Chapter 2

Noise exposure

2.1 Past noise exposure

During the Vietnam War were there conducted a few measurements at the residential areas in the vicinity of Kadena Air Base in 1968 and 1972. In 1977, the DFAA (Defense Facilities Administration Agency) of Japan made noise measurement of an extensive scale around Kadena and Futenma airfields. Some of the local authorities installed monitoring stations around the bases and have filed up measurements for about 20 years. These data are available to grasp the past state of noise exposure and its chronological change around the bases.

2.1.1 Measurement at Kadena Fire Station in 1968

The local authority of Kadena Village undertook noise measurement at Kadena Fire Station which was located very near the fence of the northwest part of Kadena Air Base where engine tuning site was and still is positioned. In those days jet engine was tuned and tested without any noise insulation facility or barrier at a distance of about 150m or so from the local residences. The measurement record is precious because sound level meter was not as popular as today in those days when even in the main land of Japan only limited local authorities used the device.

The measurement was carried out for one month in the building of Kadena Fire Station, the position of which is shown in the map of Figure 2.1, with the windows open, and the time of noise event in a day, the maximum sound level in single noise event and the duration of noise exceeding the sound level of 70 dB were recorded during the course of the measurement. Here in the present report the data obtained by the continuous measurement from 12th to 17th February 1968, are used to estimate WECPNL (Weighted Equivalent Continuous Perceived Noise Level), the index of noise exposure for aircraft

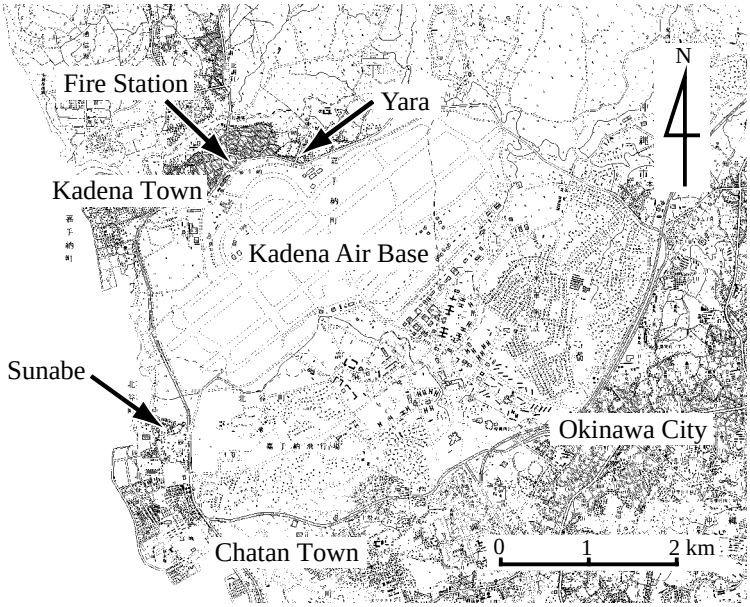

Figure 2.1 Measuring points of the noise data during Vietnam War.

noise.

WECPNL adopted by the Environment Agency of Japan is modified for simplification (Environment Agency; 1973) and is calculated by the following equation:

$$WECPNL = L_{\mathrm{A}} + 10 \log N - 27,$$

where L_{A} is the average maximum sound level of noise event on power basis in one day. The number of noise events is weighted for the time of flight in the day and the total number of noise events, N, is expressed by the following equation.

$$N = 10N_1 + N_2 + 3N_3 + 10N_4,$$

where N_1 is the number of flights from 0:00 to 7:00, N_2 is that from 7:00 to 19:00, N_3 is that from 19:00 to 22:00 and N_4 is that from 22:00 to 24:00. The Environment Agency designates the method for calculating the annual average WECPNL over daily WECPNLs on power basis as the environmental standard.

