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LEVEL II

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SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS (U)

FINAL REPORT OF BEARING STAKE TESTS
JANUARY THRU MARCH 1977

VOLUME 1A OVERALL PROGRAM PERFORMANCE RESULTS WITH TEST RESULTS SUMMARY

JANUARY 1979

Prepared For
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PENNSYLVANIA

UNDER CONTRACTS
N62269-77-C-0139
AND
N62269-78-M-6334

by

SANDERS ASSOCIATES, INC.
95 CANAL STREET
NASHUA, NEW HAMPSHIRE 03061

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VOLUME	
IA	Overall Program Status and Test Results Summary
IB	Detailed Description, Test Results
II	Data Analysis Facility and Data Reduction Methodology
IIIA	Data Points 1, 2 and 3 Raw Data
IIIB	Data Points 4, 5 and 6 Raw Data
IVA	Data Points 7, 8 and 9 Raw Data
IVB	Data Points 10, 11 and 12 Raw Data

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Acoustical arrays, at-sea performance measurements, array gain, beamwidth, signal gain, acoustic propagation, acoustic modeling, Indian Ocean

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The report describes the results of acoustic testing of the ADAS/SPRAY array during Bearing Stake exercises in the Indian Ocean, January thru March, 1977. Data collected cover three mid-to-deep water sites in the zero to 1860 meter deficiency range. Array gain, beamwidth and signal gain are compared to theoretical predictions and to results of the earlier MINYAKA tests, which included both deeper (740 meter depth excess) and very shallow (180 meters) water.

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Predictions based on measured data indicate detection ranges in excess of 100 NM for the deeper Indian Ocean sites (less than 1200 meter depth deficiency) against the postulated third-generation Soviet threat. Array performance falls between the extreme conditions experienced in the MINYAKA tests.

TABLE OF CONTENTS

VOLUME IA - SUMMARY - TEST RESULTS

1.0 (S) OVERALL PROGRAM PERFORMANCE RESULTS (U)

(C) The presently described BEARING STAKE tests are the result of the ADAS/SPRAY follow-on program to the successful MINYAKA sea tests (Reference 1) conducted off Eleuthra and Charleston, South Carolina in 1975. As with MINYAKA, the BEARING STAKE tests were performed under the sponsorship of the Naval Air Systems Command, Code AIR-370, with the technical direction of the Naval Air Development Center. This document is Volume I of a four volume final report under contract N62269-77-M-6884.

(S) The objective of the ADAS/SPRAY Sea Test Trials was to demonstrate the feasibility of developing the lowest-cost class of sonobuoy sensor to (a) detect the postulated third-generation Soviet nuclear threat when the sensor is deployed in "deep" (tending toward cylindrical spreading) water, and (b) operate at ranges in excess of 100 nautical miles. This objective has been met not only in the "deep" MINYAKA test site, but also on the medium depth BEARING STAKE test site which is the subject of this report. For these areas such a sensor provides:

- Lowest cost per unit search area or per hydrophone channel relative to VLA's circular planar arrays or conventional buoys.

- Lowest number of processor channels per unit search area.

(U) Figure 1-1 shows an ADAS operational concept for an air-launched array system. Also shown is the sea test hardware used for MINYAKA and BEARING STAKE.

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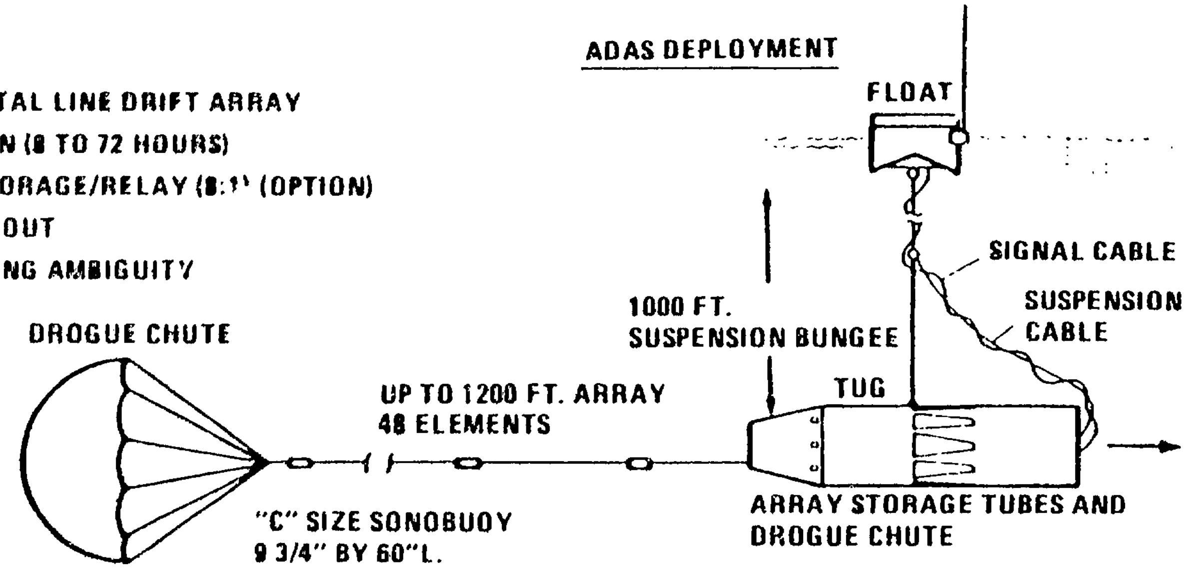
ADAS CONCEPT AND SPRAY TEST BED HARDWARE (U)

ADAS CONCEPT

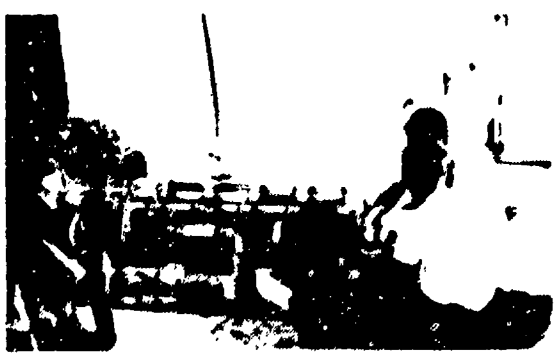
- AIR DEPLOYABLE HORIZONTAL LINE DRIFT ARRAY
- EXTENDED TIME ON STATION (8 TO 72 HOURS)
- COMPRESSED TIME DATA STORAGE/RELAY (8:1) (OPTION)
- REAL TIME AIRCRAFT READOUT
- ABILITY TO RESOLVE BEARING AMBIGUITY

ADAS DEPLOYMENT



TEST BED HARDWARE

UNDERWATER HARDWARE WITH AUTO-DEPLOYMENT SYSTEM CONTAINING 53 ELEMENT 840 FT ARRAY



OVER-THE-SIDE DEPLOYMENT

ARRAY STORAGE TUBES AND DROGUE CHUTE

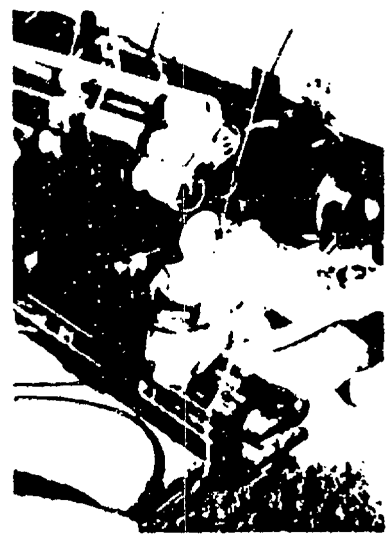


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FIGURE 1-1

(C) ADAS is a remotely-deployed self-tensioning, horizontal-line acoustic array sonobuoy. The SPRAY hardware[1] used to evaluate the operation of such a concept was fabricated by Sanders Associates, Inc. and is designed for over-the-side automatic deployment with VHF relay of the multiplexed array data. This design has been tested for apertures up to 2500 feet with design growth of up to 10,000 feet. Current multiplexing capability comprises 106 acoustic channels with a bandwidth of 10 to 300 Hz. For these tests, 53 elements were deployed. This exceeds the number of active elements (approximately 24 to 32) currently planned for the ADAS buoy. Thus, the tests were designed to (a) show that the ADAS design is adequate, and (b) obtain some indication of how much gain could be achieved.

(C) The ADAS program designed a series of tests in which data has been collected at the sites and conditions listed in Table 1-1. This report covers the BEARING STAKE results. Volume 1a does include MINYAKA results to allow comparison to BEARING STAKE measurements.

(C) For BEARING STAKE, six launches were attempted; five successful, one aborted due to a seawater short in the system. One short array (433-foot active length with 53 elements spaced $\lambda/2$ at 300 Hz) with one long array (2500-foot active length with 53 elements spaced slightly less than $\lambda/2$ at 50 Hz), were successfully launched in each site. In both sites, most of the recorded data for the long array deployment were contaminated with high level nonacoustic noise resulting, we believe, from seawater leakage through pinholes in the array cable. Thus, the BEARING STAKE data reported herein are for the short array only. Figure 1-2 shows typical sound velocity profiles for the three BEARING STAKE sites.

(1) Sanders has received two patents for the Self-Tensioning Array Concept: March 26, 1974 and January 18, 1977, Nos. 3,800,271 and 4,004,265, respectively.

TABLE 1-1 (U)

ADAS SEA TEST SITES AND CONDITIONS (U)

SITE	WATER	CONDITIONS
MINYAKA	Deep	4,740 meters; 740-meter depth excess
BEARING STAKE		5,107 meters; zero depth excess
BEARING STAKE	Medium	3,460 meters; 1,200-meter depth deficiency
BEARING STAKE		3,040 meters; 1,860-meter depth deficiency
MINYAKA	Very Shallow	180 meters

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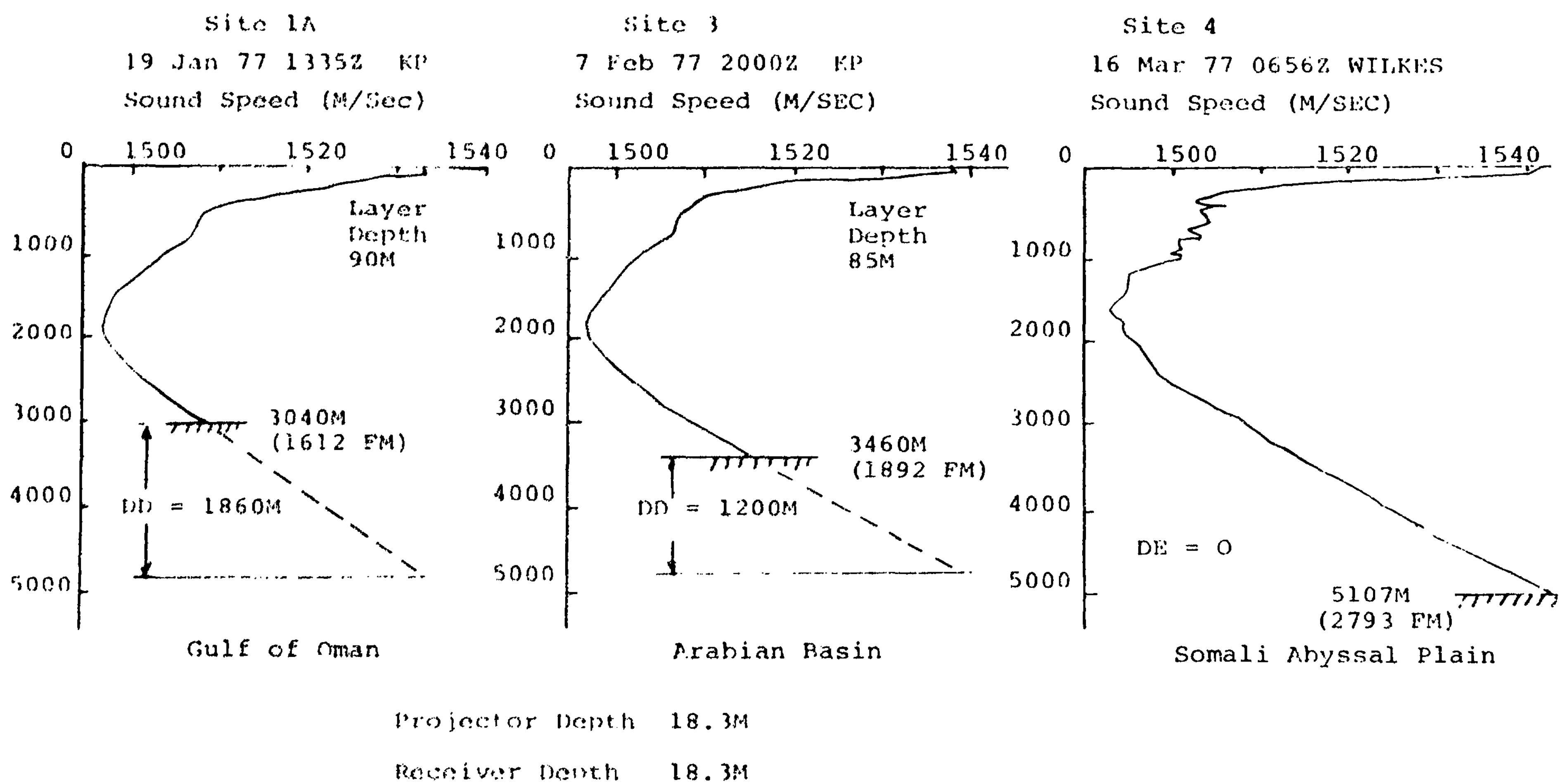

Figure 1-2

Representative Sound Velocity Profiles in Three BEARING STAKE Sites (U)

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(S) Mid-water ADAS tests were performed as a part of the BEARING STAKE test program. The overall results of this test series are quite positive, adding significantly to the MINYAKA data base and further verifying system performance goals. Tests were performed in mid-to-deep water, spanning velocity profiles with zero to rather large depth deficiencies. This filled the gap between the MINYAKA acoustic environmental envelopes of very shallow water with large depth deficiency, and very deep water with large depth excess. As might be expected, the BEARING STAKE results lie approximately between the MINYAKA extremes.

