Helicopter Noise Propagation Studies for Air Installation Compatible Use Zoning.

Philip Dickinson
Bickerdike,Allen,Partners.

With the helicopter, noise undoubtedly is the environmental pollutant which causes the greatest concern from the point of view of the general public and social acceptability (1). The noise radiated from a helicopter is very complex, composed of sound produced by several different sources, each of which generates acoustic energy by more than one mechanism. These include noise from engines, tail rotor and 'Blade Slap'. The former is adequately described in terms of dBA. Certainly the other two are not.

Externally, the noise is controlled largely by the noise component from the rotors, although high frequency compressor 'whine' is subjectively significant at relatively short distances from the helicopter. From subjective considerations, the two most important sources are the blade-slap and tail rotor noise. Blade-slap is a loud impact noise which occurs at the blade passing frequency - typically 15 to 20 Hz - and when it occurs it can cause extreme annoyance. It is usually associated with tandem rotor helicopters and those helicopters with a two blade single rotor, although it can be generated to some extent on practically all helicopters (1). Opinions differ as to the exact cause, but the most likely hypothesis (2) is that it is caused by a blade/vortex interaction mechanism.

The methodology for predicting helicopter noise in the far field is similarly very complex also; the initial process being one of pseudo-convection with the directivity of the advancing blade, resulting in many cases in an epicentric curling of vortices predominantly along one side of the flight track. In the mid-field, often these ride over on-coming low level wind; producing increased noise levels upwind, i.e., the converse of noise from conventional take-off and land aircraft, with the exception sometimes of some turbo-propeller varieties - as discovered by researchers during the design considerations for the Schiphol and

Saltholm Airports in the Netherlands (3). This lasts until the individual vortices expend all their energy as sound and heat, at which point the pulse propagates in a more conventional manner. But this too is complicated by the nature of the pulse and the directivity it has gained by the air movement. Hence the pulse itself - basically one of a narrow band signal in the 250 Hz range, on a carrier wave of about 20 Hz - is not exactly conventional and the polar spread, air attenuation and ground absorption properties differ considerably from conventional aircraft spectra.

One of the greatest problems is in determining the lateral propagation, i.e., the noise propagation at right angles to the helicopter track. Noise levels in the mid-field - up to 2000 feet or so - do not continuously decrease with distance. Nor is the noise from a single event symmetrical about the flight track, except for a few helicopters at fairly high altitude. The shape of the noise footprint also differs from one helicopter variant to another of the same model. Such considerations make the computation process very difficult and time consuming.

The effect of the topography and general climate of the area under consideration is critical and, in all helicopter noise prediction work, raw base data, within the particular geographical confines of the area under consideration, must be obtained. The noise exposure contours for a certain group of helicopters in, say, Nova Scotia will be quite different from the noise exposure contours for the same helicopters doing exactly the same operations in, say, Alberta or even another part of Nova Scotia!

Subjective Considerations

Subjectively, blade-slap is perhaps the most important noise source on helicopters in certain flight regions. It is fairly clear that conventional use of PNL or dBA rating methods do not adequately account for the subjective effects or intrusiveness of helicopter noise when it is dominated by blade-slap. This has been shown clearly by a number of

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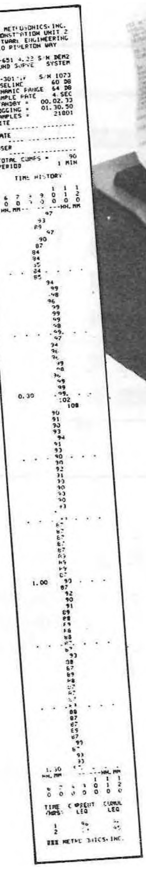

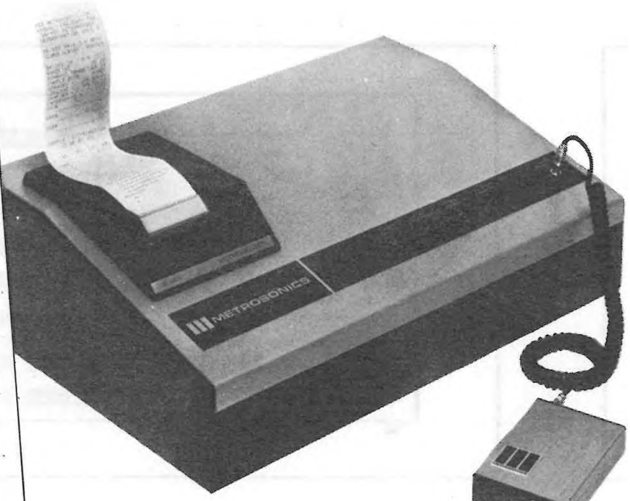

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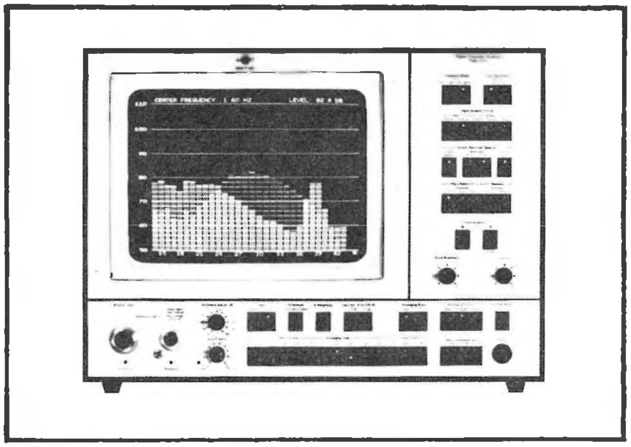

