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SEISMIC NOISE SURVEY, VOLUME 3
LONG-RANGE SEISMIC MEASUREMENTS PROGRAM

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TECHNICAL REPORT NO. 67-19

SEISMIC NOISE SURVEY, VOLUME 3
LONG-RANGE SEISMIC MEASUREMENTS PROGRAM

by

Carlos Pena

GEOTECH
A TELEDYNE COMPANY
3401 Shiloh Road
Garland, Texas

29 June 1967
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<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
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<tr>
<td>1</td>
<td>Location of LRSM sites, background noise survey</td>
<td>2</td>
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<td>2</td>
<td>Frequency response of the short-period seismograph system</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Frequency response of the long-period seismograph system</td>
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TABLES

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<th>Description</th>
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<td>LRSM site information</td>
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<td>Period correction factors</td>
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ABSTRACT

This report is the third in a series of studies which evaluate seismic noise levels at LRSM sites. Data from the short- and long-period vertical seismographs from 33 sites are reviewed, and standardized data compilation methods are discussed. Cumulative probability distribution of amplitude curves and noise spectrum curves are developed for each site studied.
1. INTRODUCTION

This report is volume 3 of a series of reports which presents the results of seismic noise measurements taken from data recorded at the Long-Range Seismic Measurements (LRSM) Program field sites. Figure 1 shows the locations and designations of the sites evaluated in this report.

Measurements were taken from data recorded by the vertical seismographs at 33 sites during 1964 - 1966. Franklin, West Virginia (FN-WV) and Fort Stockton, Texas (FO-TX) did not have long-period seismographs, and the surveys of these sites are, therefore, limited to the short-period vertical seismographs. Surveys for both short- and long-period systems are included for 31 sites. The noise survey was conducted at each site after a sufficient time (2 weeks) had elapsed after initial setup to assure that all instruments had stabilized.

This work was done under Project VT/6703, Contracts F33657-67-C-1457 and AF 33(657)-16270. This project is under the technical direction of the Air Force Technical Applications Center (AFTAC) and the overall direction of the Advanced Research Projects Agency (ARPA).

2. DATA PRESENTATION

2.1 Table 1 gives general information about each site. It includes the noise occurrence at the 50 percent level for the short-period and long-period systems and the predominant periods of the noise. Sites are listed in alphabetical order.

2.2 The frequency response of the short-period systems are shown in figure 2. Figure 3 shows the frequency response of the long-period systems at all sites.

