dBA increase (labelled "+1 dBA") to 2 dBA reduction ("-2 dBA"). As with Figure 41(b), only differences within the 1995 baseline 70 dBA SEL contour are shown. To show the impact on residential areas, the base maps indicate the approximate population density.

7.23 Figure 41(c) shows no areas where the noise levels increased as a result of the trial. Over all the area shown in this figure, there was either zero change (in the closer-in areas where all aircraft are established on the glideslope) or a small reduction in noise levels in 1996 compared with the 1995 base, i.e. a benefit as a result of the trial. (Because of the resolution of the modelling methodology, it is not possible to indicate where the transition from 'no change' to 'noise reduction' occurs.)

7.24 The hatched areas in Figure 41(d) show where the trial procedure resulted in noise increases relative to the pre-trial procedure. In all other areas there were reductions or no change, i.e. the current procedure caused the same or less noise than the pre-trial procedure. It is only the relative locations of the hatched and unhatched areas in these figures that are relevant; these show how, within the overall contour envelope, the increases and decreases of noise caused by the procedural changes were distributed and dispersed across areas of relatively high and low absolute exposures.

7.25 Figure 41(d) shows that further out most of the area again experienced a small reduction in noise levels in 1996, i.e. a benefit as a result of the trial. Two areas experienced an increase, which reached 2 dBA at the eastern edge of the map (it was not possible to compute noise levels beyond that point because of the limitations of radar coverage). The average population density within these areas where noise increases are shown is lower than in many of the areas where absolute noise levels are higher and where the trial has resulted in a reduction in noise levels.

Effect of CDA achievement

7.26 To assess the benefits of CDA it is necessary to take account of different approach power settings (e.g. comparing level flight and descent on the glideslope). This is done using 'noise-power-distance' (NPD) curves which, particularly for some approach conditions, are subject to limitations (see paras 7.4-7.5). Despite the uncertainties in this data, however, the NPD curves have established a lower limit of the noise effects, and therefore the noise benefit of CDA is unlikely to have been under-estimated.

7.27 Figure 42 shows the actual July/August 1996 L_{eq}(2-hr) contours as in Figure 38, from 48 dBA up to 63 dBA in 3 dBA steps (the fine contours). In this 'actual' case, about 50% of approaches used CDA - see Section 6. Superimposed on these for comparison (in bold) are the contours for the hypothetical case assuming that all those approaches used an idealised form of CDA. To determine the latter set of contours, the ground track of each flight was unchanged but the height profile was changed to descend at an angle of 3°. Any incidental effects that the use of CDA might have on ground tracks have been ignored for this comparison.

7.28 It may be seen that the use of CDA has a very small effect on the 54 dBA L_{eq}(2-hr) and higher contours; this is unsurprising as they close within 8 nm from touchdown. The small differences in these close-in contours (up to about 0.2 dBA) may be regarded as a random variation between two different samples of data, and are within the typical resolution of the modelling methodology. The benefits of CDA are felt further out, i.e. in lower level contours. Thus with full use of CDA the 48 dBA contour would be reduced in area by 12.6%. The 51 dBA contour is reduced in area by 3.6%.

7.29 The estimated effect of CDA on noise levels under the flight path along the extended runway centreline is illustrated in Figure 43, which shows the average SEL for straight-in approaching B747-400s. The benefit if all aircraft used CDA, compared with the current approximately 50% achievement rate, is shown to start at about 8.5 nm and reach 2 dBA SEL at 19 nm. These noise reductions are probably underestimates, due to the NPD data limitations referred to above.

7.30 When contrasting these noise benefits of CDA with the larger ones quoted in the 1970s reports (Refs 4 and 5), it must be noted that their bases are quite different. The earlier figures, namely L_{Amax} reductions ranging from 4 dBA at 9 nm to 9 dBA at 15 nm[30], related (a) all aircraft flying CDA and (b) all aircraft flying level at 3000 ft from 15 nm until glideslope intersection. In this study, the comparisons given above are between (a) all aircraft flying CDA and (b) the actual profiles flown in summer 1996. About 50% of the latter were already flying CDA - see Table 12 - and many of the remainder involved level segments higher than 3000 ft.

7.31 In theory, if all approaches achieved CDA (and followed unchanged tracks[31]), the revised early mornings trial procedure would not provide any additional noise benefit in any location, because any aircraft flying level segments - whether at 2500 ft, 3000 ft or higher - would be replaced by CDA approaches which would be both at a greater height and probably at a lower power setting.

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[30] The 1970s work revealed that CDA produces substantial noise benefits, estimated to be 4 dBA related to the aircraft's thrust, plus an additional height benefit of up to 5 dB, depending on the distance from touchdown (rising from 0 at 9 nm to 5 dBA at 15 nm). The thrust benefit was derived from noise measurements of a sample of different aircraft types, a large proportion of which were 'uncertificated' low by-pass ratio jet aircraft, i.e. pre-dating the ICAO Chapter 2 requirements (17% of the sample were Tridents, and other uncertificated aircraft types made up a further 25%-30%).

[31] If all approaches were able to achieve CDA, it is likely that the distribution of ground tracks would in fact have to change to some extent. However, 100% achievement of CDA is unlikely to be attainable in practice because of the need for ATC to ensure appropriate vertical separation.

Indeed 100% CDA would provide minimum noise.

Effect of track pattern

7.32 The noise consequence of extending the straight-in leg on the contour shapes may be seen in Figure 44 which compares the actual 1996 'all operations' case (as in Figure 38) with the (in bold) L_{eq}(2-hr) contours for just those flights which flew straight-in (i.e. joined the localizer more than 21 nm from touchdown). The numbers of straight-in operations have been scaled up to give the same numbers of landings of each aircraft type on each runway. The 1996 45 dBA L_{eq}(2-hr) contour is 'open-ended' because the available radar data did not extend far enough to be able to compute the contours beyond the end-points shown.

7.33 The results show that the straight-in contours are lengthened compared to the 'all operations' case, but the effect of extending the straight-in approach leg is predicted to be no more than 1 dBA L_{eq}(2-hr) increase in noise exposure at a distance of 18 nm on the extended runway centreline.

7.34 At 12 nm, concentration of tracks onto the extended runway centreline would appear to increase noise exposure levels by about 0.6 dBA L_{eq}(2-hr), compared with the summer 1996 (0400-0600) track pattern. The noise exposure increment on the extended runway centreline increases with distance from touchdown, but it is important to note that to the side of the centreline out to this distance there is a reduction in the numbers of overflights, and hence the noise exposure.

7.35 Table 14 shows, for January and June 1995, and for June 1996 and July 1997[32], the percentages of approaches established on the localizer at 11 nm from touchdown. This indicates that, within the limits of the available radar data coverage, there was overall little difference in ground track concentration close to the extended runway centreline before and after commencement of the trial.

[32] monthly samples taken (in the case of June and July data) as representing the summer period of each year.

Table 14: Percentage of approaches established on the localizer at 11 nm from touchdown, 0400-0600

Month	Runway	Percentage of approaches established on localizer at 11 nm from touchdown
January 1995 (pre-trial)	27L 27R All Westerly	86% 78% 84%
June 1995 (pre-trial)	27L 27R All Westerly	77% 86% 78%
June 1996 (during trial)	27L 27R All Westerly	79% 80% 79%
July 1997 (during trial)	27L 27R All Westerly	80% 86% 82%

7.36 Table 14 shows that over the three years considered there was no discernible change in the proportion of approaches established on the localizer at 11 nm; the trial procedure thus had little or no effect on the distribution of ground tracks at the extremity of the 1995 NTK radar coverage area.

Night-time runway alternation trials

7.37 Para 5.28 referred to the night-time runway alternation trials conducted in 1996 and 1997. In addition to providing alternating weekly periods of lower and higher noise exposure, a result of alternation is that the long-term average exposures tend to be more evenly distributed between the areas beneath the two approach paths. In fact Table 15 shows that, in the absence of night alternation, there were about twice as many landings on runway 27L as on 27R. Thus a consequence of alternation was a decrease in exposure in areas beneath the approach to 27L, and an increase beneath the approach to 27R. The changes are estimated from the figures in Table 15 to be slightly more than 1 dBA. At locations such as Greenwich, displacement of some approaches from runway 27L to 27R is likely to influence noise exposure more than the early mornings landings procedure trial. Because more aircraft are flying 'straight-in' approaches, changing the arrival runway has a more significant effect on noise exposures at large distances than later in the day.

Table 15: Runway utilisations 0400-0700 during night runway alternation trial periods and comparison periods

(Periods of the Night Runway Alternation trials are shown shaded.)

Period analysed		Night runway alternation trial	% of westerly approaches		% of all approaches
Start date	End date	in progress?	27L	27R	Easterly
01/01/1996	31/03/1996	No	65%	35%	58%
01/04/1996	30/06/1996	No	70%	30%	29%
01/07/1996	30/09/1996	No	67%	33%	28%
01/10/1996	27/10/1996	No	68%	32%	11%
28/10/1996	31/12/1996	Yes	59%	41%	32%
01/01/1997	16/03/1997	Yes	56%	44%	33%
17/03/1997	31/03/1997	No	85%	15%	8%
01/04/1997	15/06/1997	No	76%	24%	34%
16/06/1997	30/06/1997	Yes	48%	52%	21%
01/07/1997	30/09/1997	Yes	57%	43%	31%
01/10/1997	25/10/1997	Yes	40%	60%	30%
26/10/1997	31/12/1997	No	56%	44%	32%
01/01/1998	28/02/1998	No	66%	34%	16%
Average of all days analysed		Yes	55%	45%	23%
		No	66%	34%	17%

8 CONCLUSIONS

Early Mornings Landings Trial

8.1 Analysis of NTK data has shown that overall compliance with the early mornings landings trial procedures - not descending below 3000 ft before 10 nm from touchdown, and not intercepting the extended runway centreline later than 10 nm from touchdown - was good and reached 96% in 1997.

8.2 The effectiveness of the early mornings landings trial procedure was assessed in terms of increases and decreases in noise levels in the various areas directly affected, and of any consequential effects elsewhere. The noise level changes were estimated using the ANCON noise model which is considered reliable for the purpose. Three different 'before and after' noise contour comparisons have been made:

(a) L_{eq}(2-hr) contours based on actual traffic, tracks and profiles;

(b) contours of average Sound Event Level (SEL) for straight-in approaches of Boeing 747-400s only; and

(c) SEL contours averaged over all B747-400 approaches, along both straight and curved tracks.

8.3 These comparisons are special applications of contour methodology, and they must be interpreted accordingly. These contours cover only westerly approaches in just the two hours 0400-0600; the conventional annual L_{eq}(16-hr) contours cover all traffic, arrivals and departures, on the average summer day 0700-2300. The 16-hour contours extend down to 57 dBA; these special contours extend to very low levels: 45 dBA L_{eq}(2-hr) for exposures and 70 dBA SEL for events. The latter corresponds to about 60 dBA L_{Amax} - too low to be measured reliably by the airport's NTK monitors. Although quite audible outdoors in quiet areas, such aircraft noise events would tend to be masked by any local road traffic noise. Many sounds with levels of 60 dBA L_{Amax} and above, both natural and man-made, are commonplace in suburban environments. Indoors, they would be attenuated to the range 30-50 dBA L_{Amax}.

8.4 Comparison (a) indicated what people would have heard: there were marked improvements during the trial, but part of these were due to a reduction of traffic in July 1996 in the period 0400-0600. Comparison (b) eliminated the confounding effects of changes to traffic levels, aircraft type mixes and ground tracks; i.e. it showed only the effects of the descent profile changes. Comparison (c) additionally accounted for the effects of ground track differences, one of which was a tendency for aircraft to align with the ILS localizer further from the runway.

8.5 Comparison (b) showed that between 0400 and 0600, there was a reduction in average noise levels as a direct result of the revised procedure. For the area between 9 nm and 10 nm from touchdown, this was estimated to be up to 1 dBA SEL. Noise levels beyond, out to a distance of about 17 nm, were also reduced as a result of the trial, by about 1.5 dBA on average.

8.6 Part of the improvement is attributable to a small increase in the rate of CDA achievement (even though CDA instructions were not changed for the early mornings landings trial). CDA might have the potential to deliver greater improvements at a distance of 9 nm from threshold and beyond if achievement rates could be further increased, within the scope of ATC and pilot constraints.

8.7 CDA provides no benefit within the 54 dBA L_{eq}(2-hr) contour (about 8 nm from touchdown), because virtually all aircraft are established on the glideslope within this range. It is cautiously estimated that at distances beyond 8 nm, the benefit of increasing the achievement rate of CDA to 100% from the observed value of around 50% would rise to about 2 dBA L_{eq}(2-hr) at 19 nm. This is probably an underestimate due to limitations of the noise-power-distance data used. Of course, if all approaches achieved full CDA (following unchanged tracks[33]), the trial descent procedure would be irrelevant; it could not provide any additional noise benefit as there would be no level segments - all approaches would be at both maximum heights (dictated only by the glideslope) and low power settings.

8.8 During the trial, between 0400 and 0600, changes in ground tracks resulting from the tendency for aircraft to join the localizer further out than previously led to some redistribution of noise exposure. Although comparison (c), of average SEL contours for the B747-400, indicated an overall reduction in noise levels nearly everywhere near the westerly approach path, there were some negative side-effects. These occurred in the Deptford/ Lewisham/ Blackheath areas, where levels are estimated to have increased by up to about 2 dBA SEL, and in a small area near Clapham where the maximum increase was 0.5 dBA SEL. These areas were relatively small and were near the extremities of the low level contours. By contrast the benefits extend over tens of square kilometres, and into areas with higher population densities and where the average event levels are up to 15 dBA higher.

8.9 A number of factors which characterised approach operations during the trial were also examined:

- **Comparison of mean heights on approach**. The mean height differences are less than the appropriate height tolerances. There is thus no evidence that the trial resulted in any differences in mean heights on approach.

[33] If all approaches were able to achieve CDA, it is likely that the distribution of ground tracks would in fact have to change to some extent. However, 100% achievement of CDA is unlikely to be attainable in practice because of the need for ATC to ensure appropriate vertical separation from other traffic.

- **Variation in compliance rates between holding stacks.** There is no marked difference in the rates of trial procedures compliance for aircraft arriving via different holds.
- **Time of day effects.** Differences in mean vertical profiles between nominal night and day time periods were less than the appropriate height tolerances and are not regarded as important.
- **The use of path stretching manoeuvres.** The use of path stretching manoeuvres has been shown to increase after 0600, commensurate with the increased traffic density.
- **Distance to localizer and glide path intercept points.** There was a clear tendency in the early part of the morning (0400-0600) for approaches to join the ILS further out than approaches after 0600.
- **Comparison of easterly and westerly approaches.** Differences between the height profiles of the three runways considered (27L, 27R and 09L) were less than the appropriate height tolerances and are not regarded as significant.
- **Seasonal effects.** There was no evidence of any differences in the vertical profiles or patterns of ground tracks between summer and winter.
- **AIP requirements.** The results showed clearly that aircraft are complying with the requirements not to descend below an altitude of 2500 ft before intercepting the glidepath, or to fly below the glidepath thereafter.

Continuous Descent Approach (CDA)

8.10 Rates of achievement of CDA during the early morning period in 1996 were found to lie between 33% and 59%, compared to 54% found in a 1978 daytime study.

8.11 Change to CDA procedures was not a requirement of the early mornings trial. The CDA achievement rate between 0400 and 0600 in January 1995, i.e. before the commencement of the revised trial procedure, was between 27% and 43%. During the period of the early mornings landings trial, the rate of achievement in January 1996 was similar (between 33% and 45%), although the rate was nearer to 50% in June 1996 and January 1997.

8.12 Achievement of CDA appeared to vary slightly depending on which hold had been used; arrivals from the holds at Lambourne and Biggin achieved higher rates than those from Bovingdon and Ockham.

8.13 Achievement of CDA tended to be slightly higher in summer than in winter, but there was no apparent relationship between the achievement of CDA and traffic density during the period of observation (0400-0800).

8.14 Estimates of the minimum noise benefit, comparing 100% achievement with the current observed achievement rates of CDA, range from 0 dBA at 8.5 nm from touchdown up to 2 dBA SEL at 19 nm.

Night-time runway alternation

8.15 After the commencement of the early morning landings trial, separate trials of night-time runway alternation were conducted independently by HAL. These did not have a discernible effect on vertical profiles, but produced marked changes of noise exposure during the early morning period due to displacement of some approach paths from runway 27L to 27R. At locations such as Greenwich, such effects upon noise exposure are likely to be more consequential than those of the early mornings landings trial procedure.

Further studies

8.16 The possibility of further analyses investigating the effects of various factors on approach noise is currently being considered by the Arrivals Working Group of the DETR's Aircraft Noise Monitoring Advisory Committee (ANMAC).

9 REFERENCES

1 Night Flying restrictions at Heathrow, Gatwick and Stansted Winter 1995-6 to Summer 1998: Department of Transport: Press Notice 252: 16 August 1995.

2 Aeronautical Information Publication (Chapter AD2-EGLL): 1 January 1998.

3 Manual of Air Traffic Services (MATS) Part 2: NATS.

4 A Technical Evaluation of Initial Trials of Quieter Approach Procedures at London (Heathrow) Airport - Summary Report: CAA Paper 78002: February 1978.

5 The Noise Benefits Associated with Use of Continuous Descent Approach and Low Power/Low Drag Approach Procedures at Heathrow Airport: CAA Paper 78006: April 1978.

6 Integrated Noise Model (INM) Version 5.1 User's Guide: Federal Aviation Administration: FAA-AEE-96-02: December 1996.

FIGURE 1

HEATHROW STACKS AND STARS

(Stacks, or holds, are the 'race-track' oval shapes. STARs (Standard Arrival Routes) are the tracks shown converging on each stack. Routes from the stack to the runway are as directed by Terminal Control, LATCC.)

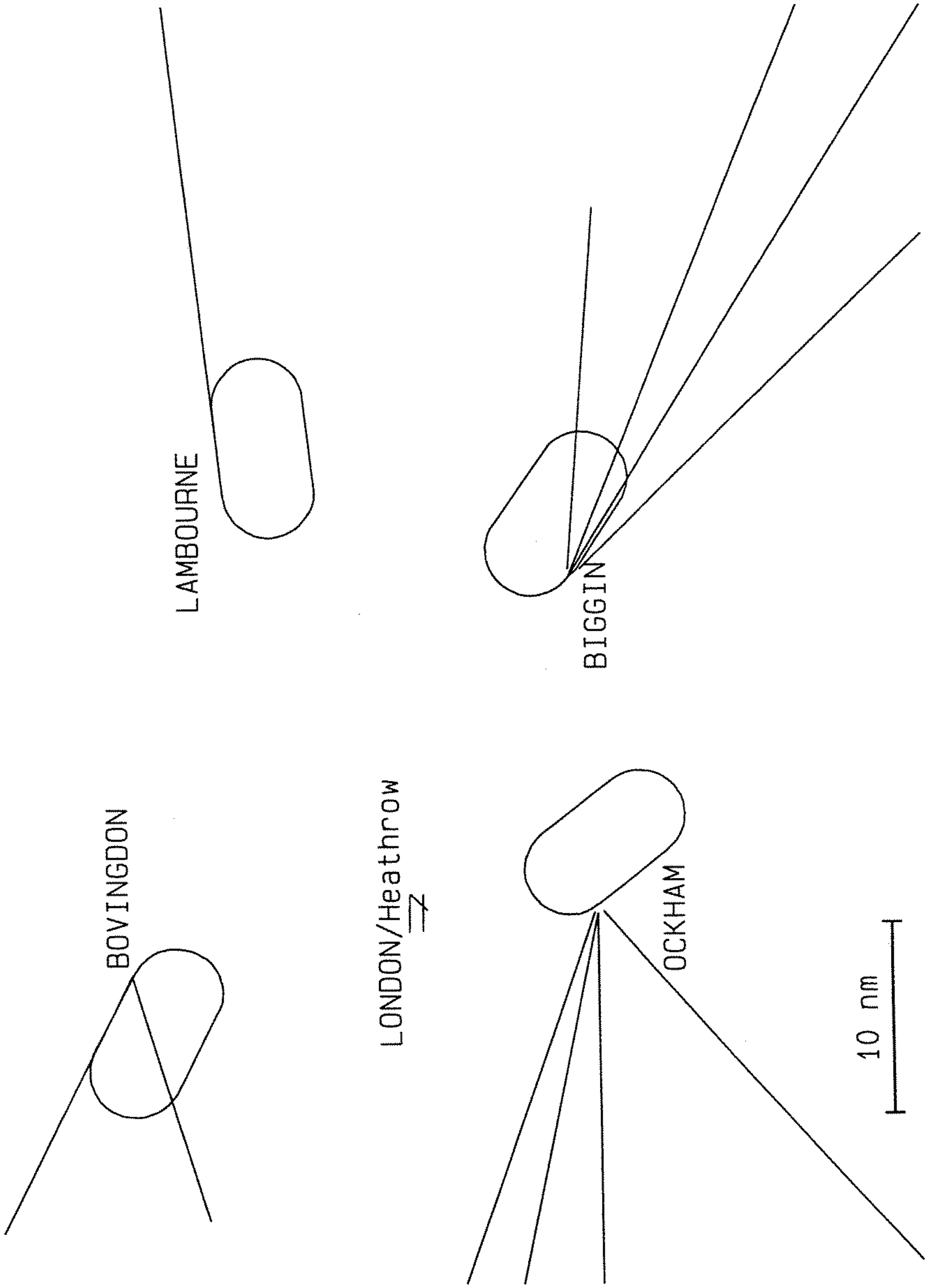


FIGURE 2
TYPICAL APPROACH TRACKS (0500-0600) AND NON-CDA HEIGHT PROFILE

Figure 2(a)

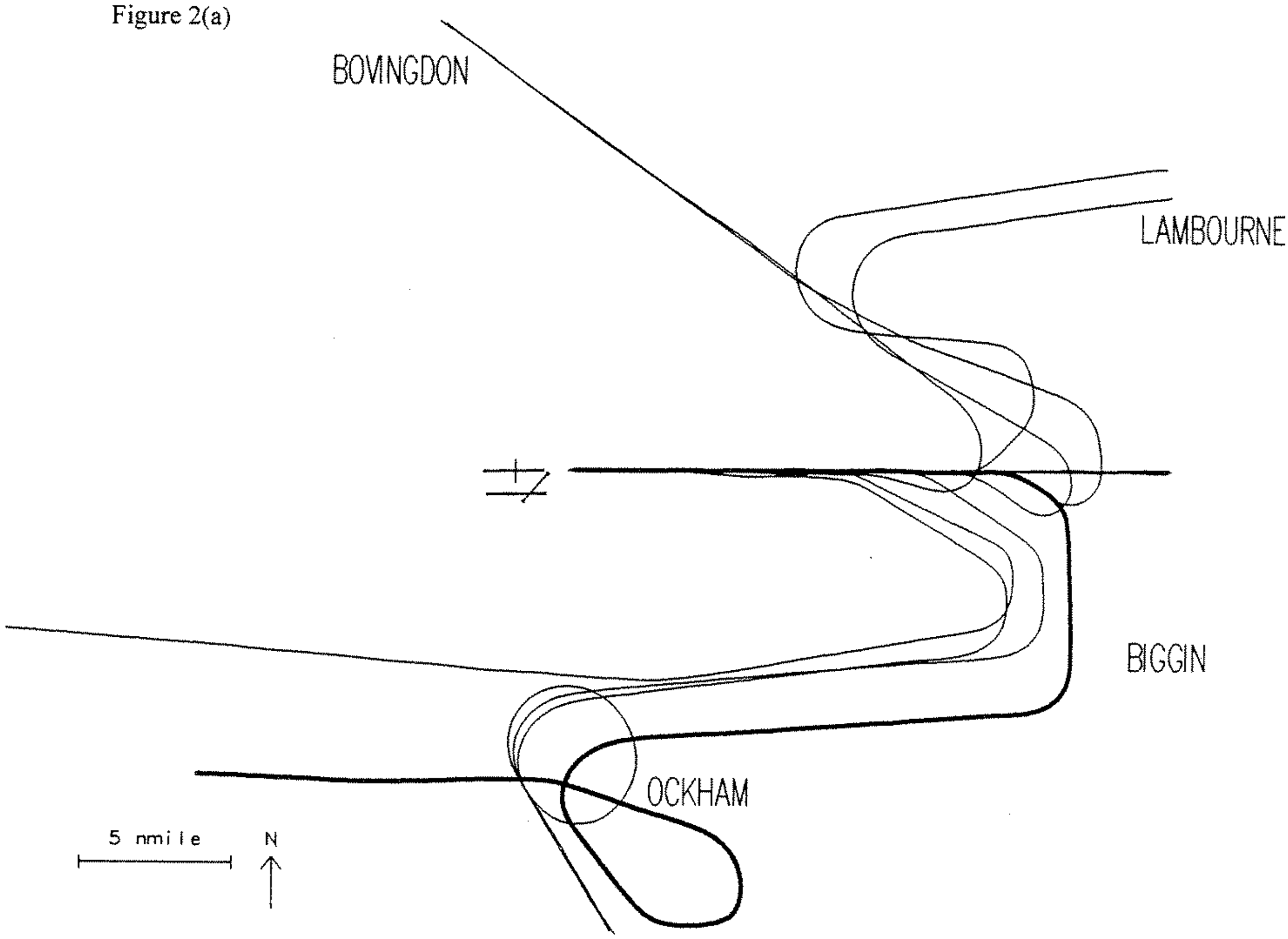


Figure 2(b)

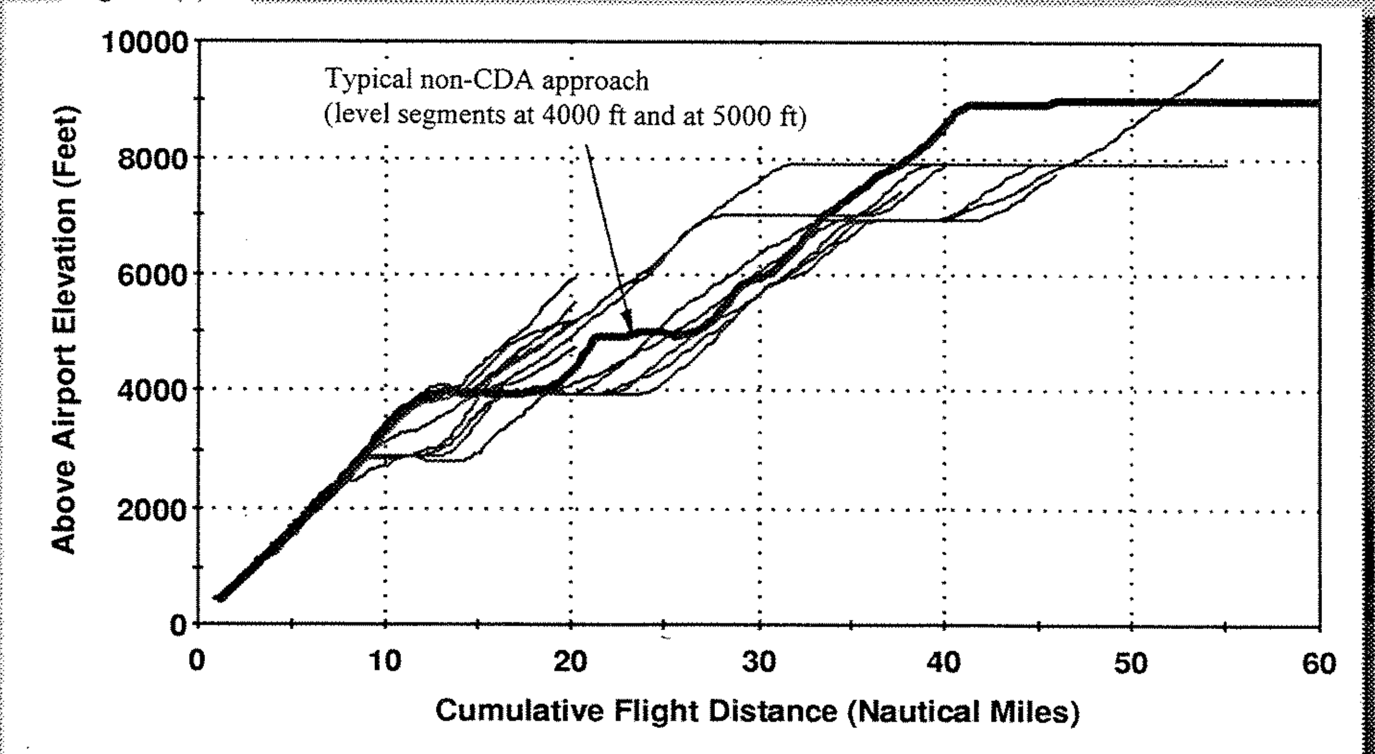


FIGURE 3
TYPICAL APPROACH TRACKS (0500-0600) AND CDA HEIGHT PROFILE

Figure 3(a)

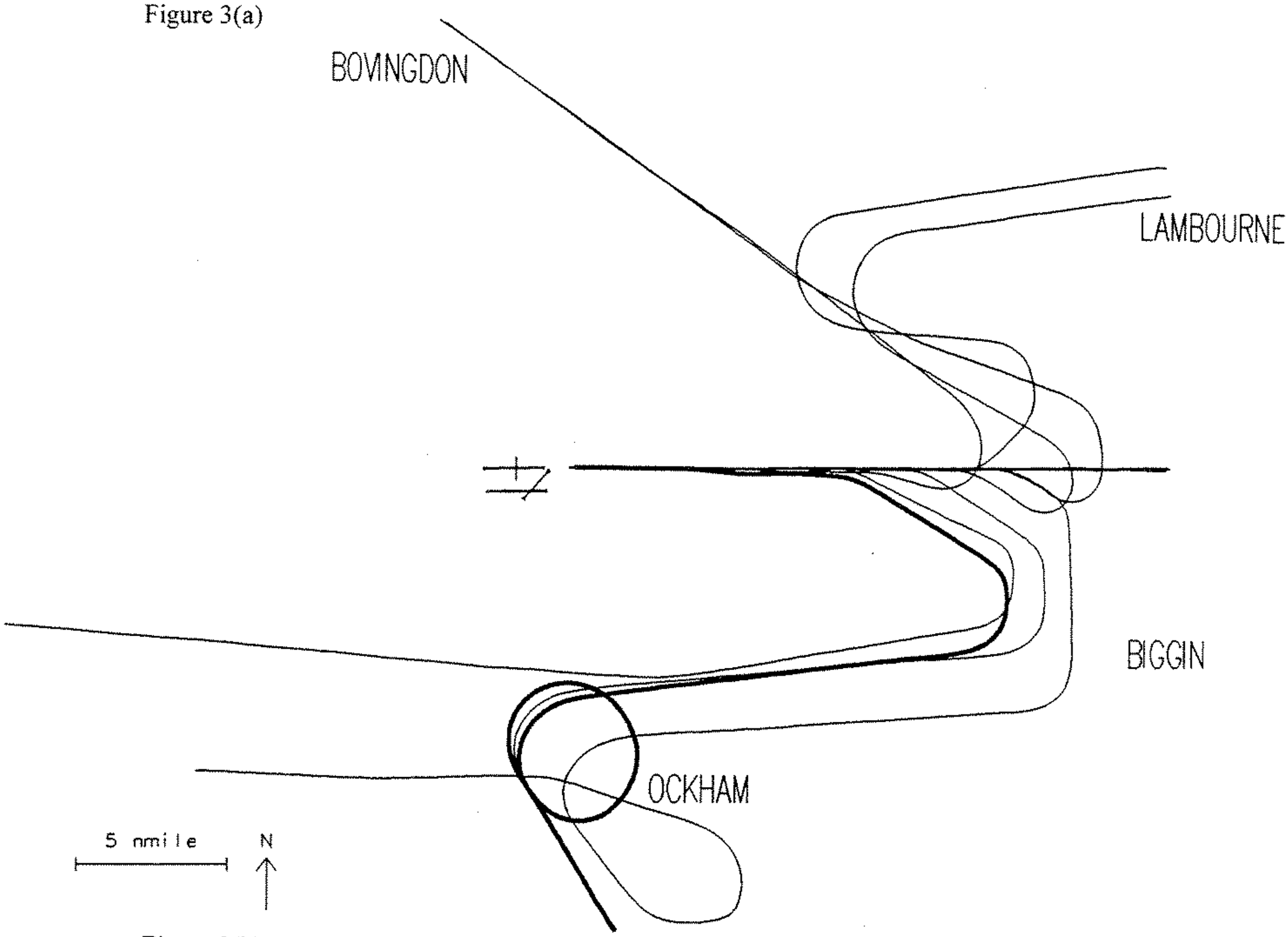


Figure 3(b)

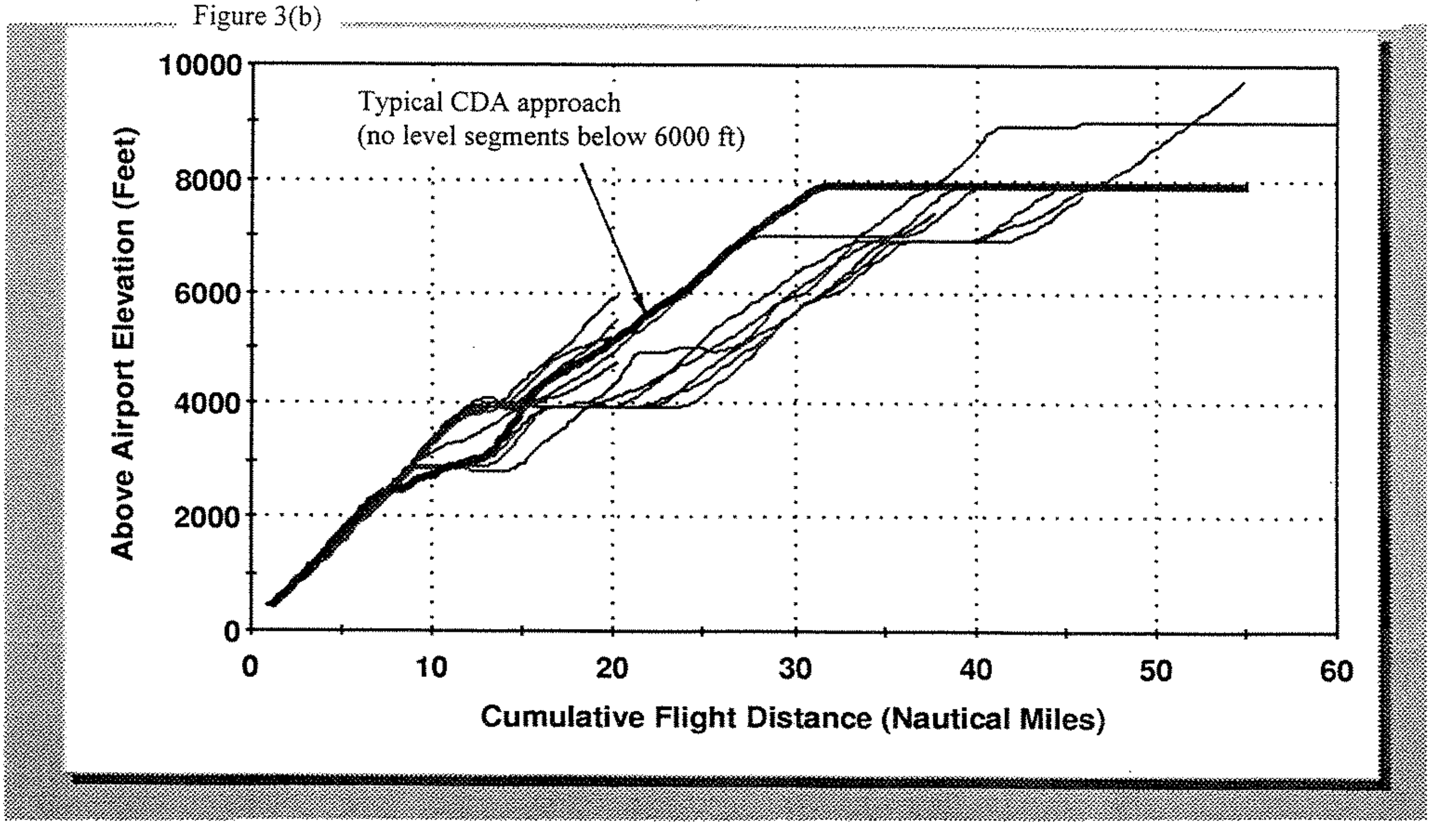


FIGURE 4

TYPICAL APPROACH TRACKS (0800-0900)

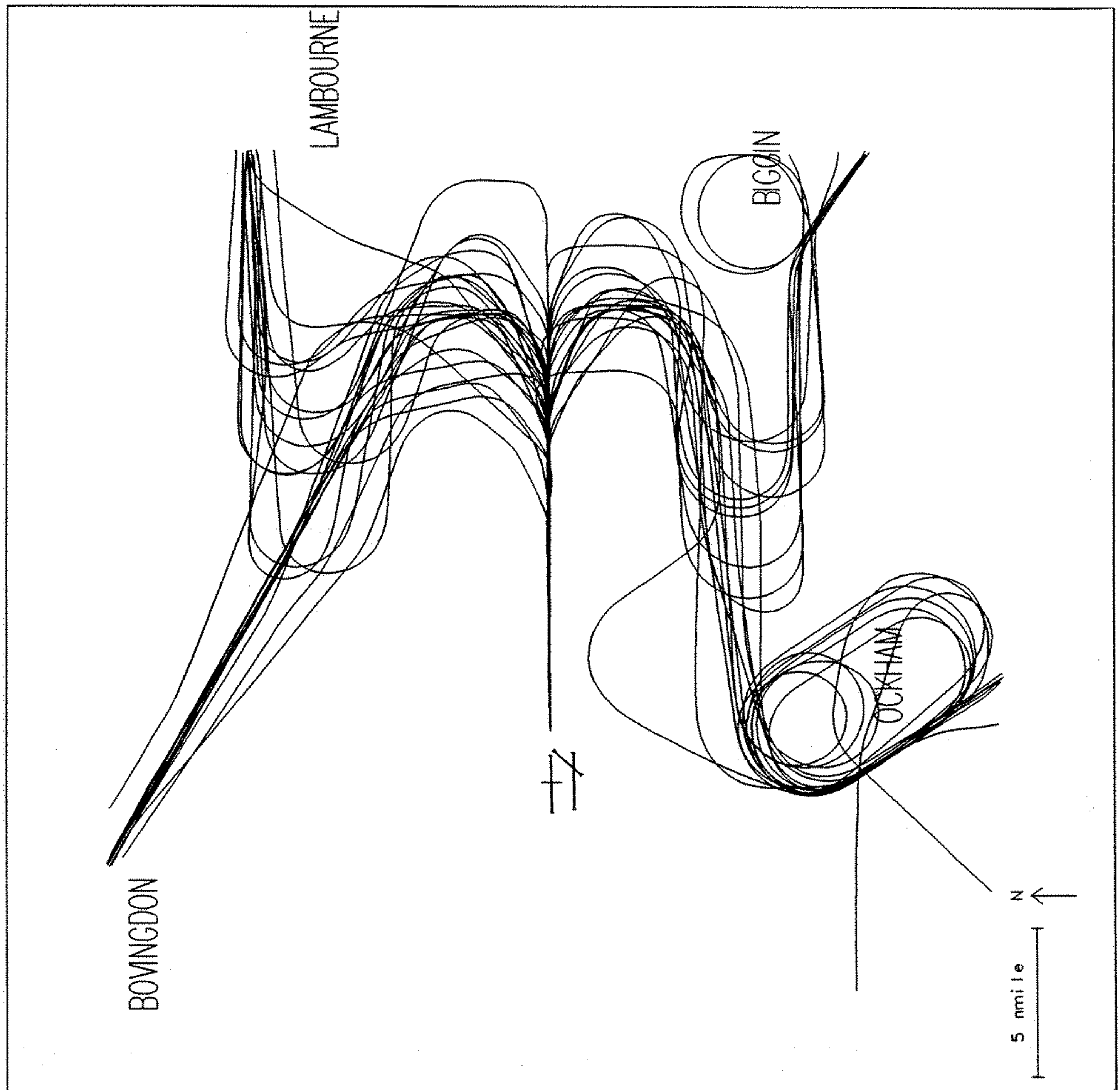


FIGURE 5

TYPICAL SEQUENCING OF ARRIVING AIRCRAFT

Notation for each aircraft:
aircraft type (IATA code)
height (ft)
groundspeed (kt)

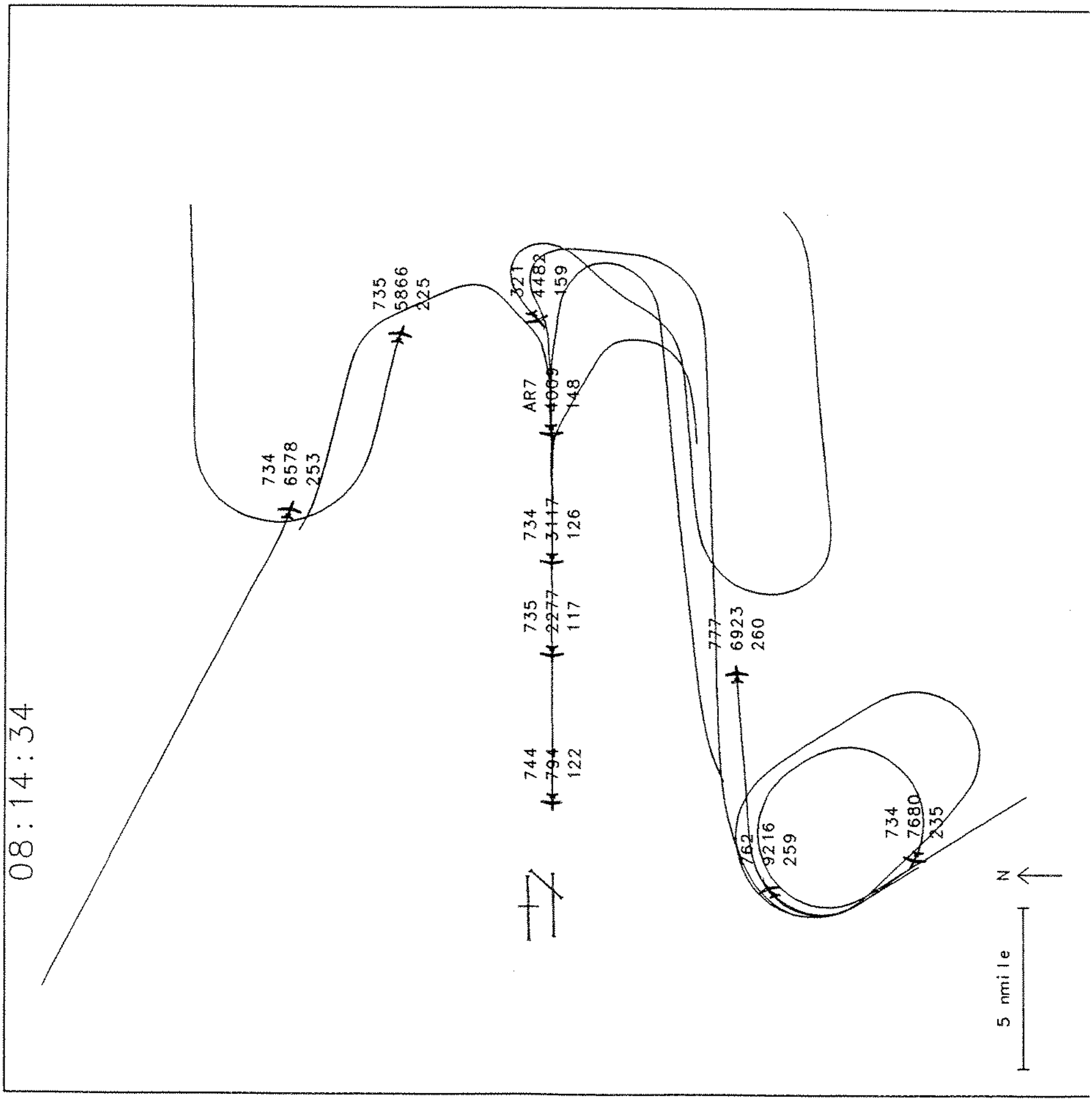


Figure 6a: Runway 27L, 7 nm from touchdown, June 1995, 0400 to 0600 (local time)

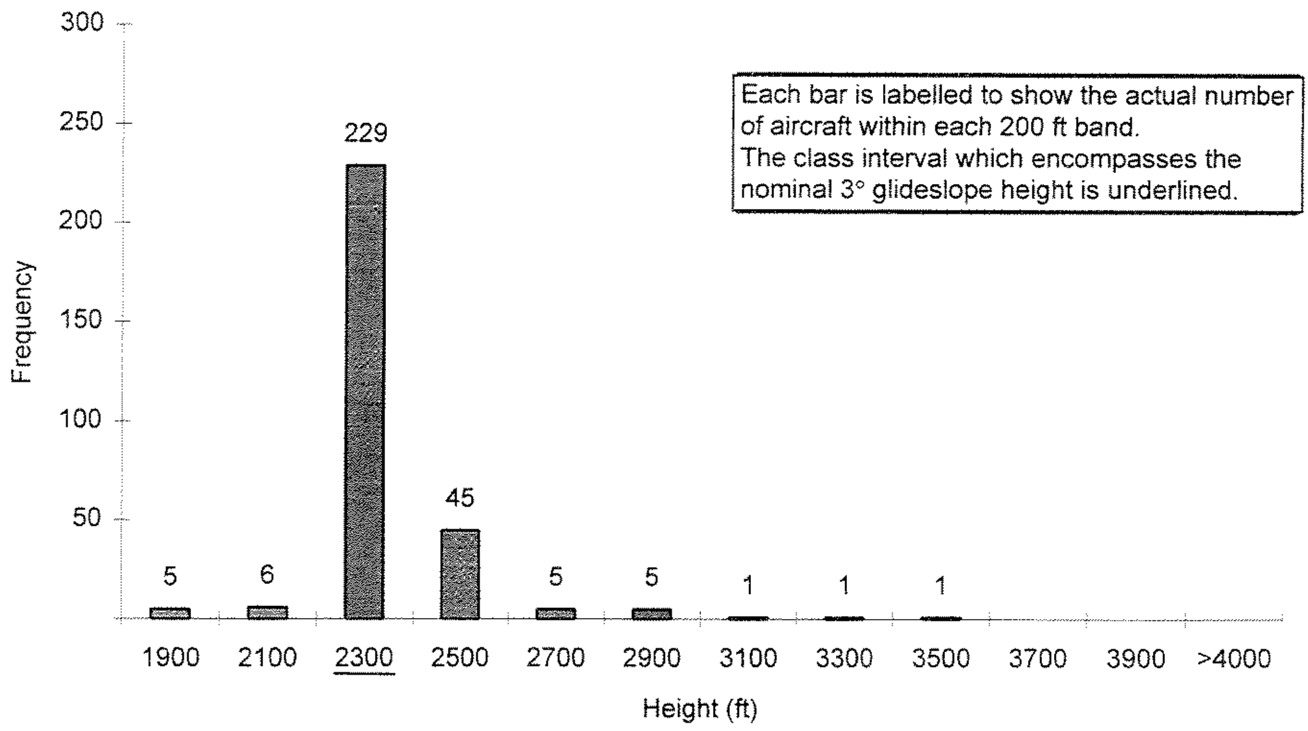


Figure 6b: Runway 27L, 8 nm from touchdown, June 1995, 0400 to 0600 (local time)

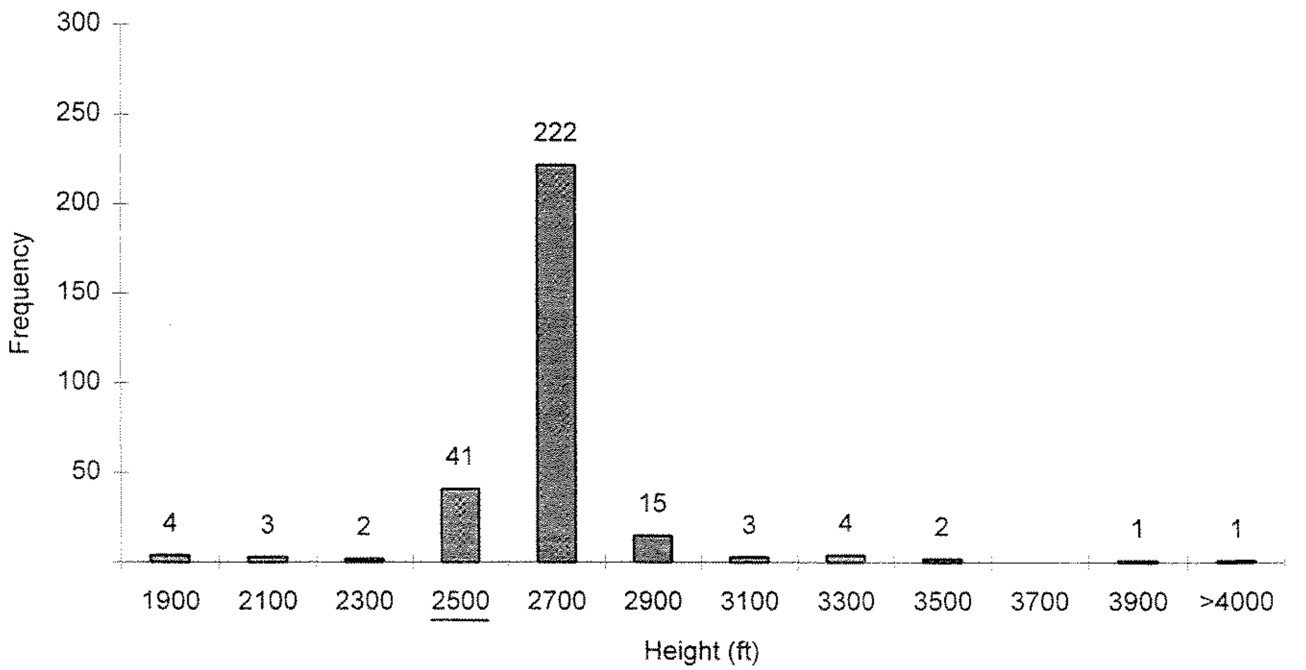


Figure 6c: Runway 27L, 9 nm from touchdown, June 1995, 0400 to 0600 (local time)

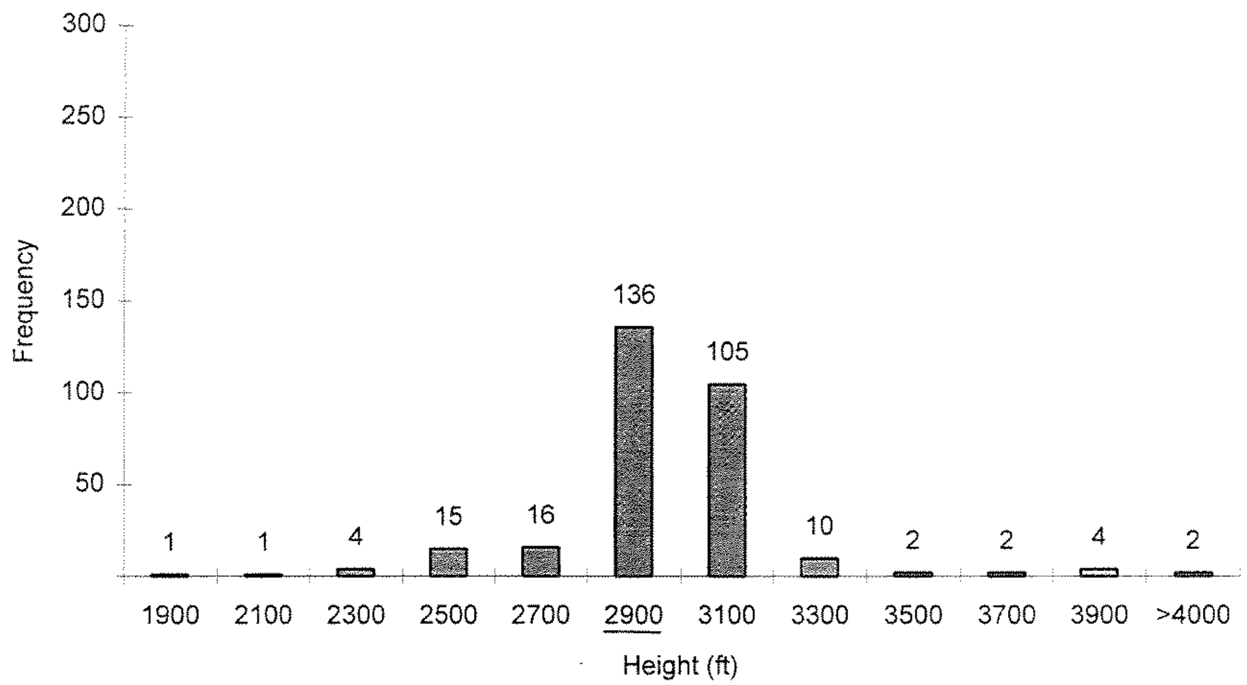
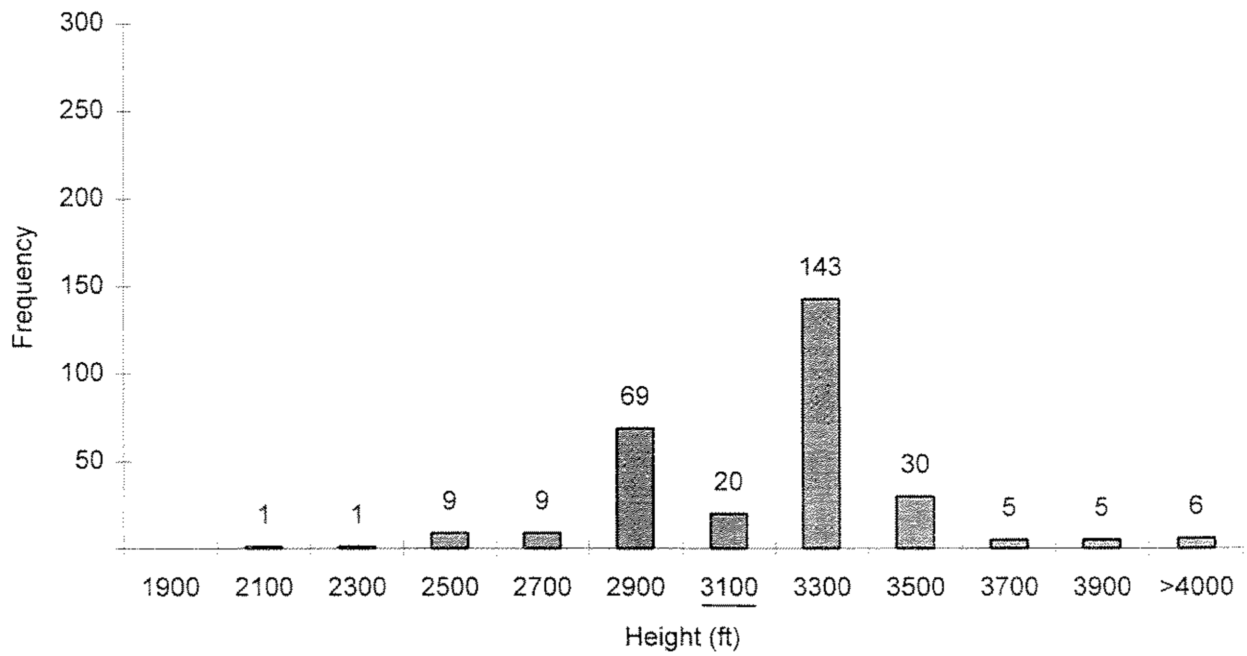


Figure 6d: Runway 27L, 10 nm from touchdown, June 1995, 0400 to 0600 (local time)



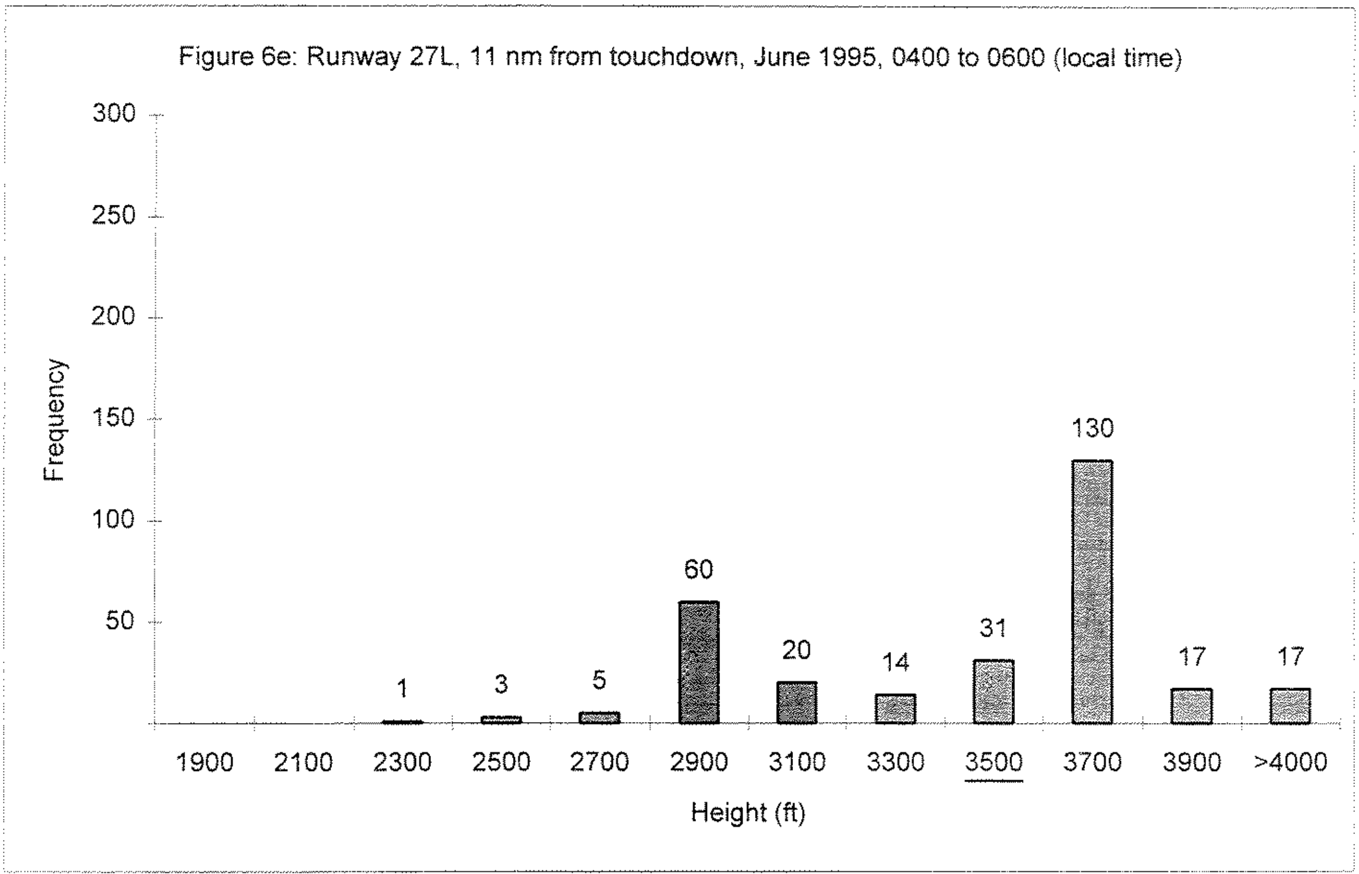


Figure 6e: Runway 27L, 11 nm from touchdown, June 1995, 0400 to 0600 (local time)
Frequency
300
250
200
150
100
50
1
3
5
60
20
14
31
130
17
17
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

Figure 6f: Runway 27R, 7 nm from touchdown, June 1995, 0400 to 0600 (local time)

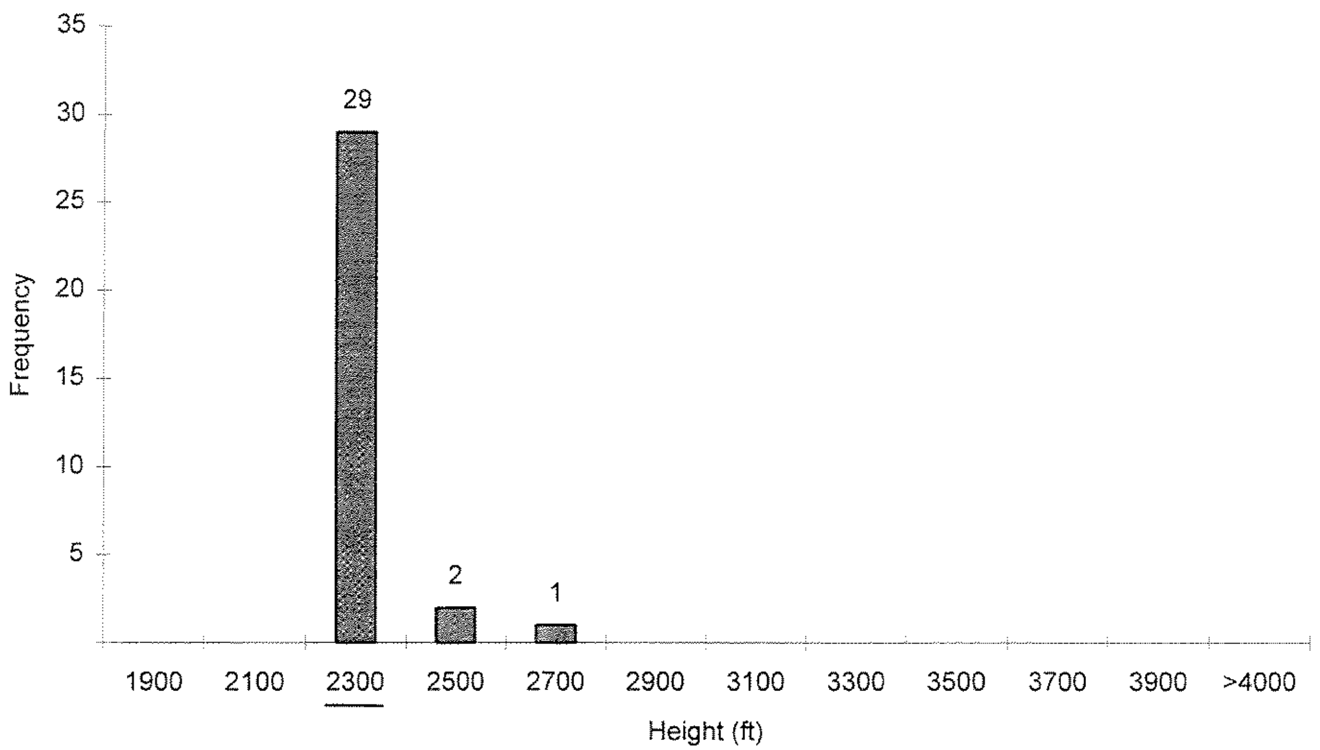


Figure 6g: Runway 27R, 8 nm from touchdown, June 1995, 0400 to 0600 (local time)

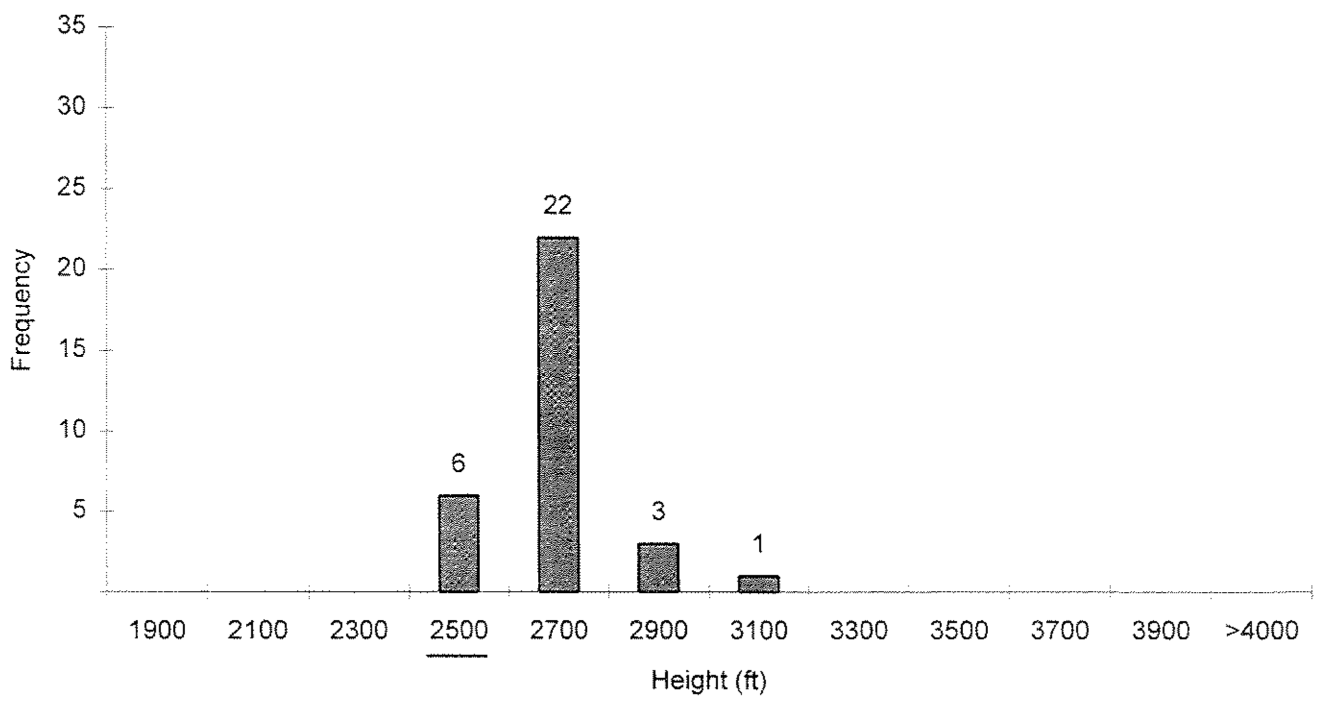


Figure 6h: Runway 27R, 9 nm from touchdown, June 1995, 0400 to 0600 (local time)