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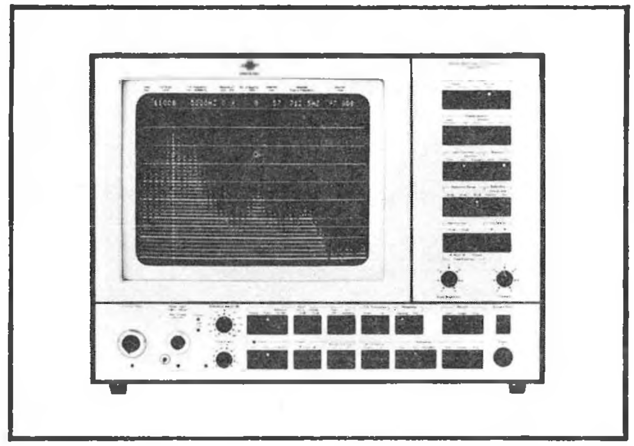

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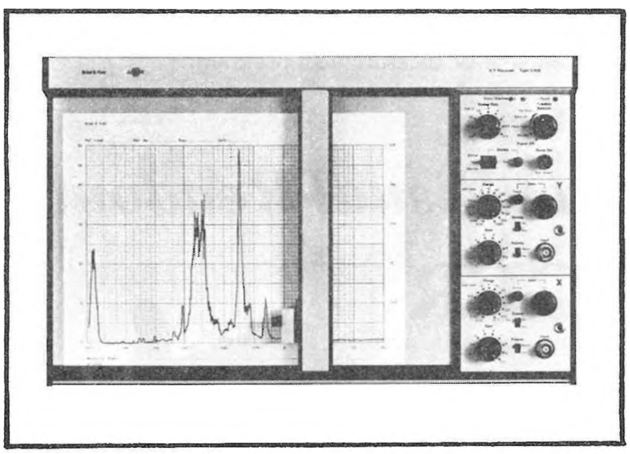

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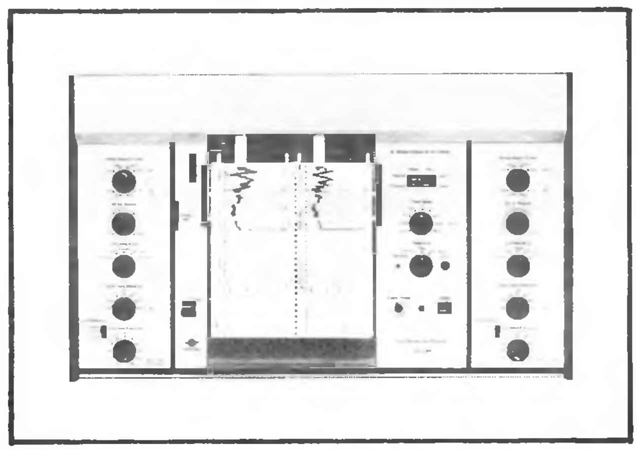

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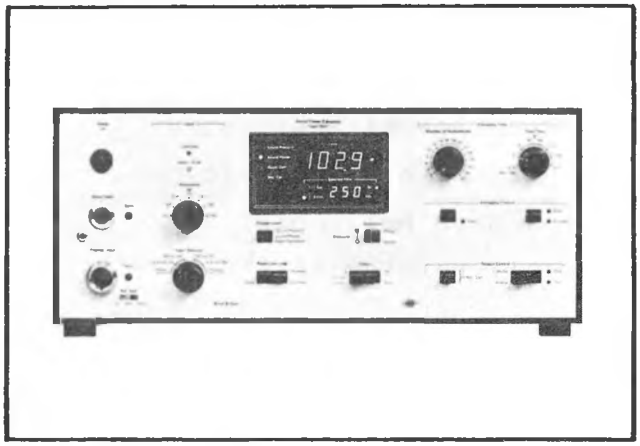

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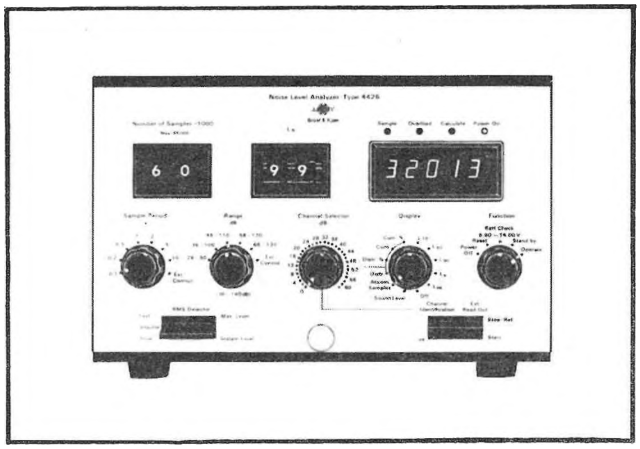

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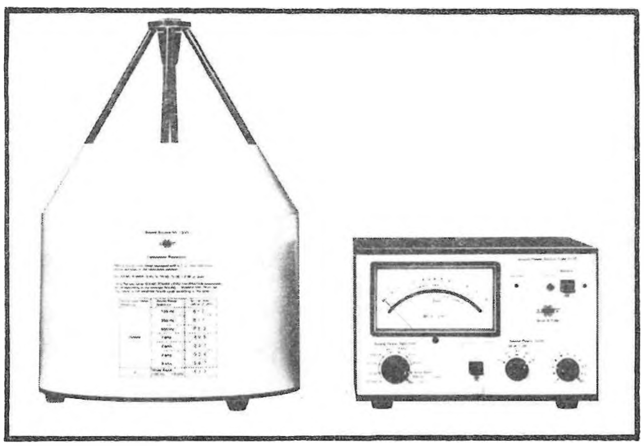

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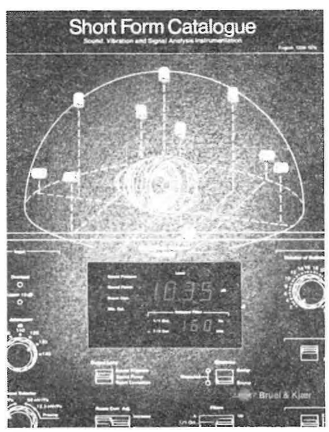

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investigations (4, 5). However, few studies have been carried out to develop a suitable method for differentiating between slapping and non-slapping helicopters or to determine the subjective penalty.

