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Environmental Noise Levels IN THE Grand Teton National Park

U.S. ENVIRONMENTAL PROTECTION AGENCY REGION VIII

AIR AND HAZARDOUS MATERIALS DIVISION

DENVER COLORADO 80295

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ENVIRONMENTAL NOISE LEVELS

IN THE

GRAND TETON NATIONAL PARK

BY

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PREFACE

A draft environmental impact statement[1], related to a proposal to expand the Jackson Hole Airport near Jackson, Wyoming, was received from the Federal Aviation Administration for review by Region VIII, U.S. Environmental Protection Agency. Jackson Hole Airport is located within the southern boundaries of the Grand Teton National Park and is operated under a lease arrangement with the National Park Service.

It was apparent that one result of the proposed airport expansion would be increased flight operations to include the flight of larger and louder aircraft over the Grand Teton National Park. Also, it was realized that the available documentation of existing noise levels in the Park was not extensive enough to support valid comments on the noise impact of the proposed expansion. Although little time remained before comments were due, we considered it imperative that more data be obtained. Representatives of the National Park Service concurred; and, with the logistical assistance of the Park Service, personnel of the Region VIII Office of the U.S. Environmental Protection Agency executed the noise survey upon which this report is based during the period January 10 to 19, 1978.

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[1]Draft Environmental Impact Statement for the Jackson Hole Airport Master Plan, October, 1977.

ABSTRACT

Results of an environmental noise survey in the Grand Teton National Park during the period January 10 to 19, 1978 are presented and discussed. It is pointed out that man made or unnatural sounds are more noticeable in that otherwise quiet environment than in most inhabited environments. The survey procedures included statistical and graphical recordings for extended periods (one or more days) and graphical recordings for brief periods (minutes) at several locations. Also discussed are questions related to the treatment of wind-induced noise and internal noise in the measuring instruments when used in a quiet environment.

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ABBREVIATIONS AND SYMBOLS

L_A= A-weighted sound level expressed in decibels (dB) and referred to a reference pressure of 20 micronewtons per square meter (2×10^{-5} N/m^2).

L_x= the A-weighted sound level that is exceeded x% of the time.

L_{max}= The maximum A-weighted sound level ($L_{max}=L_0$).

L_{eq} (T)= equivalent sound level for the period of time, T; i.e., the constant A-weighted sound having the same energy content as the actual varying level, expressed mathematically as follows:

$$L_{eq}(t_2-t_1) = 10 \log_{10} \left[\frac{1}{(t_2-t_1) p_0^2} \int_{t_1}^{t_2} p_A^2 \, dt \right]$$

where: t_1 and t_2 define the time period in hours

p_0= 2×10^{-5} N/m^2

p_A^2 is the mean square A-weighted sound pressure

L_{dn}= day-night sound level, equal to the L_{eq} (24 hrs) modified by having 10 dB added to each sound level measured between 10:00 p.m. and 7:00 a.m., and expressed mathematically as follows:

$$L_{dn} = 10 \log_{10} \left\{ \frac{1}{24 p_0^2} \left[\int_{7:00\,AM}^{10:00\,PM} p_A^2 \, dt + 10 \int_{10:00\,PM}^{7:00\,AM} p_A^2 \, dt \right] \right\}$$

$$= 10 \log_{10} \left\{ \frac{1}{24} \left[15 \log^{-1} \frac{L_{eq}(day)}{10} + 90 \log^{-1} \frac{L_{eq}(night)}{10} \right] \right\}$$

ACKNOWLEDGEMENTS

With gratitude, we acknowledge the hospitality and logistical assistance, including electric power and warmed shelter for instruments, provided by the National Park Service and the Teton Science School.

We are grateful to the City of Denver, Department of Health and Hospitals, Office of Environmental Health Services for the use of a microphone extension cable and to H.E. McKenna of Boulder, Colorado for confirming the accuracy of the Bruel & Kjaer Pistonphone that served as one of our two sound level calibrators.

Dr. Kent Williams, Jim Orban, and Ron Estes of the Region IV Office of the U.S. Environmental Protection Agency aided in the presentation of data collected by System A as a demonstration of recently-developed computer techniques for analysis of data recorded in digital form on magnetic tape cassettes, a much appreciated service.

INTRODUCTION

Noise, according to the USA Standard on "Acoustical Terminology,"[2] is any undesired sound. It follows that what is noise in one setting may be unlike what is noise in another setting. One can support the thesis that noise in the Grand Teton National Park is any unnatural or human-made sound because the Congress apparently intended the Park to be a place where people can experience a part of nature that is relatively undisturbed by humans.

The activity upon which this report is based has been referred to as a survey of environmental noise levels in the Grand Teton National Park, but the label is misleading. It was a rather brief survey of sound levels at a few locations in the Park with minimal attempts to identify sound sources and to characterize sounds as noise or otherwise. Although no single aspect of the acoustic environment is completely described by the results, what is revealed is a somewhat more detailed description than we previously had of the A-weighted sound levels that were typical in winter at a few points in the Park. Against this limited backdrop, one can begin to consider the probable impact of hypothetical changes in the environment such as, for example, the addition or removal of a given number of aircraft of a certain type that are operating in some assumed manner. Beyond that, we trust that this survey has been of value as a learning experience - a springboard from which complementary and more complete efforts may come about in the future.

Figure 1 is a map of the Grand Teton National Park which may be used for reference to the various monitoring sites that will be mentioned on the following pages. Photographs of some of the sites are shown in Figures 2a through 2f.

CONCLUSIONS

It is concluded that:

1. In the Grand Teton National Park, situations sometimes exist in which one may experience a combination of scenic beauty and quietness that most Americans seldom, if ever, experience.

2. Frequently heard in the Park are man made noises, out of concert with the environment in its natural state, that tend to oppose ones enjoyment and admiration of the beauty and quiet. Although the levels of these noise intrusions are generally below what is usual in much of America, they distract and annoy people, partly

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2. ANSI Standard S1.2-1960 (R1971), Page 10.

because they are out of character with the Park's natural amenities and partly because they are interspersed with contrasting periods of much lower sound levels.

3. Of the frequent man made noises in the Park, probably the most pervasive and annoying are those caused by aircraft.[3]

4. The total noise environment in the Park cannot be characterized without a more comprehensive effort to include more locations and varied seasons. In addition, more specialized instruments are needed for this type of environment.

RECOMMENDATIONS

Besides providing data that we trust will be useful, this survey in the Grand Teton National Park emphasized to the participants that a better job can be done. Toward that end, we recommend consideration of the following items:

1. Other sites should be surveyed, including the major acoustic environments that were not reached this time. In particular, some back country and some visitors' residential areas should be included. The choice of sites should take into consideration their accessibility at all seasons.

2. Attitudinal surveys should be conducted to assess the concerns of residents, employees, and visitors regarding noise; and the results should be considered in reference to the intent of the Congress in establishing the Park.

3. Surveys should be conducted at other seasons to reflect the seasonal variations of noise and of the concerns of the population.

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[3]Many graphical records of aircraft noise were made but are not discussed further in this report because in most instances no observers were present to confirm the source identifications.

4. The sound level measurements in future surveys should provide values of L_{eq} (24) and L_{dn} for comparison with the U.S. EPA "Levels Document."[4] Also, it is essential that several exceedance levels be provided, including at least L_0, L_1, L_{10}, L_{20}, and L_{90}.

5. Sound level instruments for this environment should be designed for low internal noise and have a dynamic range capable of measuring the noise of low-flying aircraft. The latter objective would call for measurement of maxima at 80 dB or higher. The instrumentation should be relatively insensitive to electrical interference.

6. We recommend that instruments be provided and programmed to deal with wind-induced noise. What seems to be called for is: (1) a fast-response wind speed sensor that is silent and can be mounted very close to the microphone to eliminate most errors due to spatial and temporal variations in the wind; (2) a known mathematical relationship between wind speed and wind-induced noise for the given microphone; (3) a programmed calculator that will calculate real-time wind-induced noise, subtracting its effect and that of the instrumental noise from the microphone output before registering the result; and (4) a simultaneous recording of the level of wind-induced noise for use in judging the degree of confidence in recorded sound levels.

7. We recommend that instruments be provided (preferably the same as suggested in item 6) which can distinguish, by frequency content or otherwise, between natural and unnatural sound and can provide statistical analyses of either independently.

8. It is observed that any future surveys should include protection from weather extremes for the instruments and should provide for continuous recording of weather data to include at least wind speed, wind direction, and temperature.

(These recommendations are made for the purpose of encouraging discussion and development of better methods and instruments. They are not intended to serve as invitations for proposals to the U.S. Environmental Protection Agency.)

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[4] Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. Report No. 550/9-74-004, U.S. Environmental Protection Agency, Washington, D.C. 20460, 1974.

INSTRUMENTATION

We monitored sound levels at five locations for extended periods of time by means of three instrument systems, each including a digital sound level analyzer and a graphic recording device. A fourth system, consisting of a precision sound level meter with a portable graphic level recorder, was used for short periods at ten locations. A portable weather station was operated at one location.

In more detail, the instrument systems were as follows:

System A: System A was a custom noise monitoring system, most of which was assembled for the U.S. Environmental Protection Agency by the U.S. Army Civil Engineering Research Laboratory, and included the following components:

1. Outdoor Microphone, B & K Model 4921;
2. Log Voltmeter/Converter, Hewlett-Packard Model HP 7562A;
3. Programmable Calculator, Wang Model 600-14 TP;
4. Scientific Tape Recorder, Nagra Model IV-SJ;
5. Power supply and custom circuitry;
6. Graphic Level Recorder, GenRad Model 1521-B, with an 80 dB potentiometer;
7. Anemometer, Science Associates Model 420-1.

This system was programmed to sample A-weighted sound levels ten times per second and to provide statistical analyses of the sounds registered during each successive half hour. Sounds registered during wind speeds exceeding 15 km/hr were not included in the analysis. The electronic noise floor was about 32 dB, and the range extended to 100 dB.

A few analog tape recordings of the flat (unweighted) sound levels were made by use of the microphone of System A and the Scientific Tape Recorder.

System B: This included the following components:

1. Community Noise Analyzer, GenRad Model 1945;
2. Electret-condenser microphone, 1 inch, GenRad Model 1961-9601, as part of the Weatherproof Microphone and Housing Assembly, GenRad Model 1945-9730;
3. Preamplifier, GenRad Model 1560-P42;
4. Strip Chart Recorder, Hewlett-Packard Model 7155A.

System B was programmed to measure A-weighted sound levels at intervals ranging from 0.2 to 0.7 sec, usually for three successive periods totalling about 24 hours. The three periods were chosen in such a way that one eight-hour period would approximate the defined nine hours of night time which is from 2200 to 0700 hours. The instrument has no nine-hour capability. A statistical analysis of the levels registered during each period was provided, making it possible to later calculate the equivalent sound level, L_{eq}, for the entire three periods and an approximation of the day-night sound level, L_{dn}.

The range extended from about 18 dB to 120 dB; however, the system was sensitive to electromagnetic noise, resulting in brief impulses of high amplitude which affected some values of L_0 (the period's maximum sound level) and L_{eq}. Those values that were suspect have been omitted from this report.

System C: The following components comprised this system:

1. Sound Level Analyzer, Metrosonics Model db602;
2. Electret-condenser microphone, GenRad Models 1961-9601 (one inch) and 1962-9601 (1/2 inch) used at different times, with wind screen;
3. X-Y Recorder, Hewlett-Packard Model 7015A.

System C was programmed to sample A-weighted sound levels eight times per second, disregarding any measurements during wind speeds exceeding 15 km/hr. For each half-hour period it registered four noise descriptors that were later made a matter of record via direct control of the X-Y Recorder. The electronic noise floor was about 31 to 33 dB with the 1/2 inch microphone and about 24 to 25 dB with the one inch microphone. The upper limit of dynamic range was 120 dB for the one inch microphone and 130 dB for the 1/2 inch microphone.

System D: This portable system had the following components:

1. Precision Sound Level Meter, GenRad Model 1933;
2. Electret-condenser Microphone, GenRad Models 1961-9601 (one inch), with wind screen;
3. Graphic Level Recorder, B & K Model 2306.

Calibrators: Two sound level calibrators were used frequently during the survey for accuracy checks of Systems B, C, and D. They were a B & K Pistonphone Model 4220 and a GenRad Sound Level Calibrator Model 1562A.

Weather Station: A portable mechanical weather station, Meteorology Research, Inc., Model 1072, was located approximately 15 meters from and behind Quarters Number 170 in the residential area at Moose. The device

provided a continuous strip chart record of wind direction, temperature, and air movement, from which average wind speed could be calculated.

CALIBRATION OF INSTRUMENTS

Within six months before the survey, all instruments were calibrated with National Bureau of Standards traceability except as follows:

(1) The calibration of System A was less recent, but it exhibited good agreement with the other Systems, and it was equipped with an electrostatic actuator for frequent checks of precision. When later calibrated by the manufacturer on January 11, 1979, the man who did the calibration said that he found no reason to suspect errors greater than a fraction of a decibel.

(2) The Hewlett-Packard Strip Chart Recorder and X-Y plotter were not calibrated, but both are linear instruments with capability of adjustment at any two points for agreement with the input instrument, a practice that was routine during the survey.

It was our general practice during the survey to use one or both of the two calibrators, or the electrostatic actuator for System A, to adjust the measurement system for accuracy at the beginning of a monitoring period and to recheck the system at the first opportunity upon or after termination of the period. Precision in reading Systems B and C was no better than $\pm$ 1 dB because their digital displays had that limitation. The display for System A gave readings to several decimal places. Drift in accuracy with reference to the calibrators or electrostatic actuator from beginning to termination of a monitoring period was not observed to exceed $\pm$ 0.3 dB for System A, $\pm$ 2 dB for System B, and $\pm$ 2 dB for System C. Comparisons between readings of the two calibrators were within 1 dB. Slight differences may be attributable to operational difficulties in cold weather.

In accordance with American National Standard, ANSI S1.4-1971, and manufacturers' instructions, corrections were applied to calibrator readings as follows:

	B&K 4220	GenRad 1562-A
Sea level value (dB)	123.9 at 250 Hz	114 at 1000 Hz
A-weighting coorection (dB)	-8.6	0
Elevation correction for 1980 to 2130 m. (dB)	-2.1	-1.6
Corrected value (dB)	113.2	112.4

MONITORING SITES AND PROCEDURE
(See Figs. 1 to 2f)

Moose: At House Number 170 in the residential area of the Park Headquarters at Moose, Wyoming, System A was used to monitor sound levels for 178 hours, 87 percent of the elapsed time between 2200 hours on January 10, and 0900 hours on January 19.

At the same location, System B was used to monitor for 46 hours between 1500 hours on January 13 and 1400 hours on January 15. Some, but not all, of the System B data at Moose were affected by electromagnetic interference, probably originating in the house heating system.

Excepting pre-amplifiers, the electronics equipment was protected indoors from temperature extremes, while the microphones and preamplifiers were mounted on a clothesline pole approximately 1.5 meters above snow surface and eight meters from the house toward the rear. The portable weather station was about 15 meters behind the same house.

Sound levels at the Moose site were generally higher than at the other sites monitored, due partly to the site's position in relation to the Airport and partly to other cultural activity in the vicinity.

Elbow Ranch Barn: System C was installed at Elbow Ranch with the electronics package inside the unheated log barn and the microphone about eight meters to the east and up the north-slope hillside from the barn. The microphone was supported on a tripod that was cantilevered from a tree trunk at a height of about 1.8 meters above the snow.

A ski trail passed within about six meters of the microphone; and there was evidence that at least one snowmobile used the trail occasionally, contributing to the values of L_0 and L_{eq} if not to the other descriptors.

Monitoring at the Elbow Ranch Barn continued for a total of 156.5 hours, 91 percent of elapsed time between 1330 hours on January 11 and 1800 hours on January 18.

Elbow Ranch Cabin Number 3: Cabin Number 3 at Elbow Ranch was in a quieter location than the barn because it was not near the ski trail. System B monitored there for 24 hours from 1500 hours on January 17 to 1500 hours on January 18. With the Community Noise Analyzer kept warm indoors, the microphone and preamplifier were about 1.8 meters above the snow surface among the trees at a distance of about ten meters from the cabin. The strip chart recorder was not used at this site for fear that it might provide a path for power line noise interference with the Community Noise Analyzer.

Moran Village: System B was installed at Mobile Home Number 480 in Moran Village where it monitored sound levels for 39 hours between 1800 hours on January 11 and 1100 hours on January 13. The microphone and preamplifier were about 1.5 meters above snow level in a thin grove of trees about 15 meters behind the mobile home. The other instrumentation remained warm inside the home. Sound levels at Moran were among the lowest ones measured during this study.

Beaver Creek: Sound levels near Mobile Home Number 447 at Beaver Creek were monitored by use of System B for 24 hours between 1030 hours on January 16 and 1030 hours on January 17. The microphone and preamplifier were at the edge of a grove of trees, about 1.5 meters above the snow and about nine meters behind the mobile home, with the remaining instrumentation kept warm inside the home.

WEATHER

Table 1 summarizes some weather observations that were recorded by personnel of the Teton Science School at Elbow Ranch. The data of Table 2 were extracted from a strip chart recording made at the Moose monitoring site by our portable weather station. Information on wind-induced noise found in Table 2 is discussed in the Appendix.

MEASUREMENTS DURING EXTENDED PERIODS

Table 3 presents some equivalent sound levels (L_{eq}) and day-night sound levels (L_{dn}) based on this survey. The daily periods used for calculation of these values extend approximately from noon to noon. The noon-to-noon timing was chosen to facilitate comparison between instrument systems because of operational requirements that Systems B and C be interrupted for data retrieval and reprogramming near midday instead of midnight. These values of daily L_{eq} differ from those shown in Tables 4a through 4j and Figures 3a through 3j because the latter represent periods from midnight to midnight.

Table 3 shows the number of hours of monitoring that served as the basis for each value of L_{eq}. Consistent with the definition of L_{dn}, day hours are defined here as all hours from 0700 to 2200 and night hours are from 2200 to 0700. See comments on "System B" regarding an exception to this treatment. In instances where monitoring produced data for less than a full 24-hour day, any calculation of L_{dn} includes the assumption that the day time L_{eq} and the night time L_{eq} would remain valid had 24 hours of data been available.

Tables 4a through 4j are computer transcriptions of data recorded digitally on cassettes by System A. The deleted items are those that have been questioned because of known or suspected interference or error in procedure. Note that these daily L_{eq} periods differ from those in Table 3.

Table 5 shows more of the results from System B, including, as does Table 4, some values of L_x, the level exceeded x percent of the time.

Data in graphical form, obtained over extended periods, are presented in Figures 3a through 5e. Figures 3a through 3j are computer-produced representations of System A data that had been recorded in the field on digital cassettes. Figures 4a through 4e represent System C data as transcribed in the field by the X-Y Recorder from the memory of the Sound Level Analyzer. Figures 5a through 5e are copies of sample graphic level and strip chart recordings from Systems A and B as produced in the field.

To assist in the interpretation of the graphs of L_x and L_{eq}, we include Figure 6, a similar representation of environmental noise recorded at a location 23.5m. from a rather busy four-lane street in a medium-size city of Colorado. It is clear that, whereas the city street noise produces considerable spread between all the L_x values, the Teton National Park data show little spread between values of L_x except in the vicinity of L_0 and L_1. This is evidence that the louder sounds in the Park are relatively infrequent and, therefore, more intrusive than would be true in the city.

BRIEF MEASUREMENTS

We made brief A-weighted strip chart recordings at ten locations by use of System D, using a dynamic range of 20 to 70 dB. At each location, the microphone height was about 1.5m above snow surface. The site locations are shown on Figure 1.

These samples are useful examples of presumably typical conditions, but no claim is made that they represent the usual or average conditions. Obviously, the results are not adequate for estimation of such descriptors as L_{eq} (24) or L_{dn}.

Table 6 summarizes the data, and a sample graphic level recording is shown in Figure 7. The statistical analyses included in Table 6, other than values of L_0, are calculated from strip-chart values taken at 5 sec intervals. Other observations peculiar to the respective sites are given in the following paragraphs:

Site 1, Jackson Hole Country Club: The major noise sources identified while recording at Site 1 were as follows:

Source	Maximum Level (dB)	Duration
High altitude jet aircraft	40	2 min
Construction (hammering)	42	discontinuous
Truck	51	30 sec
Single engine aircraft on approach	72	1 min
Automobile	39	15 sec
High altitude aircraft	47	50 sec

Also at Site 1, but not during the sampling, a Convair 580 aircraft on take-off to the south was measured at 82 dB, after which it turned east and then north and was audible for four minutes. The level during take-off exceeded the ambient by 57 dB.