Since the situation of noise exposure around military airfields is different from that around airports for civil aviation, there is a disparity between the objects of investigation for civil and military airport flight conditions such as daily fluctuations in the number of flights, types of aircraft, and flight formations. Thus, the DFAA provides a slightly different method for calculation (DFAA; 1980) as compared to that provided by the Environment Agency, tak-

Table 2.1 The number of noise events at Kadena Fire Station

Date	0–7	7–19	19–22	22–24 (hour)	Sum	Weighted sum
1968/2/12	34	44	12	6	96	480
1968/2/13	41	49	24	11	125	641
1968/2/14	28	49	10	5	92	409
1968/2/15	9	25	9	5	48	192
1968/2/16	37	45	13	4	99	494
1968/2/17	41	51	23	16	131	690
Average	32	44	15	8	99	484

The weighted sum is calculated by the formula; $10N_1 + N_2 + 3N_3 + 10N_4$, where N_1, N_2, N_3 and N_4 show the number of noise events during night (0:00–7:00), day (7:00–19:00), evening (19:00–22:00) and night (22:00–24:00), respectively.

ing the report (Kimura et al.; 1980) into account which concludes that the dose-response relationship around military airfields for WECPNL with the DFAA system corresponds to that around civil airport for WECPNL with the system of Environment Agency.

The biggest point of the difference between the two measurement systems is that the DFAA system employs the 90 percentile of the number of daily flights in one year as a standard number of flights while the system of Environment Agency uses the mean value of daily flights. Analysis of the data offered from the local authorities of base surroundings in Japan including Okinawa tells that the difference of the values calculated in the two systems is from 3 to 5 units, WECPNL with the DFAA system being higher than that with the system of Environment Agency (Matsui et al.; 1996).

The difference needs to be paid attention since automatic measuring devices for aircraft noise available in the market of Japan follow the system of the Environment Agency giving the outcome different from the value derived from the DFAA system around the bases.

In Table 2.1 are shown the number of noise events for the different hours of a day. From the table one can see that the number of noise events which occurred from 7 p.m. to 7 a.m. exceeded that from 7 a.m. to 7 p.m. Thus the number of noise events weighted for the time of flight in a day became as high as about 500. In Table 2.2 are shown the daily maximum sound level, WECPNL and $L_{\mathrm{Aeq,24h}}$. The index $L_{\mathrm{Aeq,24h}}$ (the equivalent continuous sound pressure level) is the level of time variant noise exposure averaged over 24 hours on power basis.

The estimation of noise exposure based on the record tells WECPNL is around 105 which is by 5 to 15 higher than the WECPNL the DFAA now

Table 2.2 Noise indices calculated by the measurements at Kadena Fire Station

Date	Greatest $L_{\max}$ (dB)	WECPNL by DFAA	$L_{\mathrm{Aeq,24h}}$ (dB)
1968/2/12	107	100 – 106	79 – 86
1968/2/13	107	101 – 110	80 – 89
1968/2/14	110	100 – 110	83 – 93
1968/2/15	100	88 – 92	68 – 73
1968/2/16	104	199 – 109	80 – 88
1968/2/17	110	99 – 107	79 – 87
Average		99 – 108	80 – 88

Table 2.3 Monthly noise measurements at Sunabe

Month	Maximum level (dB)	Avg. of daily cumulated exposure time (sec) ≥100	95–99	90–94 (dB)	Sum
1972/Nov	124	345	595	990	1,930
1972/Dec	120	300	585	1,190	2,075
1973/Jan	120	325	595	990	1,910
1973/Feb	120	410	455	830	1,695
1973/Mar	122	450	525	850	1,825
Average		366	551	970	1,887

designates, and $L_{\mathrm{Aeq,24h}}$ comes up to 85 dB which is as high as the permissible criteria for hearing conservation for eight working hours a day recommended by the Japan Society for Occupational Health.

2.1.2 Measurement at Sunabe and Yara in 1972 by the DFAA

In November 1972, half a year after the reversion of Okinawa's administrative authority to Japan and in the fierce period of Vietnam War, the DFAA installed monitoring stations at Yara in Kadena Village and at Sunabe in Chatan Village as shown in the map of Figure 2.1. Sunabe is the area under the flight paths of aircraft landing and taking off on the Kadena airfield and now suffering from the highest noise exposure in Okinawa. Yara is the area nearest to the engine tuning and testing spot. At one of the ends of the runways close to Sunabe also engine was tuned occasionally. The record of the sound level was made every 5 seconds and the statistics over 5 months from November 1972 to March 1973 were given to the local authorities which are shown in Tables 2.3 and 2.4.