- Array Gain
  Typical measured values are within about 3 dB of theoretical for the full aperture array at 290 Hz (~$\lambda/2$ spacing) in the deep Site 4 (Somali Abyssal Plain which has a fully developed sound channel), and closer for reduced aperture (16, 32 elements) or lower frequency (140 Hz). In Site 3 (Arabian Basin, 1200-meter depth deficiency), and Site 1A (Gulf of Oman, 1860-meter depth deficiency), array gains are progressively smaller, typically within about 5 dB of theoretical for Site 1A. At 140 Hz (~$\lambda/4$ spacing), measured gains are closer to theoretical. There appears to be a graceful degradation in array performance with increasing depth deficiency for these results.

- FOM and Range Predictions
  System FOM based on the 12 measured data points in the three sites averaged 89.8 dB. The maximum value of 92.8 dB in Site 4 corresponds to a mean third generation detection range of over 200 nmi. Typical ranges averaged from 98 nmi in Site 1A to 150 nmi in Site 4. Figure 1-3 shows approximate 50% P_D range circles for the third generation threat 290 Hz line, as well as maximum ranges computed at 135 dB/µPa.

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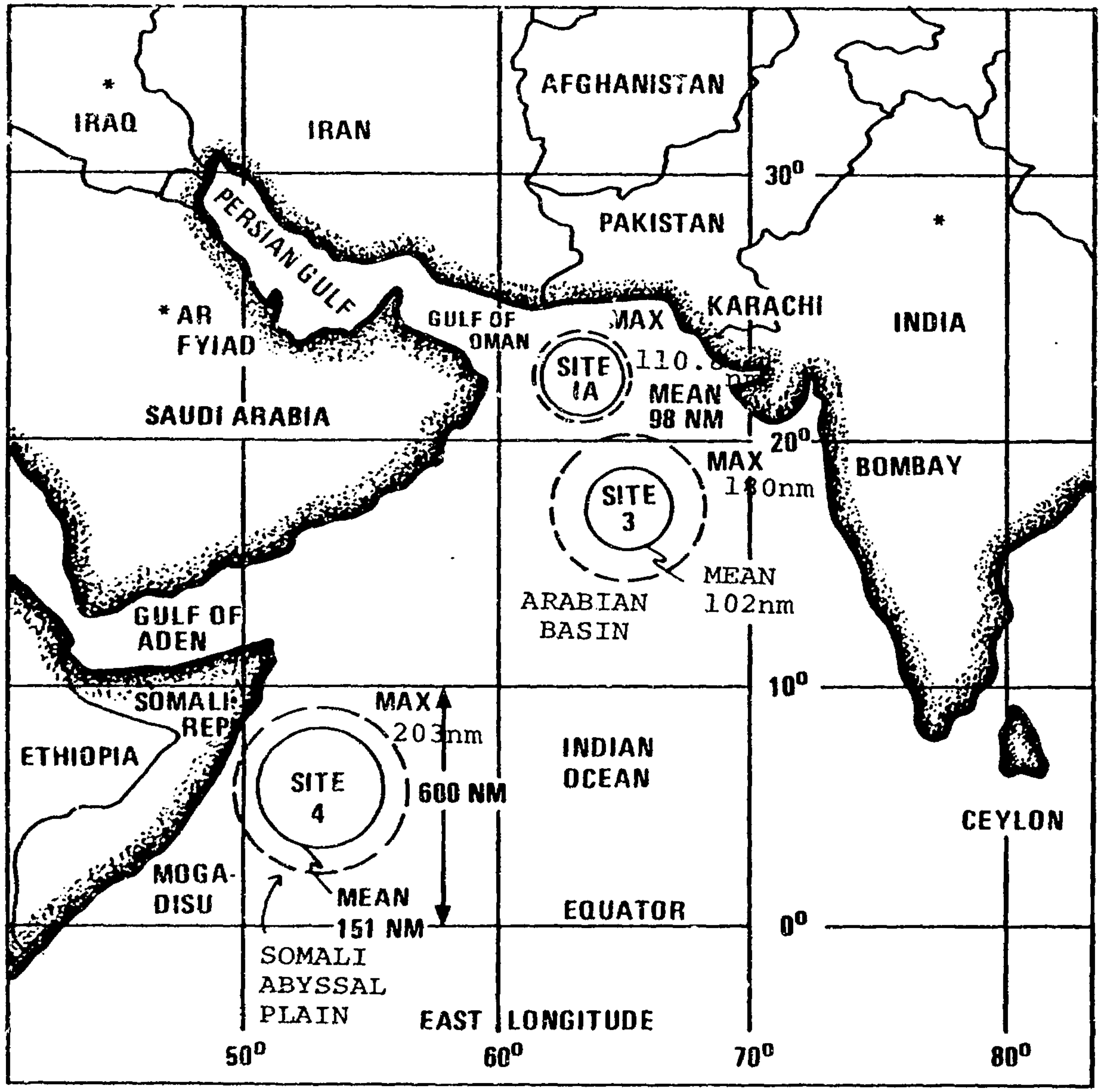
SPRAY THIRD GENERATION THREAT DETECTION CONTOURS BASED ON AVERAGE FOM (U)



PROJECTED MEAN AND MAXIMUM 50% P_D RANGES FOR THIRD GENERATION THREAT 290 HZ LINE, 135 dBuPa, 0.091 HZ WIDTH IN THREE BEARING STAKE SITES (S)

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FIGURE 1-3

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(S) • Beamwidth

Full aperture measured beamwidth is within 2.1° rms of theoretical. It appears to have no particular correlation to water depth (SVP character) but is heavily influenced by interfering sources. It is most affected in Site 3 where many (six vessels within 10 nmi) interferers are present. Beamwidth is consistently closer to theoretical than either signal gain or array gain (see Figure 1-4).

• Signal Gain

This appears to correlate well with beamwidth, and also with array gain, except in Site 1A. Here the signal gain inexplicably averages about 7.4 dB below theoretical compared with beamwidth equivalent performance which is within 0.5 dB of theoretical, and array gain 2.5 dB below theoretical. Graphical comparisons are shown in Figure 1-4 between beamwidth, signal gain and array gain.

(C) As noted on the figure, the range of elements expected for ADAS use is between 24 and 32. In this range, the maximum gain loss is 2.5 dB.

(C) It is quite plausible that this loss is attributable to under-sampling in the beamformer which samples at 1200 Hz. At 300 Hz, this would give rise to quite high phase grating lobes, whereas at 140 Hz, this effect would be negligible. (The 140 Hz data is shown in Figure 1-6.) It will be noted that the 140 Hz data is consistently better than the 290 Hz data. From this, we infer that the losses seen will tend to be eliminated through higher data sampling in the beamforming design.

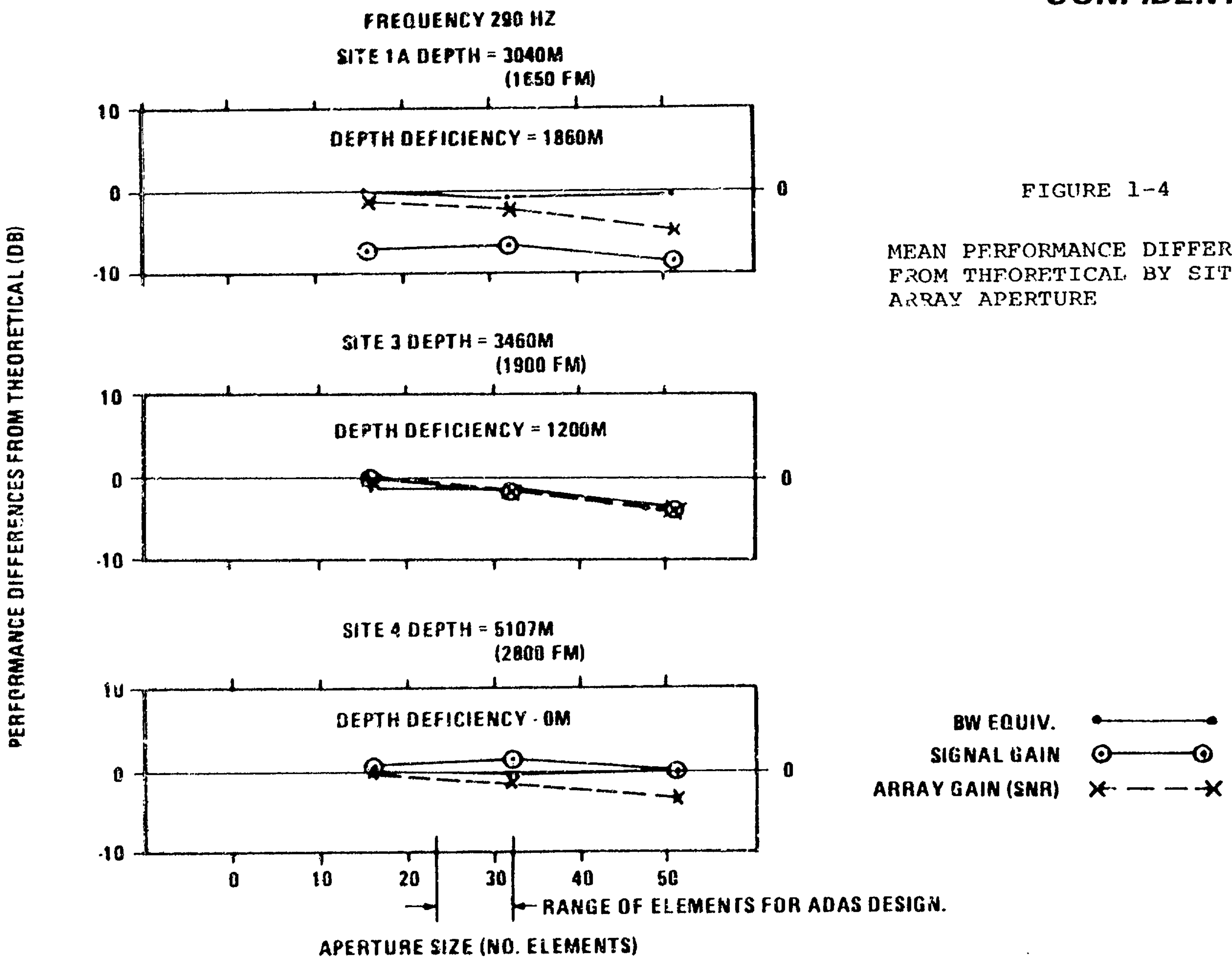

FIGURE 1-4

MEAN PERFORMANCE DIFFERENCES FROM THEORETICAL BY SITE VS ARRAY APERTURE

V-78-0462-007

(S) Target of Opportunity (U)

Figure 1-5 is a LOFAR gram showing a partial signature of a Type II, Victor class Soviet nuclear submarine detected on a single element in the short array. This contact was made at 1107Z on 19 January 1977 in Site 1A. The familiar 300 Hz cluster is evident in the right 1/3 of Figure 1.5. Duration of detection was 14 minutes, from 1107Z to 1121Z. The Tactical Support Center (TSC) at the U. S. Naval Air Station, Brunswick, Maine verified the above identification as to type and class of contact based on examination of this gram in June, 1977.

(S) Summary (U)

Figure 1-6 is a plot of all ADAS results to date for signal gain and array gain as a function of depth deficiency and excess, covering both MINYAKA and BEARING STAKE. Only for very shallow water, were the losses substantial (4 to 5 dB). For depth deficiencies of 2000 meters or less, array gain for 32 elements (16λ) was down at most 2.5 dB from theoretical (290 Hz).

(C) As already noted, it is believed that this loss is due to limitations in the beamformer used for the data reduction, and did not arise from limitations in the array performance.

(C) In terms of array performance, the goals of the ADAS/SPRAY sea test program have been achieved; that is, to show that utilizing realistic specifications, low-cost expendable drift arrays that can be deployed from sonobuoys can detect a third generation equivalent target at 100 miles or greater in broad classes of ocean conditions.

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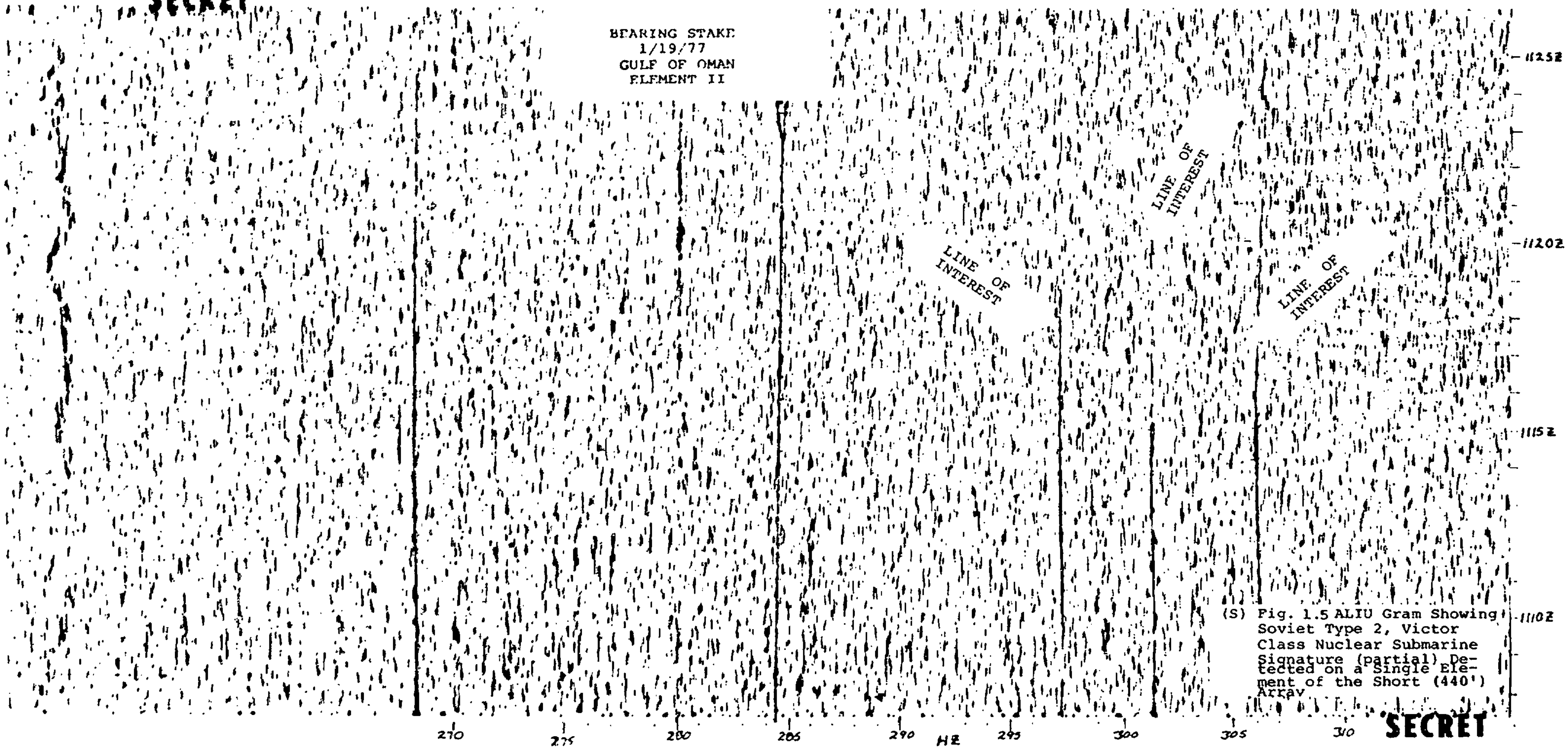