The most comprehensive study has been by John Leverton - considered the world authority on helicopter noise - and his acoustics group at Westland Helicopters (6). From a comprehensive series of subjective tests of noise from slapping and non-slapping helicopters, they found that a simple add-on type of correction for impulsive helicopter noise was possible, the correction factor being directly related to the Crest Factor of the noise in the 250 Hz octave band i.e., (Peak Linear - Slow Response) in the frequency range from about 200 to 400 Hz.

Munch and King of Sikorsky Helicopters (7) undertook a study for N.A.S.A. on the Community Acceptance of Helicopters and came to a very similar conclusion. Figure 1 shows the findings in graph form (8). Considering the two studies had no inter-relationship and were separated by some thousands of miles and subjects were of different types, the results are remarkably alike. When suitable instrumentation is not available, the F.A.A. has suggested (9) a +7 dB correction to meter readings when blade-slap is present, i.e., as a rough guide, impulsive helicopter noise is subjectively the same as that from a jet aircraft that is 7 dB noisier.

The helicopters we find most common in military circles are derivatives of the Bell model 209 (AH1), the Bell model 204 (UH1), the Boeing Vertol model 107 (CH46) and the Sikorsky S61 (CH53). On the occasions that blade-slap occurs, the envelope of propagation is in the forward direction only. The blade-slap for small single rotor helicopters, such as the AH1J and the UH1N, we believe follows that of a cone of half angle 10° centred about the forward axis of flight. Measurements on the twin rotor CH46 lead us to believe that the blade-slap, although still in a forward direction only, is not symmetrical but follows that of a skewed cone where on the left hand side of the craft the half angle is about 10° but on the right hand side the half angle approaches 44°, with a sharp transition on the flight track, if there is no wind. This angle is very difficult to measure and we are by no means certain that the figures we have used are precise. But, with all the environmental factors present, a few degrees error is not significant.

As the propagation is in the forward direction only, the subjective correction for blade-slap can be applied only on the rise of the time-history (as shown in Figure 2). The net effect is more an increase in duration and not a straight addition to the peak level as in other attempts to qualify the subjective effects. The correction is applied at half-second intervals. To bring this computation within bounds, this was applied to the interval between the initial 10 dB down point and the peak level of the time history, and the curve extrapolated back to the point where the A weighted sound pressure level + the subjective correction was 10 dB below the peak level.

We believe this Westland impulsive correction to be the most appropriate extant for this type of noise. It is understood that this correction procedure is now under deliberation by the International Standards Organisation for a standard on helicopter noise - to be issued shortly.

It must be stressed that by using a subjective correction of any sort to a noise descriptor, one changes the nature of that descriptor and should therefore change the name as well. Internationally, the use of a noise equivalent level is gaining acceptance. In the United States, a night weighted equivalent level - the Day/Night Level L_{DN} - is in general use. For our studies of helicopter noise impact in the United States, based on this unit with a subjective correction, rather than to completely change the name of the noise descriptor we have, to save confusion, used the term Impact Weighted Day/Night Level IL_{DN}.

In an Air Installation Compatible Use Zoning study (AICUZ) usually the aircraft noise assessment employs only a few spot checks of noise level; the contours being predicted solely by the use of a computer program.

This incorporates a comprehensive file of source-noise reference data on the usual aircraft types - by category only - that are encountered at military airfields. Rarely are more than 9 categories used, often considerably less. Also, this reference data is exclusively for fixed wing aircraft, there being really no comparable noise data for rotorcraft. Indeed few programs can include rotorcraft except by assuming conventional propagation applies. With only one or, maybe, two exceptions, the programs cannot accomplish predictions in, and are not intended for, cases where helicopters form a significant part of the total traffic.

Bickerdike,Allen was, a short while ago, commissioned by the U.S. Navy to produce noise contours for bases where helicopters predominate. Of course, in order to get a true idea of the base data, a four season measurement study should be undertaken. But, all programmes - particularly for the Military - have time limitations and so measurements have to be confined to a short period only. Inevitably this has, in the past, become April or May, when it has been supposed that reasonably average sort of conditions for the year occur. One such study was for the Marine Corps Air Station (Helicopter) at New River North Carolina, and its outlying fields of Oak Grove and Camp Davis.

The Marine Corps Air Station is located in the designated West Base Planning Zone in the northwest area of Camp Lejeune. The air station occupies about 4700 acres to the south and east of the city of Jacksonville, North Carolina, with two outlying fields in the nearby "Boondocks" - a word actually originating in Camp Lejeune from marine operations in the Philippines.

For data acquisition at various locations, our main measuring systems consisted of a pair of Genrad 1933 Precision Sound Level Meters each feeding one channel of a Uher CR134 stereo recorder, and, in the dc mode, an Esterline Angus Miniservorecorder. One of the sound level meters was in the slow mode recording in 'A' weighted deciBels, the other in the impact mode was specially converted to accept a 50 micro-second rise time held to a 50 milli-second decay time operating in the 250 Hz octave band. The Uher recorder was also specially prepared so that with Maxell UD tape it was capable of capturing a 70 micro-second rise time in the frequency range 18 to 15,000 Hz. This type of system enabled an immediate determination to be made of the crest factor for each event at that location, related to dBA slow response, as well as providing recorded material for later analysis. Hindsight, however, showed that if a system is working the benefits of immediate 'viewing' are marginal - except of course to show that the system is working. A system comprising a Castle CS 192B Precision Sound Level Meter feeding the Uher recorder was found much more convenient and probably more accurate. Calibration was carefully maintained, of course, and a continual check of compatibility between the several systems used made by recording some events at each location with a Bruel and Kjaer 2209 and Nagra 4S recorder, and comparing the results in the slow mode - the Nagra and its Ampex tape had not been specially prepared to accept the 70 micro-second rise time.