The maximum sound level recorded by the DFAA in 1972 was 127 dB at Yara and 124 dB at Sunabe, both in front of residences, while engine tun-

Table 2.4 Monthly noise measurements at Yara

Month	Maximum level (dB)	Avg. of daily cumulated exposure time (sec) ≥100	95–99	90–94 (dB)	Sum
1972/Nov	118	465	775	1,465	2,705
1972/Dec	123	575	950	1,575	3,100
1973/Jan	127	560	765	1,405	2,730
1973/Feb	126	320	795	1,565	2,680
1973/Mar	118	475	770	1,885	3,130
Average		479	811	1,579	2,869

Table 2.5 Statistics of noise indices at Sunabe in Nov/1972

Index	Min.	Max.	Average	90 percentile
Daily cumulated exposure time (sec)				
≥ 70 dB	17,730	7,055	10,788	13,952
≥ 80 dB	8,475	3,655	6,300	7,879
≥ 90 dB	3,115	775	1,861	2,369
≥ 100 dB	1,155	40	349	736
≥ 110 dB	85	0	16	53
WECPNL	107	98	103	105
$L_{\mathrm{Aeq,24h}}$ (dB)	87	78	83	85

Table 2.6 Statistics of noise indices at Yara in Nov/1972

Index	Min.	Max.	Average	90 percintile
Daily cumulated exposure time (sec)				
≥ 70 dB	30,645	7,610	16,352	22,564
≥ 80 dB	15,265	4,760	10,006	14,424
≥ 90 dB	5,850	825	2,589	3,866
≥ 100 dB	1,560	55	437	783
≥ 110 dB	220	0	15	40
WECPNL	109	97	104	107
$L_{\mathrm{Aeq,24h}}$ (dB)	89	77	84	87

ing was carried out. Using the record in November 1972 the noise indices WECPNL and L_{Aeq} are calculated as shown in Tables 2.5 and 2.6. The values of WECPNL and L_{Aeq} shown in the tables are extremely high and strongly suggest that the residents in the areas could suffer from hearing loss due to the noise from the base.

2.1.3 Large scale noise measurement by the DFAA in 1977

The DFAA conducted a large scale noise measurement at 127 points around Kadena Air Base and Futenma Air Station in 1977. They made con-

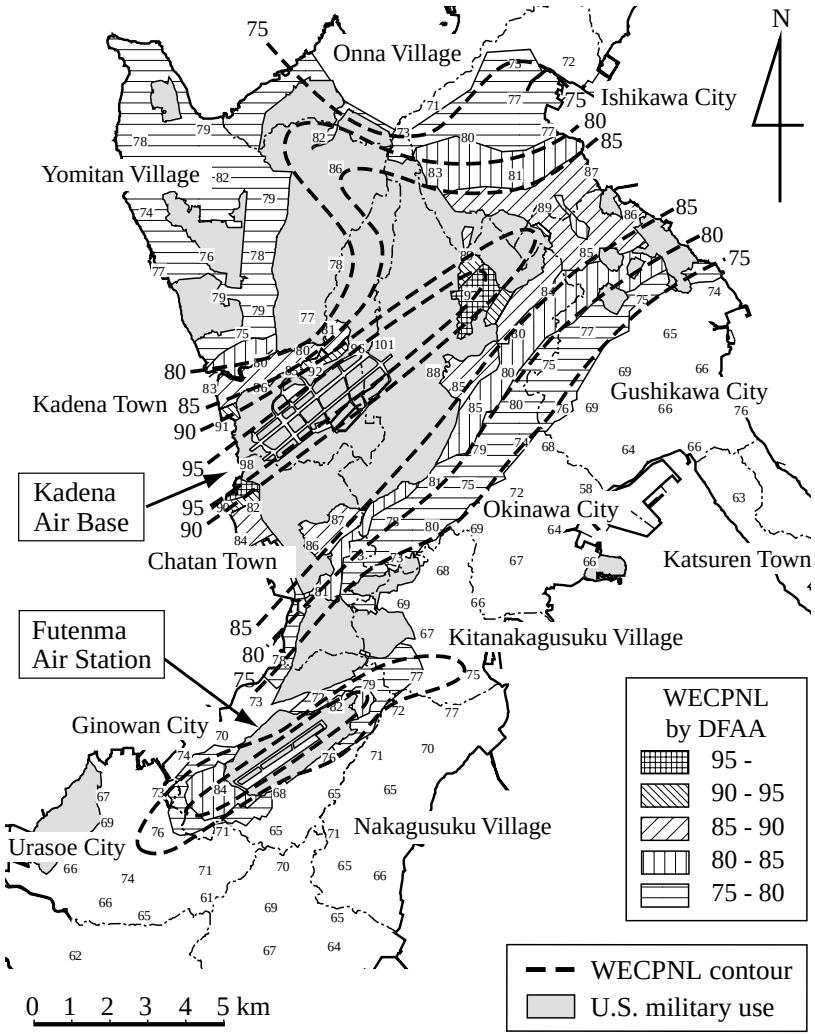

Figure 2.2 Noise contour based on the measurement in 1977.