Figure 1. Location of LRSM sites, background NOISE SURVEY
<table>
<thead>
<tr>
<th>Site designator</th>
<th>Elevation (km)</th>
<th>Type of installation</th>
<th>Large or small Benioff seismometer</th>
<th>50% Noise Level (m/s)</th>
<th>Predominate per. of noise (sec)</th>
<th>Average magnification (K)</th>
<th>Geology</th>
<th>Weathering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adak Island, Alaska</td>
<td>0.06</td>
<td>Vault</td>
<td>Large</td>
<td>53.0 140</td>
<td>1.2</td>
<td>10, 15</td>
<td>42 25</td>
<td>Glacial drift</td>
</tr>
<tr>
<td>Angola, Montana</td>
<td>0.91</td>
<td>Vault</td>
<td>Large</td>
<td>6.9 150</td>
<td>0.5</td>
<td>15</td>
<td>210 22</td>
<td>Sandstone-shale</td>
</tr>
<tr>
<td>Alexander City, Alabama</td>
<td>0.27</td>
<td>Vault</td>
<td>Large</td>
<td>9.7 301</td>
<td>0.4</td>
<td>15</td>
<td>183 40</td>
<td>Sandy clay</td>
</tr>
<tr>
<td>Berlin, Pennsylvania</td>
<td>0.65</td>
<td>Vault</td>
<td>Large</td>
<td>11.0 440</td>
<td>0.3</td>
<td>25</td>
<td>140 9.7</td>
<td>Sandstone-shale</td>
</tr>
<tr>
<td>Cumberland Gap, Virginia</td>
<td>0.40</td>
<td>Vault</td>
<td>Large</td>
<td>7.5 300</td>
<td>1.0</td>
<td>30</td>
<td>410 22</td>
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<tr>
<td>Eureka, Nevada</td>
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<td>Vault</td>
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<td>1.0</td>
<td>15, 20</td>
<td>660 42</td>
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</tr>
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<td>Franklin, West Virginia</td>
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<td>Vault</td>
<td>Small</td>
<td>6.6</td>
<td>1.0</td>
<td>--</td>
<td>170 --</td>
<td>Alluvium</td>
</tr>
<tr>
<td>Fort Stockton, Texas</td>
<td>0.88</td>
<td>Vault</td>
<td>Small</td>
<td>6.9</td>
<td>0.4</td>
<td>--</td>
<td>360 --</td>
<td>Alluvium</td>
</tr>
<tr>
<td>Globe, Arizona</td>
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<td>Vault</td>
<td>Large</td>
<td>4.5 470</td>
<td>0.4</td>
<td>5</td>
<td>350 24</td>
<td>Altered shale</td>
</tr>
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<td>Vault</td>
<td>Small</td>
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<td>35</td>
<td>140 20</td>
<td>Glacial drift</td>
</tr>
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<td>Howard, Pennsylvania</td>
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<td>Vault</td>
<td>Small</td>
<td>29.0 270</td>
<td>0.3</td>
<td>10, 15</td>
<td>100 8.3</td>
<td>Sandy clay</td>
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<tr>
<td>Hailey, Idaho</td>
<td>1.83</td>
<td>Mine</td>
<td>Large</td>
<td>1.6 320</td>
<td>0.4</td>
<td>10</td>
<td>390 20</td>
<td>Basalt-limestone</td>
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<td>Large</td>
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<td>15</td>
<td>460 21</td>
<td>Limestone</td>
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<td>15</td>
<td>180 16</td>
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<td>10, 15</td>
<td>146 43</td>
<td>Sandstone-shale</td>
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<td>Jerome, Arizona</td>
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<td>Vault</td>
<td>Large</td>
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<td>15</td>
<td>250 22</td>
<td>Limestone</td>
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<td>Vault</td>
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<td>4.0 120</td>
<td>1.0</td>
<td>20</td>
<td>630 24</td>
<td>Alluvium</td>
</tr>
<tr>
<td>Kansas City, Missouri</td>
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<td>Vault</td>
<td>Large</td>
<td>34.0 170</td>
<td>0.4</td>
<td>10</td>
<td>48 39</td>
<td>Limestone-shale</td>
</tr>
<tr>
<td>Kohler Ranch, Arizona</td>
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<td>97 12</td>
<td>Residual soil</td>
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<td>Long Valley, Arizona</td>
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<td>Vault</td>
<td>Small</td>
<td>9.0 360</td>
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<td>15</td>
<td>250 52</td>
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<td>Large</td>
<td>3.4 240</td>
<td>0.4, 0.5</td>
<td>15</td>
<td>350 20</td>
<td>Alluvium</td>
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<td>Vault</td>
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<td>Prince George, British Columbia</td>
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<td>23 90</td>
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<td>10</td>
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<td>0.6</td>
<td>45</td>
<td>204 22</td>
<td>Granite</td>
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<td>440 12</td>
<td>Sandy limestone</td>
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<td>154 25</td>
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<td>5</td>
<td>370 18</td>
<td>Granite</td>
</tr>
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<td>Small</td>
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<td>1.0</td>
<td>15, 30</td>
<td>75 32.6</td>
<td>Glacial</td>
</tr>
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<td>95 17</td>
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<td>0.4</td>
<td>15</td>
<td>310 50</td>
<td>Sandstone</td>
</tr>
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<td>Wyanof, Minnesota</td>
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<td>Vault</td>
<td>Small</td>
<td>20.0 350</td>
<td>1.2</td>
<td>15, 30</td>
<td>120 28</td>
<td>Dolomitic limestone</td>
</tr>
</tbody>
</table>

--- No LP instruments ---
Figure 2. Frequency response of the short-period seismograph system
Figure 3. Frequency response of the long-period seismograph system
2.3 Appendix 1 contains curves which show the percentage of occurrence of short-period noise versus recorded amplitude in millimeters (peak-to-peak) divided by the magnification at 1 cps. Amplitude measurements were made in the period range of 0.3 to 1.4 seconds. The amplitudes taken from the 35 mm film recordings were divided by the magnification at 1 cps to reduce the data from all sites to a common reference. Thus, the noise occurrence curves give a measure of the normalized noise as seen on film and do not give a true measure of earth motion except at 1 cps. Appendix 2 contains curves which show the percentage of occurrence of long-period noise versus recorded amplitude in millimeters (peak-to-peak) divided by the magnification. Amplitude measurements were made in the period range of 6 to 100 seconds. The amplitudes from the film were divided by the magnification at 25 seconds to reduce the data to a common reference. Thus, the curves give a measure of normalized noise as seen on film and do not give a true measure of earth motion, except at 25 seconds.

2.4 Appendix 3 contains noise spectrum curves. The average amplitude in millimicrons, corrected for instrument response, is plotted as a function of period. The measurements cover a period range from 0.3 to 1.4 seconds for the short-period systems and from 6 to 100 seconds for the long-period systems.