In addition to noise recording, meteorological conditions at each location were measured - wind, temperature, humidity etc., - and this data used in conjunction with the macro data from the local meteorological station. Polaroid photography was used to determine the altitude of each helicopter, and radio contact maintained for details of speed and power setting. Also for future use, rough estimates of the ground impedance were made by the 'Free Field Method' (11).

In the laboratory, real time analysis was not possible, and the data analysis was accomplished using Bruel and Kjaer 2120, 2113 and 2209 + 1616 frequency analysing systems recording on B & K type 2305 level recorders. An oscillograph was used to check the crest factor determinations.

The primary aim of the measurement programme was to accumulate sufficient noise data on each of the various types of aircraft under each operational mode sequence, to allow typical noise event levels to be predicted within a reasonable confidence level at any position for any operational activity. For maximum accuracy and sensitivity the majority of recordings were made in relatively close proximity to the source aircraft, and this meant most were in the air base confines. A second purpose was to measure actual events encountered in adjacent areas and on cross-country routes to act as corroborative tests of the levels predicted for such areas.

Since it was quite impracticable to obtain data on all the types of aircraft in use at these bases, the 4 main types comprising 84% of all helicopter movements were selected. Lateral and longitudinal traverses were made of the initial part of the flight envelope, as well as a complete traverse of the base itself to obtain the effects of engine testing and maintenance operations and to delimit the effects of the various barrier buildings and obstacles on base. A large number of measurements were made in the nearby city, but at no time was the helicopter noise in the same order as that from the surface transportation.

Observations.

The directionality of the impulsive blade-slap and the overall strange propagation was very noticeable. In particular, this region has many small drainage ditches and inevitably the noise recorded on the far side would be greater than that on the near side. We can give no explanation for this. Also, on base for low altitudes of rotorcraft (50 feet or so) noise levels at 800 feet laterally were often well in excess of those at 200 feet and 400 feet. This can perhaps be explained by the directionality of the pulse and the effects of fuselage shielding. With a helicopter bearing towards, but a few degrees off, the wind direction the main noise event may be completely to one side of the track. However, with no wind, by taking into account the directionality of pulse and the shielding, it has been found that a reasonable prediction can be made. A derivative of the British Noise Model has been adapted to utilise this data and performs well provided the wind can be assumed zero. Just a little wind and things are not so good at all.

The contours produced for New River and shown in Figures 3 and 4 being the true L_{DN} and the Impact corrected L_{DN} respectively. Where barriers occurred on the base, much weight was given to interpolation of measured values rather than predictions for no satisfactory theory for the passage of such a noise over a barrier has yet been devised (we believe).

Figure 5 shows the contour for Camp Davis. It is interesting to note that at one point this contour is actually outside the track. This is due to the large majority of flights by the CH46, which in a bank produces an extremely lop-sided impact noise footprint.

A selection of some of the data recorded is given in tables 1-1 to 1-4.

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This paper was presented at the Annual Meeting of the CAA, Halifax, Nova Scotia, November 1978.

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BLADE-SLAP IMPULSE CORRECTION