tinuous observations at 4 measurement bases for 8 days. In the various items of observation were type of aircraft, flight path, sound level and time of event. The DFAA drew contours of WECPNL on the basis of the results of the measurements and designated the areas for the sake of taking counter measures or mitigation around the bases such as residential sound insulation.

In Figure 2.2 are illustrated the areas designated by the DFAA as such and the noise contours which are redrawn using the data shown in the report (Acoutech; 1978) for the DFAA's measurement project. Since the areas designated by the DFAA and the measured noise contour represent good agreement, WECPNL by the DFAA has shown the noise exposure in those days. The area illustrated in the figure is the middle part of the island and densely populated district.

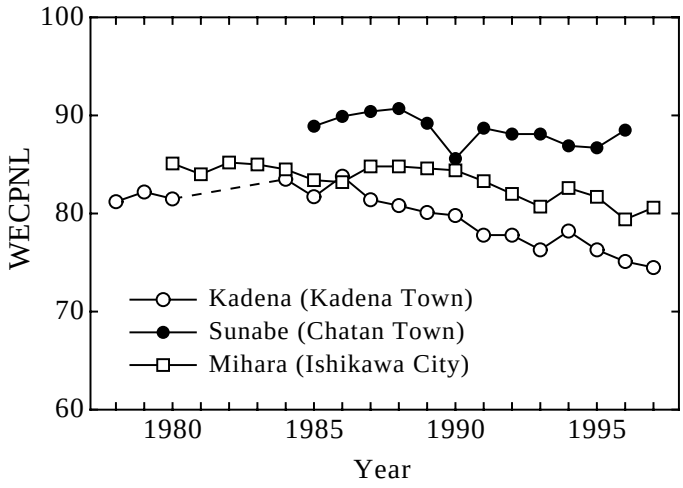

Figure 2.3 Change of the annual average of WECPNL.

2.1.4 Chronological trend of aircraft noise exposure

Okinawa Prefecture and some municipalities have monitored the aircraft noise exposure around Kadena and Futenma airfields. Records are filed up as to three monitoring stations around Kadena Air Base, Yara in Kadena Town, Sunabe in Chatan Town and Mihara in Ishikawa City, from 1978 to 1996. The results of the analysis of the records are presented in Figure 2.3. From the figure one can see that the noise exposure at Yara where noise generated by engine tunings used to be extremely intense and that at Mihara where acrobat-like flight manoeuvres were regularly conducted represent the trend of gradual decrease after 1986 because of the installation of silencers for engine tuning and the change of flight manoeuvres, but the noise exposure at Sunabe which is located under the flight paths has been basically the same for the past 10 years.

2.2 Analysis of the measurement data acquired by the monitoring system of aircraft noise installed by Okinawa Prefectural Government

Okinawa Prefectural Government set up a remote monitoring system for aircraft noise exposure surrounding the two U.S. military airfields and Naha International Airport used by both Japanese civil and military aviation. There are nineteen observation stations as of April 1998. In the following are described the state of art of the monitoring system and the results of analysis of the measurements at the 19 stations for one year.