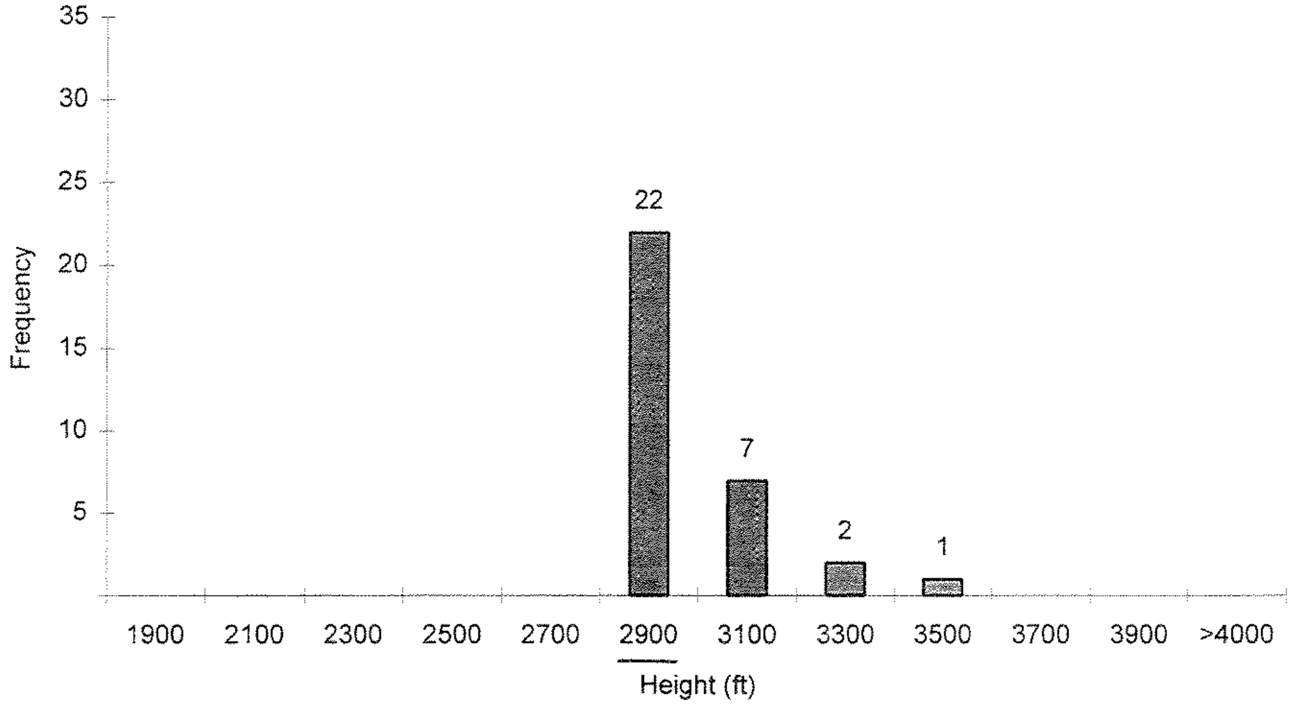
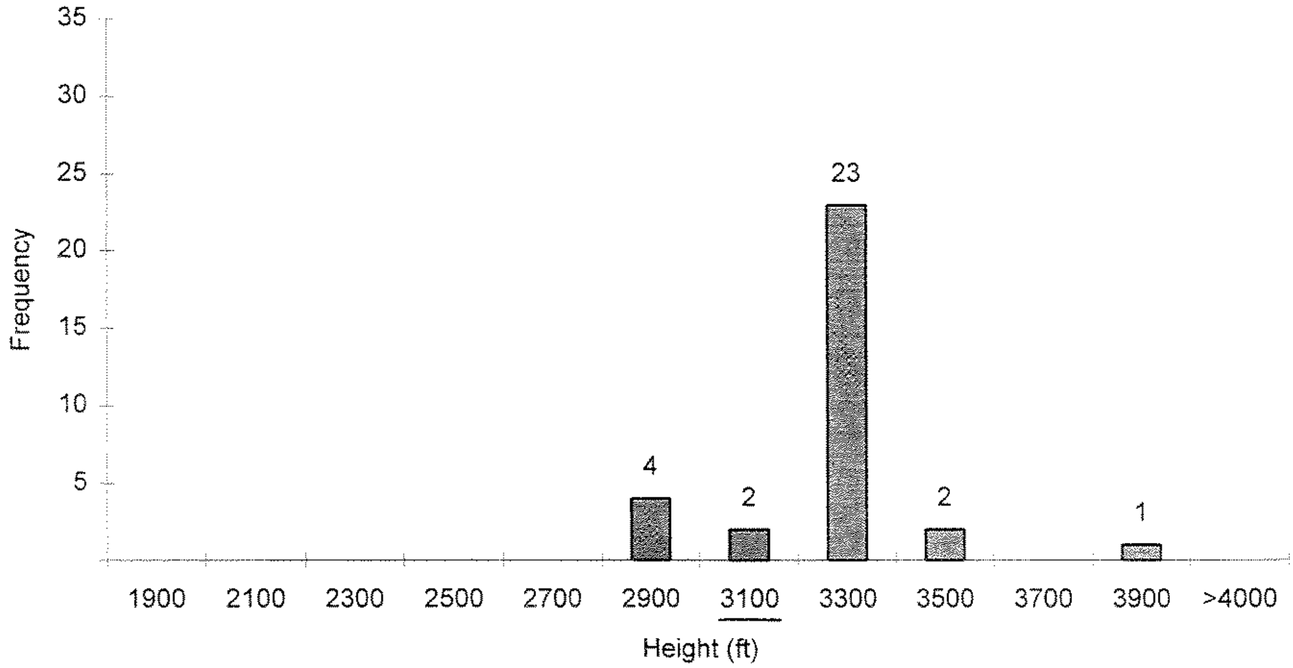


Figure 6i: Runway 27R, 10 nm from touchdown, June 1995, 0400 to 0600 (local time)



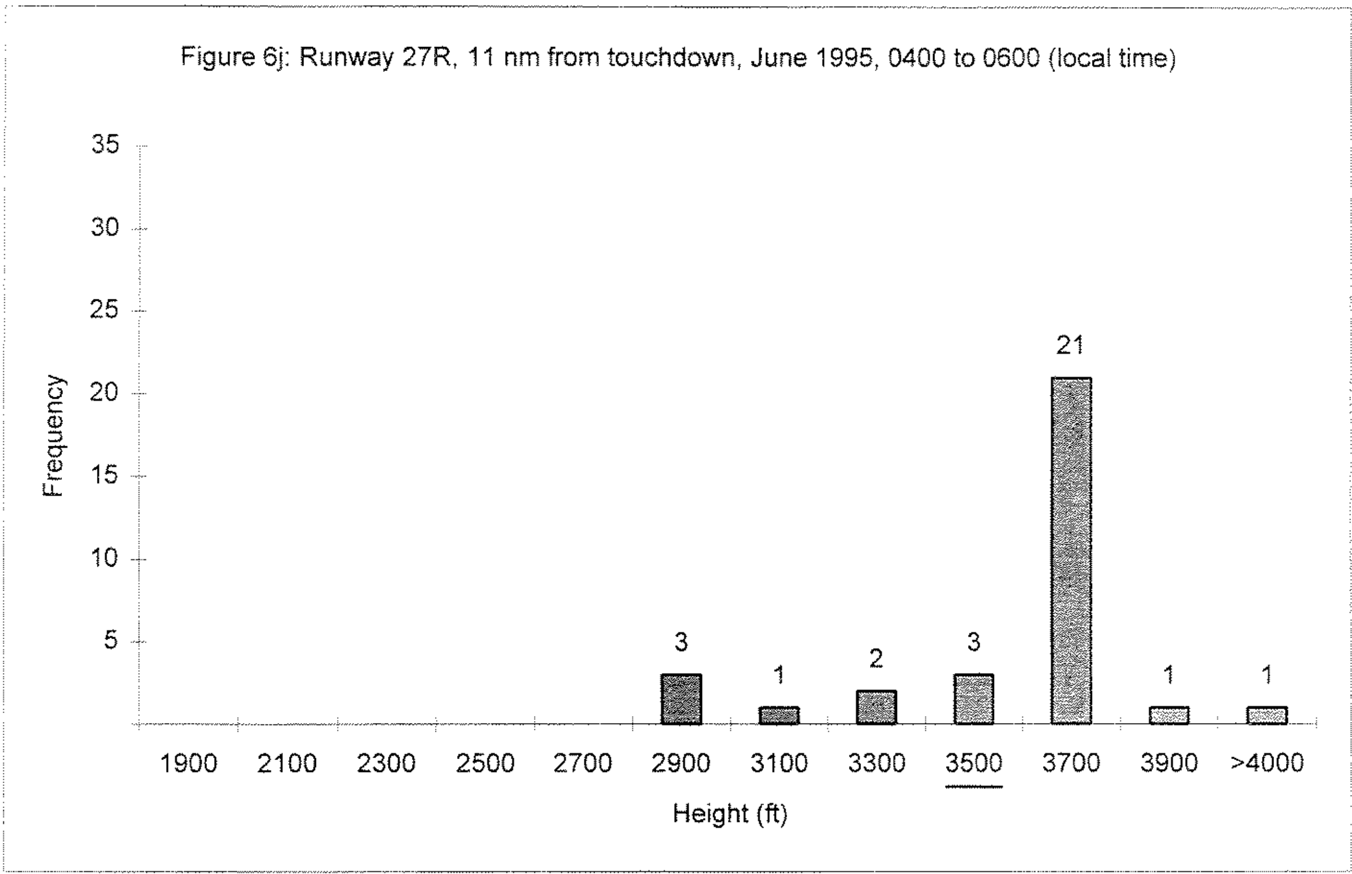


Figure 6j: Runway 27R, 11 nm from touchdown, June 1995, 0400 to 0600 (local time)
35
30
25
20
15
10
5
Frequency
21
3
1
2
3
1
1
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

Figure 6k: June 1995, 27L radar tracks, 0400-0600 local time

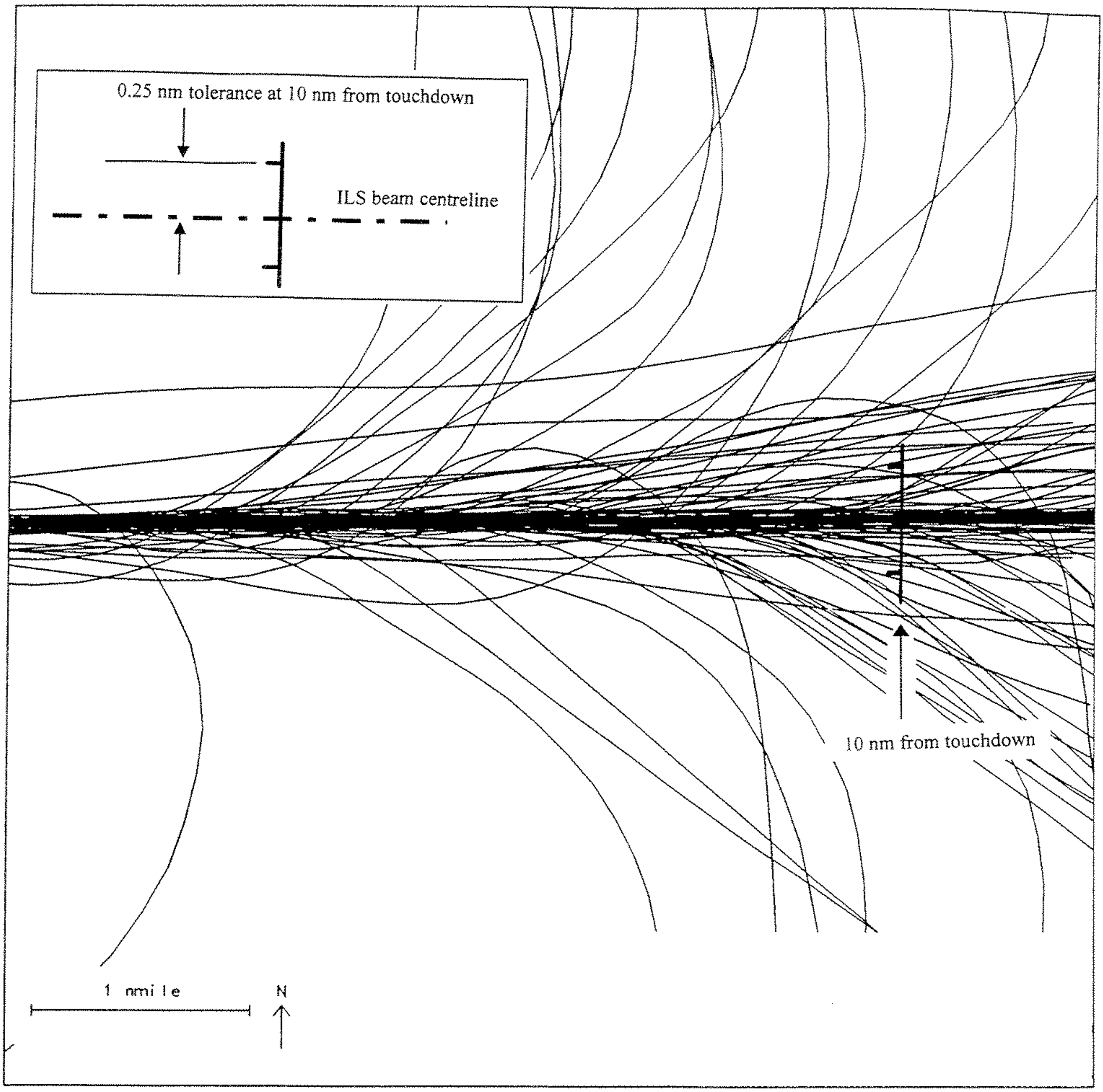


Figure 6l: June 1995, 27R radar tracks, 0400-0600 local time

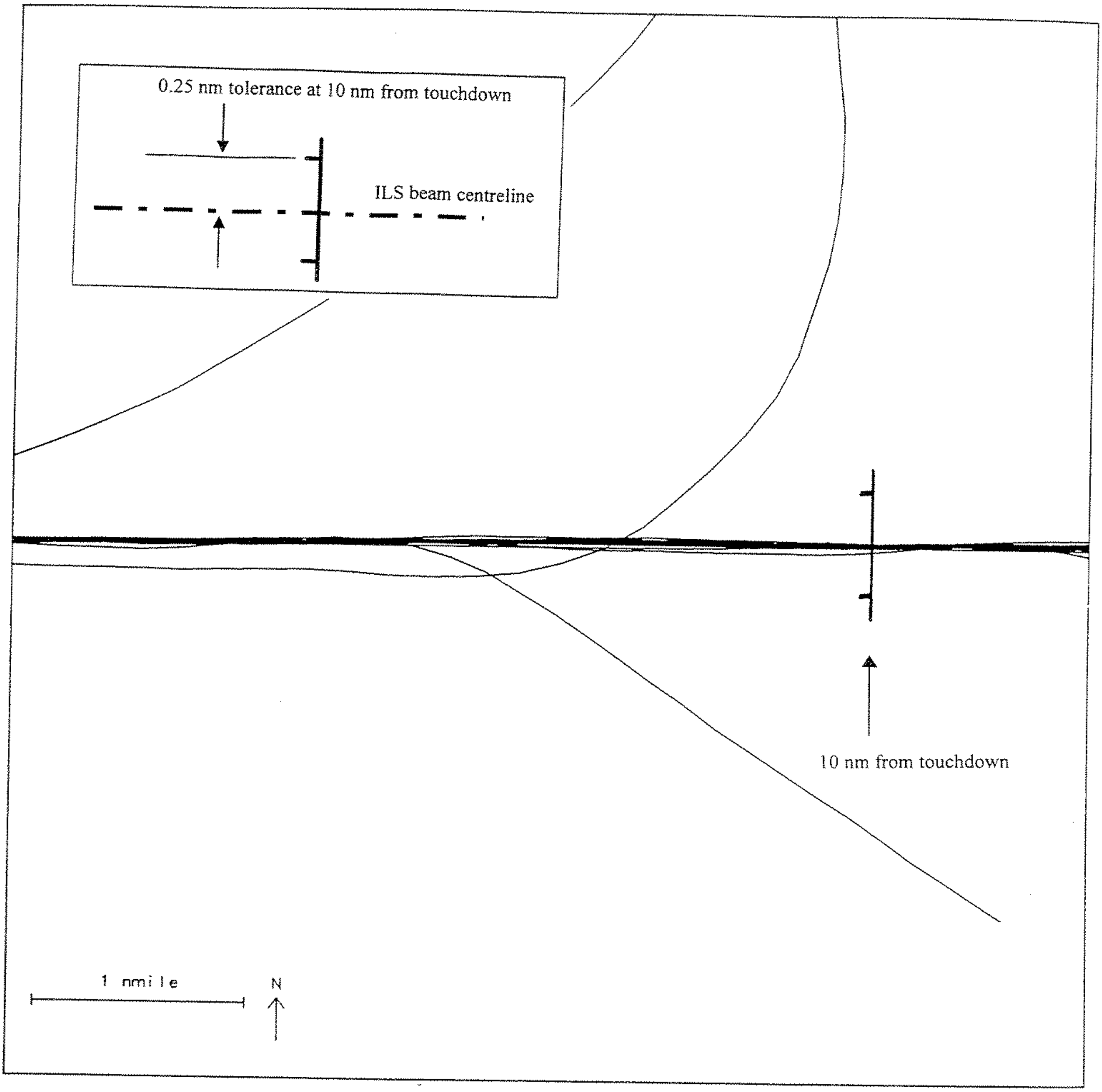


Figure 7a: Runway 27L, 7 nm from touchdown, January 1996, 04:00 to 06:00 (local time)

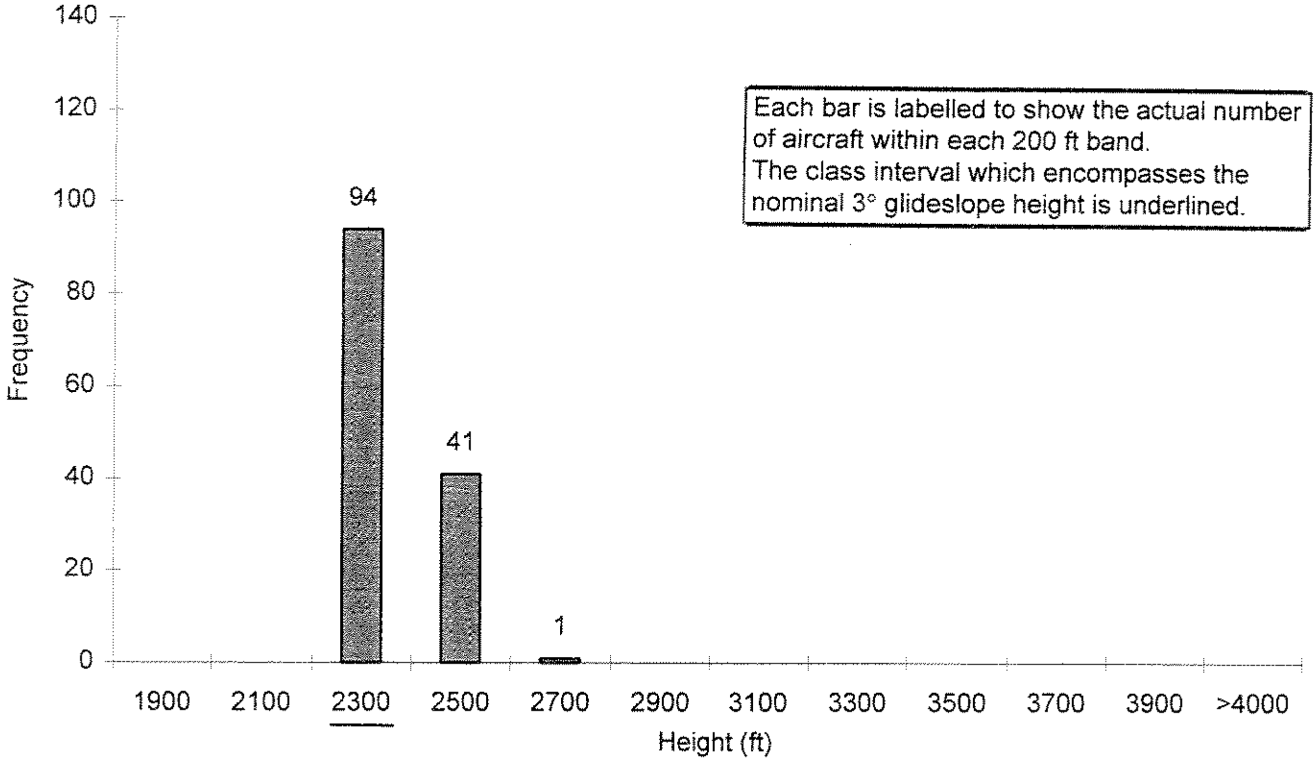
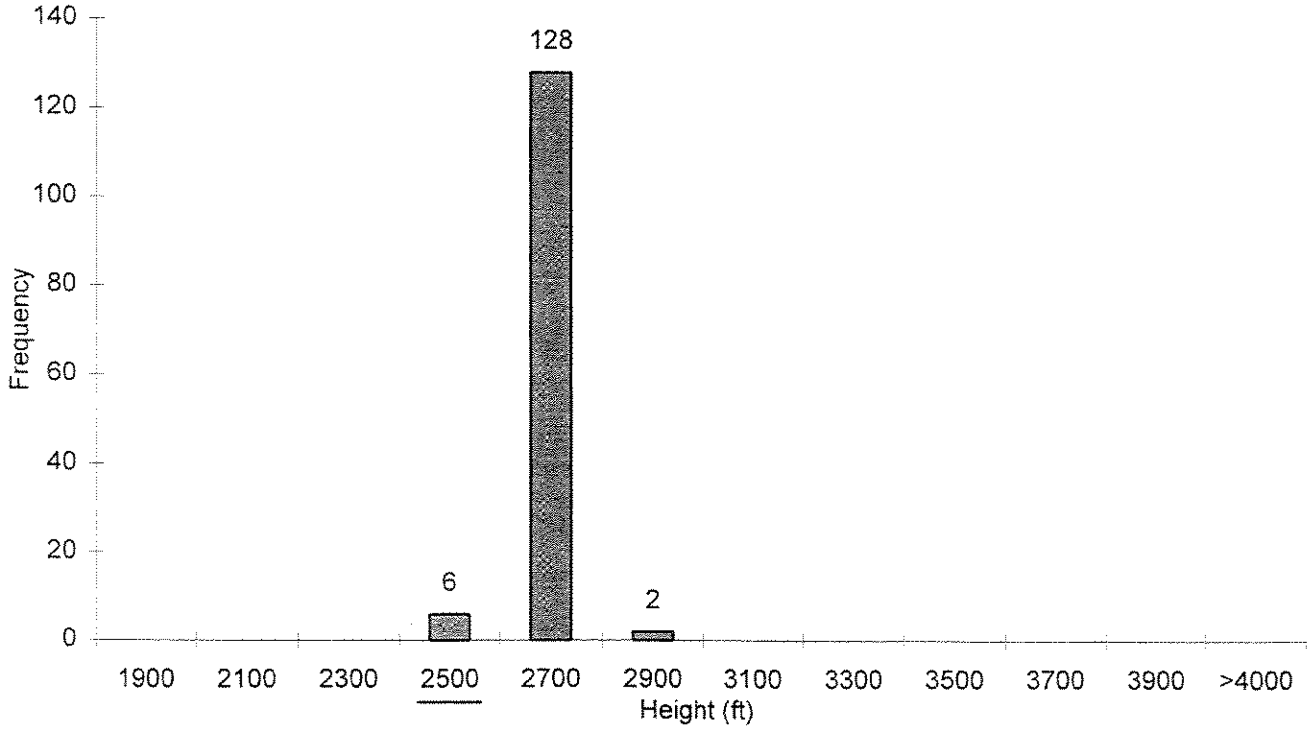


Figure 7b: Runway 27L, 8 nm from touchdown, January 1996, 04:00 to 06:00 (local time)



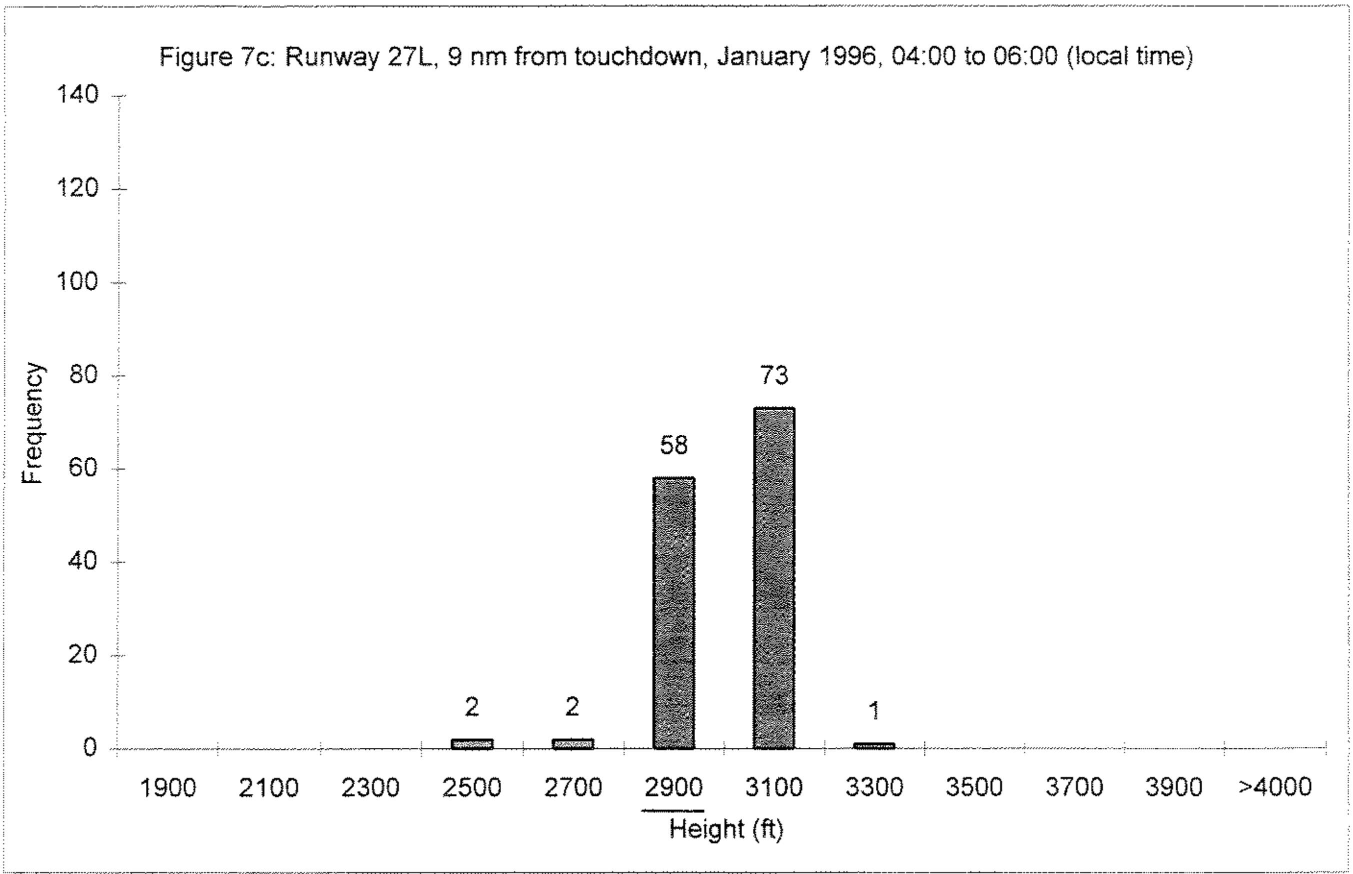


Figure 7c: Runway 27L, 9 nm from touchdown, January 1996, 04:00 to 06:00 (local time)
140
120
100
80
60
40
20
0
Frequency
58
73
2
2
1
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

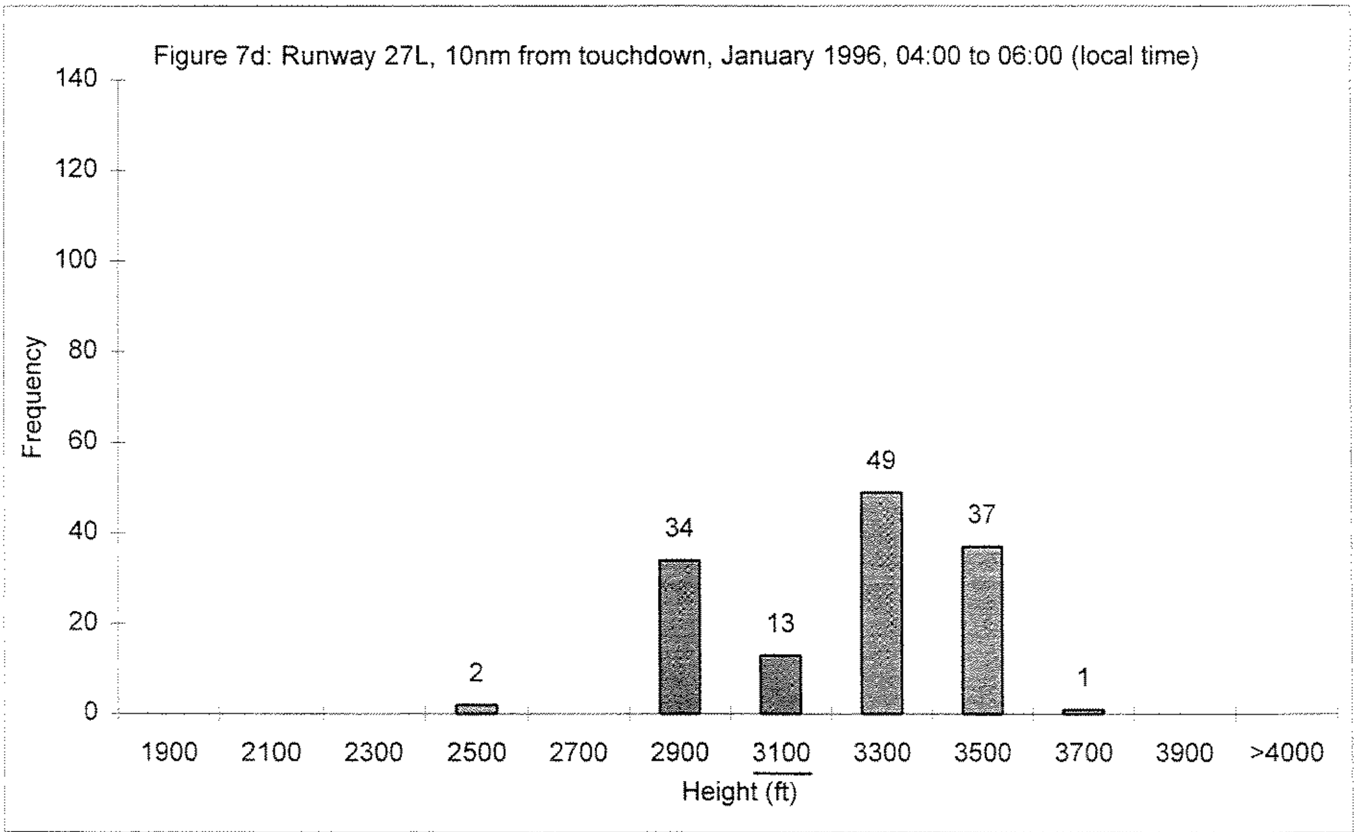


Figure 7d: Runway 27L, 10nm from touchdown, January 1996, 04:00 to 06:00 (local time)
140
120
100
80
60
40
20
0
Frequency
49
34
37
13
2
1
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

Figure 7e: Runway 27L, 11nm from touchdown, January 1996, 04:00 to 06:00 (local time)

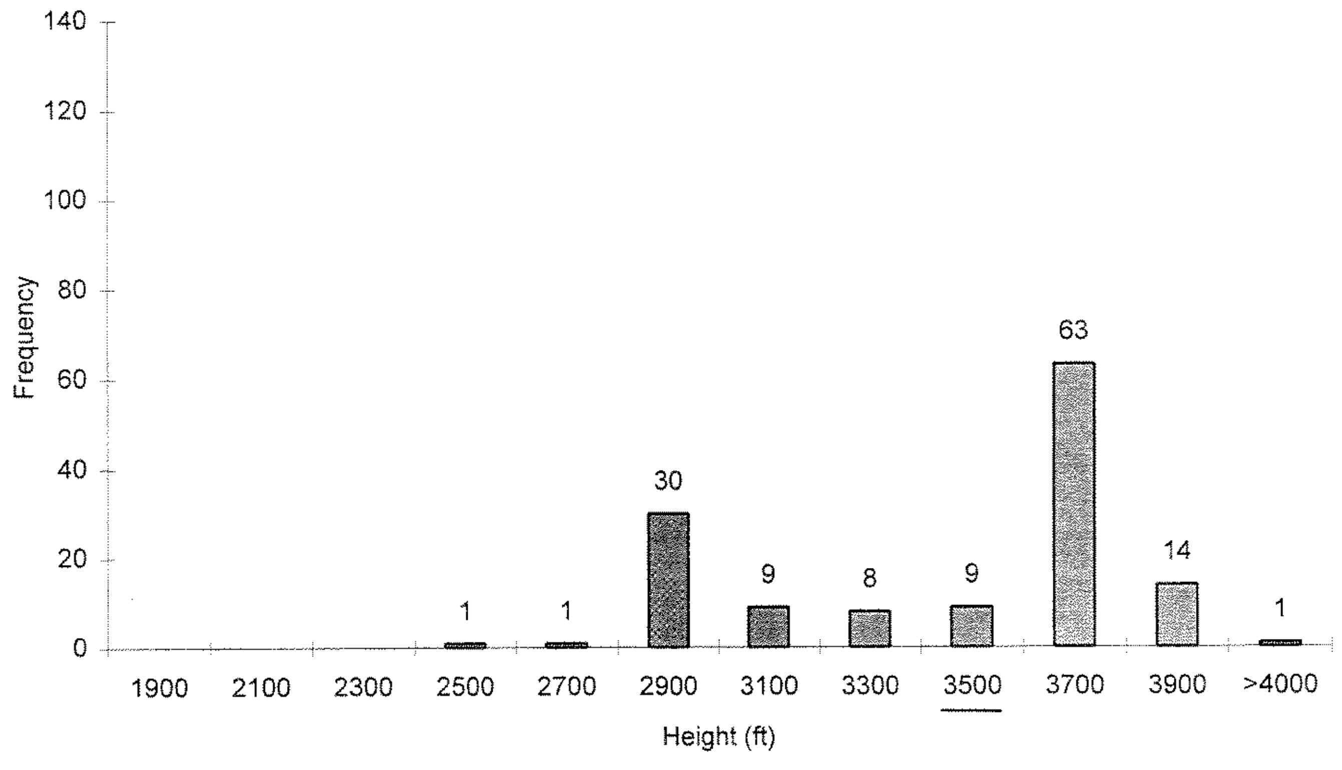


Figure 7f: Runway 27L, 12nm from touchdown, January 1996, 04:00 to 06:00 (local time)

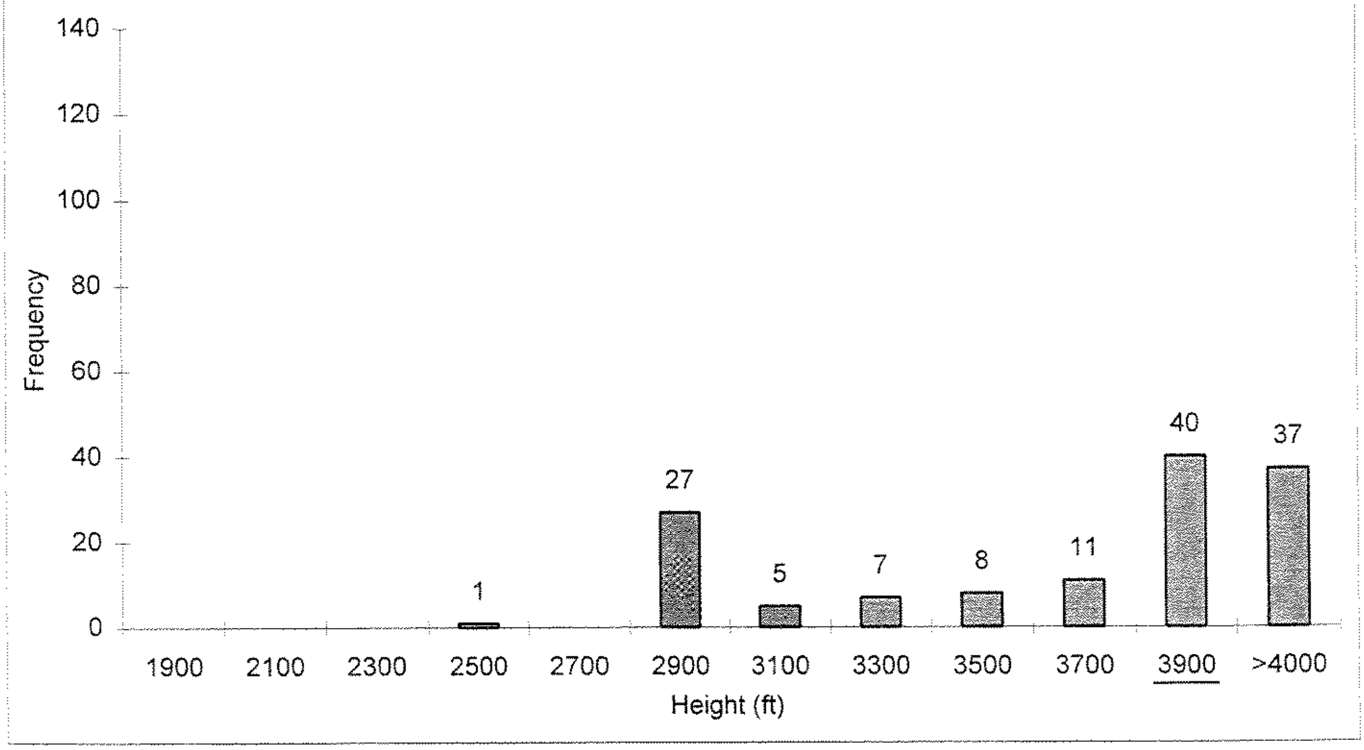


Figure 7g: Runway 27R, 7 nm from touchdown, January 1996, 04:00 to 06:00 (local time)

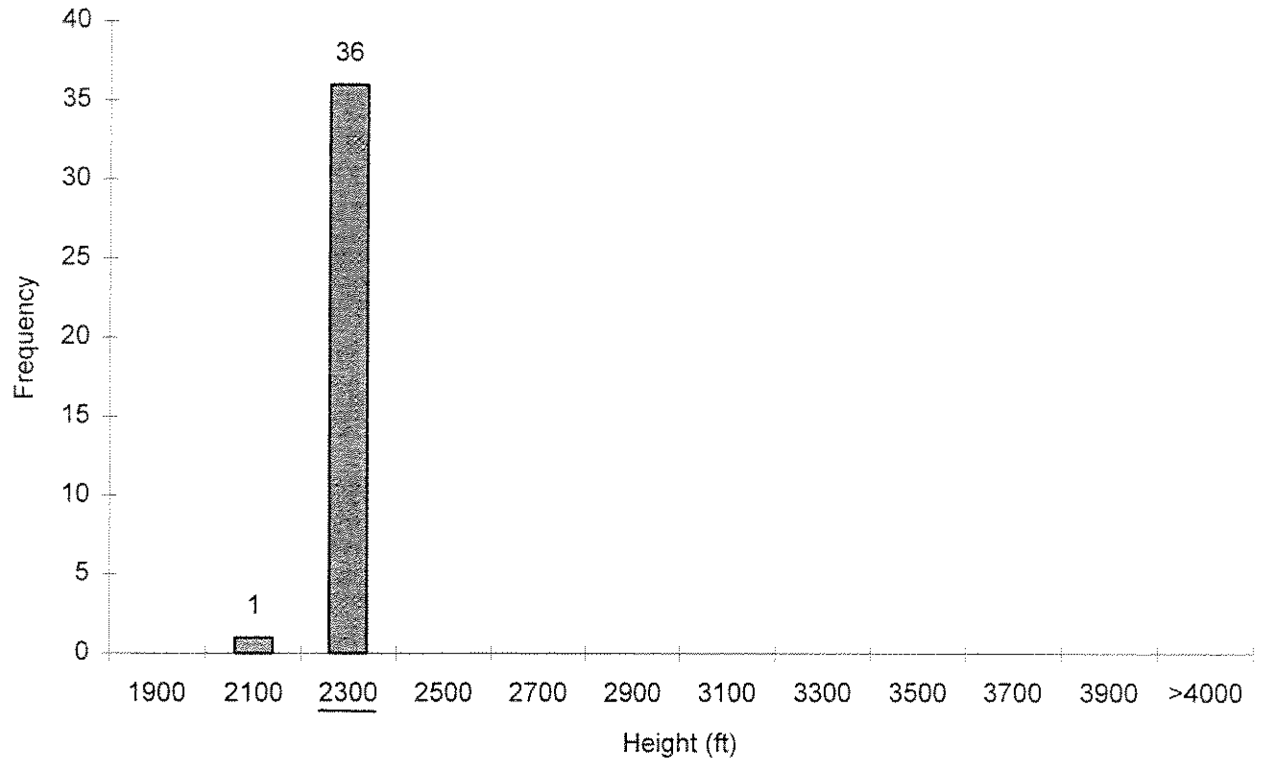


Figure 7h: Runway 27R, 8 nm from touchdown, January 1996, 04:00 to 06:00 (local time)

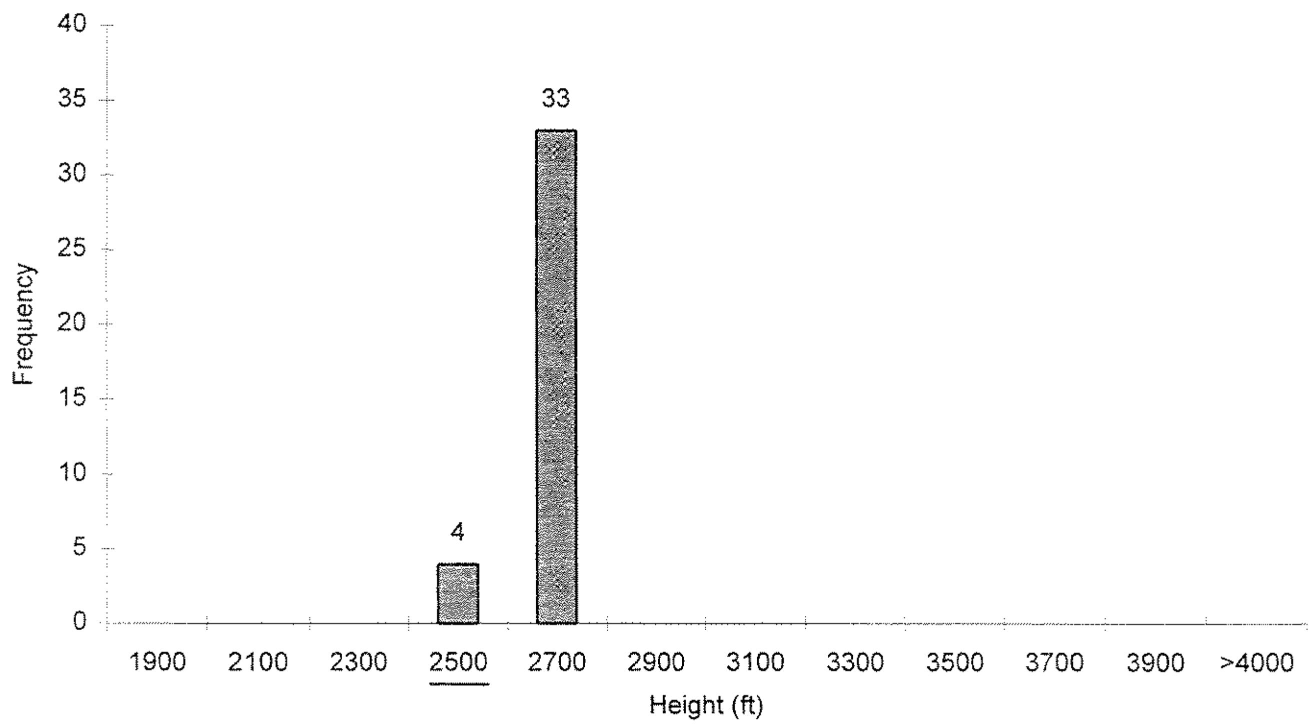


Figure 7i: Runway 27R, 9 nm from touchdown, January 1996, 04:00 to 06:00 (local time)

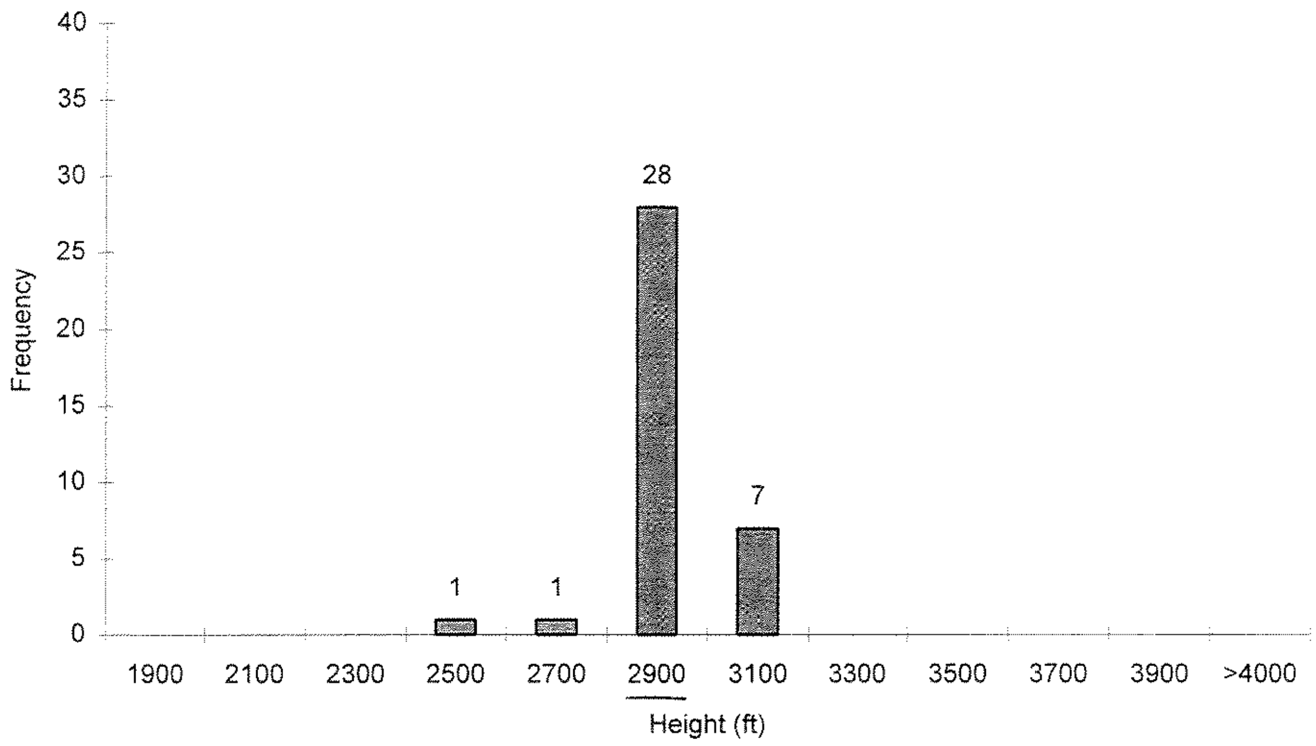


Figure 7j: Runway 27R, 10 nm from touchdown, January 1996, 04:00 to 06:00 (local time)

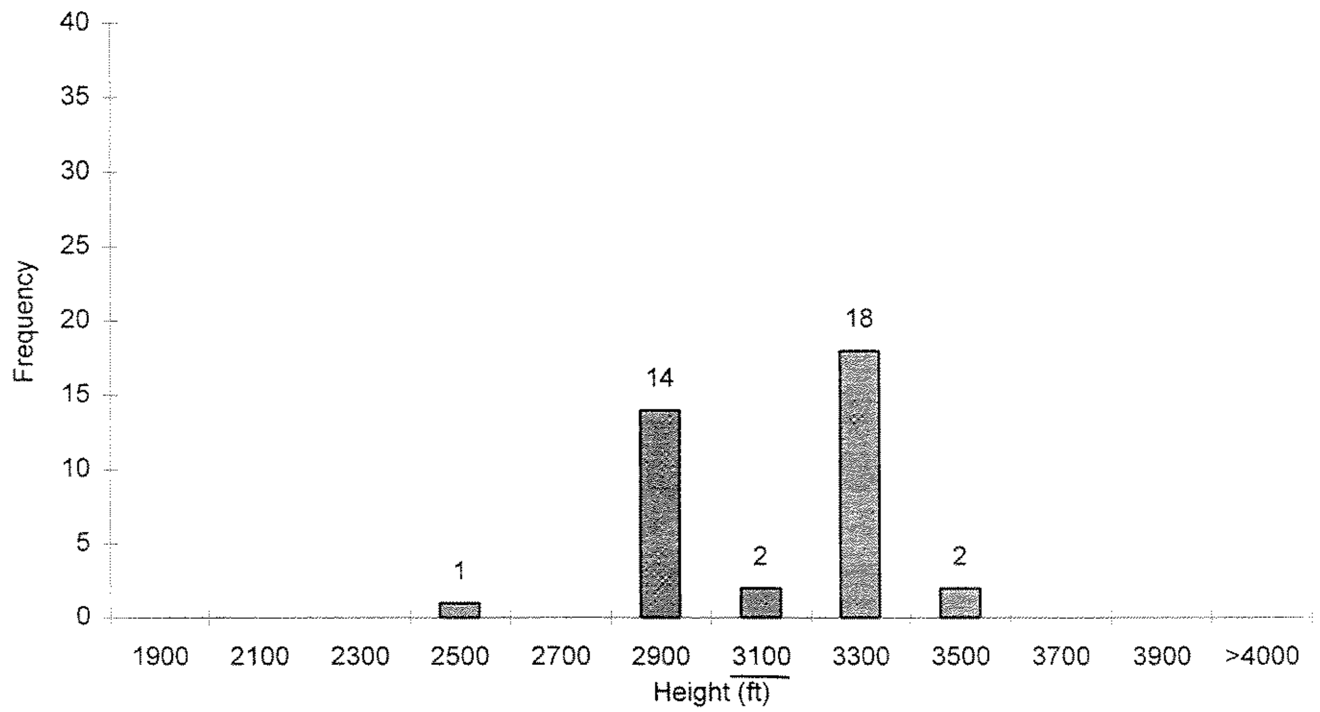


Figure 7k: Runway 27R, 11nm from touchdown, January 1996, 04:00 to 06:00 (local time)

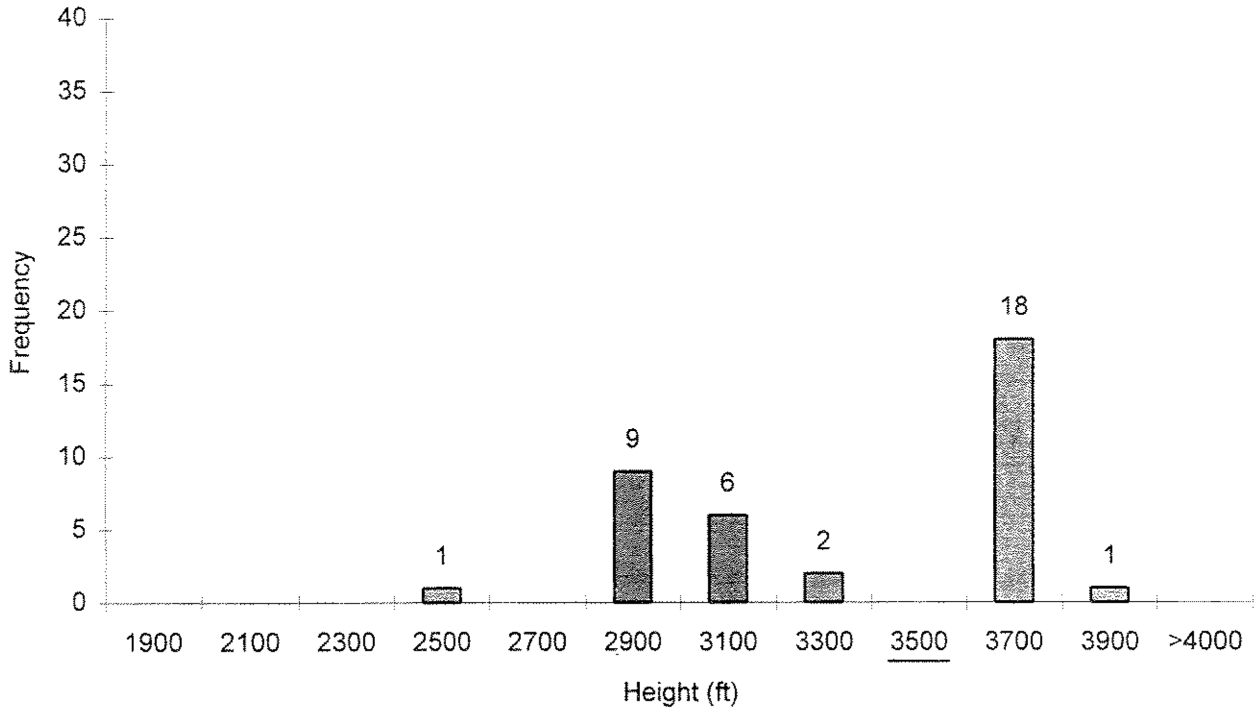


Figure 7l: Runway 27R, 12nm from touchdown, January 1996, 04:00 to 06:00 (local time)

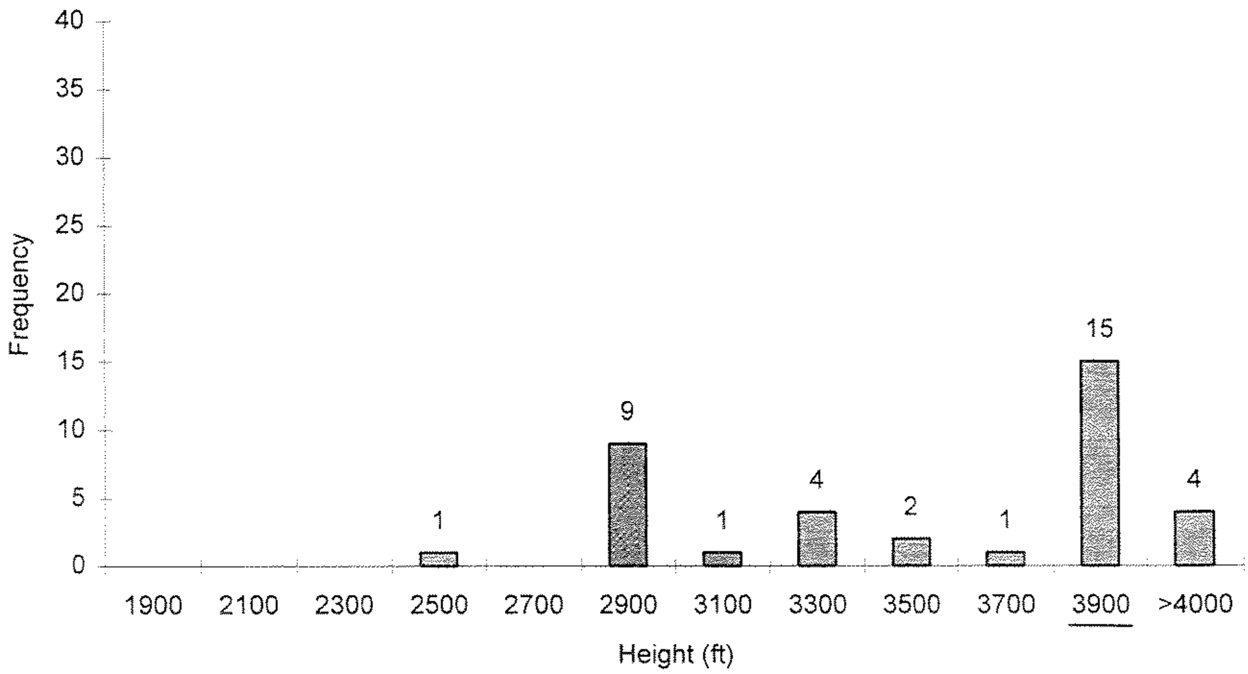


Figure 7m: January 1996, 27L radar tracks, 0400-0600 local time

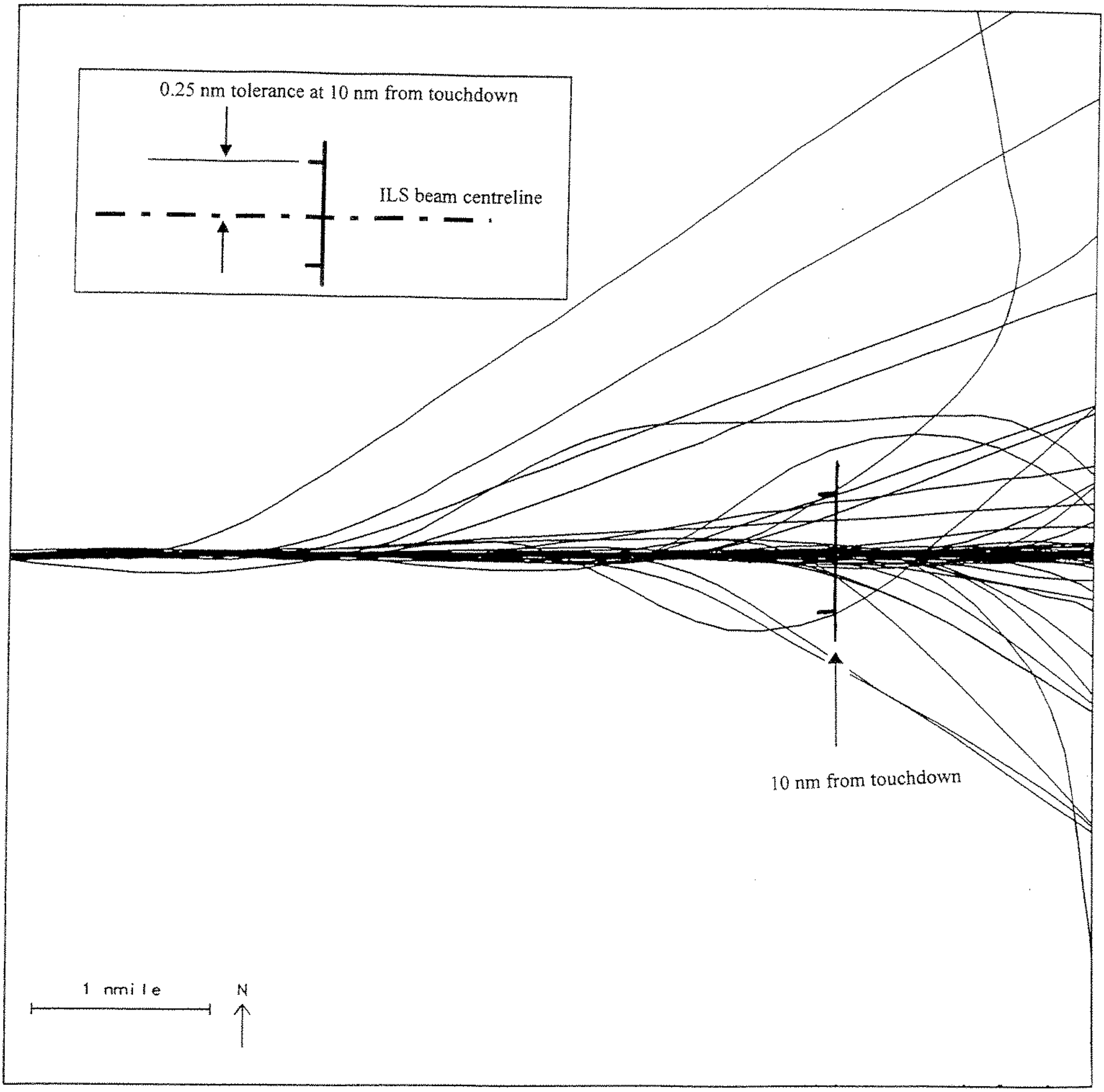


Figure 7n: January 1996, 27R radar tracks, 0400-0600 local time

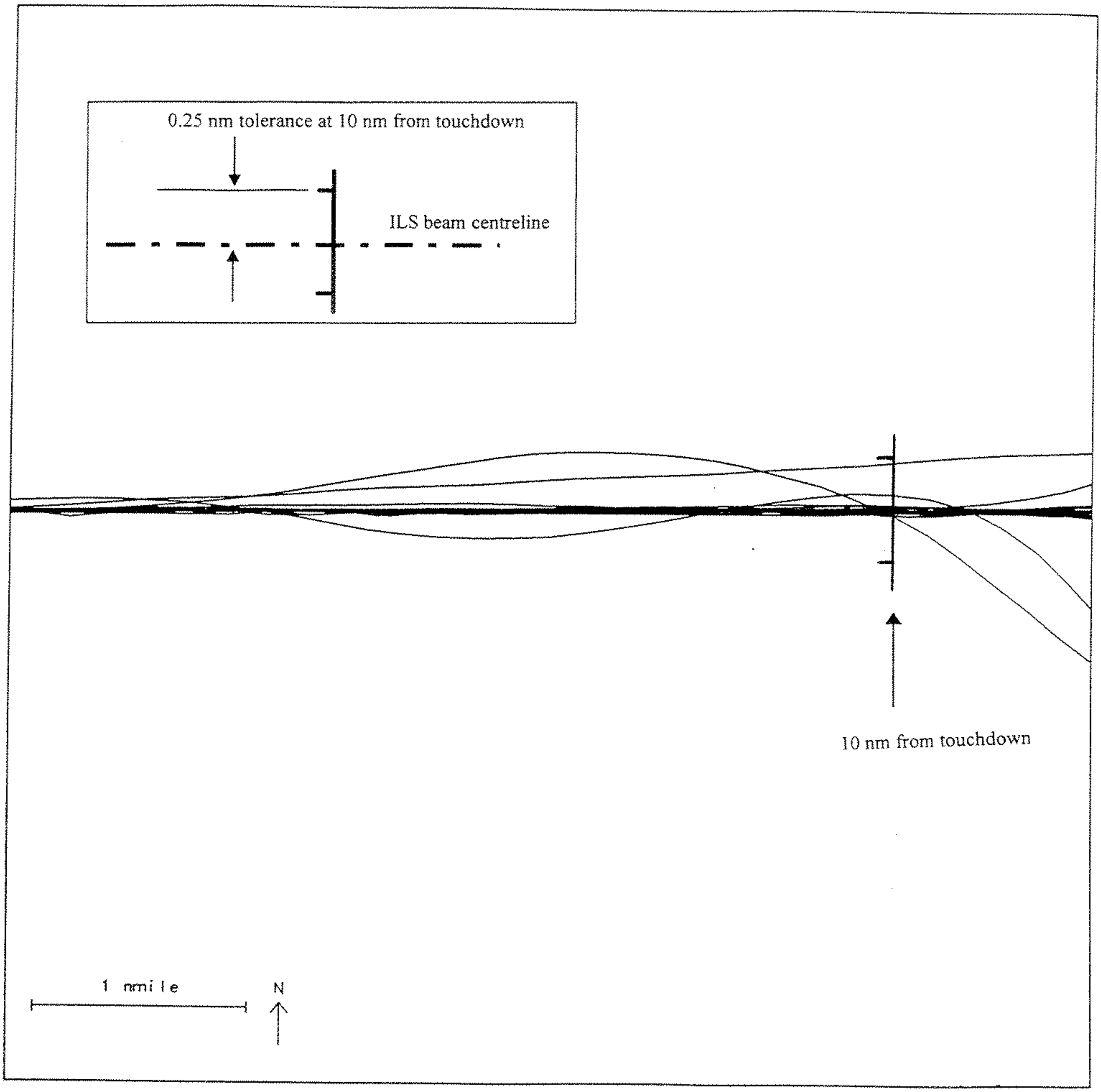


Figure 8a: Runway 27L, 7 nm from touchdown, January 1997, 0400 to 0600 (local time)