Site 2, Circle E. Road. At Site 2, the major noise source was highway traffic, peaking at 28 dB and lasting for 10 to 15 seconds.

Site 3, Murie Ranch. During the sample at Site 3, a distant single-engine aircraft peaked at 56 dB (35 dB above ambient) and was audible for 30 seconds. Birds, audible for 50 seconds, peaked at 27 dB.

Site 4, Moose. During the three sampling periods at Moose, the following sources were observed:

SITE	SOURCE	MAXIMUM (dB)	DURATION
4a	Automobile	27	10 sec
4a	Snow plow	28	30 sec
4a	Truck	29	30 sec
4b	School bus at 400m	29	10 sec
4b	Dog barking	32	discontinuous
4b	Raven at 90m	38	20 sec
4c	Aircraft at high altitude	59	2 min
4c	C-580 taxiing at airport	36	1 min
4c	C-580 take-off to south	40	1.5 min
4c	Twin engine aircraft 1000 feet above approaching for south-bound landing	62	2 min
4c	Twin engine aircraft, reverse thrust on runway	51	1 min

Site 5, Menors Ferry. During the three samples at Site 5, the following noise sources were observed:

SITE	SOURCE	MAXIMUM (dB)	DURATION
5a	River	52	5 min
5a	Birds	62	discontinuous
5b	Single engine aircraft	68	2 min
5c	Snowplow	41	20 sec
5c	Truck on highway	56	2 min

Note that the aircraft heard at Site 5b was 33 dB above ambient. Another single engine aircraft, not during the sampling period, peaked at 55 dB and was audible for nine minutes. Also, a high altitude jet, measured up to 45 dB, was audible for more than one minute.

Site 6, Chapel Road. At Site 6 the sample included noise from a high altitude jet that peaked at 55 dB, heard for five minutes, and from a single engine aircraft peaking at 53 dB, audible for 70 seconds.

Site 7, Taggert Lake. Noise sources identified at Site 7 were the following:

SOURCE	MAXIMUM (dB)	DURATION
Observer noise	28	impulsive
C-580 aircraft on south-bound approach	45	3 min
C-580 aircraft, reverse thrust on runway	37	1 min
C-580 aircraft taxiing at airport	28	1.5 min
Distant single engine aircraft	34	3 min
C-580 aircraft on south-bound approach	46	4 min
C-580 aircraft, reverse thrust on runway	44	2 min
C-580 aircraft, south-bound take-off	37	1 min

In this back country site the aircraft sounds were from eight to 24 dB above ambient, even with distant source locations.

Site 8, Baseline Flats. At Site 8, the sounds of breathing and clothing friction due to arm movements were prominent at 24 dB; and the ticking of a loud pocket watch at 20 dB was noticeable. For half the time, sound levels were below the instrumental noise floor.

Site 9, Antelope Flats. The peak noise level at Site 9, lasting about 20 seconds, was due to a snow plow and measured 35 dB. A more distant snow plow droned continuously at about 22 dB.

Site 10, Cunningham Cabin. Principal contributors to noise at Site 10 were the following:

SOURCE	MAXIMUM (dB)	DURATION
Convair 580 estimated 11 km away	39	2 min
Aircraft, single engine	36	1 min 40 sec
Automobiles on highway	34 to 38	20 sec. each