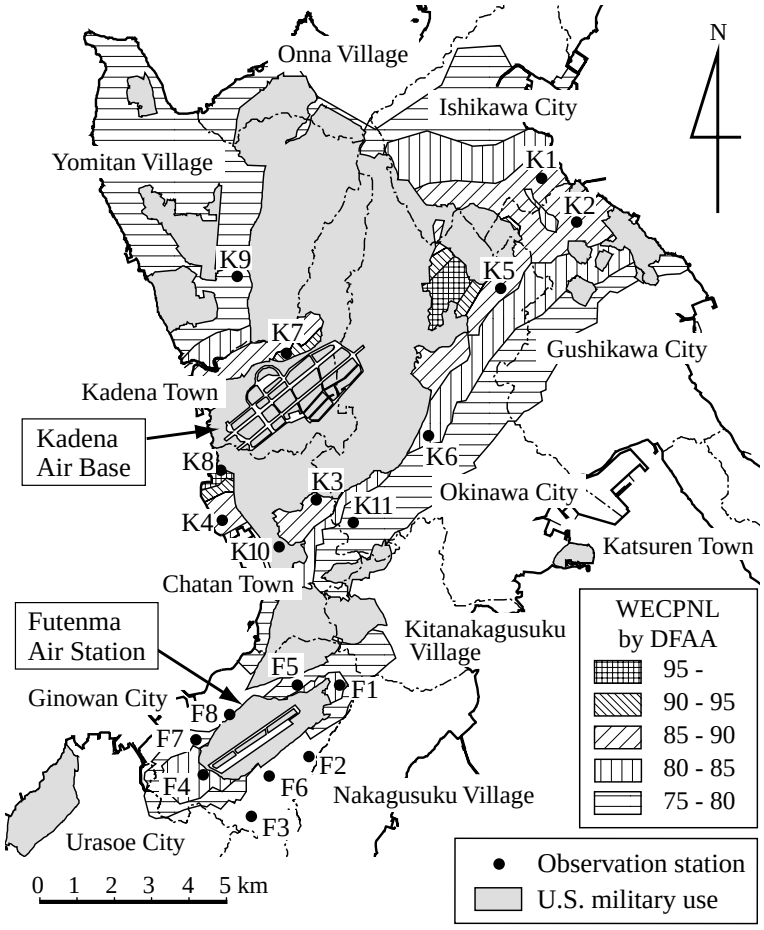

Figure 2.4 Observation stations of the monitoring system for aircraft noise.

2.2.1 System of monitoring aircraft noise in Okinawa

Figure 2.4 shows the positions of nineteen observation stations around the three airfields. Each station has a sound level meter and a computer for data acquisition. The items of observation are the maximum sound level, the time of a day of each noise event, duration of noise event and L_{AE}. Transponder signals emitted from air planes are also monitored to tell the aircraft noise from the other noises. The observed data are transferred via available telephone line to the central station installed at the prefectural government office. Some of the data integrated in the central station are accessible from local municipalities via telephone line.

2.2.2 Analysis of aircraft noise

Several noise indices were calculated from the observed data. Table 2.7 shows the statistics of daily WECPNL and L_{dn}. The items max, 98%, 90%

Table 2.7 Statistics of the daily WECPNL and L_{dn}

Observation station		WECPNL by DFAA	Num. of days	WECPNL				L_{dn} (dB)			
				Max.	98%	90%	Mean	Max.	98%	90%	Mean
K1	Mihara	85–90	357	91	86	85	81	77	75	72	68
K2	Konbu	85–90	337	88	83	81	77	74	71	68	64
K3	Kamisei	85–90	293	86	83	76	73	70	68	62	58
K4	Miyagi	85–90	342	84	82	79	75	71	69	65	61
K5	Kitami	85–90	346	84	80	77	73	70	67	64	60
K6	Yaejima	80–85	315	77	74	71	66	61	59	55	50
K7	Yara	90–95	281	85	83	81	77	74	70	68	64
K8	Sunabe	95–	297	101	98	95	91	87	82	79	75
K9	Iramina	75–80	177	82	76	68	67	69	60	53	51
K10	Kuwae	–75	79	80	79	74	69	64	63	58	54
K11	Yamauchi	75–80	60	74	72	67	64	59	57	53	50
F1	Nodake	80–85	350	88	83	80	77	73	68	65	61
F2	Aichi	70–75	331	76	73	70	66	61	58	55	51
F3	Ganeko	70–75	356	76	71	68	63	62	56	53	49
F4	Ueohjana	80–85	279	96	91	87	83	78	74	69	66
F5	Aragusuku	75–80	296	88	80	76	73	71	66	62	58
F6	Ginowan	70–75	315	76	75	72	67	61	59	57	53
F7	Mashiki	75–80	342	80	76	74	70	64	62	59	55
F8	Ohyama	70–75	79	73	73	70	65	58	57	55	51

and mean, in the table indicate the maximum value, the 98 percentile, the 90 percentile and the power mean of the noise indices over one year, respectively. The power mean of daily WECPNL is used to compare with the environmental quality standard for aircraft noise set by Environment Agency. As is shown in Table 2.7, the maximum value of WECPNL is as high as over 100 at the monitoring point K8 which is located in a residential area in the vicinity of Kadena Air Base, and the differences between the maximum and the mean values are remarkable suggesting the daily noise exposure varies one day after another.