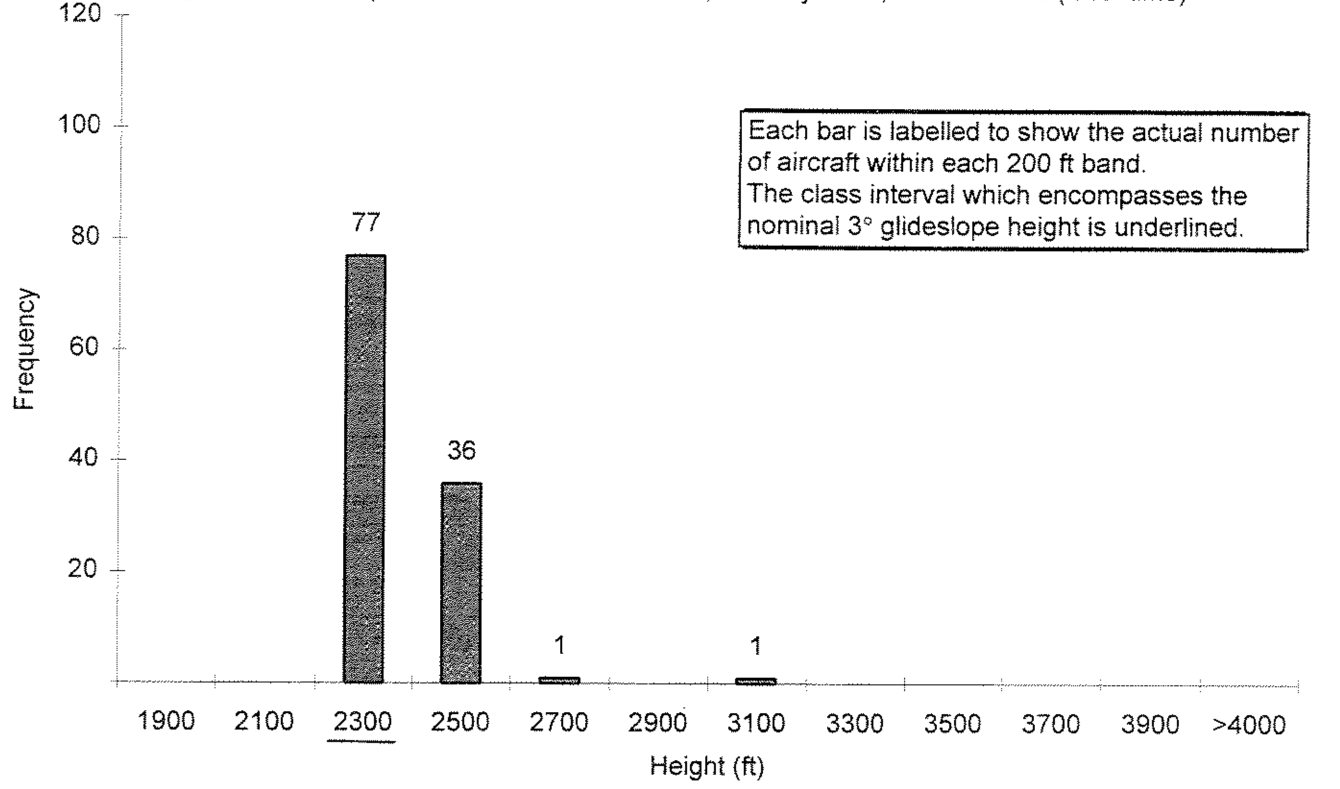
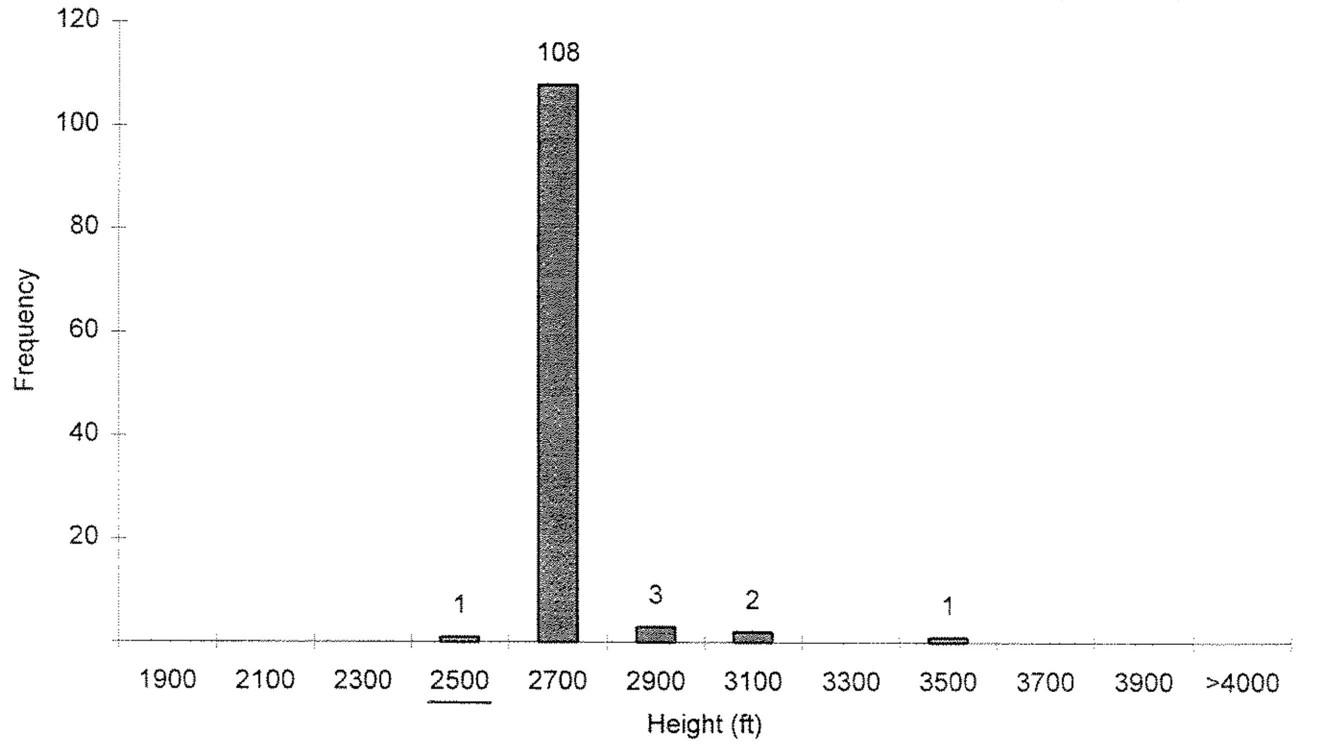


Figure 8b: Runway 27L, 8 nm from touchdown, January 1997, 0400 to 0600 (local time)



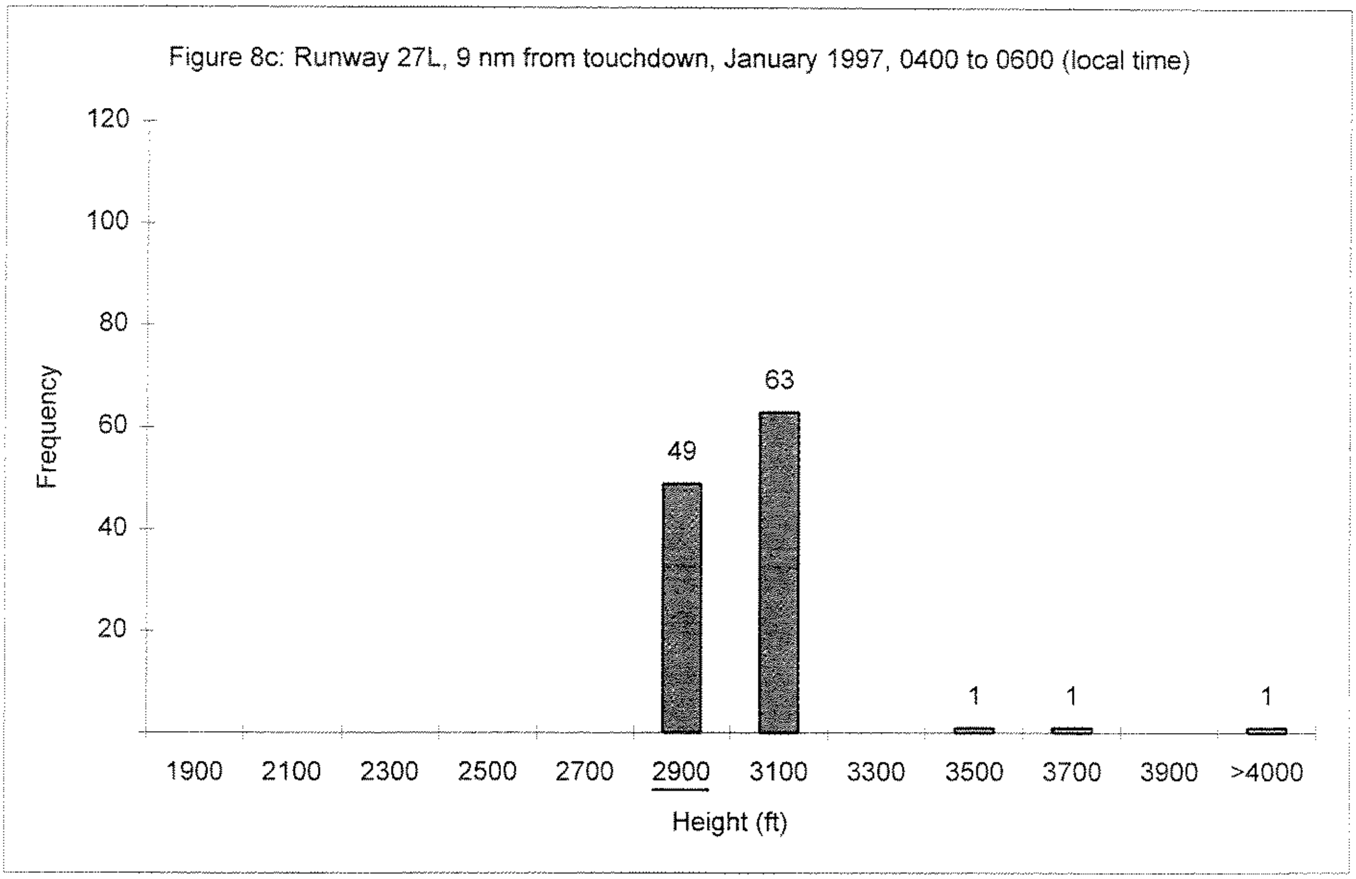


Figure 8c: Runway 27L, 9 nm from touchdown, January 1997, 0400 to 0600 (local time)
120
100
80
60
40
20
Frequency
49
63
1
1
1
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

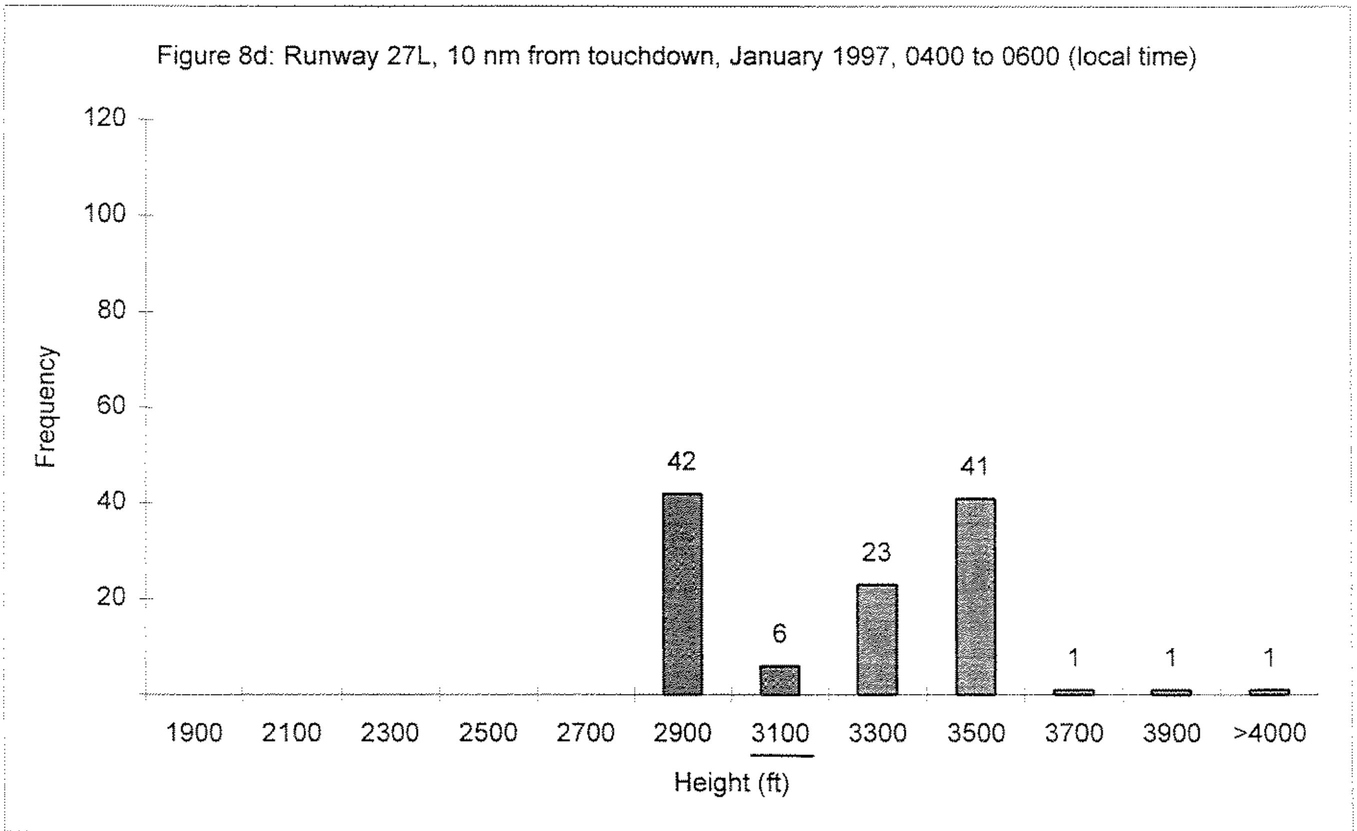


Figure 8d: Runway 27L, 10 nm from touchdown, January 1997, 0400 to 0600 (local time)
120
100
80
60
40
20
Frequency
42
6
23
41
1
1
1
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

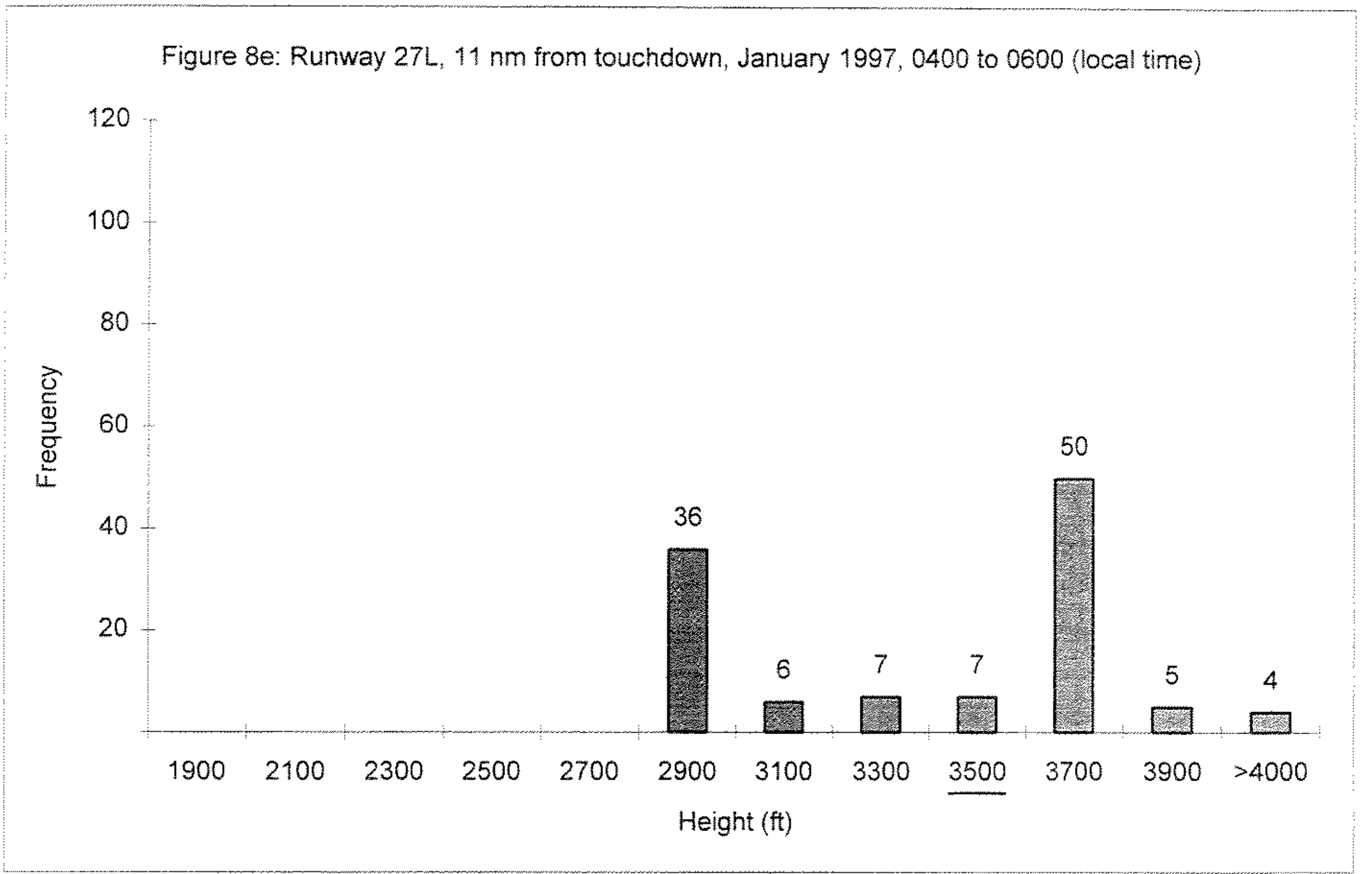


Figure 8e: Runway 27L, 11 nm from touchdown, January 1997, 0400 to 0600 (local time)
Frequency
120
100
80
60
40
20
36
6
7
7
50
5
4
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

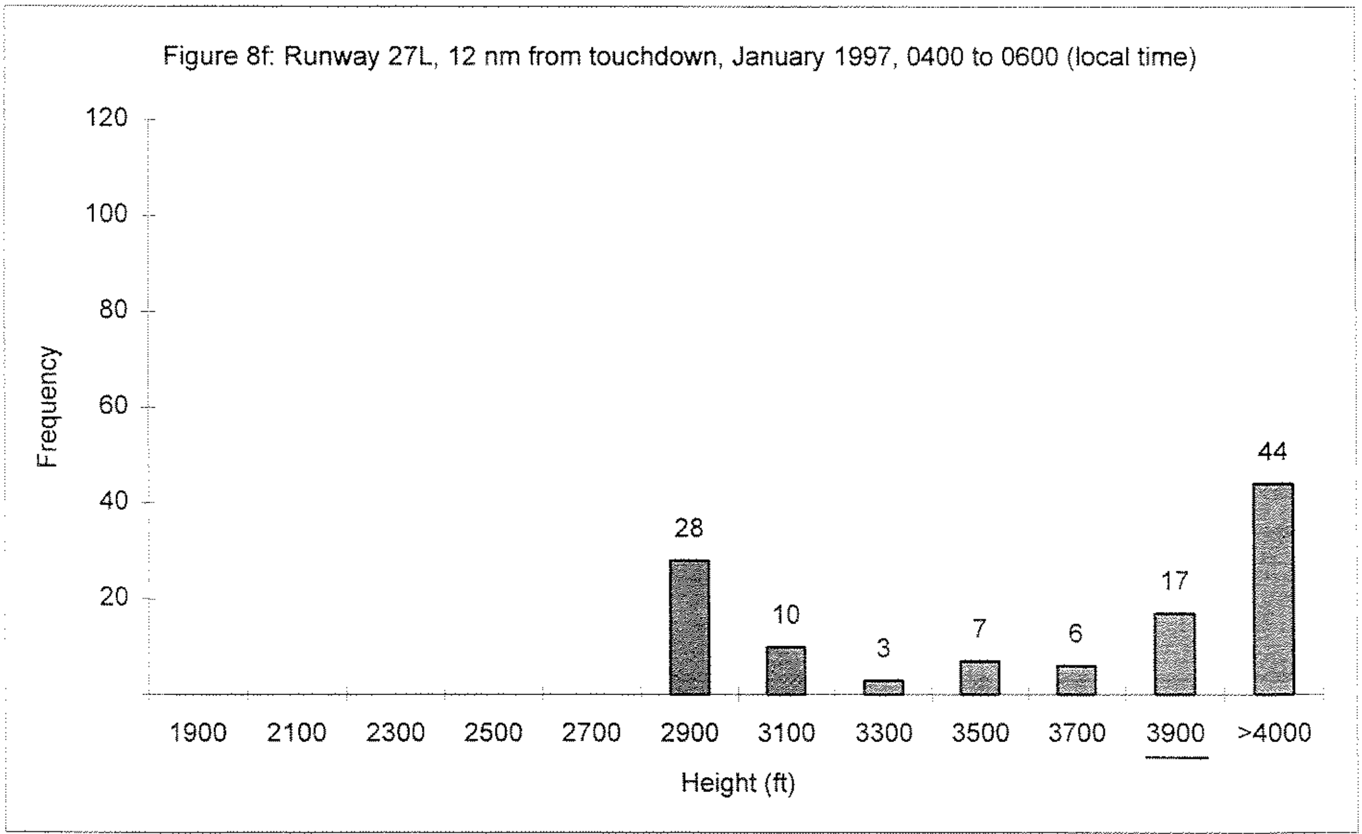


Figure 8f: Runway 27L, 12 nm from touchdown, January 1997, 0400 to 0600 (local time)
Frequency
120
100
80
60
40
20
28
10
3
7
6
17
44
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

Figure 8g: Runway 27R, 7 nm from touchdown, January 1997, 0400 to 0600 (local time)

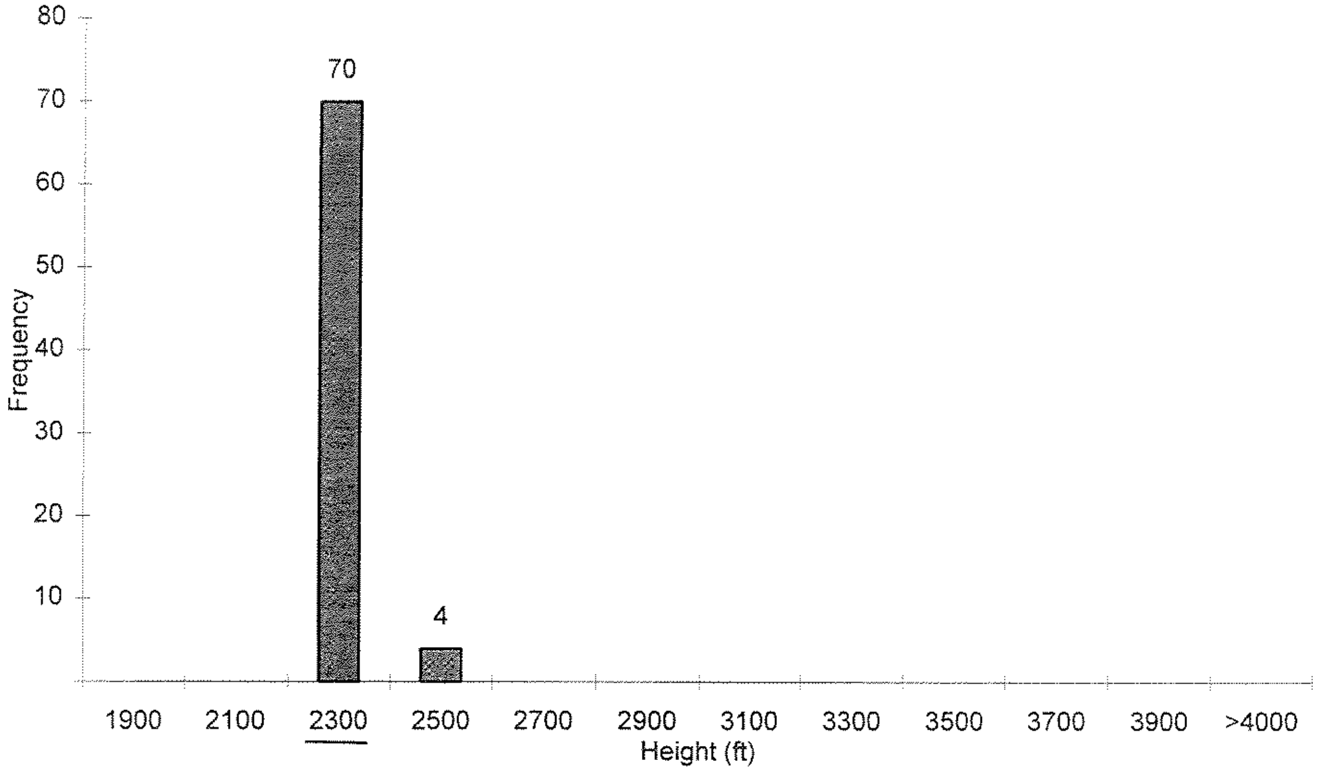


Figure 8h: Runway 27R, 8 nm from touchdown, January 1997, 0400 to 0600 (local time)

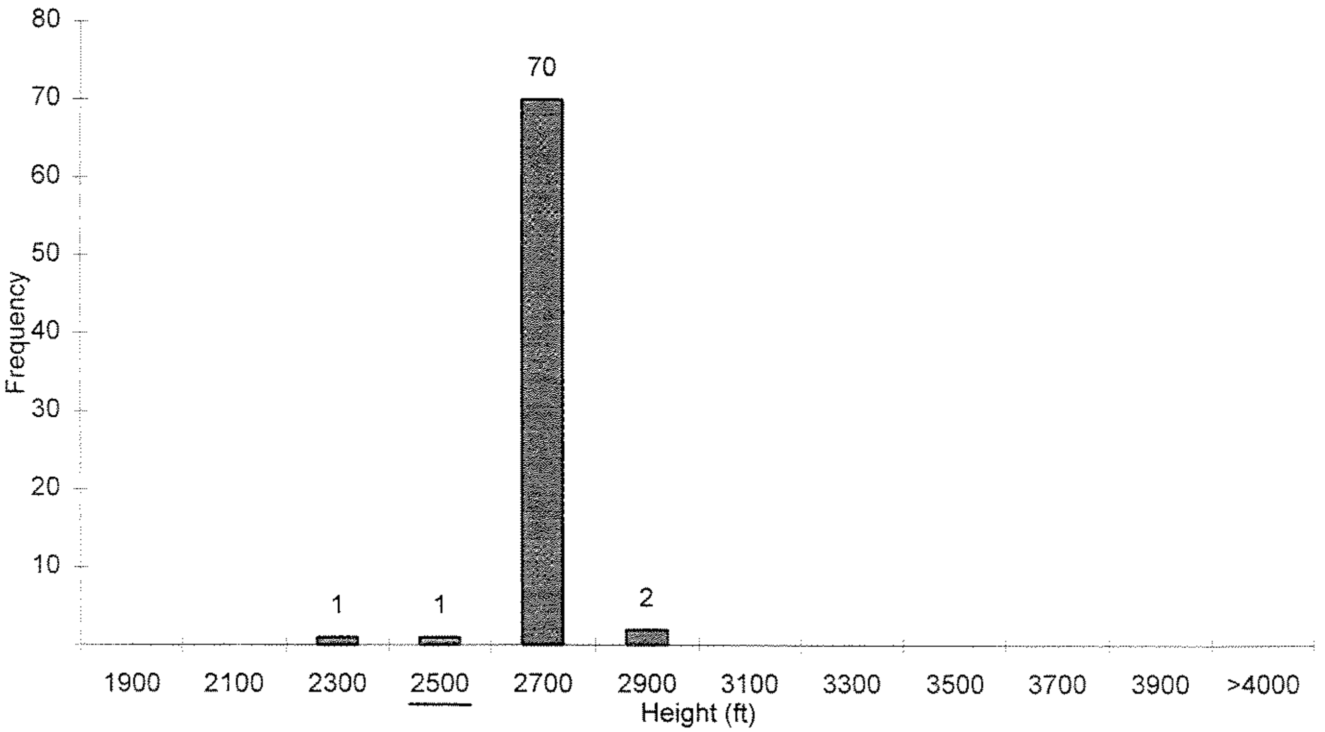


Figure 8i: Runway 27R, 9 nm from touchdown, January 1997, 0400 to 0600 (local time)

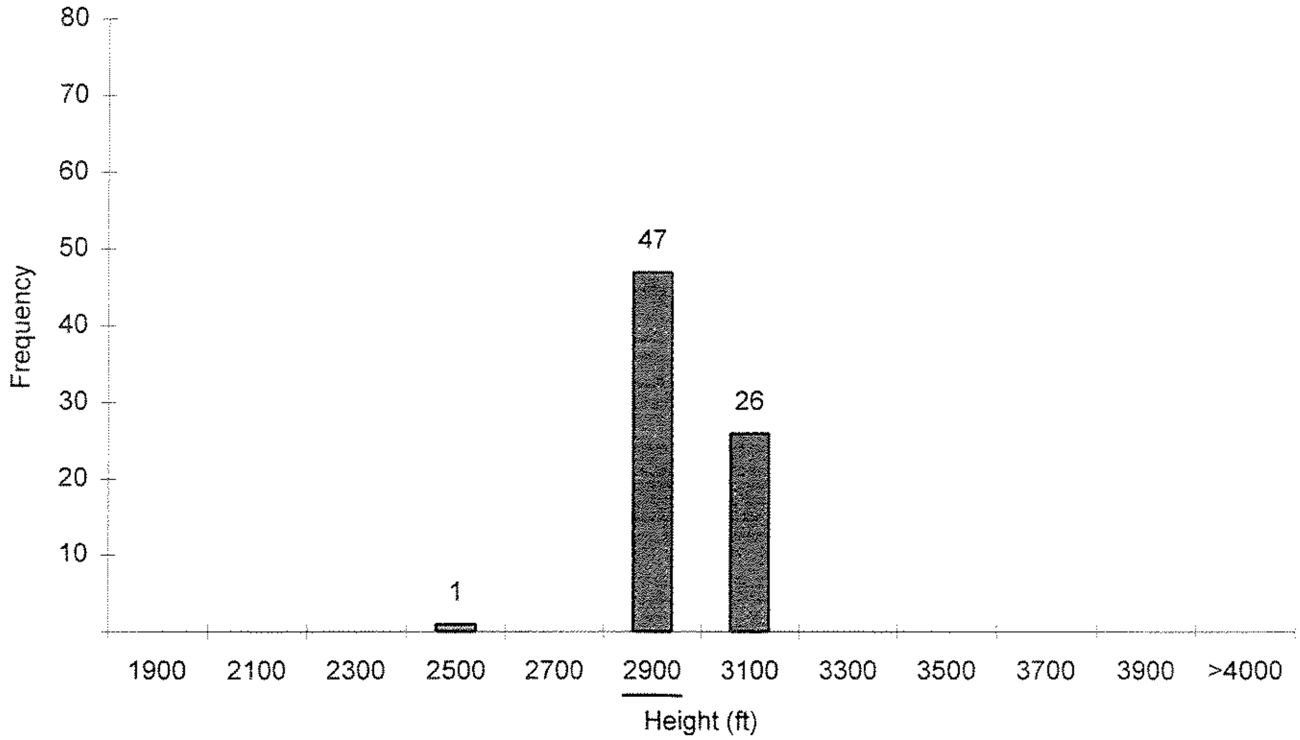


Figure 8j: Runway 27R, 10 nm from touchdown, January 1997, 0400 to 0600 (local time)

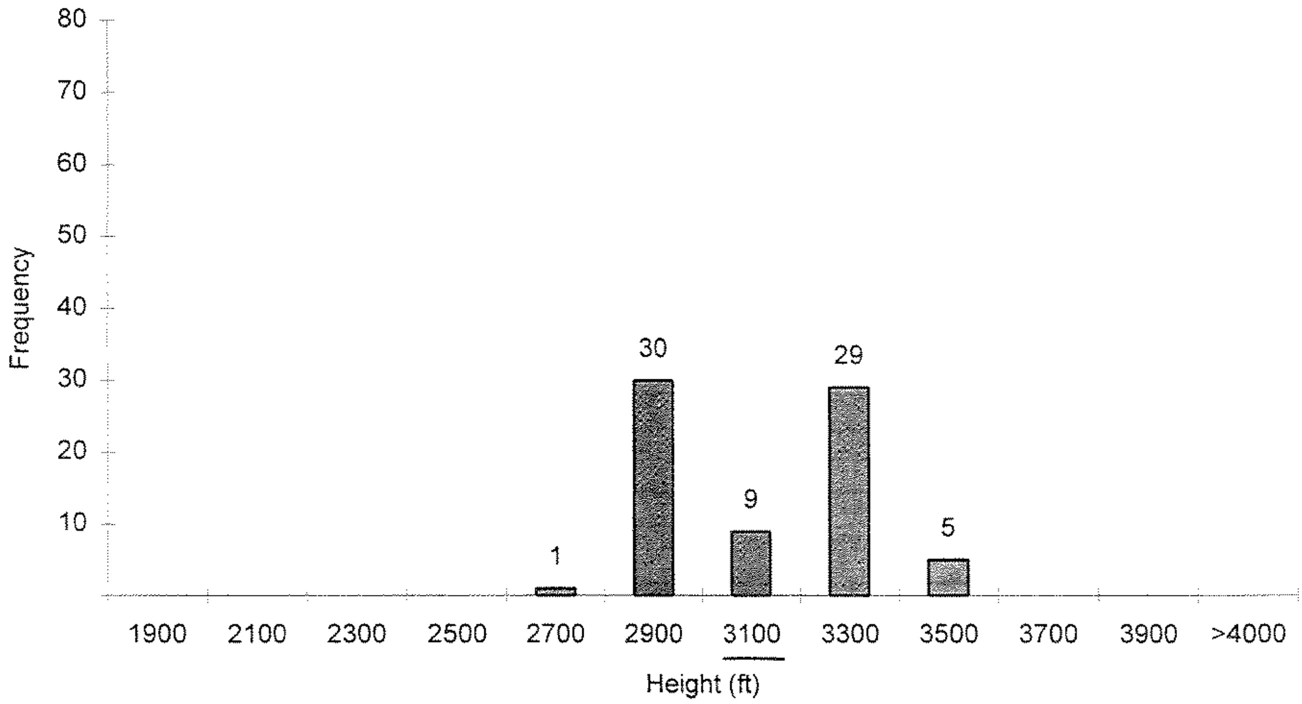


Figure 8k: Runway 27R, 11 nm from touchdown, January 1997, 0400 to 0600 (local time)

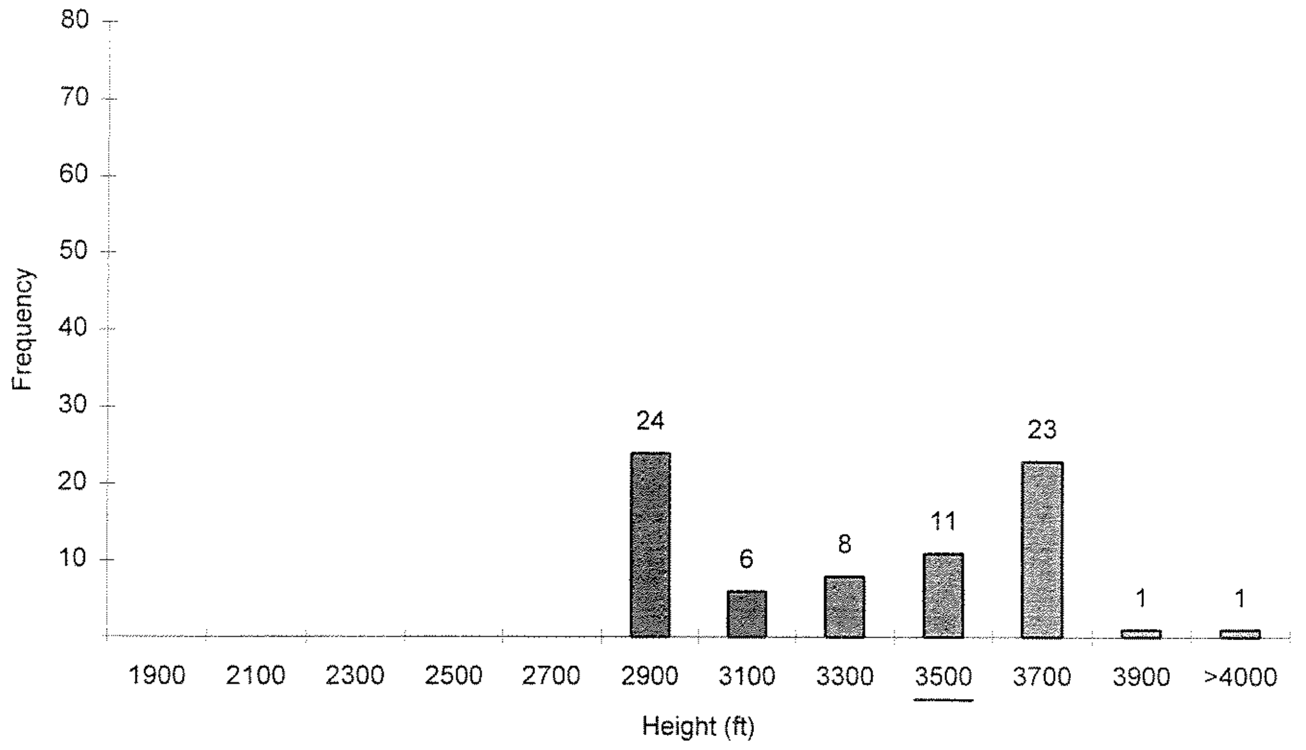


Figure 8l: Runway 27R, 12 nm from touchdown, January 1997, 0400 to 0600 (local time)

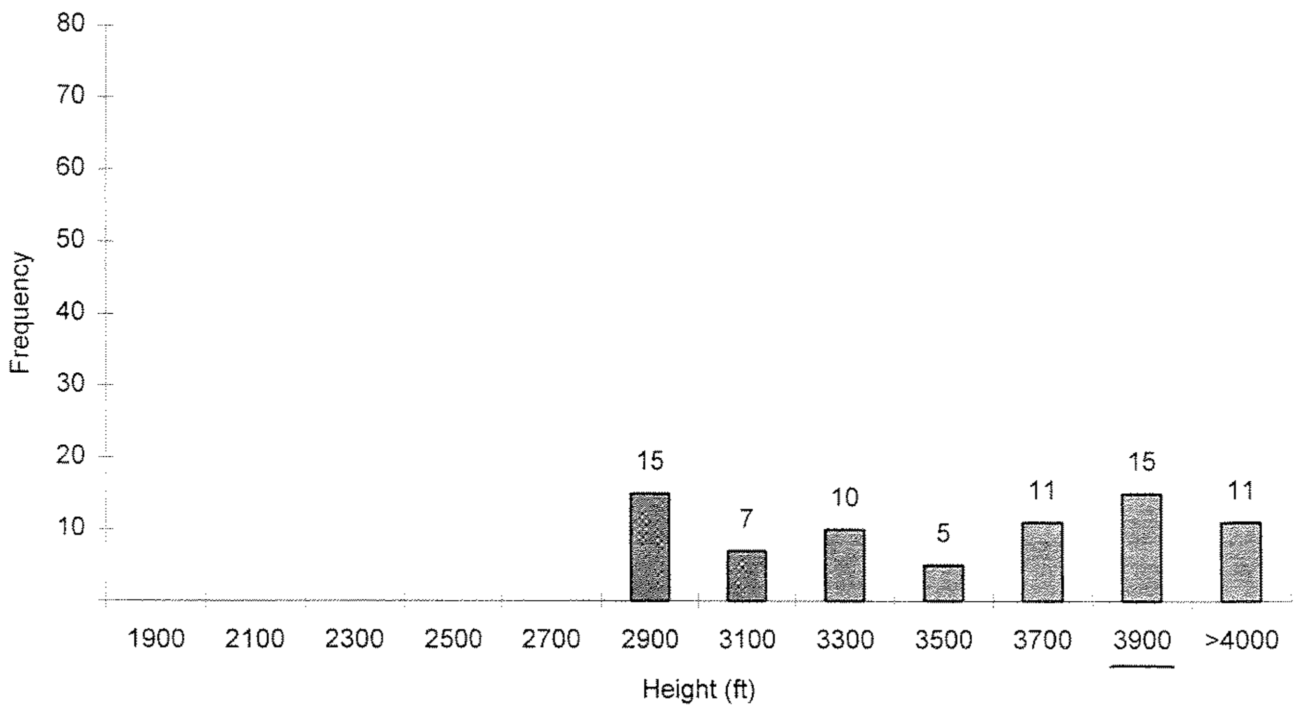


Figure 8m: January 1997, 27L radar tracks, 0400-0600 local time

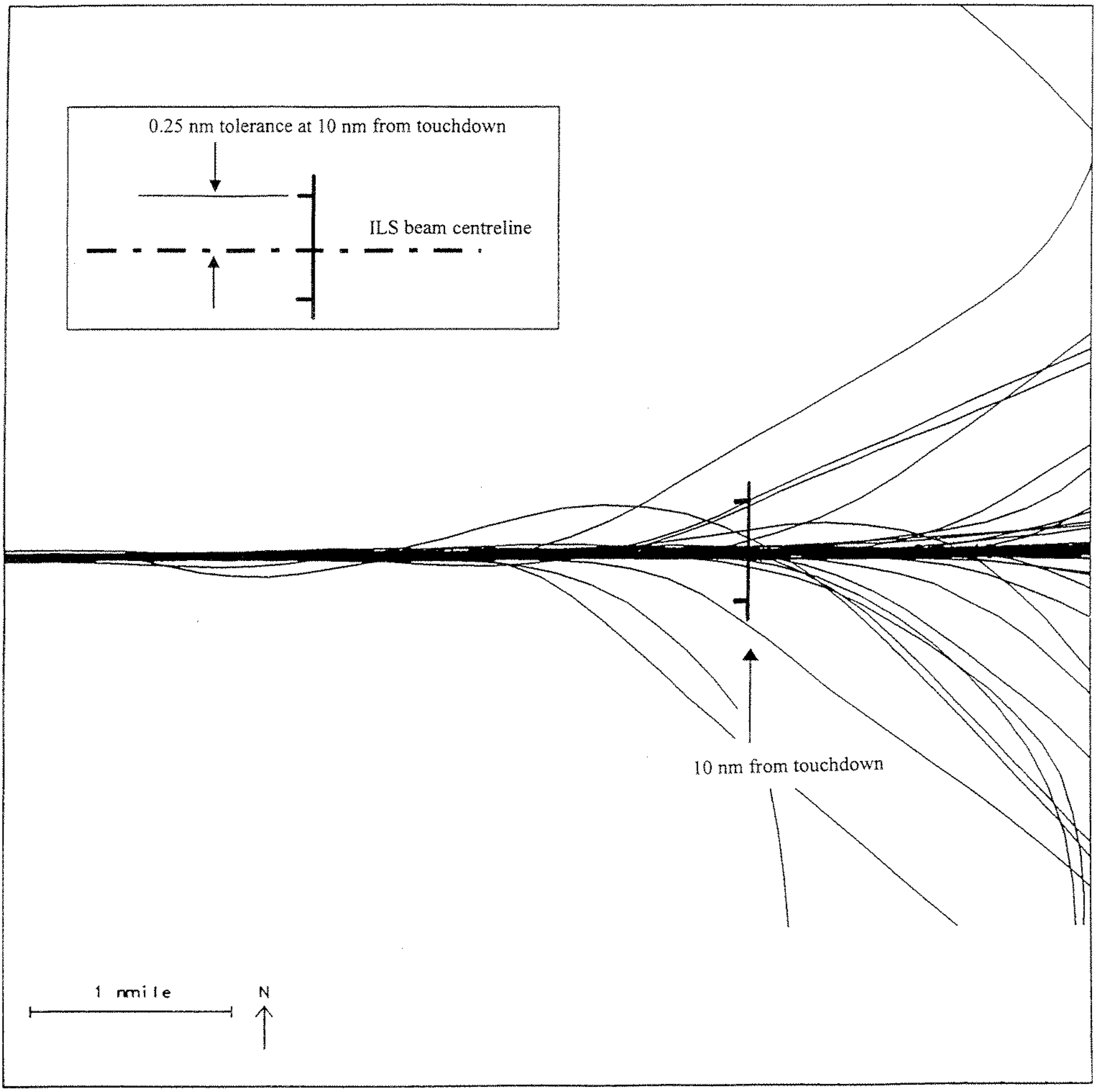


Figure 8n: January 1997, 27R radar tracks, 0400-0600 local time

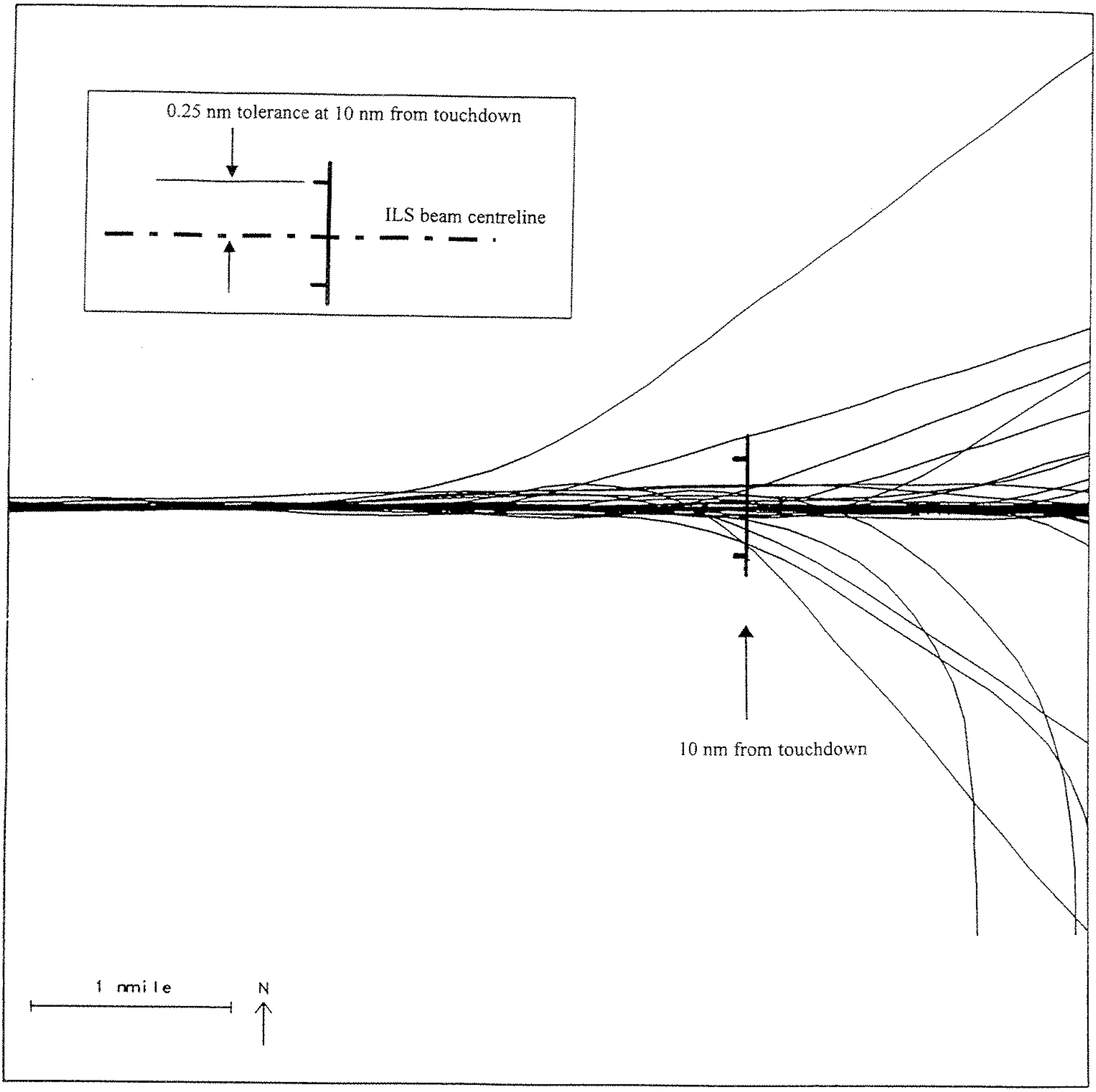


Figure 9a: Runway 27L, 7 nm from touchdown, July 1997, 0400 to 0600 (local time)

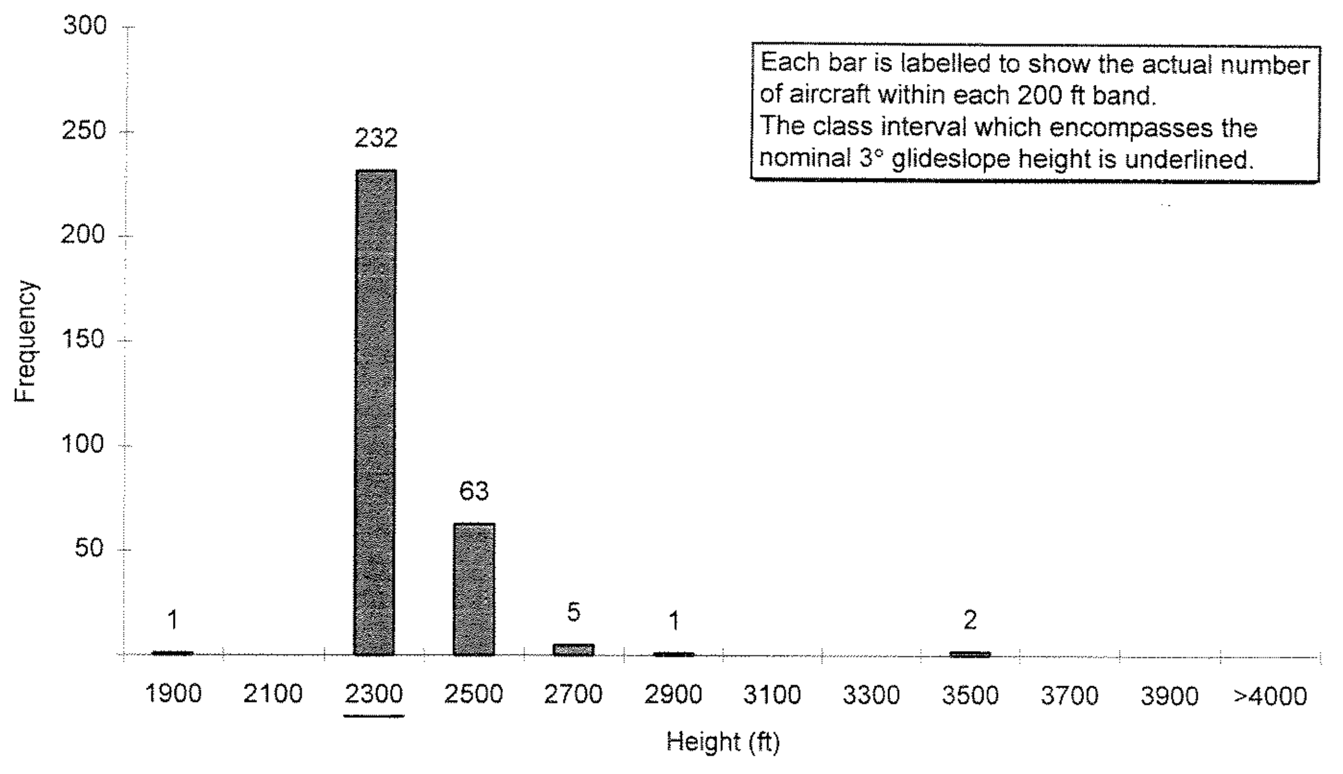
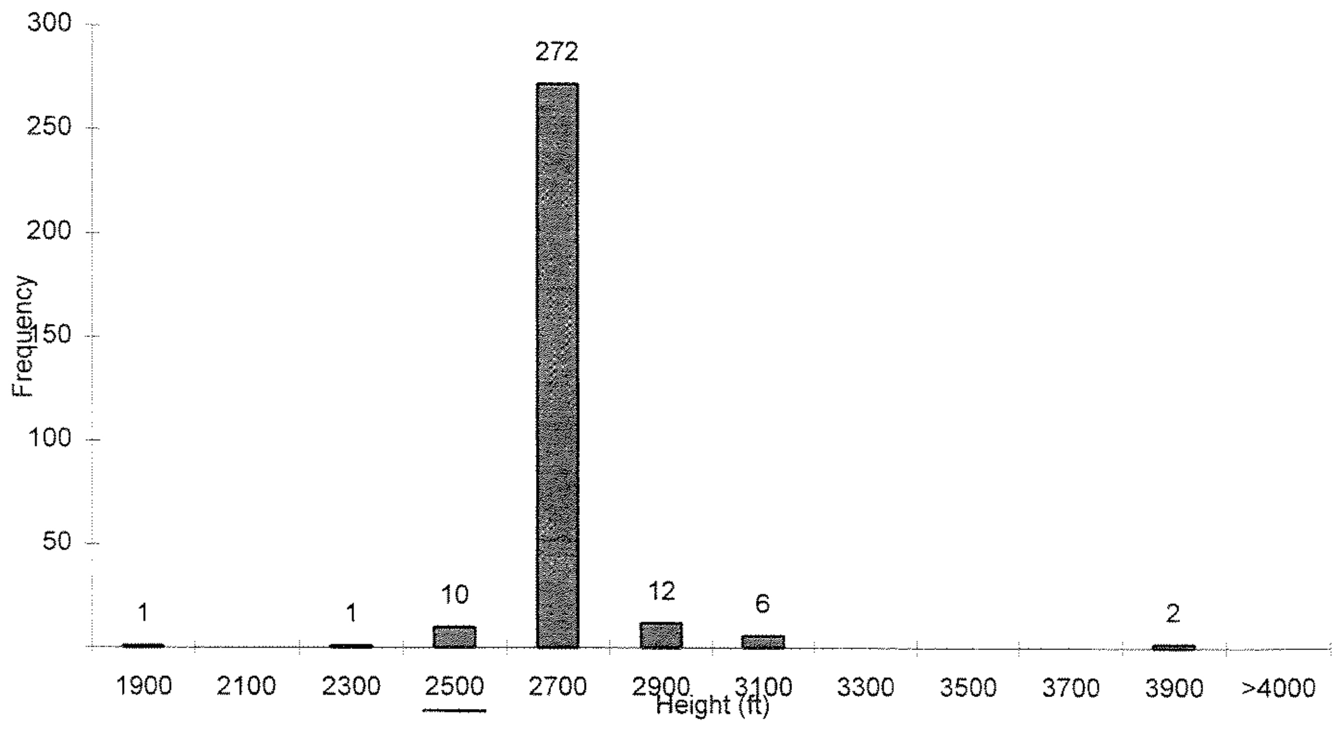


Figure 9b: Runway 27L, 8 nm from touchdown, July 1997, 0400 to 0600 (local time)



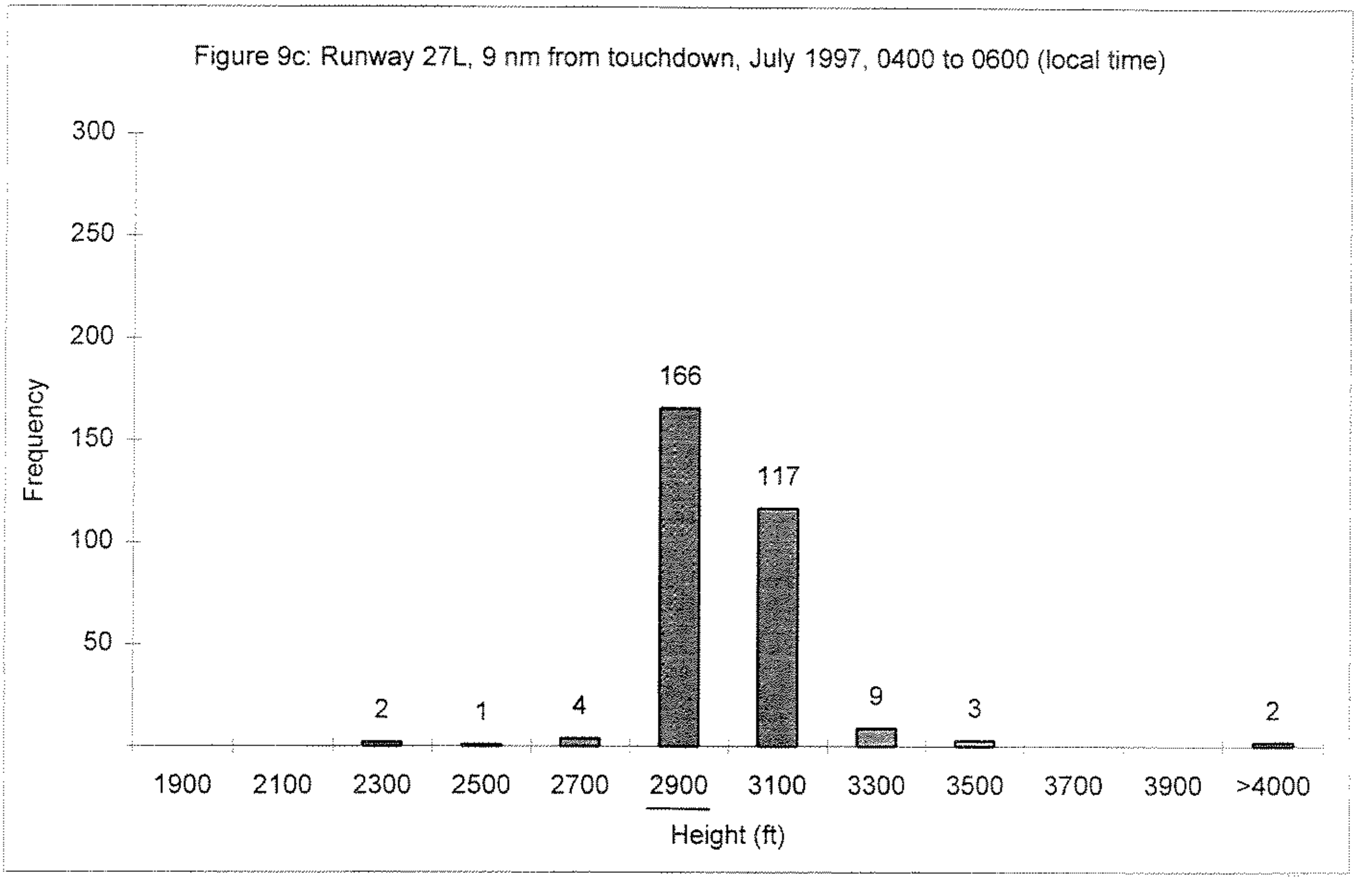


Figure 9c: Runway 27L, 9 nm from touchdown, July 1997, 0400 to 0600 (local time)
Frequency
300
250
200
150
100
50
166
117
2
1
4
9
3
2
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

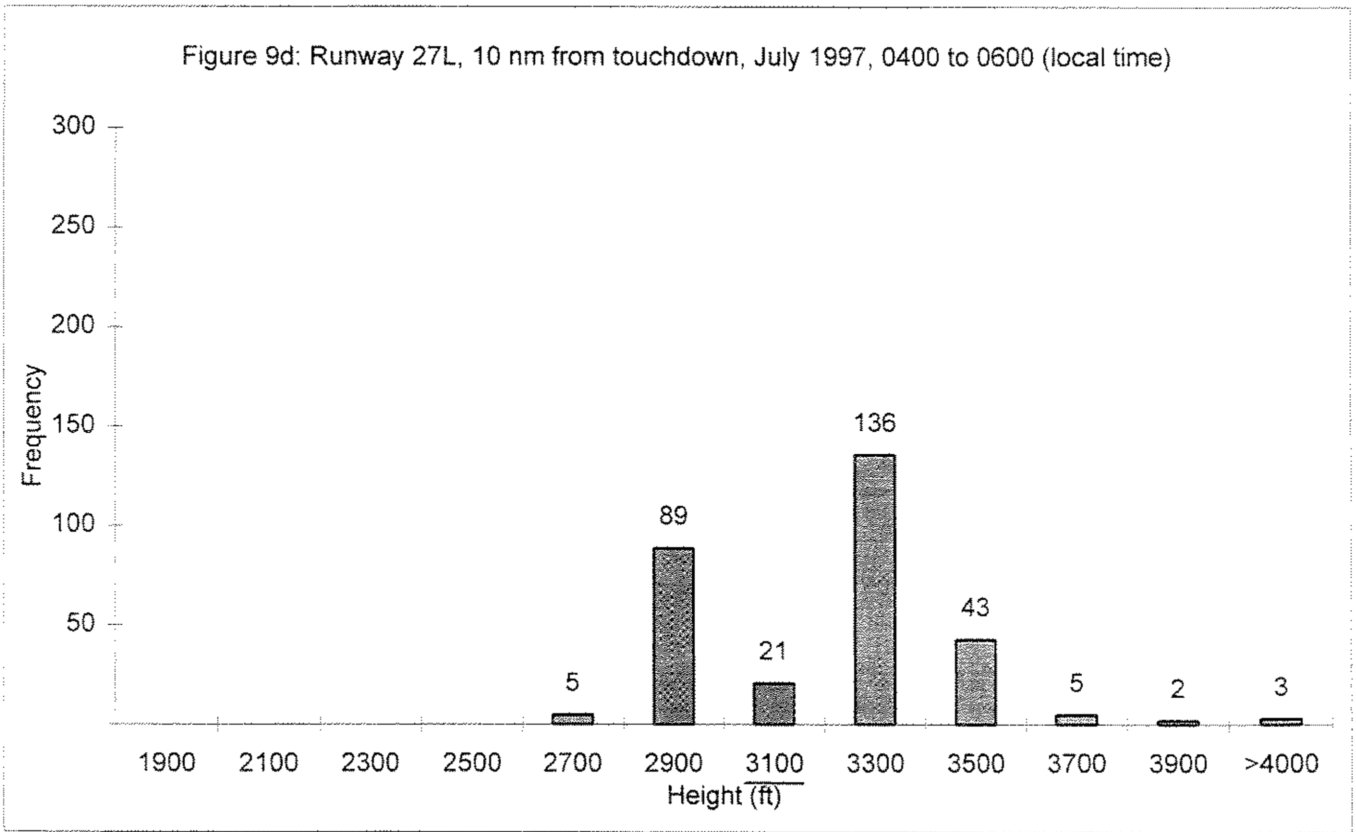


Figure 9d: Runway 27L, 10 nm from touchdown, July 1997, 0400 to 0600 (local time)
Frequency
300
250
200
150
100
50
5
89
21
136
43
5
2
3
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
>4000
Height (ft)

Figure 9e: Runway 27L, 11 nm from touchdown, July 1997, 0400 to 0600 (local time)

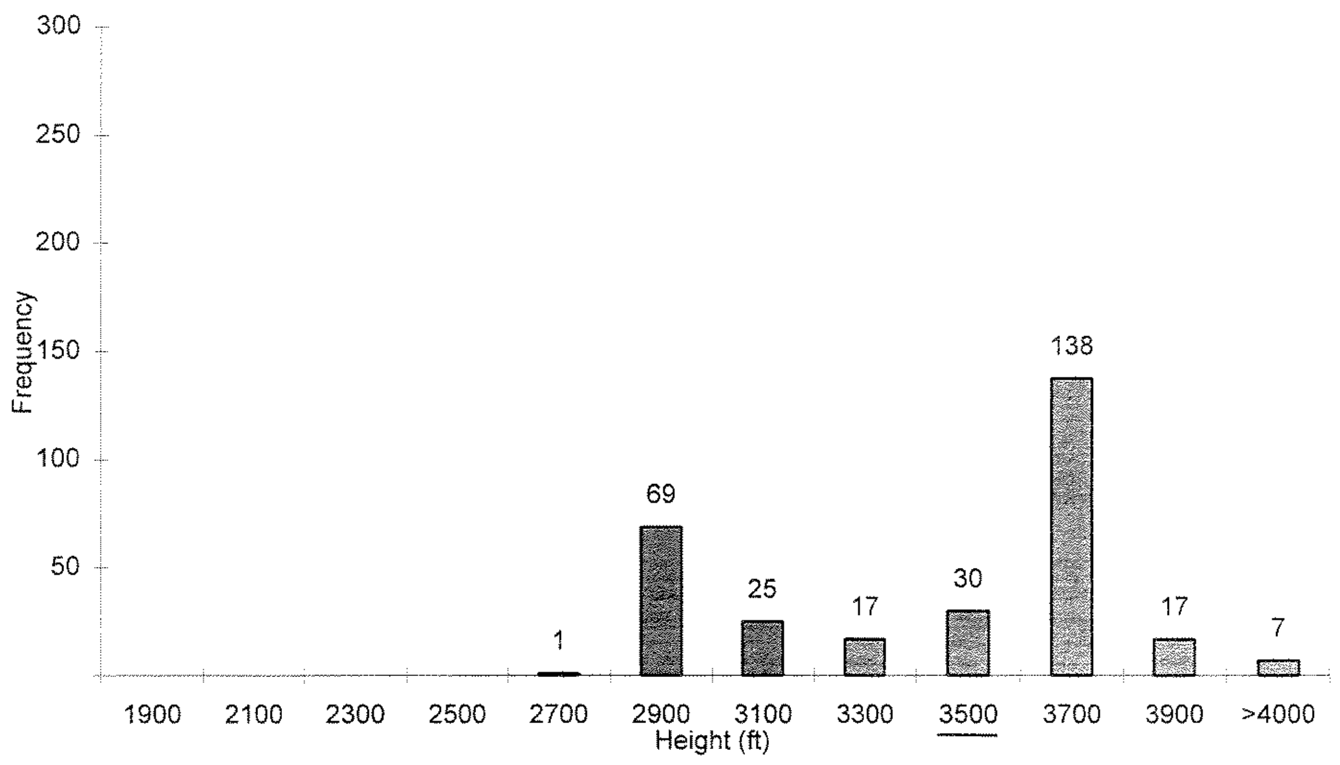


Figure 9f: Runway 27L, 12 nm from touchdown, July 1997, 0400 to 0600 (local time)