(S) Fig. 1.5 ALIU Gram Showing Soviet Type 2, Victor Class Nuclear Submarine Signature (partial) Detected on a Single Element of the Short (440') Array

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ADAS TEST RESULTS (U)

COMPARISON OF MINYAKA AND BEARING STAKE SIGNAL GAIN (GS) AND ARRAY GAIN (AG) VS. DEPTH EXCESS (DEFICIENCY) FOR SHORT ARRAY (U)

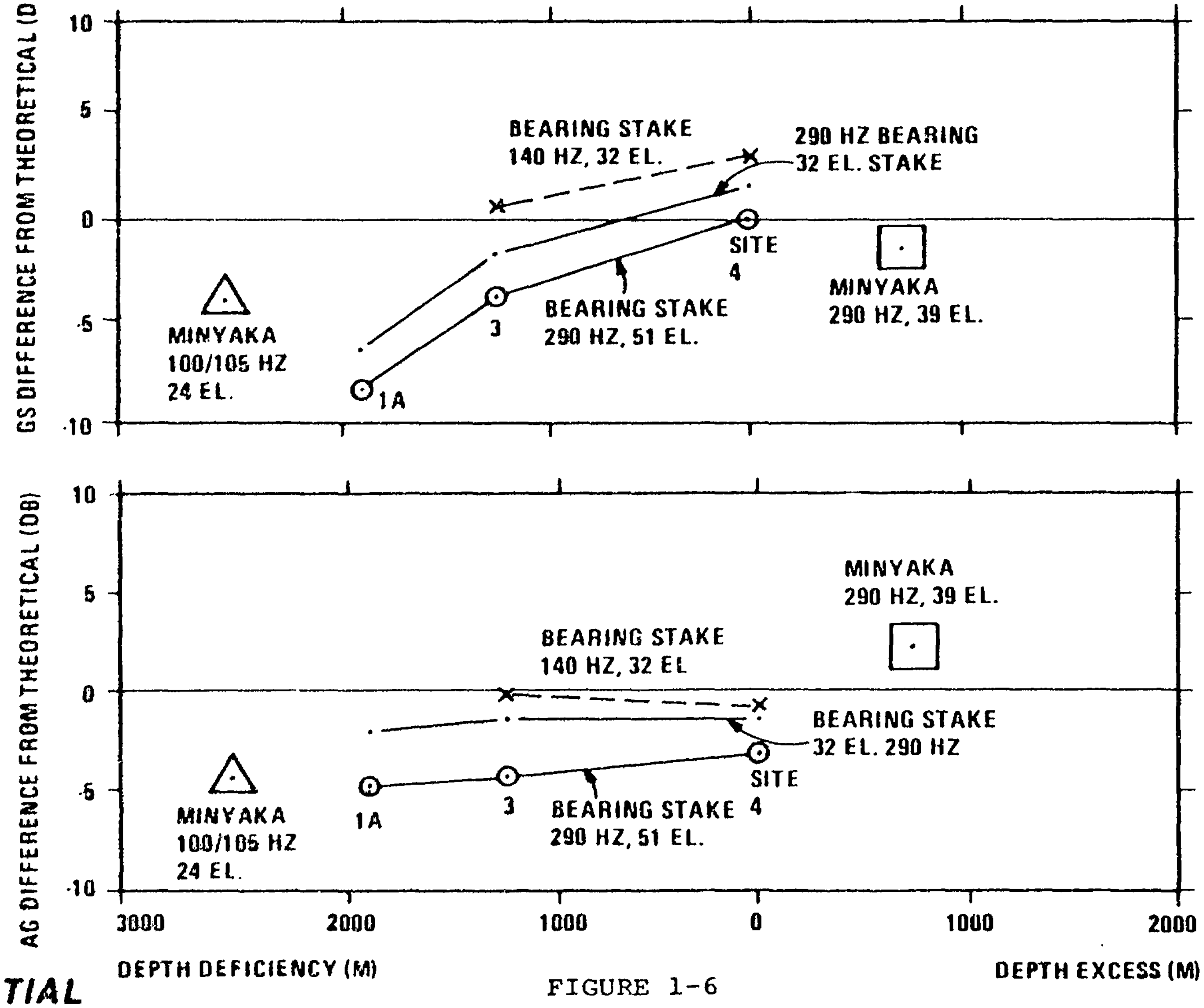

FIGURE 1-6

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1.1(S) TEST RESULTS SUMMARY (U)

(C) The purpose of the current test series was to add to the MINYAKA data base and determine system performance against tonals that are representative of both second and third generation targets in the 140 to 300 Hz band. Tests were run in moderate (9900 ft.) to deep (16,800 ft.) water using a 433 foot linear array of 53 elements with uniform $\lambda/2$ spacings (8.33 ft.) at 300 Hz. Such an array has a nominal gain of 17.2 dB (10 log 53) at 300 Hz and the gain has a 3 dB/octave slope about 300 Hz. Nominal beamwidth is 1.95° at 300 Hz for the full aperture. Array gain is diminished at approximately 3 dB per halving of aperture (by processing fewer elements, for example) but beamwidth is broadened.

(C) The types of measurements planned and executed are as follows:

- Signal, noise, and signal-to-noise ratio on individual omni hydrophones, and the mean values over a representative set of omnis.
- Measurement on and about the main response axis to determine direction to target, signal level and main lobe beam pattern response.
- Signal-to-noise gain versus number of elements.
- Measured beamwidths for quarter, half and full aperture and comparison to theoretical.
- Variation in range — 22 to 175 NM
- Variation in beamwidth (due to variation steering angle and aperture size) — 2.7° to 30.8°
- Variation in steering angle (relative to broadwide) — 12° to 64°

(C) The extremes in measured array (signal-to-noise) gain of the full aperture (51 elements nominal) relative to the average omni in the array are as follows:

(S) Maximum/Minimum Measured Array Gains
(Relative to Average Omni) (U)

SNR Gain Versus Omni (dB)	Freq (Hz) 140	Freq (Hz) 290	Freq (Hz) 295
Maximum	15.5	16.8	4.5
Minimum	6.8	7.1	3.9

The theoretical SNR gain at 140 Hz is reduced approximately 3.3 dB relative to the 300 Hz array design frequency.

(S) The tonals of most interest were 140 Hz and 290 Hz. Relatively high source levels were utilized for these tonals as shown in Table 1-2, the 295 Hz tonal more nearly approaches the third generation 290-300 Hz line level of 135 dBμPA. It is noted that in Site 1A, the low level 295 Hz line was detected at 91 NM and in Site 4, data point (DP) 9, at 72 NM. These are within the region of expected 50% P_D detection based on the computed FOM's of 93 dB and 97.1 dB* from which ranges of 127 and at least 240 NM respectively are predicted.

(C) The stronger-signal-levels provide less uncertainty in signal measurements and data reduction due to greater noise immunity and a more-nearly-linear processing correction (for the envelope detection performed in the MCPS-32 Analyzer, see Volume II, Section 2). Thus, greater data reliability is provided by the stronger signal-level data.

* Used conservative array gain of 11.7 dB for DP 9 where omni data was not available to compute array gain.

(S) TABLE 1-2
BRIEF SUMMARY OF DATA (U)

	DATA POINT	SIGNAL LEVEL (dBreμPa) 140 Hz	290 Hz	295 Hz	DEPTH (FMS)	RANGE (NM)	STEERING ANGLE	MEASURED BEAM WIDTH 140 Hz	290 Hz	295 Hz
SITE 1A	1	---	155	145	1650	91	-59.0°	*	4.1°	4.1°
SITE 1A	2	---	155	140	1650	91	-58.5°	*	4.7°	***
SITE 3	3	182	180	*	1900	175	$+27.0^{\circ}$	4.2°	2.7°	*
SITE 3	4	182	180	*	1900	159	$+32.0^{\circ}$	9.9°	11.0°	*
SITE 3	5	182	180	*	1900	110	$+40.0^{\circ}$	7.9°	5.9°	*
SITE 3	6	182	180	*	1900	70	$+15.0^{\circ}$	7.5°	7.8°	*
SITE 3	7	182	180	143	1900	28	-21.5°	7.4°	6.1°	8.6°
SITE 4	8	186	182	143	2800	22	$+20.0^{\circ}$	8.1°	4.2°	5.2°
SITE 4	9	186	182	143	2800	72	$+51.5^{\circ}$	6.4°	3.0°	3.0°
SITE 4	10	186	182	143	2800	128	$+62.0^{\circ}$	8.7°	4.7°	**
SITE 4	11	186	182	143	2800	122	$+64.0^{\circ}$	15.2°	4.0°	**
SITE 4	12	186	182	143	2800	122	$+62.0^{\circ}$	9.6°	4.2°	**

* Not Projected
** Not Detected
*** Detected-Not enough points for 3 dB point beamwidth measurement

(C) Array Performance at 295 Hz - Only a limited and somewhat dubious data base (2 data points) for array gain is reported for the 295 Hz line. Because the low 295 Hz signal levels radiated were detected on omni channels only in Site 1A (DP 1 and 2), array gain is reported only for these data points. The beamformed array output, however, indicated detections of the 295 Hz line in all three sites. See Section 2.6, Volume IB.

(C) For the 295 Hz data, the conclusion drawn is that measured omni signal levels are suspect and the resulting SNR and AG values, including other data presented is questionable. It is noted that the AG for data points 8 and 9 must exceed 9.7 and 11.7 dB respectively, since presumably the omni SNR for these points is zero dB or less.

(C) It will be noted throughout that the maximum nominal aperture comprises 51 elements, rather than the greatest possible value of 53 elements. This is because several of the elements during the various launches turned out to be excessively noisy (sufficient to product channel clipping in some instances). At various times, the following elements were eliminated:

Element Number	Problem	Data Points Affected
7	Clipping	2, 8, 10
8	Clipping	2, 8, 10
15	Clipping	1, 2, 8
28	Intermittent, from satisfactory to "large spikes"	3, 4, 5, 6, 7, 8 9, 10
29	"	3, 4, 5, 6, 7, 8 9, 10

(C) Such "holes" in the aperture were accounted for in the modeling performed to generate theoretical beam patterns and gain values throughout this report. Thus, when elements 7, 8, 15, 28, 29 are eliminated from Site 8 data, for example, the pattern presented in Figure 1-7 has accounted for these missing sensors, and the effect is apparent as higher-than-normal side lobes at the 0° and 180° scale azimuth values.* (The pattern spikes at 26°, 68°, 292° and 334° are due to sampling the data at a frequency below that required to eliminate sampling grating lobes.) The azimuth gain value 16.92 dB is based on the actual pattern displayed.

(S) A virtually complete summary of the data measured for the entire exercise appears in Table 1-3. This will be discussed in detail in the following sections, but a few over-all observations can be made immediately. Measured array gains are somewhat below the values obtained in the deep water MINYAKA exercise, and data dispersion is more apparent. This is expected because of greater signal interaction with the surface and bottom boundaries for the present SVP's. Although all data was checked carefully, there is an apparent error in the measured gain for DP 5, at least for the 16-element aperture, where a value of 18 dB (double the computed value) is reported. The value of 16.4 dB for the 32 element aperture also appears optimistic.

(U) In data locations denoted (b), good array data is available. The reference omni data, however, had insufficient signal level to detect a tonal in the analysis bandwidth. For data denoted (a), there was either insufficient signal-to-noise or signal-to-interfering tonal to determine a meaningful pattern response. Both cases would improve with greater projected signal level.

---

* For the azimuth scale shown in the beam pattern plots a 90° offset is included. Thus, 110° corresponds to 20° off broadside.

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Figure 1-7 Predicted Pattern at Beamformer Output, Site 4, Data Point 8, 290 Hz, 48 elements. Elements 7, 8, 15, 27, 28 are deleted. (U)

DATA POINT 8
1200 HZ. SAMPLING FREQUENCY DISTORTS PATTERN.
290.0 HZ., 48 ELEMENTS, -0.86 DB MAX., AC:S4343,SU:S4343,WT:
90.0 DEG. VERT. RESP., 110.0 DEG. HORIZ. STEER, 90.0 DEG. VERT STEER
2.09 DEC. 3 DB BEAM, 16.92 DB AZ. GAIN, MAX. AT 110.0 DEG. HORIZ.