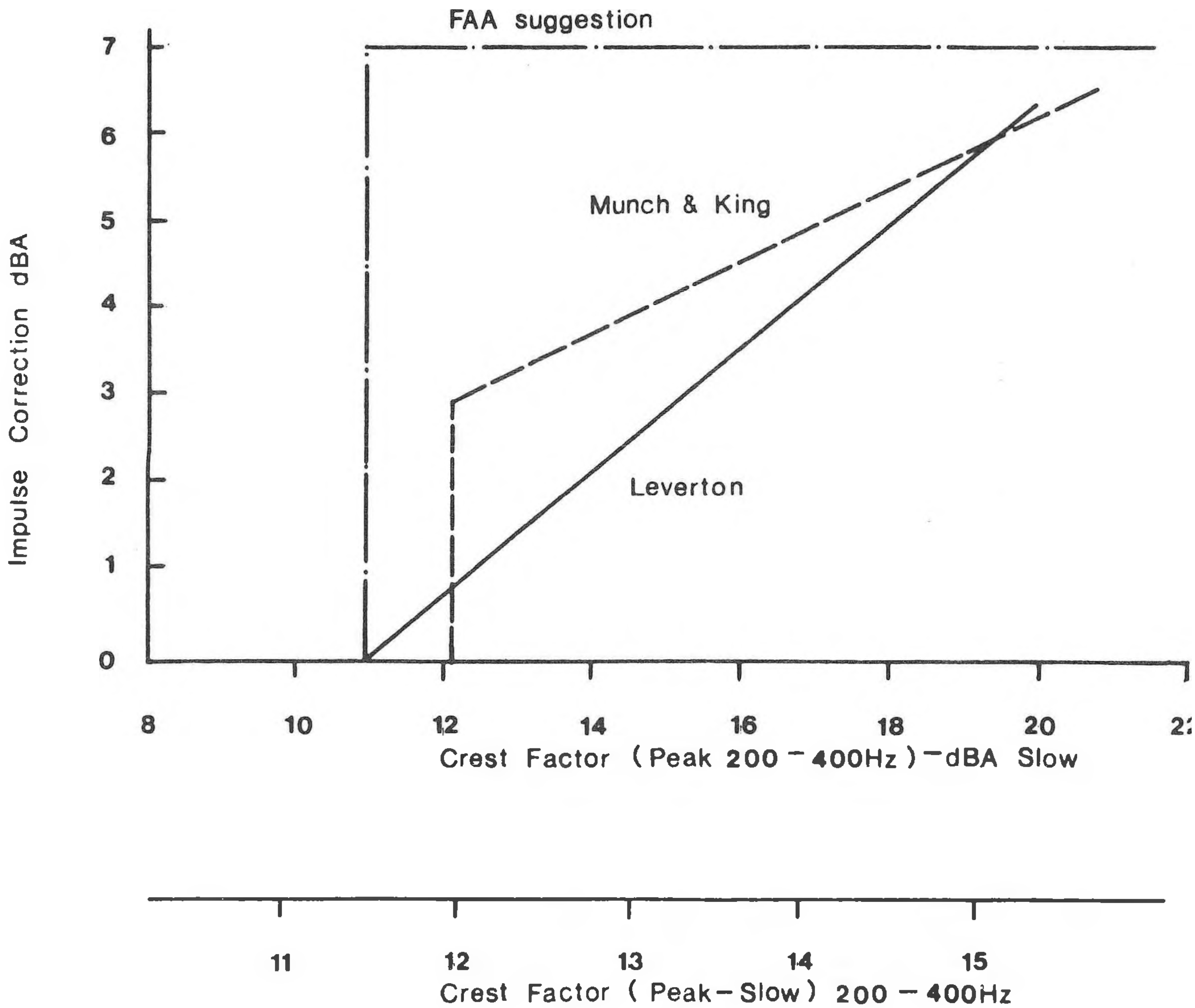


FIGURE 1

EXAMPLE OF IMPACT CORRECTED dBA TIME HISTORY FOR A HELICOPTER OVERFLIGHT

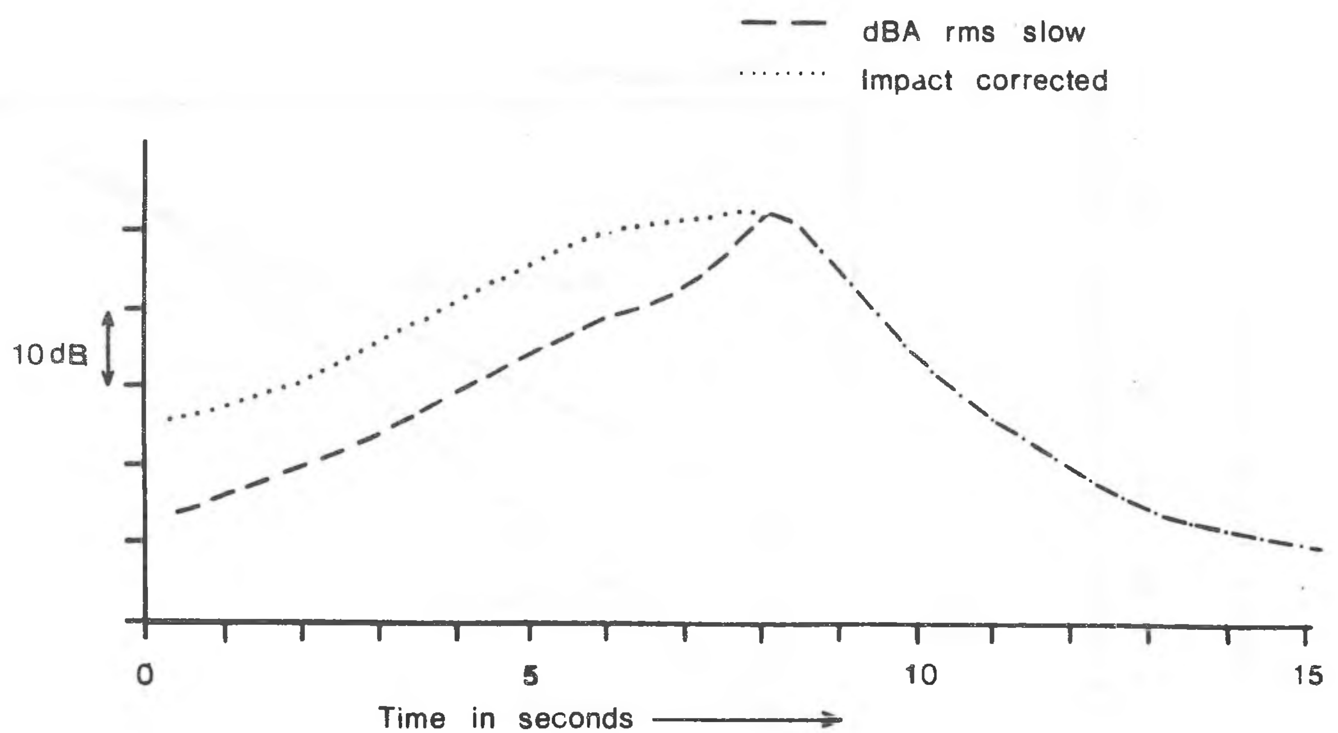
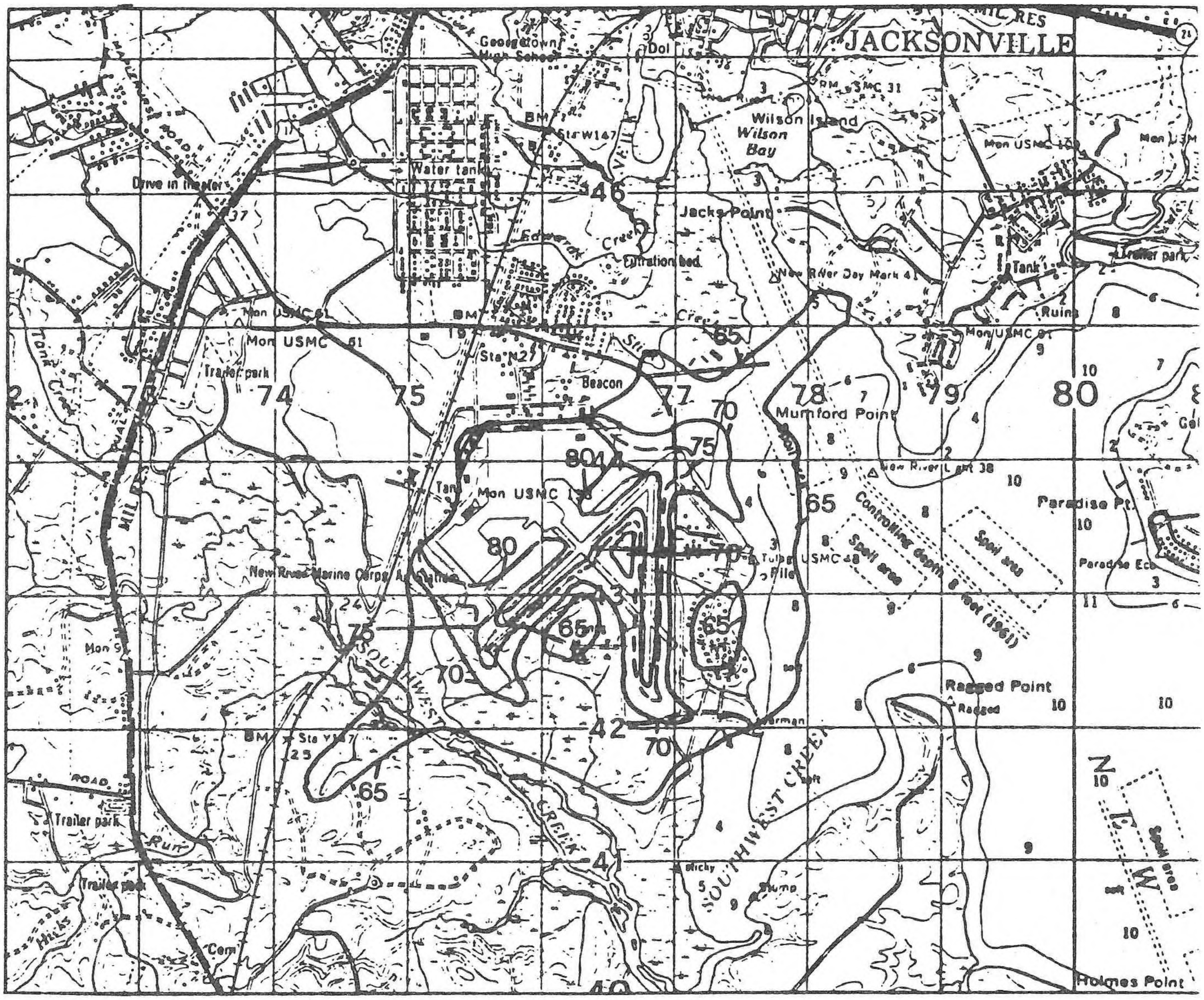