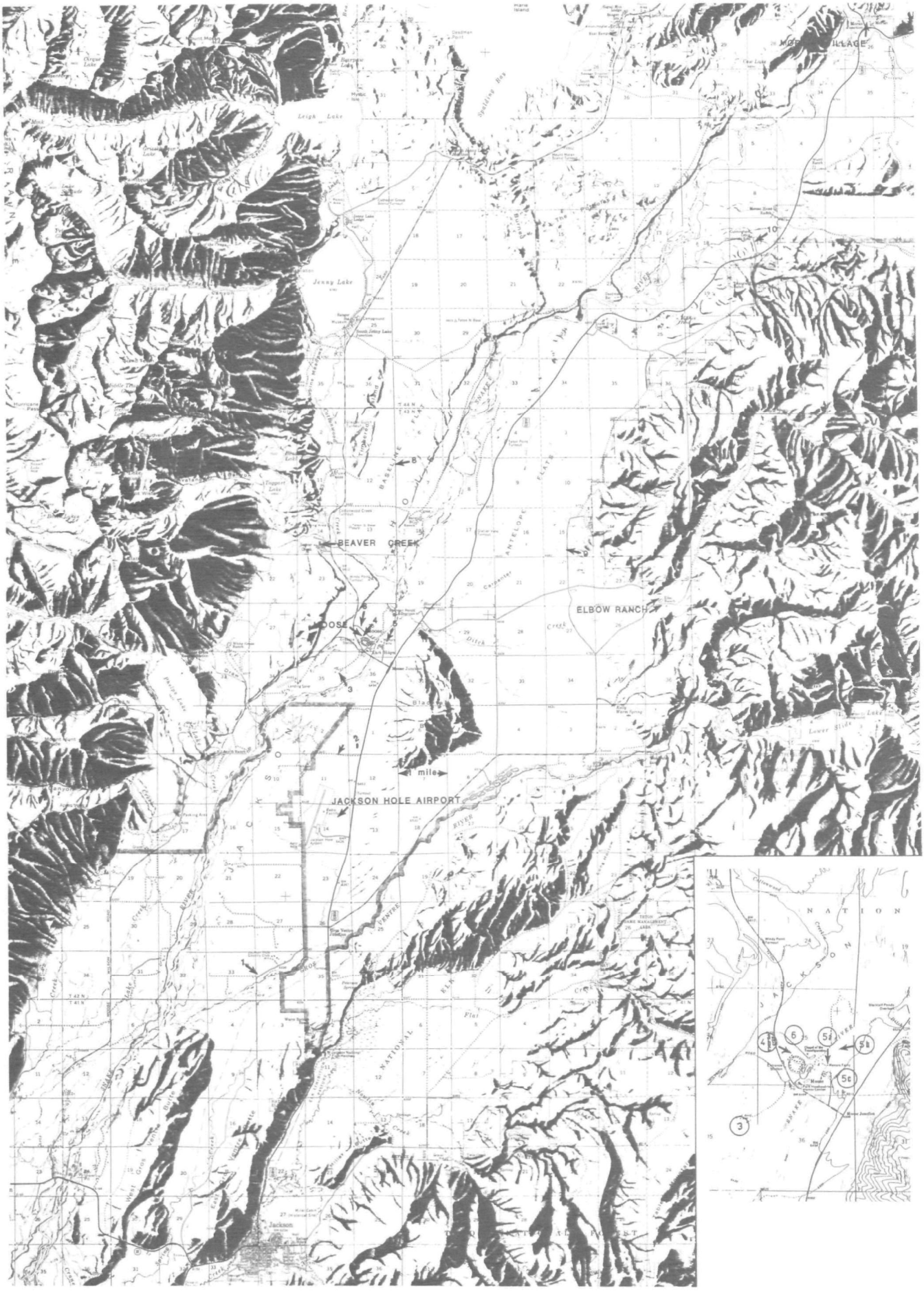


Fig. 1. Map of the Monitoring Sites

Fig. 2a. Monitoring Site at Moose

Fig. 2b. Site above Taggart Lake

Fig. 2c. Elbow Ranch Barn

Fig. 2d. Elbow Ranch Cabin No. 3

Fig. 2e. Beaver Creek Site

Fig. 2f. Moran Village Site

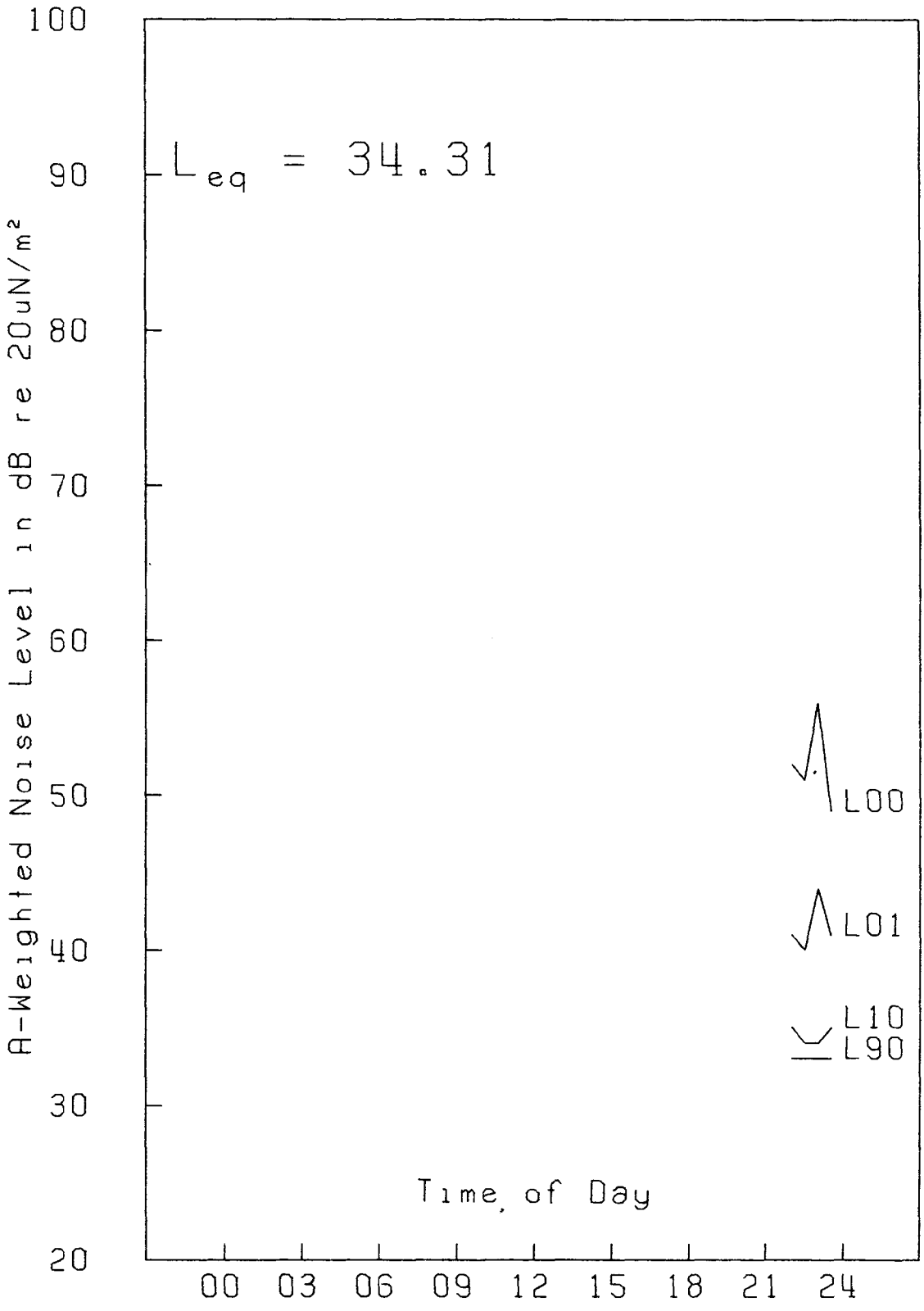


Fig. 3a. Sound Levels at Moose Measured by System A

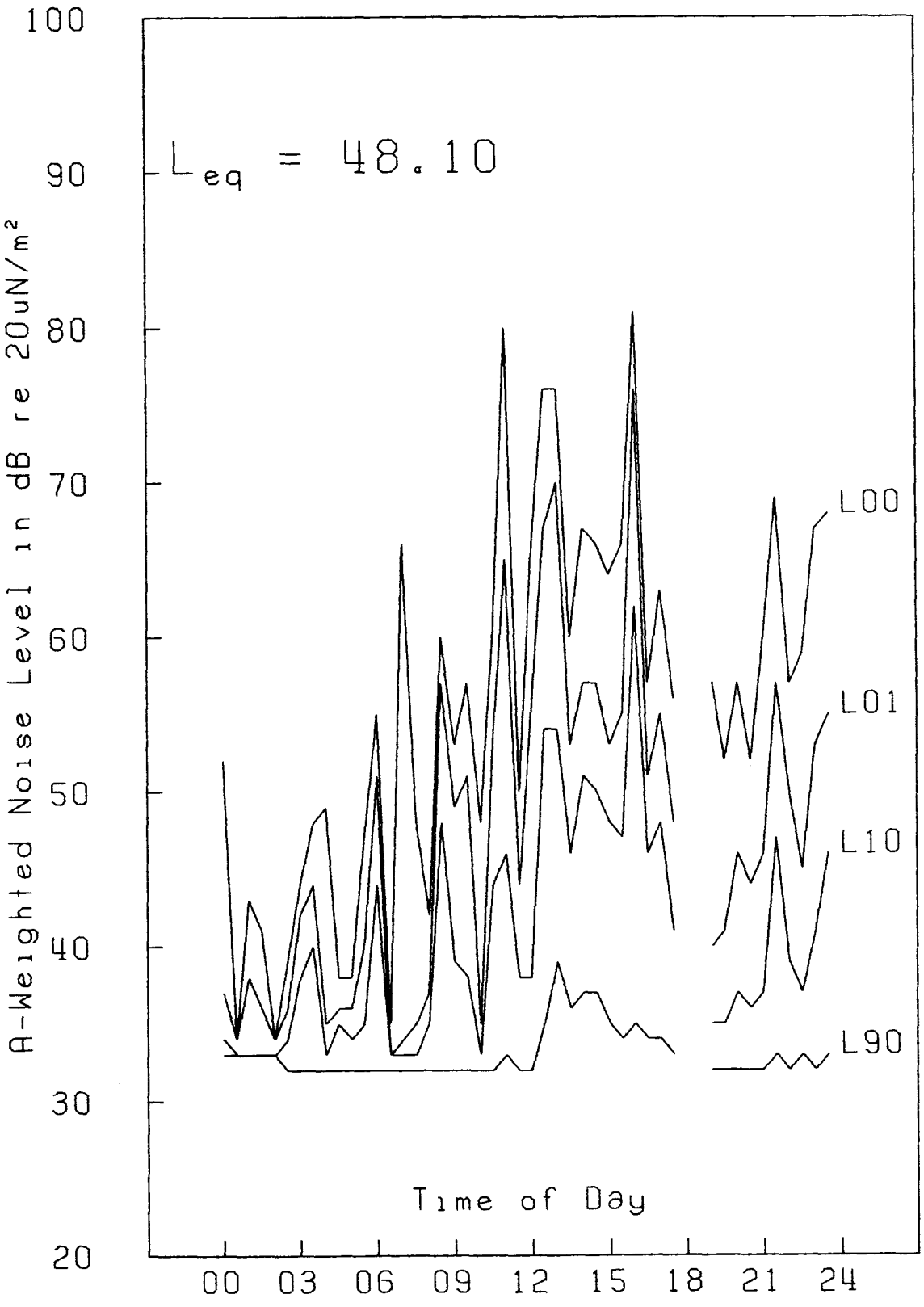


Fig. 3b. Sound Levels at Moose Measured by System A

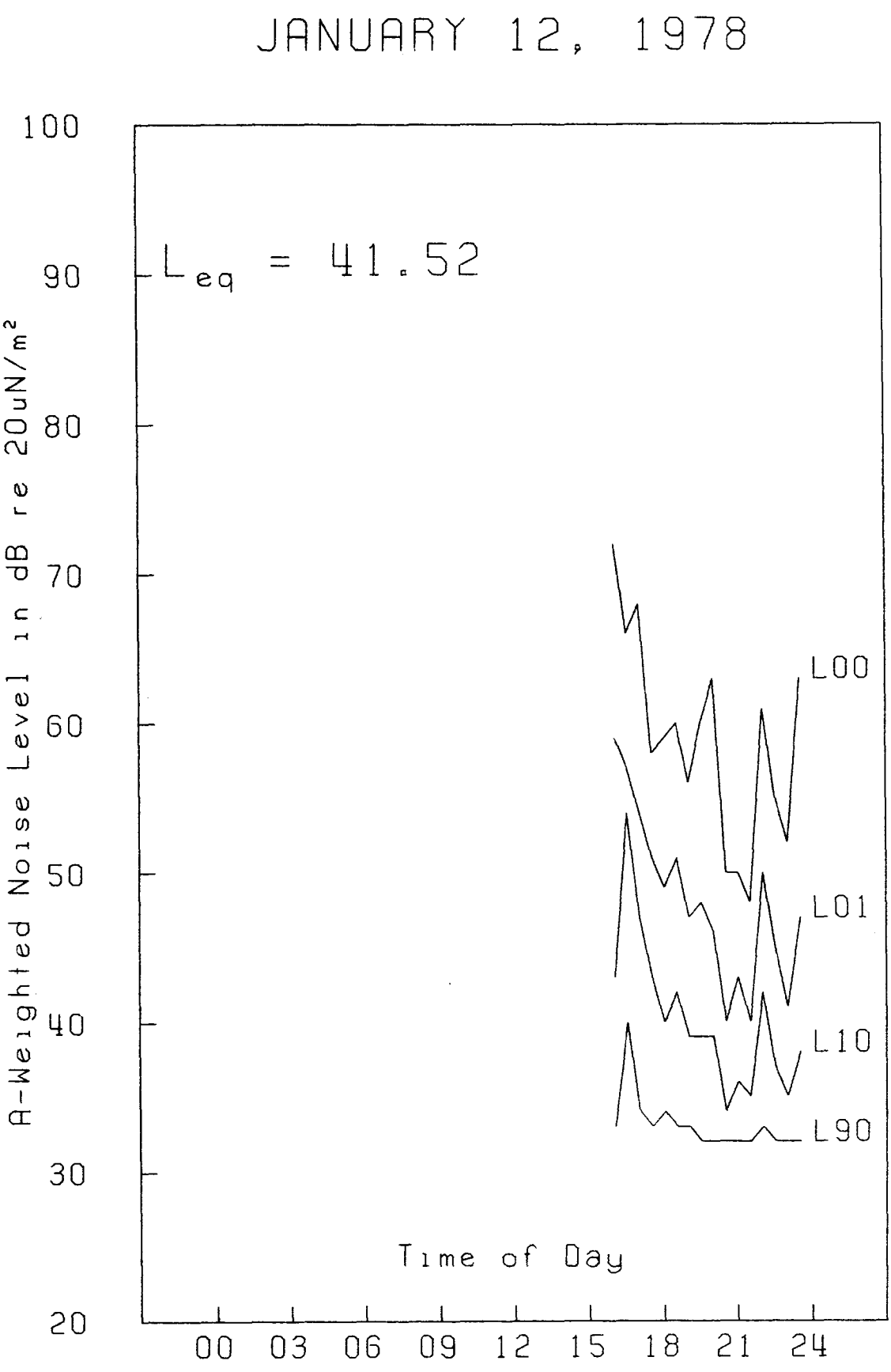


Fig. 3c. Sound Levels at Moose Measured by System A

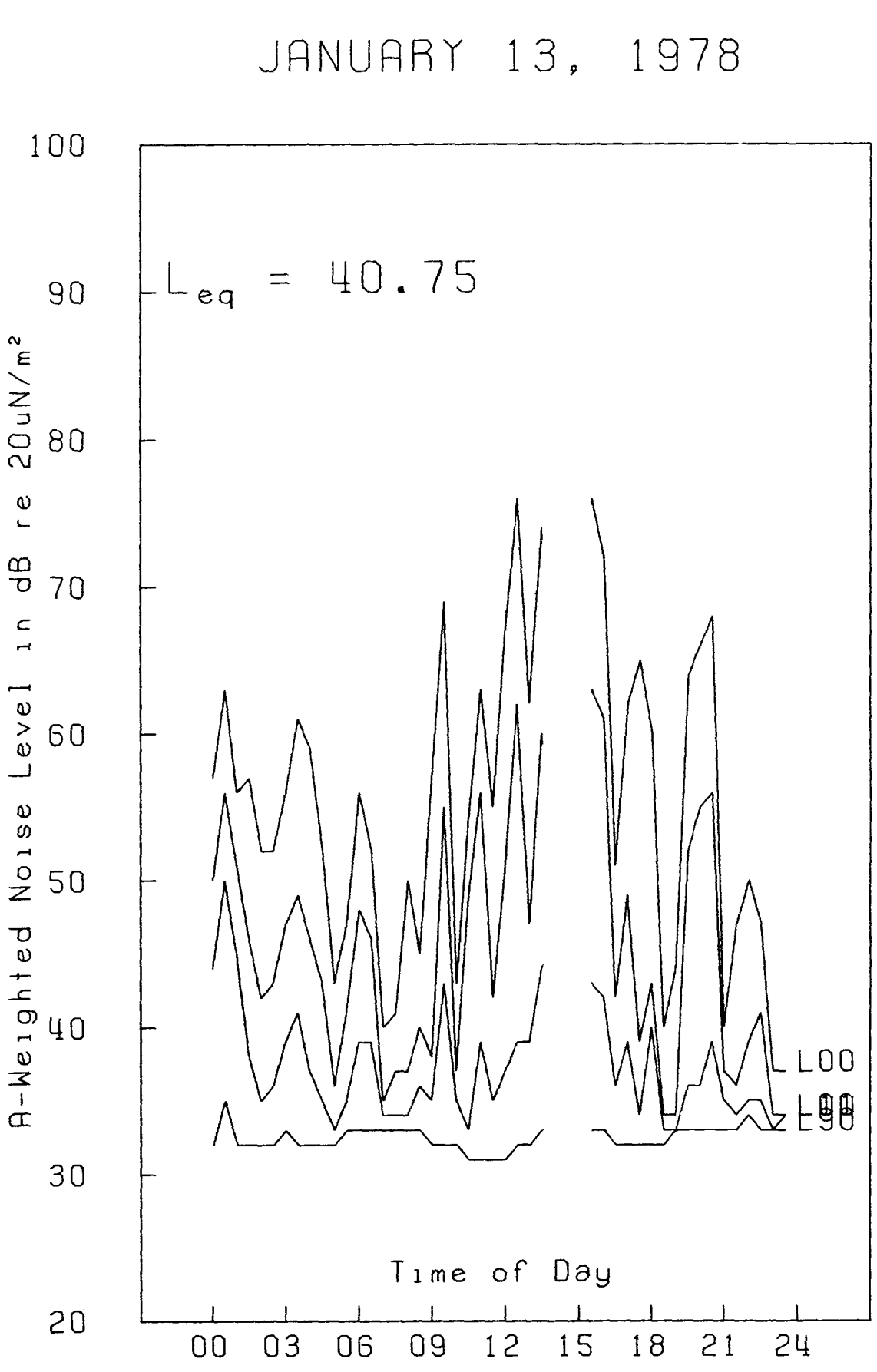


Fig. 3d. Sound Levels at Moose Measured by System A