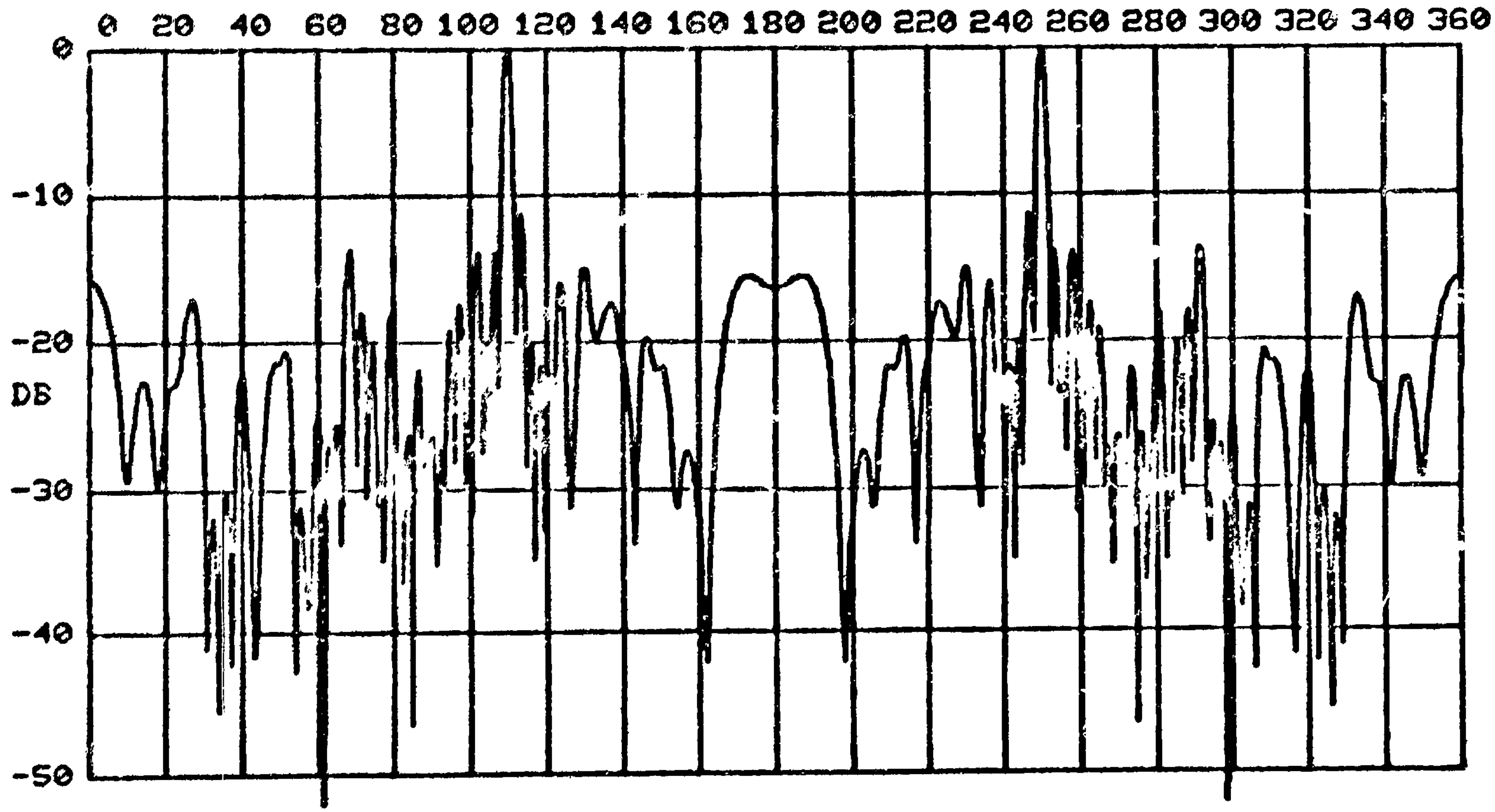

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TABLE 1 - 3

SUMMARY OF MEASURED VS THEORETICAL ARRY PERFORMANCE (ALL ANALYZED DATA INCLUDED) (U)

SITE	DP	FREQ	STEERING ANGLE			THEORETICAL BEAMWIDTH			MEASURED BEAMWIDTH			THEO. AZIMUTH GAIN (dB)			MEASURED ARRAY GAIN (dB)		
			16 ELE.	32 ELE.	MAX ELE.	16 ELE.	32 ELE.	MAX ELE.	16 ELE.	32 ELE.	MAX ELE.	16 ELE.	32 ELE.	MAX ELE.	16 ELE.	32 ELE.	MAX ELE.
1A	1	290	-60°	58.5°	59°	17.1°	5.8°	3.8°	15.4°	6.5°	4.1°	10.5	13.3	15.4	12.1	12.2	9.9
		295	-56°	58.5°	58°	13.1°	5.8°	3.7°	(a)	8.8°	4.1°	10.3	13.4	16.5	7.8	8.7	4.5 (c)
	2	290	-57°	58.5°	59°	12.3°	5.9°	3.8°	12.3°	7.0°	4.7°	10.4	13.3	15.4	3.8	9.9	11.3
		295	-59°	59.5°	64°	13.3°	5.8°	3.7°	17.3°	(a)	(a)	10.4	13.4	15.4	2.5	4.6	3.9 (c)
	3	140	27°	25.5°	26°	15.1°	7.2°	4.5°	15.0°	7.5°	4.2°	13.0	13.1	15.1	10.8	12.1	15.5
		290	27°	25.5°	27°	7.3°	3.5°	2.1°	9.0°	2.9°	2.7°	12.3	15.2	17.2	14.2	14.9	16.8
	4	140	39°	35.5°	35.5°	16.8°	7.1°	4.8°	17.8°	8.7°	9.9°	9.6	12.6	14.8	3.4	7.8	9.3
		290	29.5°	39.5°	31.5°	7.6°	3.8°	6.3°	7.2°	3.7°	4.4°	12.2	15.0	17.1	12.2	11.8	9.8
3	5	140	40°	43°	44°	19.7°	9.0°	5.6°	31.1°	11.2°	7.9°	9.2	12.2	14.2	18.2	16.4	14.9
		290	40°	41°	41°	10.3°	4.7°	3.0°	13.1°	6.7°	5.9°	11.3	14.4	16.3	12.8	15.0	11.7
	6	140	12°	13°	16°	14.2°	6.7°	4.2°	18.1°	12.8°	7.5°	10.4	13.5	15.5	8.6	11.5	14.8
		290	16°	17°	19°	6.8°	3.2°	2.6°	8.7°	5.3°	7.8°	12.5	15.3	17.5	14.4	14.0	12.6
	7	140	-20°	-20°	-21°	16°	8.0°	5.0°	18.8°	8.4°	7.4°	16.0	12.6	14.7	9.4	8.3	8.5
		290	-19°	-21.5°	-22°	9°	3.4°	2.1°	18.0°	4.8°	6.1°	12.0	14.7	17.1	6.4	8.6	7.1
		295	-19°	-21.5°	-21.5°	6.8°	3.3°	2.1°	16.4°	6.5°	8.6°	11.7	15.1	17.2	(b)	(b)	(b)
	8	140	20°	20°	19°	14.1°	6.8°	4.2°	16.3°	8.7°	8.1°	10.4	13.4	16.3	6.3	14.7	11.4
		290	20°	20°	20°	7.0°	3.3°	2.1°	7.0°	4.0°	4.2°	12.1	15.2	16.9	13.2	12.8	10.8
		295	19°	20°	19°	6.6°	3.2°	2.0°	6.3°	3.9°	5.2°	12.3	14.7	17.0	(b)	(b)	(b)
	9	140	52.5°	51.5°	52°	22.7°	10.9°	6.6°	24.6°	10.8°	6.4°	8.5	11.7	13.6	3.8	10.2	13.2
		290	51°	51.5°	51.5°	10.6°	4.9°	3.0°	10.8°	4.6°	3.0°	11.1	14.2	16.0	14.0	15.1	15.5
		295	51°	51.5°	51.5°	10.3°	4.9°	7.0°	10.0°	4.8°	3.0°	11.0	14.0	16.3	(b)	(b)	(b)
4	10	140	59°	63.6°	63°	25.9°	13.0°	8.6°	33.6°	14.5°	8.1°	7.8	10.8	12.4	6.3	9.9	10.5
		290	63°	61°	61.5°	11.9°	6.8°	4.1°	18.5°	7.2°	4.7°	10.2	13.4	16.0	11.0	11.5	12.6
	11	140	60°	59°	63°	22.5°	12.9°	8.3°	30.8°	16.0°	15.2°	7.6	10.9	12.4	7.4	8.4	7.2
		290	61°	63°	64°	15.9°	6.9°	4.5°	19.0°	7.8°	4.0°	9.4	13.0	14.9	7.7	11.7	12.1
	12	140	60°	61.5°	60°	34.9°	17.9°	8.1°	29.1°	16.0°	9.6°	7.4	10.6	12.6	8.7	8.5	6.8
		290	61.5°	63.8°	63°	14.4°	6.5°	4.1°	14.4°	4.3°	4.2°	9.8	13.4	15.2	6.7	7.6	6.7

(a) Insufficient SNR on beamformed output to develop adequate pattern response
(b) Unable to discern tonal on omni channels in analysis bandwidth
(c) Questionable values

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1.2 ENVIRONMENTAL ACOUSTIC AND GEOGRAPHIC DATA (U)

(C) Tests were conducted at three Indian Ocean sites denoted by 0's on the relief map in Figure 1-8. Site numbers and locations are listed in Table 1-4 along with pertinent environmental acoustic data. Representative sound velocity profiles (SVP's) were picture in Figure 1-2 and show diminishing depth deficiency as depth increases from Site 1A to Site 4. These SVP's were input to the FACT model to generate the arrival angle and transmission loss curves plotted in Figures 1-9 through 1-17, which were used to estimate range in Section 2.1. The array was at a nominal 100 ft. depth and the projector at 60 ft. depth throughout the exercises. Projector frequencies and levels are noted in Table 1-2.

(C) Arrival structure plots are typical of mid-depth to deep water with significant energy at high arrival angles in close (<20 NM), but with most of the signal contained within $\pm 10^{\circ}$ (even less for Site 4) beyond about 50 NM. All six transmission loss plots exhibit very low loss, with slopes in the vicinity of 10 dB/decade (cylindrical spreading) out to 240 NM. One would, therefore, expect large detection ranges even for a modest horizontal array (assuming approximately coherent signal summation), and handsome rewards in added surveillance area covered with increased array aperture. The key, of course, is coherent signal summation, which we have observed, appears to become more difficult to obtain when the jump is made from approximately half aperture (32 elements) to full aperture at 300 Hz ($\simeq \lambda/2$ spacing). See Figures 2-1 and 2-2. It is felt that the plane wave model used is inadequate for the amount of signal decorrelation experienced at the 25 λ aperture, at least for depth deficient conditions.

(C) Ambient noise levels measured during the test series agree reasonably well (within 2 to 10 dB) with previously reported data. As shown in Figure 1-18, the omni noise levels are approximately -5 dB, +2 dB and -6 to -9 dB for Sites 1A, 3 and 4 respectively, relative to the Vidale data.* Mean noise levels for the three sites are plotted against the Trident noise curves for reference in Figure 1-19. The measured BEARING STAKE data falls between the E and F shipping levels and sea state 4. Although the reported level was sea state 1, the combined shipping and sea state components appear to be reasonable.

(U) Navigation plots for the data reported appear as Figures 1-20, 1-21, and 1-22 for the three sites. Data points are designated in circles along the projector ship (Kingsport) track. Array launch location is indicated by a triangle.

*Reference 2

REFERENCES

1. (U) Self-Tensioning Acoustical Horizontal Line Array (SPRAY) Data Analysis (*)
Final Report of Deep and Shallow Minyaka Tests April and July 1975, 6 May 1977
Prepared for Naval Air Development Center
Johnsville, Warminster, Pennsylvania 18974
by Sanders Associates, Inc.

2. (U) Test Site Data for Third SPRAY Sea Test, Sanders Associates Internal Memorandum dated 11 October 1976 S. S. Ballard

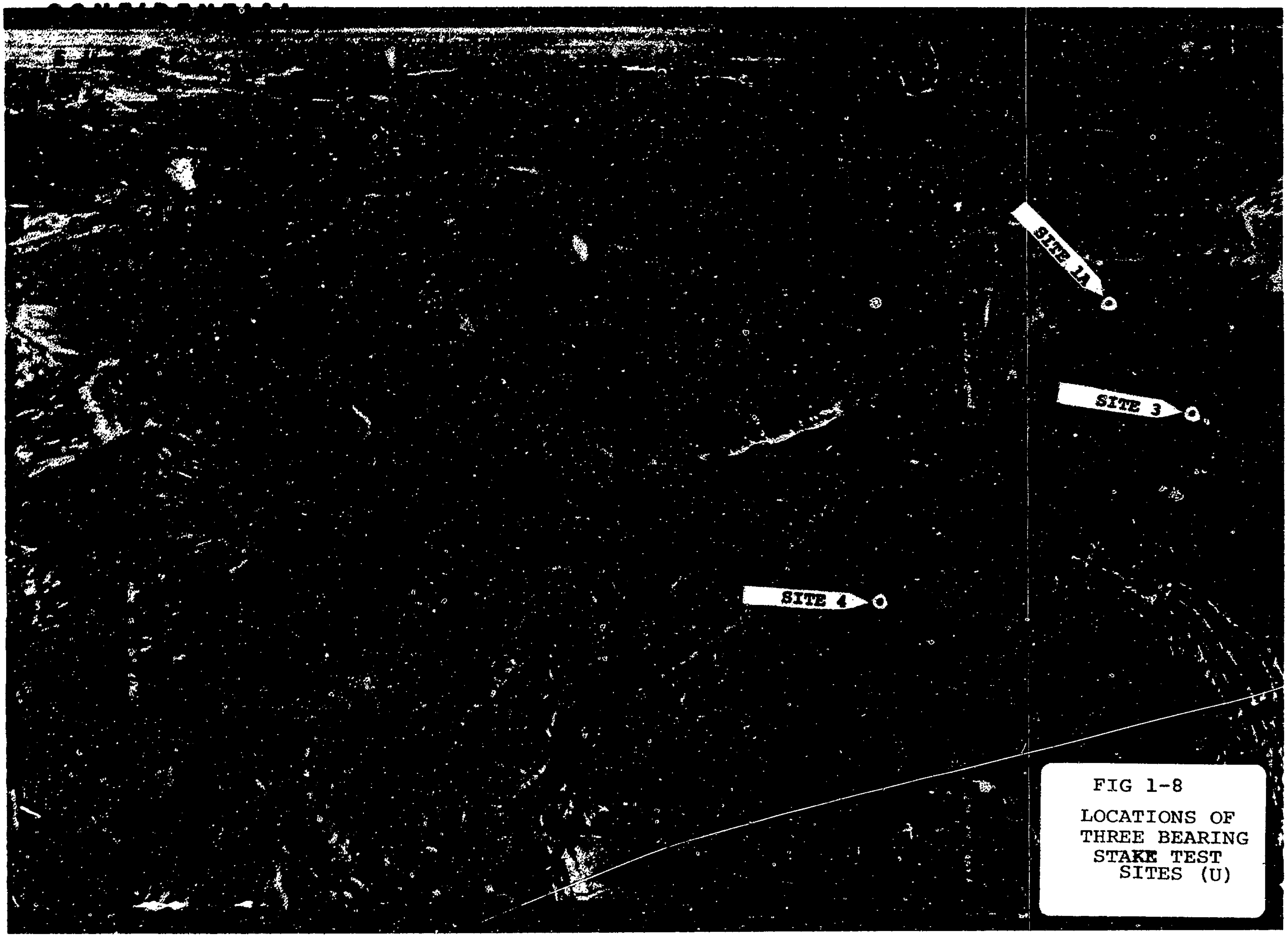

FIG 1-8

LOCATIONS OF THREE BEARING STAKE TEST SITES (U)