FIGURE 2

New River Marine Corps Air Station.

True L_{DN} 1977

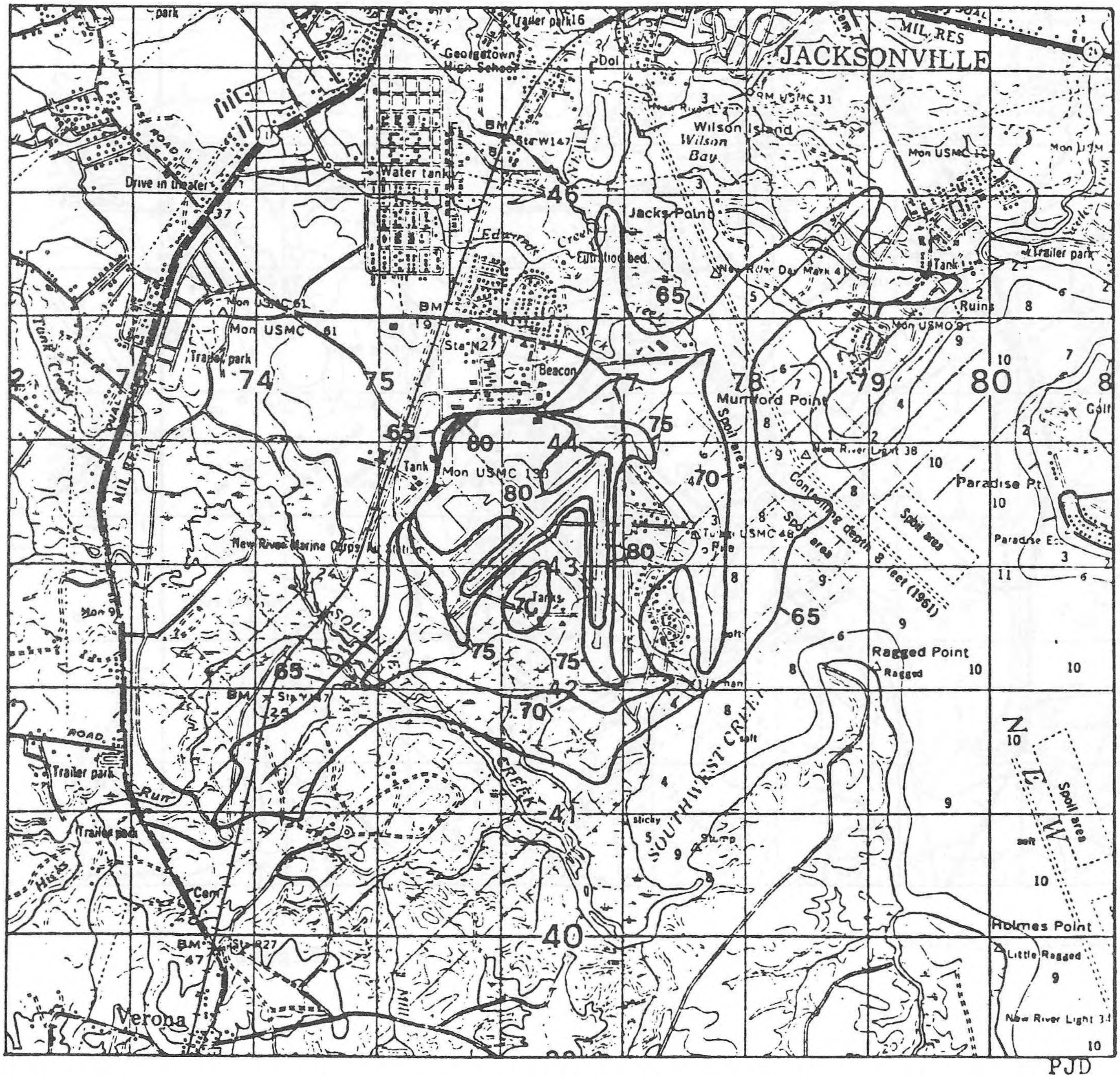


Scale 1:50,000

Figure 3

New River Marine Corps Air Station (Helicopter)