2.5 Appendix 4 contains histograms showing the percentage of occurrence of noise at given periods for the short-period and long-period systems.

At X20 magnification 1 mm = 0.2 seconds on the short-period film seismograms. This can introduce bias caused by a tendency for analysts to read in even increments of period, for example, 0.2, 0.4, 0.6, etc. Recognizing this, efforts are made to avoid this tendency. The short-period histogram for EK-NV exhibits a saw-tooth appearance favoring the even periods. Additional data will be analyzed from this site and the results will be published in Noise Study No. 4.

3. METHODS OF DATA COMPILATION

A random sampling procedure was used, taking samples from night operating periods as well as daytime, windy as well as quiet days were sampled. Earthquake signals were not measured. Two hundred samples were taken from each team. The samples were read from 35 mm film at X20 magnification. The maximum trace amplitude present within the given period range was measured from peak-to-peak, to the nearest 0.5 millimeter; periods were measured to the nearest 0.1 second on the short-period records and to the nearest 1 second on the long-period records. Table 2 lists the period correction factors used to plot the noise spectrum curves.
<table>
<thead>
<tr>
<th>Period (seconds)</th>
<th>Correction factor</th>
<th>Period (seconds)</th>
<th>Correction factor</th>
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<td>SP</td>
<td></td>
<td>LP</td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td>0.357</td>
<td>6</td>
<td>22.727</td>
</tr>
<tr>
<td>0.4</td>
<td>0.344</td>
<td>7</td>
<td>14.925</td>
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<td>0.5</td>
<td>0.377</td>
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<tr>
<td>0.6</td>
<td>0.418</td>
<td>9</td>
<td>7.246</td>
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<tr>
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<td>5.319</td>
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<td>0.591</td>
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<td>0.769</td>
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<td>1.042</td>
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<td>1.000</td>
<td>25</td>
<td>1.000</td>
</tr>
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<td>1.234</td>
<td>30</td>
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<td>1.515</td>
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<td>2.000</td>
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<tr>
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<td>20.000</td>
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<tr>
<td></td>
<td></td>
<td>100</td>
<td>22.727</td>
</tr>
</tbody>
</table>
4. CONCLUSIONS

4.1 GENERAL

The geologic structure at each of the sites used for this report must be regarded as a variable which affects background noise.

There are several instances where sites, which are located on virtually the same type of geologic medium, have widely different noise levels. An explanation of this difference in levels does not readily present itself. However, many factors must naturally be considered in drawing conclusions from studies of the type dealt with in this report. Some of the most apparent factors are:

a. The depth and extent of weathering of the geologic medium;

b. The particular type of geology. In some cases, the composition of the medium may vary from point to point, which in turn causes variation of the noise level;

c. The adequacy of seismometer vault protection procedures, that is, how well the vaults are sealed, how much covering they have, and the relative depth (with respect to ground level) of the seismometer emplacements;

d. The environment (trees near the instruments, wind exposure and velocity, general climatic differences of various sites);

e. Cultural noise; activity near the site (traffic, mining, or logging operations).

All of the above factors, separately and in combination, act on the sites' data. The extent of variation caused by these factors is, however, beyond the scope and purpose of this report.

4.2 OBSERVATIONS ON SHORT-PERIOD DATA

4.2.1 Four sites were located on limestone, and short-period noise (at the 50 percent occurrence level) at three of these (Heber, Arizona, Jerome, Arizona and Vinton, Iowa) measured less than 22 millimicrons. The fourth site, Kansas City, Missouri, measured 34 millimicrons.

4.2.2 There were three sites located on granite. Of these, the maximum noise level (at 50 percent occurrence) was 18 millimicrons, which occurred at Redig, South Dakota. The noise level at Red Lake, Ontario was computed to be 5.2 millimicrons and Sunflower, Arizona was 2.6 millimicrons.
4.2.3 Seven sites were located on sandstone; noise levels ranged from 2.5 millimicrons at Eureka, Nevada to 14 millimicrons at Smithers, British Columbia.

4.2.4 Twenty-one of the 33 sites included in this report exhibited noise levels (at the 50 percent occurrence level) of 10 millimicrons or less.

4.3 OBSERVATION ON LONG-PERIOD DATA

4.3.1 For the majority of the sites studied, noise from the long-period systems was predominantly in the 10-15 second period range.

4.3.2 It is impractical to correlate long-period noise level on the basis of geology alone.

4.3.3 Noise at the 50 percent occurrence level ranges from 120 millimicrons at Juno, Texas, to 600 millimicrons at Pinedale, Wyoming; noise at the remainder of the sites studied showed a random variation between these low and high levels. The average noise level from all sites is approximately 305 millimicrons.