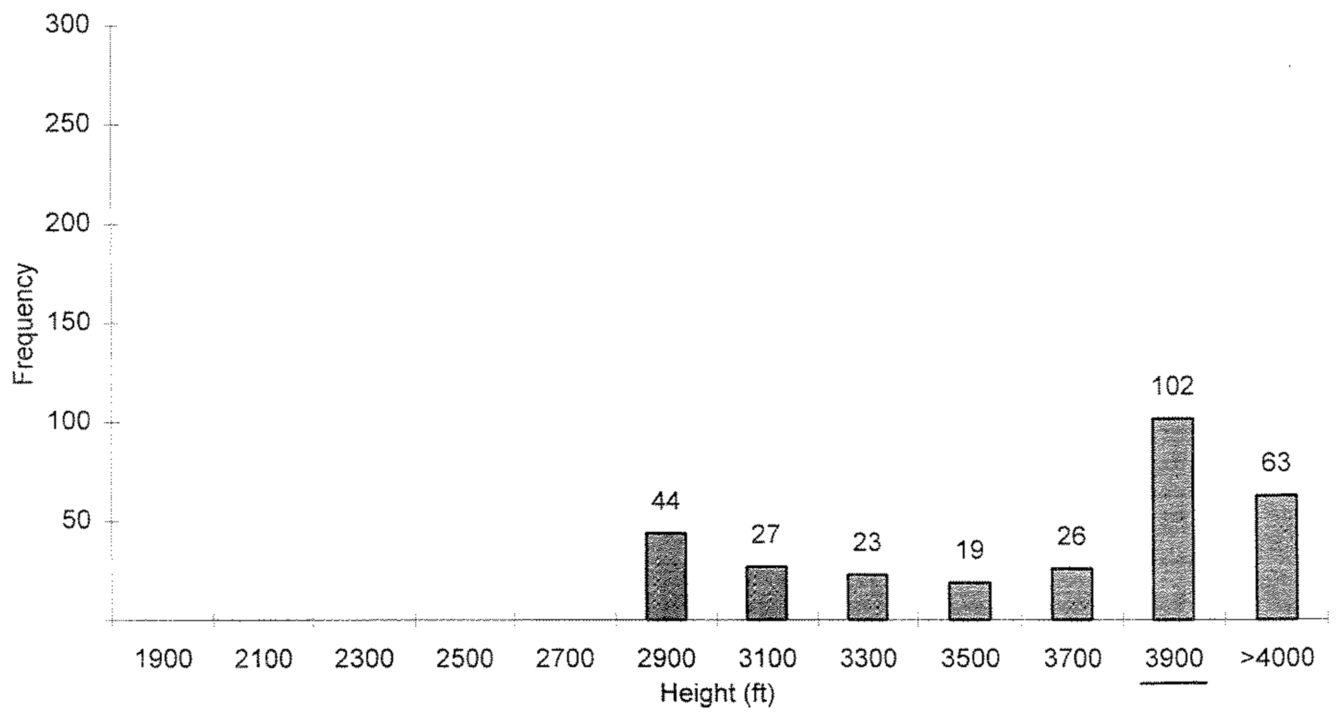


Figure 9g: Runway 27R, 7 nm from touchdown, July 1997, 0400 to 0600 (local time)

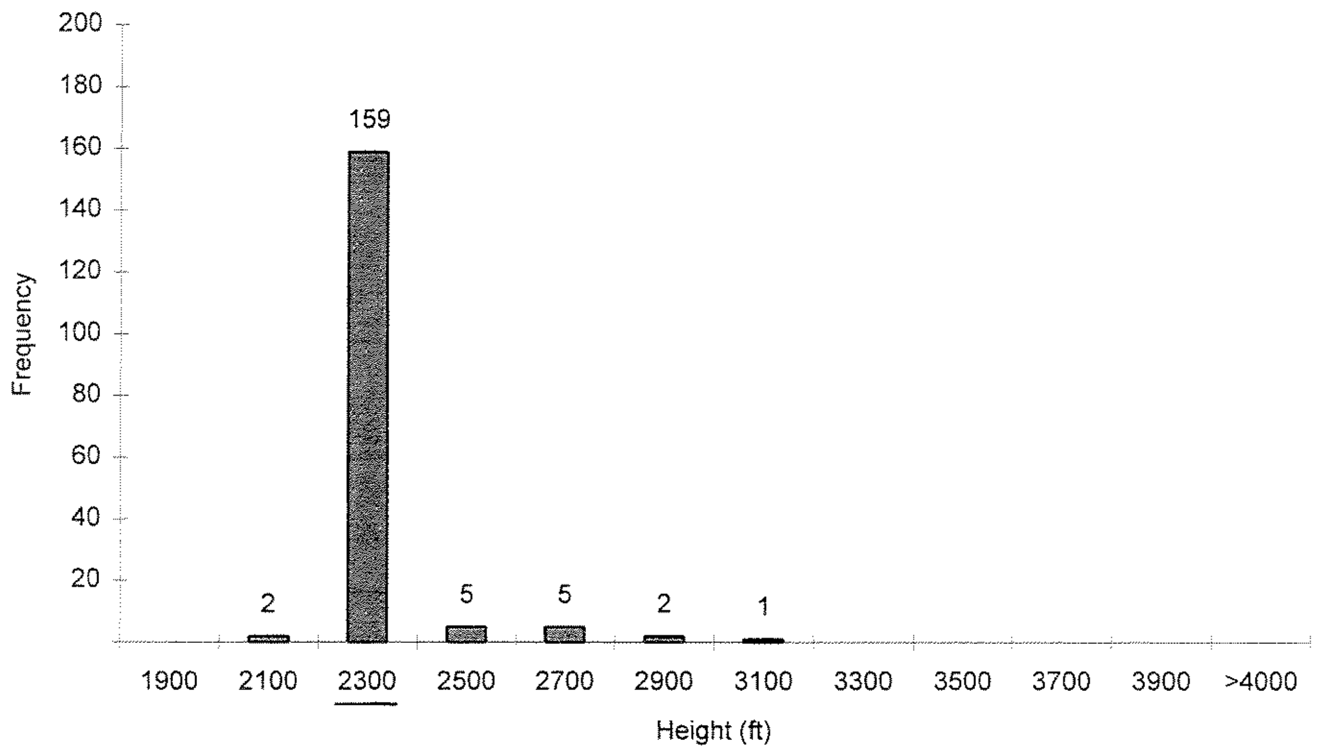


Figure 9h: Runway 27R, 8 nm from touchdown, July 1997, 0400 to 0600 (local time)

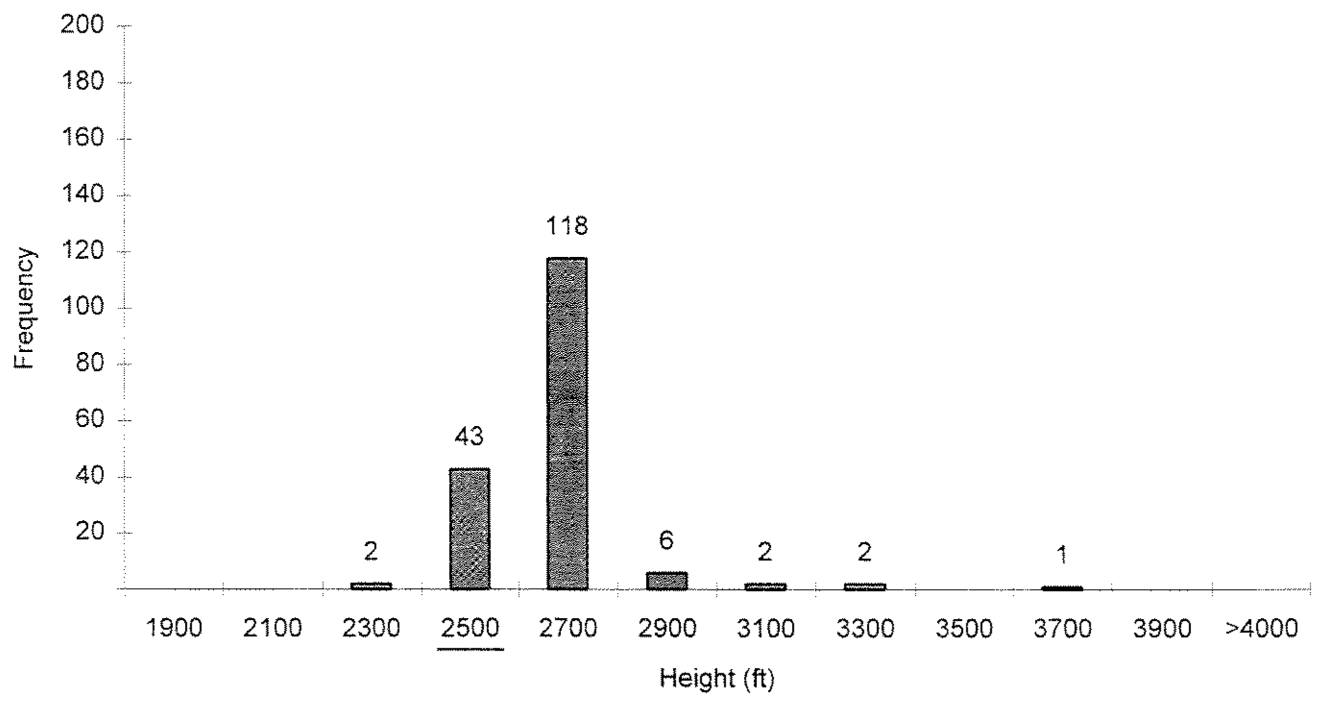


Figure 9i: Runway 27R, 9 nm from touchdown, July 1997, 0400 to 0600 (local time)

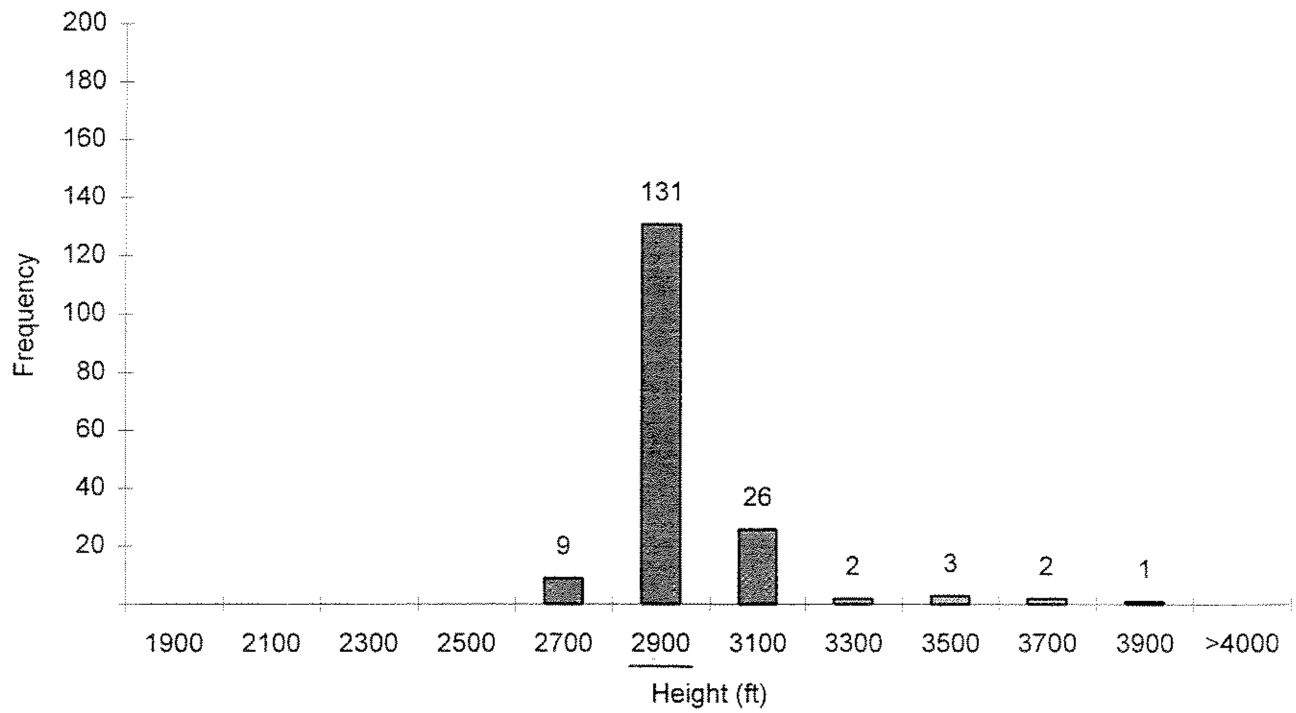


Figure 9j: Runway 27R, 10 nm from touchdown, July 1997, 0400 to 0600 (local time)

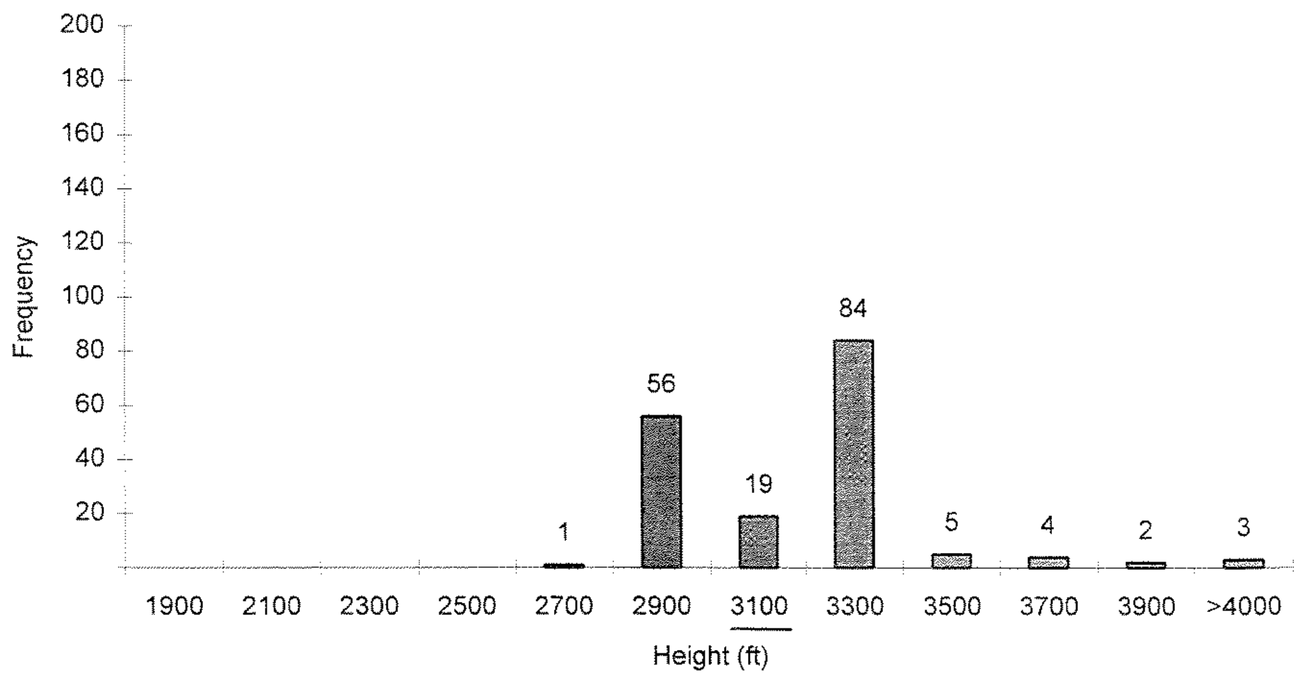


Figure 9k: Runway 27R, 11 nm from touchdown, July 1997, 0400 to 0600 (local time)

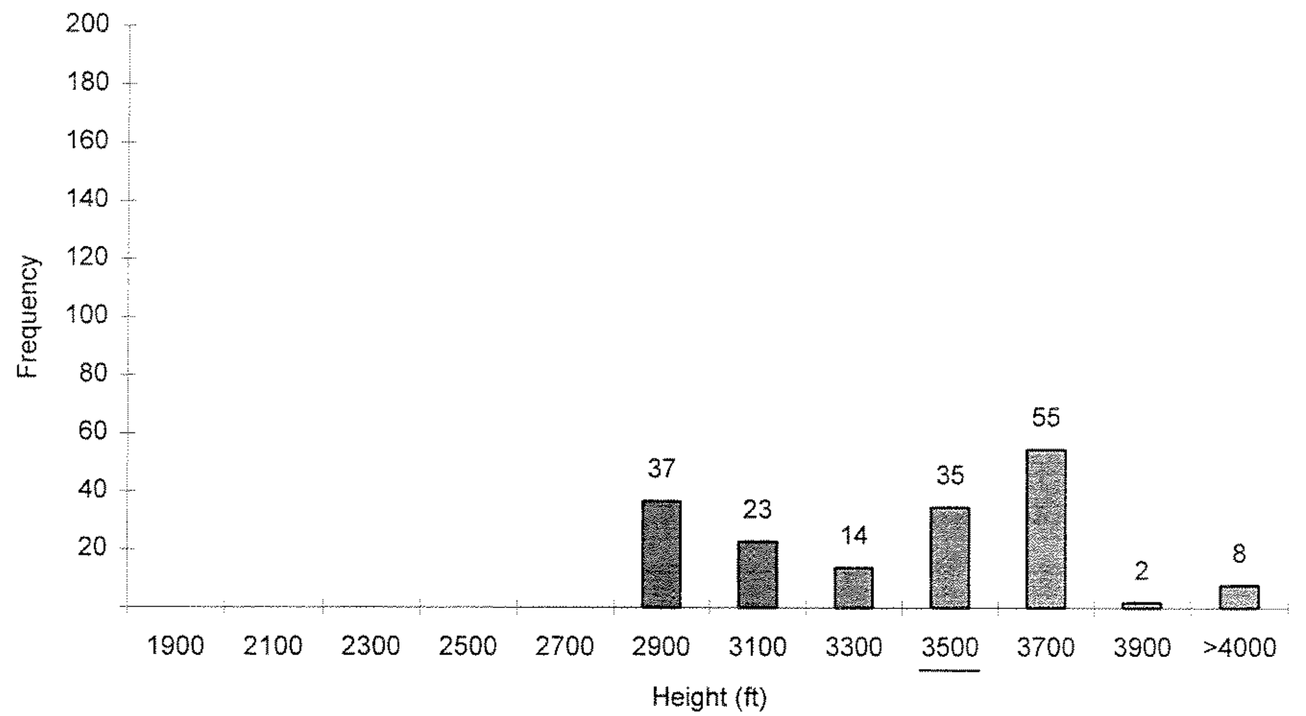


Figure 9l: Runway 27R, 12 nm from touchdown, July 1997, 0400 to 0600 (local time)

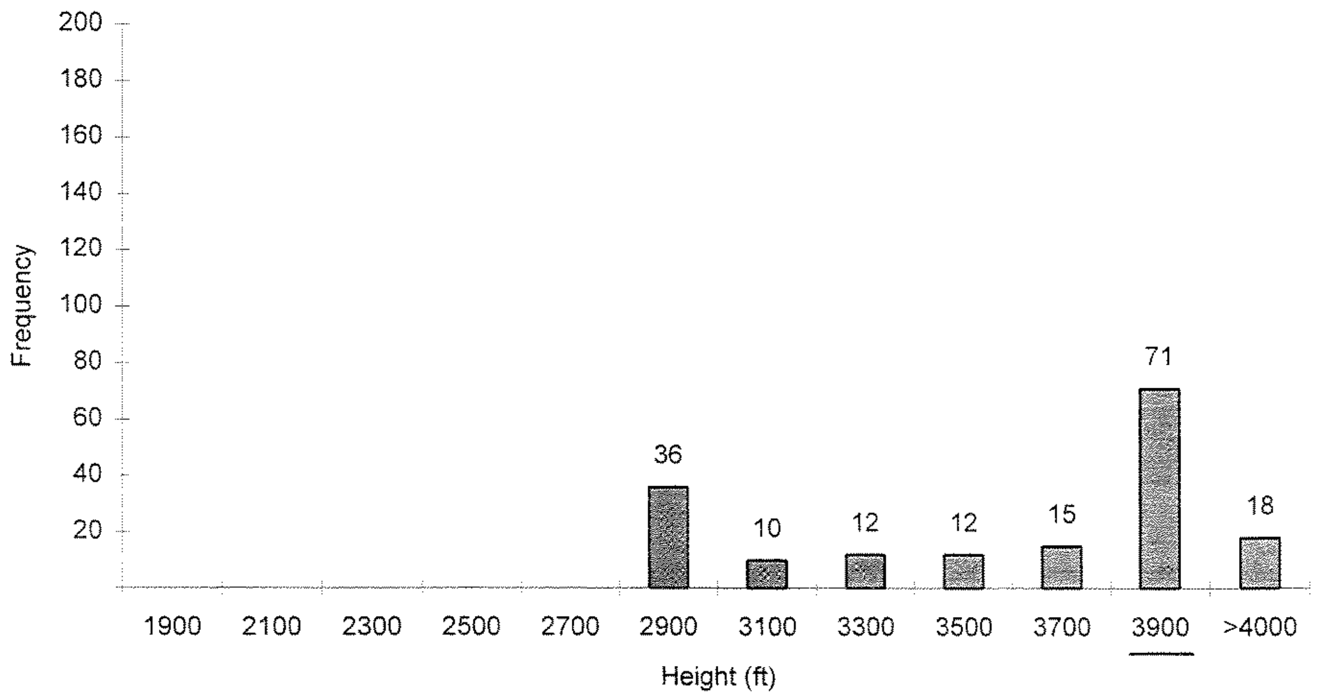


Figure 9m: July 1997, 27L radar tracks, 0400-0600 local time

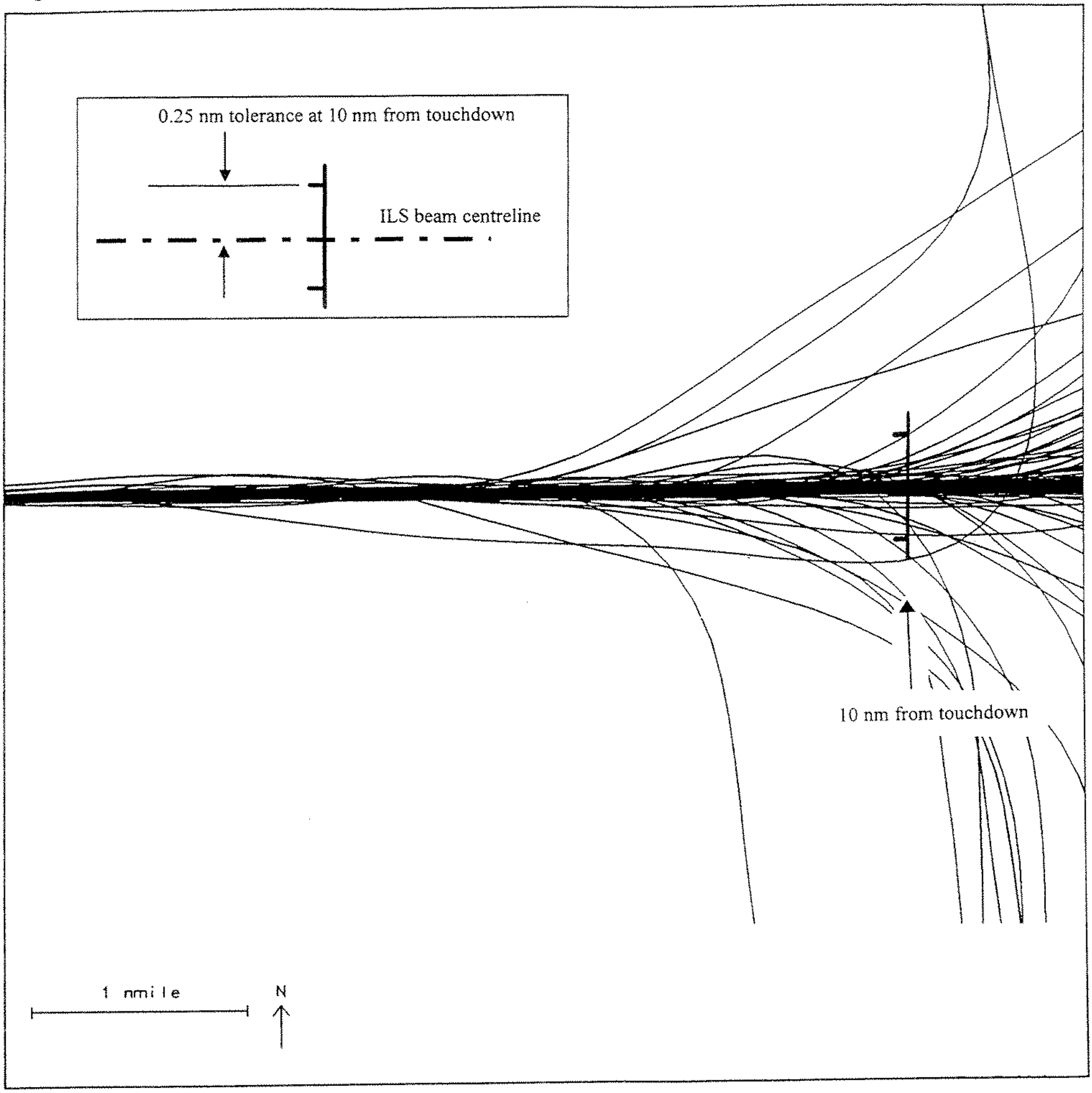
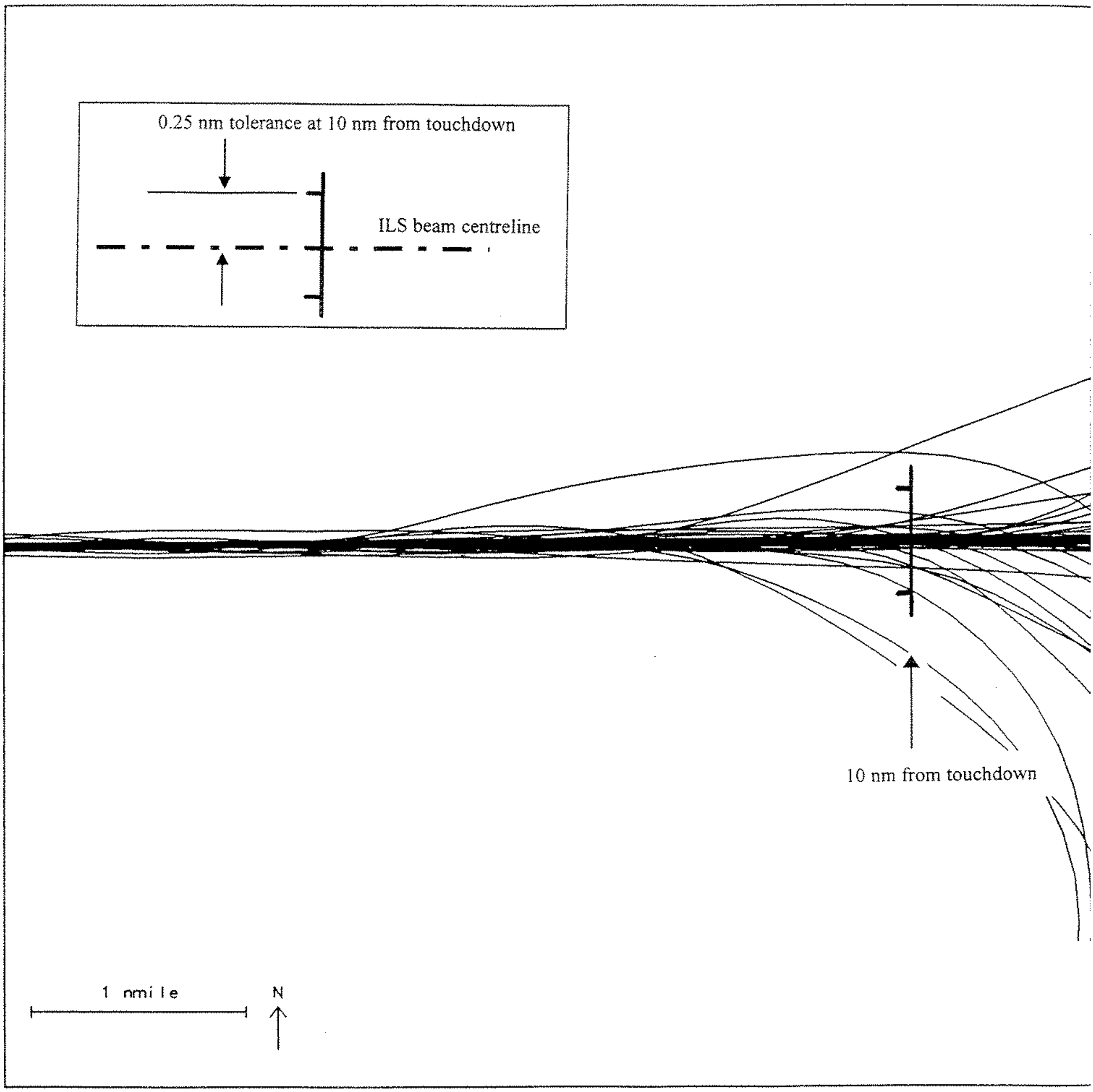


Figure 9n: July 1997, 27R radar tracks, 0400-0600 local time



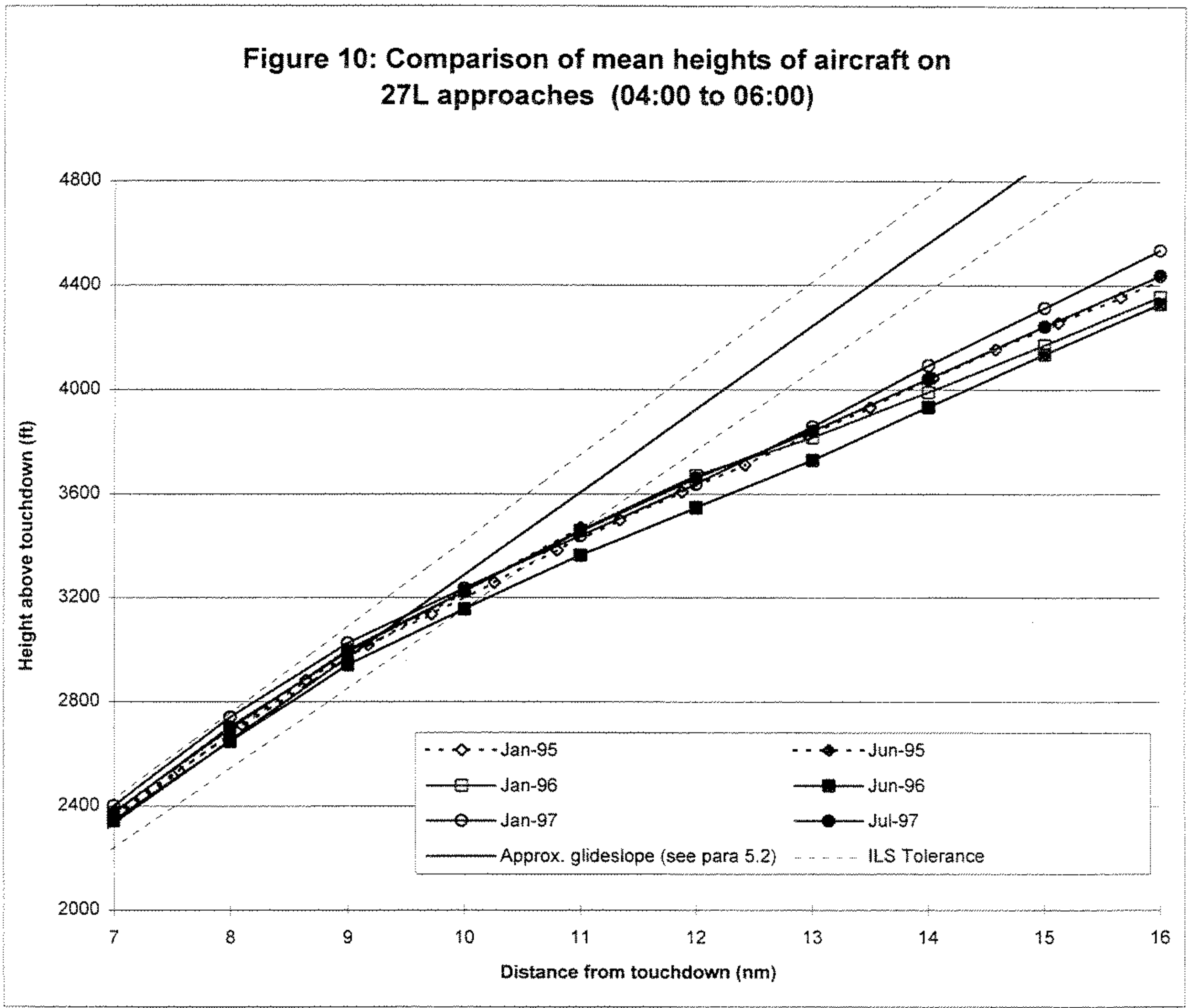


Figure 10: Comparison of mean heights of aircraft on 27L approaches (04:00 to 06:00)
4800
4400
4000
3600
3200
2800
2400
2000
Height above touchdown (ft)
7
8
9
10
11
12
13
14
15
16
Distance from touchdown (nm)
Jan-95
Jun-95
Jan-96
Jun-96
Jan-97
Jul-97
Approx. glideslope (see para 5.2)
ILS Tolerance

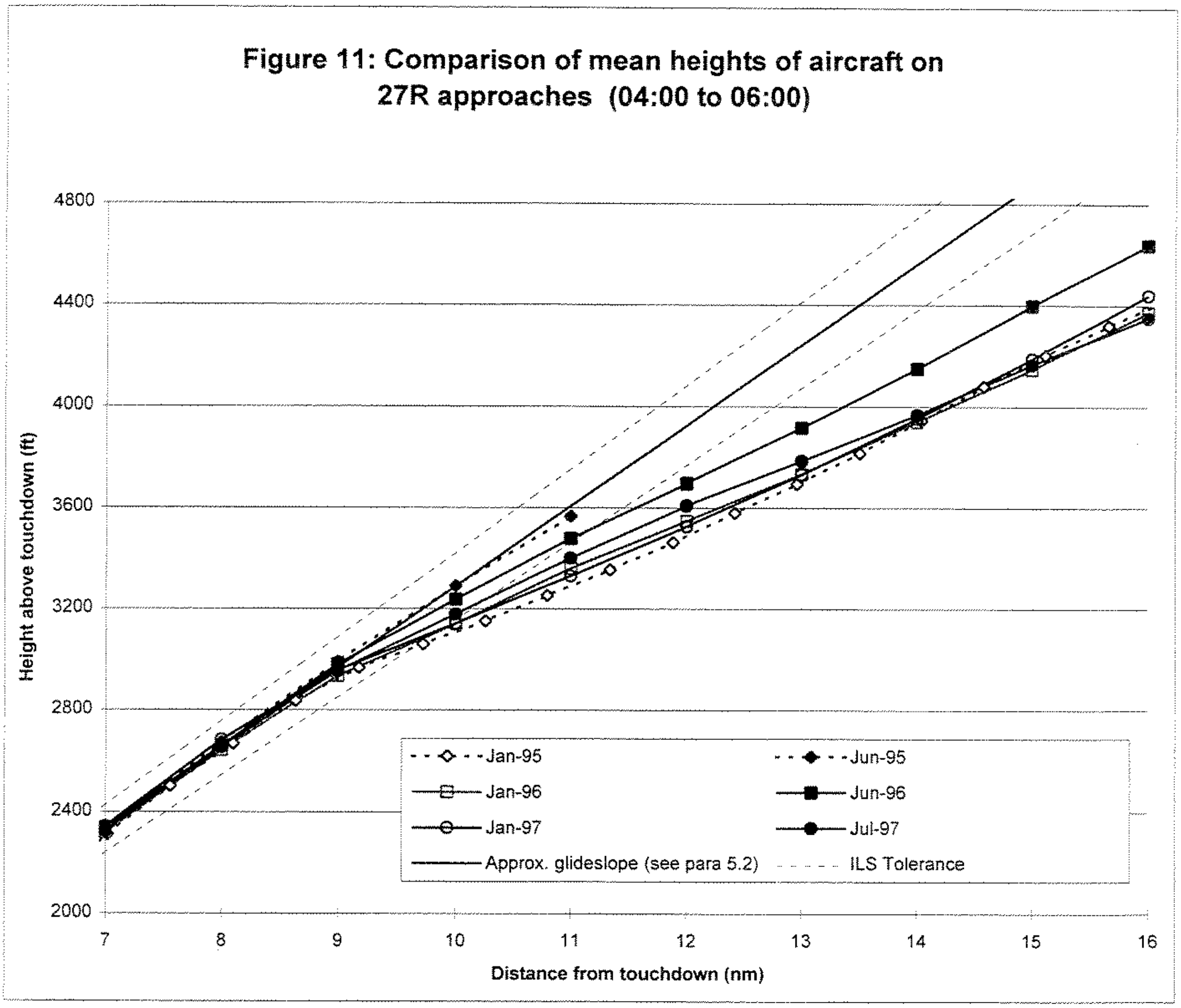


Figure 11: Comparison of mean heights of aircraft on 27R approaches (04:00 to 06:00)
Height above touchdown (ft)
4800
4400
4000
3600
3200
2800
2400
2000
7
8
9
10
11
12
13
14
15
16
Distance from touchdown (nm)
Jan-95
Jun-95
Jan-96
Jun-96
Jan-97
Jul-97
Approx. glideslope (see para 5.2)
ILS Tolerance

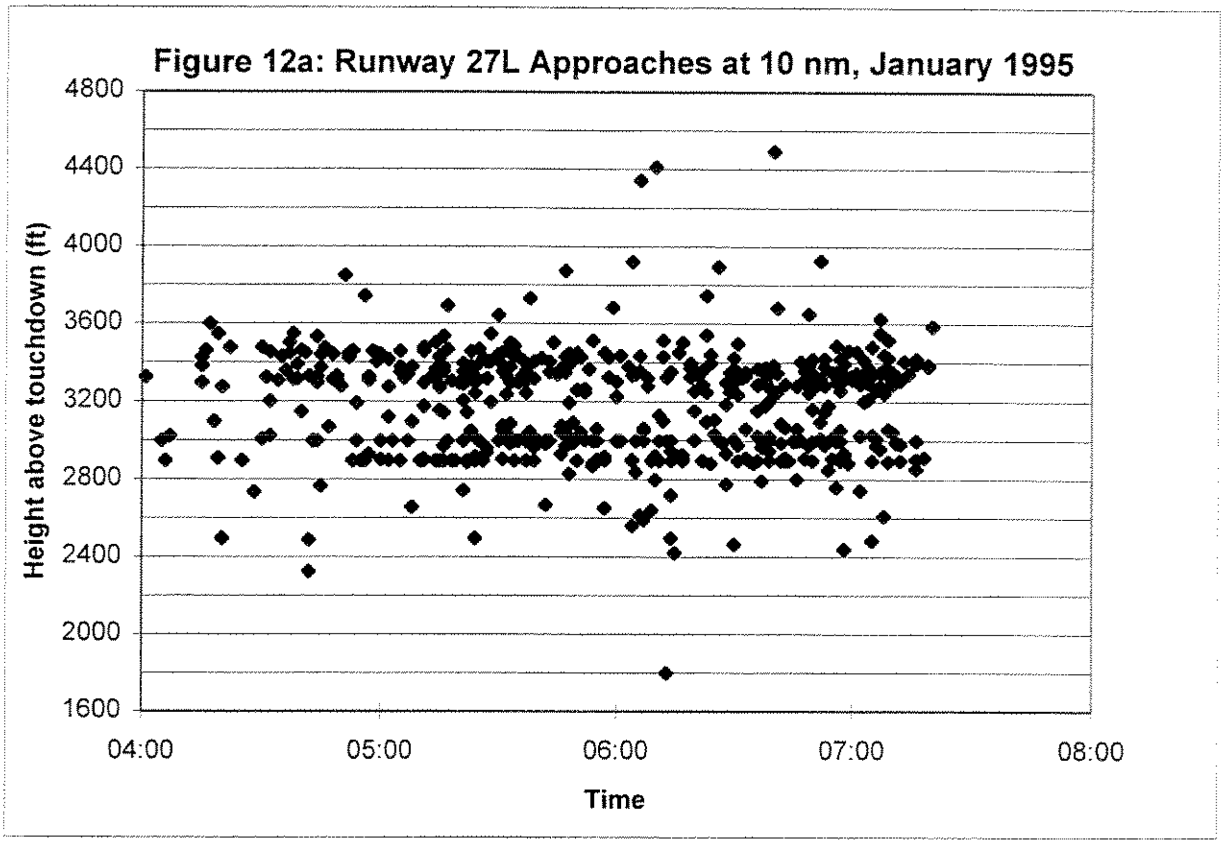


Figure 12a: Runway 27L Approaches at 10 nm, January 1995
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
04:00
05:00
06:00
07:00
08:00
Time

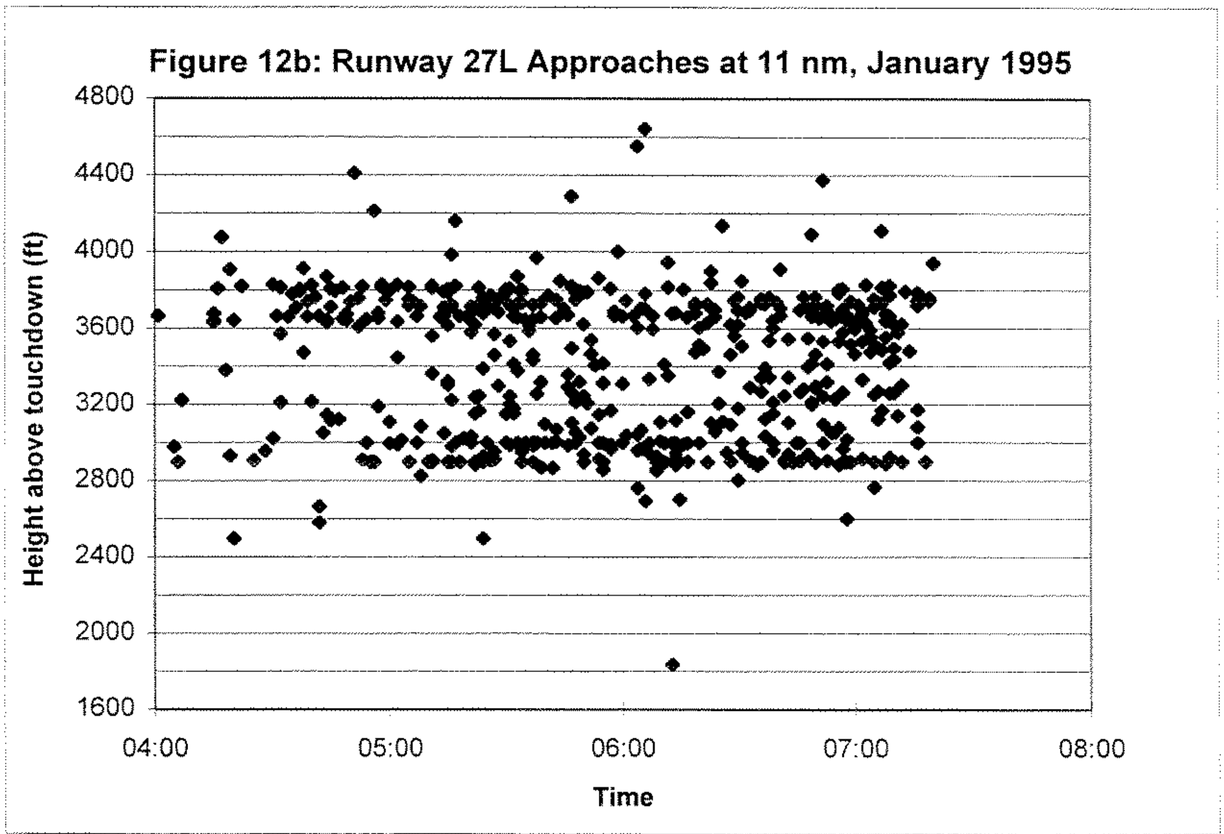


Figure 12b: Runway 27L Approaches at 11 nm, January 1995
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
04:00
05:00
06:00
07:00
08:00
Time

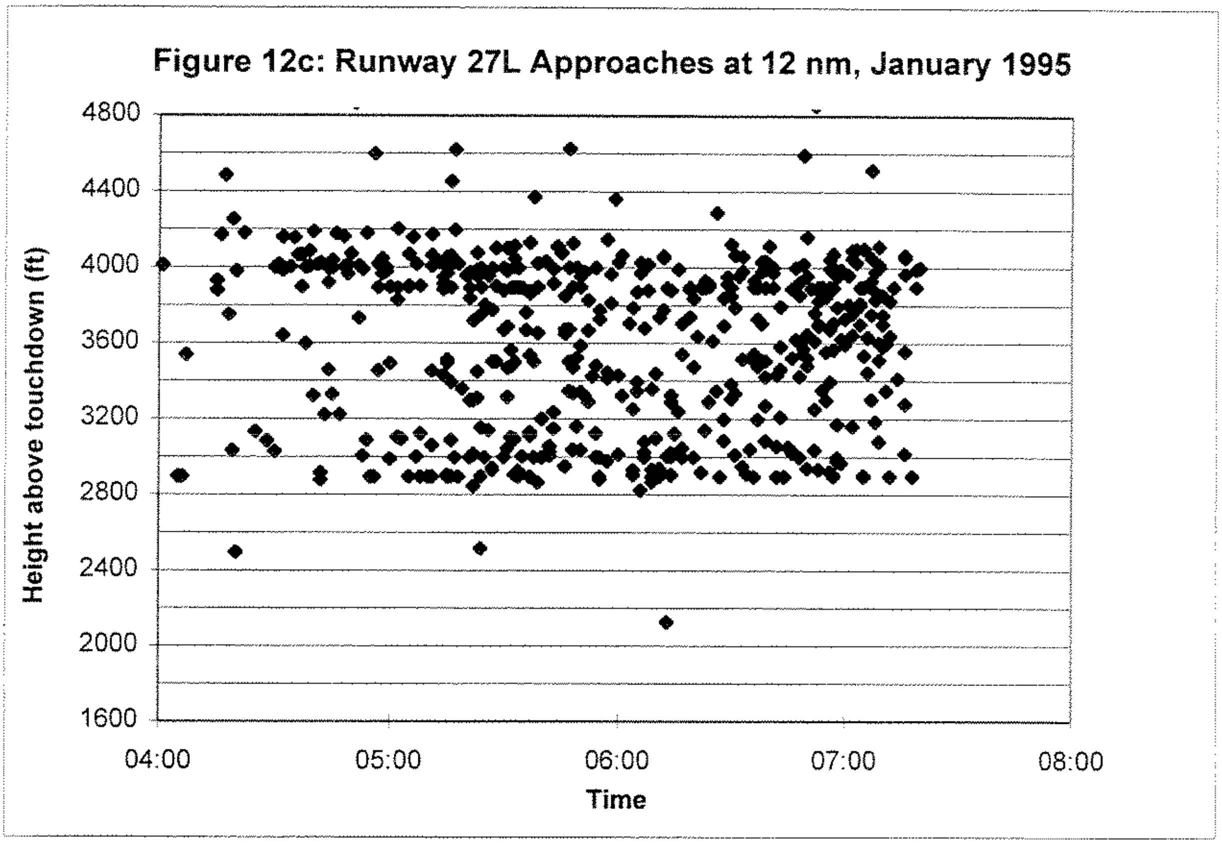


Figure 12c: Runway 27L Approaches at 12 nm, January 1995
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
04:00
05:00
06:00
07:00
08:00
Time

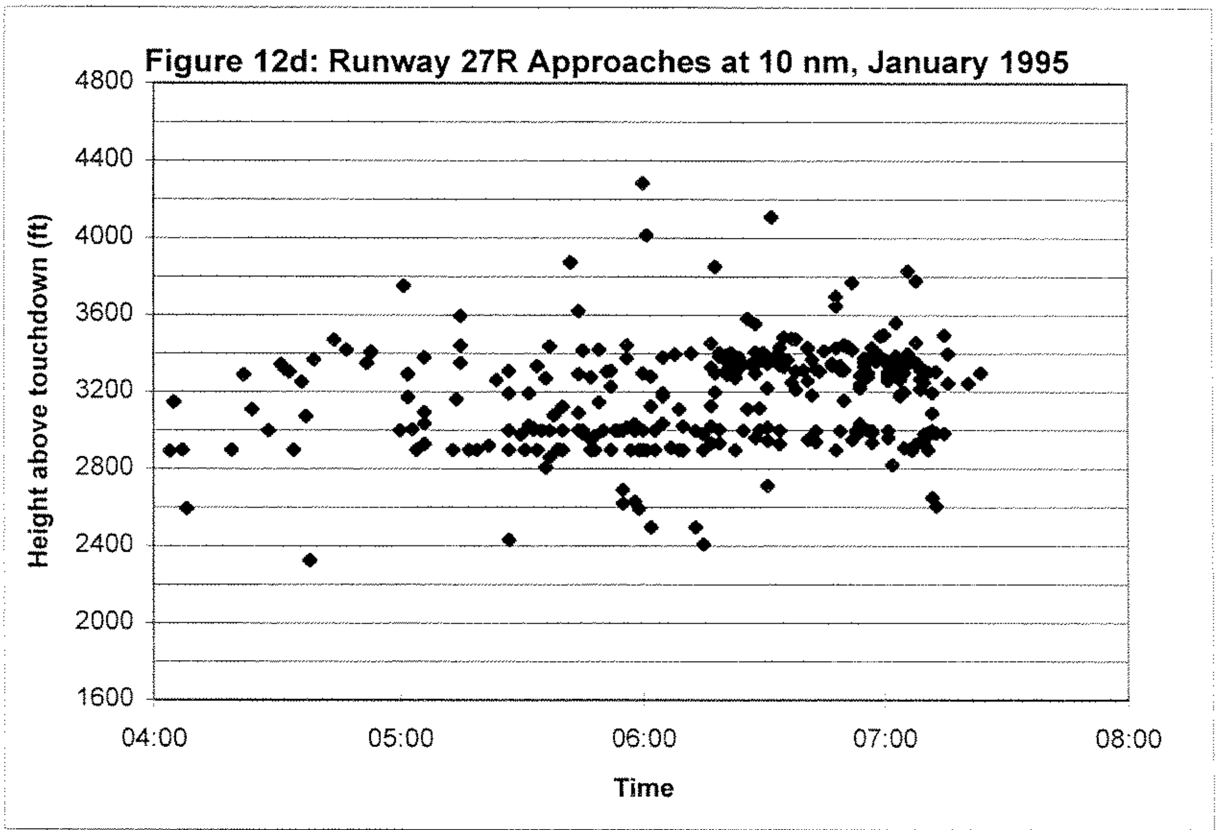


Figure 12d: Runway 27R Approaches at 10 nm, January 1995
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
04:00
05:00
06:00
07:00
08:00
Time

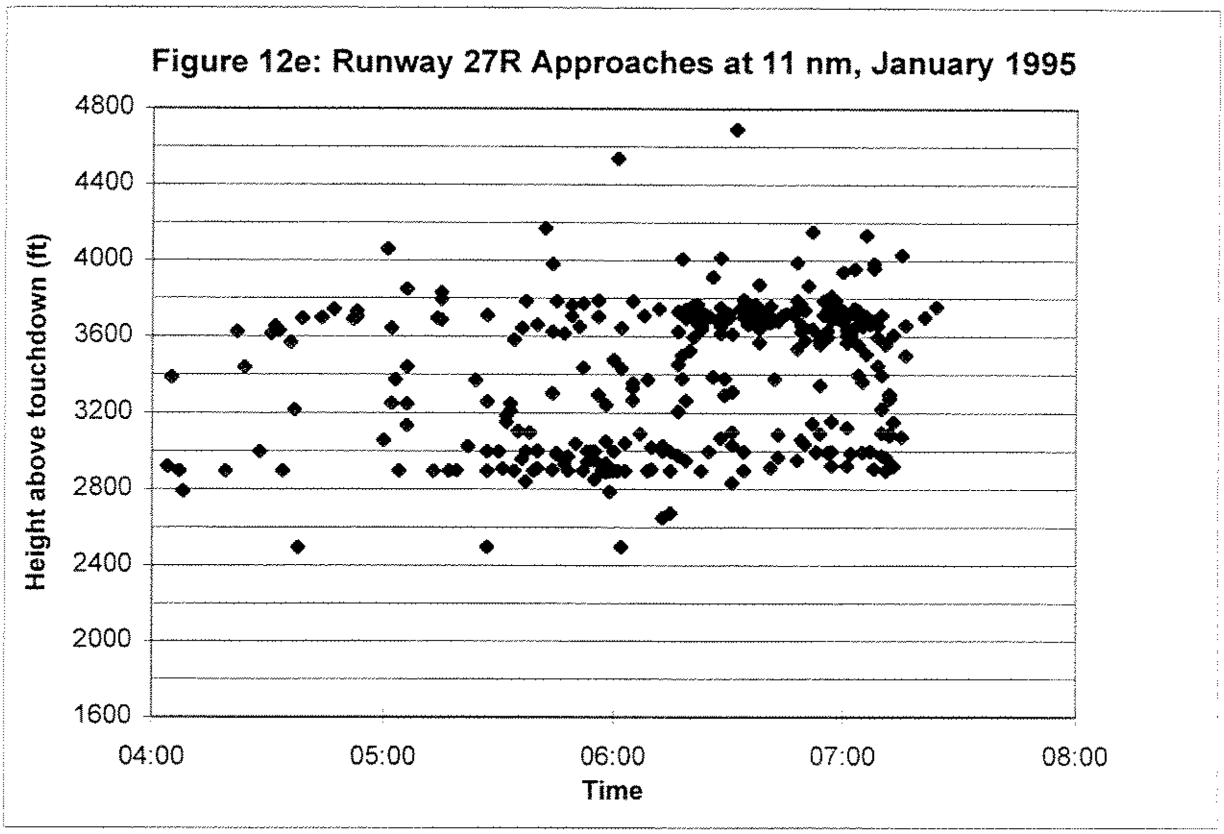


Figure 12e: Runway 27R Approaches at 11 nm, January 1995
Height above touchdown (ft)
4800
4400
4000
3600
3200
2800
2400
2000
1600
04:00
05:00
06:00
07:00
08:00
Time

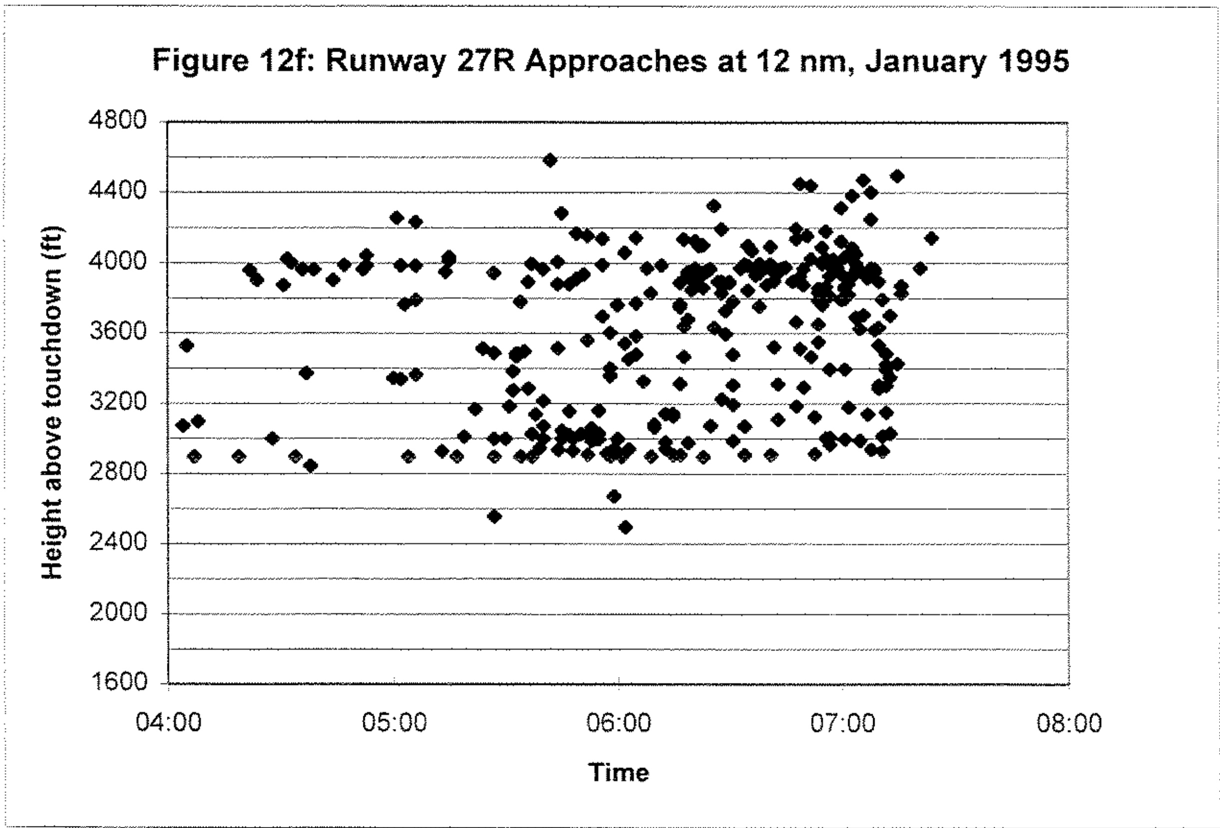


Figure 12f: Runway 27R Approaches at 12 nm, January 1995
Height above touchdown (ft)
4800
4400
4000
3600
3200
2800
2400
2000
1600
04:00
05:00
06:00
07:00
08:00
Time

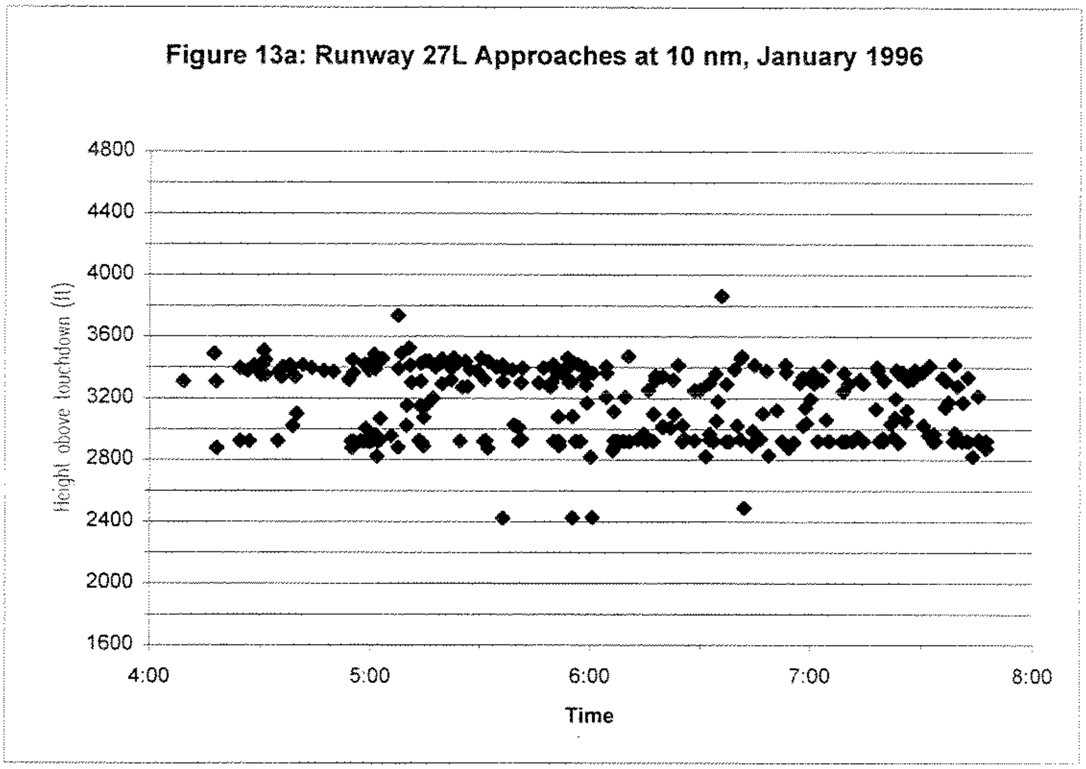


Figure 13a: Runway 27L Approaches at 10 nm, January 1996
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00
5:00
6:00
7:00
8:00
Time

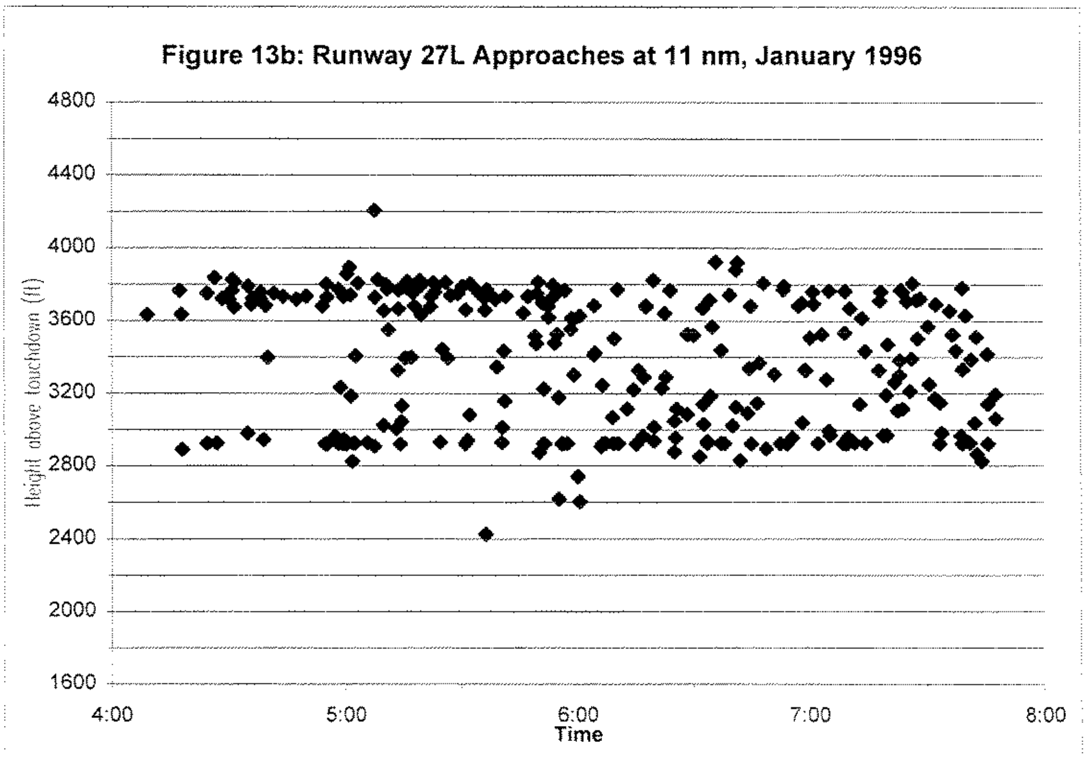


Figure 13b: Runway 27L Approaches at 11 nm, January 1996
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00
5:00
6:00
7:00
8:00
Time

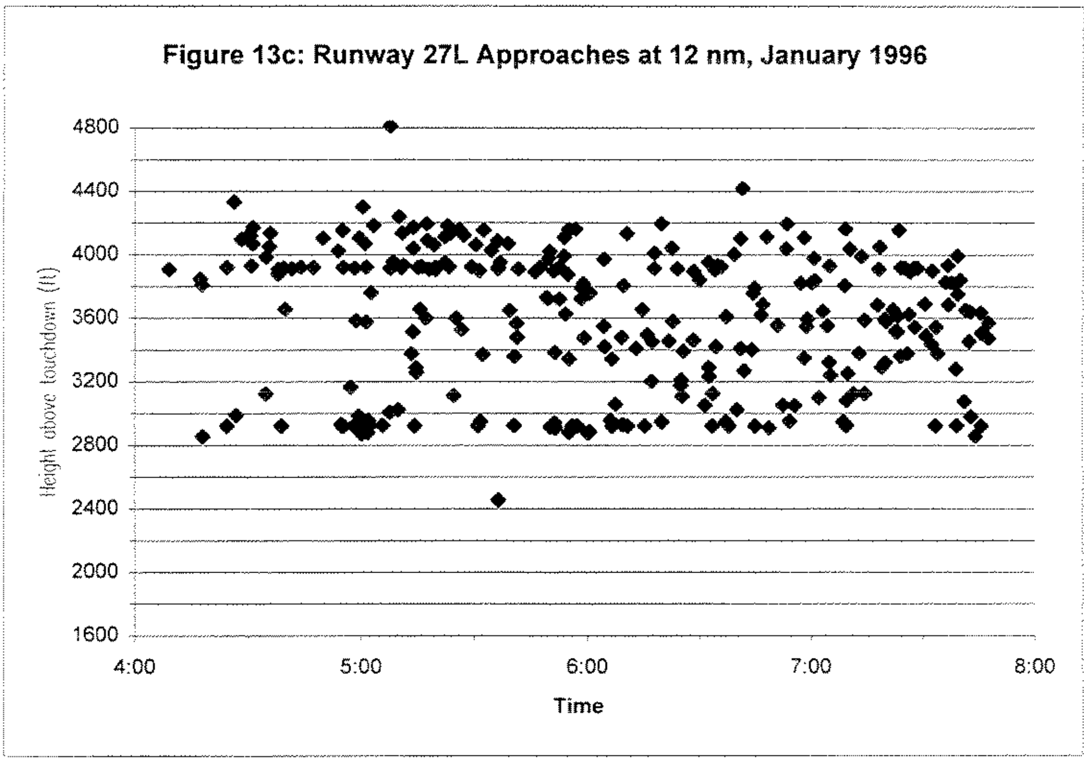


Figure 13c: Runway 27L Approaches at 12 nm, January 1996
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00
5:00
6:00
7:00
8:00
Time