Impact weighted L_{DN} at 4'6"   1977

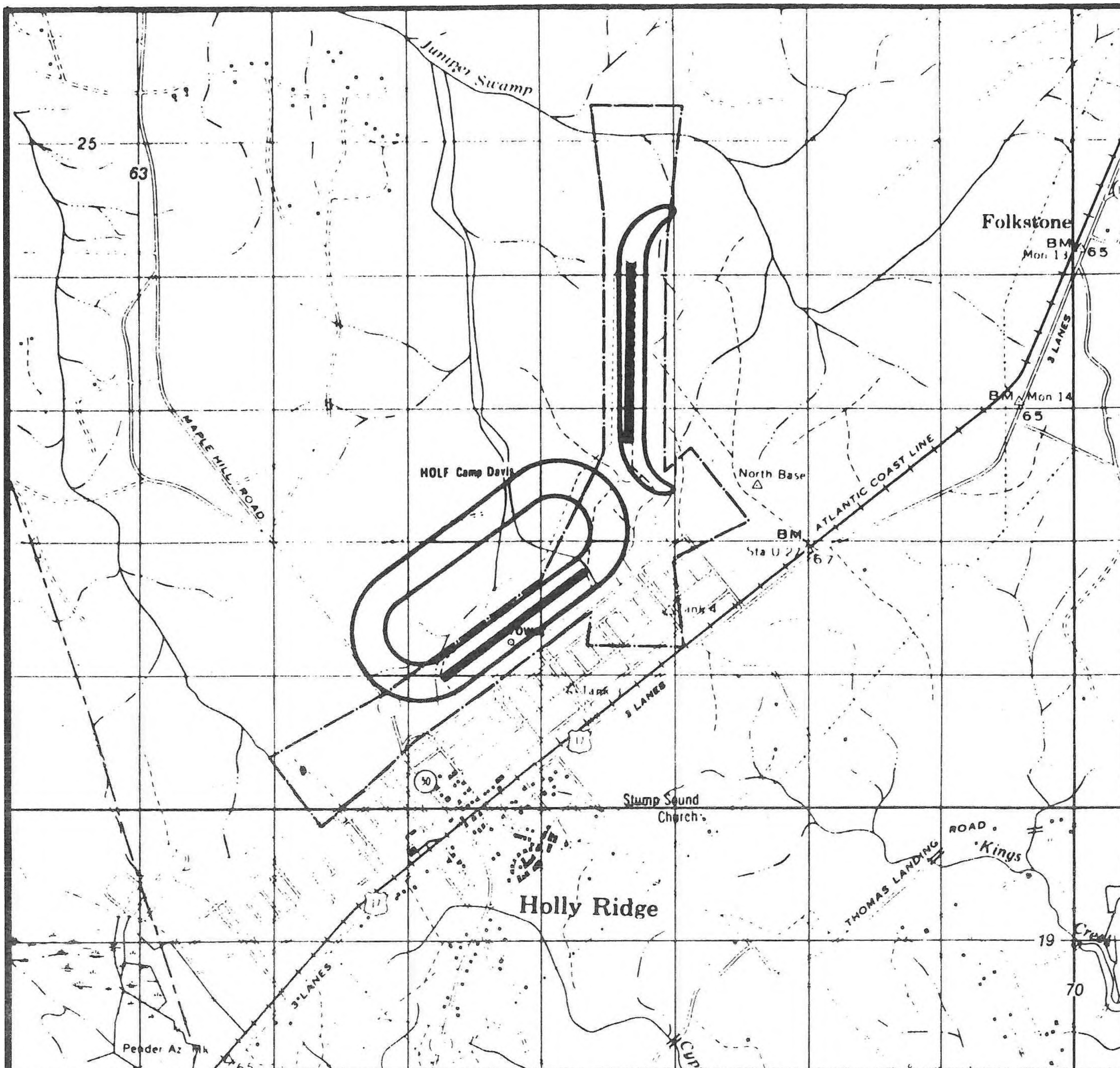


Scale 1:50 000

0 1 2 3 4 5 6 7 8 9 10

thousands of feet

Figure 4



Noise Contour Map

Impact Weighted L_{DN} 1977

Zone 2 (65-75 L_{DN})

Station Boundary

0 2,000 4,000 FEET

Figure 5

Exhibit 9B

HOLF CAMP DAVIS, NC

Table 1-1 Representative Single Event Noise Levels. dBA

Maneuver: Level Flight

Temperature °F		R.H.	Wind	Ground Imped. estim. 3 - 9i Roughness length estim. .005m Skies: Clear
ground 77	500ft 66	55%	Not signif	

Aircraft	Hor.dist	Slant ht	Track	Bearing	Speed	Crest	SEL	SEL_{Imp}
CH46	0	500	230	-	240	20+	94.6	98.8
	800	950	230	320	ft/s	20+	90.9	95.4
	1600	1690	230	320	240	20+	85.4	90.5
	0	1000	230	-	240	20+	90.6	95.2
	800	1300	230	320	240	20+	89.2	94.2
	1600	1900	230	320	240	20+	86.9	92.2
CH53	400	640	230	140	250	11-	92.3	92.3
	800	950	230	320	250	11-	89.6	89.6
	1600	1700	230	320	250	11-	83.4	83.4
	400	1080	230	140	250	11-	88.7	88.7
	1600	1900	230	320	250	11-	84.8	84.8
UH1N	0	500	230	-	180	20+	95.6	100.4
	800	940	230	320	180	20+	92.7	97.8
	1600	1670	230	320	180	20+	87.8	93.1
AH1J	400	570	230	140	300	20+	93.0	97.7
	800	895	230	140	300	20+	90.3	95.6
	800	940	230	320	300	20+	89.9	95.2
	3200	3240	230	320	300	20+	78.1	83.5
OV10	0	500	180	-	290		92.0	92.0
	800	950	180	090	290		88.5	88.5
	1600	1680	180	090	290		82.3	82.3
	0	1000	180	090	290		87.8	87.8
	800	1280	180	090	290		85.6	85.6
	1600	1890	180	090	290		81.8	81.8
	feet	feet				At 10dB down		

Table 1-2 Representative Single Event Noise Levels. dBA.