4.4 OBSERVATIONS ON THE NAZLINI, ARIZONA SITES

The site which was designated NL-AZ was operated for the 10-month period April 1964 through January 1965. At this time the site was moved approximately 7 miles to take advantage of more stable soil in which to emplant the seismometer vaults. The new site, designated NL2AZ, became operational during mid-February 1965 and was closed early in October 1965.

In terms of background noise level, the move appears to have been propitious. The average noise levels (not corrected for period) of the vertical components at the two sites are summarized below:

<table>
<thead>
<tr>
<th>Vertical SP</th>
<th>LP Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL-AZ</td>
<td>6.4 µm</td>
</tr>
<tr>
<td>NL2AZ</td>
<td>3.4 µm</td>
</tr>
</tbody>
</table>

A comparison of the average operating magnifications of the two seismographs support the data shown above. The average magnification of the short-period vertical seismograph at NL-AZ was 260K; at NL2AZ it increased to 350K. The average long-period vertical magnification increased nearly 200 percent (from 7K to 20K) as a result of the site relocation.
5. ACKNOWLEDGMENTS

The author wishes to express his thanks to the members of the Data Reduction Section, LRSM, for their help in taking the noise samples and preparing drafts of the several curves included in this report.
APPENDIX 1 to TECHNICAL REPORT NO. 67-19

SHORT-PERIOD NOISE OCCURRENCE CURVES
Cumulative probability distribution of amplitude, standard LRSM survey

AD-IS - Aug-Sept 1964

RECORDED AMPLITUDE/MAGNIFICATION AT 1 CPS (millimicrons)

Period range 0.3-1.4 seconds
Short-period vertical seismograph

PERCENTAGE OF OCCURRENCE

100

10

0

1.0

TR 67-19, app 1
Short-period vertical seismograph
Period range 0.3-1.4 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Short-period vertical seismograph
Period range 0.3-1.4 seconds

Cumulative probability distribution of amplitude, standard LRSM survey.
Short-period vertical seismograph
Period range 0.3-1.4 seconds

RECORDED AMPLITUDE/MAGNIFICATION AT 1 CPS (millimicrons)
Short-period vertical seismograph
Period range 0.3-1.4 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Cumulative probability distribution of amplitude, standard LRSM survey.
Short-period vertical seismograph
Period range 0.3-1.4 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Cumulative probability distribution of amplitude, standard LRSM survey
Short-period vertical seismograph
Period range 0.3-4 seconds

RECORDED AMPLITUDE/MAGNIFICATION AT 1 CPS (millimicrons)

Cumulative probability distribution of amplitude, standard LRSM survey
Short-period vertical seismograph
Period range 0.3-1.4 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Short-period vertical seismograph
Period range 0.3-1.4 seconds

Cumulative probability distribution of amplitude, standard LRSM survey

RECORDED AMPLITUDE/MAGNIFICATION AT 1 CPS (millimicrons)
Short period vertical seismograph
Period range 0.3-1.4 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Cumulative probability distribution of amplitude, standard LRSM survey
Short-period vertical seismograph
Period range 0.3-1.4 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
APPENDIX 2 to TECHNICAL REPORT NO. 67-19

LONG-PERIOD NOISE OCCURRENCE CURVES
<table>
<thead>
<tr>
<th>Period range 6-100 seconds</th>
<th>Percentage of occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AD-15 - Aug-Sept 1964

RECORDED AMPLITUDE/MAGNIFICATION AT 25 SECONDS (millimicrons)

Cumulative probability distribution of amplitude, standard LRSM survey
Long-period vertical seismograph
Period range 6-100 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Long-period vertical seismograph
Period range 6-100 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Cumulative probability distribution of amplitude, standard LRSM survey

Long-period vertical seismograph
Period range 6-100 seconds

RECORDED AMPLITUDE/MAGNIFICATION AT 25 SECONDS (millimicrons)
Long-period vertical seismograph

Period range 6-100 seconds

RECORDED AMPLITUDE/MAGNIFICATION AT 25 SECONDS (millimicrons)

Cumulative probability distribution of amplitude, standard IRSM survey
Long-period vertical seismograph

Period range 6-100 seconds

RECORDED AMPLITUDE/MAGNIFICATION AT 25 SECONDS (millimicrons)

Cumulative probability distribution of amplitude, standard LRSM survey

TR 67-19, app 2
Cumulative probability distribution of amplitude distribution of amplitude, standard I.RSM survey.
Long-period vertical seismograph
Period range 6-100 seconds