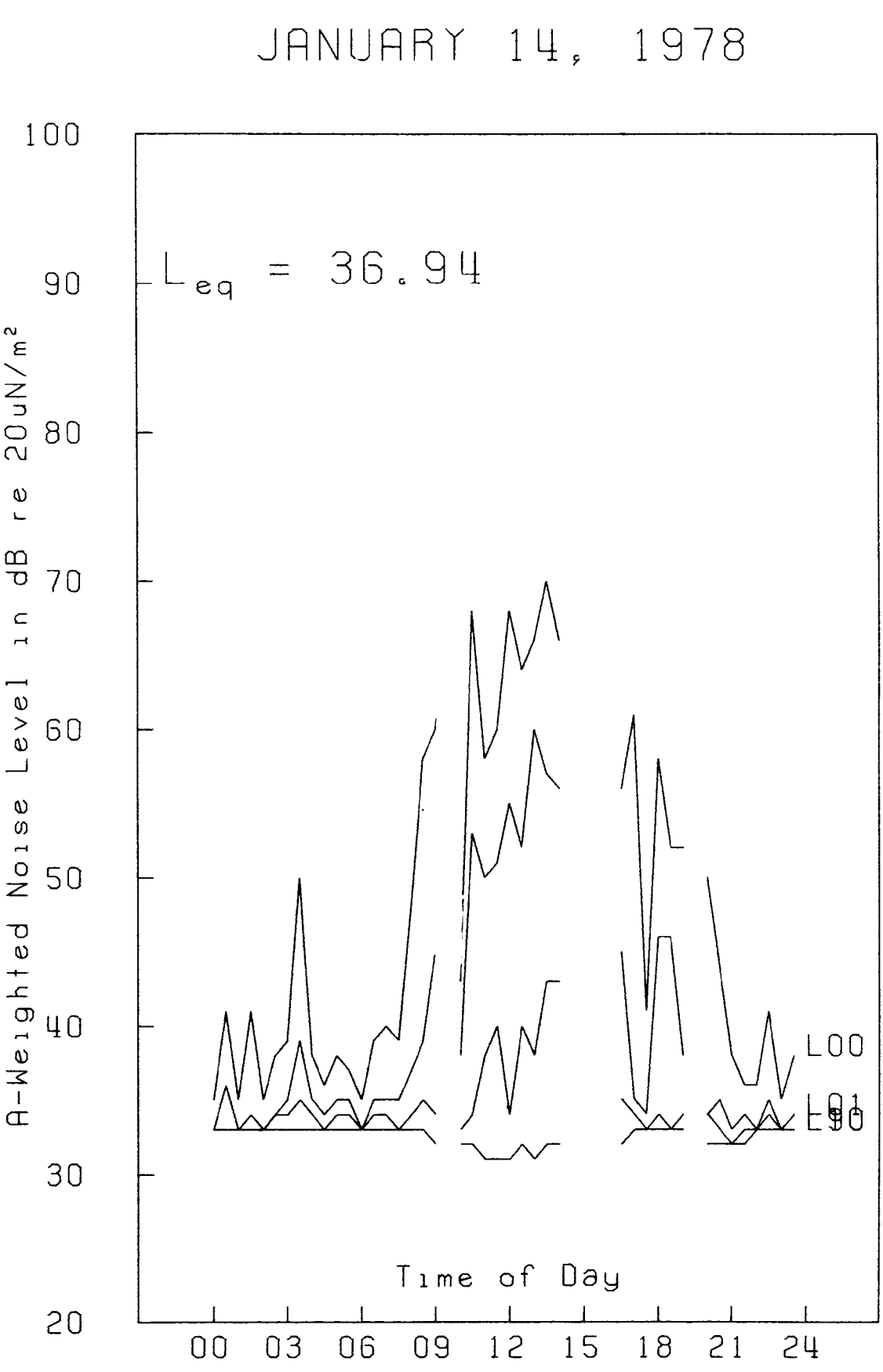


Fig. 3e. Sound Levels at Moose Measured by System A

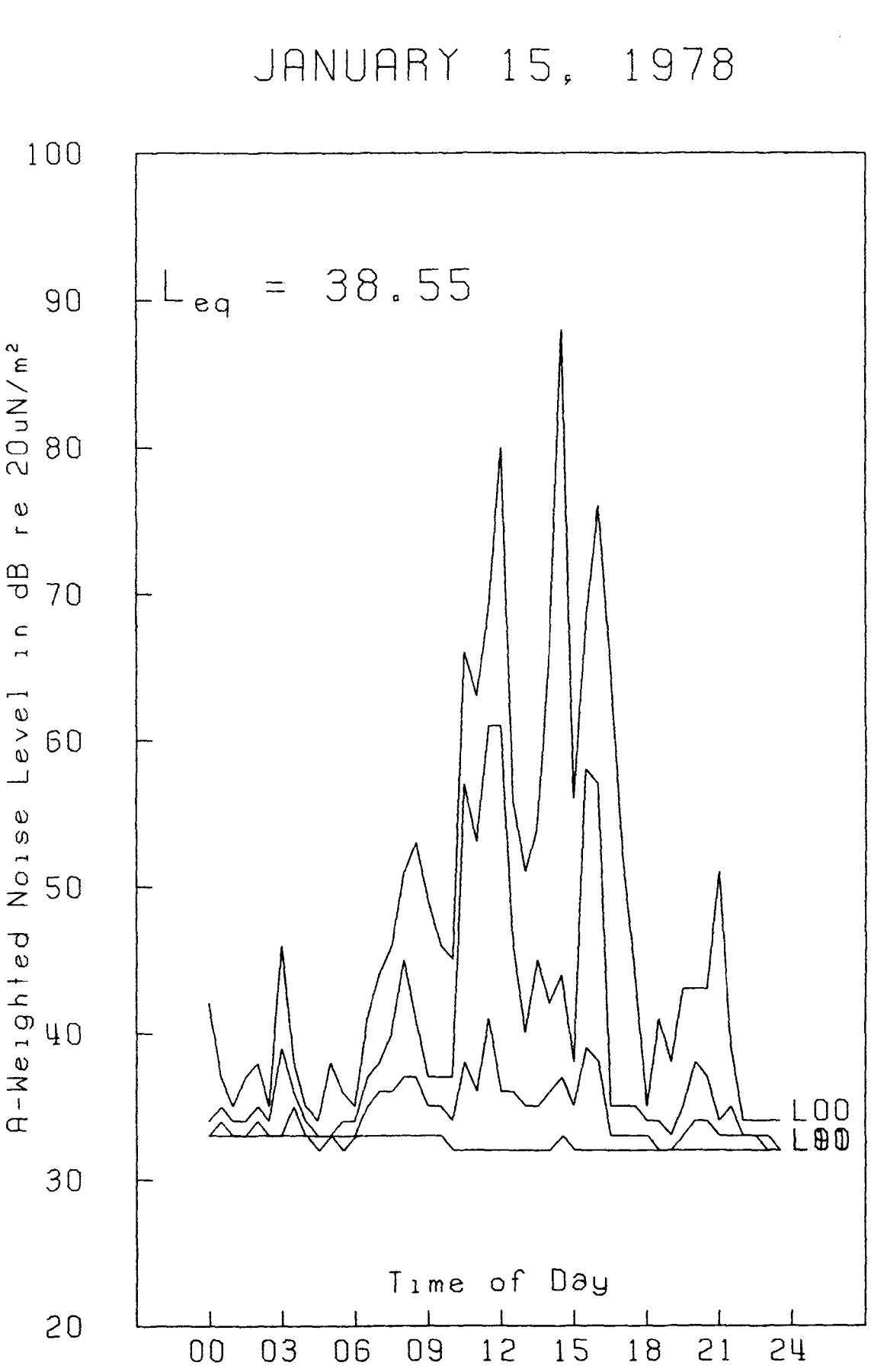


Fig. 3f. Sound Levels at Moose Measured by System A

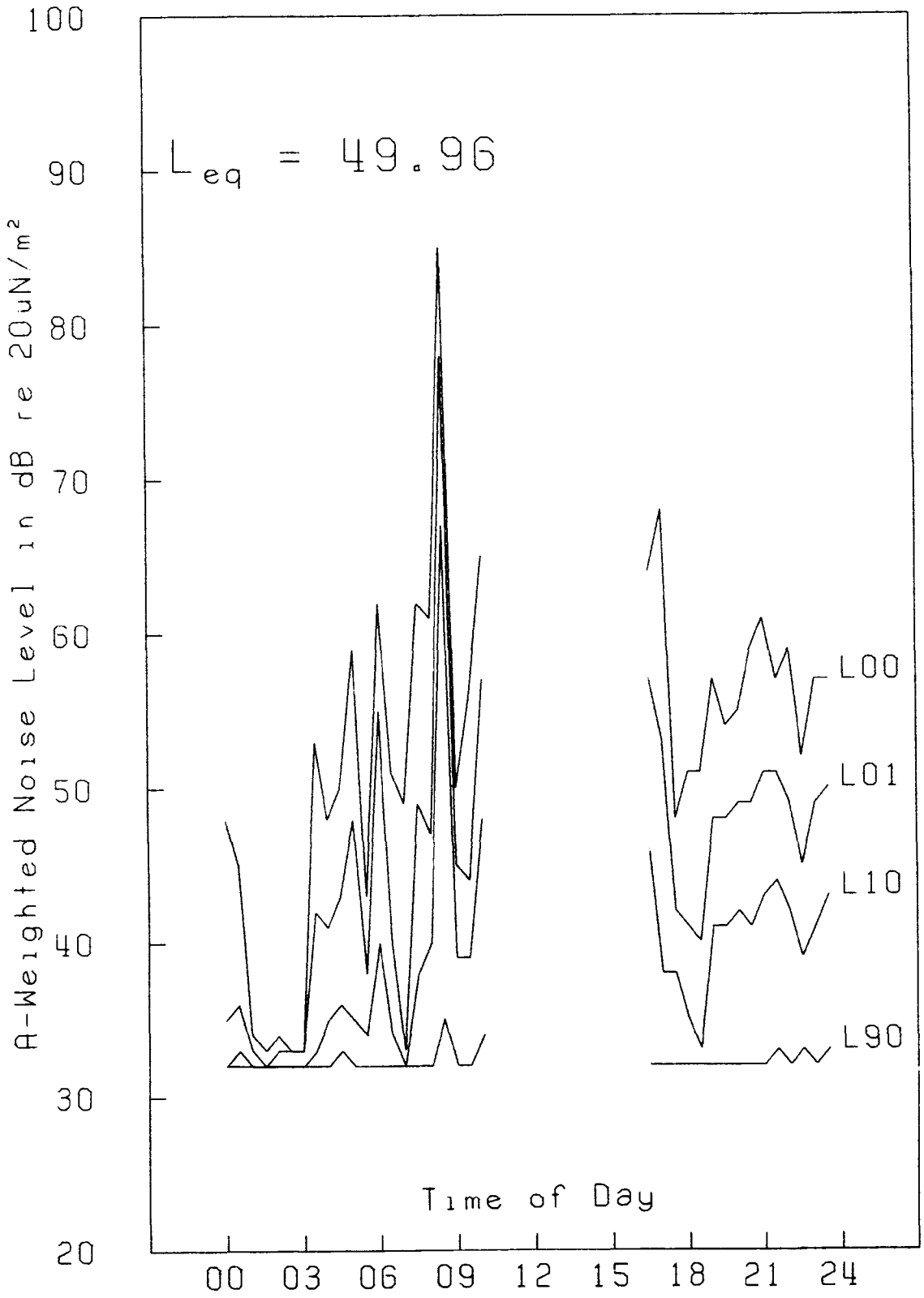


Fig. 3g. Sound Levels at Moose Measured by System A

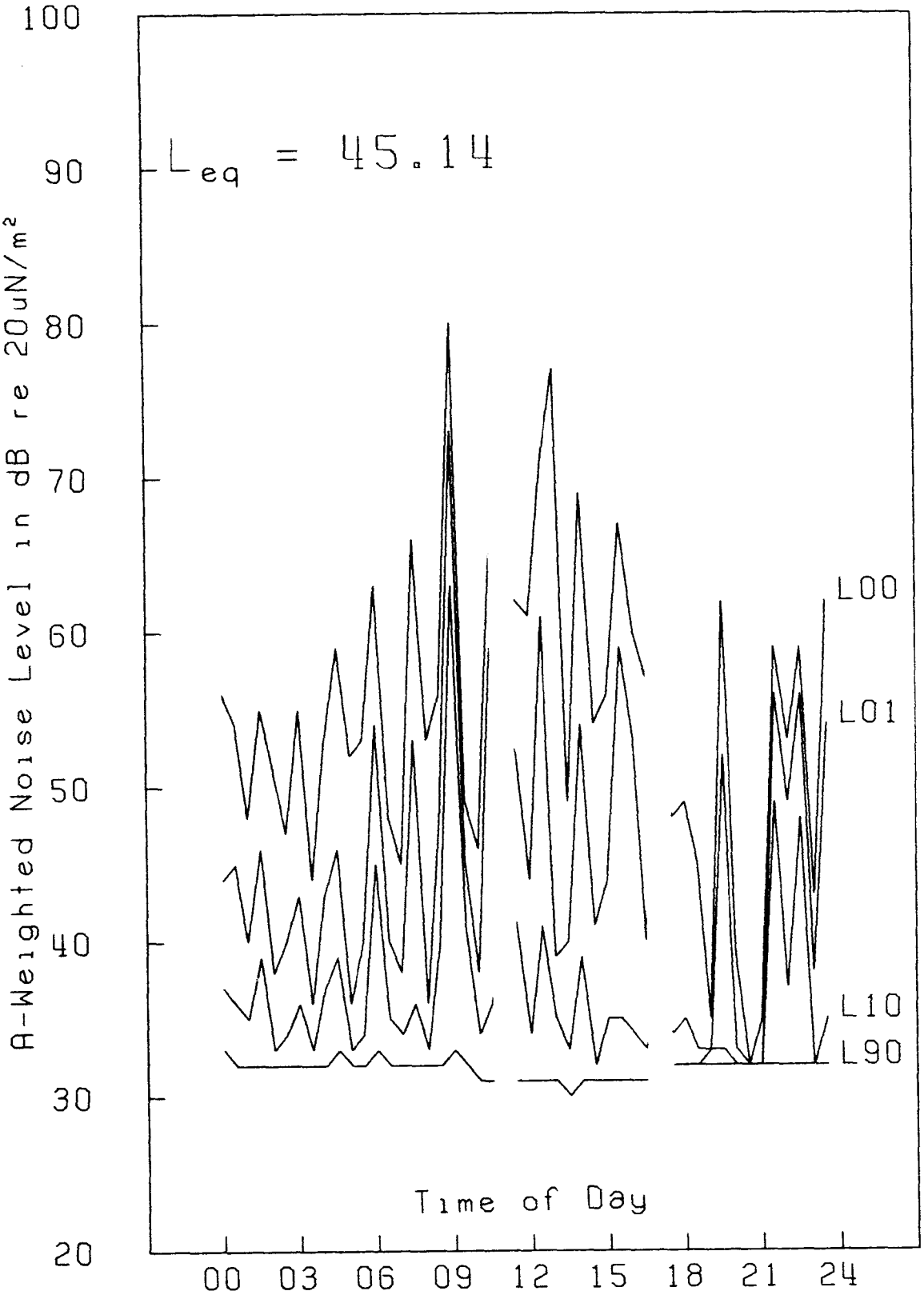


Fig. 3h. Sound Levels at Moose Measured by System A

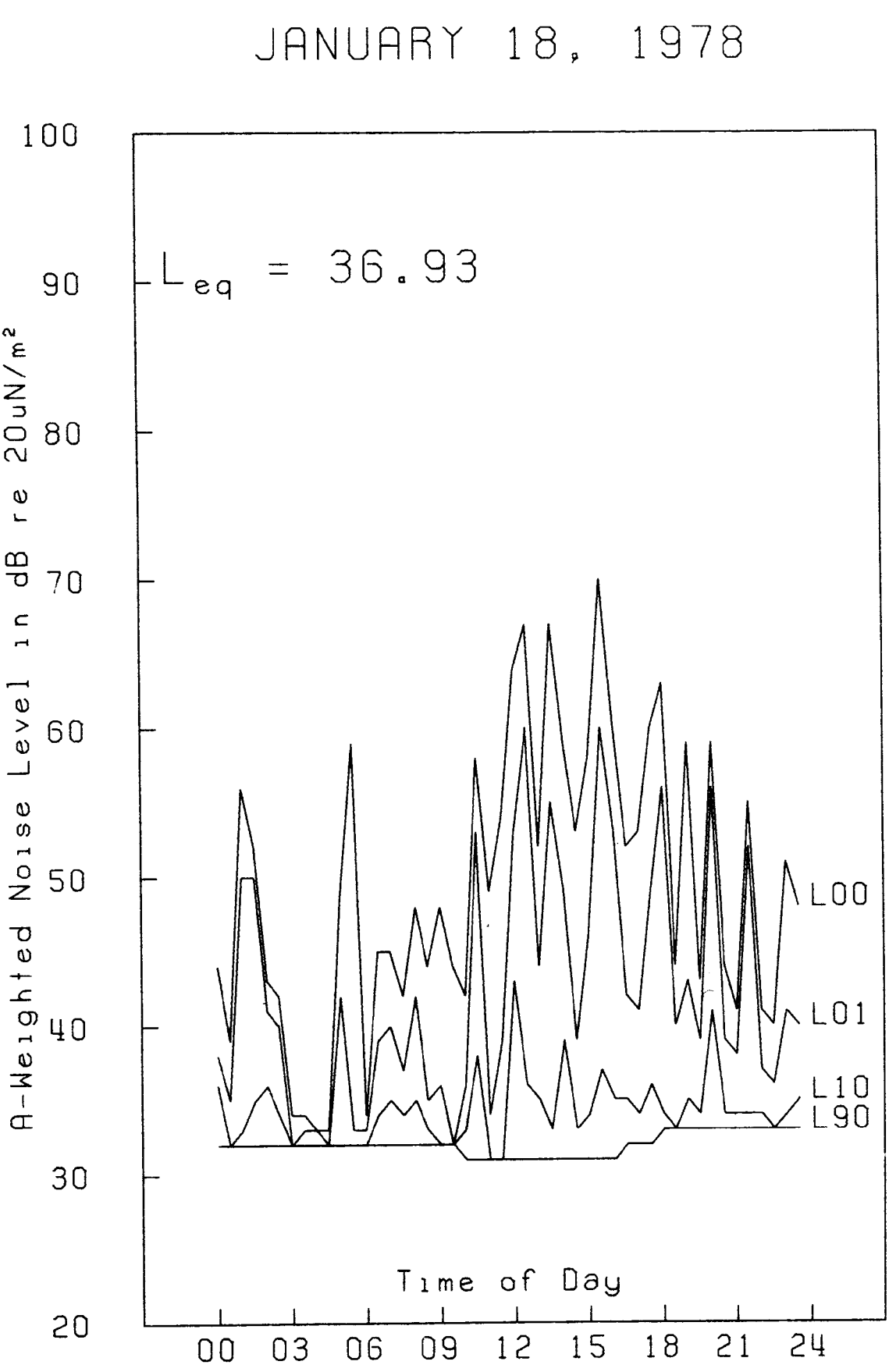


Fig. 3i. Sound Levels at Moose Measured by System A

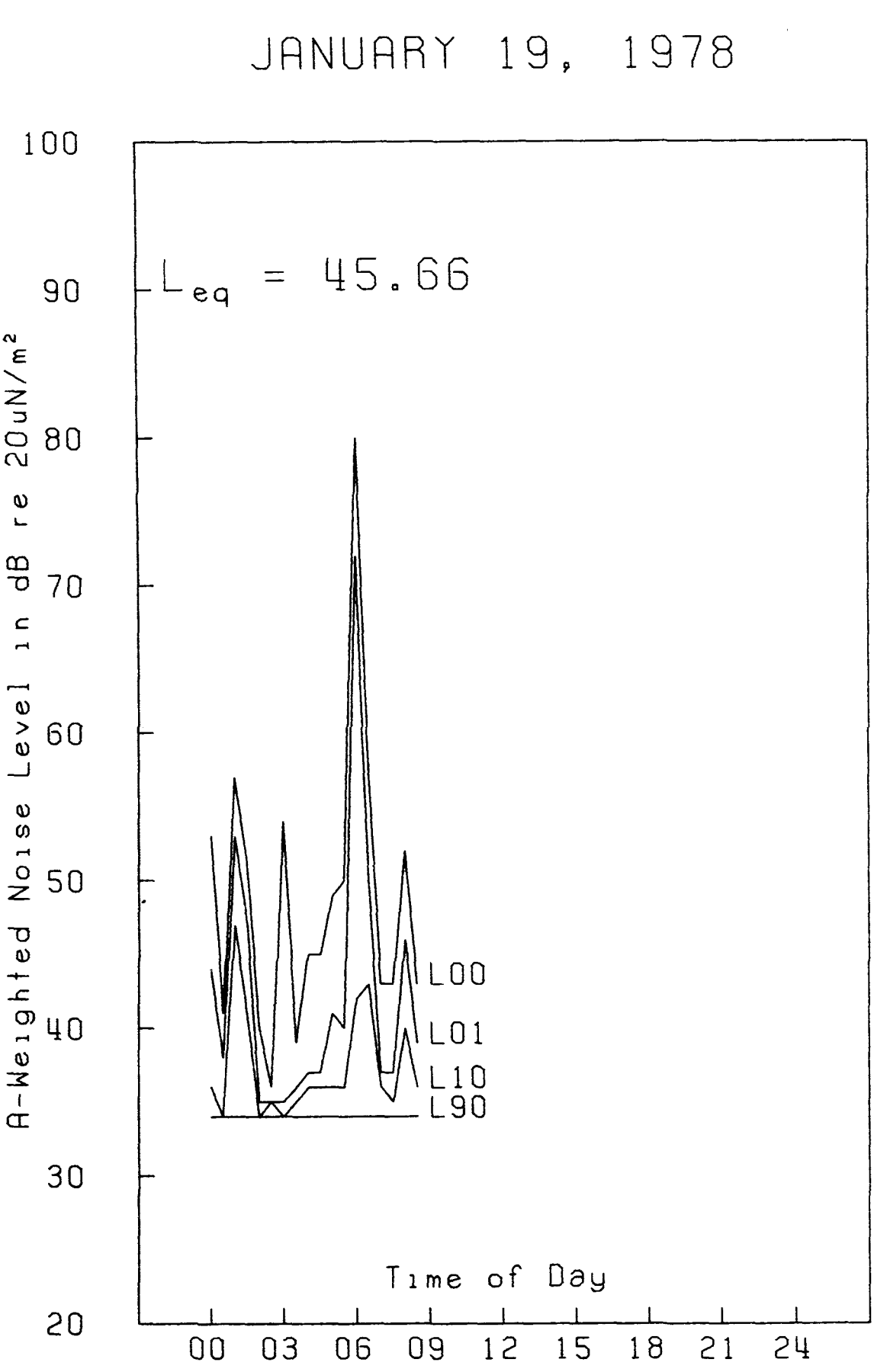


Fig. 3j. Sound Levels at Moose Measured by System A

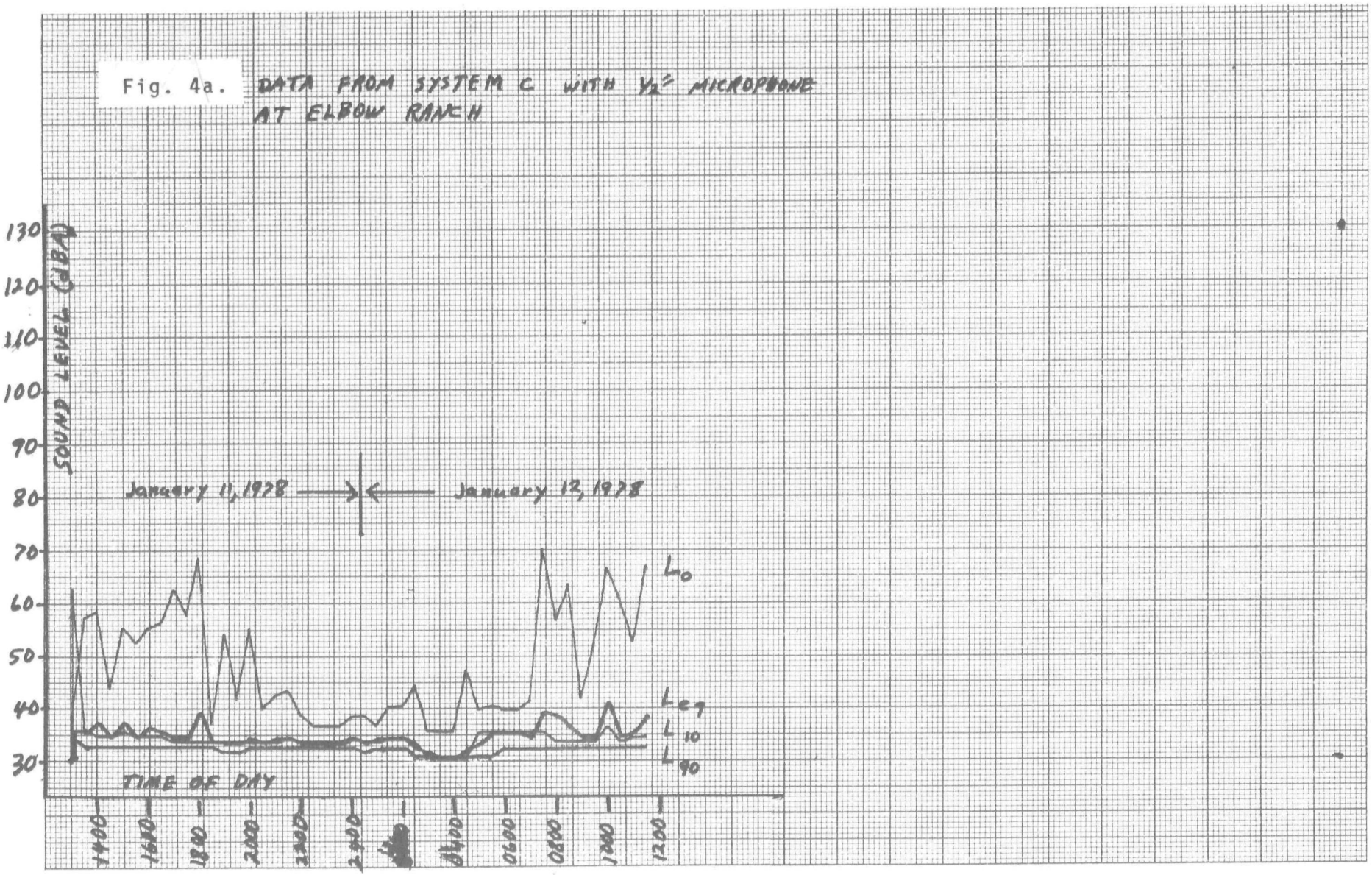