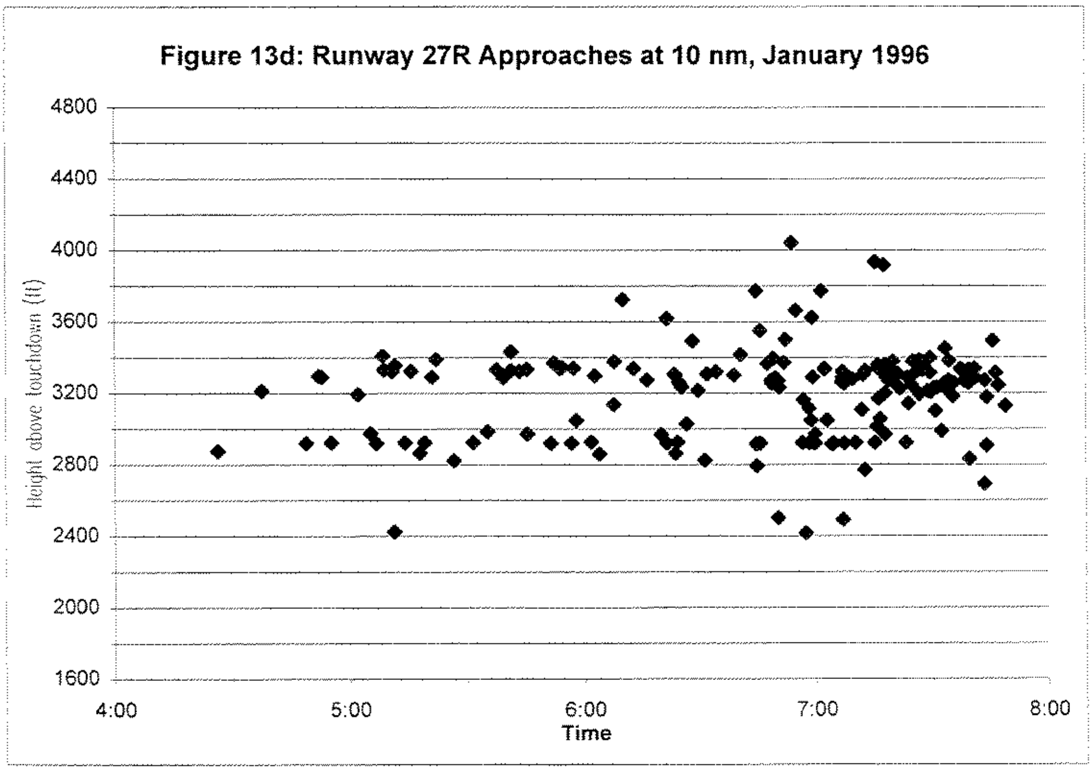


Figure 13d: Runway 27R Approaches at 10 nm, January 1996
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00
5:00
6:00
7:00
8:00
Time

Figure 13e: Runway 27R Approaches at 11 nm, January 1996

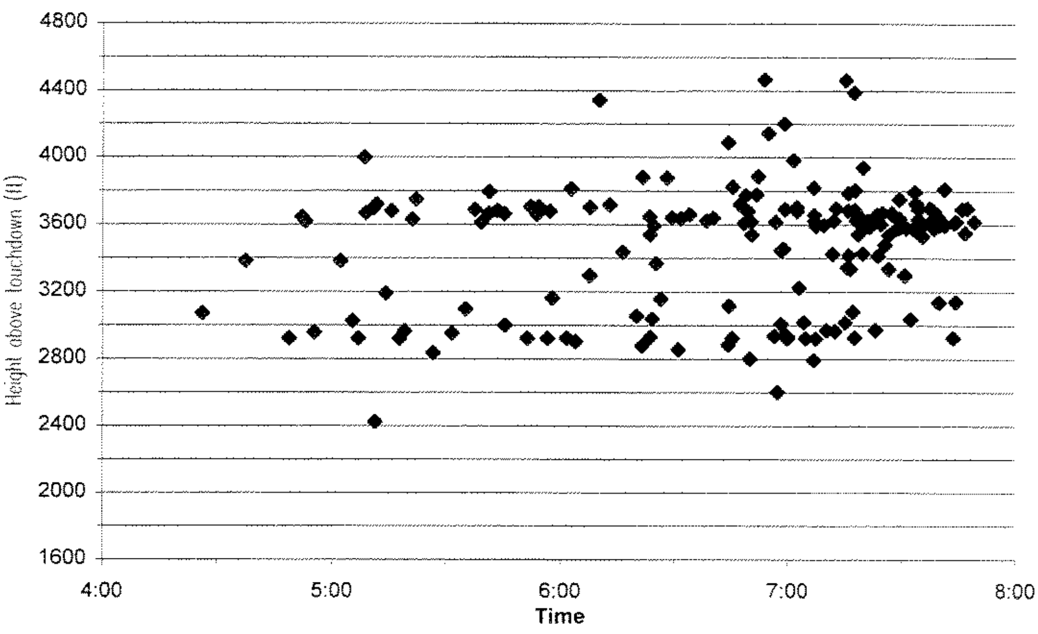
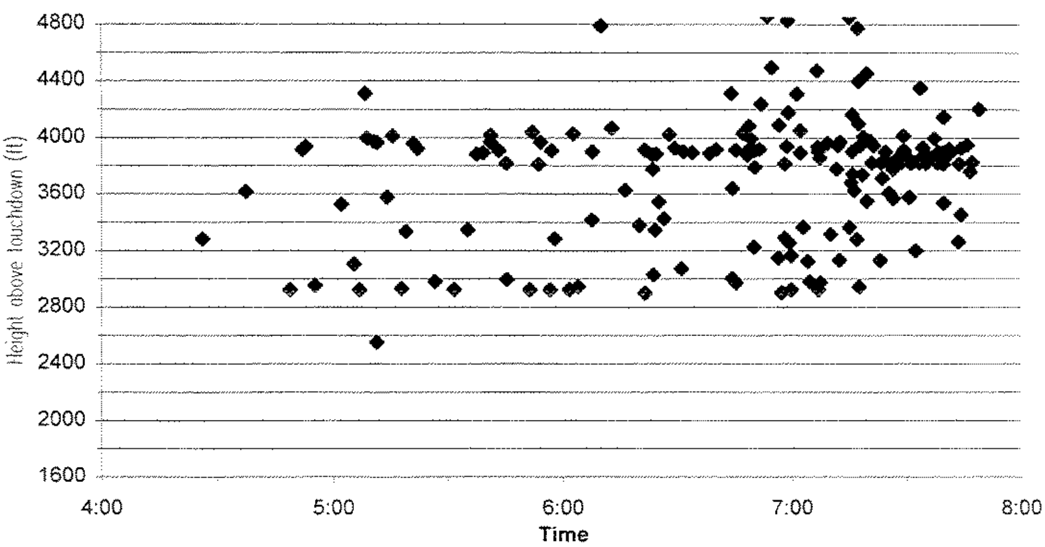


Figure 13f: Runway 27R Approaches at 12 nm, January 1996



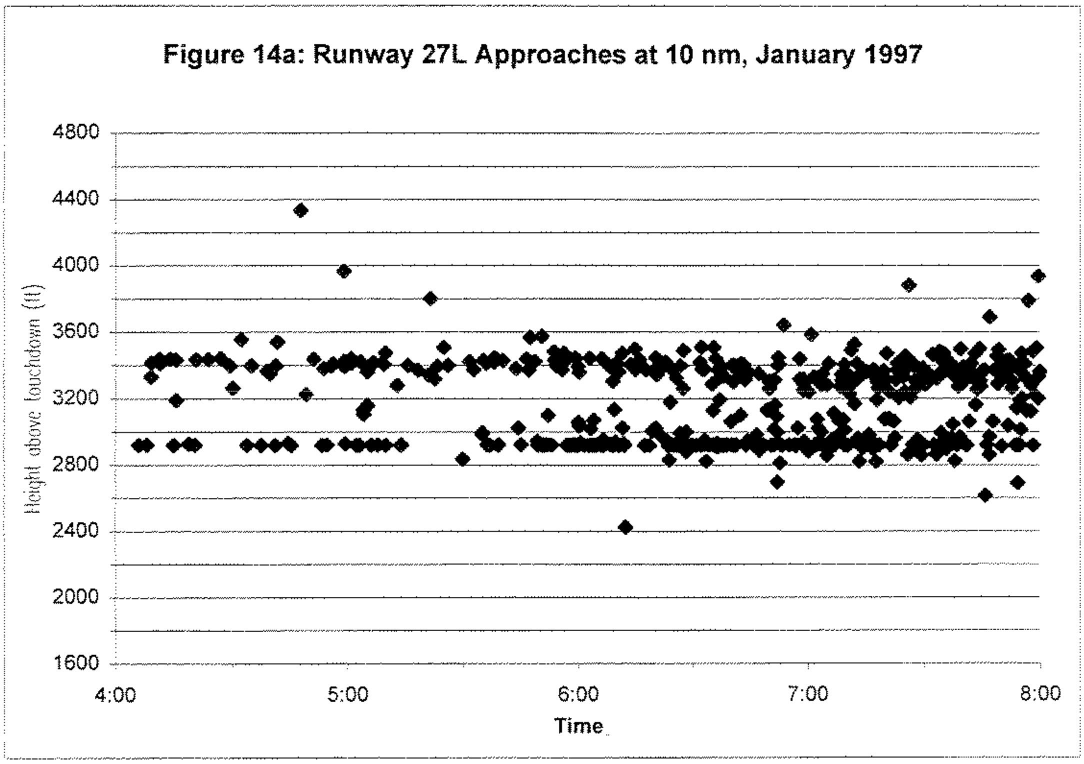


Figure 14a: Runway 27L Approaches at 10 nm, January 1997
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00
5:00
6:00
7:00
8:00
Time

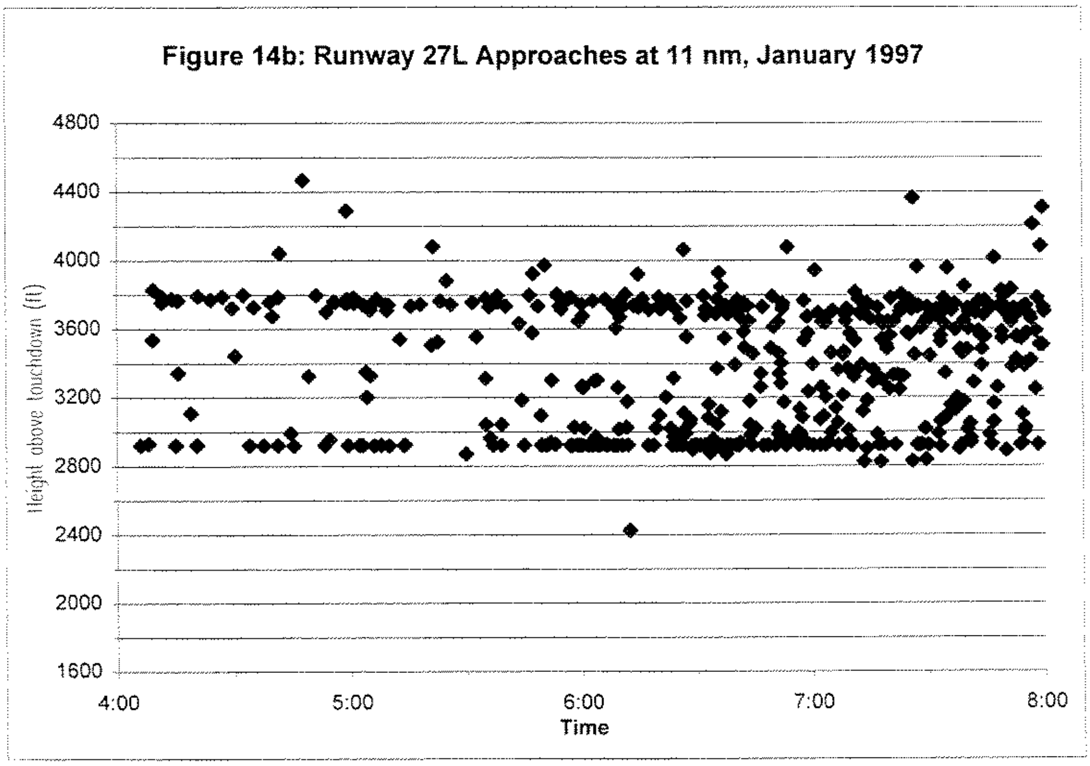


Figure 14b: Runway 27L Approaches at 11 nm, January 1997
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00
5:00
6:00
7:00
8:00
Time

Figure 14c: Runway 27L Approaches at 12 nm, January 1997

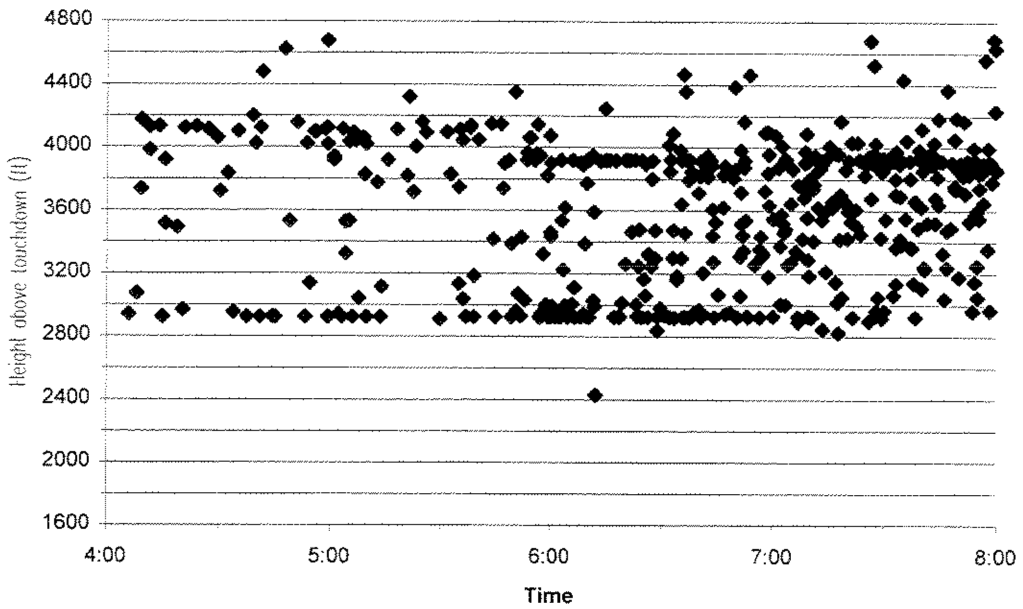
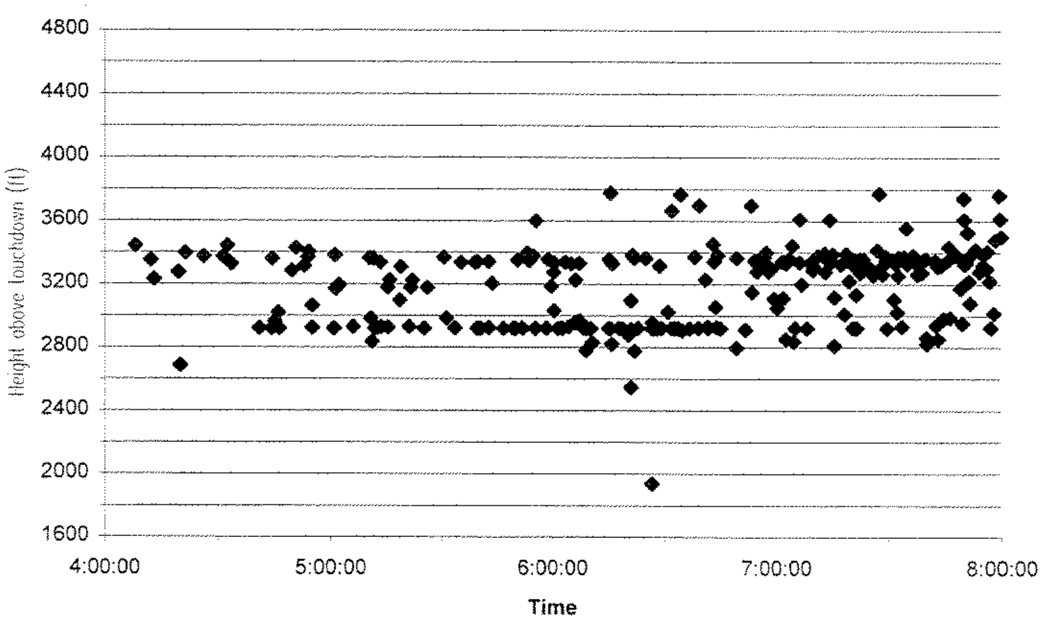


Figure 14d: Runway 27R Approaches at 10 nm, January 1997



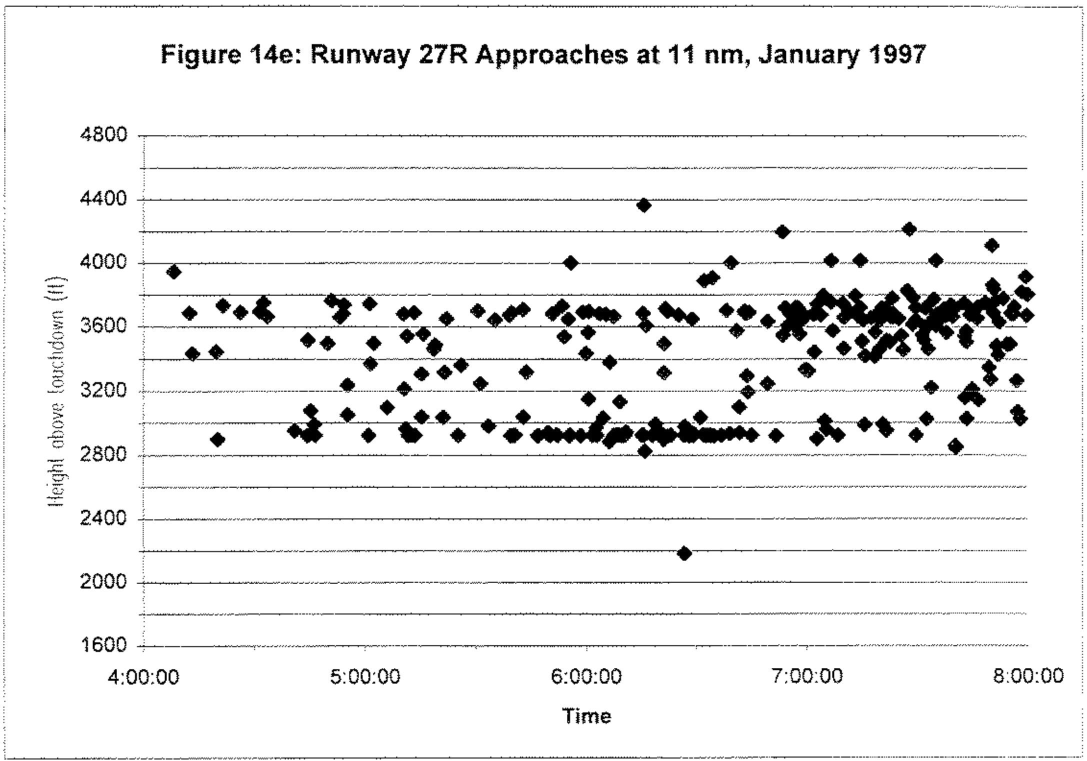


Figure 14e: Runway 27R Approaches at 11 nm, January 1997
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00:00
5:00:00
6:00:00
7:00:00
8:00:00
Time

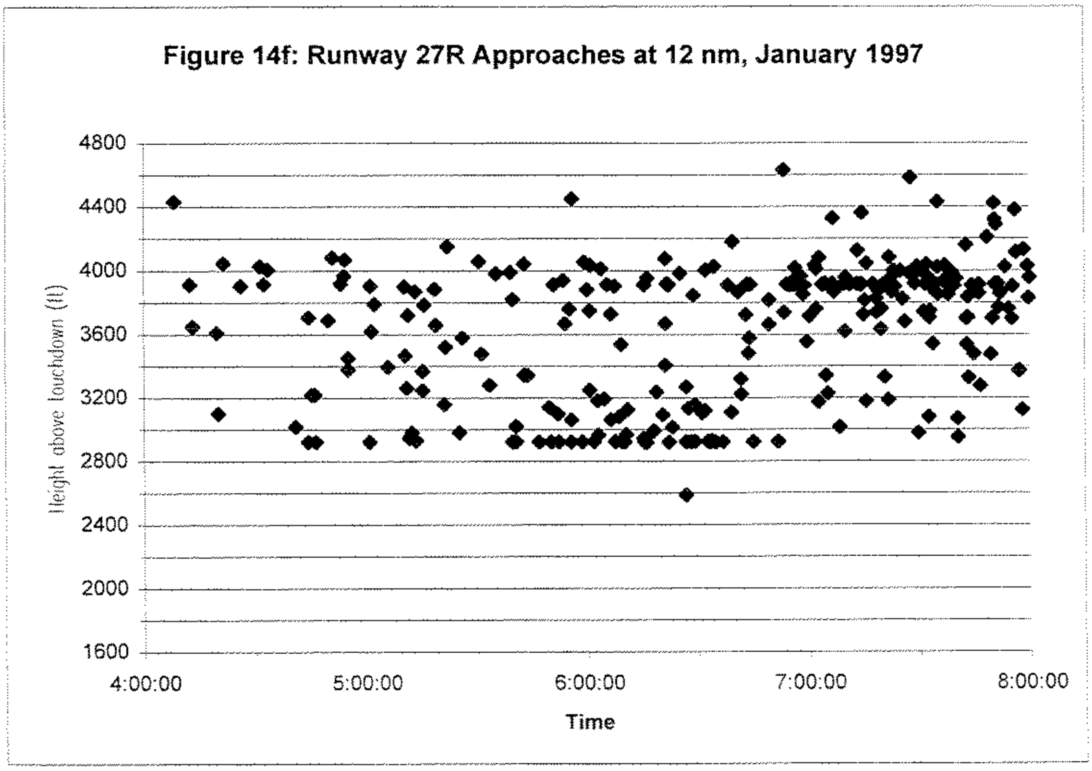


Figure 14f: Runway 27R Approaches at 12 nm, January 1997
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00:00
5:00:00
6:00:00
7:00:00
8:00:00
Time

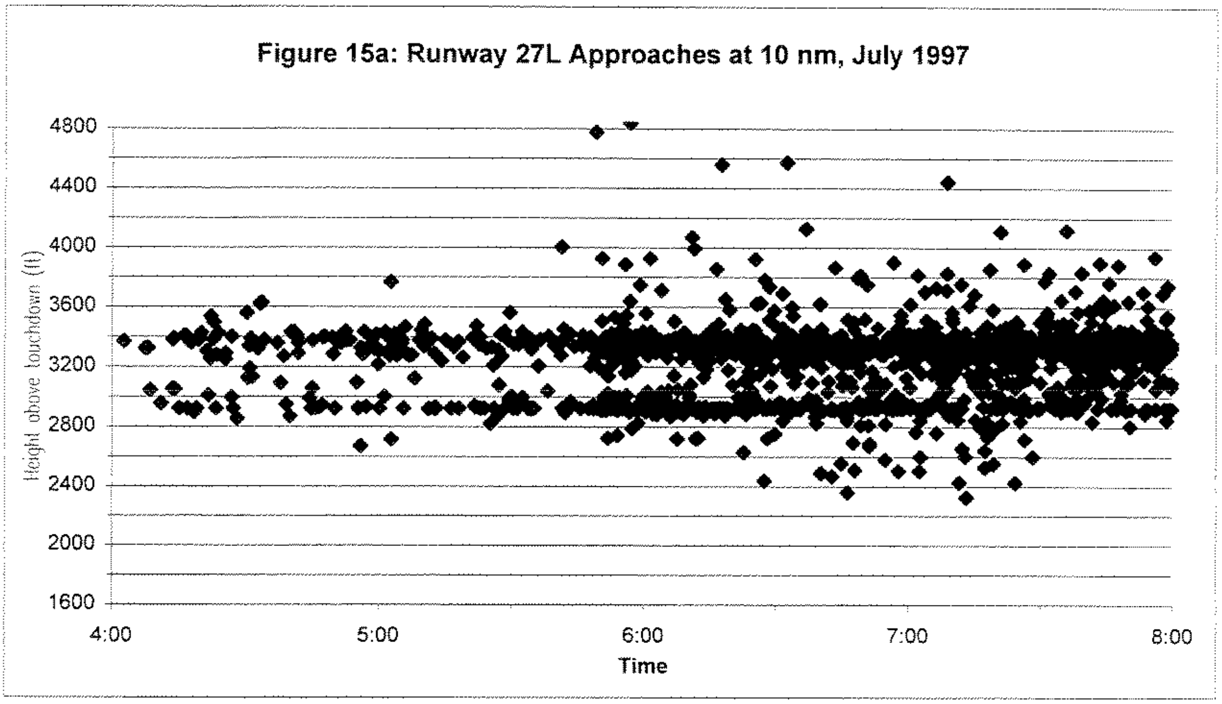


Figure 15a: Runway 27L Approaches at 10 nm, July 1997
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00
5:00
6:00
7:00
8:00
Time

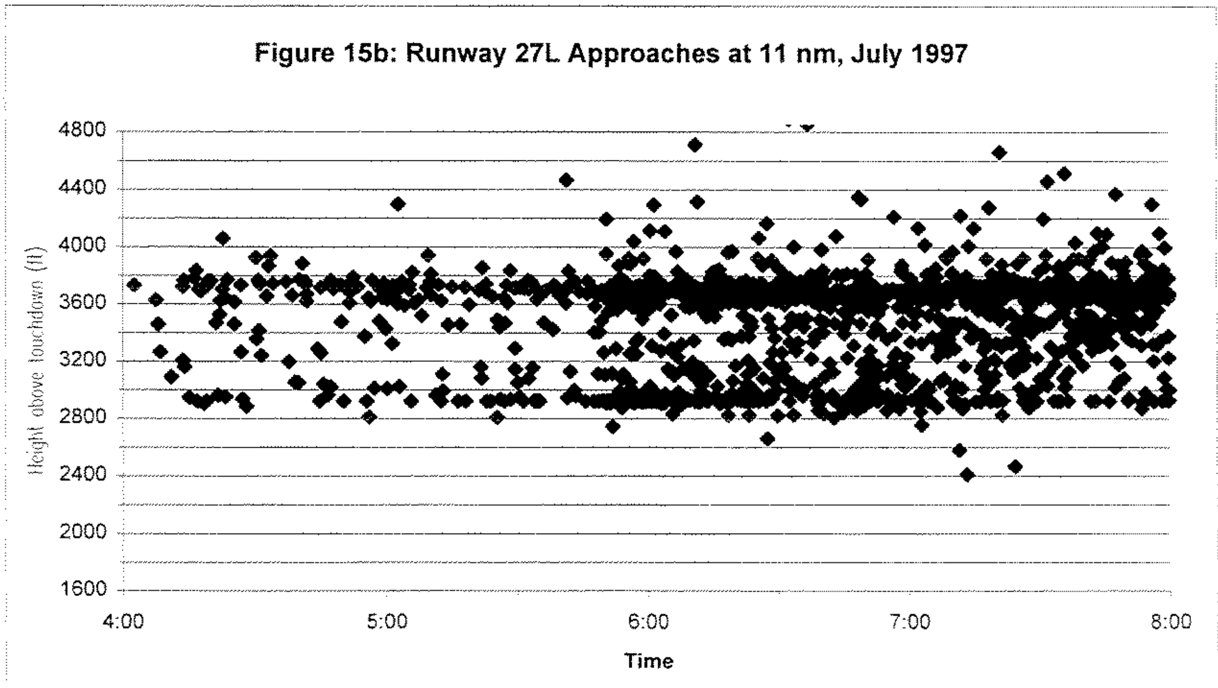


Figure 15b: Runway 27L Approaches at 11 nm, July 1997
4800
4400
4000
3600
3200
2800
2400
2000
1600
Height above touchdown (ft)
4:00
5:00
6:00
7:00
8:00
Time

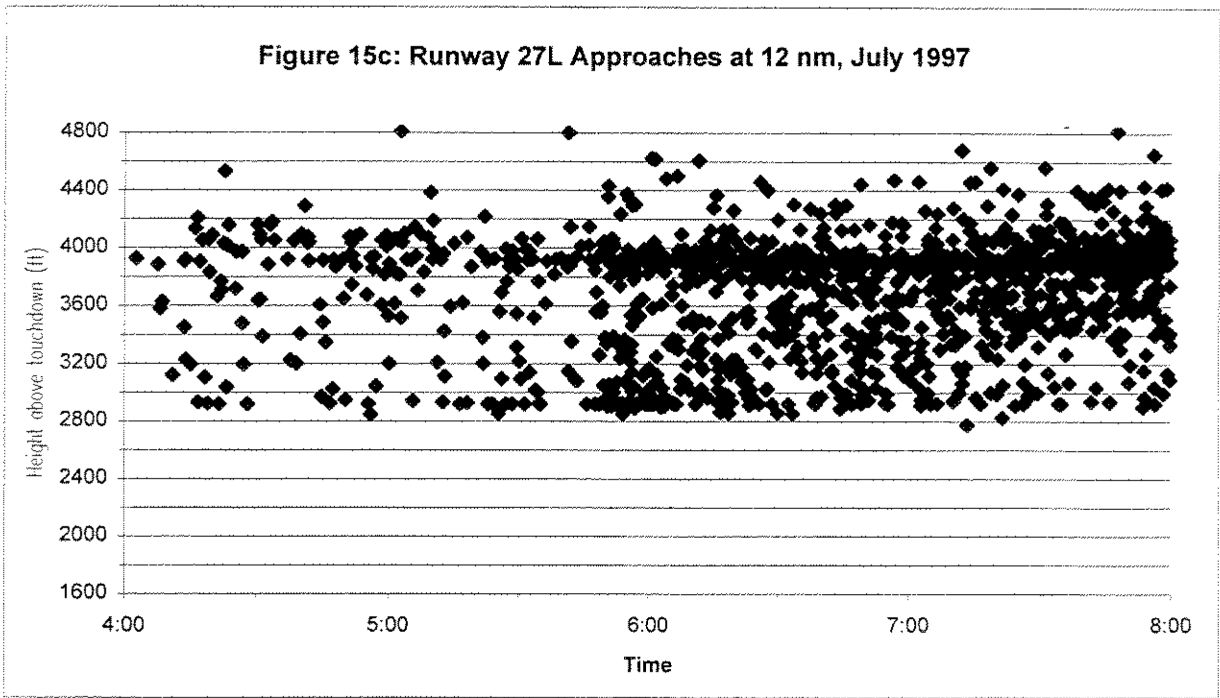


Figure 15c: Runway 27L Approaches at 12 nm, July 1997
Height above touchdown (ft)
4800
4400
4000
3600
3200
2800
2400
2000
1600
4:00
5:00
6:00
7:00
8:00
Time

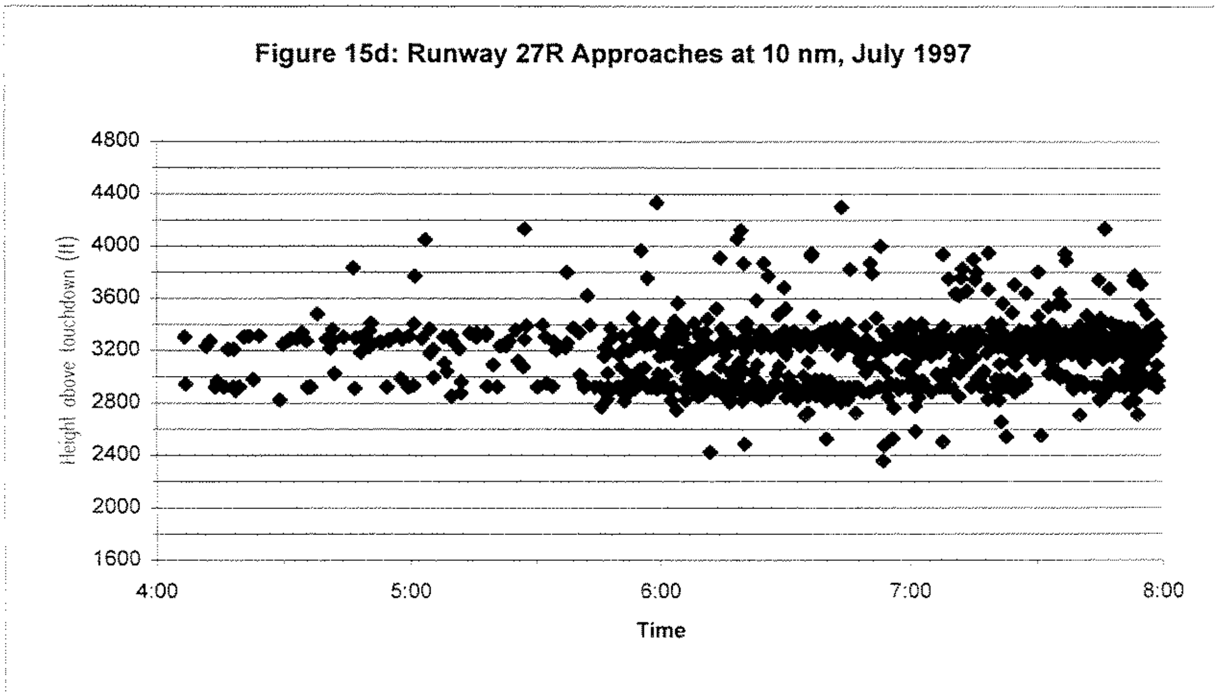


Figure 15d: Runway 27R Approaches at 10 nm, July 1997
Height above touchdown (ft)
4800
4400
4000
3600
3200
2800
2400
2000
1600
4:00
5:00
6:00
7:00
8:00
Time

Figure 15e: Runway 27R Approaches at 11 nm, July 1997

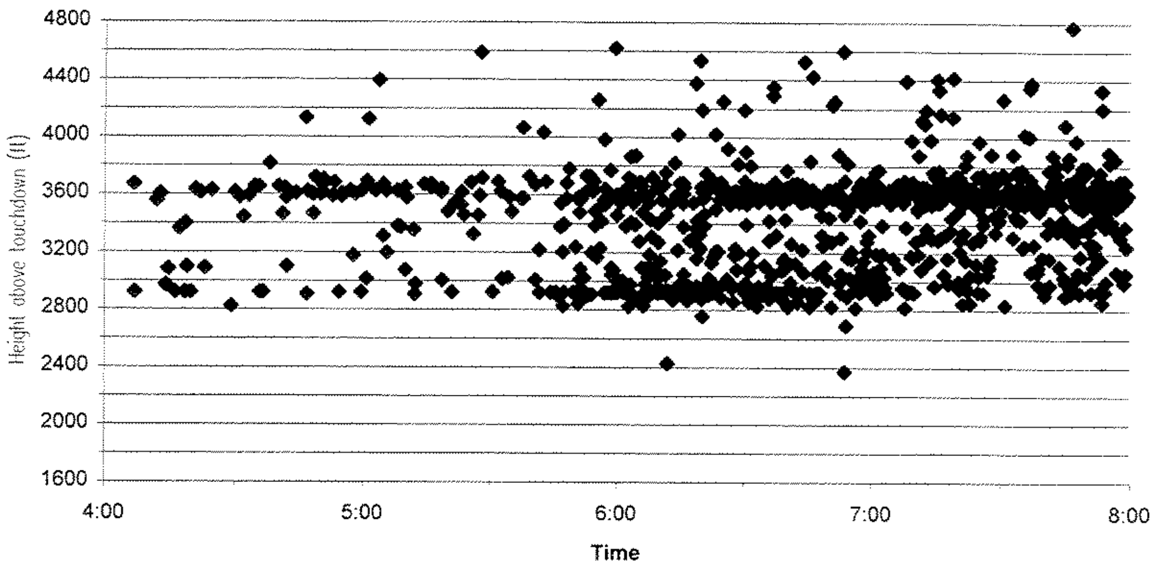


Figure 15f: Runway 27R Approaches at 12 nm, July 1997

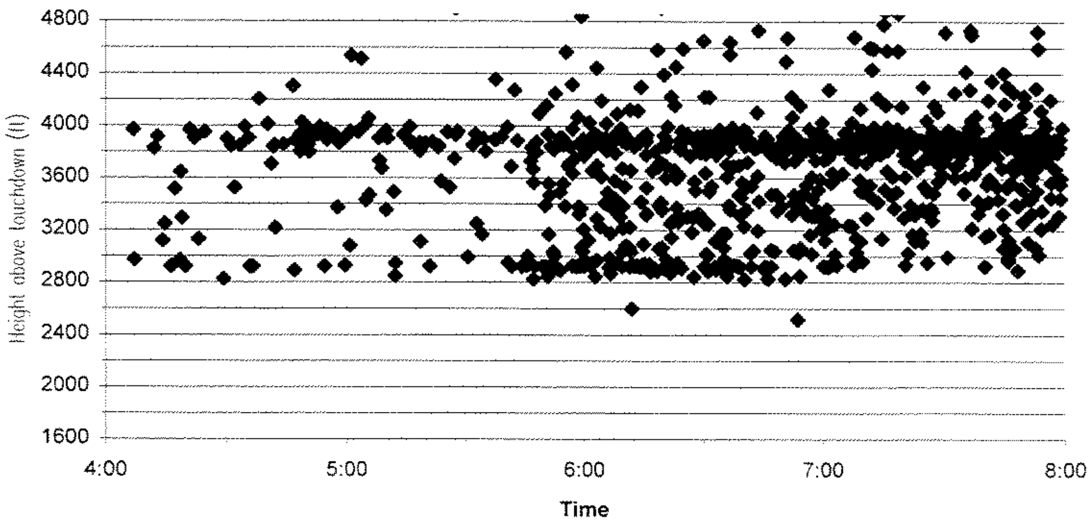
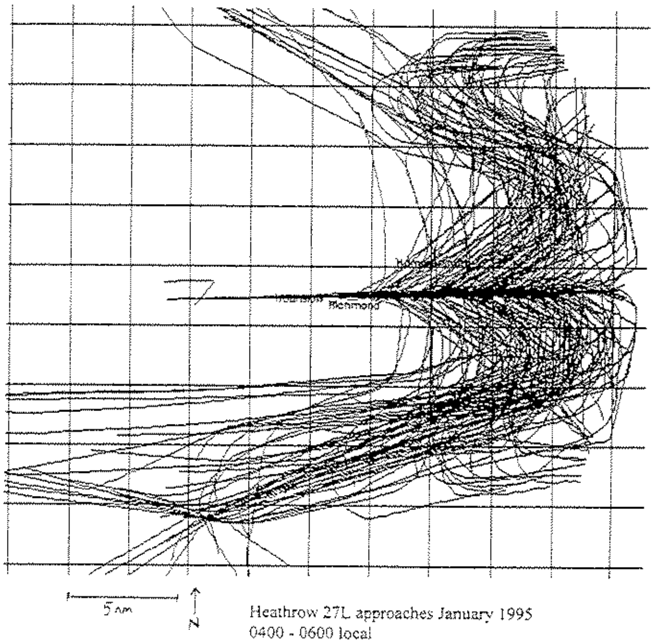
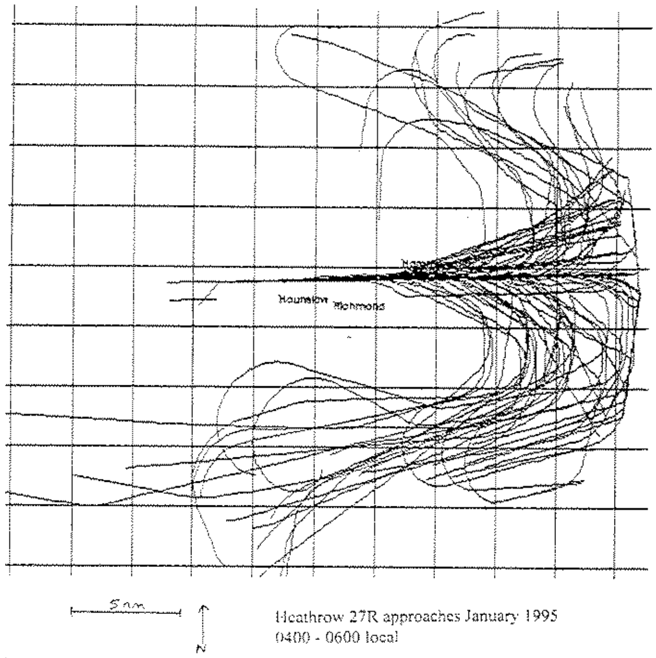


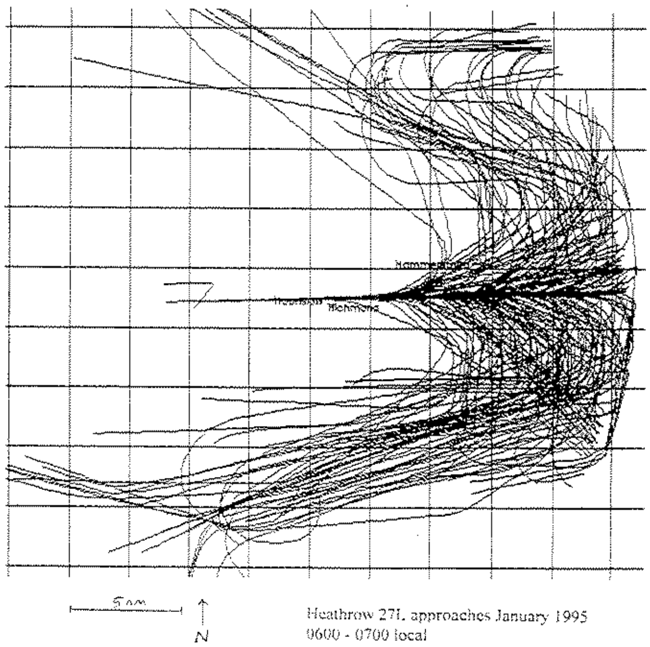
Figure 16: Westerly ground tracks, January 1995



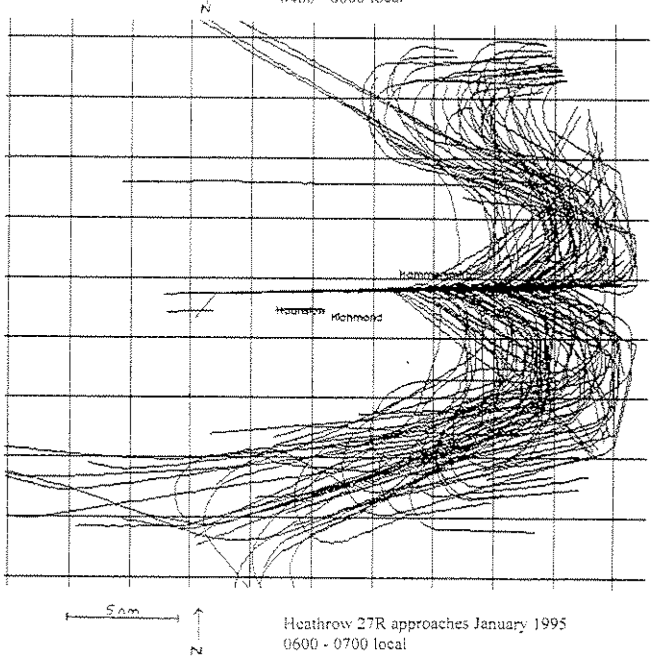
Heathrow 27L approaches January 1995
0400 - 0600 local



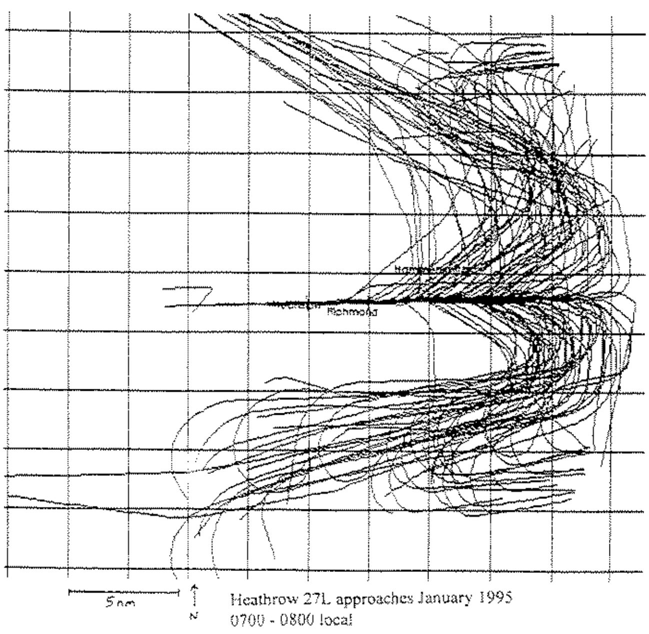
Heathrow 27R approaches January 1995
0400 - 0600 local



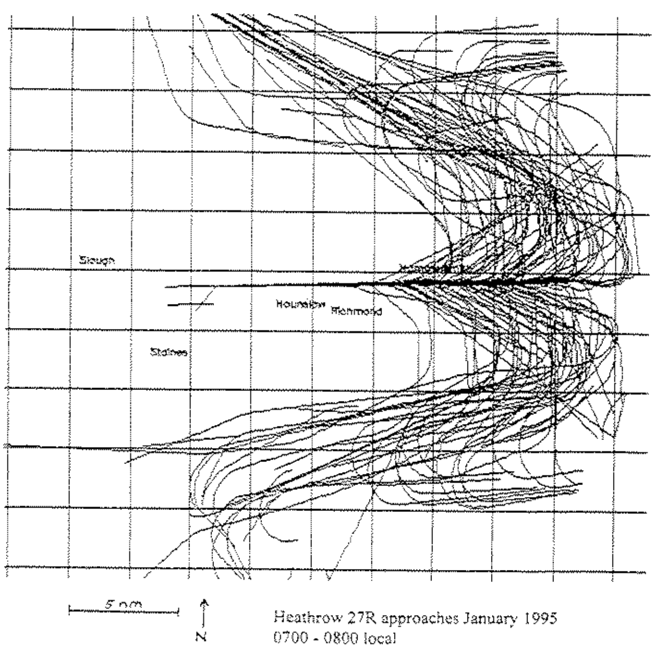
Heathrow 27L approaches January 1995
0600 - 0700 local



Heathrow 27R approaches January 1995
0600 - 0700 local



Heathrow 27L approaches January 1995
0700 - 0800 local



Heathrow 27R approaches January 1995
0700 - 0800 local

Figure 17: Westerly ground tracks, January 1996

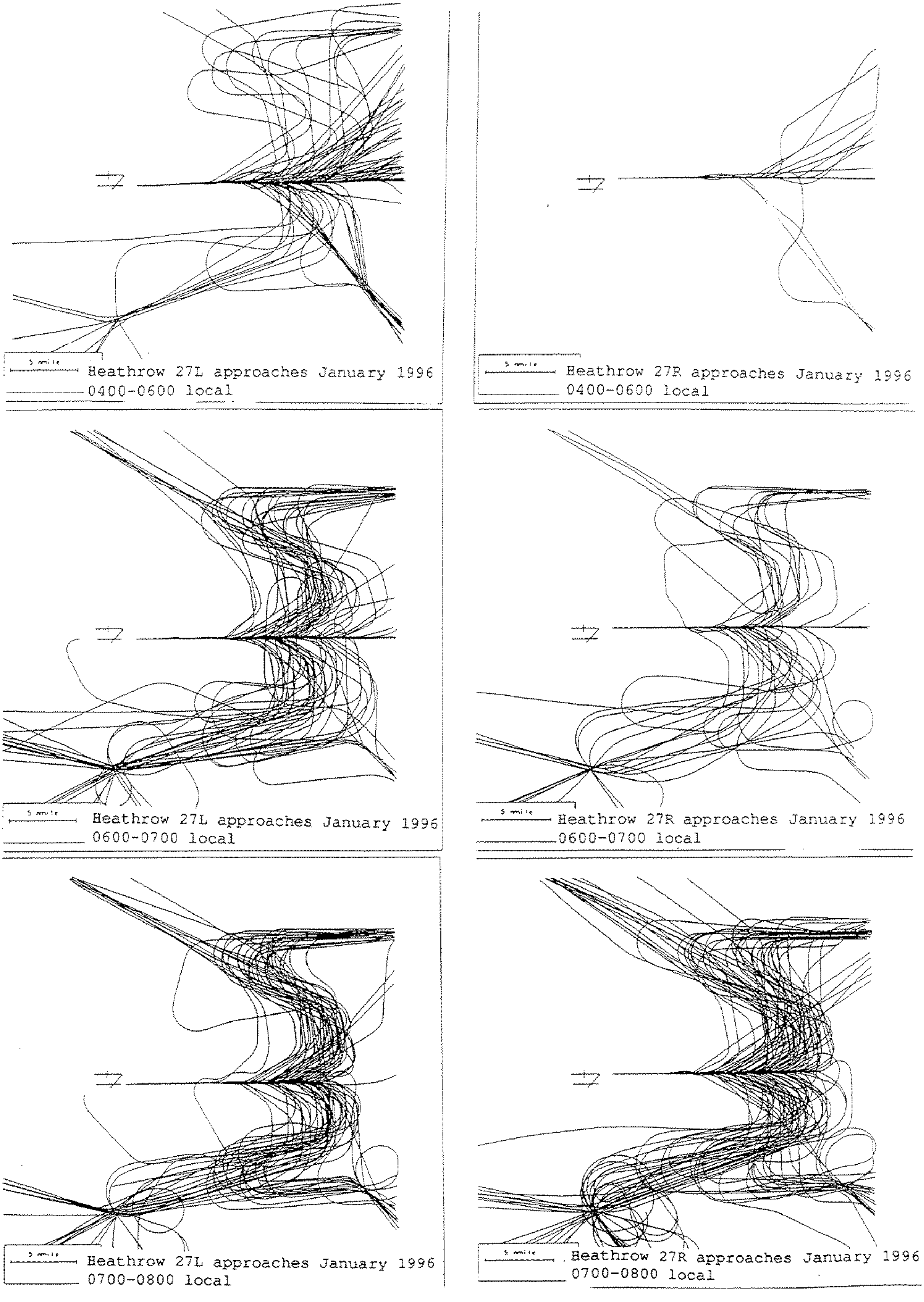


Figure 18: Westerly ground tracks, June 1996

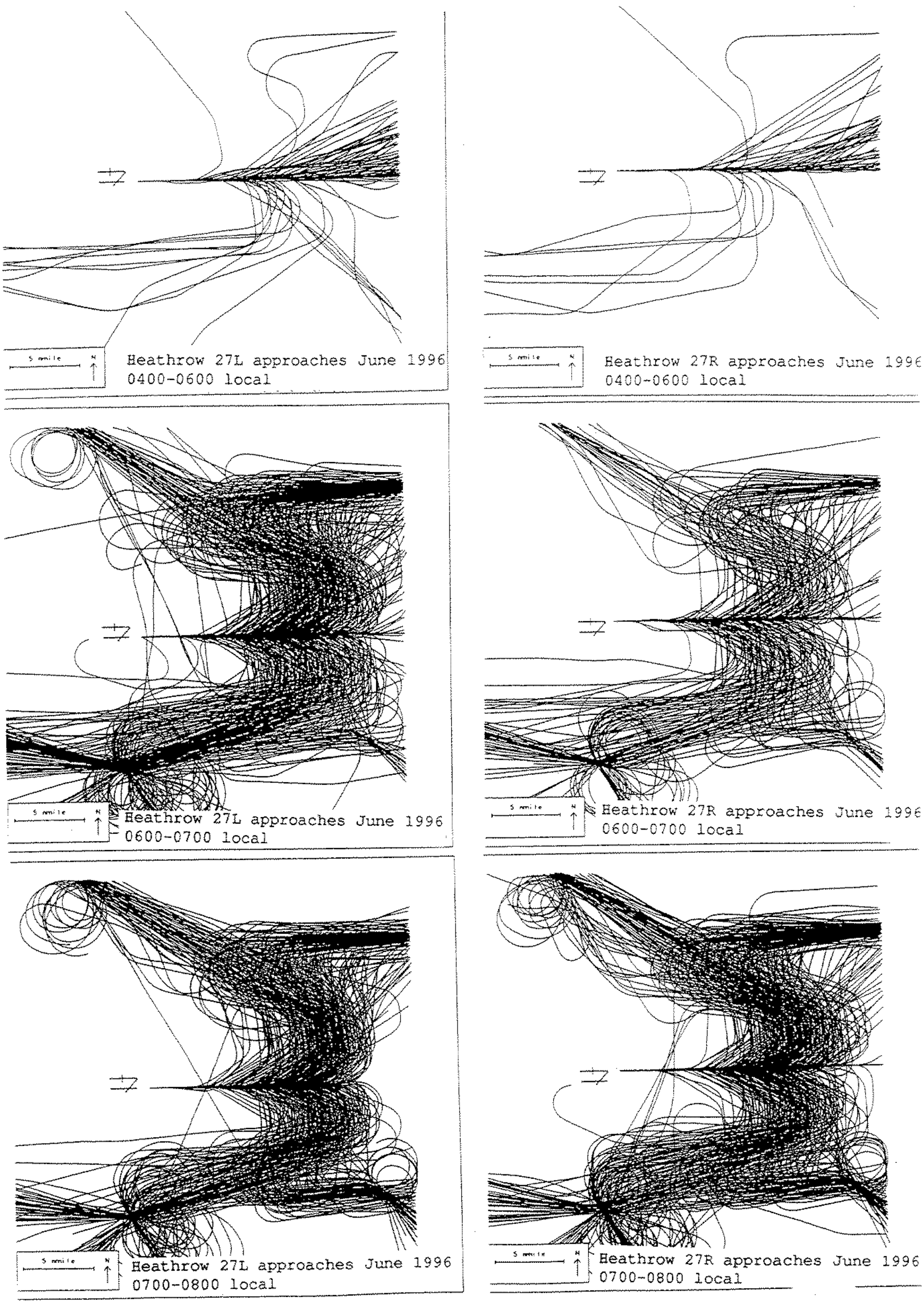
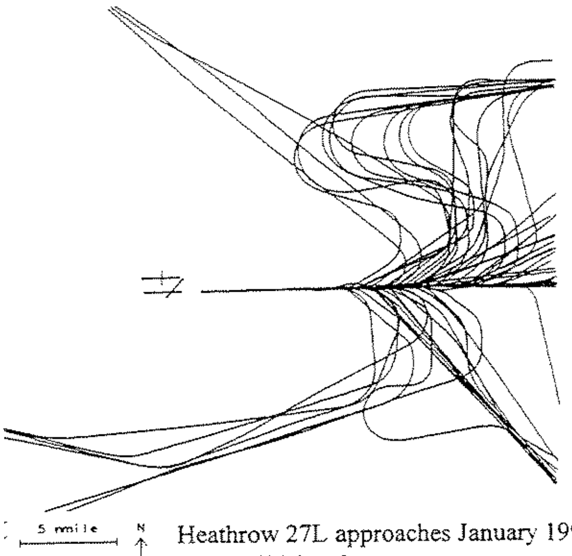
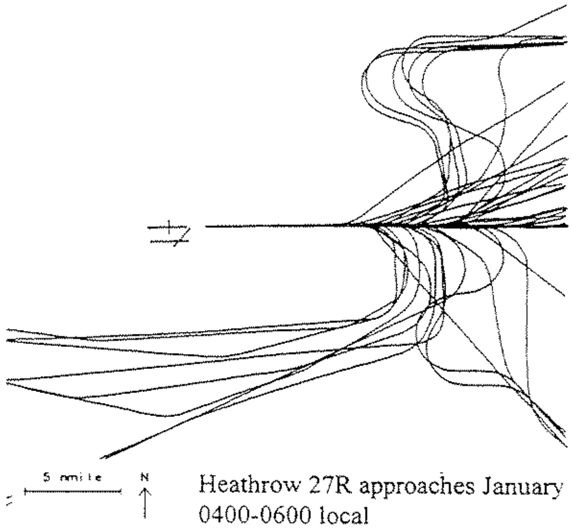


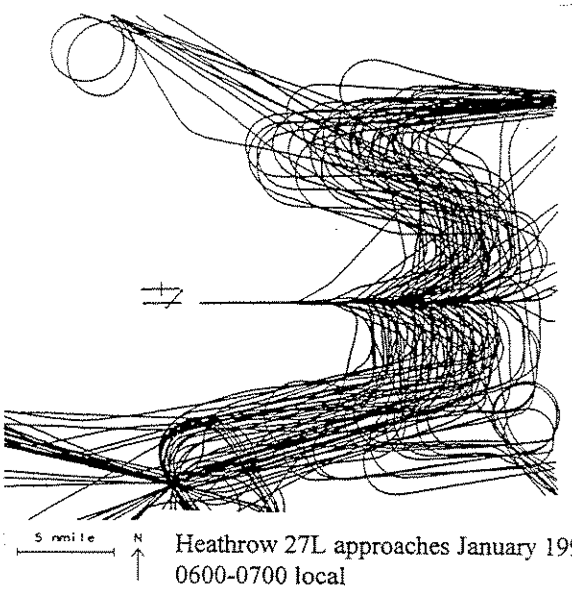
Figure 19: Westerly ground tracks, January 1997



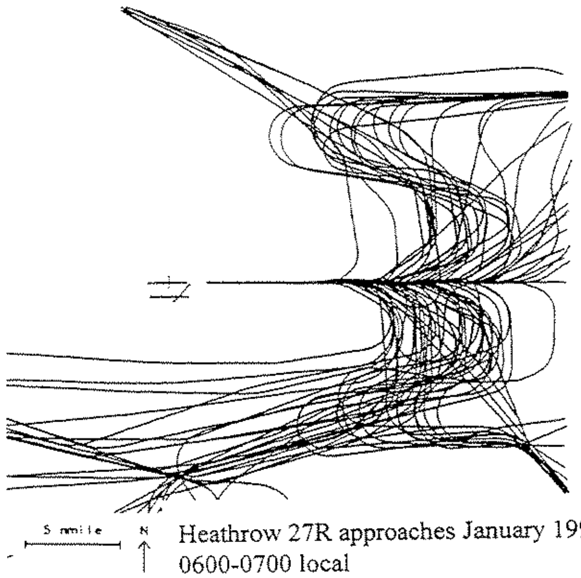
Heathrow 27L approaches January 1997
0400-0600 local



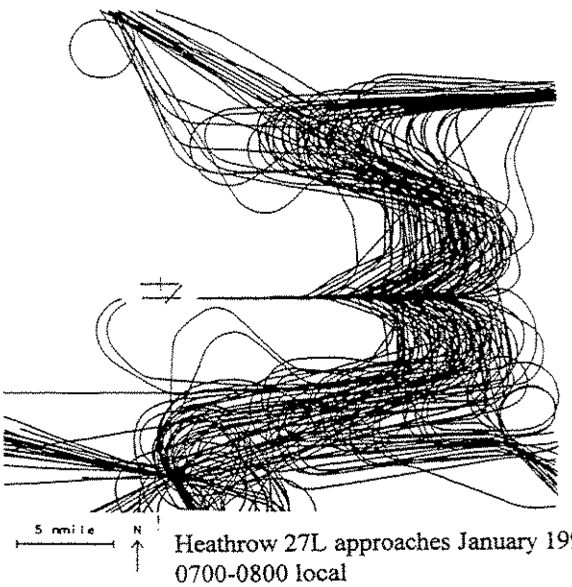
Heathrow 27R approaches January 199
0400-0600 local



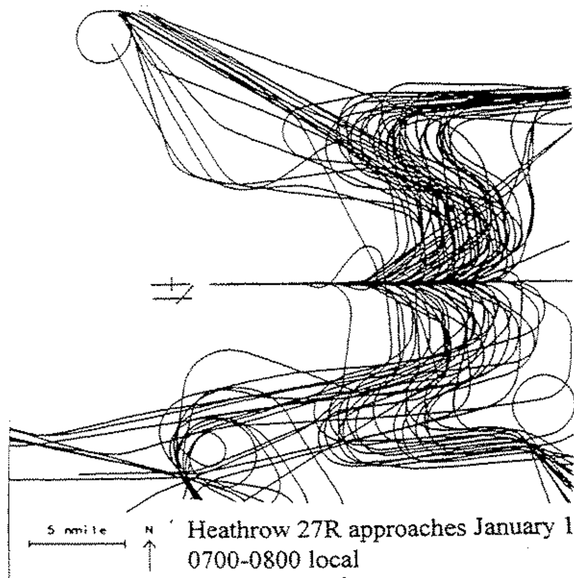
Heathrow 27L approaches January 1997
0600-0700 local



Heathrow 27R approaches January 1997
0600-0700 local

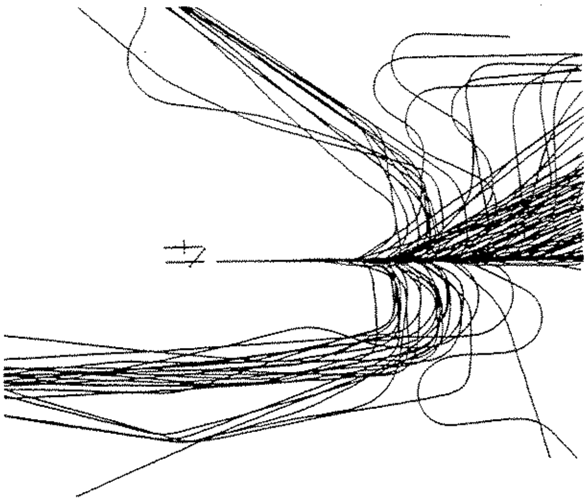


Heathrow 27L approaches January 1997
0700-0800 local



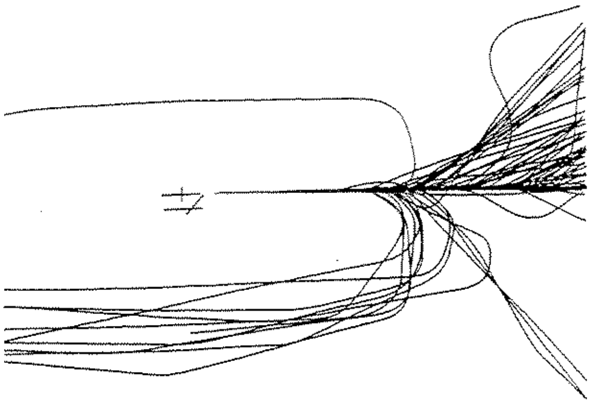
Heathrow 27R approaches January 1997
0700-0800 local

Figure 20: Westerly ground tracks, July 1997



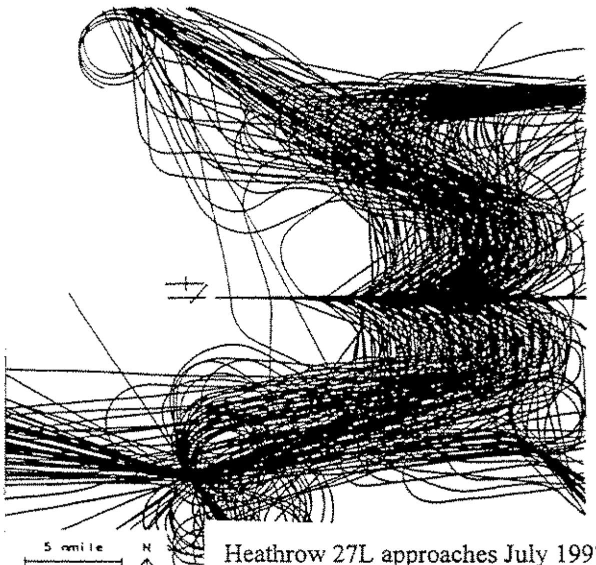
5 nmile N

Heathrow 27L approaches July 1997
0400-0600 local



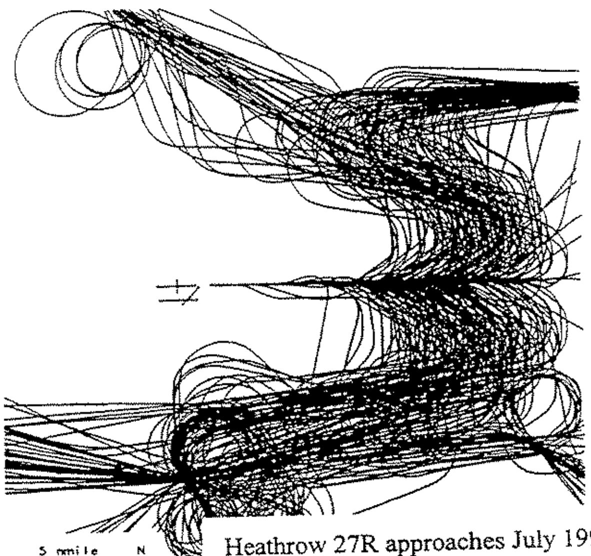
5 nmile N

Heathrow 27R approaches July 1997
0400-0600 local



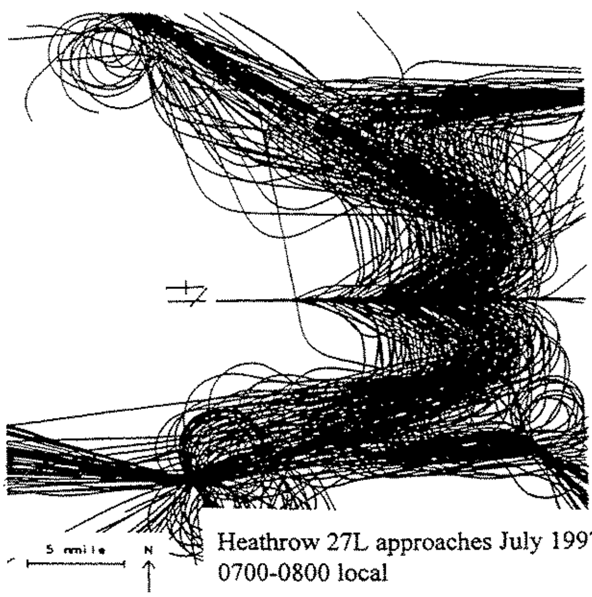
5 nmile N

Heathrow 27L approaches July 1997
0600-0700 local



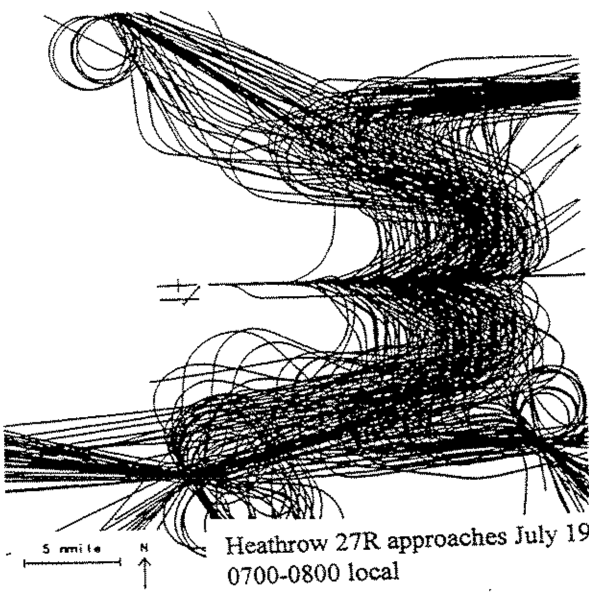
5 nmile N

Heathrow 27R approaches July 1997
0600-0700 local



5 nmile N

Heathrow 27L approaches July 1997
0700-0800 local



5 nmile N

Heathrow 27R approaches July 1997
0700-0800 local

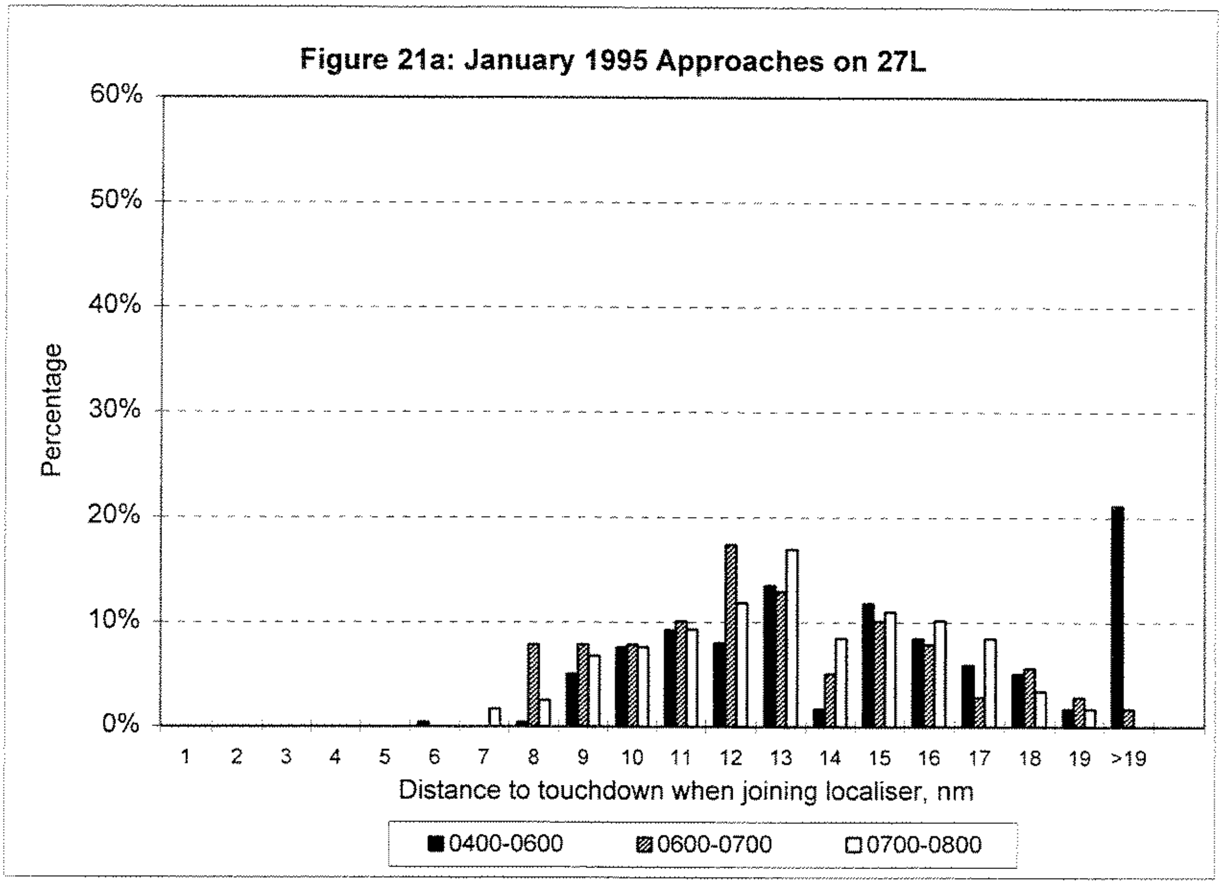


Figure 21a: January 1995 Approaches on 27L
60%
50%
40%
30%
20%
10%
0%
Percentage
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 >19
Distance to touchdown when joining localiser, nm
0400-0600
0600-0700
0700-0800