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TABLE 1-4 SITE LOCATIONS AND ENVIRONMENTAL CONDITIONS (U)

SITE NO.	ASSOCIATED DATA POINTS	ARRAY LOCATION	DATES DATA COLLECTED	NOMINAL DEPTH (FM)	SVP (1) CHARACTER	FNWC (2) BOTTOM TYPE	WAVE HEIGHT (M)
1A	1, 2	22^{O} 55'N 63^{O} 30'E Gulf of Oman	19 Jan. '77	1650 (3040M)	1860M DD	1	1.2
3	3,4,5,6,7	17^{O} 12'N 65^{O} 08'E Arabian Basin	7,8 Feb. '77	1900 (3460M)	1200M DD	1	1.1
4	8,9,10,11, 12	05^{O} 05'N 53^{O}E Somali Abyssal Plain	15,16 Mar. '77	2800 (5107M)	0M DD	1	0.6

(1) DD = Depth Deficient Sound Velocity Profile

(2) Fleet Numerical Weather Central Value used for Transmission Loss Calculation using Fact Model

Figure 1-9 Arrival Structure in Site 1A, The Gulf of Oman (U)

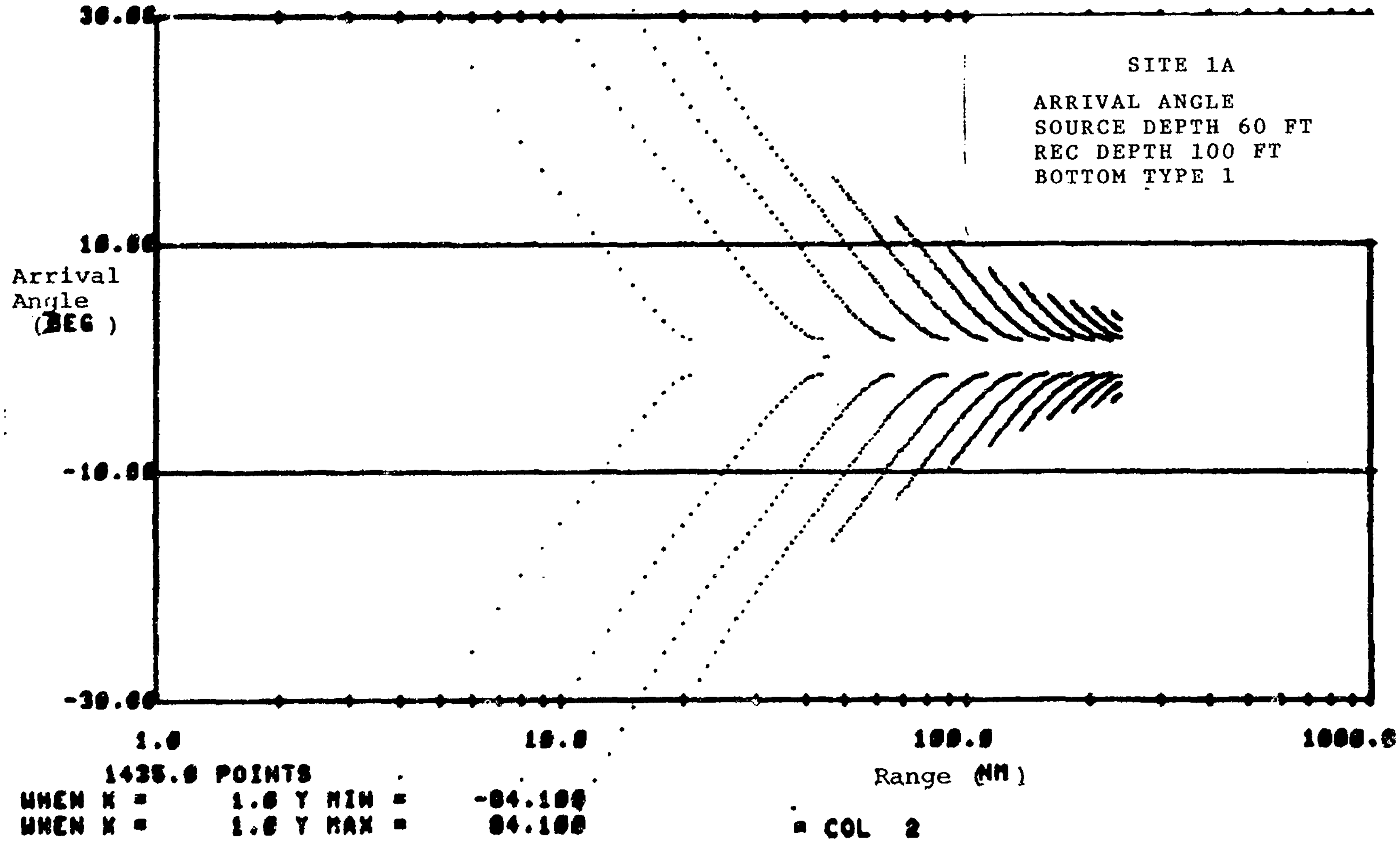

Figure 1-10 Transmission Loss in Site 1A, The Gulf of Oman, 140 Hz. (U)

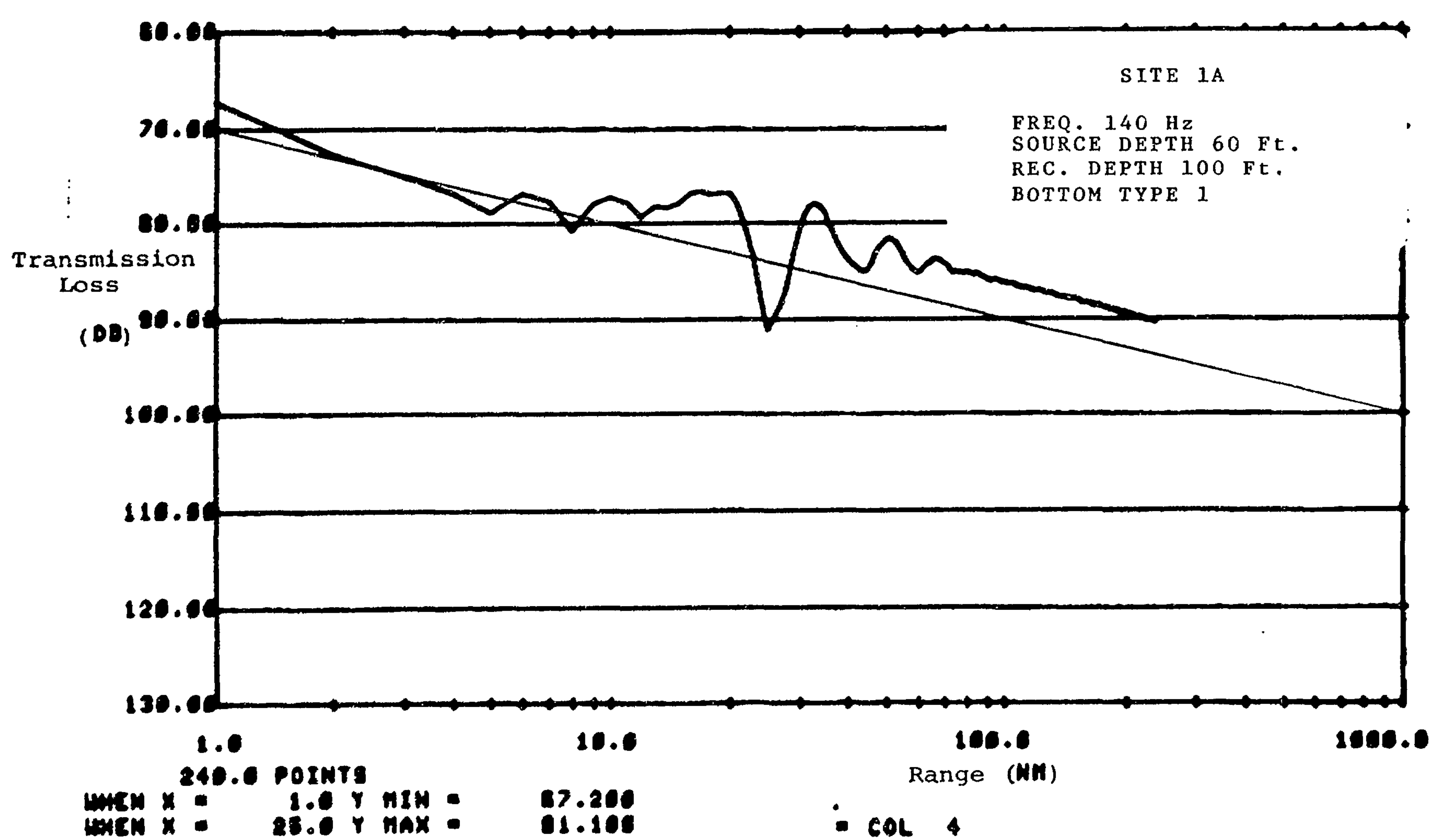

Figure 1-11 Transmission Loss in Site 1A, The Gulf of Oman, 290 Hz (U)

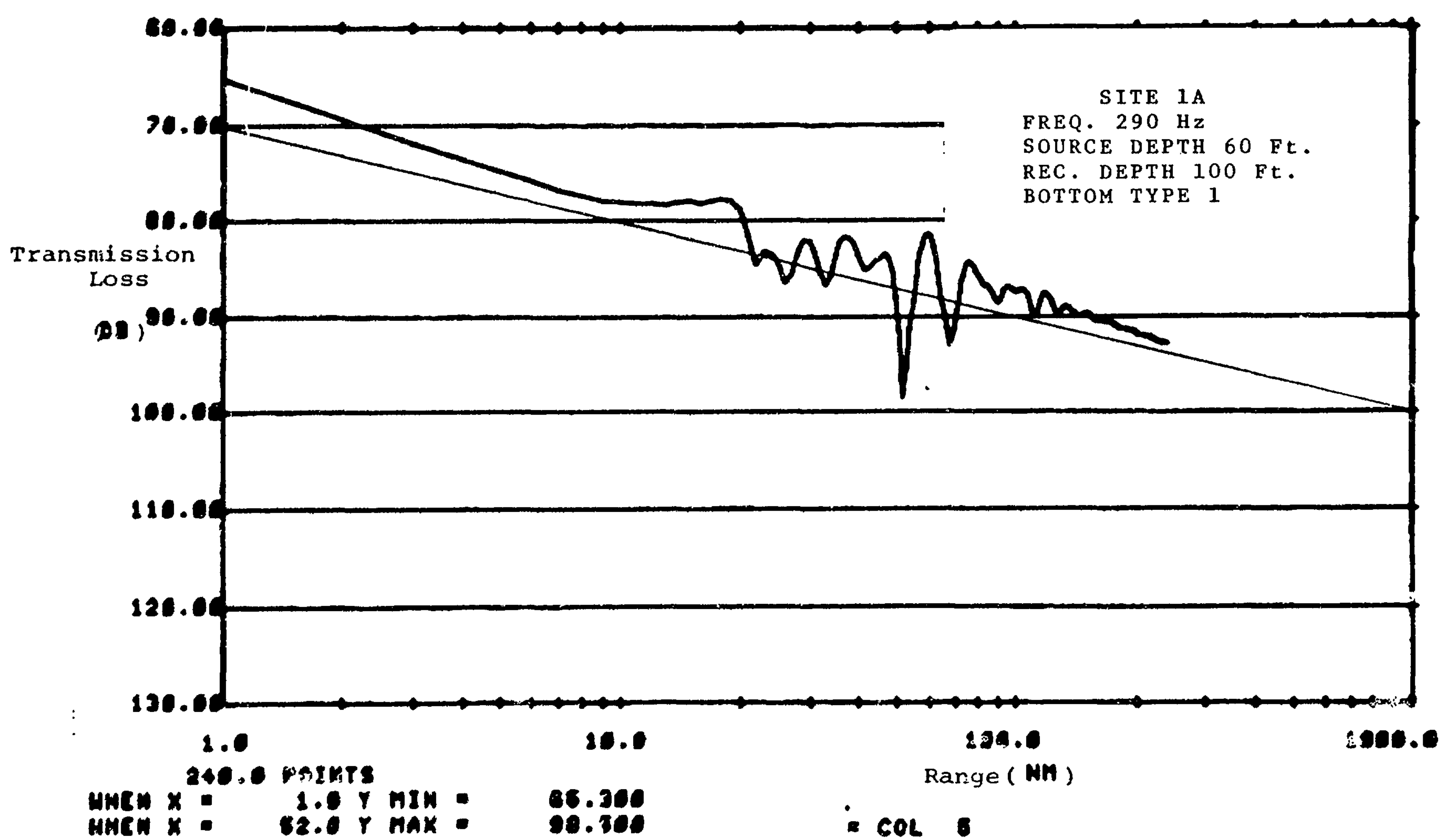

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Figure 1-12 Arrival Structure in Site 3, The Arabian Basin (u)