Tables 2.8 and 2.9 show the statistics of the daily maximum levels and the numbers of noise events. In the table, (7–22) and (0–7, 22–24) indicate the hours in a day. The statistics tells that the maximum level is over 110 dB at 6 among 19 observation points. Even in the nighttime, they exceed 100 dB at 6 observation points.

When one looks at the statistics of the number of noise event over one year as tabulated in Table 2.9, he or she will see that the number of noise event varies one day after another. The maximum numbers observed are 4 to 6 times of the mean value in the daytime and 6 to 50 times in the nighttime.

Table 2.8 Statistics of the daily $L_{\max}$

Observation station		Num. of days	$L_{\max,\mathrm{day}}$ (dB) (7–22)				$L_{\max,\mathrm{night}}$ (dB) (0–7, 22-24)			
			Max.	98%	90%	Mean	Max.	98%	90%	Mean
K1	Mihara	357	113	107	103	100	109	106	95	94
K2	Konbu	337	111	103	99	96	107	94	89	86
K3	Kamisei	293	112	105	97	95	92	88	75	76
K4	Miyagi	342	108	103	98	95	97	90	85	80
K5	Kitami	346	107	99	94	91	92	88	83	79
K6	Yaejima	315	102	98	93	89	87	81	75	70
K7	Yara	281	104	102	99	95	100	95	86	85
K8	Sunabe	297	118	115	113	109	115	111	106	100
K9	Iramina	177	102	96	91	87	96	85	75	77
K10	Kuwae	79	104	103	97	92	70	68	–	54
K11	Yamauchi	60	100	95	89	86	79	77	–	64
F1	Nodake	350	110	107	104	99	100	94	86	83
F2	Aichi	331	98	93	90	87	91	85	71	73
F3	Ganeko	356	101	95	89	86	87	81	69	69
F4	Ueohjana	279	119	115	109	106	109	97	79	88
F5	Aragusuku	296	109	103	98	95	98	88	78	78
F6	Ginowan	315	99	95	93	88	92	84	70	72
F7	Mashiki	342	106	97	94	90	92	80	74	73
F8	Ohyama	79	97	93	90	86	82	–	–	63

Table 2.9 Statistics of the number of noise events

Observation station		Num. of days	N_{day} (7–22)				N_{night} (0–7, 22-24)			
			Max.	98%	90%	Mean	Max.	98%	90%	Mean
K1	Mihara	357	211	143	103	51	23	13	6	2.4
K2	Konbu	337	179	98	75	40	13	9	5	1.9
K3	Kamisei	293	191	133	90	36	20	6	2	0.6
K4	Miyagi	342	200	141	95	43	11	8	3	1.2
K5	Kitami	346	141	71	51	23	19	8	3	1.2
K6	Yaejima	315	69	62	29	11	10	1	1	0.2
K7	Yara	281	351	261	191	88	22	15	9	3.5
K8	Sunabe	297	545	463	343	128	58	30	10	4.7
K9	Iramina	177	43	28	14	6	7	5	1	0.3
K10	Kuwae	79	82	75	48	15	1	1	0	0.0
K11	Yamauchi	60	80	70	45	18	3	2	0	0.1
F1	Nodake	350	124	88	66	30	18	5	2	0.5
F2	Aichi	331	107	69	46	18	5	3	1	0.3
F3	Ganeko	356	79	65	39	16	8	3	1	0.3
F4	Ueohjana	279	217	186	135	60	6	4	1	0.4
F5	Aragusuku	296	330	227	159	68	40	17	3	1.3
F6	Ginowan	315	184	122	79	31	7	2	1	0.3
F7	Mashiki	342	330	180	115	53	16	3	2	0.5
F8	Ohyama	79	70	61	36	14	1	0	0	0.0

The maximum number of daily noise events occurred at the point K8, that is Sunabe, is over 500 and the maximum number of flights having occurred in the nighttime at the point is 58.

Judging from the analysis of the acquired data in the monitoring system of aircraft noise, it can be said that the state of noise exposure observed in the communities around the two military airfields are still high over the extended area in the middle part of Okinawa Island.

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