Fig. 4a. DATA FROM SYSTEM C WITH ½" MICROPHONE AT ELBOW RANCH
SOUND LEVEL (dBA)
130
120
110
100
90
80
70
60
50
40
30
January 11, 1978
January 12, 1978
L_0
L_{eq}
L_{10}
L_{90}
TIME OF DAY
1400
1600
1800
2000
2200
2400
0400
0600
0800
1000
1200

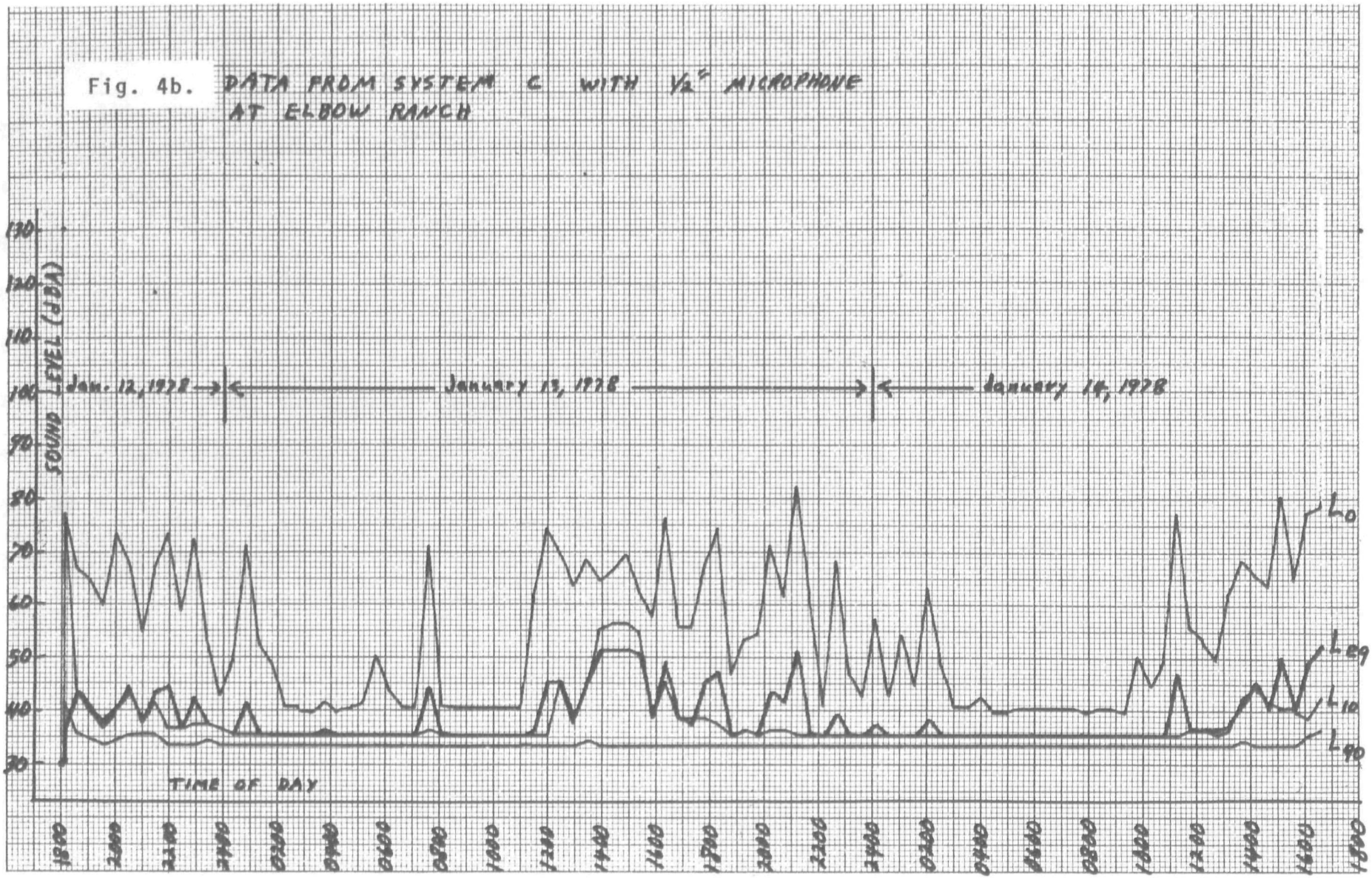
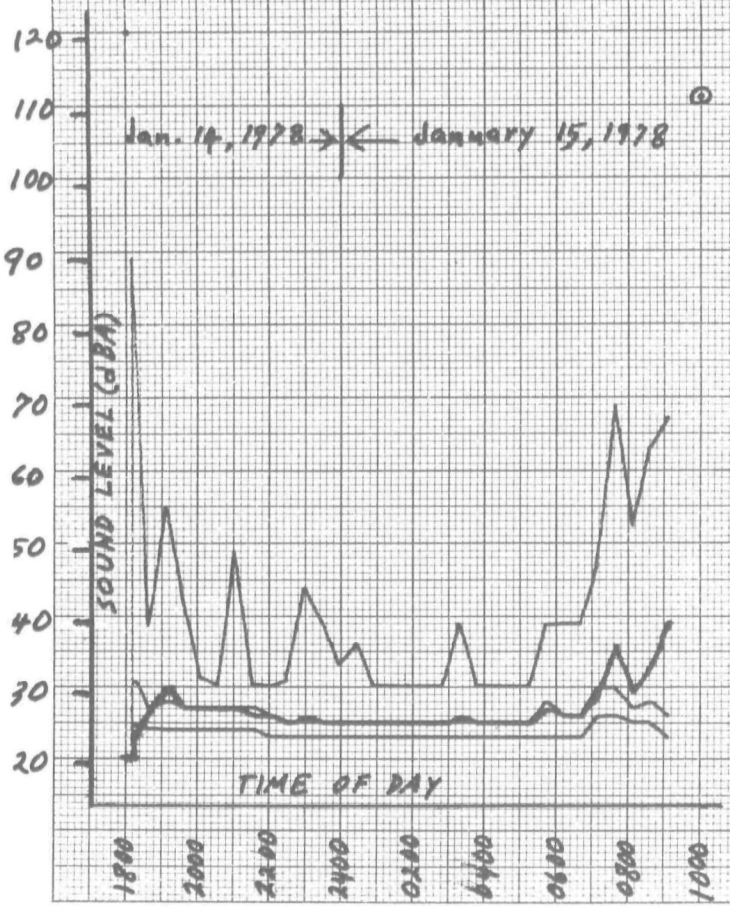


Fig. 4b. DATA FROM SYSTEM C WITH ½" MICROPHONE AT ELBOW RANCH
SOUND LEVEL (dBA)
130
120
110
100
90
80
70
60
50
40
30
Jan. 12, 1978
January 13, 1978
January 14, 1978
L_0
L_{eq}
L_{10}
L_{90}
TIME OF DAY

Fig. 4c. DATA FROM SYSTEM C WITH 1st MICROPHONE AT ELBOW RANCH



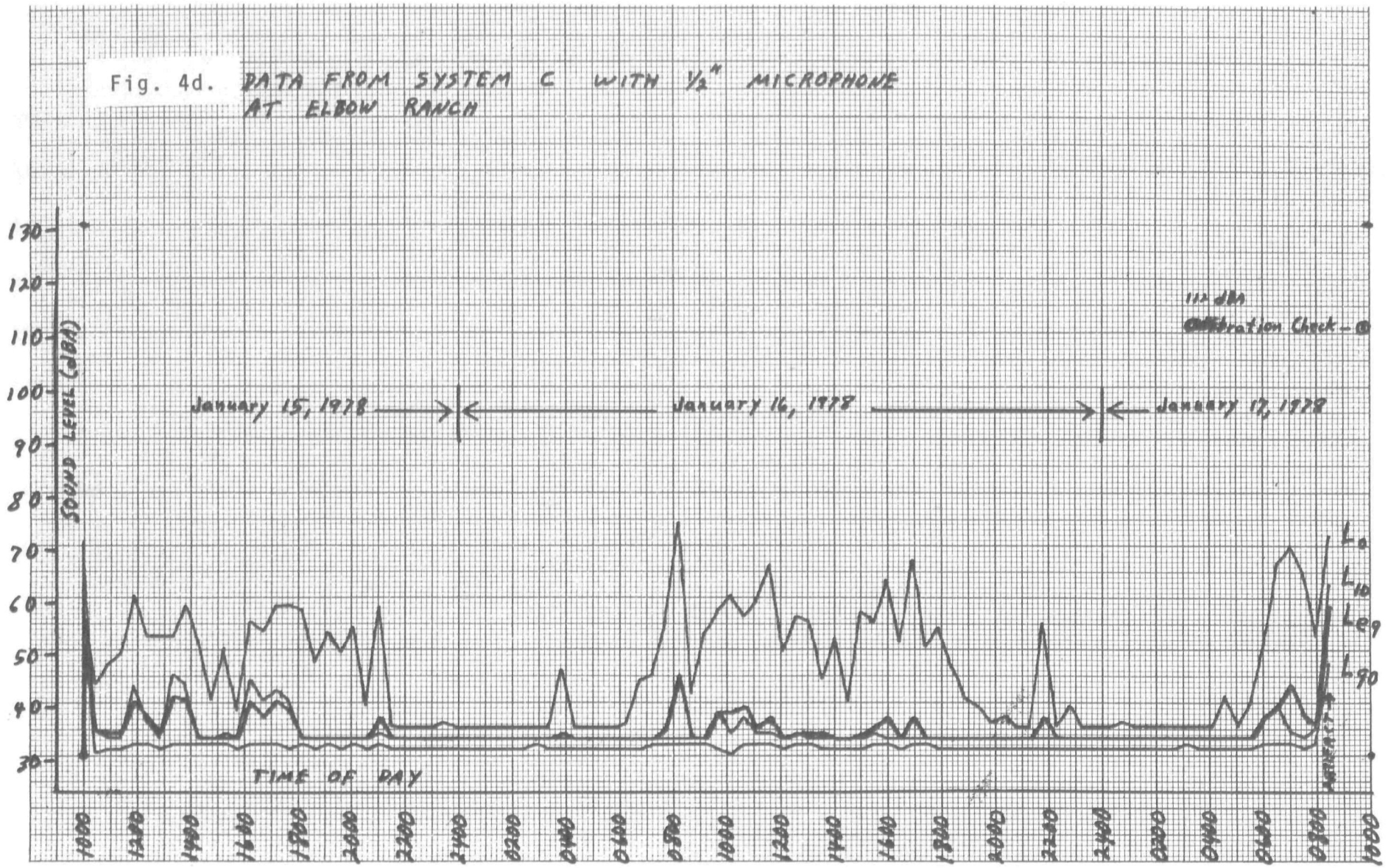
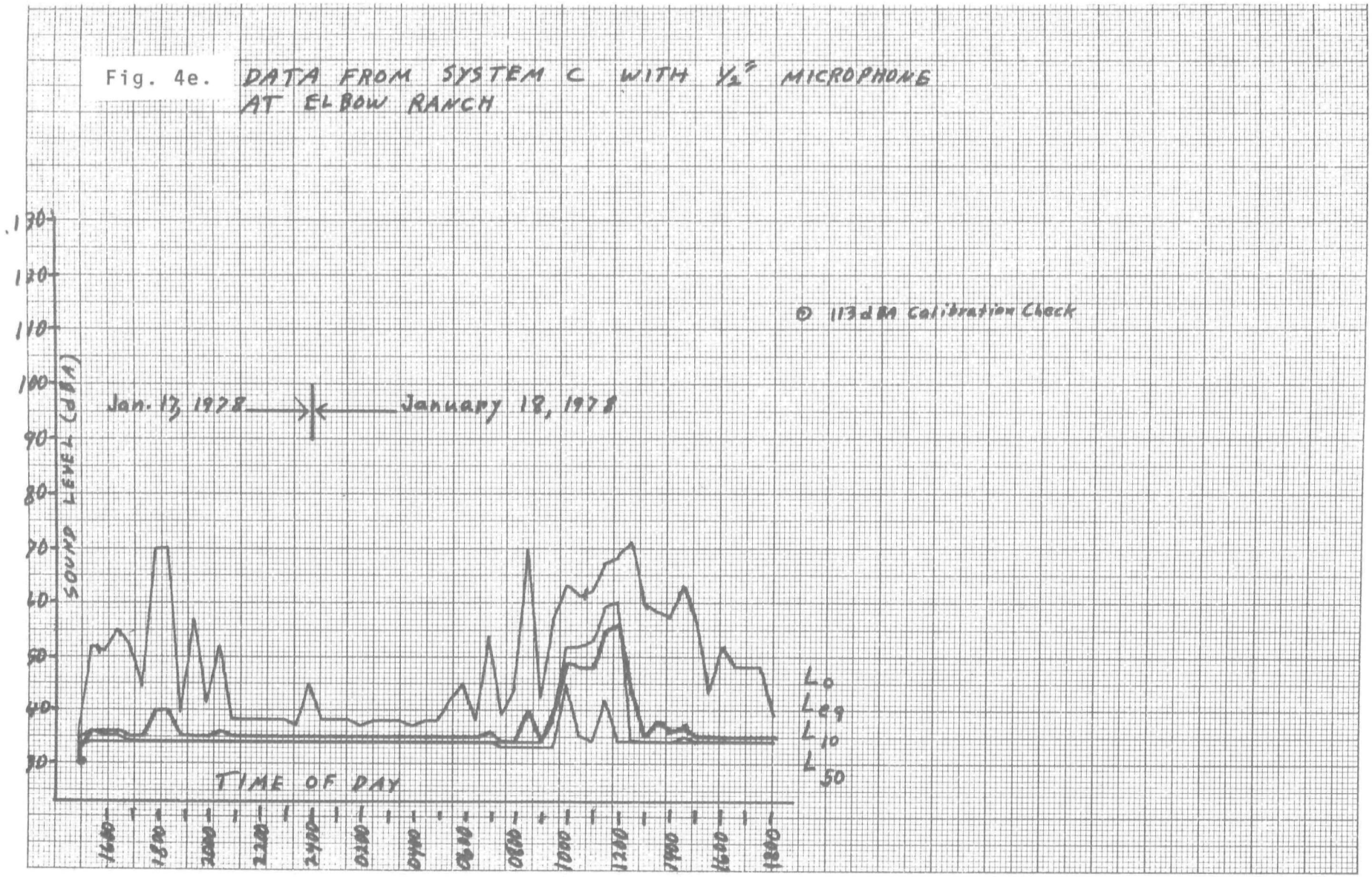