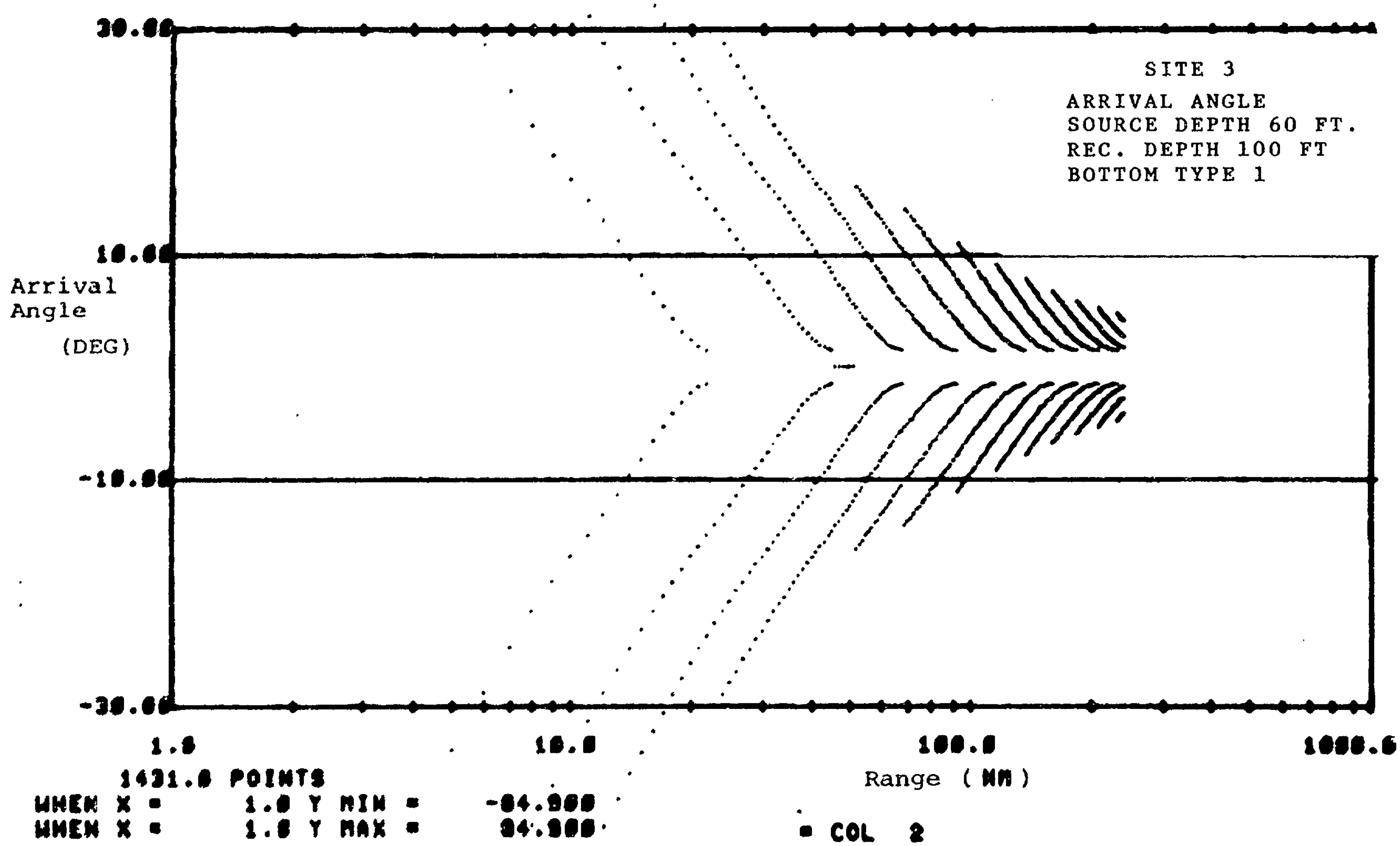

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Figure 1-13 Transmission Loss in Site 3, The Arabian Basin, 140 Hz (U)

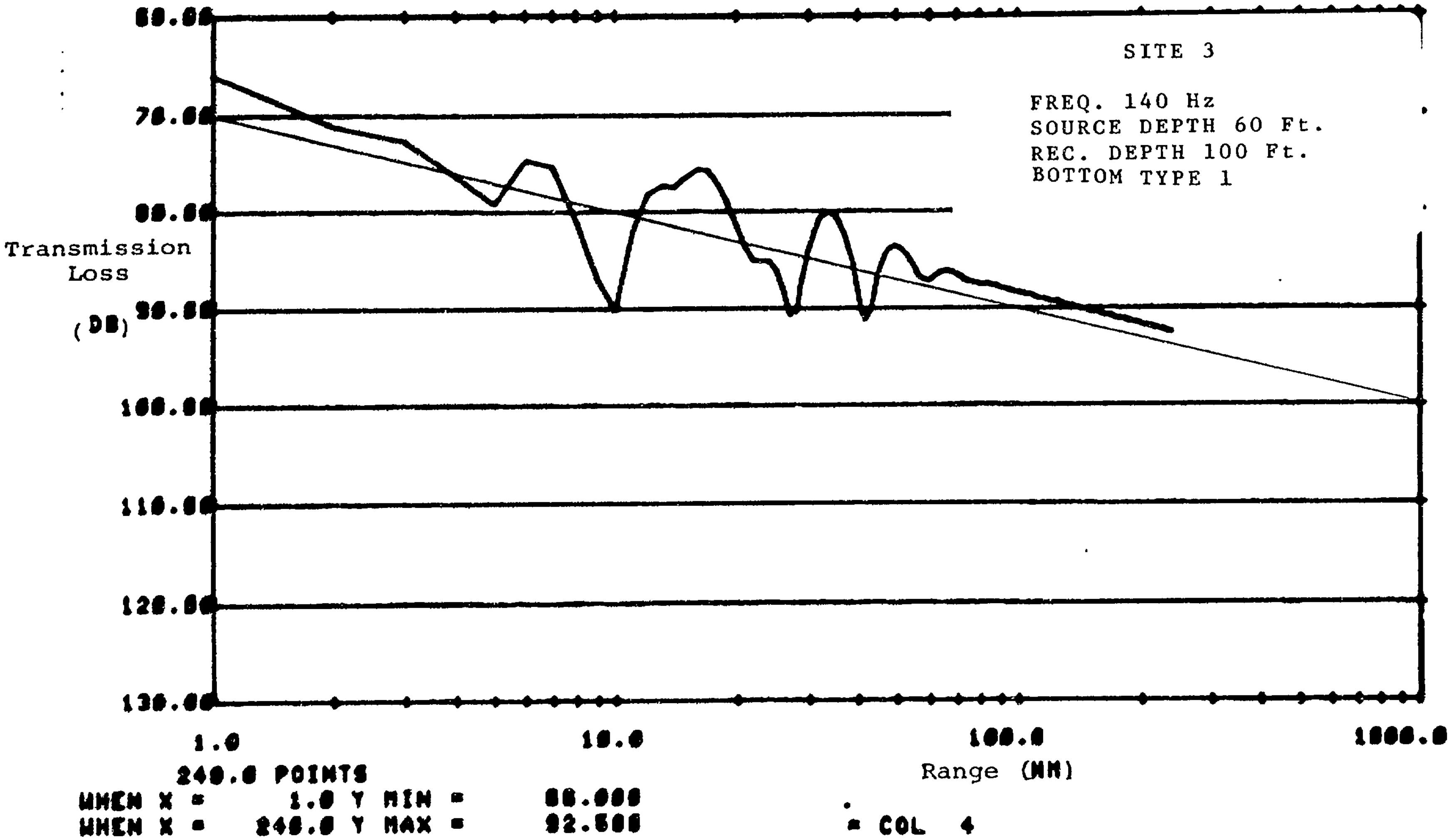

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Figure 1-14 Transmission Loss in Site 3, The Arabian Basin, 290 Hz (u)

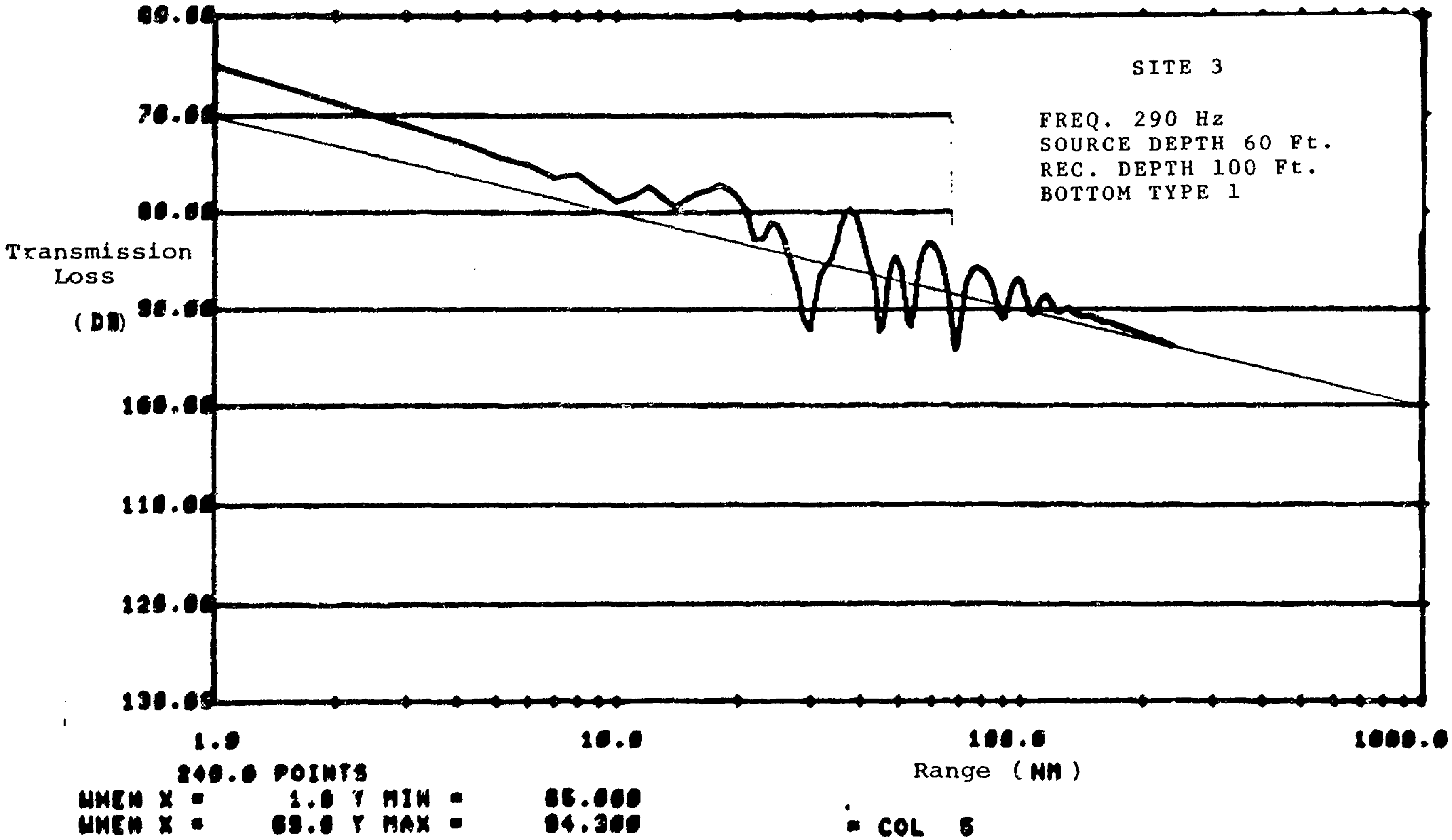

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Figure 1-15 Arrival Structure in Site 4, The Somali Abyssal Plain (U)

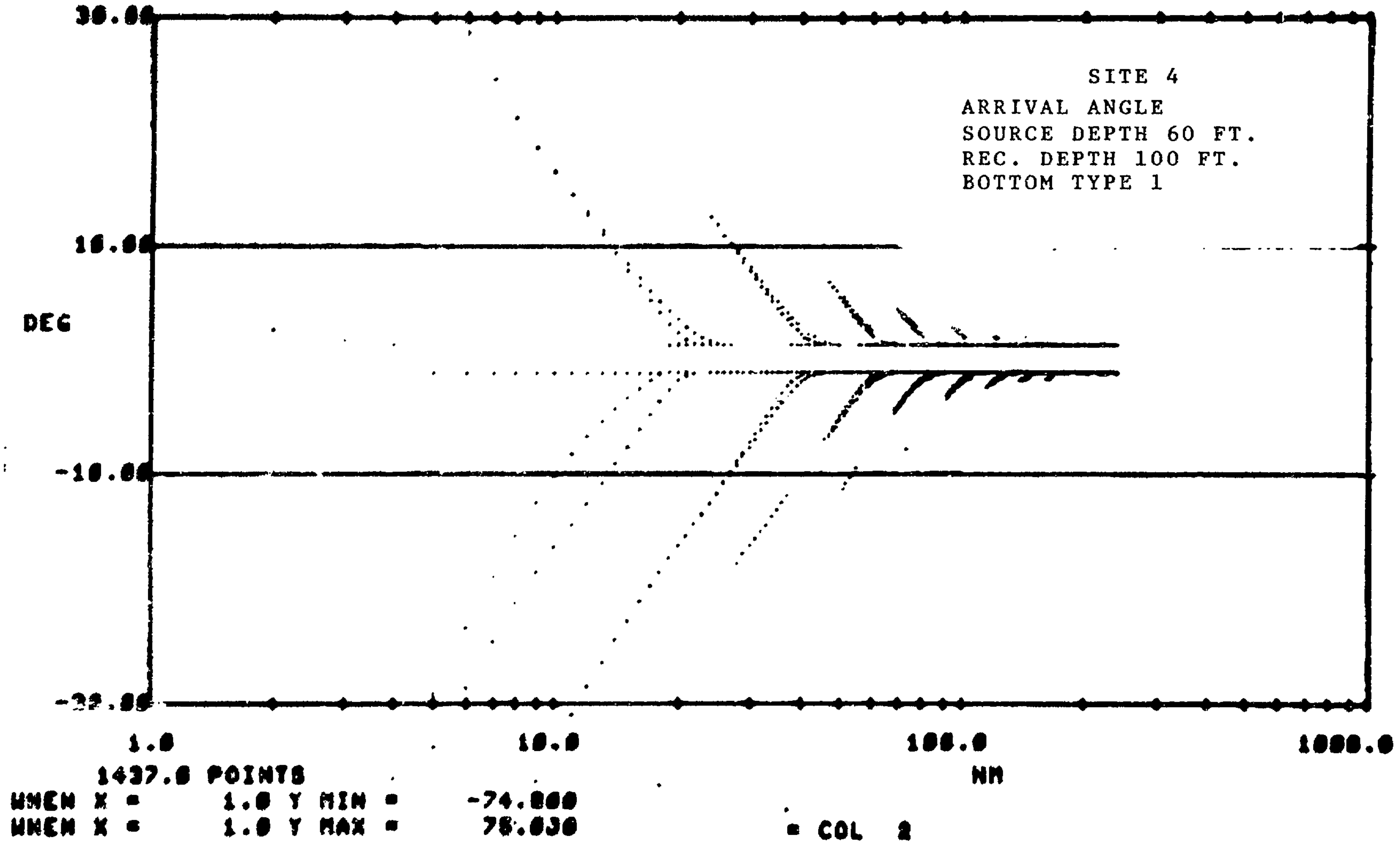

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Figure 1-16 Transmission Loss in Site 4, The Somali Abyssal Plain, 140 Hz (U)