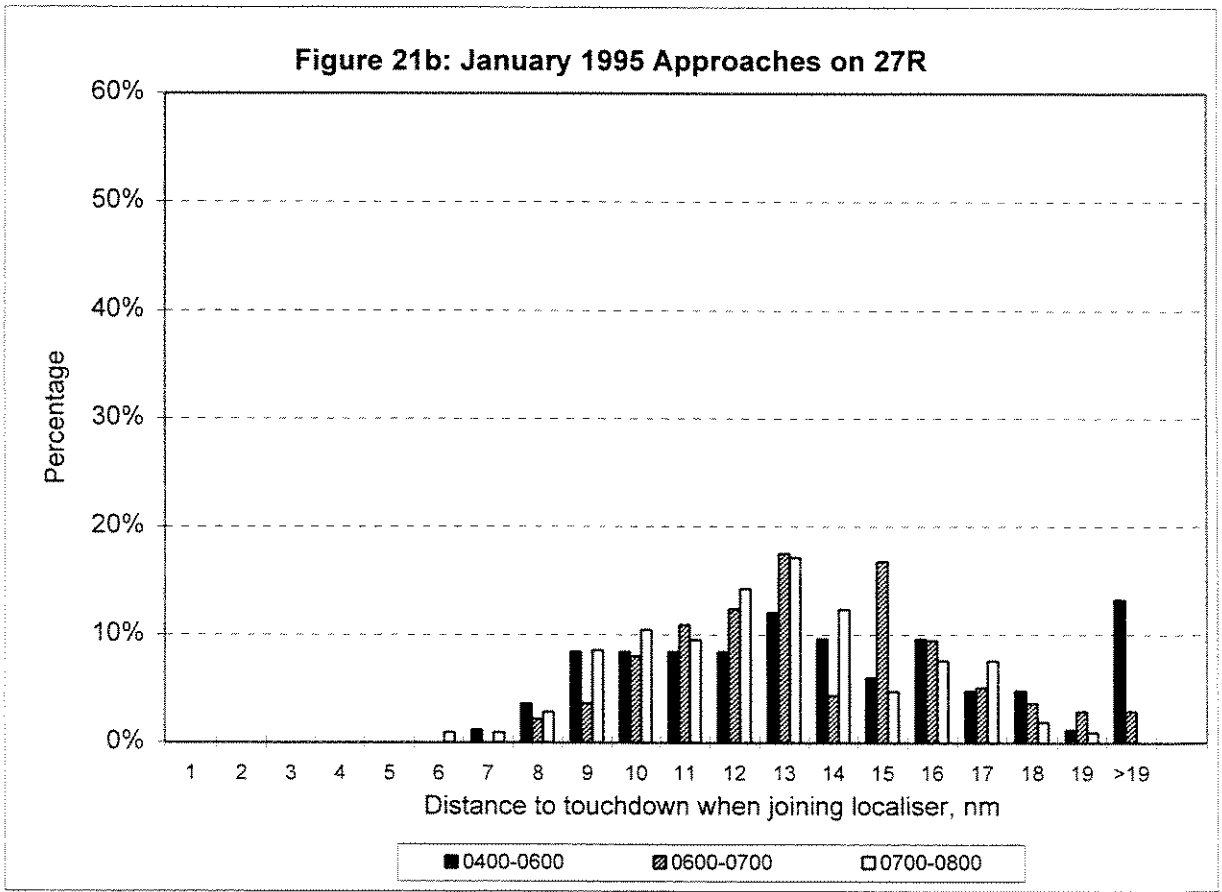


Figure 21b: January 1995 Approaches on 27R
60%
50%
40%
30%
20%
10%
0%
Percentage
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 >19
Distance to touchdown when joining localiser, nm
0400-0600
0600-0700
0700-0800

Figure 22a: January 1996 Approaches on 27L

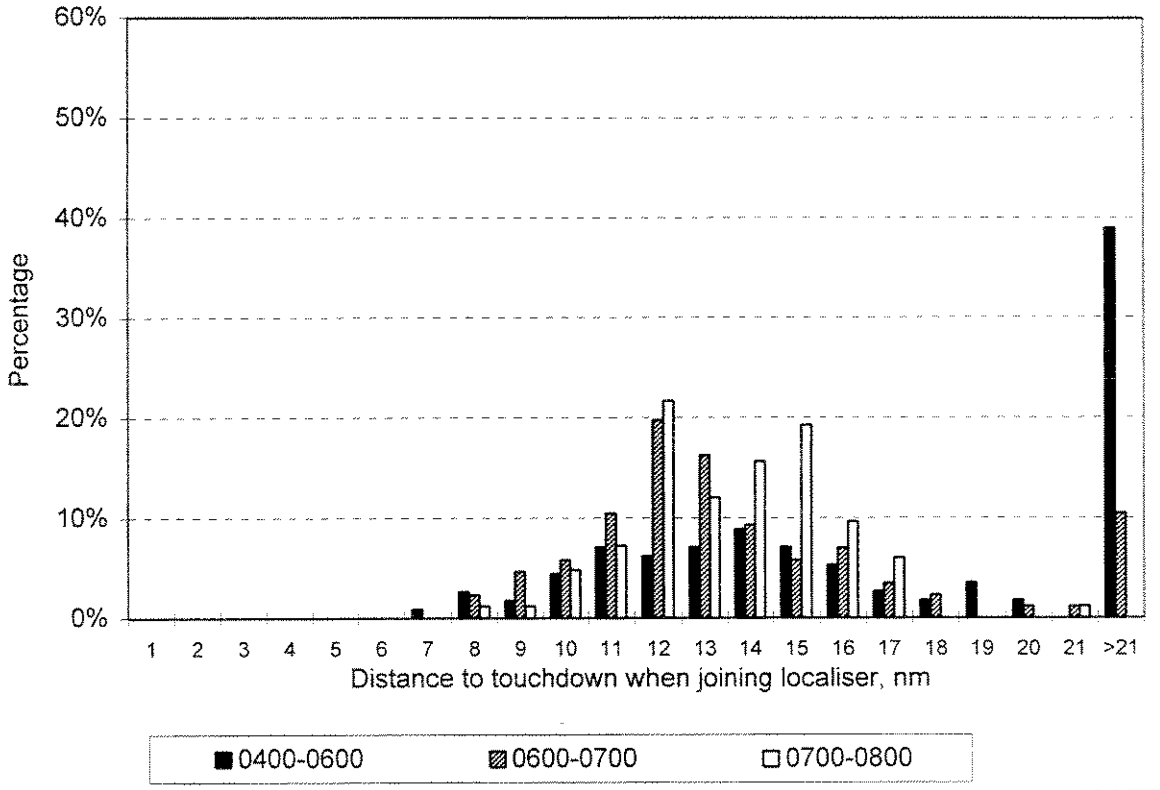


Figure 22b: January 1996 Approaches on 27R

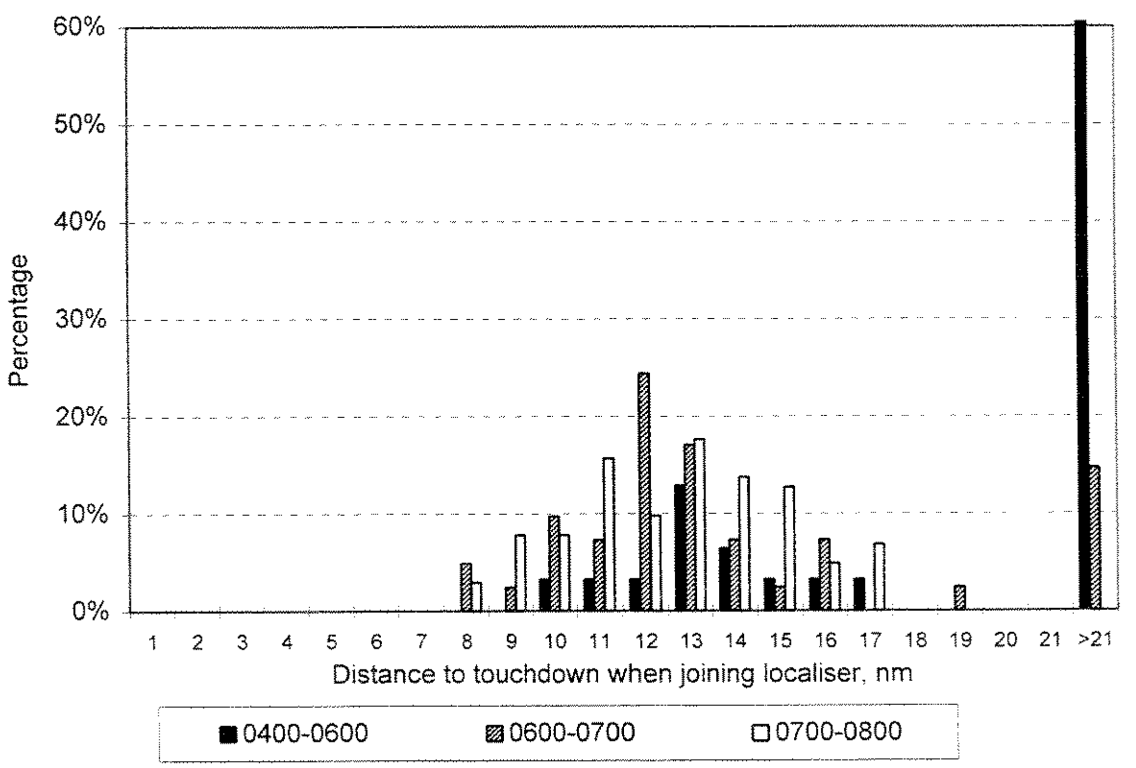


Figure 23a: January 1997 Approaches on 27L

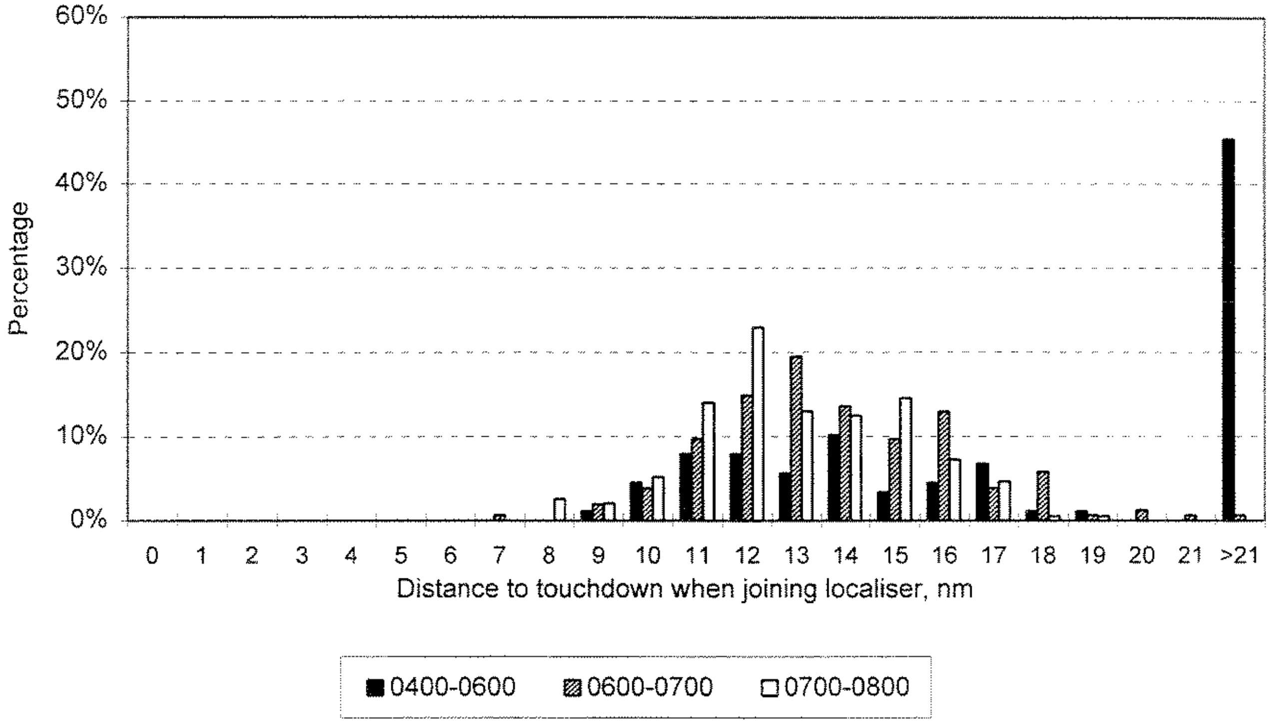


Figure 23b: January 1997 Approaches on 27R

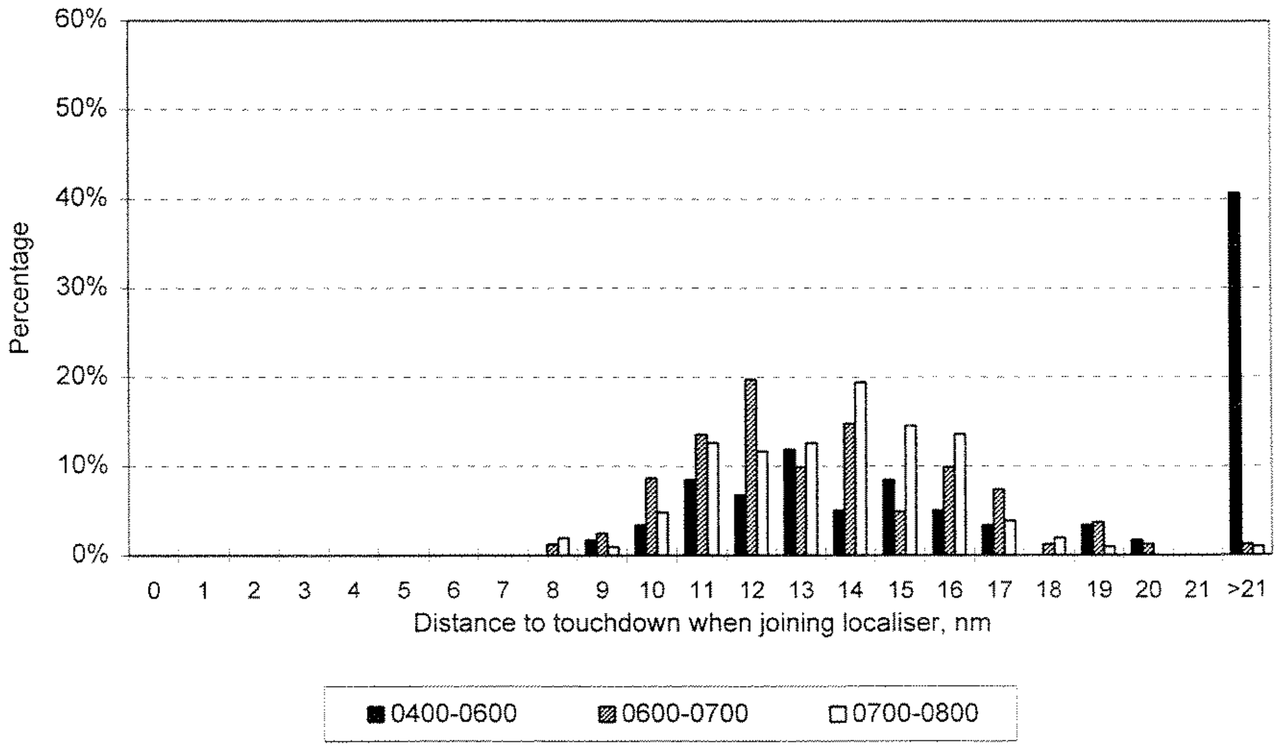


Figure 24a: July 1997 Approaches on 27L

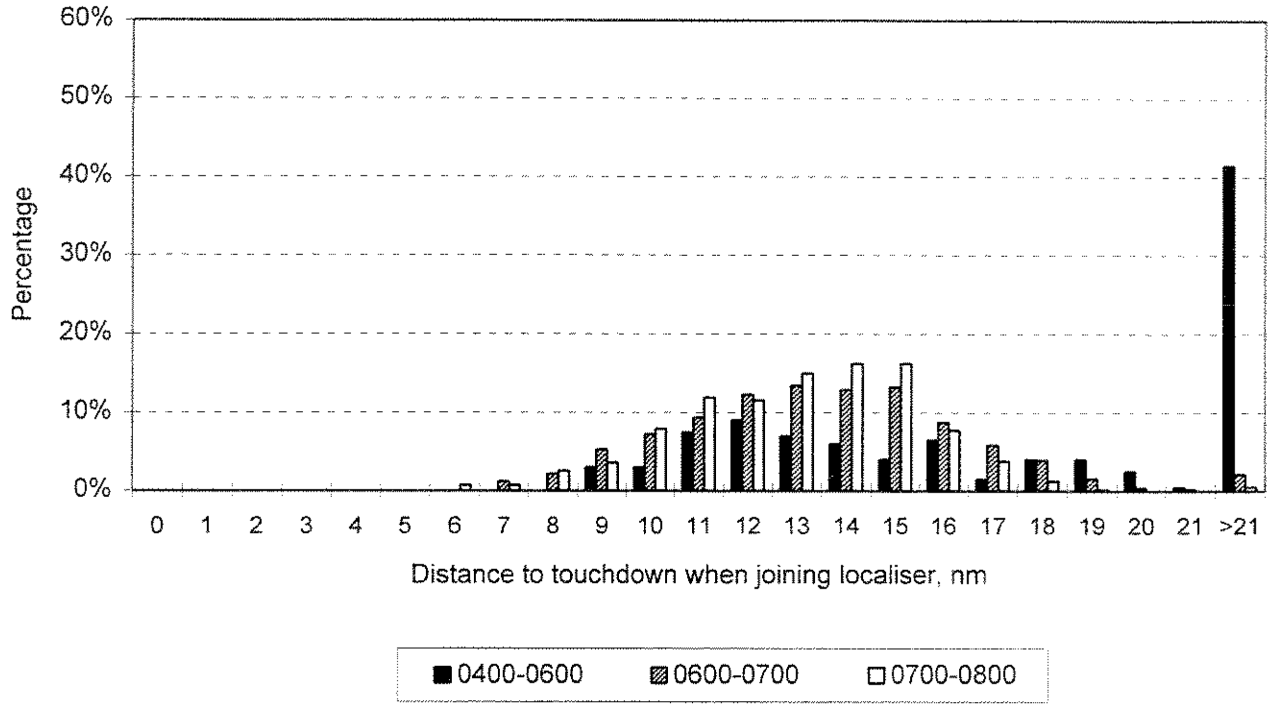


Figure 24b: July 1997 Approaches on 27R

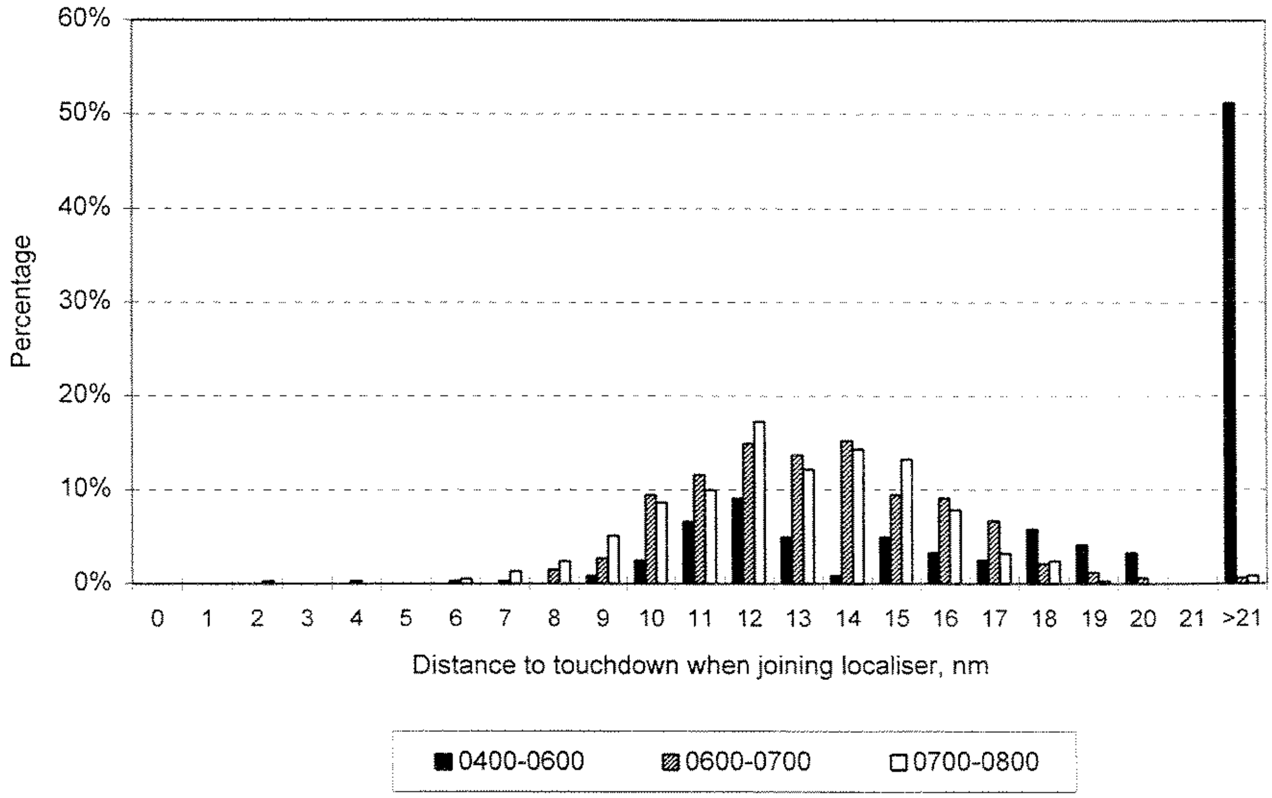


Figure 25a: January 1995 Approaches on 27L

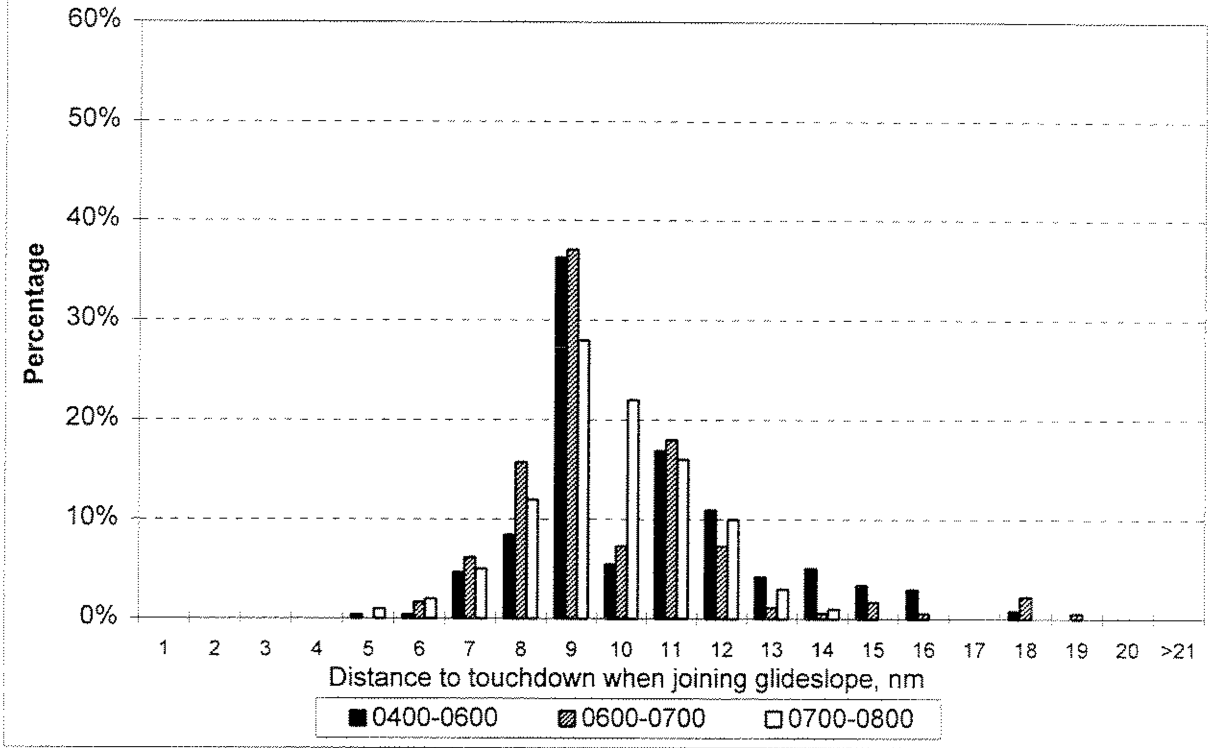


Figure 25b: January 1995 Approaches on 27R

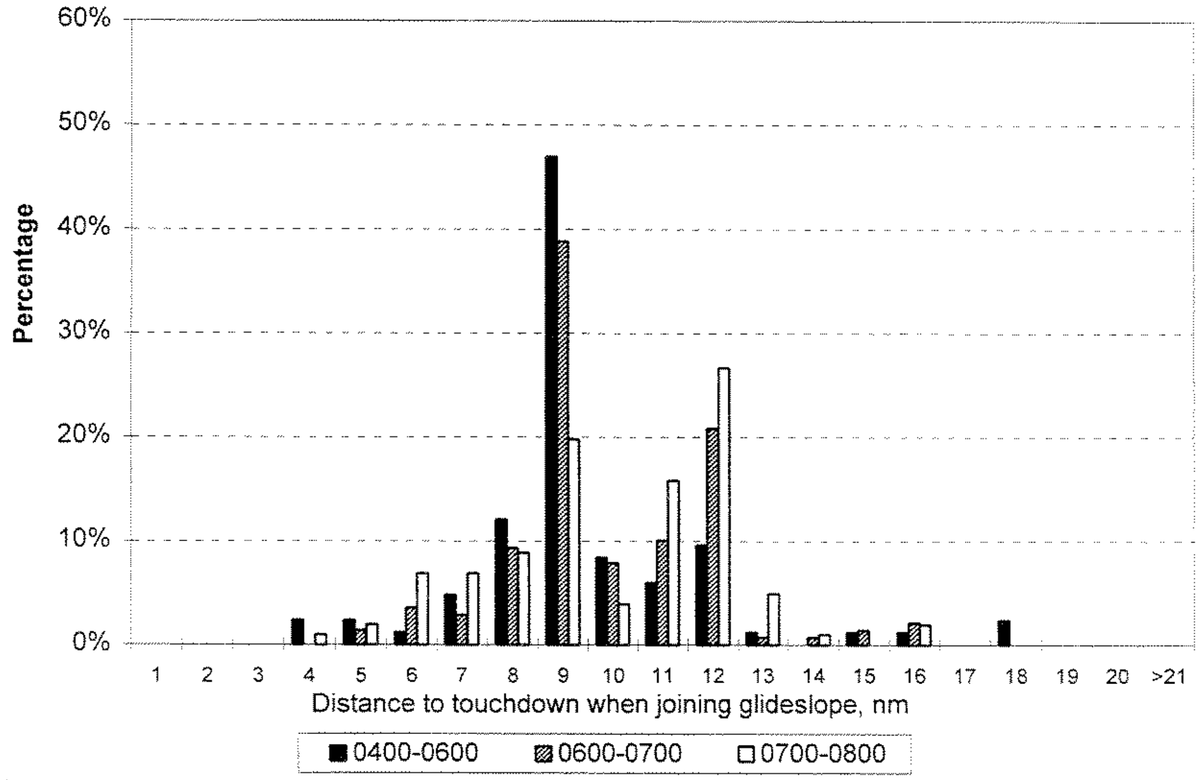


Figure 26a: January 1996 Approaches on 27L

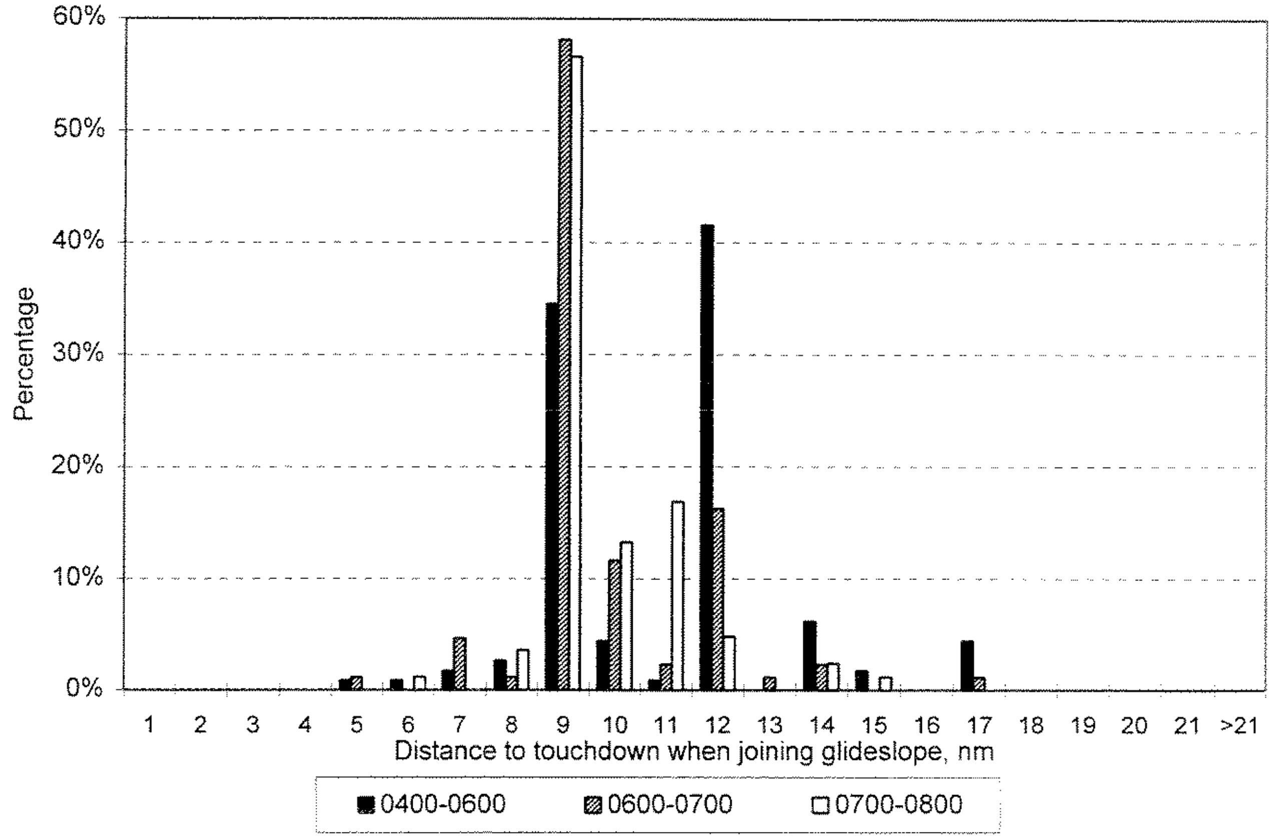
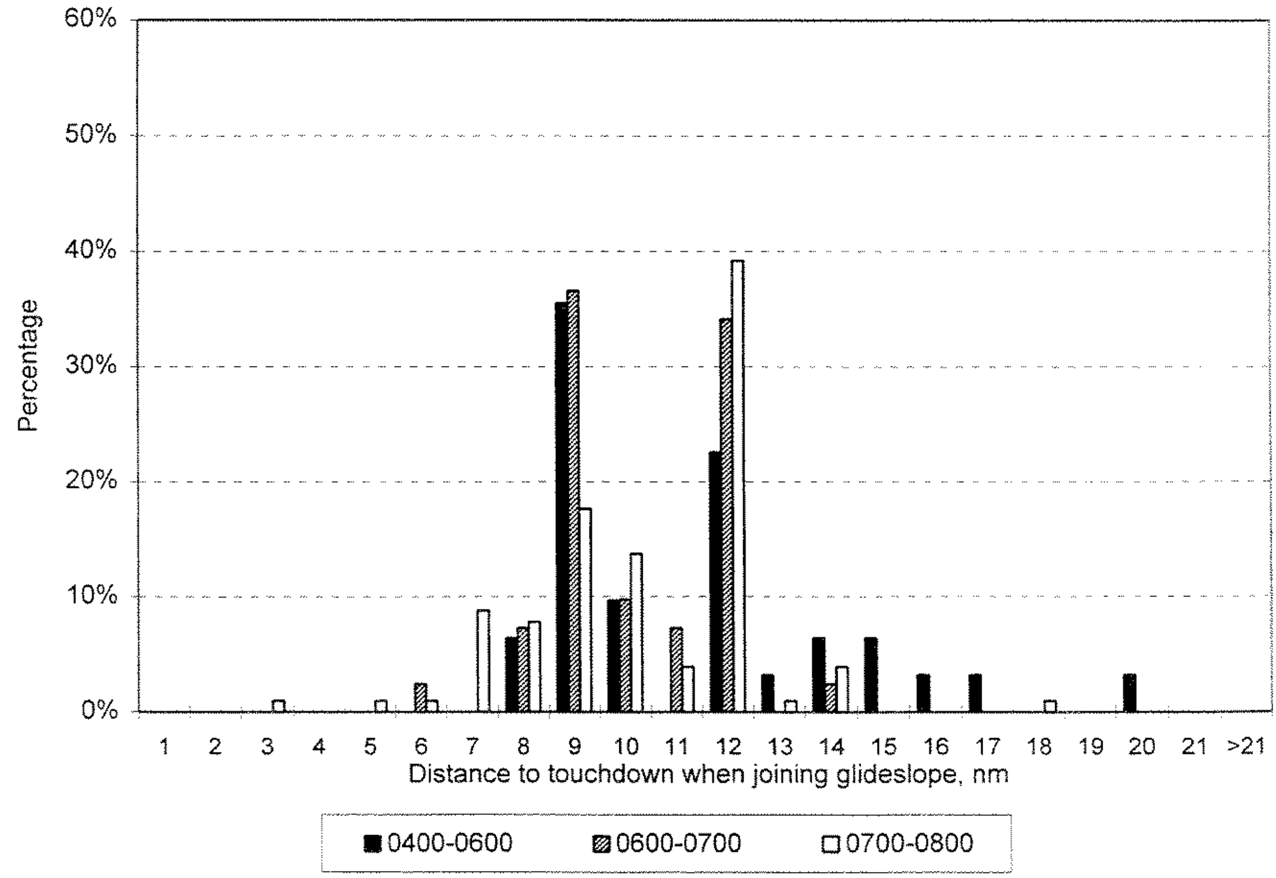


Figure 26b: January 1996 Approaches on 27R



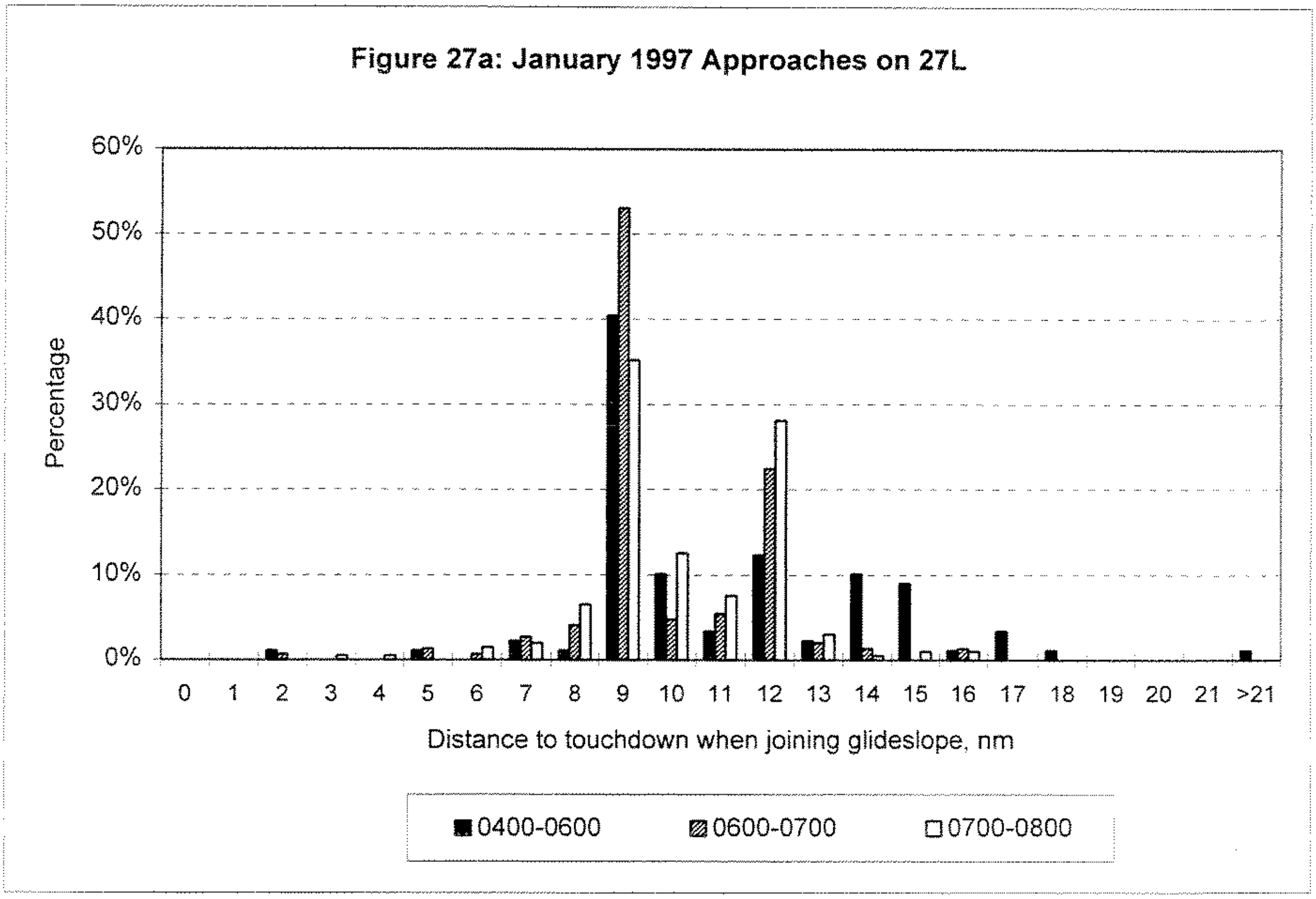


Figure 27a: January 1997 Approaches on 27L
60%
50%
40%
30%
20%
10%
0%
Percentage
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 >21
Distance to touchdown when joining glideslope, nm
0400-0600
0600-0700
0700-0800

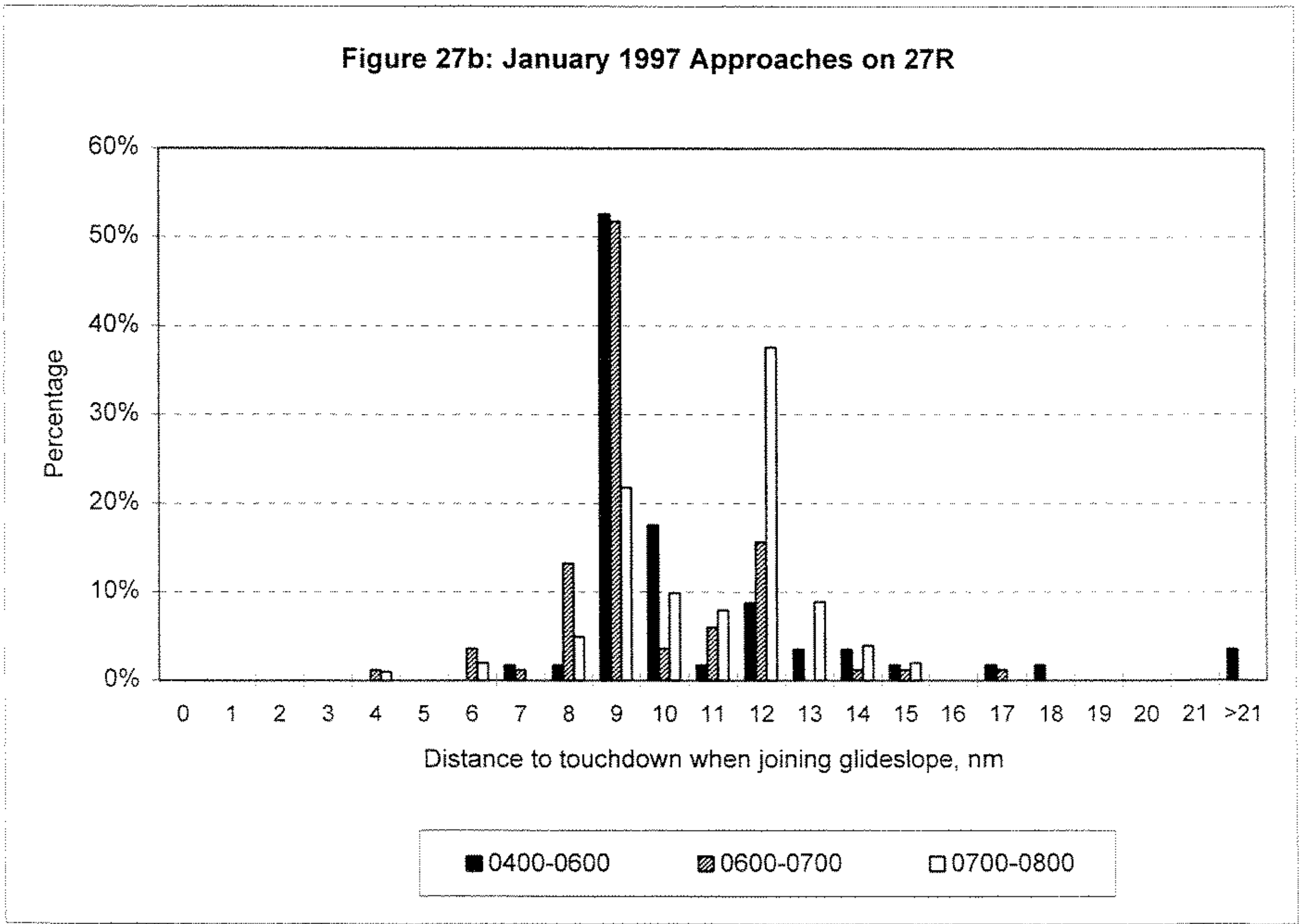


Figure 27b: January 1997 Approaches on 27R
60%
50%
40%
30%
20%
10%
0%
Percentage
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 >21
Distance to touchdown when joining glideslope, nm
0400-0600
0600-0700
0700-0800

Figure 28a: July 1997 Approaches on 27L

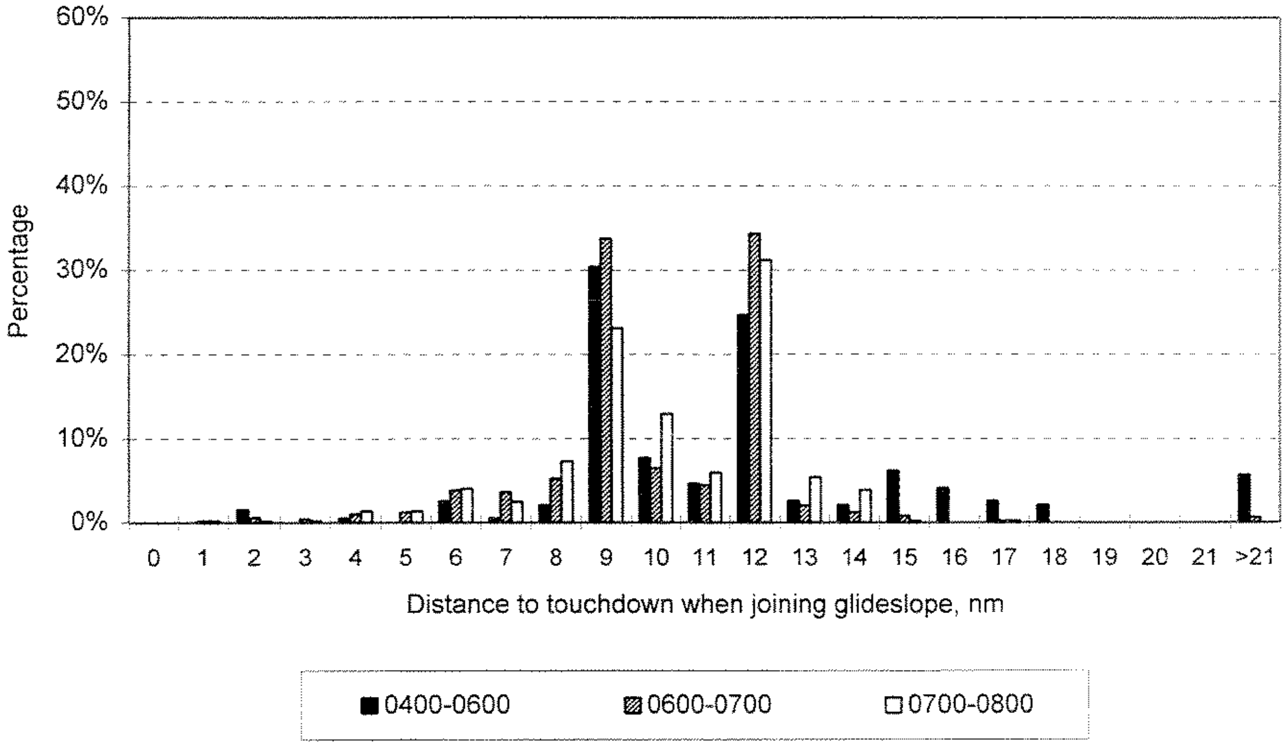


Figure 28b: July 1997 Approaches on 27R

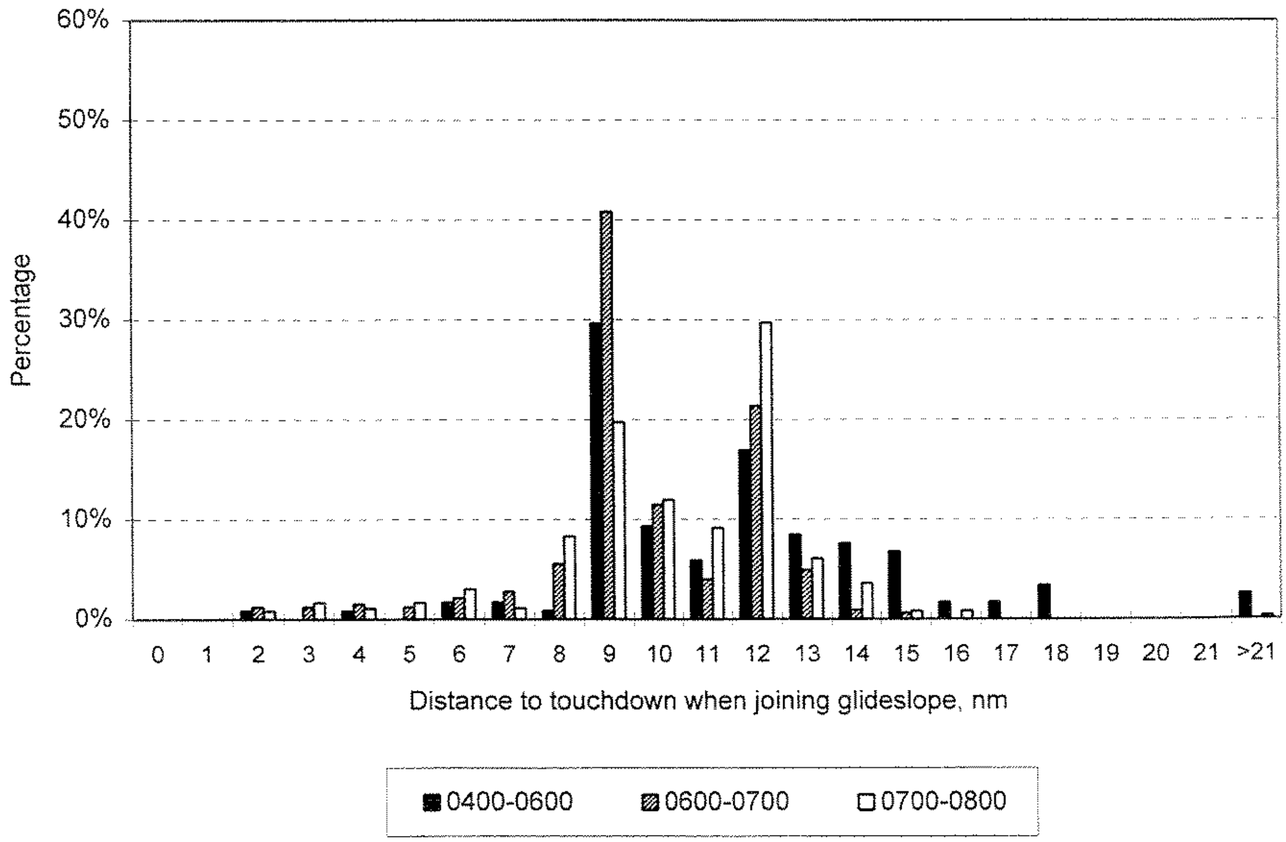


Figure 29: Distance to joining glideslope:

June 1996 sample data

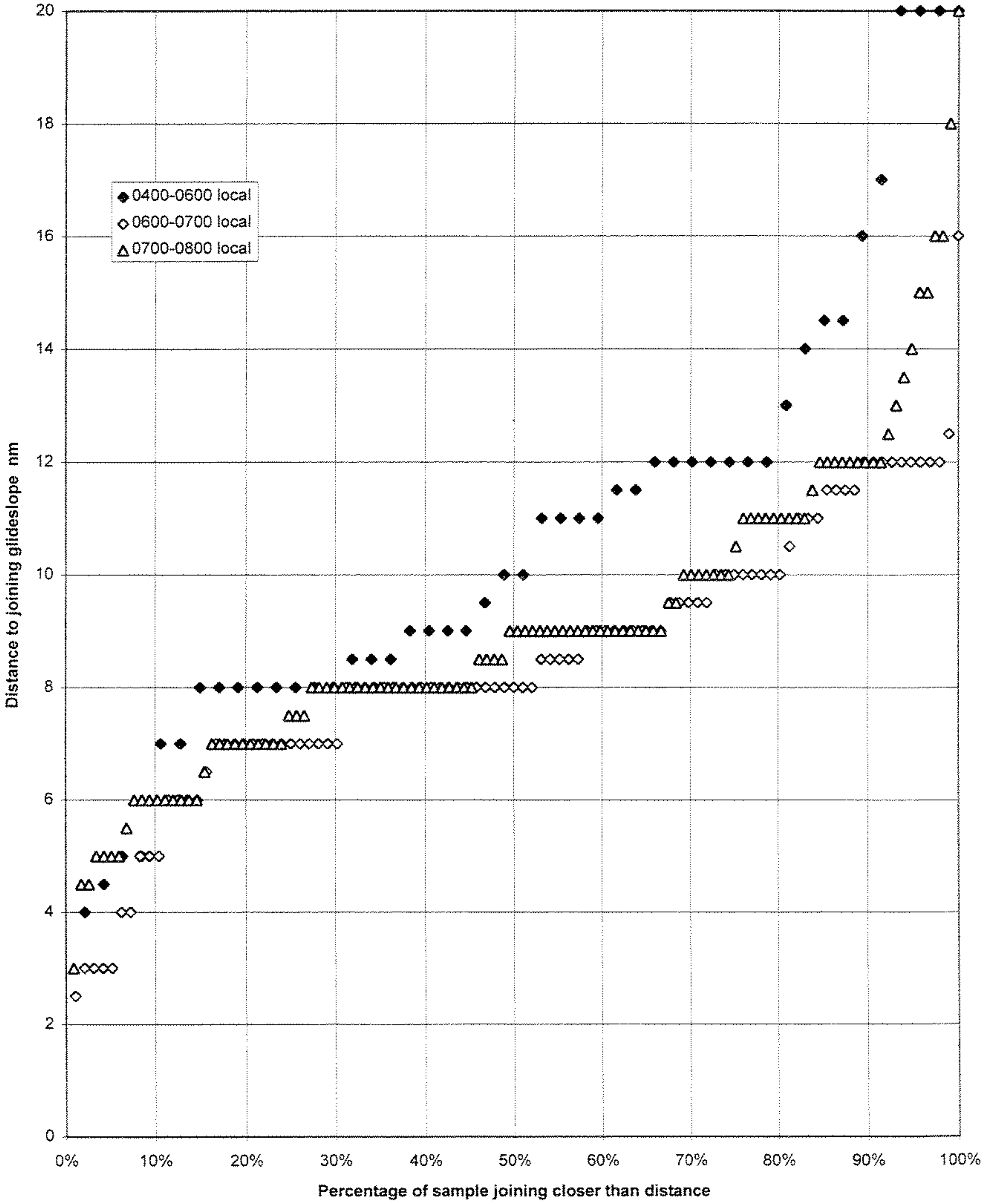


Figure 30: NTK Gate Analysis, January 1996

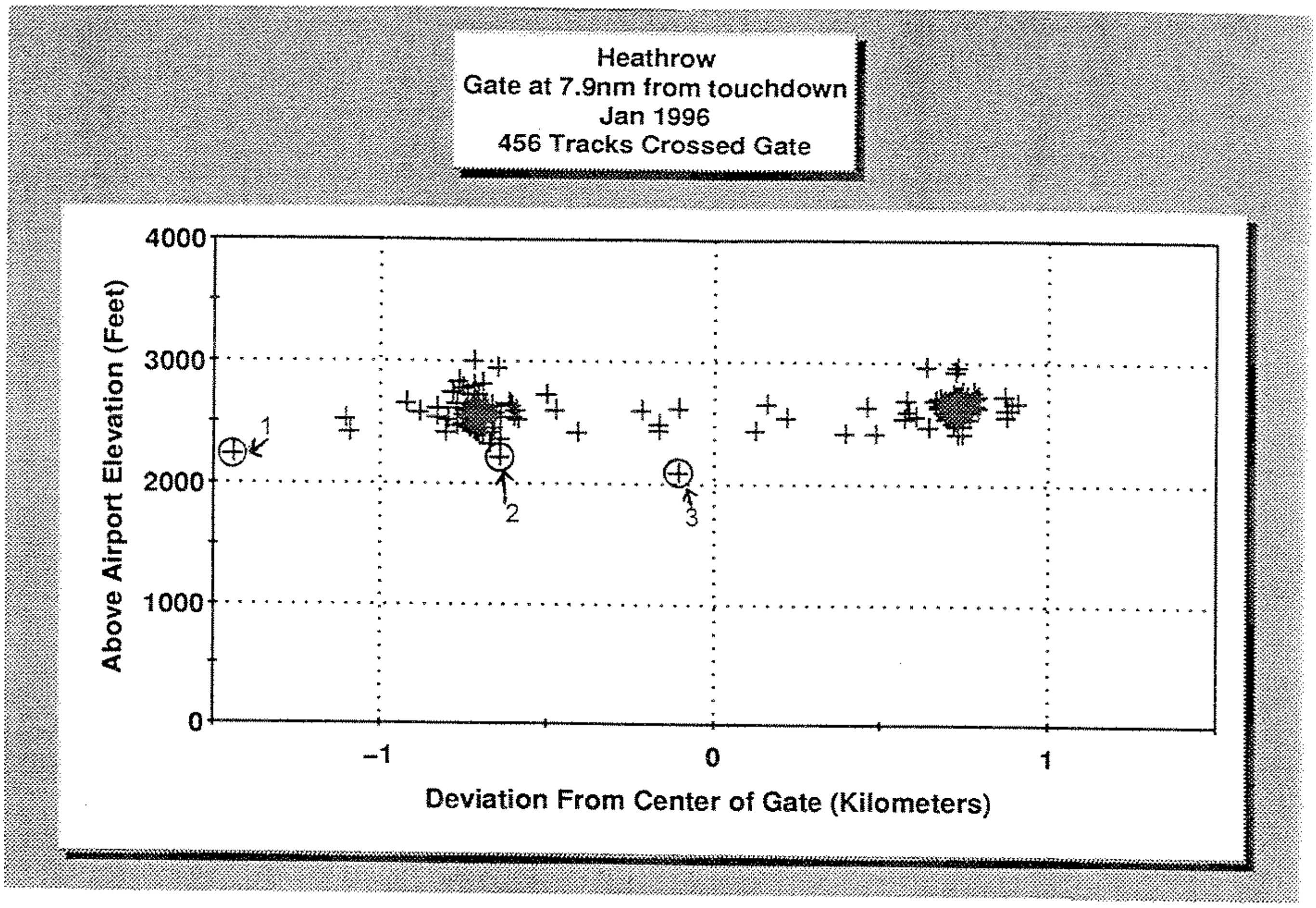


Figure 31: NTK Height Profile, January 1996

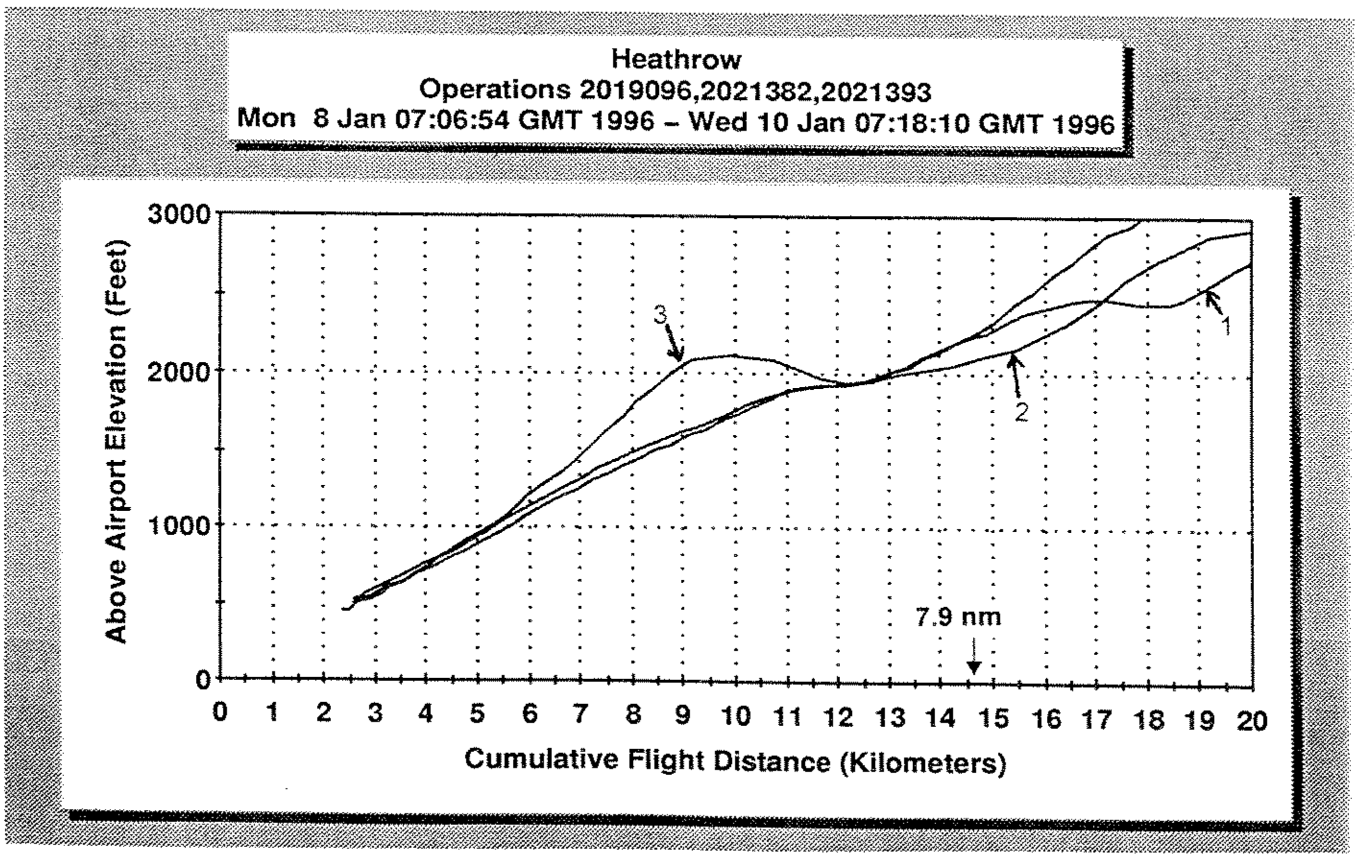


Figure 32a: Comparison of mean heights of aircraft on 27L approaches, Day (0600-2300) vs Night (2300-0600)