Fig. 4d. DATA FROM SYSTEM C WITH ½" MICROPHONE AT ELBOW RANCH
SOUND LEVEL (dBA)
130
120
110
100
90
80
70
60
50
40
30
112 dBA
Calibration Check
January 15, 1978
January 16, 1978
January 17, 1978
L_a
L_{10}
L_{eq}
L_{90}
TIME OF DAY
1000
1200
1400
1600
1800
2000
2200
2400
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
0200
0400
0600
0800
1000

Fig. 4e. DATA FROM SYSTEM C WITH ½" MICROPHONE AT ELBOW RANCH



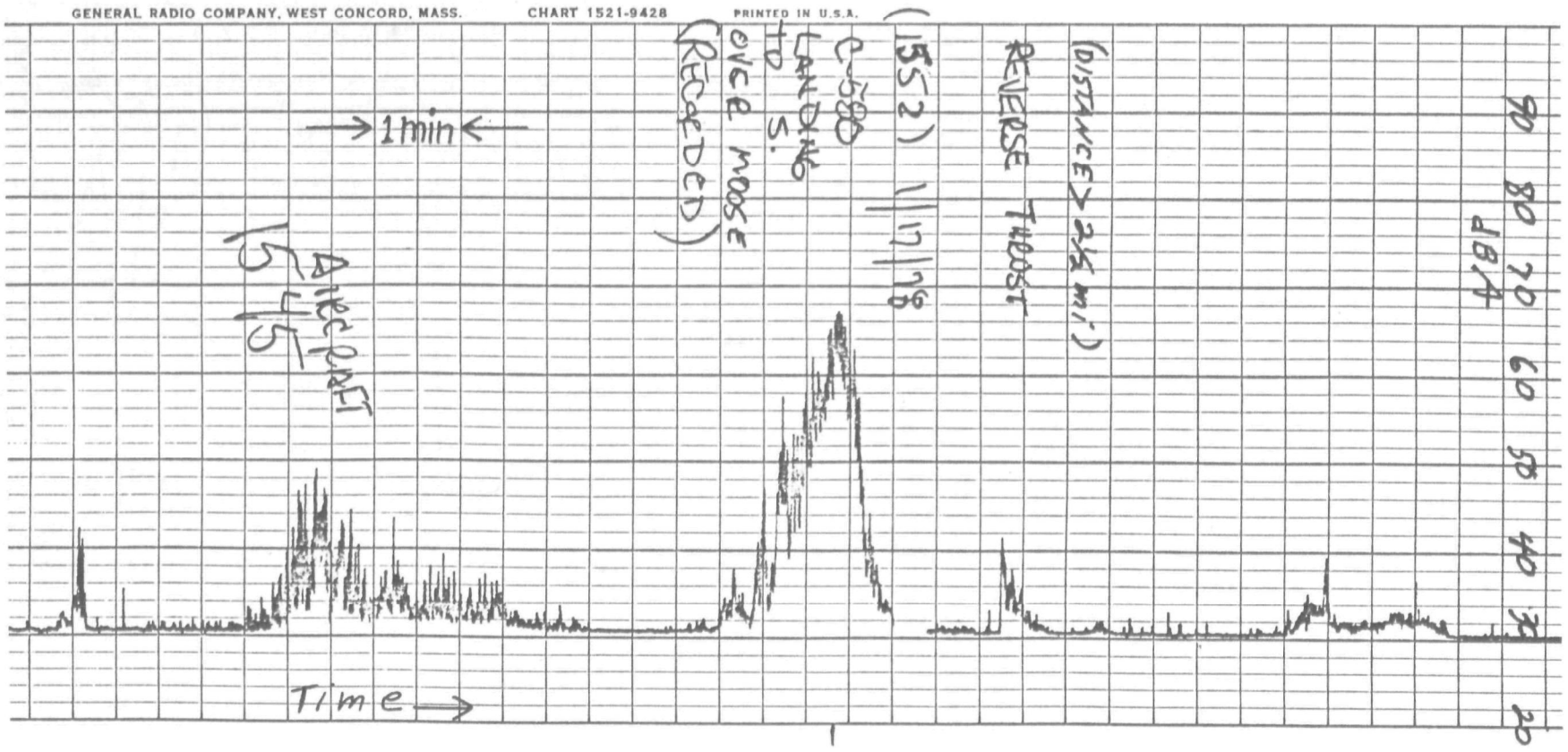


Fig. 5a. Sample Graphic Level Recording at Moose

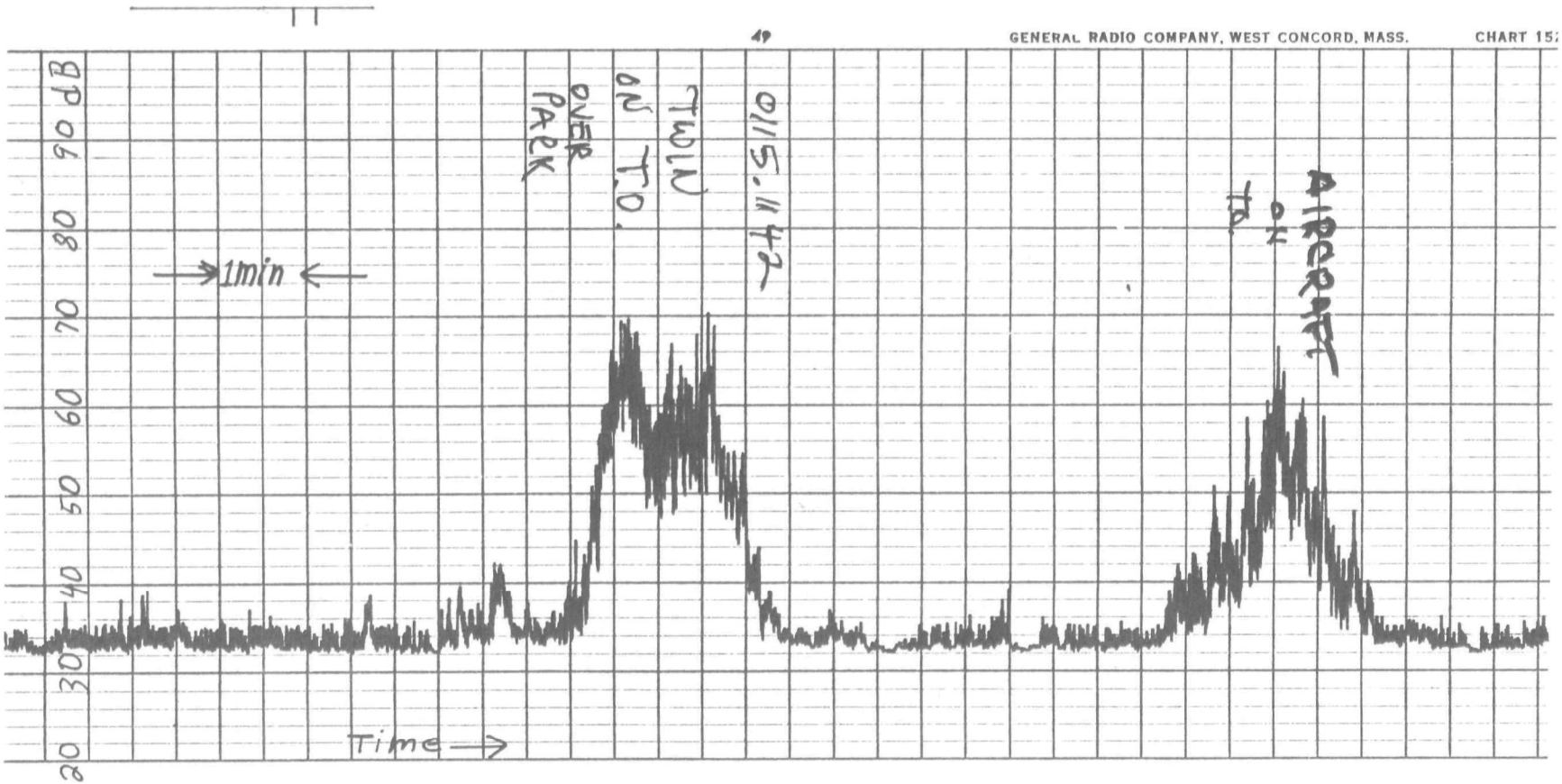


Fig. 5b. Sample Graphic Level Recording at Moose

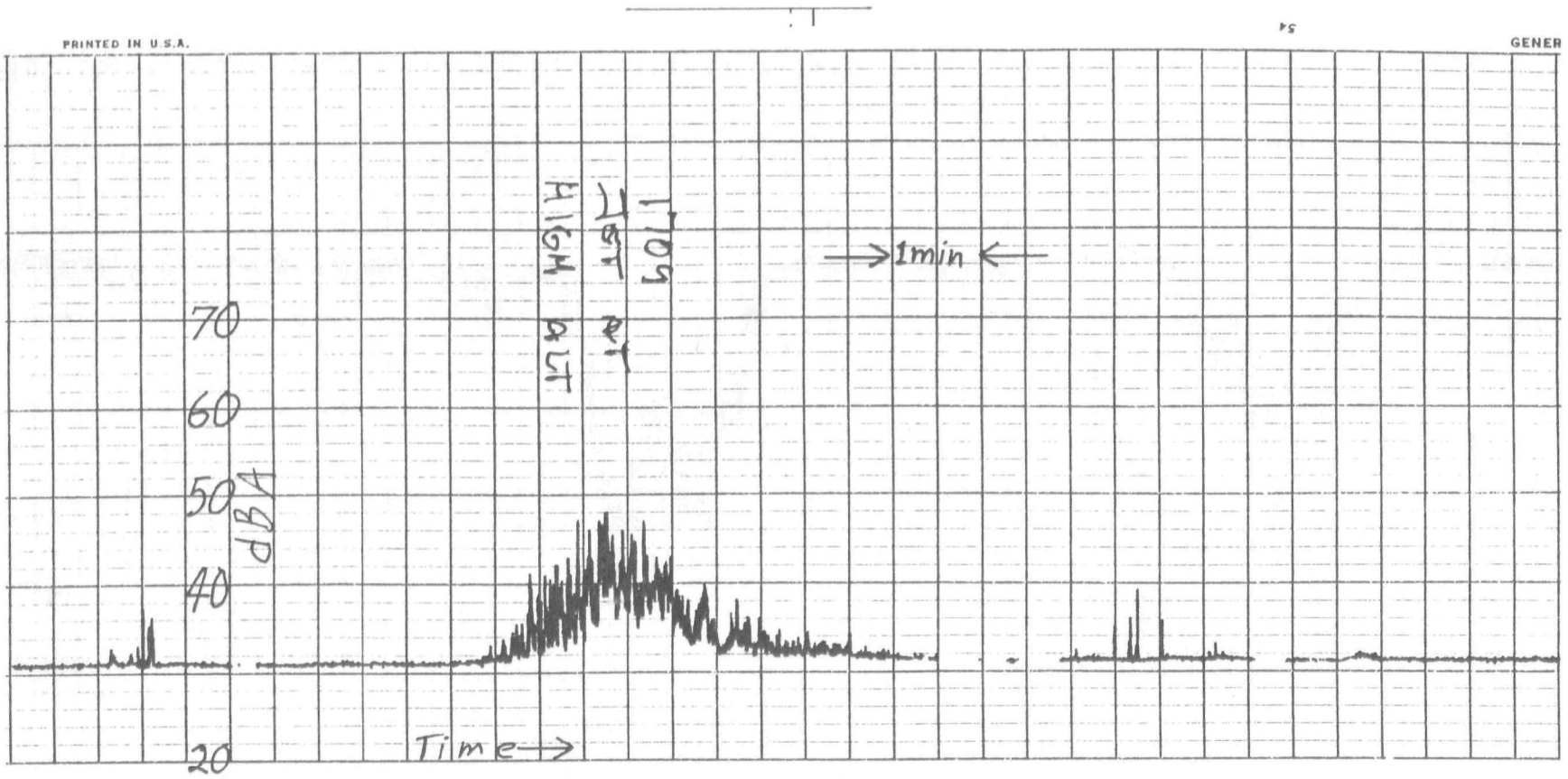


Fig. 5c. Sample Graphic Level Recording at Moose

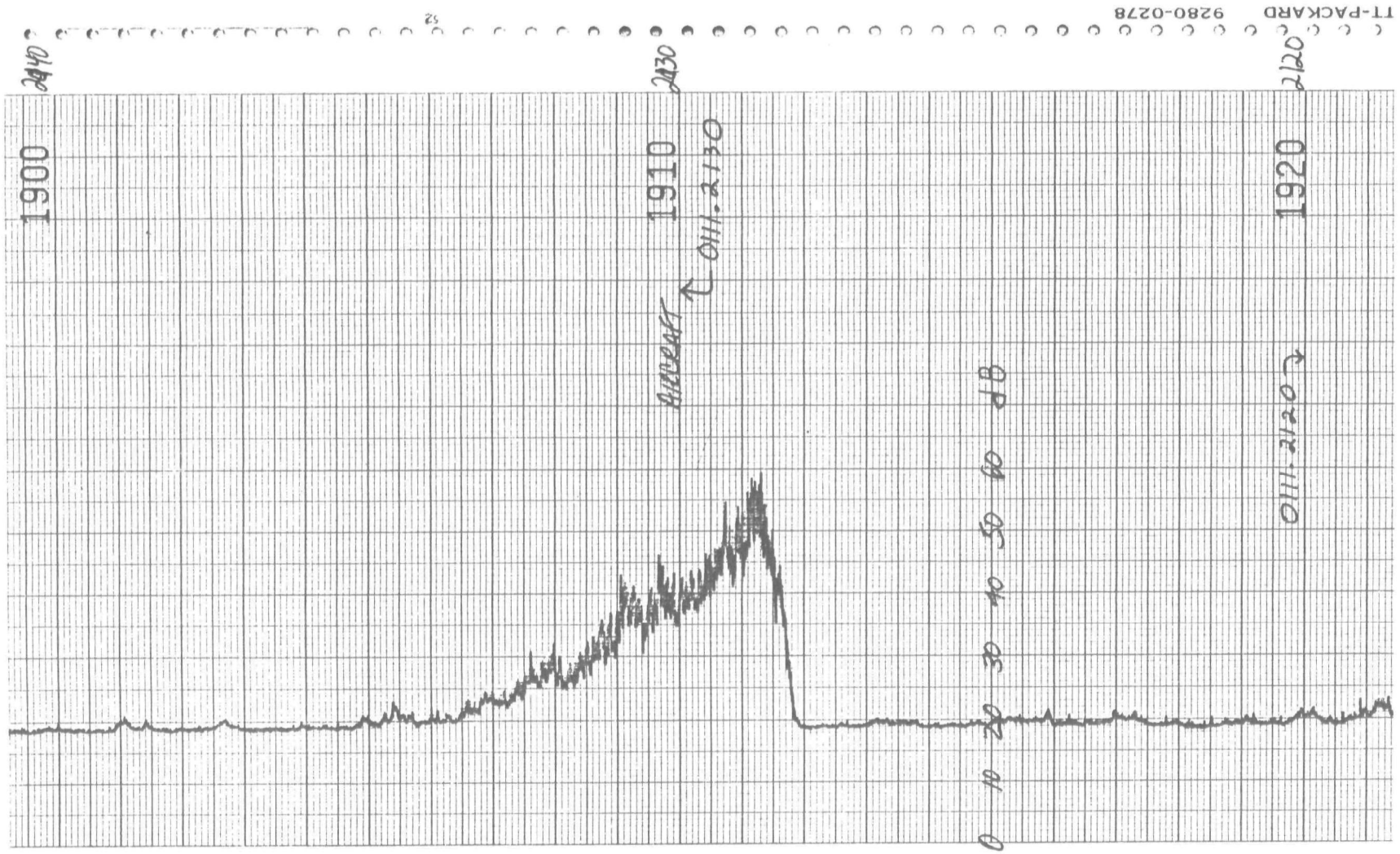


Fig. 5d. Sample Strip Chart Recording at Moran Village

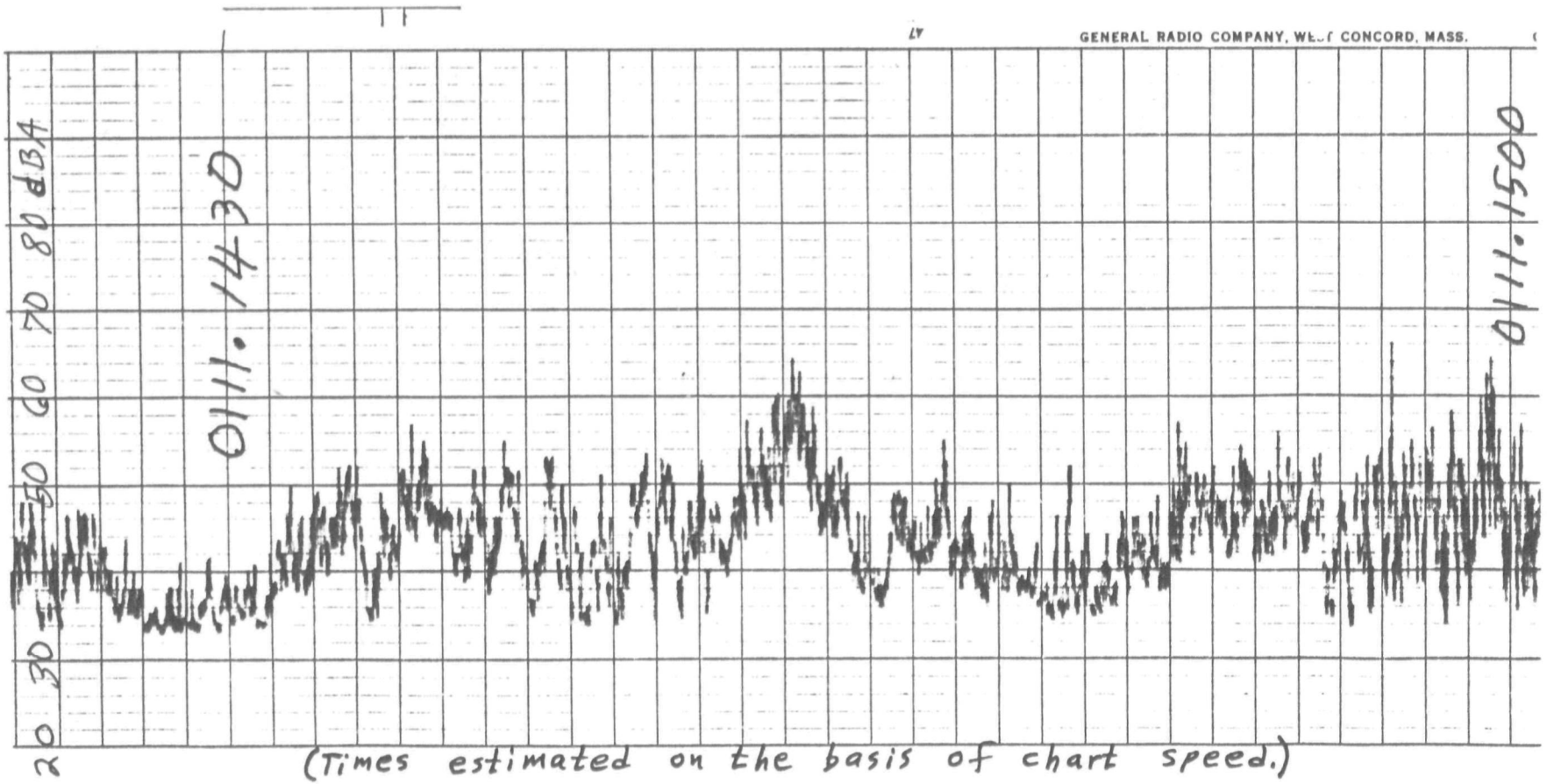


Fig. 5e. Graphic Level Recording on a Windy Day

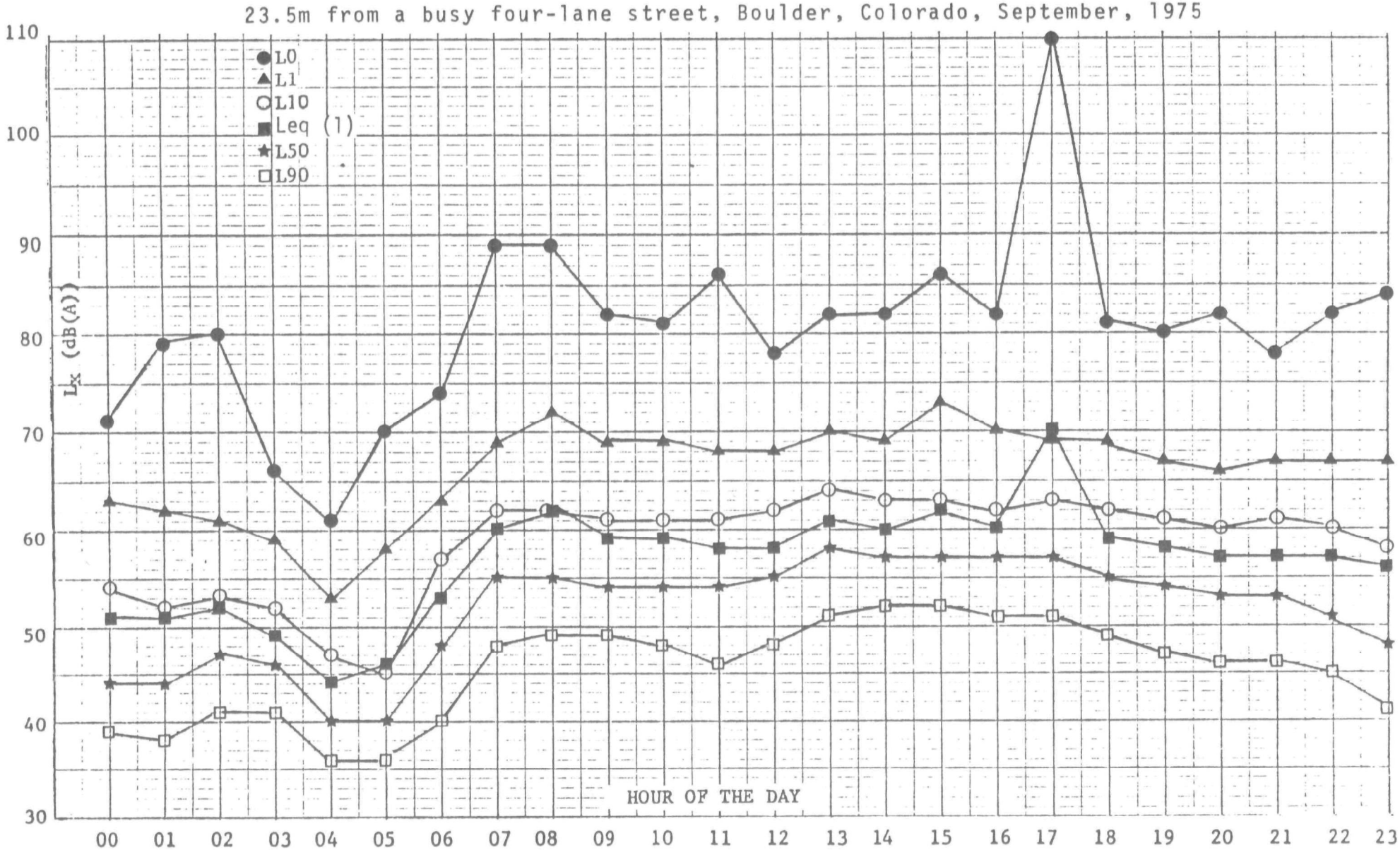


Fig. 6. City Noise Included for Comparison

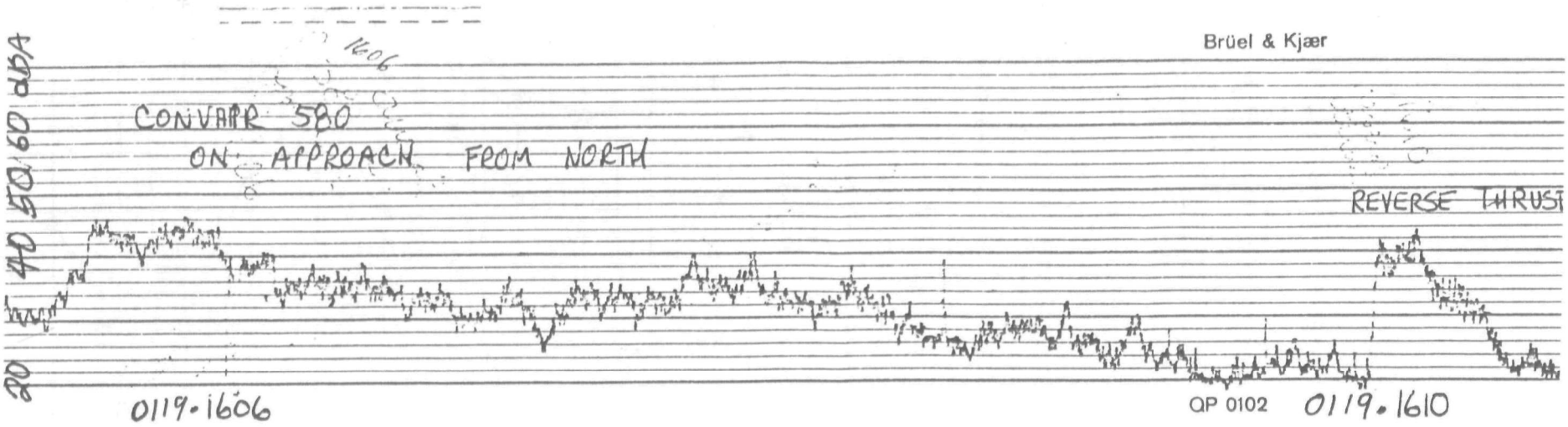


Fig. 7. Sample Graphic Level Recording above Taggert Lake

Table 1. Weather at Elbow Ranch [1]

DATE (1978)	MAXIMUM TEMP. (°F)	(°C)	MINIMUM TEMP. (°F)	(°C)	BAROMETER (cm of Hg)	NEW SNOW DEPTH (cm)	SKY
0109	36	2	10	-12	76.3	0	Pt. Cldy
0110	34	1	12	-11	75.8	0	Cloudy
0111	32	0	19	-7	75.8	3	Cloudy
0112	35	2	21	-6	76.1	4	Cloudy
0113	37	3	14	-10	76.8		Pt. Cldy
0114	34	1	12	-11	76.4	3.8	Cloudy
0115	32	0	20	-7	75.3		Cloudy
0116	34	1	19	-7	75.6	8.0	Cloudy
0117	40	4	18	-8	75.5	5.8	Cloudy
0118					76.2	2.0	Cloudy

* Based on records of the Teton Science School, Box 68, Kelly, Wyoming 83011

TABLE 2. Weather Moose

DATE & TIME (1978) FROM	TO	TEMP.(°C)	WIND FROM	AVG. WIND SPEED (km/h)	L_W(dB)**
0113.2005	0113.2400	-9	N	4	32
0114.000	0114.0315	-9	N	5	32
.0330	.0530	-10	NNE	8	32
.0530	.0800	-10	NNE	6	32
.0800	.1150	-10 to 3	NNW	4	32
.1150	.1550	-3 to 1	NE	4	32
.1550	.2100	-4 to -3	variable	3	32
.2100	0115.0210	-4	N	3	32
0115.0210	.0615	-5	variable	4	32
.0615	.0815	-5	variable	8	32
.0815	.1000	-4	variable	9	33
.1000	.1110	-4	N	14	38
.1110	.1315	-4 to -3	NE	8	32
.1315	.1455	-3	NE	10	33
.1455	.1620	-3	N	11	35
.1620	.1830	-4	N	7	32
.1830	.2130	-4	NNE	5	32
.2130	0116.0350	-4	variable	3	32
0116.0350	.0730	-4	variable	4	32
.0730	.0955	-4	SSW	7	32
.0955	.1140	-3	SSW	9	33
.1140	.1320	-2	SSW	10	33
.1320	.1455	-2	SSW	10	34
.1455	.1650	-2	SSW	8	33
.1650	.1845	-2	SSW	8	33
.1845	.2020	-3	SSW	10	34
.2020	.2115	-4	SSW	18	44
.2115	.2305	-4	SSW	9	33
.2305	0116.0045	-4	S	10	33
0117.0045	.0220	-4	S	10	34
.0220	.0355	-4	S	10	34
.0355	.0600	-5	S	8	32
.0600	.0800	-4	S	8	32
.0800	.1215	-5 to 4	ENE	4	32
.1215	.1640	-2	variable	4	32
.1640	0118.0100	-3 to -2	variable	2	32
0118.0100	.0310	-5 to -4	variable	0	32
.0310	.0610	-4	N	1	32
.0610	.1000	-5 to -4	N	4	32
.1000	.1310	-5 to 2	variable	5	32

*Based on portable weather station records
** Assumed wind-induced microphone noise for System A plus internal electronic noise at the stated average wind speed. Gusts not accounted for.

TABLE 2. (Continued)

FROM & TIME (1978) FROM	TO	TEMP. (°C)	WIND FROM	AVG. WIND SPEED (km/h)	L_W(dB)[2]
.1310	.1530	0 to 2	S	7	32
.1530	.1730	-5 to 1	S	4	32
.1730	.2210	-11 to -5	VARIABLE	2	32
.2210	0119.0210	-18 to -11	VARIABLE	2	32
0119.0210	.0325	-18 to -17	N	7	32
.0325	.0505	-17 to -16	N	10	33
.0505	.0645	-16	NNE	10	33
.0645	.0810	-17	N	11	35
.0810	.0945	-17	N	10	34

TABLE 3. Results of Measurements for Extended Periods

DATE & TIME (1978) START FROM	STOP TO	SITE	DAY HRS.	DAY L_{eq}	NIGHT HRS.	NIGHT L_{eq}	COMBINED L_{dn}
SYSTEM A							
0110.2200	0111.1200	Moose	5	44	9	35	14	40	--
0111.1200	0112.0030	Moose	9	52	2.5	41	11.5	51	--
0112.1600	0113.1200	Moose	11	41	9	38	20	40	45
0113.1200	0114.1200	Moose	13	42	9	33	22	40	42
0114.1200	0115.1200	Moose	13	39	9	33	22	38	41
0115.1200	0116.1030	Moose	13.5	51	9	34	22.5	49	50
0116.1630	0117.1200	Moose	10	48	9	37	19	46	48
0117.1200	0118.1200	Moose	15	39	9	36	24	38	43
0118.1200	0119.0900	Moose	12	39	9	46	21	43	51
							176	44.8	
SYSTEM B									
0111.1800	0112.0900	Moran	7	29	8	24	15	27	32
0112.1100	0113.1100	Moran	16	30	8	22	24	29	31
0113.1500	0114.1500	Moose	16	--	8	--	24	--	--
0114.1600	0115.1400	Moose	14	--	8	--	22	--	--
0116.1030	0117.1030	Beaver Creek	16	40	8	28	24	39	40
0117.1500	0118.1500	Elbow	16	32	8	21	24	30	32
							133		
SYSTEM C									
0111.1330	0112.1200	Elbow Barn	13.5	37	9	34	22.5	36	41
0112.1800	0113.1200	Elbow Barn	9	40	9	37	18	39	44
0113.1200	0114.1200	Elbow Barn	15	46	9	36	24	44	46
0114.1200	0115.1200	Elbow Barn	12.5	43	9	27	21.5	41	42
0115.1200	0116.1200	Elbow Barn	15	38	9	34	24	37	41
0116.1200	0117.0800	Elbow Barn	11	36	9	36	20	36	43
0117.1530	0118.1530	Elbow Barn	11.5	46	9	35	20.5	44	46
0118.1200	0118.1800	Elbow Barn	6	37	0	--	6	--	--

*L_o, L_{eq}, and L_{dn} affected by electromagnetic noise; therefore, not reported.

Table 4a. Sound Levels at Moose Measured by System A

JANUARY 10, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	22:00	34.322	0.	33.	34.	35.	41.	46.	52.
2	22:30	33.729	0.	33.	33.	34.	40.	46.	51.
3	23:00	34.629	0.	33.	33.	34.	44.	49.	56.
4	23:30	34.519	0.	33.	34.	35.	41.	45.	49.

SUMMARY: 4 OBSERVATIONS AND LEQ = 34.31

Table 4b. Sound Levels at Moose Measured by System A

JANUARY 11, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	00:00	33.462	0.	33.	33.	34.	37.	41.	52.
2	00:30	33.034	0.	33.	33.	33.	34.	34.	34.
3	01:00	33.339	0.	33.	33.	33.	38.	41.	43.
4	01:30	33.159	0.	33.	33.	33.	36.	40.	41.
5	02:00	33.009	0.	33.	33.	33.	34.	34.	34.
6	02:30	33.358	0.	32.	33.	34.	36.	38.	39.
7	03:00	35.386	0.	32.	33.	38.	42.	43.	44.
8	03:30	36.631	0.	32.	34.	40.	44.	48.	48.
9	04:00	32.732	0.	32.	33.	33.	35.	41.	49.
10	04:30	33.251	0.	32.	33.	35.	36.	37.	38.
11	05:00	32.668	0.	32.	32.	34.	36.	37.	38.
12	05:30	33.761	0.	32.	33.	35.	40.	46.	47.
13	06:00	40.829	0.	32.	36.	44.	51.	54.	55.
14	06:30	32.580	0.	32.	33.	33.	33.	33.	35.
15	07:00	33.582	0.	32.	33.	33.	34.	38.	66.
16	07:30	32.416	0.	32.	32.	33.	35.	38.	48.
17	08:00	33.555	0.	32.	33.	35.	37.	40.	42.
18	08:30	44.793	0.	32.	34.	48.	57.	58.	60.
19	09:00	37.461	0.	32.	33.	39.	49.	51.	53.
20	09:30	38.725	0.	32.	32.	38.	51.	54.	57.
21	10:00	32.241	0.	32.	32.	33.	35.	39.	48.
22	10:30	41.291	0.	32.	34.	44.	53.	58.	60.
23	11:00	52.789	0.	33.	35.	46.	65.	77.	80.
24	11:30	35.240	0.	32.	33.	38.	44.	48.	50.
25	12:00	41.377	0.	32.	33.	38.	55.	61.	65.
26	12:30	54.271	0.	35.	41.	54.	67.	74.	76.
27	13:00	55.535	0.	39.	45.	54.	70.	74.	76.
28	13:30	43.041	0.	36.	39.	46.	53.	58.	60.
29	14:00	48.115	0.	37.	45.	51.	57.	63.	67.
30	14:30	46.600	0.	37.	43.	50.	57.	61.	66.
31	15:00	44.181	0.	35.	41.	48.	53.	58.	64.
32	15:30	43.915	0.	34.	38.	47.	55.	60.	66.
33	16:00	62.307	0.	35.	45.	62.	76.	79.	81.
34	16:30	42.242	0.	34.	39.	46.	51.	54.	57.
35	17:00	44.842	0.	34.	40.	48.	55.	59.	63.
36	17:30	38.033	0.	33.	35.	41.	48.	51.	56.
37	19:00	34.171	0.	32.	33.	35.	40.	46.	57.
38	19:30	33.843	0.	32.	33.	35.	41.	45.	52.
39	20:00	36.065	0.	32.	33.	37.	46.	52.	57.
40	20:30	34.925	0.	32.	33.	36.	44.	49.	52.
41	21:00	35.954	0.	32.	33.	37.	46.	51.	60.
42	21:30	45.034	0.	33.	35.	47.	57.	64.	69.
43	22:00	38.060	0.	32.	33.	39.	50.	55.	57.
44	22:30	35.768	0.	33.	33.	37.	45.	52.	59.
45	23:00	42.061	0.	32.	33.	41.	53.	64.	67.
46	23:30	43.569	0.	33.	35.	46.	55.	64.	68.

SUMMARY: 46 OBSERVATIONS AND LEQ = 48.10

L_{dn} = 49.21

Table 4c. Sound Levels at Moose Measured by System A

JANUARY 12, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	00:00	42.987	0.	33.	35.	46.	55.	60.	64.
2	16:00	45.710	0.	33.	36.	43.	59.	67.	72.
3	16:30	49.761	0.	40.	47.	54.	57.	62.	66.
4	17:00	43.412	0.	34.	38.	47.	54.	57.	68.
5	17:30	39.624	0.	33.	35.	43.	51.	54.	58.
6	18:00	38.717	0.	34.	35.	40.	49.	55.	59.
7	18:30	39.708	0.	33.	35.	42.	51.	56.	60.
8	19:00	36.813	0.	33.	34.	39.	47.	51.	56.
9	19:30	37.121	0.	32.	33.	39.	48.	53.	60.
10	20:00	36.491	0.	32.	33.	39.	46.	50.	63.
11	20:30	33.432	0.	32.	32.	34.	40.	45.	50.
12	21:00	34.582	0.	32.	33.	36.	43.	48.	50.
13	21:30	33.502	0.	32.	33.	35.	40.	43.	48.
14	22:00	39.618	0.	33.	34.	42.	50.	56.	61.
15	22:30	35.404	0.	32.	33.	37.	45.	49.	55.
16	23:00	34.092	0.	32.	33.	35.	41.	47.	52.
17	23:30	36.838	0.	32.	33.	38.	47.	55.	63.