Maneuver: Level Flight

Temperature °F		R.H.	Wind	Ground Imped.estim. 4 - 11i
ground	500ft			Roughness length estim. .00005m
80	66	58%	Not signif	Skies: Clear

Aircraft	Hor.dist	Slant ht	Track	Bearing	Speed	Crest	SEL	SEL_{Imp}
CH46	0	490	270	-	240	20+	97.4	101.5
	400	630	270	360	ft/s	20+	95.8	100.1
	800	930	270	360	240	20+	93.6	98.1
CH53	0	500	270	-	250	11-	96.5	96.5
	400	640	270	360	250	11-	94.8	94.8
	800	940	270	360	250	11-	92.1	92.1
AH1J	0	490	270	-	300	20+	96.2	100.3
	400	650	270	360	300	20+	94.7	99.5
	800	950	270	360	300	20+	92.3	97.7
CH46	400	640	090	360	240	20+	95.3	99.7
	800	940	090	360	240	20+	93.0	97.6
	400	1100	090	360	240	20+	92.7	97.5
	800	1300	090	360	240	20+	91.8	96.9
CH53	400	1100	090	360	250	11-	91.5	91.5
	800	1300	090	360	250	11-	90.2	90.2

Hor.dist: feet

Slant ht: feet

Crest: At 10dB down

Table 1-3 Representative Single Event Noise Levels. dBA.

Maneuver: Climbing turn

Temperature °F		R.H.	Wind	Ground Imped.estim. 3 - 9i
ground	500ft	55%		Roughness length estim. .005m
77	66	55%	Not signif	Skies: Clear

Aircraft	Hor.dist	Slant ht	Track	Bearing	Speed	Crest	SEL	SEL_{Imp}
CH46	0	300	left	-		20+	97.6	102.6
	400	510	turn	inside		20+	95.6	100.5
	800	850		turn		20+	91.4	96.4
	400	490		outside		20+	94.6	99.5
	800	850		turn		20+	90.0	95.2
	800	900		inside		20+	92.0	97.3
	800	900		outside		20+	90.8	95.9
	800	850	right	inside		20+	93.0	98.7
	800	850	turn	outside		20+	90.4	95.3
CH53	0	300	left	-		11-	97.6	97.6
	400	500	turn	inside		11-	95.0	95.0
	800	850		"		11-	90.2	90.2
	400	500		outside		11-	94.0	94.0
	800	850		"		11-	88.8	88.8
	800	900		inside		11-	90.8	90.8
	800	900		outside		11-	89.7	89.7
UH1N	0	290	left	-		11-	97.9	97.9
	400	500	turn	inside		11-	96.2	96.2
	800	850		"		11-	93.0	93.0
	400	500		outside		11-	95.6	95.6
	800	850		"	Not assessed	11-	91.7	91.7
	800	900		inside		11-	93.8	93.8
	800	900		outside		11-	92.6	92.6
AH1J	0	300	left	-		11-	96.8	96.8
	400	490	turn	inside		11-	94.7	94.7
	800	850		"		11-	90.4	90.4
	400	510		outside		11-	93.7	93.7
	800	850		"		11-	89.4	89.4
	800	900		inside		11-	91.1	91.1
	800	900		outside		11-	90.0	90.0
	800	850	right	inside		11-	89.9	89.9
	800	850	turn	outside		11-	89.1	89.1
	feet	feet				At 10dB down		

Table 1-4 Representative Single Event Noise Levels. dBA

Maneuver: Approach

Temperature °F		R.H.	Wind		Ground Imped.estim. 3 - 91			
ground 77	500ft 66	55%	Not signif		Roughness length estim. .005m Skies: Clear			
Aircraft	Hor.dist	Slant ht	Track	Bearing	Speed	Crest	SEL	SEL_{Imp}
CH46	0	400	050	-		20+	95.9	101.1
	400	570	050	140		20+	93.9	99.6
	1600	1650	050	140		20+	85.0	91.0
	400	570	050	320		20+	93.8	99.7
	1600	1650	050	320		20+	85.1	91.4
	0	200	050	-		20+	100.0	105.0
	400	450	050	140		20+	95.3	100.8
	800	825	050	140		20+	90.0	95.8
	400	450	050	320		20+	95.1	100.8
	800	825	050	320		20+	90.0	96.0
CH53	0	400	050	-		11-	95.6	95.6
	400	570	050	140		11-	93.2	93.2
	1600	1650	050	320		11-	83.1	83.1
	0	200	050	140		11-	100.4	100.4
	400	450	050	140		11-	94.8	94.8
	1600	1610	050	320		11-	82.2	82.2
UH1N	0	400	050	-	Not assessed	13	96.1	97.6
	400	560	050	140		14	95.0	96.8
	800	890	050	320		14	92.9	94.9
	0	200	050	-		16	99.7	103.3
	400	450	050	140		17	96.1	100.0
	800	820	050	320		17	91.6	95.8
AH1J	0	400	050	-		13	94.4	96.2
	400	570	050	140		14	93.0	95.0
	800	900	050	320		15	90.3	92.5
	0	200	050	-		16	99.2	103.0
	400	450	050	140		18	94.4	98.5
	800	820	050	320		18	89.0	93.3
OV10	0	400	180	-			92.0	92.0
	800	890	180	270			86.3	86.3
	0	200	180	-			97.8	97.8
	800	820	180	270			87.0	87.0
	↑ feet	↑ feet				↑ At 10dB down		