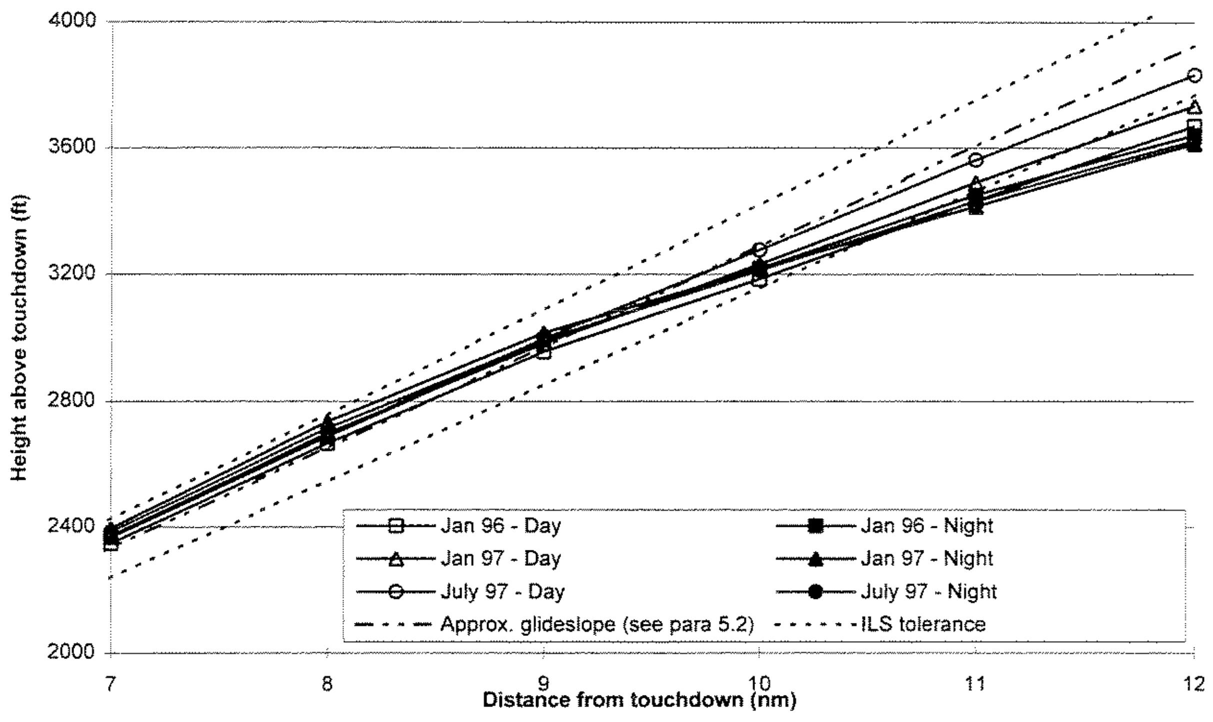
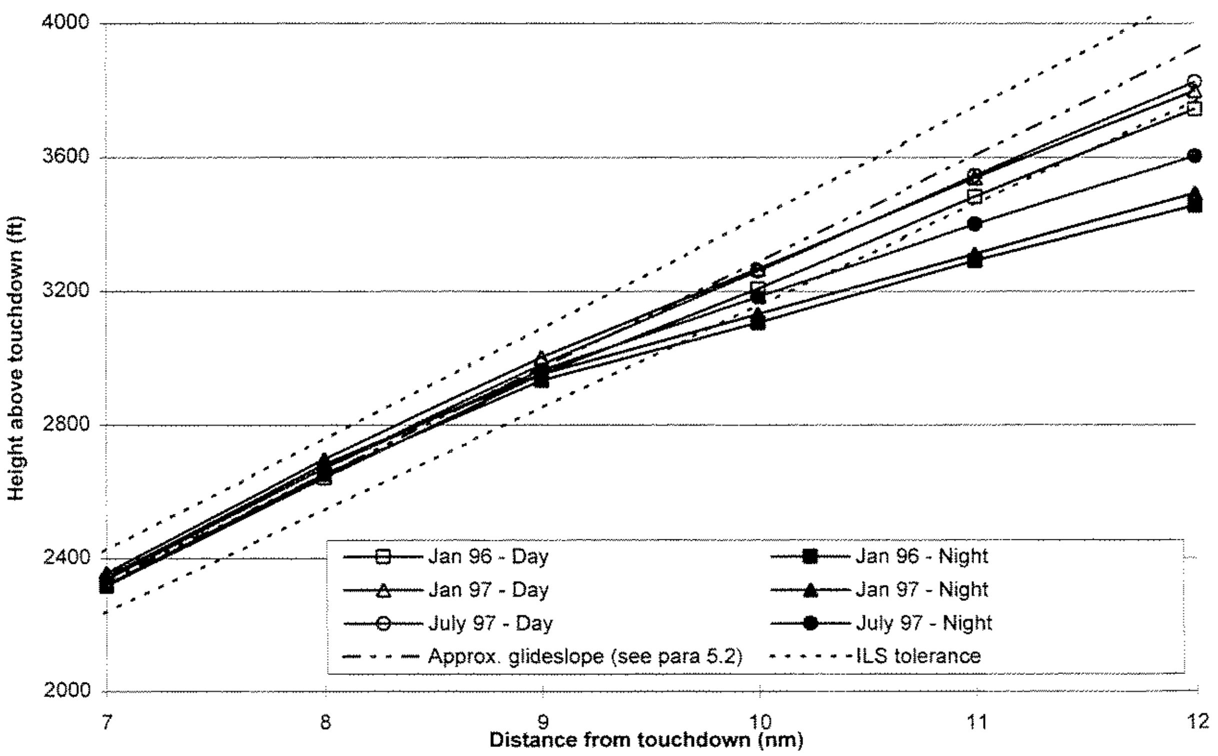


Figure 32b: Comparison of mean heights of aircraft on 27R approaches, Day (0600-2300) vs Night (2300-0600)



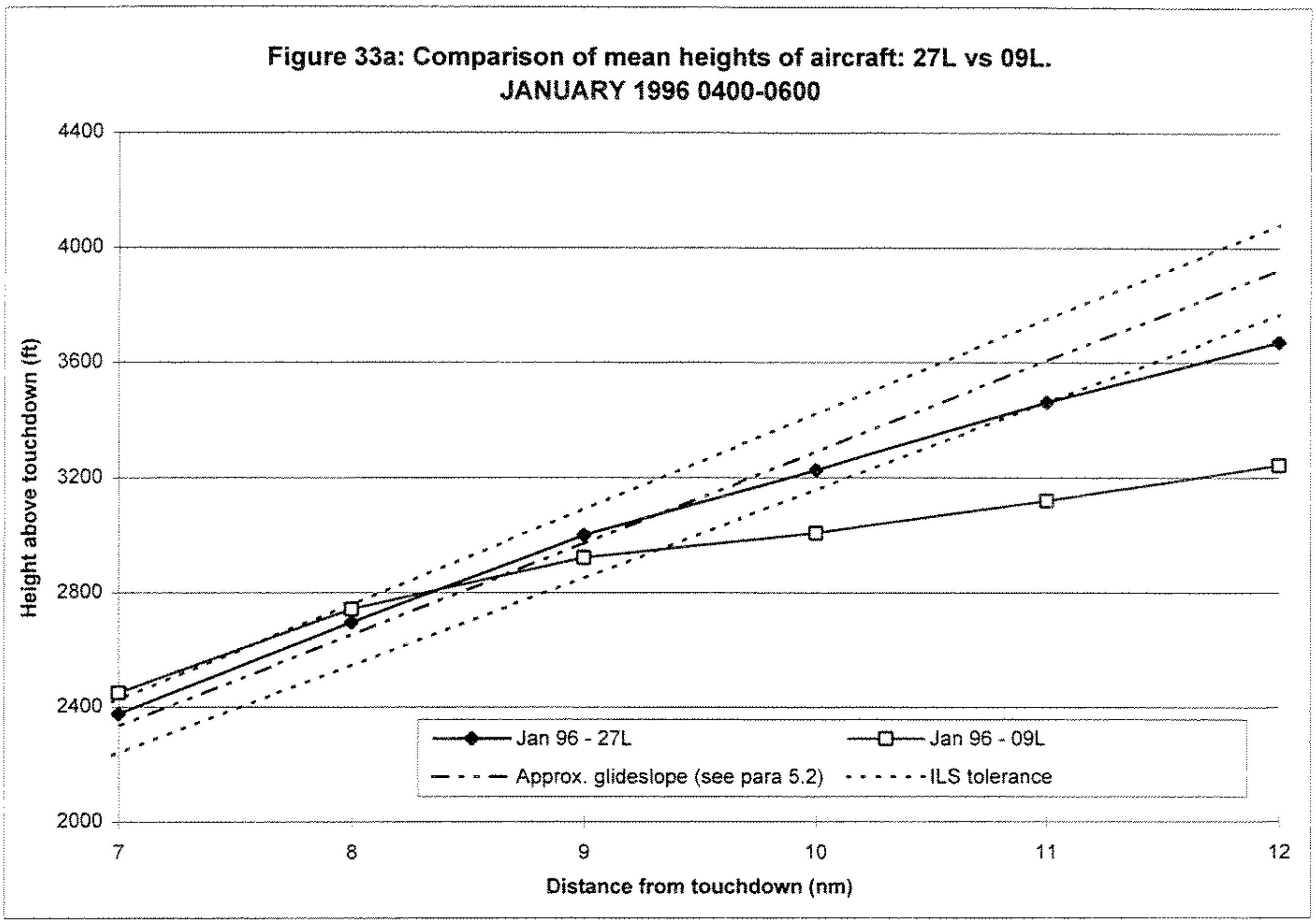


Figure 33a: Comparison of mean heights of aircraft: 27L vs 09L.
JANUARY 1996 0400-0600
Height above touchdown (ft)
4400
4000
3600
3200
2800
2400
2000
7
8
9
10
11
12
Distance from touchdown (nm)
Jan 96 - 27L
Jan 96 - 09L
Approx. glideslope (see para 5.2)
ILS tolerance

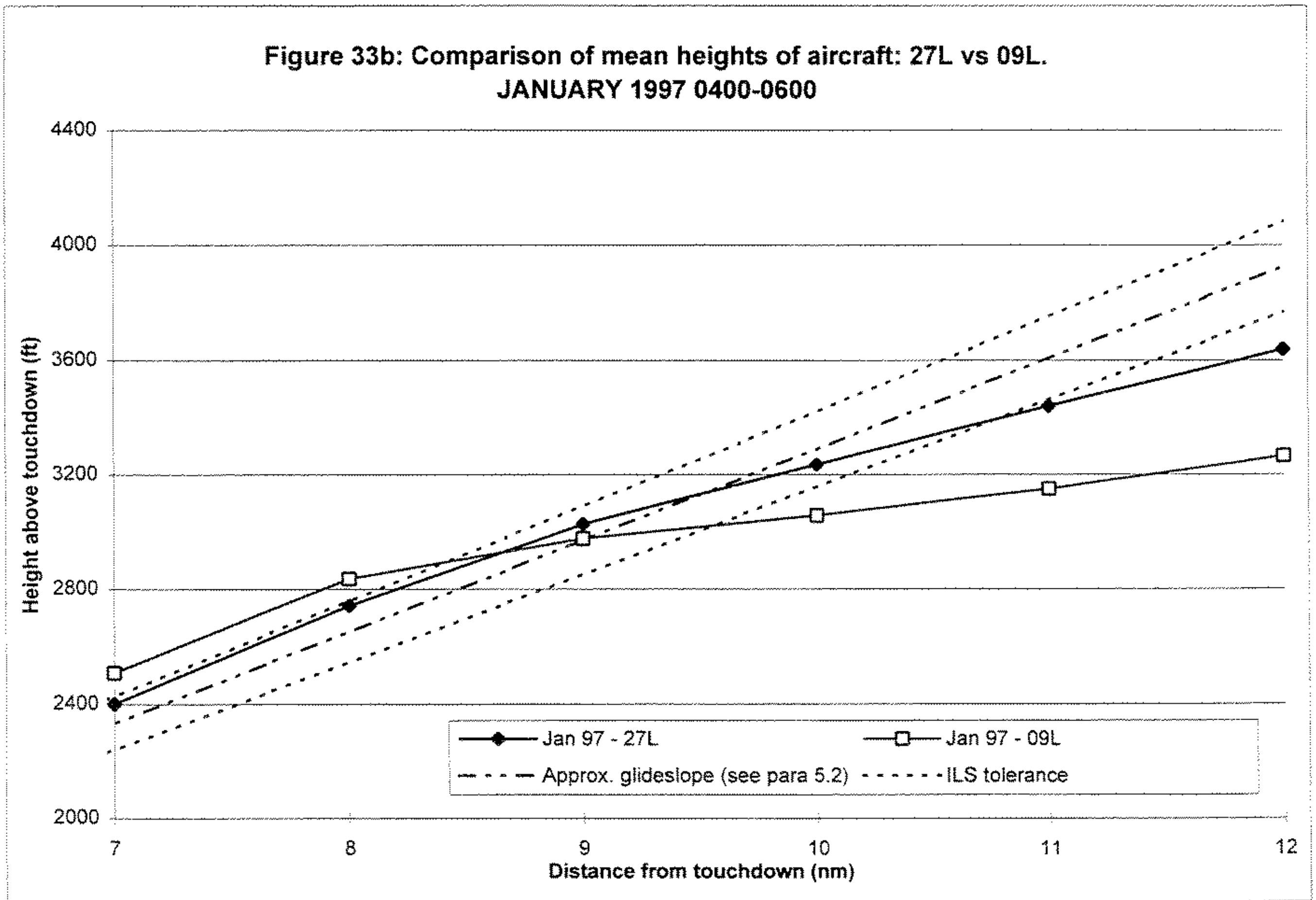


Figure 33b: Comparison of mean heights of aircraft: 27L vs 09L.
JANUARY 1997 0400-0600
Height above touchdown (ft)
4400
4000
3600
3200
2800
2400
2000
7
8
9
10
11
12
Distance from touchdown (nm)
Jan 97 - 27L
Jan 97 - 09L
Approx. glideslope (see para 5.2)
ILS tolerance

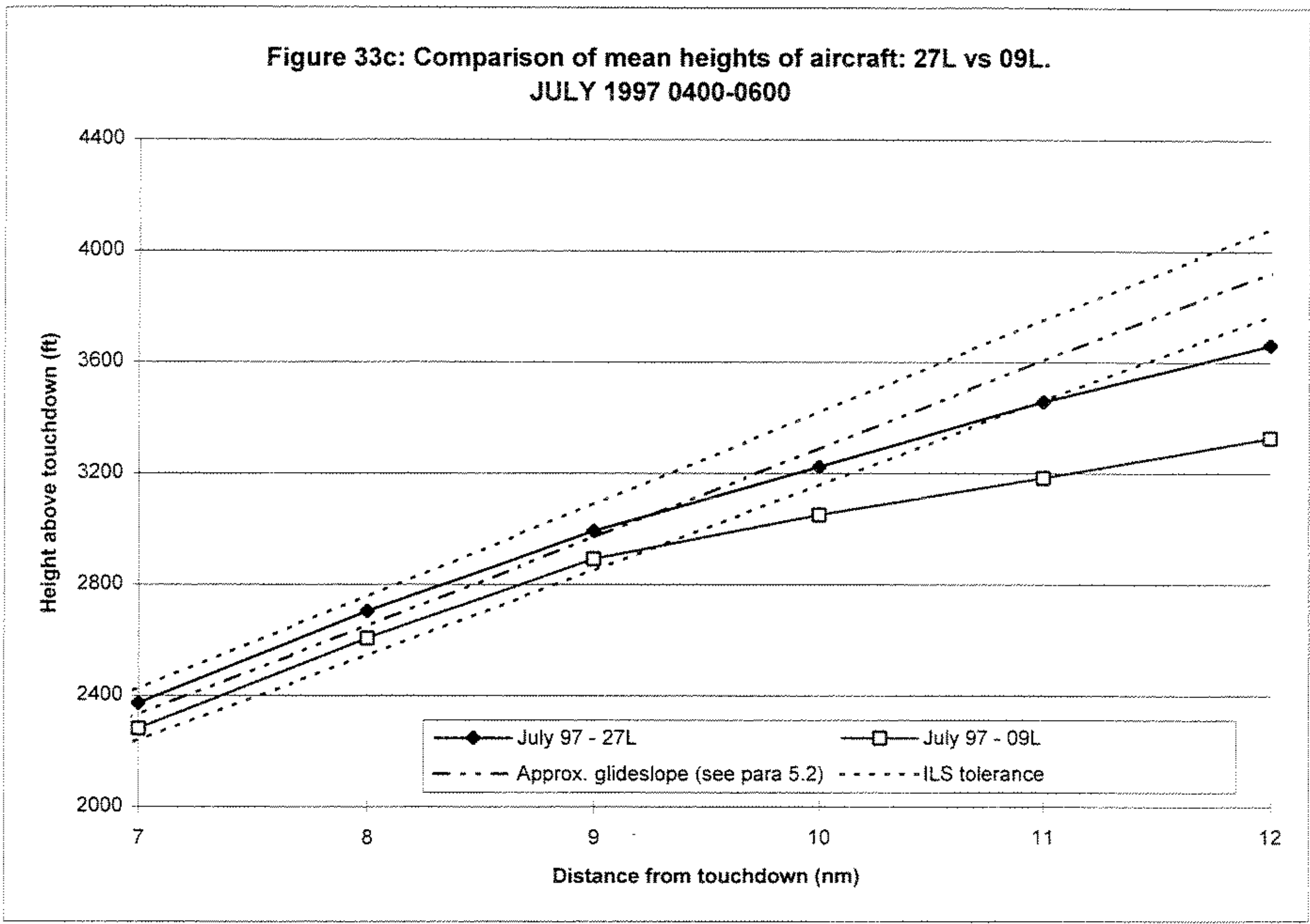


Figure 33c: Comparison of mean heights of aircraft: 27L vs 09L.
JULY 1997 0400-0600
Height above touchdown (ft)
4400
4000
3600
3200
2800
2400
2000
7
8
9
10
11
12
Distance from touchdown (nm)
July 97 - 27L
July 97 - 09L
Approx. glideslope (see para 5.2)
ILS tolerance

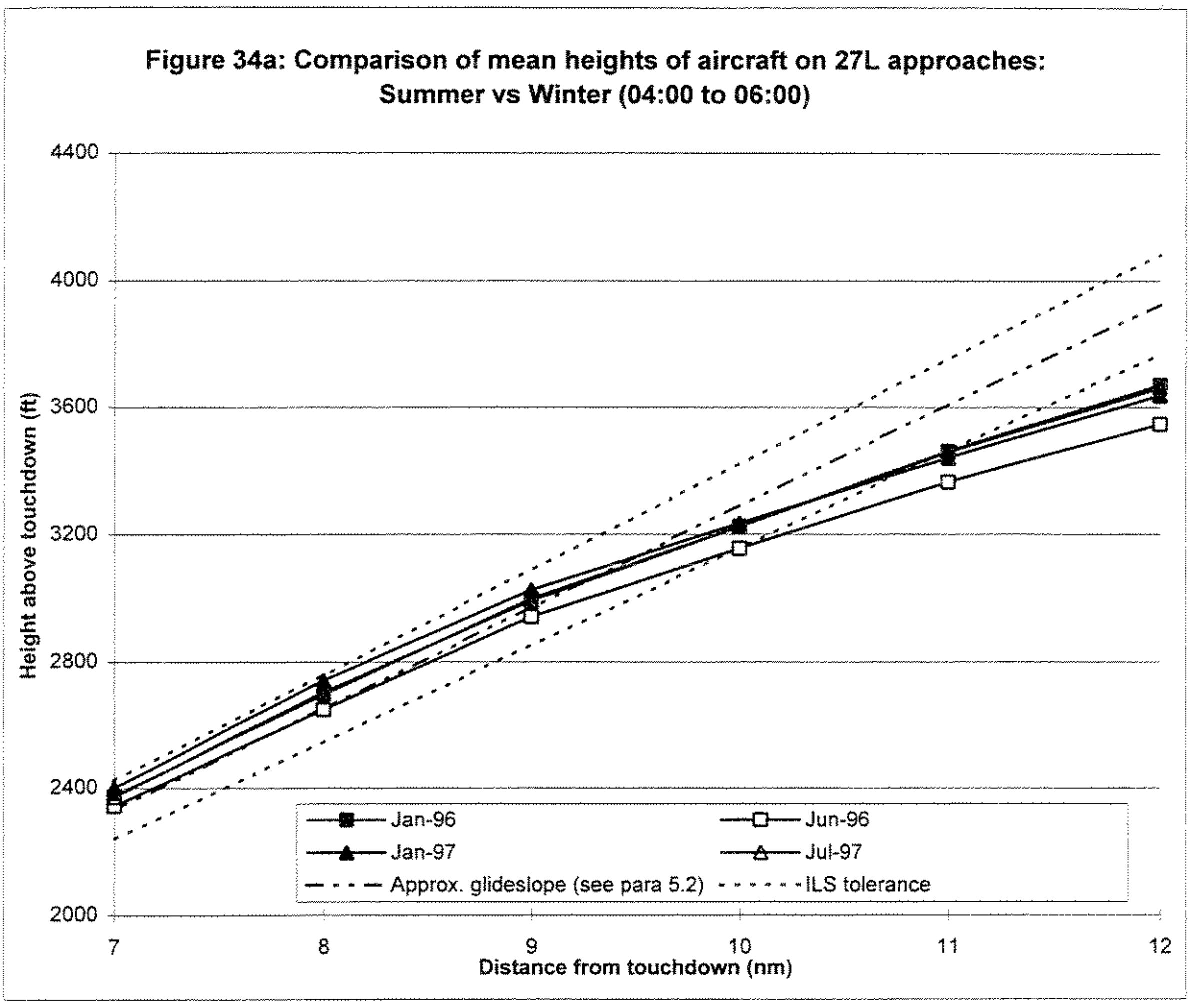


Figure 34a: Comparison of mean heights of aircraft on 27L approaches:
Summer vs Winter (04:00 to 06:00)
4400
4000
3600
3200
2800
2400
2000
Height above touchdown (ft)
7
8
9
10
11
12
Distance from touchdown (nm)
Jan-96
Jun-96
Jan-97
Jul-97
Approx. glideslope (see para 5.2)
ILS tolerance

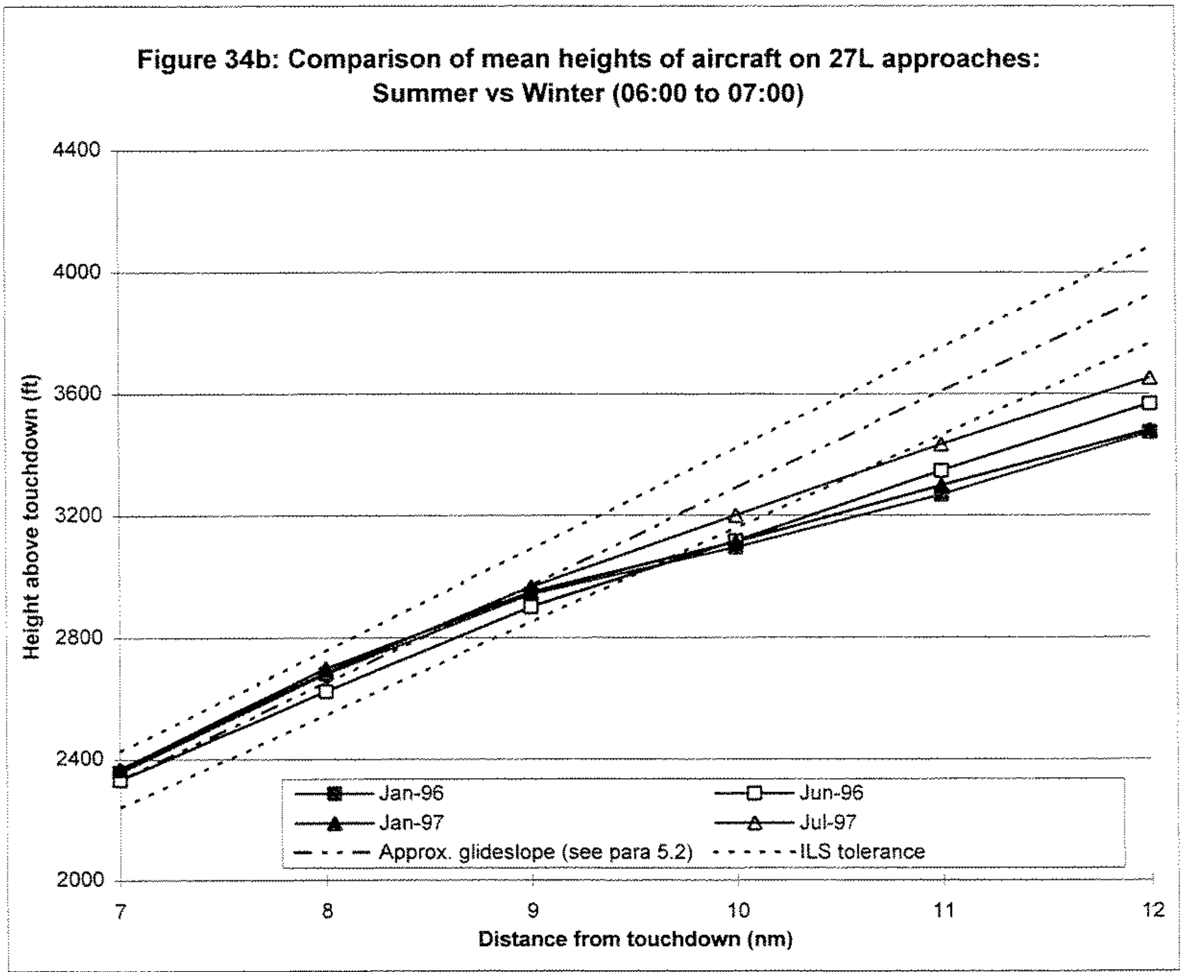


Figure 34b: Comparison of mean heights of aircraft on 27L approaches:
Summer vs Winter (06:00 to 07:00)
4400
4000
3600
3200
2800
2400
2000
Height above touchdown (ft)
7
8
9
10
11
12
Distance from touchdown (nm)
Jan-96
Jun-96
Jan-97
Jul-97
Approx. glideslope (see para 5.2)
ILS tolerance

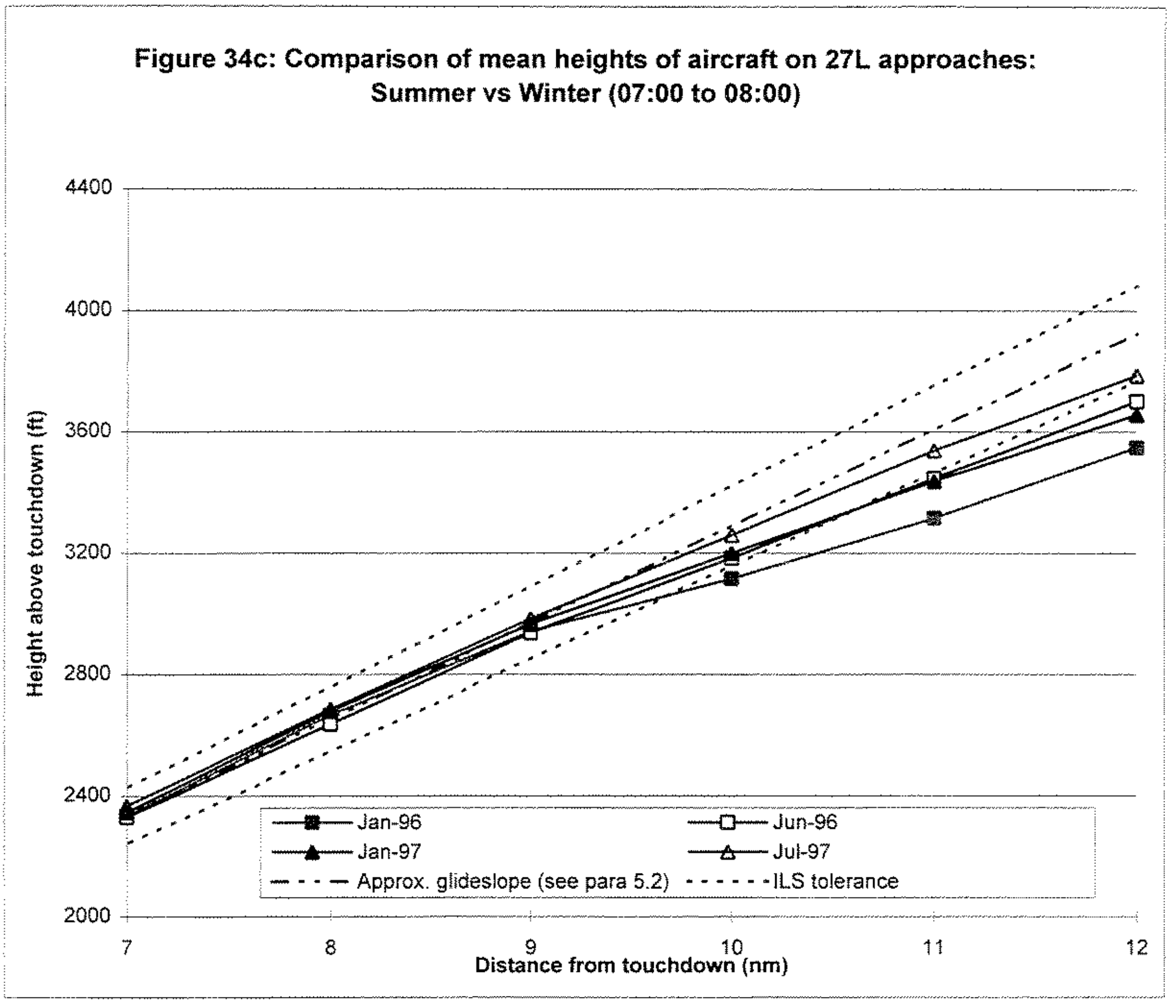


Figure 34c: Comparison of mean heights of aircraft on 27L approaches:
Summer vs Winter (07:00 to 08:00)
Height above touchdown (ft)
4400
4000
3600
3200
2800
2400
2000
Distance from touchdown (nm)
7
8
9
10
11
12
Jan-96
Jun-96
Jan-97
Jul-97
Approx. glideslope (see para 5.2)
ILS tolerance

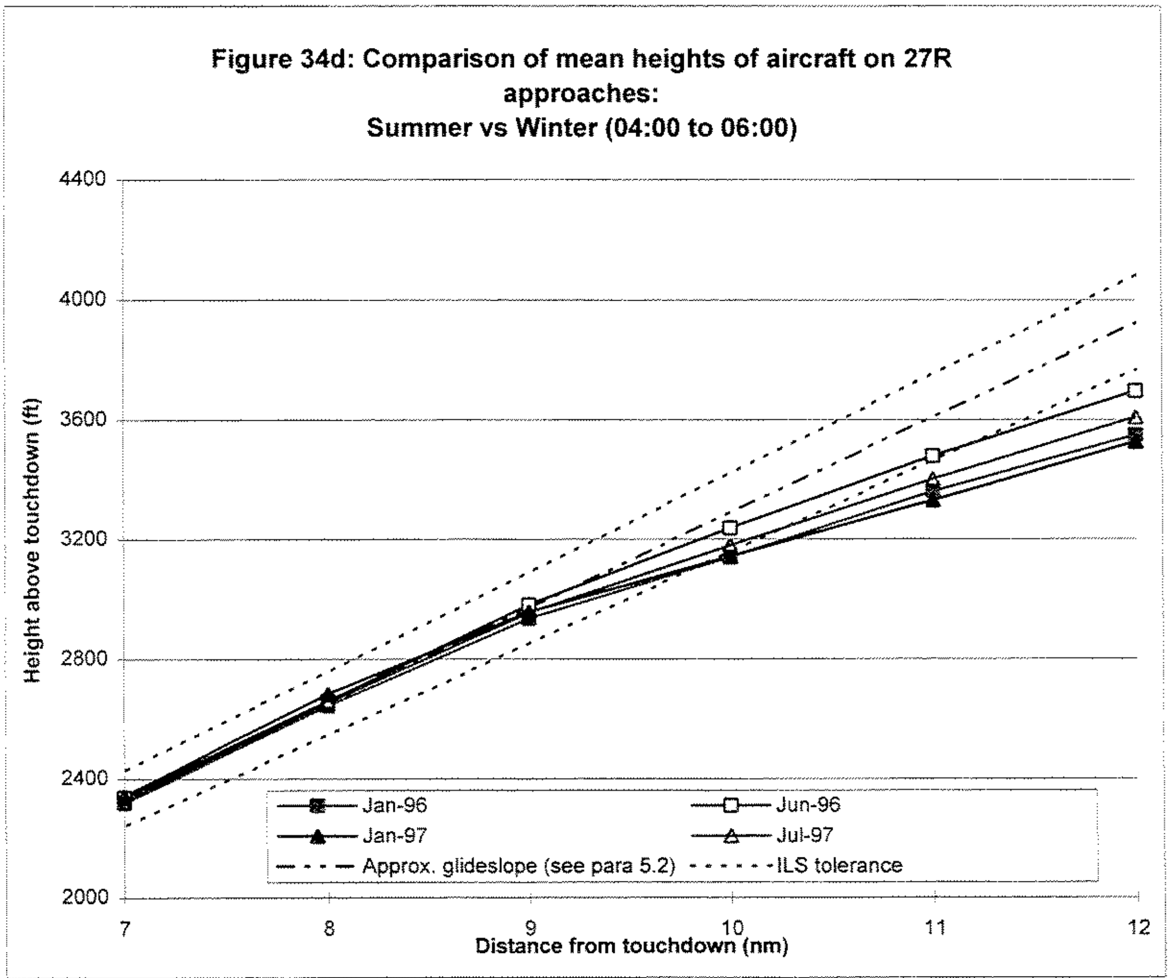


Figure 34d: Comparison of mean heights of aircraft on 27R approaches:
Summer vs Winter (04:00 to 06:00)
Height above touchdown (ft)
4400
4000
3600
3200
2800
2400
2000
Distance from touchdown (nm)
7
8
9
10
11
12
Jan-96
Jun-96
Jan-97
Jul-97
Approx. glideslope (see para 5.2)
ILS tolerance

Figure 34e: Comparison of mean heights of aircraft on 27R approaches: Summer vs Winter (06:00 to 07:00)

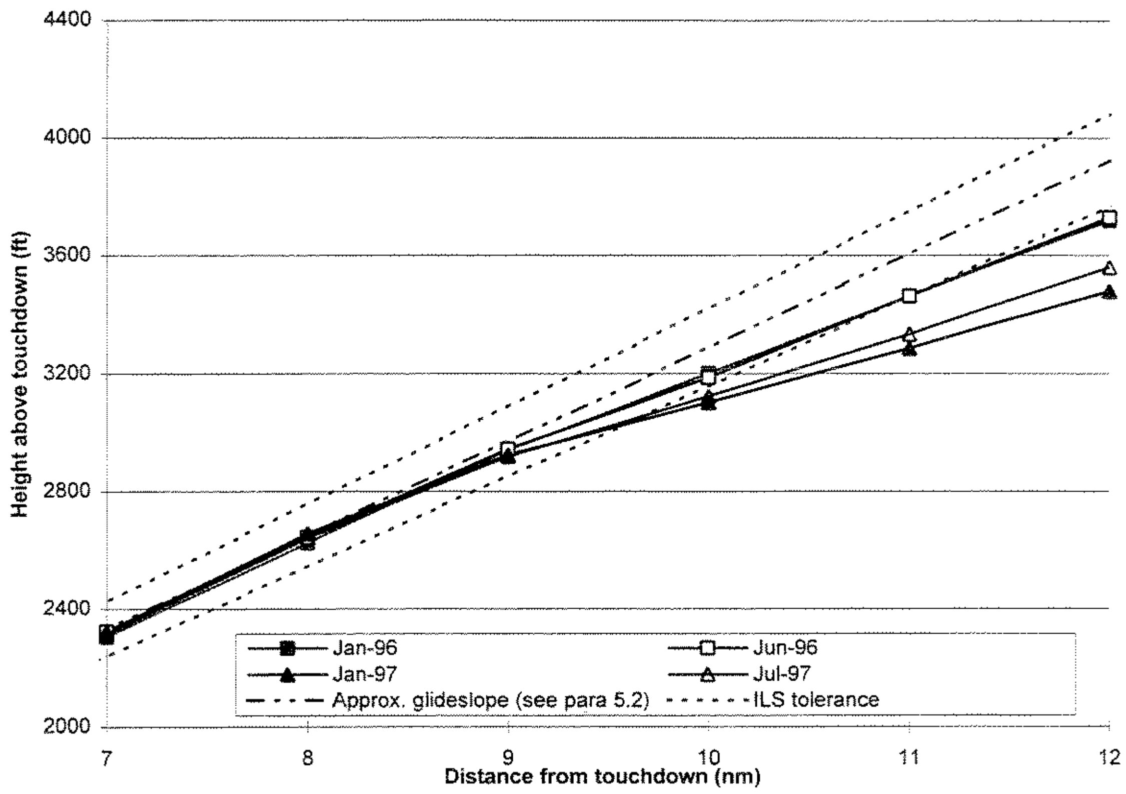


Figure 34f: Comparison of mean heights of aircraft on 27R approaches: Summer vs Winter (07:00 to 08:00)

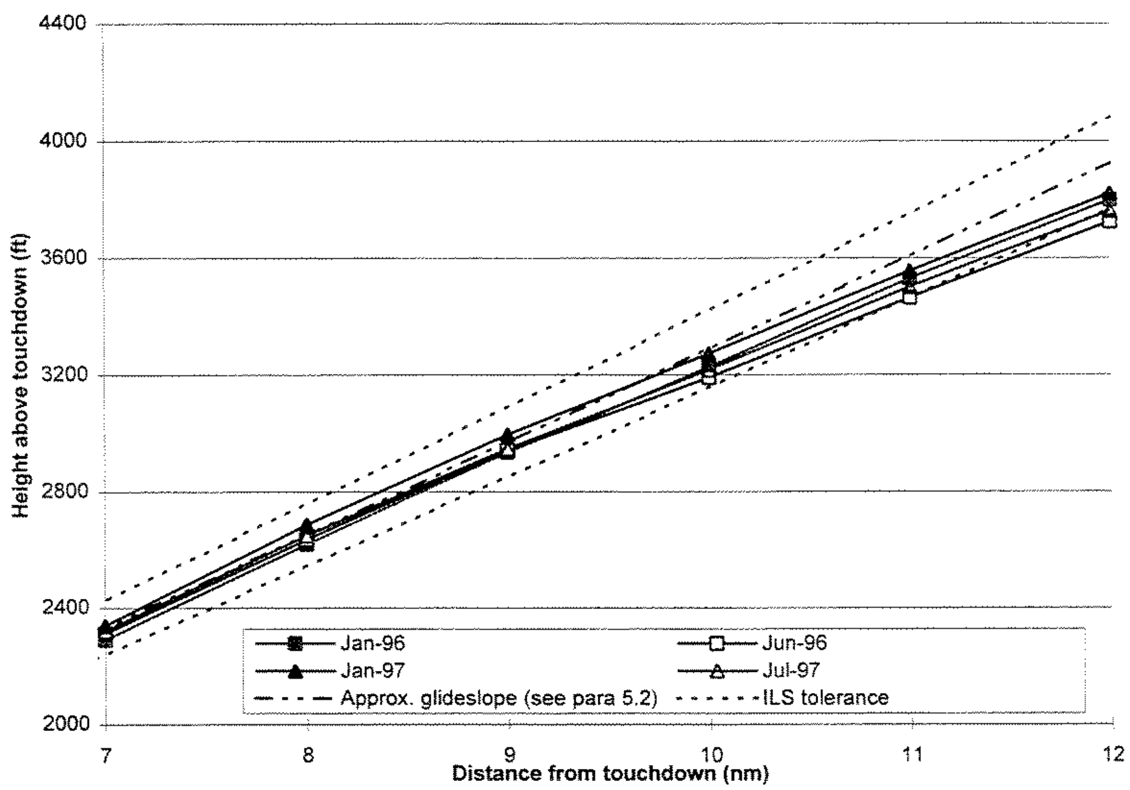
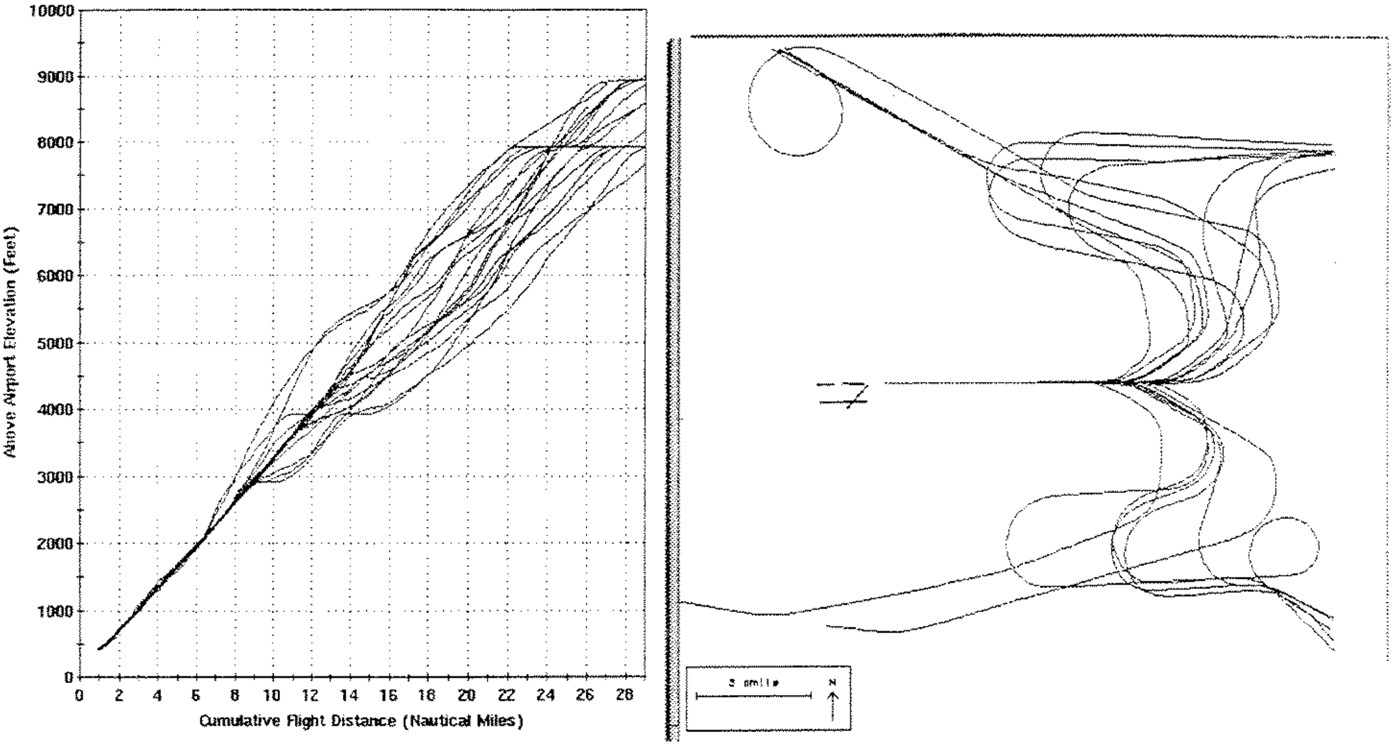


FIGURE 35

COMPARISONS OF CDA AND NON-CDA APPROACHES (0700-0800)

(a) CDA APPROACHES



(b) NON-CDA APPROACHES

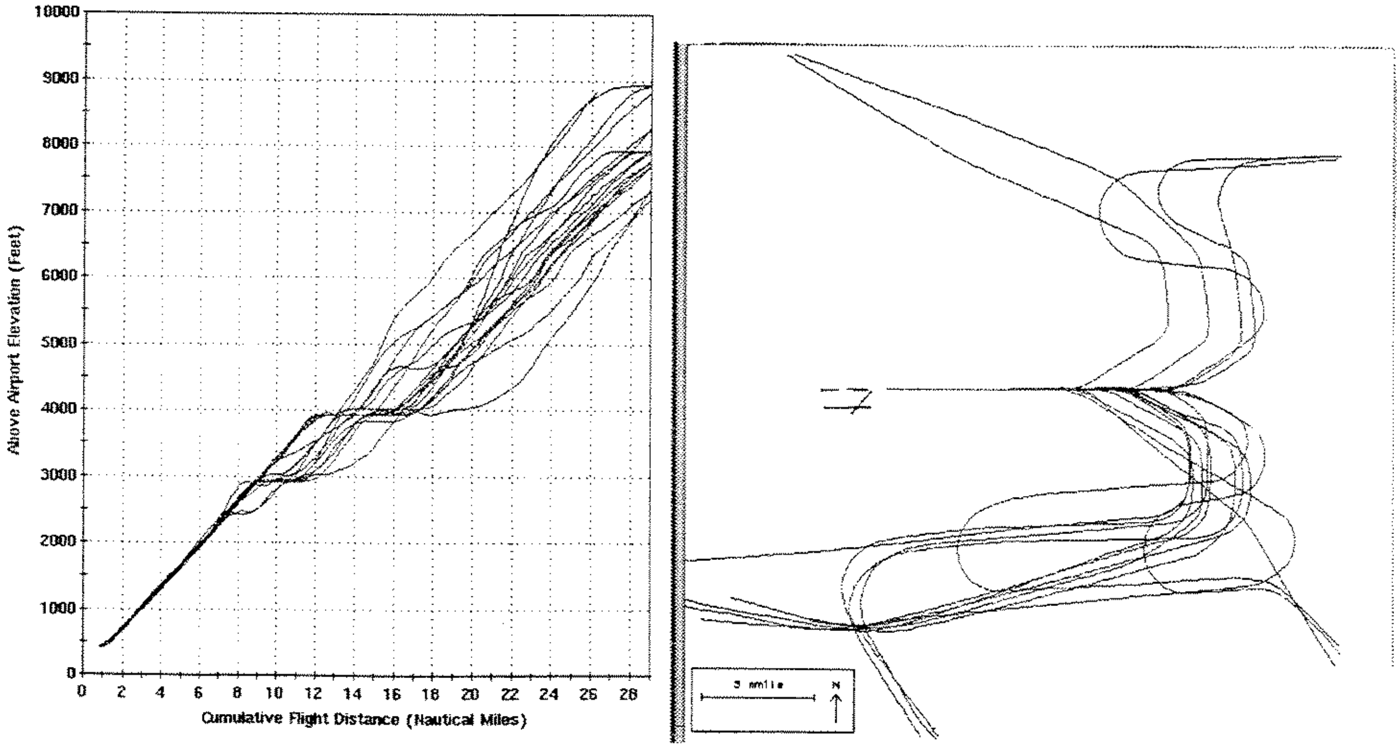


FIGURE 36

PERCENTAGE ACHIEVEMENT OF CDA

Dashed lines show the range of CDA achievement before the early morning trial; other points are during the trial.

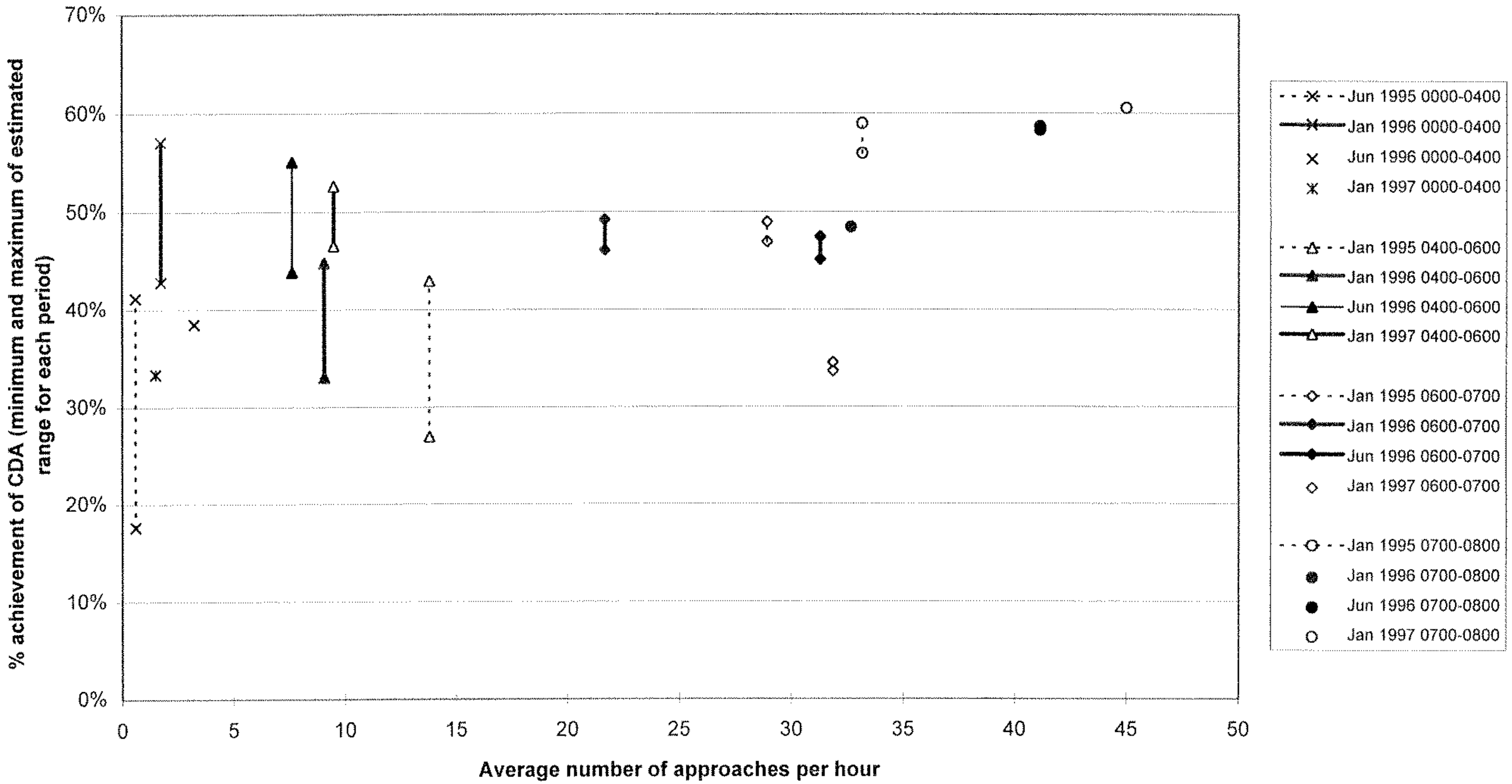


FIGURE 37

CDA USAGE BY HOLD (0400-0800)

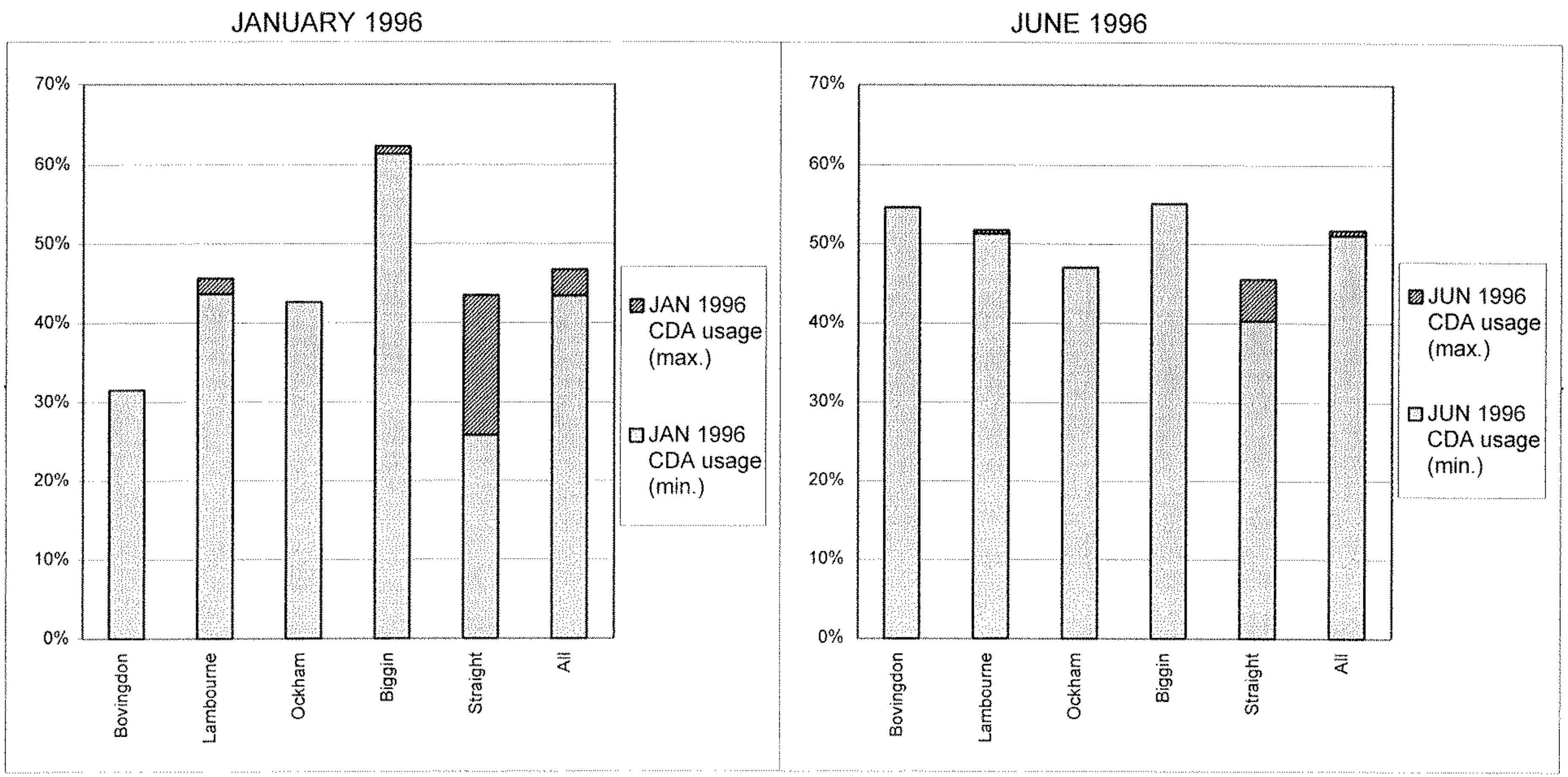
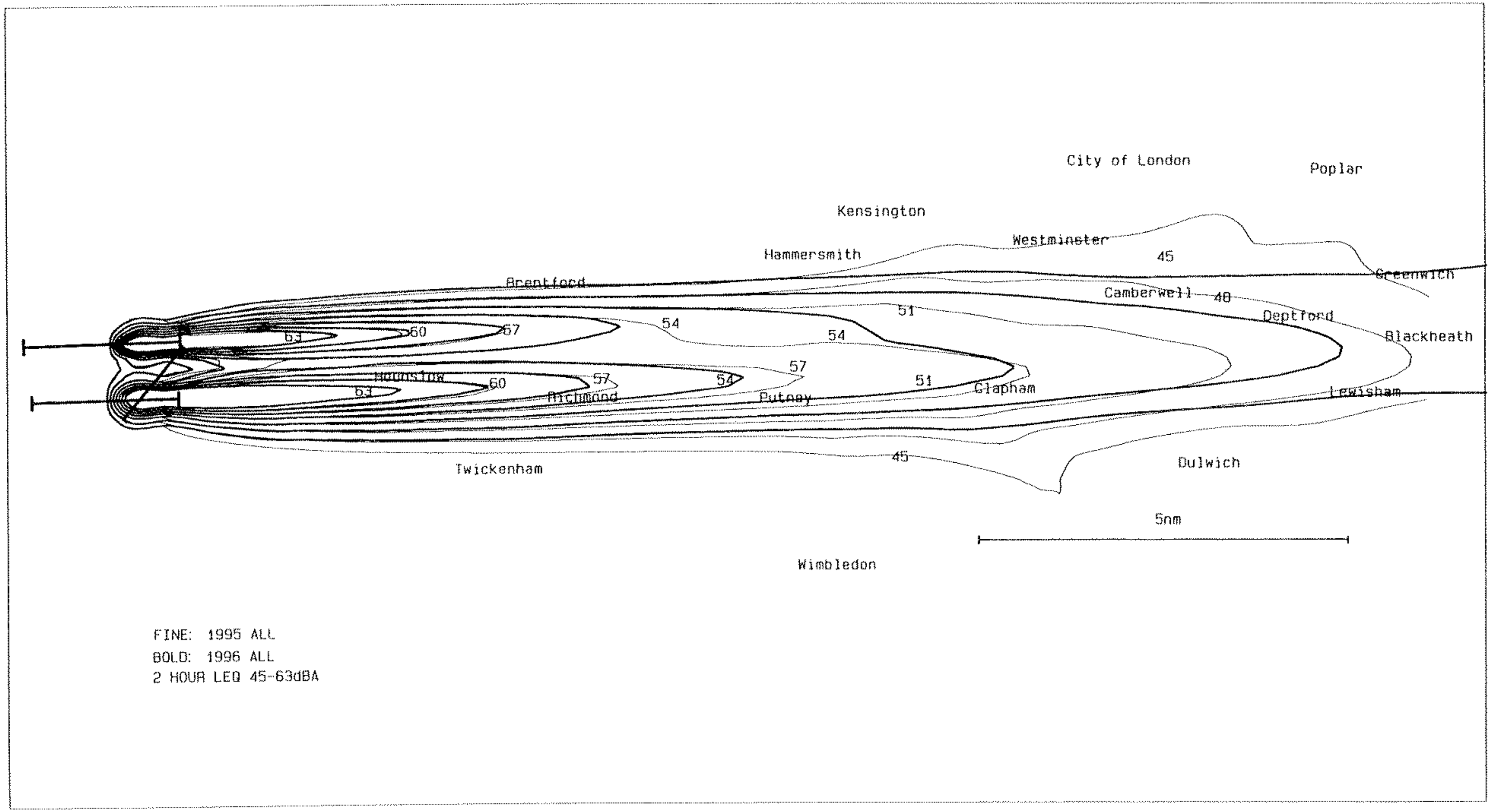


FIGURE 38

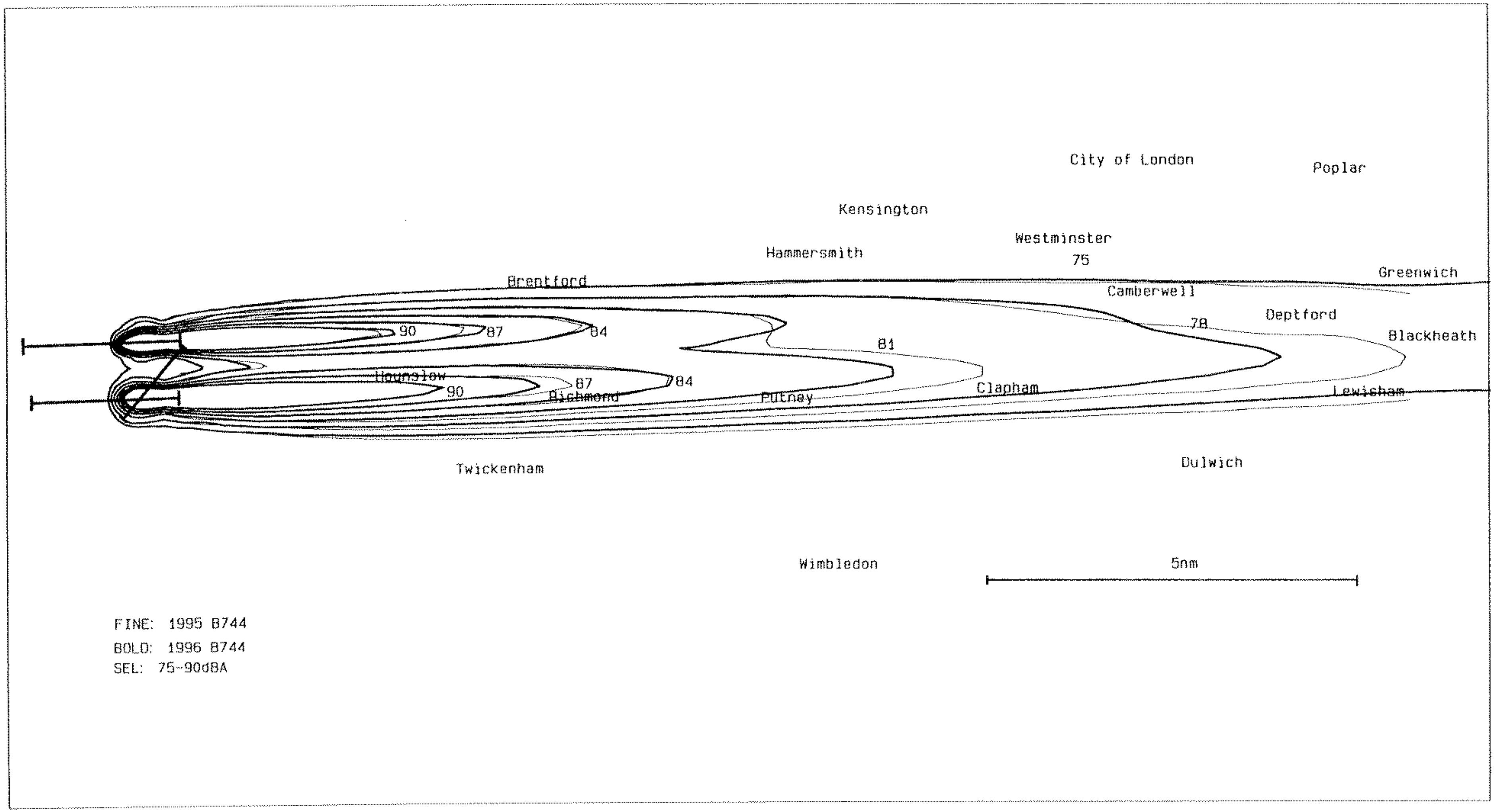
L_{eq} CONTOURS FOR 0400-0600 ACTUAL TRAFFIC AND TRACKS, JANUARY 1995 vs. JULY/AUGUST 1996



1995 vs 1996 ALL ARRIVALS 2 HOUR LEQ

FIGURE 39

SEL CONTOURS FOR 0400-0600 B747-400 STRAIGHT-IN APPROACHES: PRE-TRIAL vs. POST-TRIAL, TRAFFIC SCALED TO JULY-AUGUST 1996



B747-400 STRAIGHT-IN ARRIVALS 1995 vs 1996 SEL CONTOURS

FIGURE 40

SEL vs. DISTANCE FROM TOUCHDOWN FOR B747-400 STRAIGHT-IN 27L APPROACHES (0400-0600): PRE-TRIAL (JANUARY 1995) vs. POST-TRIAL (SUMMER 1996)

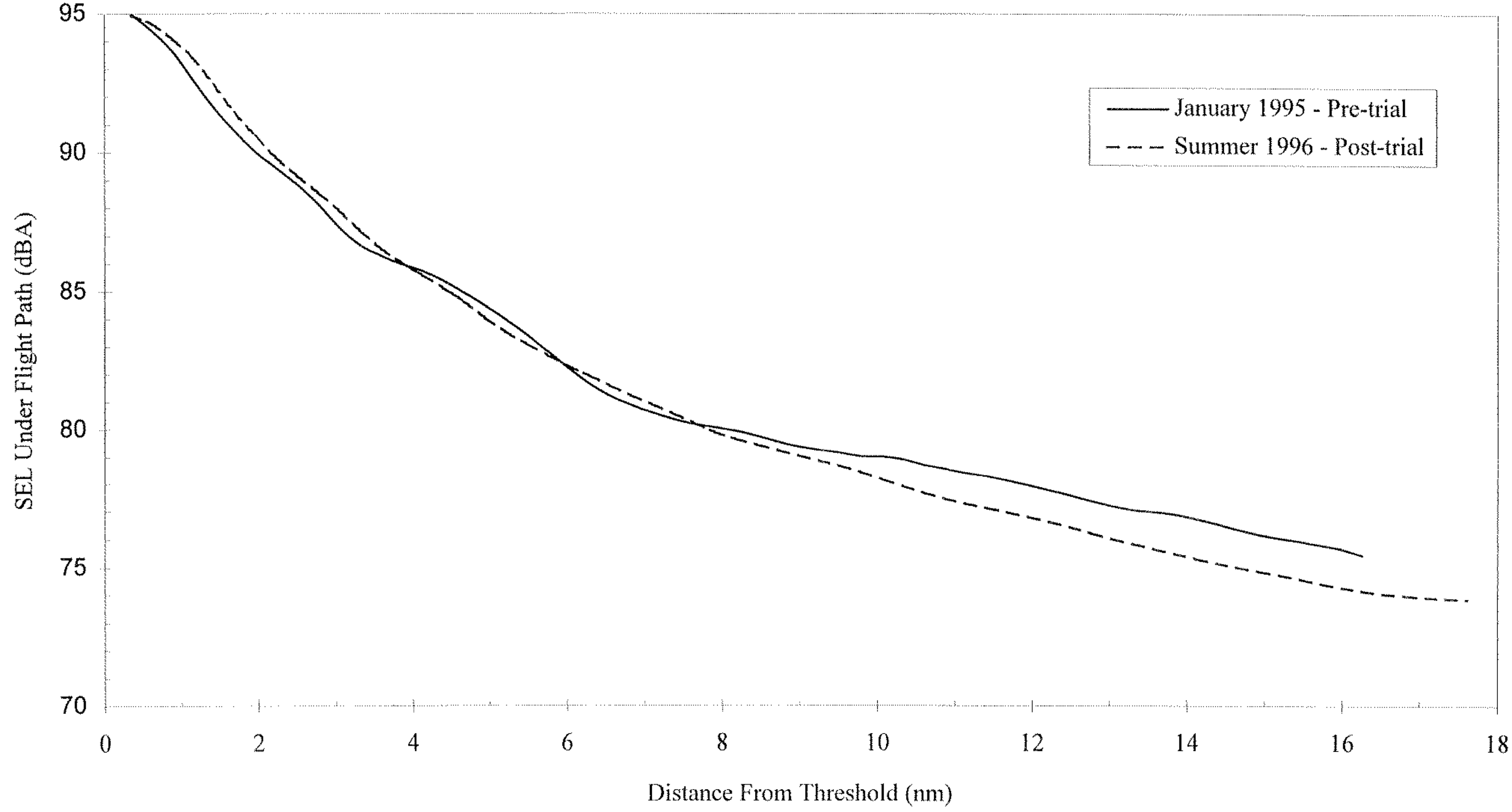


FIGURE 41(a)