RECORDED AMPLITUDE/MAGNIFICATION AT 25 SECONDS (millimicrons),
Cumulative probability distribution of amplitude, standard LRSM survey
Long-period vertical seismograph
Period range 6-100 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Long-period vertical seismograph
Period range 6-100 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Long-period vertical seismograph
Period range 6-100 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
Long-period vertical seismograph
Period range 6-100 seconds

RECORDED AMPLITUDE/MAGNIFICATION AT 25 SECONDS (millimicrons)

Cumulative probability distribution of amplitude, standard LRSM survey
Long-period vertical seismograph
Period range 6-100 seconds

Cumulative probability distribution of amplitude, standard LRSM survey
APPENDIX 3 to TECHNICAL REPORT NO. 67-19

NOISE SPECTRUM CURVES
Noise spectrum curve, LRSM
Noise spectrum curve, LRSM

TR 67-19, app 3
Noise spectrum curve, LRSM
Noise spectrum curve, LRSM
1000

PERIOD (seconds)

—— HR-AZ - Aug-Sept 1964
— KH-AZ - June 1964
— WO-AZ - April 1964

GROUND MOTION (millimicrons)

100

10

1

0

0.1 SPZ 1.0

PERIOD (seconds)

Noise spectrum curve, LRSM

-5-

TR 67-19, app 3
Noise spectrum curve, LRSM

TR 67-19, app 3
Noise spectrum curve, LRSM

TR 67-19, app 3
Noise spectrum curve, LRSM

TR 67-19, app 3
Noise spectrum curve, LRSM
Noise spectrum curve, LRSM

TR 67-19, app 3
Noise spectrum curve, LRSM

-11-
Noise spectrum curve, LRSM
Noise spectrum curve, LRSM

TR 67-19, app 3
Noise spectrum curve, LRSM

-13-
Noise spectrum curve, LRSM
APPENDIX 4 to TECHNICAL REPORT NC. 67-19

SHORT-PERIOD AND LONG-PERIOD SPECTRUM HISTOGRAMS
Long-period vertical seismometer
Aug - Sept 1964

Short-period vertical seismometer
Aug - Sept 1964

Percentage of occurrence for indicated periods for AD-IS
Long-period vertical seismometer
Jan - Feb 1965

Short-period vertical seismometer
Jan - Feb 1965

Percentage of occurrence for indicated periods for HY-MA
Percentage of occurrence for indicated periods for AN-MA
Percentage of occurrence for indicated periods for HL2ID
Percentage of occurrence for indicated periods for EK-NV
Percentage of occurrence for indicated periods for GE-AZ
Percentage of occurrence for indicated periods for LG-AZ
Long-period vertical seismometer
June 1964

Short-period vertical seismometer
June 1964

Percentage of occurrence for indicated periods for KH-AZ
Percentage of occurrence for indicated periods for HR-AZ.
Percentage of occurrence for indicated periods for NL-AZ.
Percentage of occurrence for indicated periods for SN-AZ
Percentage of occurrence for indicated periods for JR-AZ

TR 67-19, app 4
Percentage of occurrence for indicated periods for SG-AZ
Short-period vertical seismometer
July - Aug 1964

Percentage of occurrence for indicated periods for FO-TX
Percentage of occurrence for indicated periods for JU-TX
Percentage of occurrence for indicated periods for CG-VA

Long-period vertical seismometer
July 1965

Short-period vertical seismometer
July 1965

PERIOD (seconds)

Percentage of occurrence

TR 67-19, app 4
Percentage of occurrence for indicated periods for VO-10
Percentage of occurrence for indicated periods for HD-PA
Percentage of occurrence for indicated periods for BR-PA
Percentage of occurrence for indicated periods for PI-WY
Percentage of occurrence for indicated periods for GP-MN
Percentage of occurrence for indicated periods for WF-MN
Percentage of occurrence for indicated periods for RK-CN
Percentage of occurrence for indicated periods for SI-BC
Seismic Noise Survey, Volume 3, Long-Range Seismic Measurements Program

Technical Data Report

Pena, Carlos

29 June 1967

F33657-7-C-1457

VT/6703

Technical Report No. 67-19

None

None

Air Force Technical Applications Center

This report is the third in a series of studies which evaluate seismic noise levels at LRSM sites. Data from the short- and long-period vertical seismographs from 33 sites are reviewed, and standardized data compilation methods are discussed. Cumulative probability distribution of amplitude curves and noise spectrum curves are developed for each site studied.
UNCLASSIFIED

Seismic Noise Survey
Long-Range Seismic Measurement Program
Short-Period System
Long-Period System

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