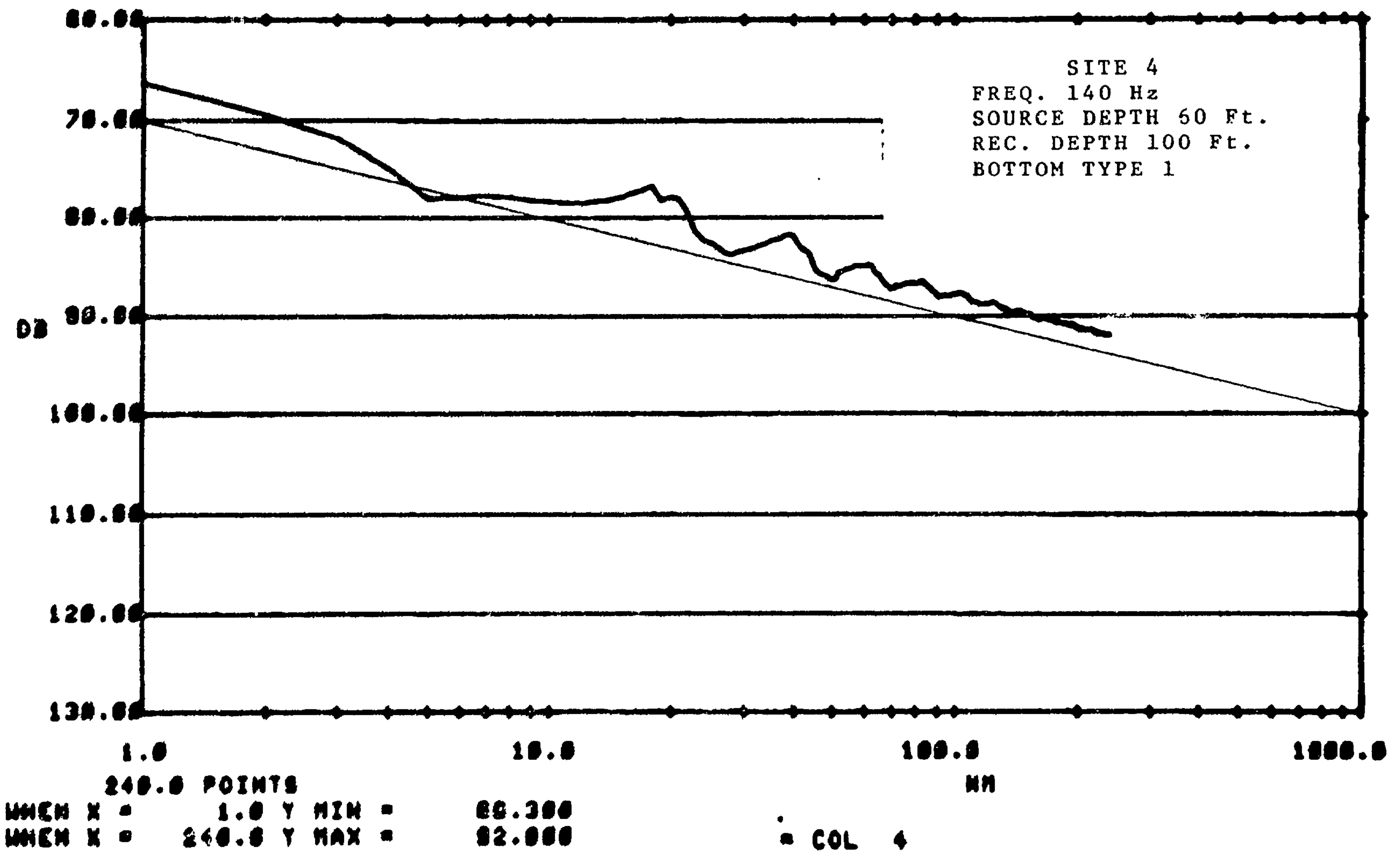
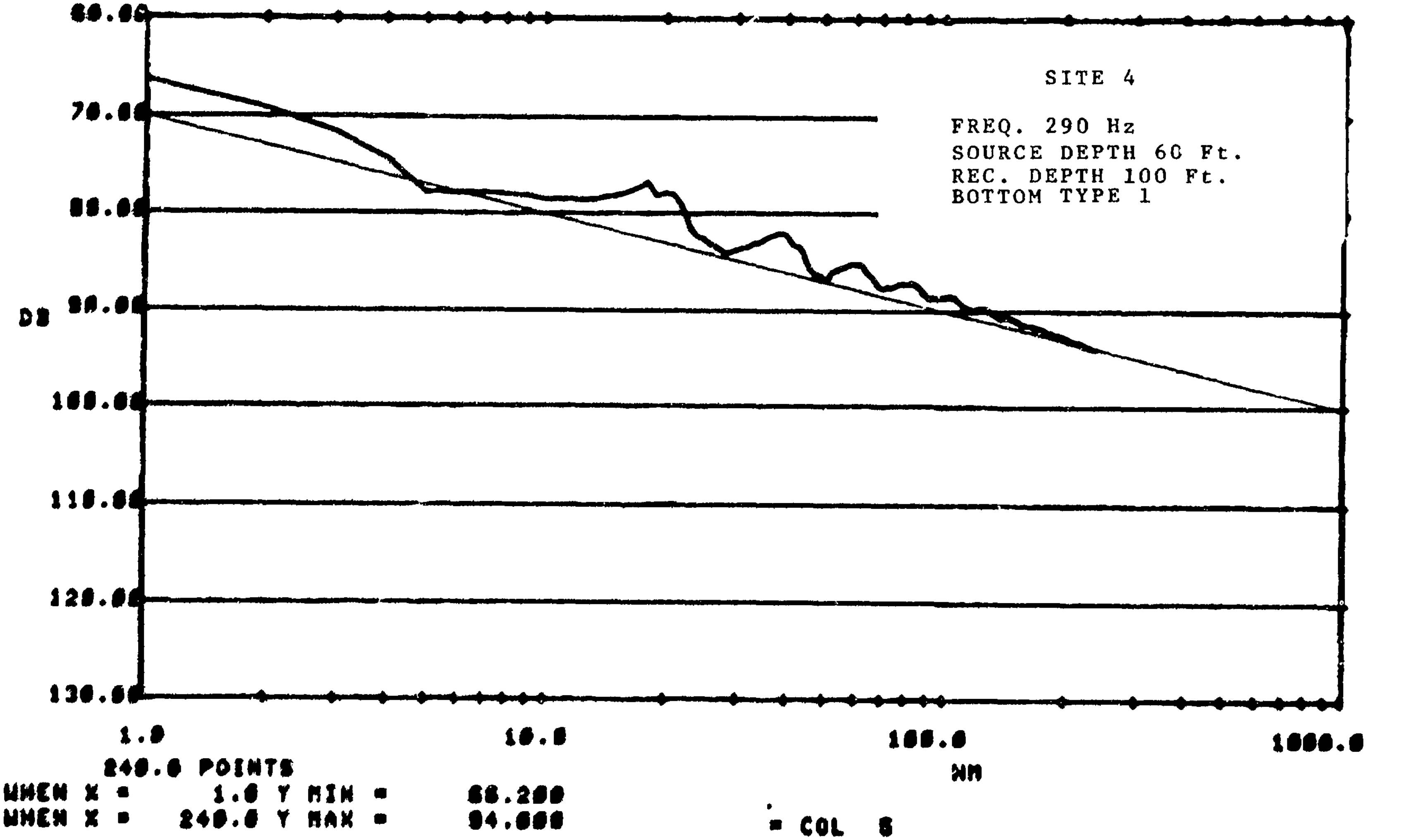


Figure 1-17 Transmission Loss in Site 4, The Somali Abyssal Plain, 290 Hz. (U)



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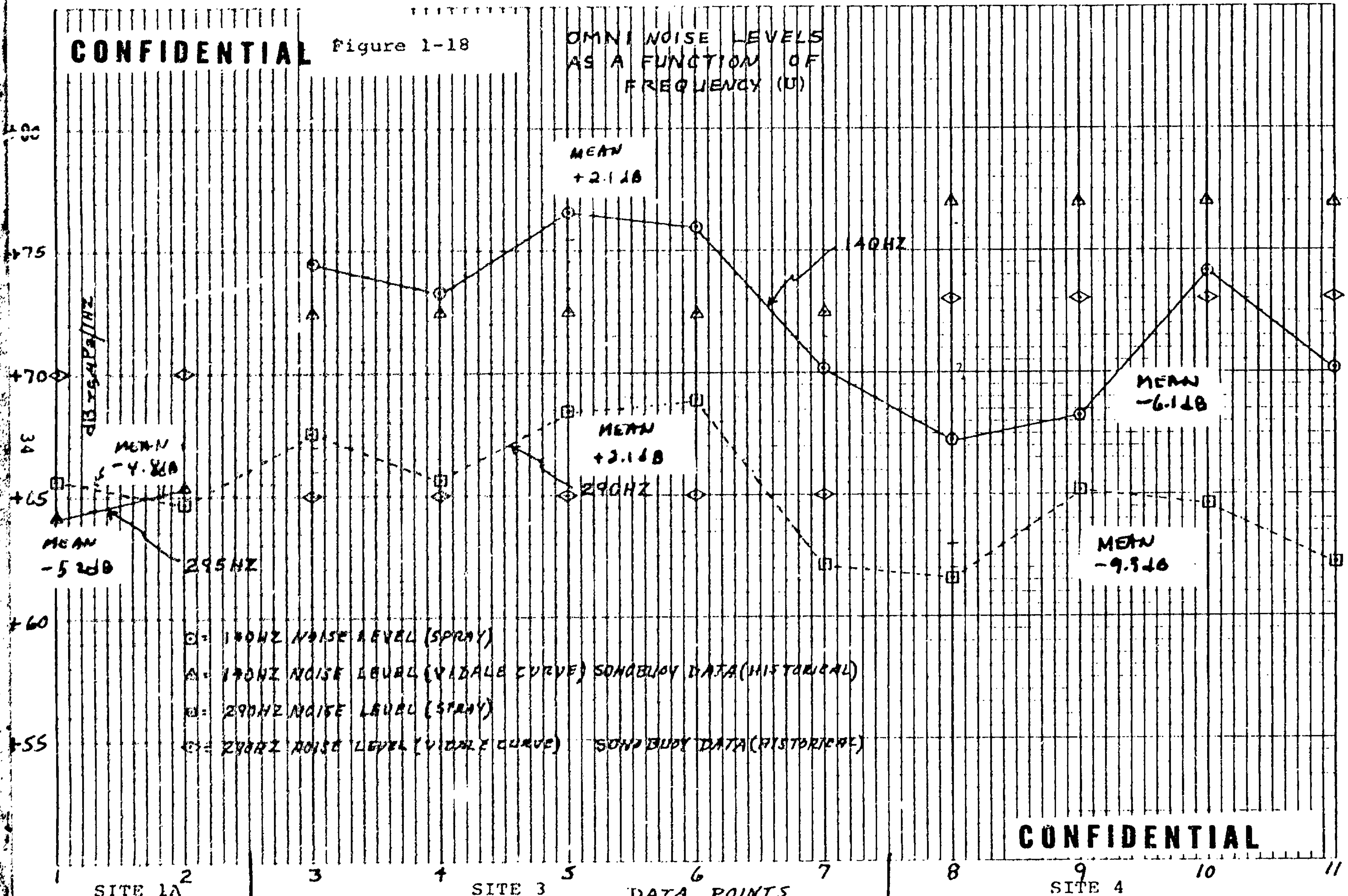

Figure 1-18

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Figure 1-19 Comparison of Bearing Stake Measured Noise Levels with Trident Data (U)