SEL CONTOURS FOR 0400-0600 B747-400 APPROACHES:
PRE-TRIAL vs. POST-TRIAL, RUNWAY SPLIT SCALED TO JULY-AUGUST 1996

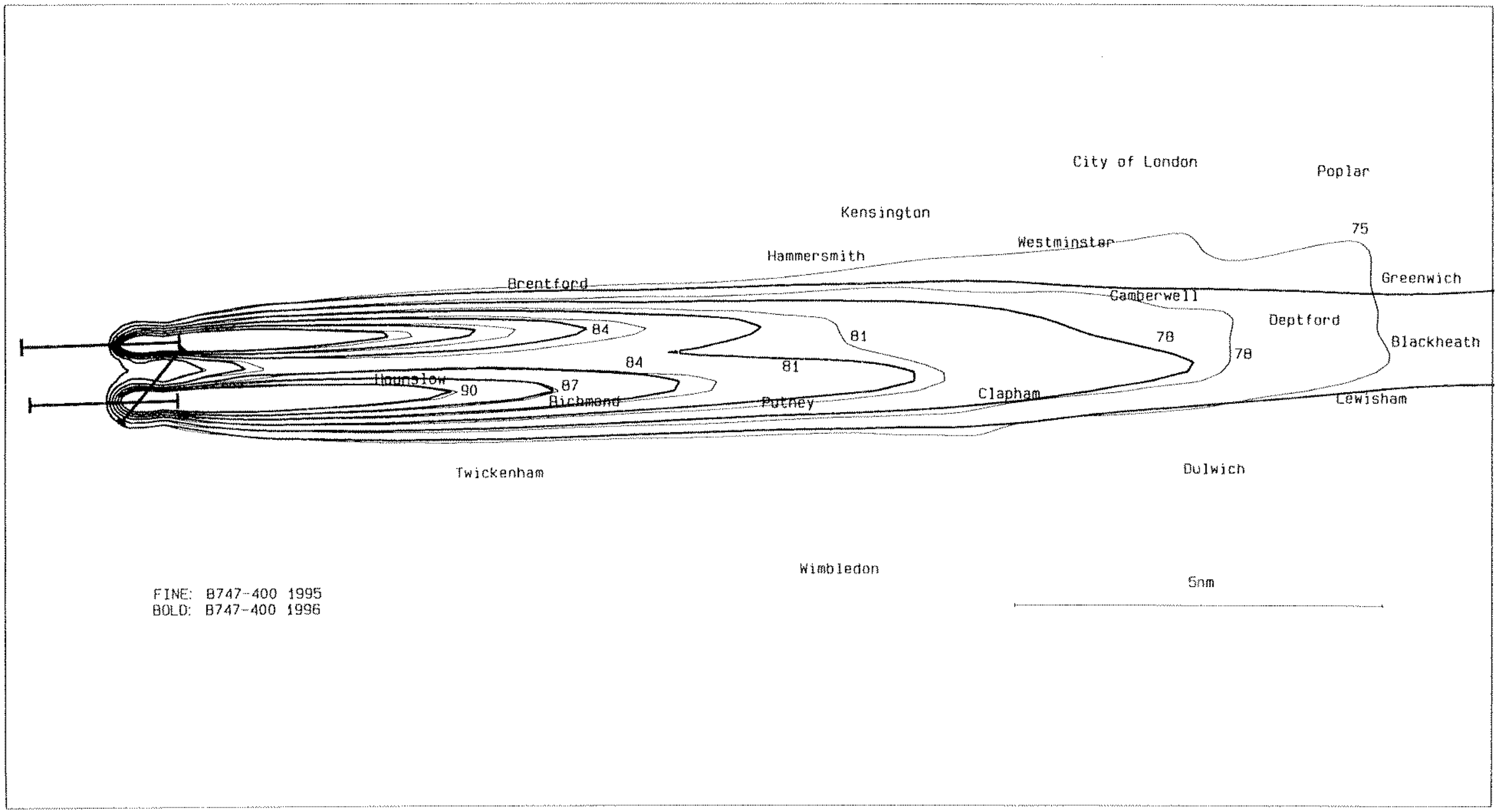


FIGURE 41(b)

AREAS OF (i) UNCHANGED OR REDUCED NOISE LEVELS, AND (ii) INCREASED NOISE LEVELS FOLLOWING THE EARLY MORNINGS LANDINGS TRIAL
0400-0600 B747-400 APPROACH SEL: RUNWAY SPLIT SCALED TO JULY-AUGUST 1996

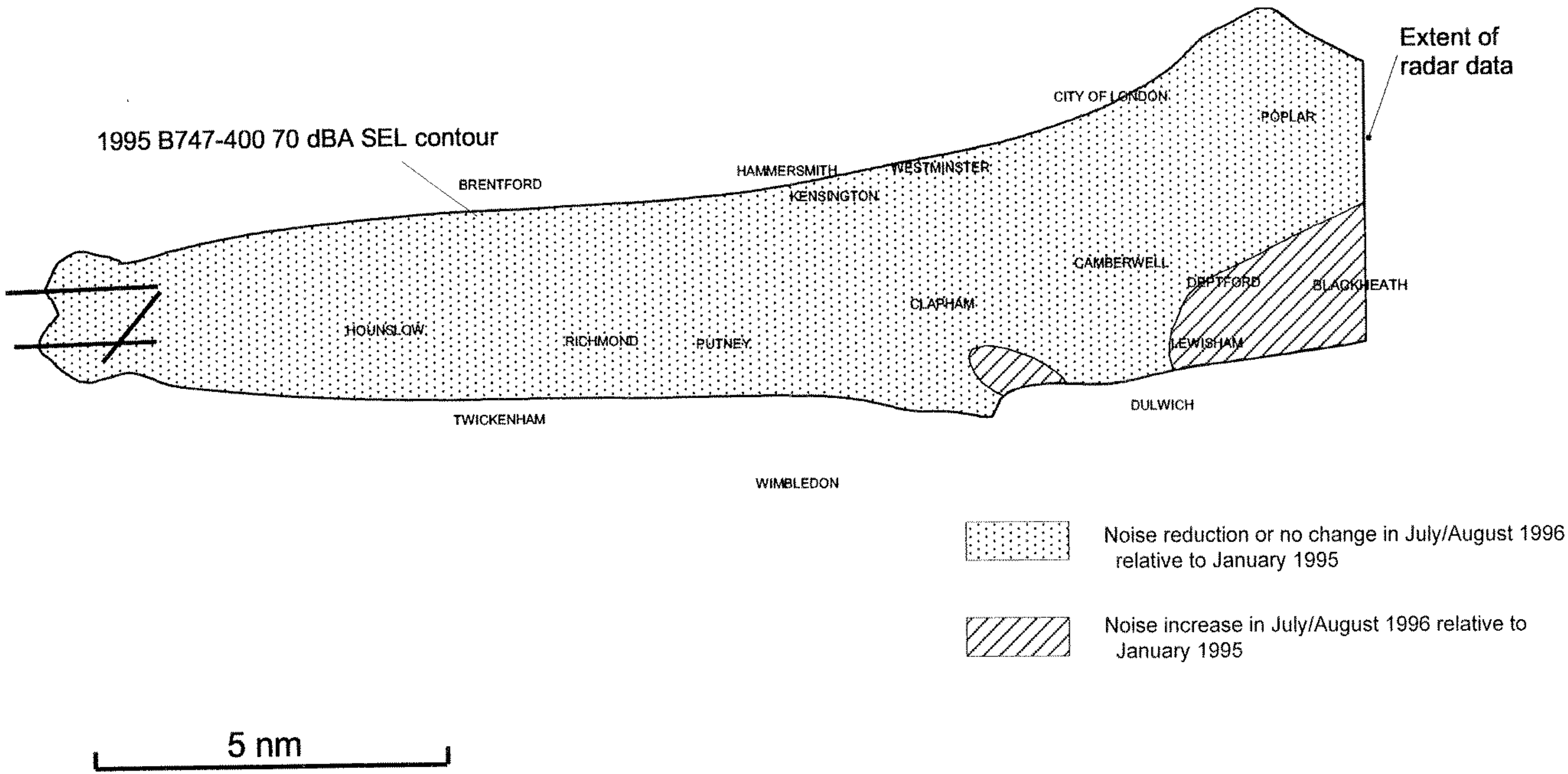


FIGURE 41(c)

SEL DIFFERENCE CONTOURS FOR 0400-0600 B747-400 APPROACHES:
PRE-TRIAL vs. POST-TRIAL, RUNWAY SPLIT SCALED TO JULY-AUGUST 1996
AREA BETWEEN RICHMOND AND CLAPHAM

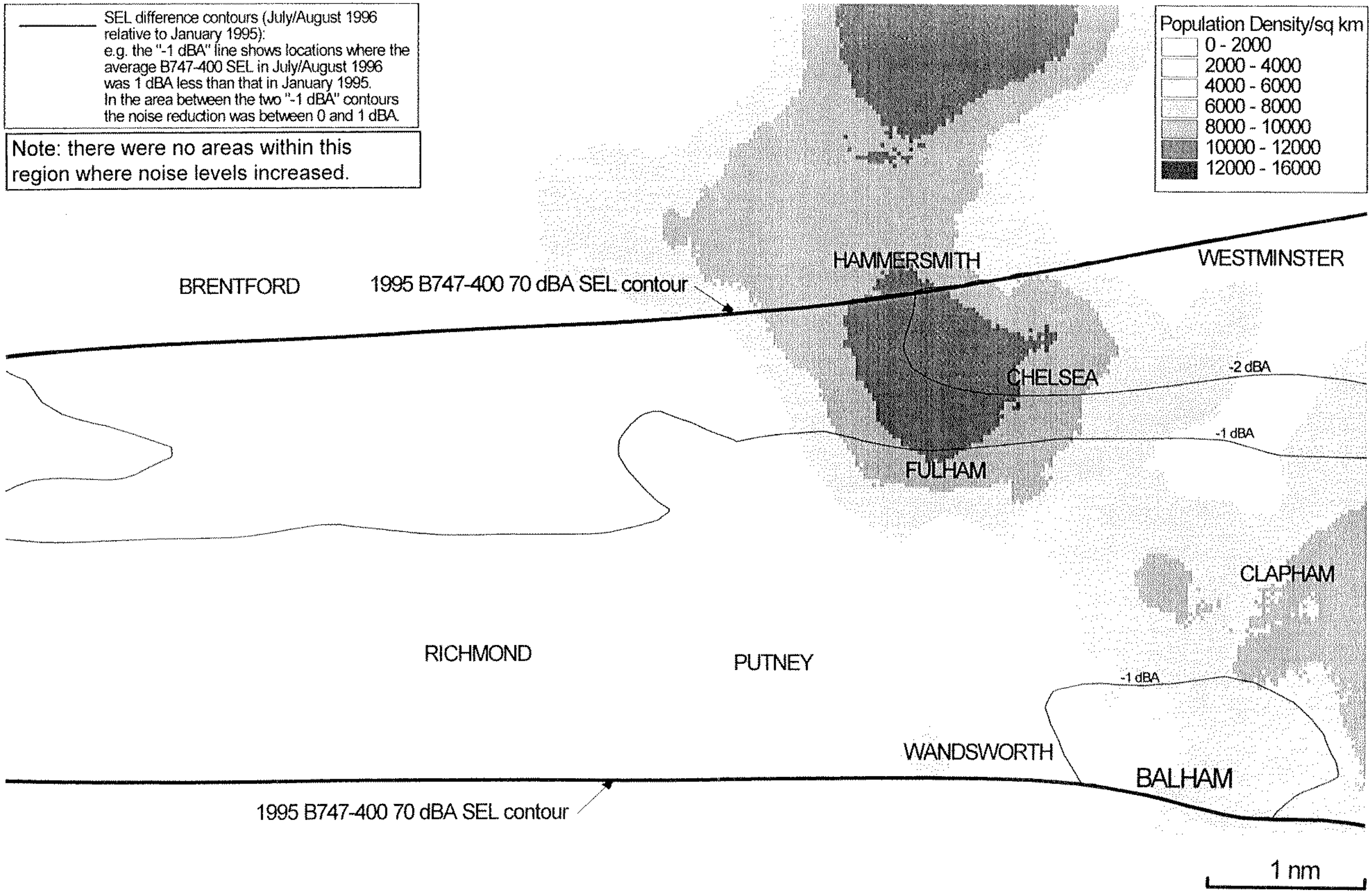


FIGURE 41(d)

SEL DIFFERENCE CONTOURS FOR 0400-0600 B747-400 APPROACHES:
PRE-TRIAL vs. POST-TRIAL, RUNWAY SPLIT SCALED TO JULY-AUGUST 1996
AREA BETWEEN CLAPHAM AND BLACKHEATH

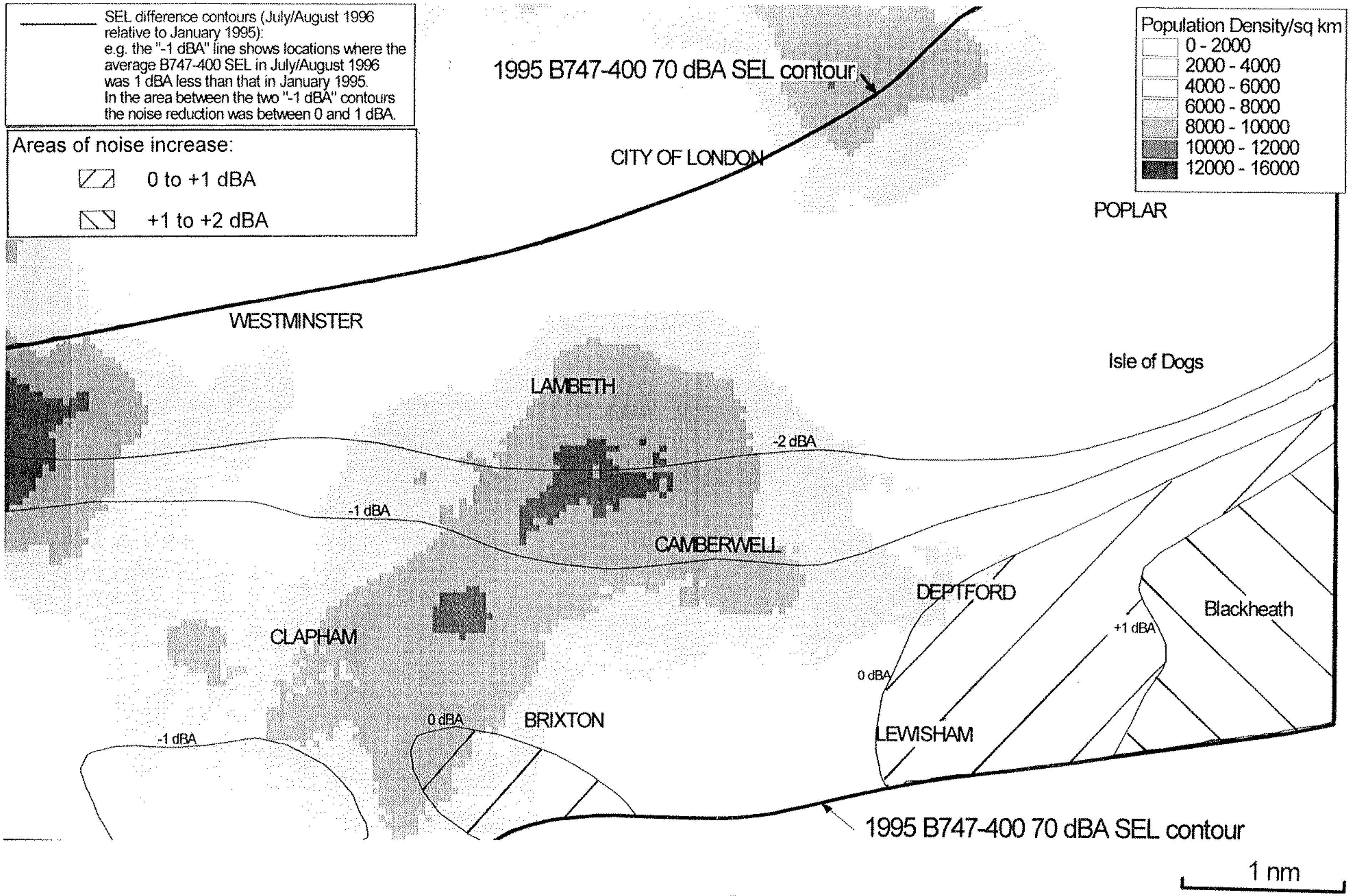
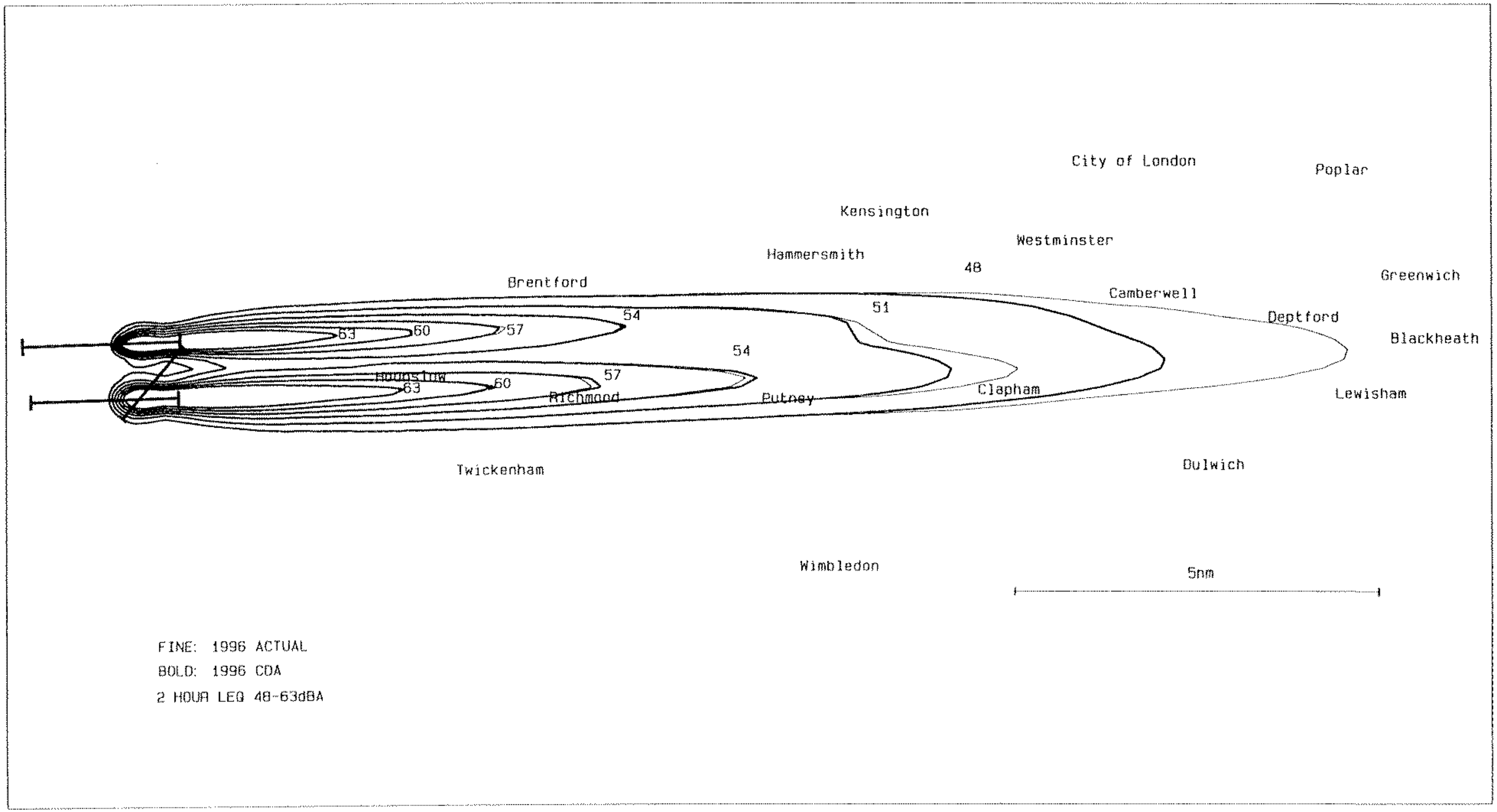


FIGURE 42

L_{eq} CONTOURS FOR 0400-0600 ACTUAL TRAFFIC AND TRACKS JULY/AUGUST 1996: IDEALISED CDA vs. ACTUAL PROFILES



1996 ALL ARRIVALS ACTUAL HEIGHT PROFILES vs CDA 2 HOUR LEQ

FIGURE 43

SEL vs. DISTANCE FROM TOUCHDOWN FOR B747-400 27L APPROACHES (0400-0600):
100% IDEALISED CDA USAGE vs. ACTUAL PROFILES (SUMMER 1996)

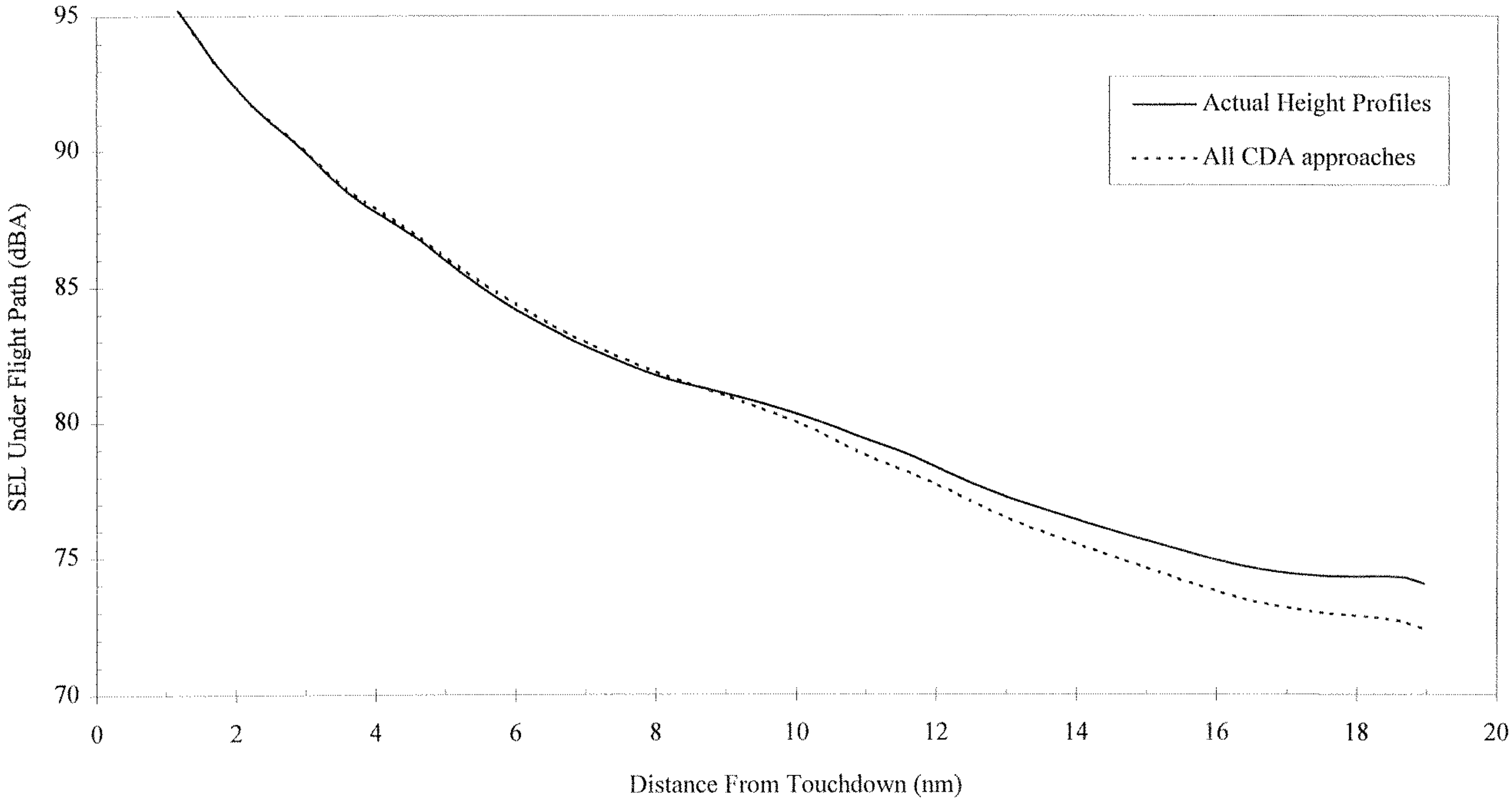
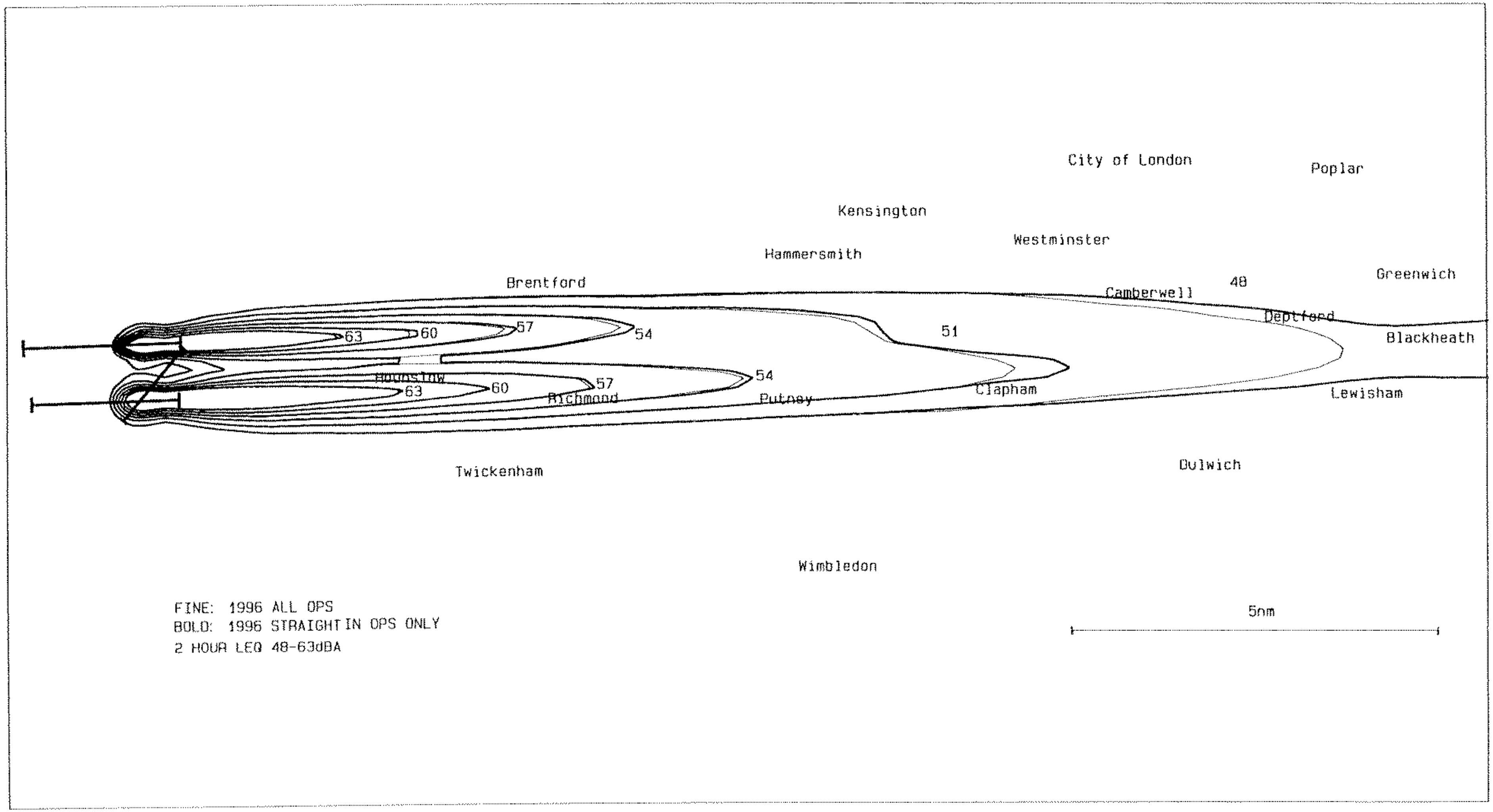


FIGURE 44

L_{eq} CONTOURS FOR 0400-0600 ACTUAL TRAFFIC AND TRACKS JULY/AUGUST 1996: ALL STRAIGHT-IN vs. ACTUAL TRACKS



EFFECT OF EXTENDING STRAIGHT-IN APPROACH LEG (1996 CONTOURS)

ERROR MARGIN RATIONALE

Introduction

A.1 For the purposes of assessing compliance with the night-time westerly approach trial procedure, tolerances have been applied to the NTK height and track data. In terms of the procedural requirement not to descend below 3000 ft altitude within 10 nm of touchdown, a 200 ft tolerance was applied to the height data. To determine compliance with the requirement to intercept the centreline no closer than 10 nm from touchdown, a localizer tolerance margin (of 2.88°) was allowed for. This appendix provides a rationale for the use of these error margin criteria.

ATC Prescribed Tolerance

A.2 The Manual of Air Traffic Services (MATS) states that "an aircraft may be considered to be at an assigned level provided that the Mode C readout indicates 200 ft or less from that level." (Ref A1).

A.3 This has an important influence on aircraft height-keeping, as it follows that although ATC may have cleared an aircraft to the 3000 ft minimum altitude, it would not be judged to be outside the bounds of accepted tolerance unless it was below 2800 ft.

Height Errors

A.4 The source of data for this study was the NTK system (and to a limited extent DERA radar data), for which aircraft height data is obtained via NATS Secondary Surveillance Radar (SSR) from Mode C transponder readouts. Sources of errors and uncertainty in the use of the height data derived in this way are composed of several contributions, including those described below:

- **SSR Mode C Correspondence Error (CE).** The Mode C transponder on board the aircraft is linked to the aircraft's barometric altimeter; the transponder reports the Flight Level (which has a resolution of 100 ft, and represents one hundredth of the altitude in feet, adjusted to a reference atmospheric pressure of 1013.2 mbar). Below Flight Level 60 (approximately 6000 ft altitude) the Flight Level is adjusted by the radar data processing system to give the sea level altitude at the London Area local atmospheric pressure. The error introduced from the Flight Level resolution is a maximum of ±50 ft.

- **Altimetry System Error (ASE).** The altimeter barometric pressure is subject to on-board measurement accuracy and local pressure variations. The magnitude of these errors is not usually known unless there is some external reference to the aircraft height, however they may be of the order of ±50 ft.

- **Airfield elevation adjustment**. Heathrow is at an airfield elevation of 80 ft above sea level, which generally represents the difference between 'altitude' and 'height' in this report. NTK only allows analysis in terms of aircraft height (i.e. above the airfield), and this was used as it was most relevant in terms of assessing noise exposure.

- **Conversion errors**. Examples which apply to this study are errors introduced by pressure corrections, the time base of the radar, quantisation (e.g. NTK range data[34] has a resolution of 1/16 nm), smoothing of height and positional data within NTK, interpolation (used to derive height values at integer nautical mile intervals of track distance) and co-ordinate transformations (e.g. SSR polar to Cartesian co-ordinates). These factors are estimated to contribute further possible height errors of the order of at most 25 ft.

A.5 When considering height errors the ability of an aircraft to actually maintain a flight level also has to be taken into account (this is characterised by the 'assigned altitude deviation' - AAD). This is affected by external factors, such as wind speed and direction and turbulence. Based on work carried out to support the safety assessment of RVSM (Reduced Vertical Separation Minimum) in the North Atlantic (Ref A2), it is estimated that the AAD error may be around 50 ft.

A.6 A detailed examination of height uncertainties was beyond the scope of this study and it must be noted that the values given above for ASE, conversion errors and AAD are broadly-based estimates. However, these estimations show that the errors on the NTK height data are likely to be less than the 200 ft tolerance allowed for within MATS; therefore no additional allowance has to be made for NTK height errors in assessing compliance with the procedure.

A.7 Having considered the potential height errors given above, the MATS 200 ft tolerance seems reasonable for identifying compliance with the early mornings landings trial procedure with any degree of certainty.

ILS Glideslope Tolerance

A.8 Once aircraft are established on the ILS, then the governing factor for estimating the allowable error margin for height is glideslope tolerance. At 10 nm from touchdown this error margin will be greater than 200 ft. However, closer to the airport the margins are proportionately smaller.

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[34] the straight line distance from the radar head to the aircraft.

A.9 The tolerance on the ILS glideslope beam is such that although it is nominally set to 3°, the system is still within specification if the actual beam angle lies between 2.88° and 3.12°. Thus the glideslope angles on the different runways at Heathrow could lie anywhere within these limits, and changes due to drift and maintenance work etc. could result in variations between runways and from month to month.

Lateral Errors

A.10 Within the NTK data there is uncertainty in the lateral position of aircraft; for Heathrow at 10 nm from touchdown the resolution of the data is of the order of 30 m (based on the radar azimuthal resolution of 0.088°).

A.11 Attention also needs to be given to the allowable tolerance for aircraft to be considered established on the runway centreline. The lateral error margin is a function of the Instrument Landing System (ILS) localizer beam width at the point at which aircraft are considered to be established. From discussions with pilots and flight inspection experts, it is understood that a full scale deflection on the ILS indicator corresponds to a beam angle of 2.88° at Heathrow. Thus for the purposes of this study aircraft are considered to be established on the localizer when they are within this beam angle of 2.88°. This is equivalent to a lateral tolerance of ±0.25 nm (approximately 500 m) to either side of the centreline at 10 nm from touchdown. Figure A1 illustrates the concept of the localizer tolerance.

A.12 For the purposes of this study the NTK resolution of 30 m has been considered insignificant relative to the lateral tolerance of ±0.25 nm (±500 m) at 10 nm from touchdown.

References

A1 MATS Part 1, Chapter 5, Section 9, 'Use of Mode C for vertical separation'.

A2 Private communication: Data to support the safety assessment of NAT MNPS Phase 1 RVSM Airspace, NATSPG (North Atlantic Planning Group), Mathematicians Working Group meeting number 20, London November 1996.

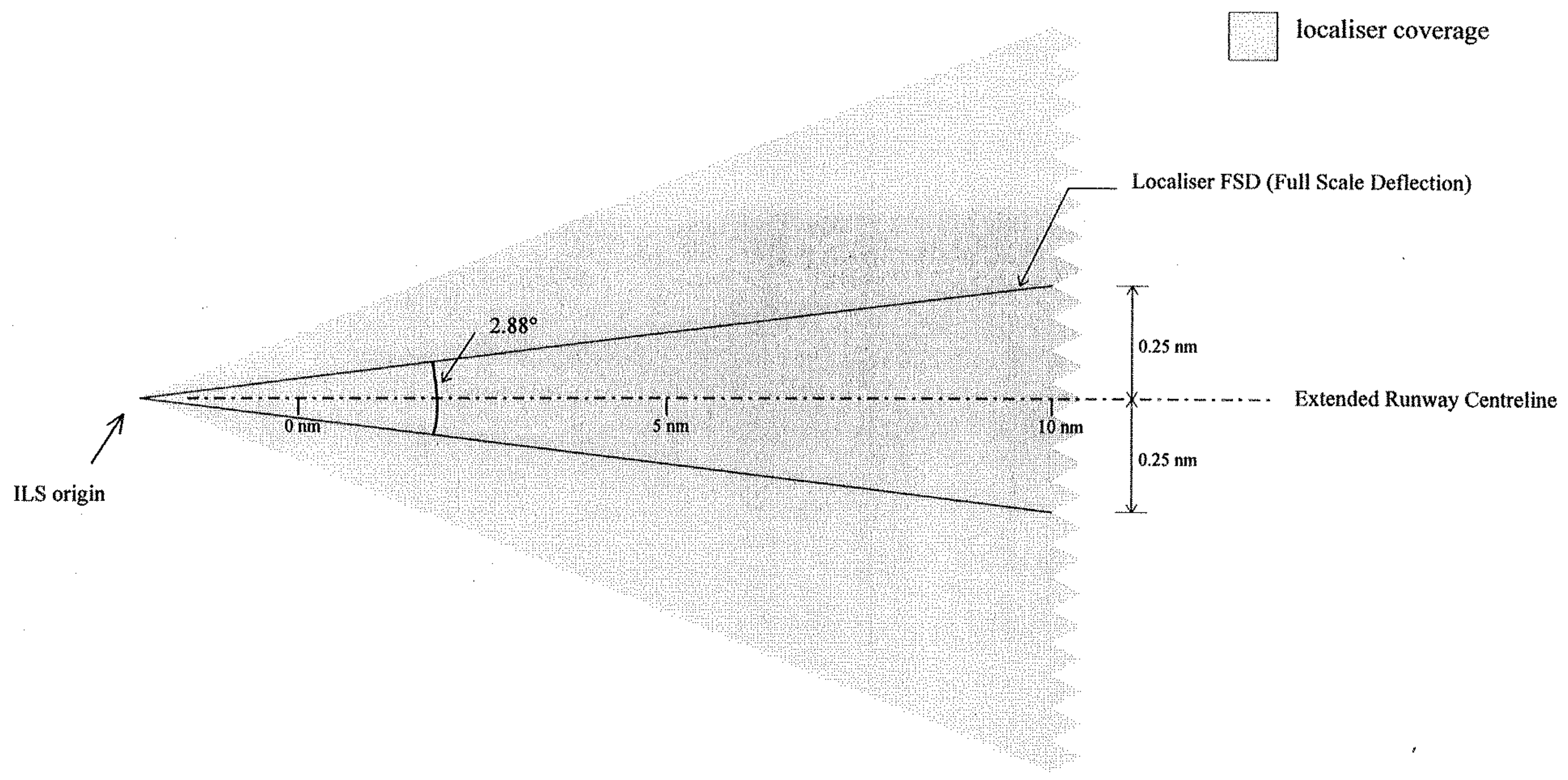

Figure A1: Diagrammatic Representation of ILS Lateral Tolerance from the Runway Centreline

DEFINITION OF THE CDA PROCEDURE

B.1 The CDA procedure has generally been taken to be self-explanatory, but the exact meaning of CDA, and the way it is facilitated by ATC and flown by pilots, is not defined in detail in either the AIP or MATS. The intention of the procedure is that when practicable any significant segments of level flight should be replaced by continuously descending flight.

B.2 To identify CDA approaches from the NTK system, it is necessary to establish a practical criterion which accommodates the characteristics of both the source radar data and aircraft operating practices. In the absence of a published definition, that used in the most recent DORA assessments of CDA achievement was adopted for this study.

Definition of CDA procedure used in the late 1970s

> "The criterion for categorising an approach as 'CDA' or 'not CDA' is at first sight simple and readily apparent - to be classified as a CDA, the approach as represented by the radar plot must contain no level segments. However, such a definition strictly applied would take no account of the precision of the radar output. Due to the revolution of the radar head, information on the aircraft's position and altitude is received only at intervals of approximately 6 seconds[35], during which time the aircraft will have travelled about one third of a nautical mile, and thus some short level segments will not be recorded. Further, the altitude data are only given to the nearest 100 ft. It should also be noted that aircraft often fly a very short level segment without increasing power (and hence noise) as one method of losing airspeed during descent. Accepting that some short level segments may not necessarily generate extra noise, for the purpose of the monitoring study an approach is classified as a CDA if its plot representation indicates no level segments of two nautical miles or more below an altitude of 6000 feet."

B.3 In this definition, the altitude of 6000 ft is of the order of 1000 ft below the lowest level of the holds. The choice of 6000 ft is thus the highest practicable which avoids the categorisation of those aircraft at the lowest holding level as if they were flying level segments. (There is no published start altitude for a CDA procedure - for 'straight-in' early morning flights, for example, CDA might be commenced at very much higher altitudes; conversely CDA could be commenced at lower altitudes in cases where ATC require flexibility to carry out the vertical integration of traffic flows using standard vertical separations

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[35] The time interval for the radar heads currently in use, both in the NTK and the DERA radar data as used in this study, was 4 seconds.

on the leg leaving the stack.) 6000 ft (or strictly FL60) also represents the transition altitude (see Appendix A para A4), above which the reference atmospheric pressure is used rather than the local pressure.

B.4 The use of a minimum 2 nm level segment length prevents unjustified classification as non-CDA of flights which for example fly level without any increase in power.

CDA CATEGORISATION OF APPROACHES

C.1 This Appendix examines the way in which approaches recorded by the NTK system were categorised as 'CDA' or 'non-CDA'. The method of categorisation accounts for bias arising from differences between the NTK areas used for 1995 and for 1996 onwards. The method used for analysis of the January 1995 DERA radar data is also outlined.

NTK data

C.2 The criterion for the selection of CDAs requires analysis of aircraft heights up to 6000 ft. Together with the NTK coverage area, a volume of airspace is thus defined for the identification of CDAs.

C.3 The NTK system acquires data from a defined area. For Heathrow in 1995, this area was a 24 nm square area centred on the ARP. In December 1995 these dimensions were increased to obtain radar data over a rectangular area extending 42 nm east to west, and 30 nm north to south, centred on the ARP.

C.4 For all approaches entering the volume from above it can readily be established whether or not they met the criterion for a CDA. For approaches entering the volume from the side, it follows that the maximum heights given in NTK are less than 6000 ft. Thus even for a flight that exhibits no level segments within the volume, it cannot be concluded whether or not there were any level segments in the region immediately outside the volume and up to 6000 ft in height. Thus approaches entering the volume from the side can be categorised as either 'non-CDA' - through having level segments within the volume - or 'indeterminate' if they have no level segments in the volume.

C.5 Whether an approach enters the volume from above or the side depends largely on the distance flown within the volume. With typical descent angles of around 3°, the boundary for 1995 would be crossed at a height of around 3500 ft for approaches which pass from the NTK boundary directly to the runway, and thus originate typically from Biggin or Lambourne during light traffic, or are straight-in. Those approaches entering from above tend to follow quite long paths to the runway within the NTK area, e.g. approaches originating from Bovingdon or Ockham.

C.6 It follows that analysis of only those flights for which complete data were available could lead to the sample being biased towards Bovingdon and Ockham holds. Therefore the analyses of CDA achievement rates give a range, corresponding to the inclusion of both types of approach, i.e. those entering the airspace volume from above and those entering from the side.

C.7 Results of analyses using these methods of categorisation are given in Table C1. Part (a) of the table shows the number of arrivals analysed during seven days of each month (June 1995, January 1996 and June 1996), for the periods 0400-0600, 0600-0700 and 0700-0800, and the numbers of level segments within three height bands. Where an approach had more than one level segment of more than 2 nm, only the lowest was considered. Table C1 part (b) shows the numbers of approaches for which the radar data were available up to the maximum height of the four height bands.

C.8 Part (c) of the table gives the proportion of flights in each category, as a percentage of the total number of approaches analysed.

C.9 Figures C1 and C2 illustrate height variations for the periods 0400-0600 and 0600-0800 on three days in January 1996. The figures are in three parts:

i) *The height where the glideslope was joined.* Analysis of the data plotted in Figure C1 (i) shows that 11% of approaches did not appear to be established on the glideslope until 2000 ft or 2500 ft, but the majority joined at 3000 ft or 3500 ft - 4500 ft. 10% appeared to be on the glideslope at 5000 ft or above. After 0550, and for the whole of the two hours covered in Figure C2, a higher proportion of flights joined the glideslope very close in (at 2000 ft or even 1500 ft), but the great majority joined at 3000 ft.

ii) *The height of the lowest level segment.* For those approaches that had one or more level segments of 2 nm or more in length, the height of the lowest segment was most commonly 3000 ft. Only one flight before 0600 had a level segment at 2500 ft. After 0600, there were only 2% of approaches with level segments below 3000 ft.

iii) *The maximum height of the radar data for each approach.* This shows that approach data were rarely available right up to 10,000 ft, the maximum height of NTK radar data (because approach tracks usually enter the NTK radar coverage area at a lower height). Before 0600, the average 'cut-off' height is about 7000 ft; and for a significant proportion of flights there is no data above 5000 ft. Note that a low height cut-off usually results from 'straight-in' approaches, where the track distance is least because the track is direct from the edge of the radar coverage area.

DERA January 1995 data

C.10 The data supplied through DERA had a cut-off height typically above 7000 ft, although as with NTK data the proportion with no data above 6000 ft - which includes those flights for which achievement of CDA is 'indeterminate' - is much greater before 0600 than after, because of the higher number of 'straight-in' approaches before 0600. The process used for categorising approaches was similar to that used for the NTK data, although the distributions of the heights of the level segments below 6000 ft and of the radar cut-off heights were not provided. The available results for January 1995 have been included in Table C1.

Table C1: Numbers of level segments and CDA achievement

	0400-0600 Local							0600-0700 Local							0700-0800 Local						
(a) Numbers of level segments																					
HEIGHT OF LEVEL SEGMENT	2000-2500ft	3000-3500ft	4000-5500ft	non-CDA	CDA	Indeterminate*	Total no. of approaches	2000-2500ft	3000-3500ft	4000-5500ft	non-CDA	CDA	Indeterminate*	Total no. of approaches	2000-2500ft	3000-3500ft	4000-5500ft	non-CDA	CDA	Indeterminate*	Total no. of approaches
Jan. 95	na	na	na	204	98	55	357	na	na	na	174	159	6	339	na	na	na	56	77	4	137
June 95	1	15	1	17	8	87	112	10	32	4	46	27	122	195	3	22	0	25	29	217	271
Jan. 96	3	36	31	70	42	15	127	3	38	25	66	60	4	130	1	24	75	100	95	1	196
June 96	1	21	26	48	47	12	107	7	38	70	115	99	5	219	5	32	82	119	168	1	288
(b) Available sample sizes																					
RADAR CUT-OFF HEIGHT	>2500 ft	>3500 ft	>5500 ft	10000 ft			Total no. of approaches	>2500 ft	>3500 ft	>5500 ft	10000 ft			Total no. of approaches	>2500 ft	>3500 ft	>5500 ft	10000 ft			Total no. of approaches
Jan. 95	na	na	na	na			357	na	na	na	na			339	na	na	na	na			137
June 95	111	76	11	0			112	195	121	36	3			195	270	178	31	0			271
Jan. 96	127	124	77	7			127	129	128	119	29			130	196	196	192	37			196
June 96	107	107	76	11			107	218	217	206	37			219	287	287	286	36			288
(c) Percentages of total number of approaches																					
LEVEL SEGMENTS & CDA ACHIEVEMENT	2000-2500ft	3000-3500ft	4000-5500ft	non-CDA	Indeterminate*	CDA achievement (min.)	CDA achievement (max.)	2000-2500ft	3000-3500ft	4000-5500ft	non-CDA	Indeterminate*	CDA achievement (min.)	CDA achievement (max.)	2000-2500ft	3000-3500ft	4000-5500ft	non-CDA	Indeterminate*	CDA achievement (min.)	CDA achievement (max.)
Jan. 95	na	na	na	57%	15%	27%	43%	na	na	na	51%	2%	47%	49%	na	na	na	41%	3%	56%	59%
June 95	1%	13%	1%	15%	78%	7%	85%	5%	16%	2%	24%	63%	14%	76%	1%	8%	0%	9%	80%	11%	91%
Jan. 96	2%	28%	24%	55%	12%	33%	45%	2%	29%	19%	51%	3%	46%	49%	1%	12%	38%	51%	1%	48%	49%
June 96	1%	20%	24%	45%	11%	44%	55%	3%	17%	32%	53%	2%	45%	47%	2%	11%	28%	41%	0%	58%	59%

*The percentage of the total number of flights having no level segments for the extent of the available radar data, but for which, because the radar data did not extend as high as 6000 ft, definitive categorisation as CDA or non-CDA is not possible.

na = not available (from analysis of January 1995 DERA data)

(7 days sample in each month except January 1995, for which there were 12 days of data, and January 1996 after 0600, when only 6 days were available.)

Figure C1: Height Variations (0400-0600)

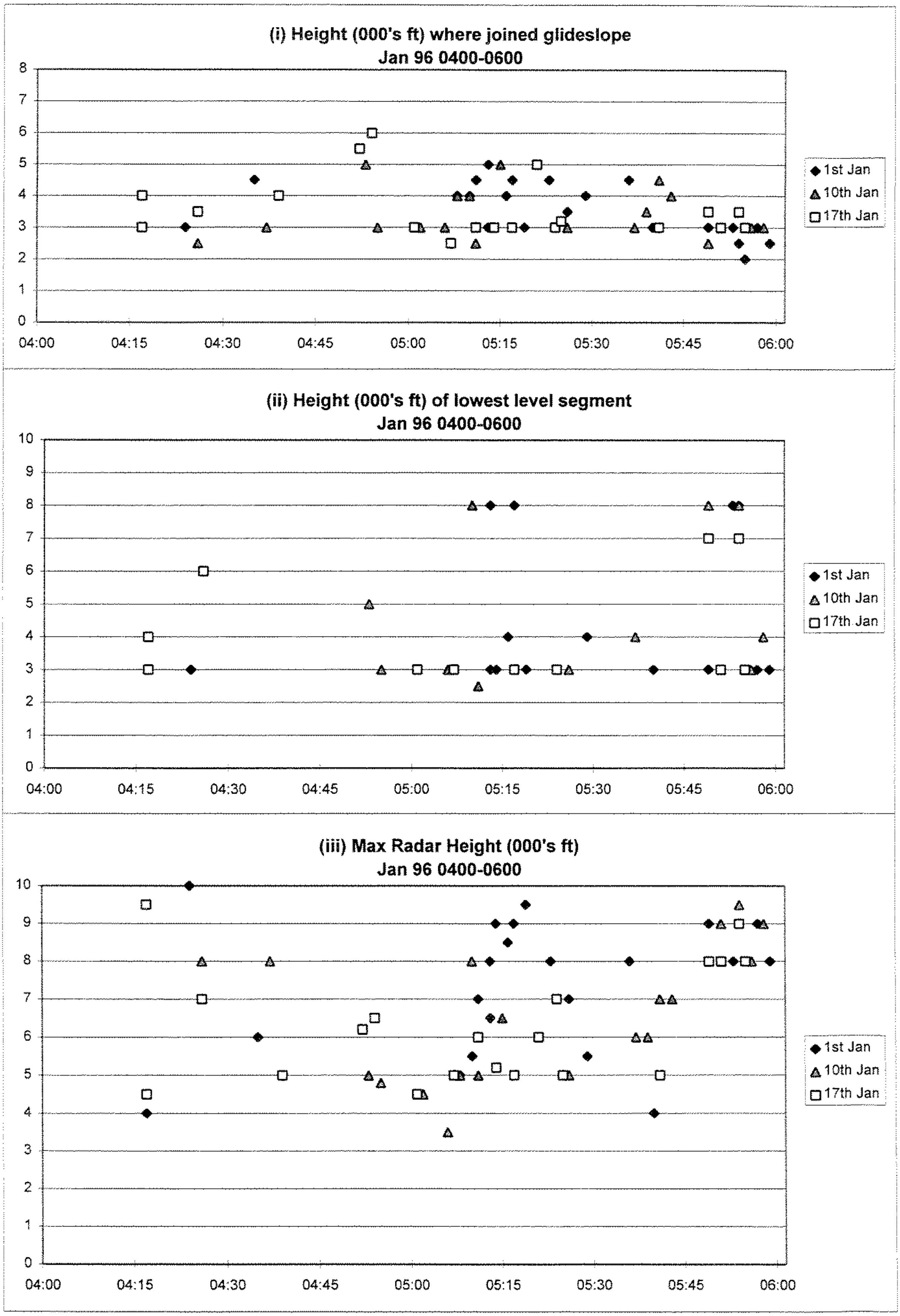
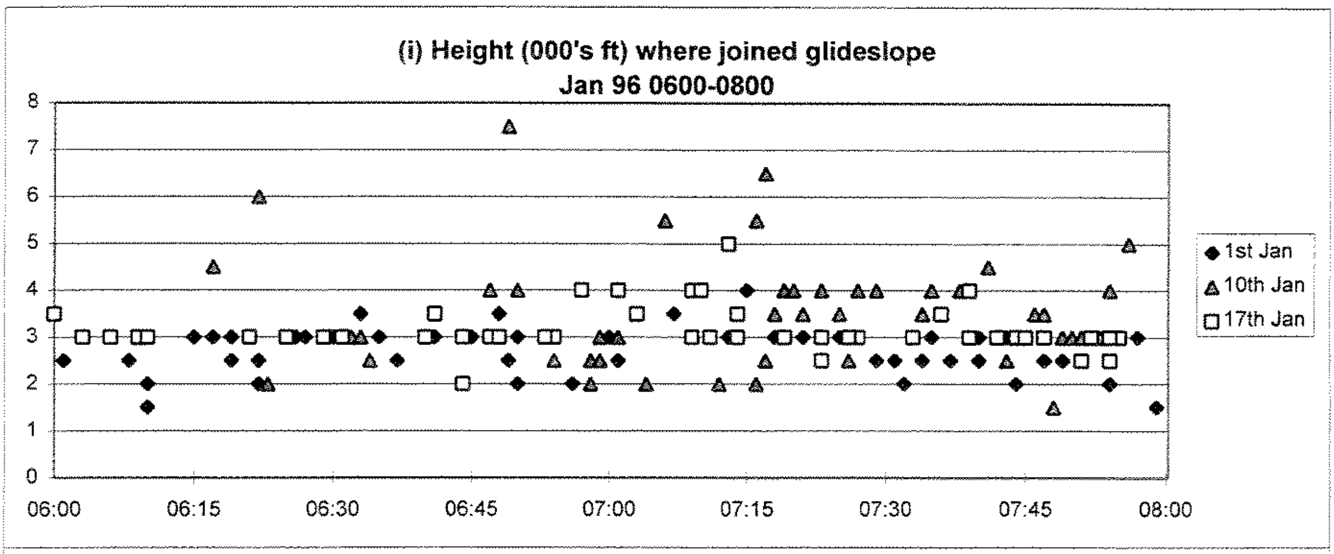
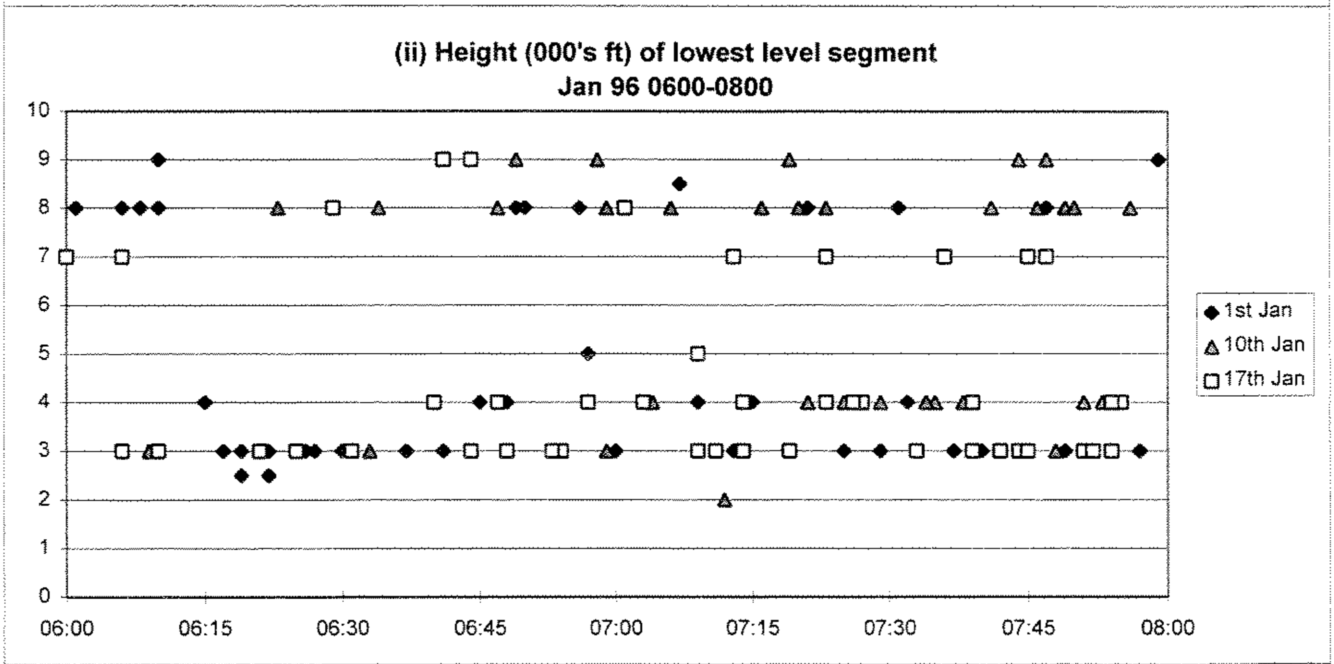
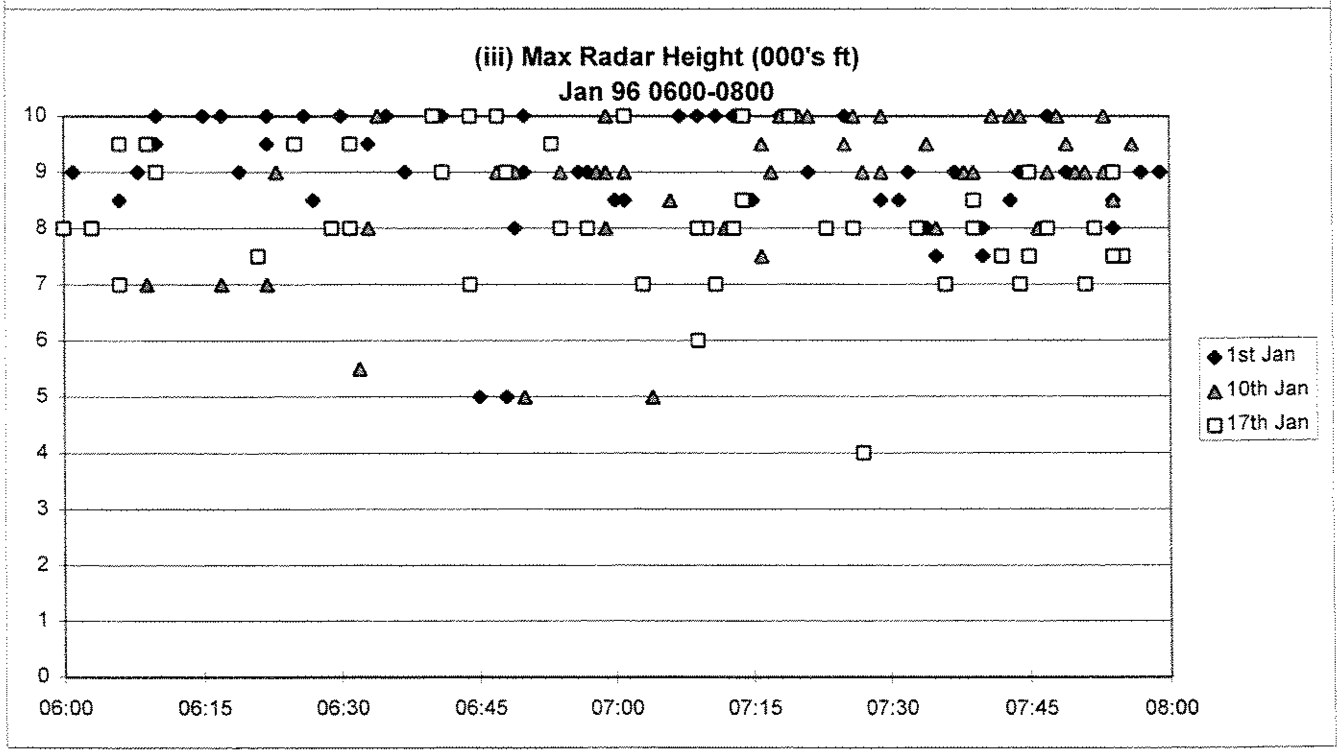


Figure C2: Height Variations (0600-0800)







COMPARISON OF SUMMER AND WINTER RESULTS

D.1 This appendix presents tables of the mean heights of aircraft on approach to give an indication of any differences between summer and winter seasons. The comparison was based on the mean heights of arrivals during the periods 0400 to 0600, 0600 to 0700, and 0700 to 0800. Comparisons (for each runway separately) were made between:

- January 1996 (winter) and June 1996 (summer);
- January 1997 (winter) and July 1997 (summer).

The 0400 to 0600 results are plotted in Figures 10 and 11 of the main text, and this data extends to 16 nm from touchdown.

Table D1: Comparison of mean heights of aircraft approaching runway 27L during period 0400 to 0600

	Jan 1996		June 1996	
Distance from touchdown nm	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2376	56	2344	122
8	2696	69	2649	143
9	2999	117	2942	181
10	3225	240	3156	262
11	3461	375	3364	381
12	3671	478	3549	471
13	3816	550	3730	536
14	3989	629	3933	596
15	4170	698	4136	649
16	4356	769	4329	704

Table D2: Comparison of mean heights of aircraft approaching runway 27L during period 0600 to 0700

Distance from touchdown nm	Jan 1996		June 1996	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2358	43	2333	141
8	2681	77	2624	168
9	2942	131	2901	217
10	3094	242	3115	291
11	3267	350	3346	391
12	3473	428	3567	463

Table D3: Comparison of mean heights of aircraft approaching runway 27L during period 0700 to 0800

Distance from touchdown nm	Jan 1996		June 1996	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2333	45	2329	114
8	2667	49	2636	141
9	2942	64	2937	188
10	3116	194	3184	267
11	3315	311	3445	357
12	3548	345	3701	403

Table D4: Comparison of mean heights of aircraft approaching runway 27R during period 0400 to 0600

Distance from touchdown nm	Jan 1996		June 1996	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2318	36	2337	208
8	2644	61	2660	242
9	2936	118	2982	273
10	3140	236	3237	349
11	3360	386	3478	458
12	3548	475	3698	545
13	3734	517	3916	608
14	3940	548	4150	661
15	4148	596	4398	728
16	4373	669	4639	780

Table D5: Comparison of mean heights of aircraft approaching runway 27R during period 0600 to 0700

Distance from touchdown nm	Jan 1996		June 1996	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2307	96	2325	172
8	2626	122	2644	213
9	2941	197	2944	272
10	3201	310	3187	351
11	3462	441	3463	442
12	3719	506	3730	494

Table D6: Comparison of mean heights of aircraft approaching runway 27R during period 0700 to 0800

Distance from touchdown nm	Jan 1996		June 1996	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2290	86	2312	130
8	2620	122	2636	162
9	2936	165	2943	227
10	3226	220	3190	309
11	3529	301	3463	389
12	3800	366	3725	429

Table D7: Comparison of mean heights of aircraft approaching runway 27L during period 0400 to 0600

Distance from touchdown nm	Jan 1997		July 1997	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2401	83	2373	118
8	2742	93	2704	138
9	3026	146	2992	168
10	3235	274	3224	265
11	3440	408	3457	386
12	3638	520	3661	472
13	3856	602	3841	520
14	4091	651	4040	572
15	4312	688	4241	635
16	4534	709	4436	690

Table D8: Comparison of mean heights of aircraft approaching runway 27L during period 0600 to 0700

Distance from touchdown nm	Jan 1997		July 1997	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2369	63	2367	135
8	2700	78	2686	167
9	2949	112	2966	206
10	3112	229	3199	287
11	3297	369	3433	385
12	3481	463	3653	439

Table D9: Comparison of mean heights of aircraft approaching runway 27L during period 0700 to 0800

Distance from touchdown nm	Jan 1997		July 1997	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2346	72	2367	93
8	2679	90	2686	123
9	2966	127	2984	167
10	3199	231	3259	239
11	3435	338	3537	313
12	3657	391	3786	352

Table D10: Comparison of mean heights of aircraft approaching runway 27R during period 0400 to 0600

Distance from touchdown nm	Jan 1997		July 1997	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2343	39	2325	121
8	2684	55	2655	136
9	2958	91	2955	164
10	3142	213	3179	253
11	3330	343	3401	364
12	3526	439	3608	464
13	3731	506	3784	535
14	3952	571	3967	587
15	4188	640	4165	641
16	4438	693	4350	689

Table D11: Comparison of mean heights of aircraft approaching runway 27R during period 0600 to 0700

Distance from touchdown nm	Jan 1997 Mean Height ft	Jan 1997 Standard Deviation ft	July 1997 Mean Height ft	July 1997 Standard Deviation ft
7	2325	84	2317	117
8	2657	124	2641	134
9	2925	184	2919	173
10	3103	289	3123	269
11	3286	407	3334	383
12	3479	493	3560	462

Table D12: Comparison of mean heights of aircraft approaching runway 27R during period 0700 to 0800

Distance from touchdown nm	Jan 1997 Mean Height ft	Jan 1997 Standard Deviation ft	July 1997 Mean Height ft	July 1997 Standard Deviation ft
7	2339	85	2322	98
8	2687	93	2650	113
9	2996	122	2947	150
10	3273	204	3217	232
11	3556	285	3500	317
12	3821	323	3762	358

DAY-NIGHT EFFECTS

E.1 This appendix presents tables of the mean heights of aircraft on approach to compare between the nominal 'daytime' (0600 to 2300) and 'night-time' (2300 to 0600) periods. The analysis has been conducted (separately for each runway) for January 1996, January 1997 and July 1997.

Table E1: Comparison of mean heights of aircraft approaching during daytime and night-time on runway 27L, January 1996

Distance from touchdown nm	0600-2300 (Day)		2300-0600 (Night)	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2347	146	2367	93
8	2665	186	2687	102
9	2955	237	2992	133
10	3186	309	3218	244
11	3433	395	3451	378
12	3671	450	3642	479

Table E2: Comparison of mean heights of aircraft approaching during daytime and night-time on runway 27R, January 1996

Distance from touchdown nm	0600-2300 (Day)		2300-0600 (Night)	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2317	124	2321	75
8	2642	162	2653	100
9	2952	215	2933	146
10	3208	294	3106	251
11	3484	383	3293	386
12	3746	442	3457	476

Table E3: Comparison of mean heights of aircraft approaching during daytime and night-time on runway 27L, January 1997

Distance from touchdown nm	0600-2300 (Day)		2300-0600 (Night)	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2372	91	2396	83
8	2698	126	2735	98
9	2982	178	3015	153
10	3232	270	3218	278
11	3490	363	3415	416
12	3735	414	3614	530

Table E4: Comparison of mean heights of aircraft approaching during daytime and night-time on runway 27R, January 1997

Distance from touchdown nm	0600-2300 (Day)		2300-0600 (Night)	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2356	122	2345	71
8	2698	149	2683	69
9	3003	194	2952	99
10	3268	284	3132	218
11	3540	376	3313	351
12	3801	430	3494	450

Table E5: Comparison of mean heights of aircraft approaching during daytime and night-time on runway 27L, July 1997

Distance from touchdown nm	0600-2300 (Day)		2300-0600 (Night)	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2367	134	2385	132
8	2694	169	2714	148
9	2997	215	2992	175
10	3277	290	3212	272
11	3562	365	3431	395
12	3834	409	3625	487

Table E6: Comparison of mean heights of aircraft approaching during daytime and night-time on runway 27R, July 1997

Distance from touchdown nm	0600-2300 (Day)		2300-0600 (Night)	
	Mean Height ft	Standard Deviation ft	Mean Height ft	Standard Deviation ft
7	2339	147	2337	169
8	2671	180	2671	186
9	2982	227	2965	200
10	3261	303	3183	276
11	3546	385	3401	390
12	3827	438	3605	499

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