SUMMARY: 17 OBSERVATIONS AND LEQ = 41.52

Table 4d. Sound Levels at Moose Measured by System A

JANUARY 13, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	00:00	40.016	0.	32.	34.	44.	50.	54.	57.
2	00:30	46.294	0.	35.	43.	50.	56.	59.	63.
3	01:00	40.828	0.	32.	34.	45.	51.	55.	56.
4	01:30	35.973	0.	32.	33.	38.	46.	51.	57.
5	02:00	34.064	0.	32.	33.	35.	42.	47.	52.
6	02:30	34.408	0.	32.	33.	36.	43.	48.	52.
7	03:00	37.124	0.	33.	33.	39.	47.	53.	56.
8	03:30	38.637	0.	32.	34.	41.	49.	54.	61.
9	04:00	35.990	0.	32.	33.	37.	46.	53.	59.
10	04:30	34.345	0.	32.	33.	35.	43.	49.	52.
11	05:00	32.743	0.	32.	33.	33.	36.	39.	43.
12	05:30	33.917	0.	33.	33.	35.	41.	44.	47.
13	06:00	37.512	0.	33.	34.	39.	48.	53.	56.
14	06:30	36.834	0.	33.	34.	39.	46.	50.	52.
15	07:00	33.151	0.	33.	33.	34.	35.	38.	40.
16	07:30	33.254	0.	33.	33.	34.	37.	40.	41.
17	08:00	33.511	0.	33.	33.	34.	37.	45.	50.
18	08:30	34.328	0.	33.	33.	36.	40.	43.	45.
19	09:00	33.783	0.	32.	33.	35.	38.	44.	57.
20	09:30	42.703	0.	32.	33.	43.	55.	63.	69.
21	10:00	32.892	0.	32.	32.	35.	37.	39.	43.
22	10:30	35.604	0.	31.	32.	33.	49.	52.	54.
23	11:00	41.635	0.	31.	33.	39.	56.	60.	63.
24	11:30	33.870	0.	31.	32.	35.	42.	50.	55.
25	12:00	39.663	0.	31.	32.	37.	51.	62.	67.
26	12:30	49.866	0.	32.	32.	39.	62.	73.	76.
27	13:00	36.982	0.	32.	33.	39.	47.	52.	62.
28	13:30	47.113	0.	33.	35.	44.	60.	69.	74.
~~29~~	~~14:00~~	~~43.408~~	~~0.~~	~~33.~~	~~36.~~	~~46.~~	~~55.~~	~~60.~~	~~64.~~
~~30~~	~~14:30~~	~~54.809~~	~~0.~~	~~34.~~	~~36.~~	~~50.~~	~~66.~~	~~77.~~	~~84.~~
~~31~~	~~15:00~~	~~41.236~~	~~0.~~	~~33.~~	~~35.~~	~~44.~~	~~52.~~	~~57.~~	~~60.~~
32	15:30	48.763	0.	33.	35.	43.	63.	69.	76.
33	16:00	47.118	0.	33.	34.	42.	61.	69.	72.
34	16:30	34.380	0.	32.	33.	36.	42.	48.	51.
35	17:00	38.077	0.	32.	33.	39.	49.	55.	62.
36	17:30	34.078	0.	32.	33.	34.	39.	46.	65.
37	18:00	35.959	0.	32.	33.	40.	43.	46.	60.
38	18:30	32.823	0.	32.	33.	33.	34.	37.	40.
39	19:00	33.015	0.	33.	33.	33.	34.	35.	44.
40	19:30	39.761	0.	33.	33.	36.	52.	61.	64.
41	20:00	42.447	0.	33.	34.	36.	55.	65.	66.
42	20:30	43.783	0.	33.	34.	39.	56.	66.	68.
43	21:00	34.221	0.	33.	34.	35.	37.	39.	40.
44	21:30	33.713	0.	33.	34.	34.	36.	41.	47.
45	22:00	34.430	0.	34.	34.	35.	39.	42.	50.
46	22:30	34.172	0.	33.	33.	35.	41.	45.	47.
47	23:00	33.065	0.	33.	33.	33.	34.	36.	37.
48	23:30	33.204	0.	33.	33.	34.	34.	35.	37.

SUMMARY: ~~48~~ 45 OBSERVATIONS AND LEQ = ~~42.59~~ 40.75

L_{dn} = 45.33

Table 4e. Sound Levels at Moose Measured by System A

JANUARY 14, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	00:00	32.995	0.	33.	33.	33.	33.	33.	35.
2	00:30	33.152	0.	33.	33.	33.	36.	40.	41.
3	01:00	32.990	0.	33.	33.	33.	33.	34.	35.
4	01:30	33.004	0.	33.	33.	33.	34.	34.	41.
5	02:00	33.001	0.	33.	33.	33.	33.	34.	35.
6	02:30	33.176	0.	33.	33.	34.	34.	36.	38.
7	03:00	33.182	0.	33.	33.	34.	35.	36.	39.
8	03:30	34.181	0.	33.	34.	35.	39.	43.	50.
9	04:00	33.396	0.	33.	33.	34.	35.	36.	38.
10	04:30	33.081	0.	33.	33.	33.	34.	34.	36.
11	05:00	33.273	0.	33.	33.	34.	35.	36.	38.
12	05:30	33.295	0.	33.	33.	34.	35.	35.	37.
13	06:00	33.007	0.	33.	33.	33.	33.	34.	35.
14	06:30	33.151	0.	33.	33.	34.	35.	37.	39.
15	07:00	33.229	0.	33.	33.	34.	35.	38.	40.
16	07:30	33.134	0.	33.	33.	33.	35.	37.	39.
17	08:00	33.459	0.	33.	33.	34.	37.	43.	48.
18	08:30	34.182	0.	33.	33.	35.	39.	45.	58.
19	09:00	35.447	0.	32.	33.	34.	45.	54.	60.
~~20~~	~~09:30~~	~~38.026~~	~~0.~~	~~32.~~	~~33.~~	~~35.~~	~~41.~~	~~60.~~	~~69.~~
21	10:00	32.479	0.	32.	32.	33.	38.	41.	43.
22	10:30	42.194	0.	32.	32.	34.	53.	65.	68.
23	11:00	37.230	0.	31.	32.	38.	50.	54.	58.
24	11:30	38.698	0.	31.	32.	40.	51.	57.	60.
25	12:00	42.838	0.	31.	32.	34.	55.	66.	68.
26	12:30	40.009	0.	32.	33.	40.	52.	59.	64.
27	13:00	44.342	0.	31.	32.	38.	60.	64.	66.
28	13:30	44.520	0.	32.	33.	43.	57.	66.	70.
29	14:00	42.613	0.	32.	33.	43.	56.	62.	66.
30	16:30	35.495	0.	32.	33.	35.	45.	53.	56.
31	17:00	33.670	0.	33.	33.	34.	35.	47.	61.
32	17:30	33.073	0.	33.	33.	33.	34.	36.	41.
33	18:00	35.639	0.	33.	33.	34.	46.	56.	58.
34	18:30	34.439	0.	33.	33.	33.	46.	50.	52.
35	19:00	33.882	0.	33.	33.	34.	38.	48.	52.
36	20:00	32.861	0.	32.	33.	34.	34.	39.	50.
37	20:30	32.217	0.	32.	32.	33.	35.	37.	44.
38	21:00	32.071	0.	32.	32.	32.	33.	34.	36.
39	21:30	32.844	0.	32.	33.	33.	34.	35.	36.
40	22:00	32.974	0.	33.	33.	33.	33.	34.	36.
41	22:30	33.237	0.	33.	33.	34.	35.	39.	41.
42	23:00	33.005	0.	33.	33.	33.	33.	34.	35.
43	23:30	33.057	0.	33.	33.	33.	34.	35.	38.

SUMMARY: ~~43~~ 42 OBSERVATIONS AND LEQ = ~~36.97~~ 36.94

L_{dn} = 40.87

Table 4f. Sound Levels at Moose Measured by System A

JANUARY 15, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	00:00	33.072	0.	33.	33.	33.	34.	35.	42.
2	00:30	33.238	0.	33.	33.	34.	35.	36.	37.
3	01:00	33.037	0.	33.	33.	33.	34.	34.	35.
4	01:30	33.029	0.	33.	33.	33.	34.	36.	37.
5	02:00	33.165	0.	33.	33.	34.	35.	37.	38.
6	02:30	33.016	0.	33.	33.	33.	34.	35.	35.
7	03:00	33.526	0.	33.	33.	33.	39.	43.	46.
8	03:30	33.774	0.	33.	34.	35.	36.	37.	38.
9	04:00	33.015	0.	33.	33.	33.	34.	34.	35.
10	04:30	32.895	0.	32.	33.	33.	33.	33.	34.
11	05:00	33.003	0.	33.	33.	33.	33.	35.	38.
12	05:30	32.857	0.	32.	33.	33.	34.	35.	36.
13	06:00	33.025	0.	33.	33.	33.	34.	34.	35.
14	06:30	33.725	0.	33.	33.	35.	37.	39.	41.
15	07:00	34.703	0.	33.	34.	36.	38.	42.	44.
16	07:30	34.307	0.	33.	34.	36.	40.	43.	46.
17	08:00	35.925	0.	33.	34.	37.	45.	49.	51.
18	08:30	35.253	0.	33.	34.	37.	41.	45.	53.
19	09:00	33.902	0.	33.	33.	35.	37.	41.	49.
20	09:30	33.655	0.	33.	33.	35.	37.	39.	46.
21	10:00	33.209	0.	32.	33.	34.	37.	41.	45.
22	10:30	43.105	0.	32.	33.	38.	57.	63.	66.
23	11:00	40.058	0.	32.	33.	36.	53.	61.	63.
24	11:30	47.002	0.	32.	33.	41.	61.	67.	69.
25	12:00	31.563	0.	32.	33.	36.	61.	75.	80.
26	12:30	35.552	0.	32.	33.	36.	46.	52.	56.
27	13:00	33.604	0.	32.	33.	35.	40.	45.	51.
28	13:30	34.901	0.	32.	33.	35.	45.	50.	54.
29	14:00	36.062	0.	32.	33.	36.	42.	55.	66.
30	14:30	48.906	0.	33.	34.	37.	44.	57.	88.
31	15:00	33.481	0.	32.	33.	35.	38.	41.	56.
32	15:30	44.490	0.	32.	33.	39.	58.	66.	68.
33	16:00	48.340	0.	32.	32.	38.	57.	70.	76.
34	16:30	34.780	0.	32.	32.	33.	35.	55.	65.
35	17:00	32.964	0.	32.	33.	33.	35.	42.	52.
36	17:30	32.876	0.	32.	33.	33.	35.	39.	44.
37	18:00	32.565	0.	32.	33.	33.	34.	34.	35.
38	18:30	32.381	0.	32.	32.	32.	34.	35.	41.
39	19:00	32.194	0.	32.	32.	32.	33.	34.	38.
~~40~~	~~19:30~~	~~33.388~~	~~0.~~	~~33.~~	~~33.~~	~~34.~~	~~36.~~	~~36.~~	~~37.~~
41	19:30	32.538	0.	32.	32.	33.	35.	38.	43.
42	20:00	33.110	0.	32.	33.	34.	38.	41.	43.
43	20:30	32.951	0.	32.	33.	34.	37.	41.	43.
44	21:00	33.140	0.	32.	33.	33.	34.	47.	51.
45	21:30	32.948	0.	32.	33.	33.	35.	38.	39.
46	22:00	32.623	0.	32.	33.	33.	33.	33.	34.
47	22:30	32.447	0.	32.	32.	33.	33.	34.	34.
48	23:00	32.040	0.	32.	32.	32.	33.	34.	34.
49	23:30	32.000	0.	32.	32.	32.	32.	32.	34.

SUMMARY: ~~49~~ 48 OBSERVATIONS AND LEQ = ~~38.55~~ 38.61

L_{dn} = 41.46

Table 4g. Sound Levels at Moose Measured by System A

JANUARY 16, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	00:00	32.237	0.	32.	32.	32.	35.	40.	48.
2	00:30	32.529	0.	32.	32.	33.	36.	43.	45.
3	01:00	32.031	0.	32.	32.	32.	33.	33.	34.
4	01:30	32.001	0.	32.	32.	32.	32.	33.	33.
5	02:00	32.013	0.	32.	32.	32.	33.	33.	34.
6	02:30	32.019	0.	32.	32.	32.	33.	33.	33.
7	03:00	32.015	0.	32.	32.	32.	33.	33.	33.
8	03:30	33.559	0.	32.	32.	33.	42.	48.	53.
9	04:00	33.633	0.	32.	32.	35.	41.	44.	48.
10	04:30	34.787	0.	33.	33.	36.	43.	47.	50.
11	05:00	36.164	0.	32.	33.	35.	48.	54.	59.
12	05:30	33.332	0.	32.	33.	34.	38.	42.	43.
13	06:00	40.574	0.	32.	32.	40.	55.	60.	62.
14	06:30	33.022	0.	32.	32.	34.	40.	46.	51.
15	07:00	32.149	0.	32.	32.	32.	33.	35.	49.
16	07:30	39.179	0.	32.	34.	38.	49.	60.	62.
17	08:00	37.751	0.	32.	34.	40.	47.	54.	61.
18	08:30	65.240	0.	35.	44.	67.	78.	82.	85.
19	09:00	36.216	0.	32.	34.	39.	45.	49.	50.
20	09:30	35.930	0.	32.	33.	39.	44.	51.	56.
21	10:00	45.765	0.	34.	40.	48.	57.	62.	65.
22	16:30	44.089	0.	32.	37.	46.	57.	61.	64.
23	17:00	41.252	0.	32.	33.	38.	53.	63.	68.
24	17:30	35.440	0.	32.	34.	38.	42.	47.	48.
25	18:00	33.499	0.	32.	32.	35.	41.	45.	51.
26	18:30	32.939	0.	32.	32.	33.	40.	47.	51.
27	19:00	37.811	0.	32.	33.	41.	48.	53.	57.
28	19:30	37.908	0.	32.	34.	41.	48.	53.	54.
29	20:00	38.675	0.	32.	35.	42.	49.	52.	55.
30	20:30	38.347	0.	32.	33.	41.	49.	54.	59.
31	21:00	39.914	0.	32.	34.	43.	51.	56.	61.
32	21:30	40.602	0.	33.	35.	44.	51.	54.	57.
33	22:00	38.614	0.	32.	34.	42.	49.	53.	59.
34	22:30	36.640	0.	33.	34.	39.	45.	49.	52.
35	23:00	38.161	0.	32.	34.	41.	49.	54.	57.
36	23:30	39.513	0.	33.	35.	43.	50.	55.	57.

SUMMARY: 36 OBSERVATIONS AND LEQ = 49.95

Table 4h. Sound Levels at Moose Measured by System A

JANUARY 17, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	00:00	35.243	0.	33.	33.	37.	44.	50.	56.
2	00:30	35.196	0.	32.	33.	36.	45.	51.	54.
3	01:00	33.607	0.	32.	33.	35.	40.	45.	48.
4	01:30	36.347	0.	32.	33.	39.	46.	51.	55.
5	02:00	33.255	0.	32.	33.	33.	38.	44.	51.
6	02:30	33.466	0.	32.	33.	34.	40.	45.	47.
7	03:00	34.713	0.	32.	33.	36.	43.	49.	55.
8	03:30	32.749	0.	32.	33.	33.	36.	40.	44.
9	04:00	34.997	0.	32.	33.	37.	43.	47.	53.
10	04:30	36.714	0.	33.	34.	39.	46.	49.	59.
11	05:00	32.759	0.	32.	32.	33.	36.	44.	52.
12	05:30	33.274	0.	32.	32.	34.	40.	45.	53.
13	06:00	42.724	0.	33.	35.	45.	54.	60.	63.
14	06:30	33.581	0.	32.	33.	35.	40.	44.	48.
15	07:00	33.273	0.	32.	33.	34.	38.	43.	45.
16	07:30	40.095	0.	32.	33.	36.	53.	62.	66.
17	08:00	32.527	0.	32.	32.	33.	36.	46.	53.
18	08:30	37.303	0.	32.	34.	40.	48.	54.	56.
19	09:00	60.526	0.	33.	42.	63.	73.	77.	80.
20	09:30	36.898	0.	32.	34.	41.	45.	48.	49.
21	10:00	32.560	0.	31.	32.	34.	38.	40.	46.
22	10:30	43.129	0.	31.	32.	36.	59.	63.	65.
~~23~~	~~11:00~~	~~43.162~~	~~0.~~	~~31.~~	~~32.~~	~~44.~~	~~56.~~	~~63.~~	~~69.~~
24	11:30	39.676	0.	31.	32.	41.	52.	58.	62.
25	12:00	34.028	0.	31.	31.	34.	44.	50.	61.
26	12:30	47.219	0.	31.	31.	41.	61.	67.	71.
27	13:00	48.513	0.	31.	31.	35.	39.	72.	77.
28	13:30	32.253	0.	30.	31.	33.	40.	45.	49.
29	14:00	40.668	0.	31.	31.	39.	54.	60.	69.
30	14:30	32.676	0.	31.	31.	32.	41.	49.	54.
31	15:00	34.197	0.	31.	31.	35.	44.	50.	56.
32	15:30	~~24.294~~[1]	0.	31.	31.	35.	59.	65.	67.
33	16:00	39.230	0.	31.	31.	34.	53.	58.	60.
34	16:30	33.452	0.	31.	32.	33.	40.	50.	57.
~~35~~	~~17:00~~	~~79.107~~	~~0.~~	~~32.~~	~~32.~~	~~40.~~	~~90.~~	~~90.~~	~~94.~~
36	17:30	32.224	0.	32.	32.	32.	34.	43.	48.
37	18:00	32.216	0.	32.	32.	32.	35.	39.	49.
38	18:30	32.117	0.	32.	32.	32.	33.	38.	45.
39	19:00	32.134	0.	32.	32.	33.	33.	33.	35.
40	19:30	38.449	0.	32.	32.	33.	52.	59.	62.
41	20:00	32.062	0.	32.	32.	32.	33.	37.	39.
42	20:30	31.979	0.	32.	32.	32.	32.	32.	32.
43	21:00	31.987	0.	32.	32.	32.	32.	33.	35.
44	21:30	44.375	0.	32.	33.	49.	56.	58.	59.
45	22:00	36.619	0.	32.	33.	37.	49.	52.	53.
46	22:30	43.650	0.	32.	32.	48.	56.	57.	59.
47	23:00	32.608	0.	32.	32.	32.	38.	42.	43.
48	23:30	40.245	0.	32.	32.	35.	54.	61.	62.

[1] 15:30 ~~48~~ 43.958

SUMMARY: ~~48~~ OBSERVATIONS AND LEQ = ~~62.37~~ 45.14

L_{dn} = 47.10

Table 4i. Sound Levels at Moose Measured by System A

JANUARY 18, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	00:00	33.824	0.	32.	33.	36.	38.	40.	44.
2	00:30	32.231	0.	32.	32.	32.	35.	37.	39.
3	01:00	36.268	0.	32.	32.	33.	50.	55.	56.
4	01:30	36.282	0.	32.	32.	35.	50.	51.	52.
5	02:00	33.591	0.	32.	32.	36.	41.	42.	43.
6	02:30	32.982	0.	32.	32.	34.	40.	41.	42.
7	03:00	32.003	0.	32.	32.	32.	32.	33.	34.
8	03:30	32.016	0.	32.	32.	32.	33.	33.	34.
9	04:00	32.018	0.	32.	32.	32.	33.	33.	33.
10	04:30	32.000	0.	32.	32.	32.	32.	32.	33.
11	05:00	33.248	0.	32.	32.	32.	42.	46.	49.
12	05:30	32.313	0.	32.	32.	32.	33.	39.	59.
13	06:00	32.025	0.	32.	32.	32.	33.	33.	34.
14	06:30	33.029	0.	32.	32.	34.	39.	44.	45.
15	07:00	33.366	0.	32.	32.	35.	40.	43.	45.
16	07:30	32.759	0.	32.	32.	34.	37.	39.	42.
17	08:00	34.611	0.	32.	33.	35.	42.	45.	48.
18	08:30	32.253	0.	32.	32.	33.	35.	38.	44.
19	09:00	32.291	0.	32.	32.	32.	36.	42.	46.
20	09:30	31.992	0.	32.	32.	32.	32.	35.	44.
21	10:00	32.146	0.	31.	32.	33.	36.	40.	42.
22	10:30	39.097	0.	31.	31.	38.	53.	56.	58.
23	11:00	31.418	0.	31.	31.	31.	34.	44.	49.
24	11:30	32.556	0.	31.	31.	31.	39.	50.	54.
25	12:00	41.023	0.	31.	31.	43.	53.	58.	64.
26	12:30	45.029	0.	31.	31.	36.	60.	66.	67.
27	13:00	33.992	0.	31.	32.	35.	44.	49.	52.
28	13:30	42.080	0.	31.	31.	33.	55.	65.	67.
29	14:00	37.086	0.	31.	31.	39.	49.	56.	59.
30	14:30	32.580	0.	31.	31.	33.	39.	47.	53.
31	15:00	35.319	0.	31.	32.	34.	46.	54.	58.
32	15:30	45.174	0.	31.	33.	37.	60.	66.	70.
33	16:00	38.924	0.	31.	32.	35.	53.	58.	60.
34	16:30	33.955	0.	32.	33.	35.	42.	45.	52.
35	17:00	33.332	0.	32.	32.	34.	41.	45.	53.
36	17:30	37.265	0.	32.	32.	36.	49.	56.	60.
37	18:00	41.247	0.	33.	33.	34.	56.	62.	63.
38	18:30	33.534	0.	33.	33.	33.	40.	43.	44.
39	19:00	34.630	0.	33.	33.	35.	43.	49.	59.
40	19:30	33.748	0.	33.	33.	34.	39.	42.	43.
41	20:00	41.620	0.	33.	34.	41.	56.	58.	59.
42	20:30	34.075	0.	33.	34.	34.	39.	42.	44.
43	21:00	33.397	0.	33.	33.	34.	38.	40.	41.
44	21:30	38.713	0.	33.	33.	34.	52.	54.	55.
45	22:00	33.316	0.	33.	33.	34.	37.	40.	41.
46	22:30	33.108	0.	33.	33.	33.	36.	38.	40.
47	23:00	34.127	0.	33.	33.	34.	41.	45.	51.
48	23:30	34.335	0.	33.	34.	35.	40.	44.	48.

SUMMARY: 48 OBSERVATIONS AND LEQ = 36.92

L_{dn} = 40.95

Table 4j. Sound Levels at Moose Measured by System A

JANUARY 19, 1978

OBS	TIME	LEQ	L99	L90	L50	L10	L01	L.1	L00
1	00:00	35.317	0.	34.	34.	36.	44.	47.	53.
2	00:30	34.193	0.	34.	34.	34.	38.	41.	41.
3	01:00	43.563	0.	34.	40.	47.	53.	56.	57.
4	01:30	37.478	0.	34.	35.	41.	47.	49.	51.
5	02:00	34.017	0.	34.	34.	34.	35.	35.	40.
6	02:30	34.308	0.	34.	34.	35.	35.	35.	36.
7	03:00	34.087	0.	34.	34.	34.	35.	35.	54.
8	03:30	34.377	0.	34.	34.	35.	36.	38.	39.
9	04:00	34.802	0.	34.	35.	36.	37.	40.	45.
10	04:30	34.669	0.	34.	34.	36.	37.	38.	45.
11	05:00	35.273	0.	34.	35.	36.	41.	45.	49.
12	05:30	34.935	0.	34.	34.	36.	40.	44.	50.
13	06:00	57.645	0.	34.	34.	42.	72.	77.	80.
14	06:30	39.667	0.	34.	35.	43.	50.	55.	58.
15	07:00	35.220	0.	34.	35.	36.	37.	39.	43.
16	07:30	34.689	0.	34.	34.	35.	37.	40.	43.
17	08:00	36.926	0.	34.	35.	40.	46.	49.	52.
18	08:30	35.007	0.	34.	35.	36.	39.	41.	43.

SUMMARY: 18 OBSERVATIONS AND LEQ = 45.65

TABLE 5. DATA FROM SYSTEM B

DATE & TIME (1978) FROM	TO	PLACE	HOURS	L_{eq}	L_{max}	$L_{.01}$	L_1	L_{10}	L_{50}	L_{90}	L_{99}	L_{min}
0111.1800	0111.2200	MORAN	4	31	61	52	43	32	21	19	18	18
0111.2200	0112.0600	MORAN	8	24	--	38	30	22	19	18	18	18
0112.0600	0112.0900	MORAN	3	25	46	40	37	26	20	18	18	18
0112.1100	0112.2300	MORAN	12	31	62	53	43	30	21	19	18	17
0112.2300	0113.0700	MORAN	8	22	(58)	35	27	21	19	18	18	18
0113.0700	0113.1100	MORAN	4	26	(60)	43	36	27	21	19	18	18
0113.1500	0113.2300	MOOSE	8	--	--	63	48	35	27	24	22	20
0113.2300	0114.0700	MOOSE	8	--	--	35	30	27	25	23	22	21
0114.0700	0114.1500	MOOSE	8	41	78	63	51	35	25	22	21	20
0114.1600	0114.2200	MOOSE	6	--	--	56	41	30	26	21	19	18
0114.2200	0115.0600	MOOSE	8	--	--	38	32	28	26	24	23	22
0115.0600	0115.1400	MOOSE	8	--	--	63	49	32	28	25	24	22
0116.1030	0116.2230	BEAVER CK	12	31	60	50	42	33	26	22	20	19
0116.2230	0117.0630	BEAVER CK	8	28	47	41	38	32	25	20	19	19
0117.0630	0117.1030	BEAVER CK	4	46	72	66	59	44	21	19	19	18
0117.1500	0117.2300	ELBOW #3	8	27	57	47	39	25	19	18	18	18
0117.2300	0118.0700	ELBOW #3	8	21	45	39	32	19	19	18	18	18
0118.0700	0118.1500	ELBOW #3	8	34	62	51	47	37	20	19	18	18

TABLE 6. Results of Brief Measurements

Site	1*	2	3*	4.a	4.b	4.c*	5.a
Date	1/18/78	1/15/78	1/15/78	1/14/78	1/17/78	1/17/78	1/18/78
Time	1302-1315	1254-1302	1055-1104	1011-1018	1530-1541	1808-1816	1035-1040
Duration (min)	13	8	9	7	11	8	5
L_0	72	28	56	32	40	58	62
L_1	62	28	37	32	40	58	62
L_{10}	44	24	25	28	26	46	52
L_{50}	30	20	22	25	24	28	51
L_{90}	25	20	21	23	22	21	50
L_{99}	24	19	20	22	21	20	49
L_{min}	21	18	20	22	20	20	49
Temperature(°C)	-4	-4	-2	-4	-4	-4	-1
Wind (km/h)	0-5	0-5	3-11	0-5	0-5	0-5	0
Wind Direction	Variable	Variable	North	Variable	Variable	Variable	Variable
Ground Cover	Snow	Snow	Snow	Snow	Snow	Snow	Snow
Topography	Flat	Flat	Flat	Flat	Flat	Flat	Flat
Vegetation	Near deciduous trees	None	Conif. trees 60yds	None	None	None	Near dead trees;river

Site	5b*	5c	6*	7*	8	9	10*
Date	1/18/78	1/18/78	1/14/78	1/19/78	1/18/78	1/19/78	1/18/78
Time	1050-1055	1106-1120	1145-1153	1548-1605	0936-0945	1413-1425	1546-1556
Duration (min)	5	14	8	17	9	12	10
L_0	68	56	55	45	24	35	39
L_1	68	56	55	40	24	35	36
L_{10}	46	41	42	30	22	29	30
L_{50}	36	30	25	25	18	26	25
L_{90}	35	28	23	22	18	24	19
L_{99}	35	27	23	20	18	22	19
L_{min}	34	27	23	20	18	22	18
Temperature(°C)	-1	-1	-3	-4	-2	-3	-2
Wind (km/h)	0	0	8-11	0	0-11	0	5-8
Wind Direction	Variable	Variable	North	--	Variable	--	South
Ground Cover	Snow	Snow	Snow	Snow	Snow	Snow	Snow
Topography	Flat	Flat	Flat	Flat	Flat	Flat	Flat
Vegetation	Near deciduous trees; river.	None	None	Near coniferous trees.	None	Near deciduous trees.	Sage brush

*Includes aircraft noise

APPENDIX. Wind-Induced and Instrumental Noise

When measuring low-level sounds, one must give more attention to the effects of wind-induced noise and instrumental electronic noise than when measuring high level sounds. Although the sound of the breeze in the trees is an environmental sound that should be included in any measurement of the background ambient, wind-induced noise is a spurious sound that is generated in the microphone as a result of interactions with flowing air; and, like the electronic noise in the instrument, it serves only to mask the environmental sounds. The problem is serious when the spurious sounds approach or exceed the level of the sounds being measured.

Unfortunately, information on the wind response of particular microphones is not plentiful. Figure 8 gives the expected combination of wind-induced and electronic noise for a microphone of the type used in System A. The curve is based on five datum points from the manufacturer's literature and certain assumptions regarding curve shape between points. The wind-induced noise values of Table 2 were taken from this graph on the basis of average wind speeds. The true values would undoubtedly be greater due to gusting and turbulence that are not expressed by average wind speed. In fact, a review of the sound level strip charts recorded during this survey revealed some apparent wind-induced noise levels in excess of 60 dB.

Fortunately, wind-induced noise was relatively low during most of this survey. Systems A and C were programmed to disregard any measurements made when the wind speed exceeded 15 km/hr, but it is interesting to note that half of the actual values of daily Leq during the survey would have been exceeded by the microphone noise that a 15 km/hr wind would induce.

On many occasions it was so quiet and still that the instrument readings represented electronic noise alone for extend periods. As stated elsewhere, the respective A-weighted noise floors were as follows:

System	Noise Floor (dB)
A	32
B	18
C (1-in microphone)	24 - 25
C ($^1/_2$-in microphone)	31 - 33
D	18

Sound level readings having values near the instrument's noise floor cannot be taken at face value because they represent combinations of environmental noise with electronic noise and any wind-induced noise that may be present. In effect, the instrument presents the level of the sum of the apparent mean square sound pressures due to the respective sources.

Figures 9 and 10 are intended to aid in the interpretation of sound level meter readings which represent situations where the spurious noises are significant. These graphs are useful only if all but one of the variables are known or assumed. As an example problem using Figure 9, assume a reading of 29 dB where the instrument noise level is known to be 25 dB. Find 29 dB on the ordinate (y-axis), find the point where the 25 dB curve has that value, and below that point read the environmental-plus-wind-induced noise level on the abscissa (x-axis), i.e., 27 dB.

It is noted that System A, with its noise floor about 14 dB above that of System B, would provide values of Leq and L_{dn} slightly higher than would System B because of the electronic noise content. The difference is appreciable only for values within a few decibels of the noise floors. A simple hypothetical case illustrates the effect: Assume that System A, with a noise floor of 32 dB, and System B, with noise floor at 18 dB, are used to monitor for two days. The true Leq due to environmental noise alone is 32 dB during the first day and 45 dB during the second. Each instrument would register an Leq equal to the sum of true Leq plus its internal noise, assuming no wind-induced noise were involved. The results would be as follows (shown to the nearest 0.1 dB for purposes of illustration):

	System A	System B
Instrument noise (dB)	32.0	18.0
First day		
True Leq (dB)	32.0	32.0
Reading (dB)	35.0	32.2
Second day		
True Leq (dB)	45.0	45.0
Reading (dB)	45.2	45.0

Fig. 8. EXPECTED WIND RESPONSE OF SYSTEM A
(Curve shape between points based on authors' assumptions.)

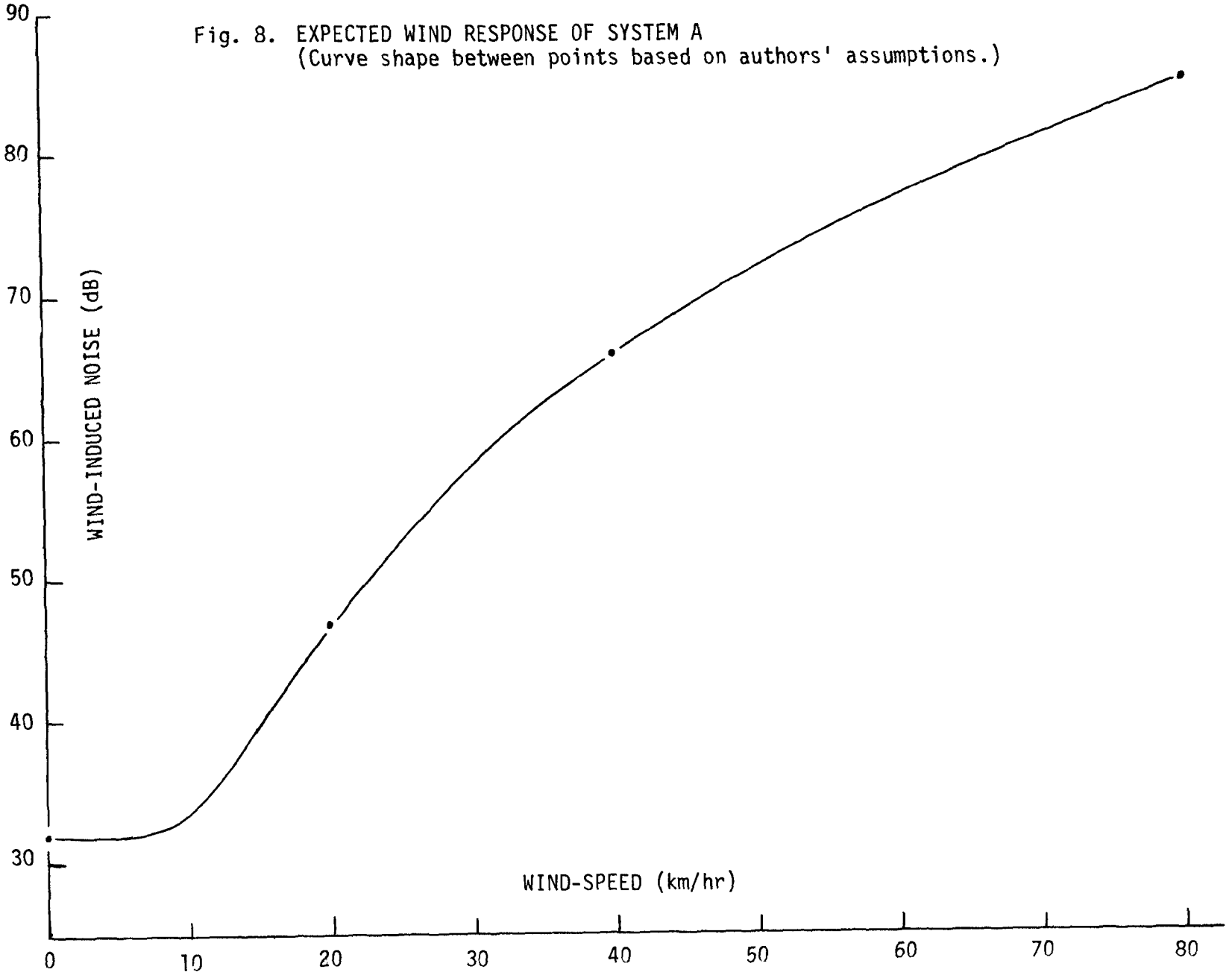


Fig. 9. COMBINATION OF ENVIRONMENTAL, WIND-INDUCED, AND INSTRUMENT NOISE

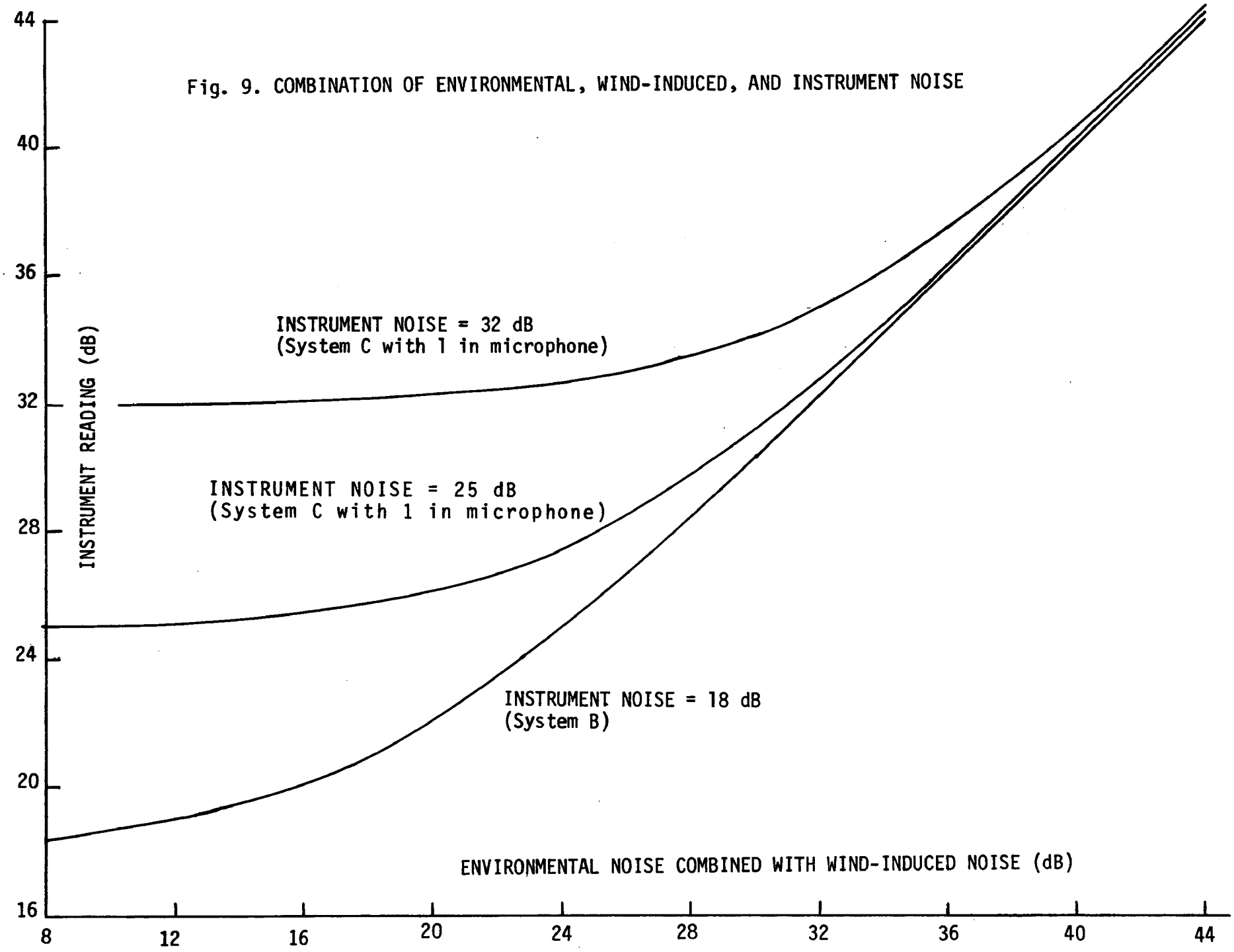
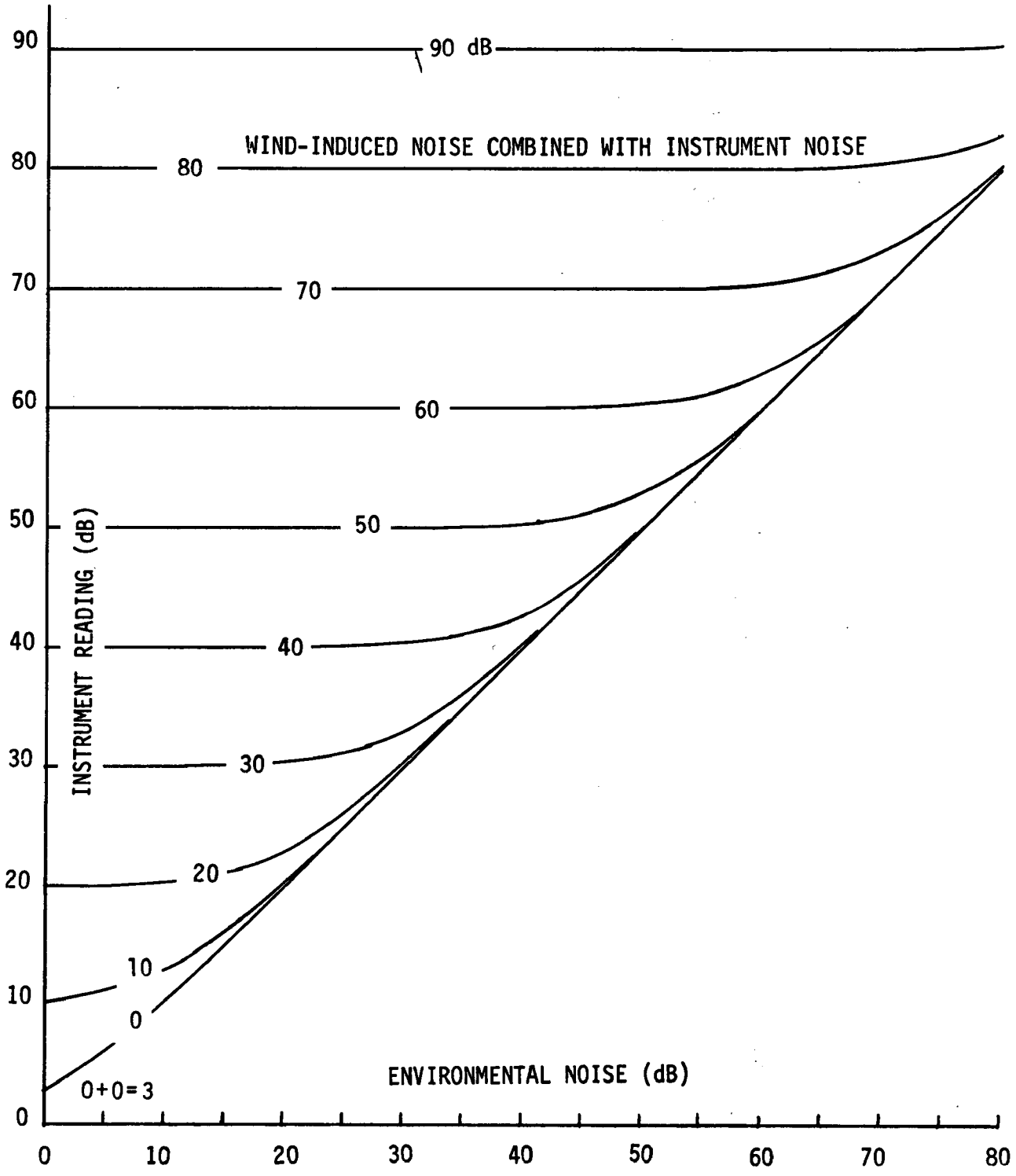


Fig.10. COMBINATION OF ENVIRONMENTAL, WIND-INDUCED, AND INSTRUMENT NOISE



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