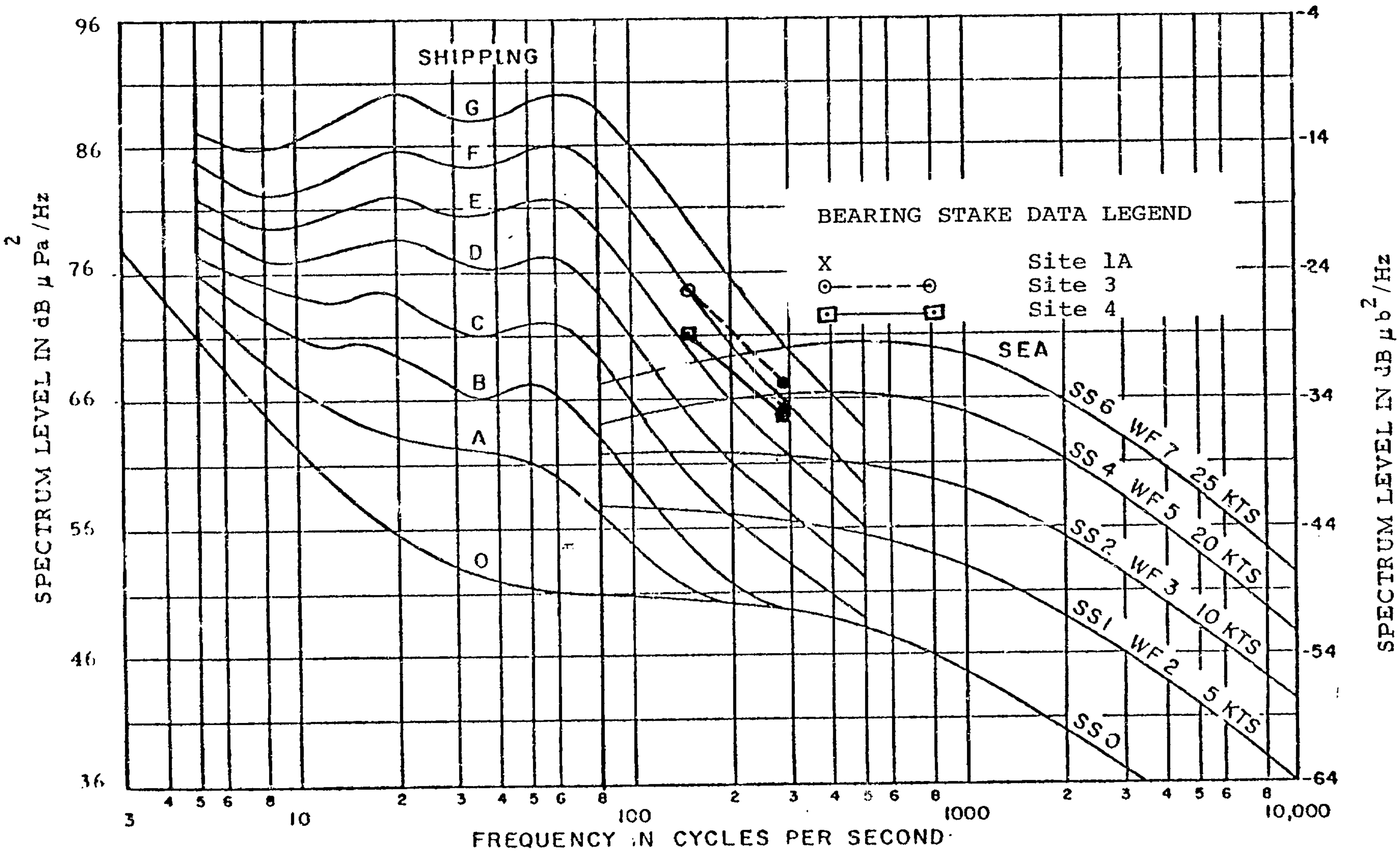

FIGURE 1-20 NAVIGATION PLOT FOR SITE 1A

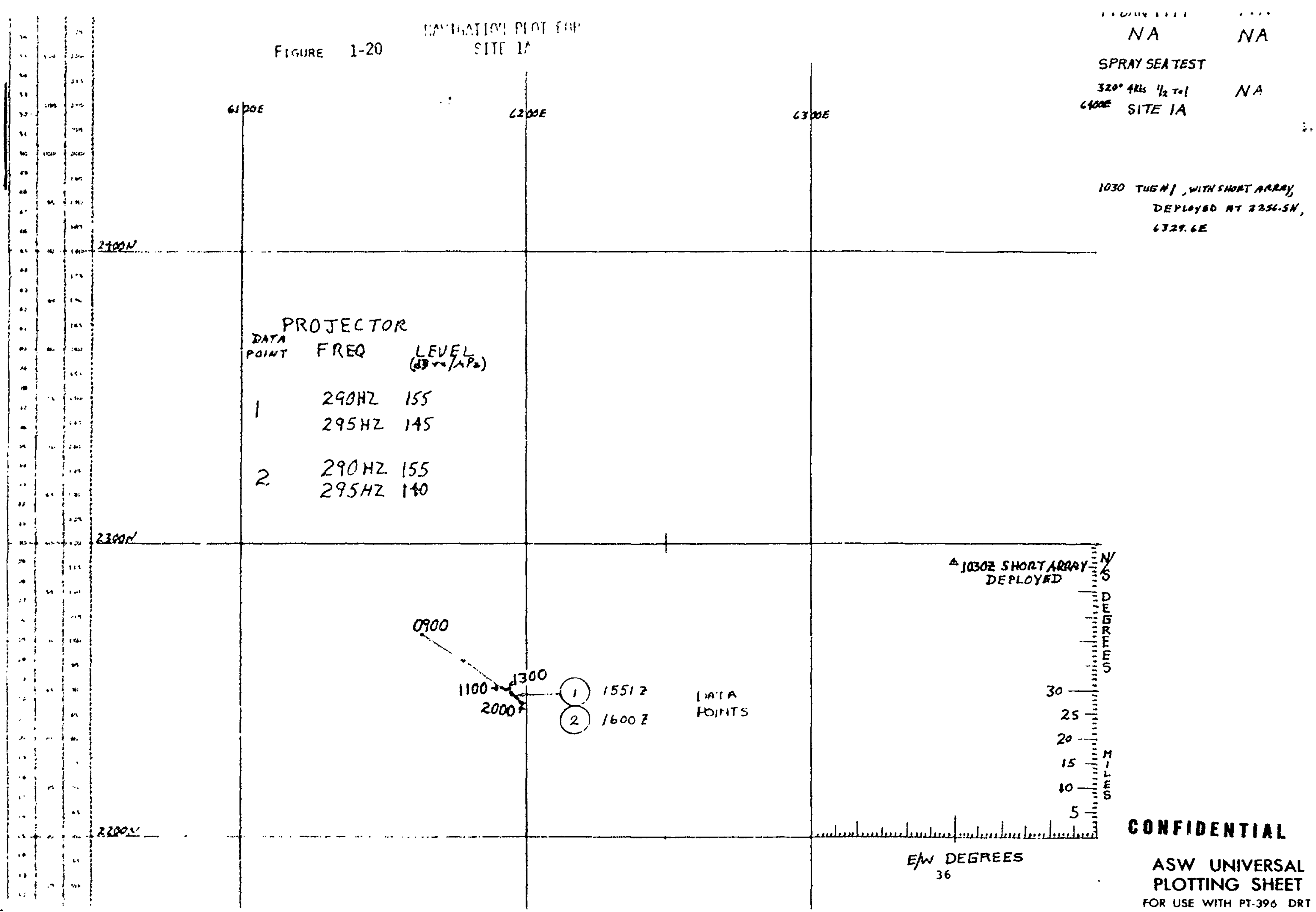

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FIGURE 1-21 NAVIGATION PLOT FOR SITE 3

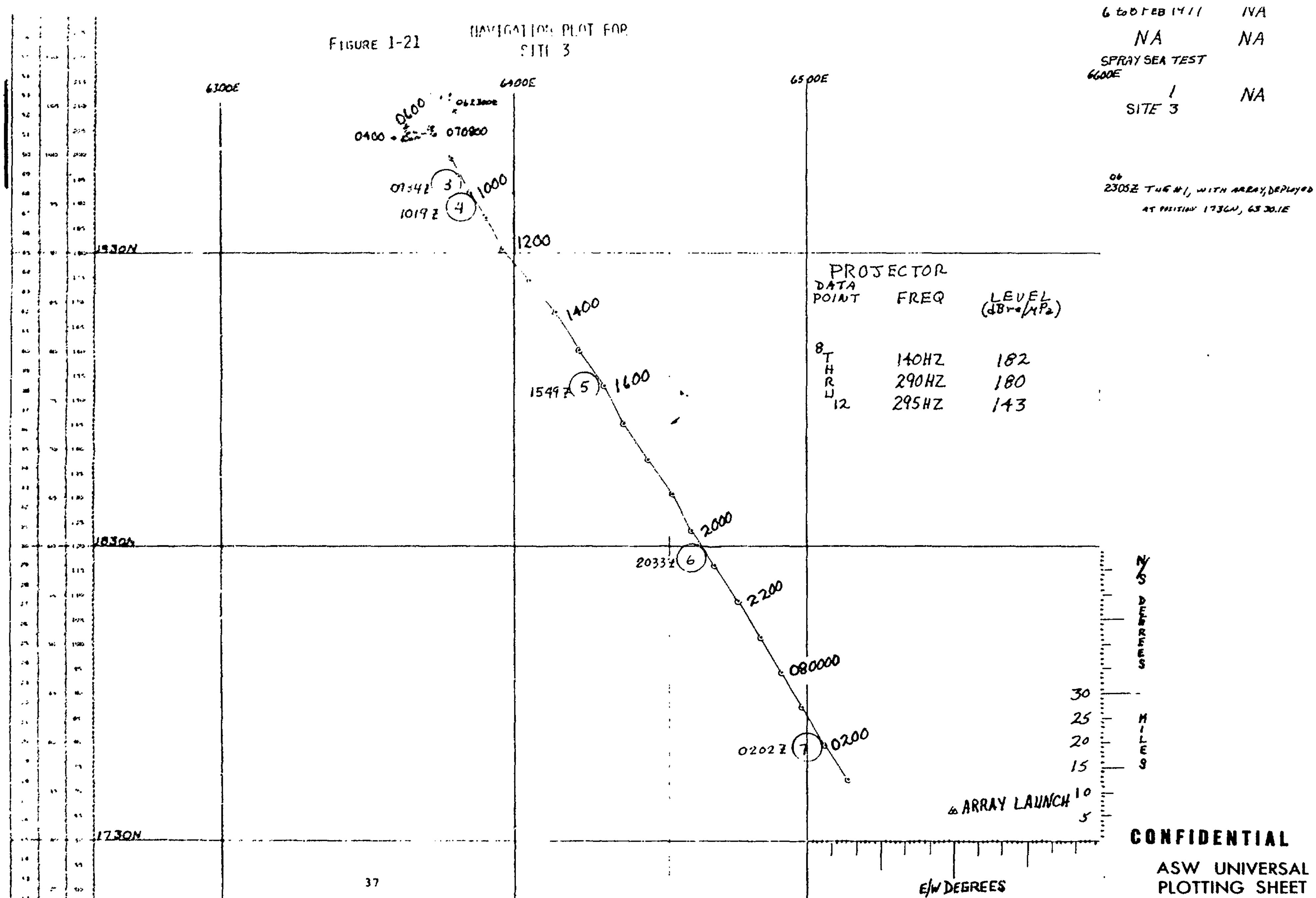

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Figure 1-22

NAVIGATION PLOT FOR SITE 4

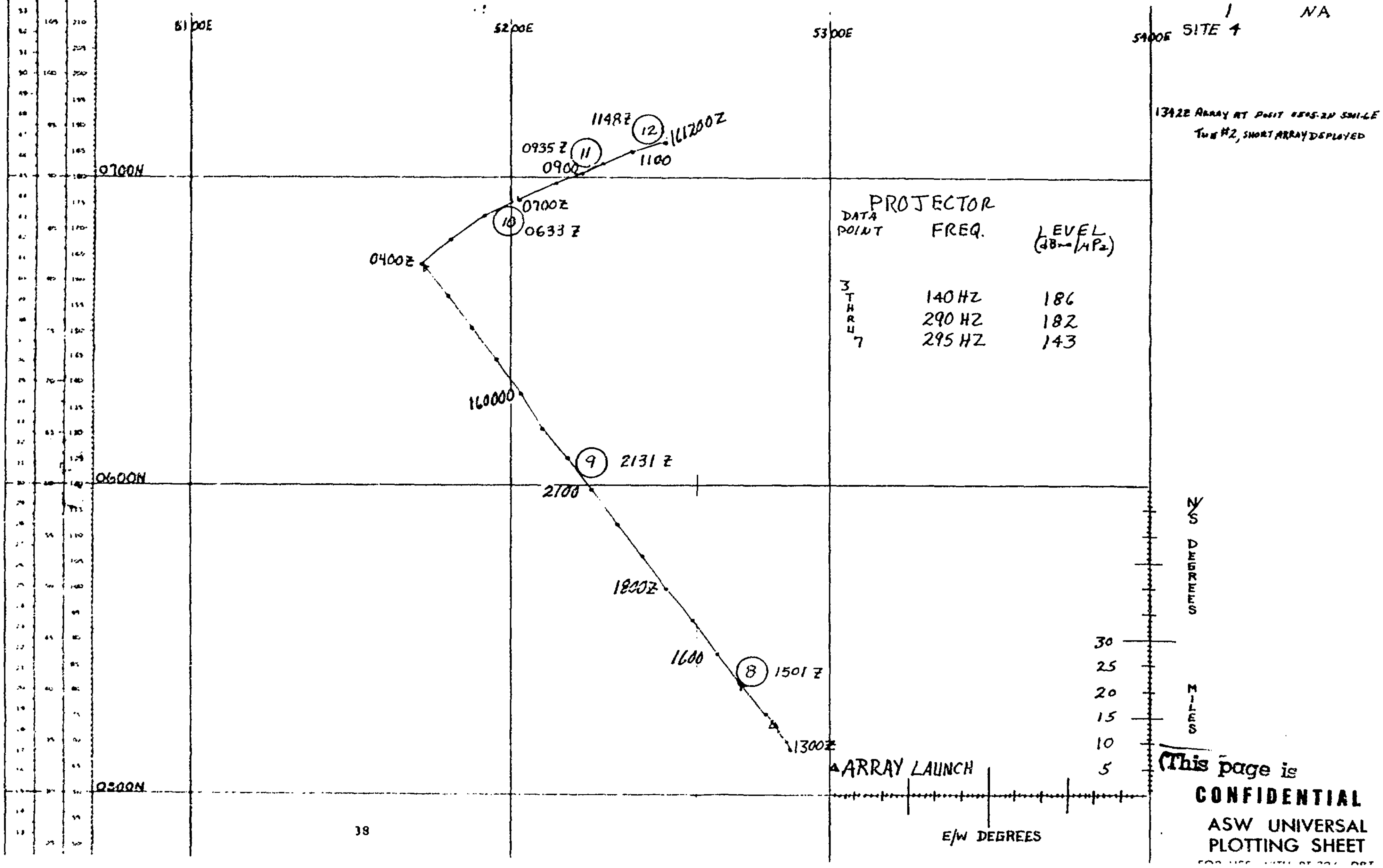
15/16 MARCH 1977 NA NA

SPRAY SEA TEST

1 NA

SITE 4

1342Z ARRAY AT POSIT 05°05.2N 53°16.6E
TUG #2, SHORT ARRAY DEPLOYED



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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
Unavailable	Bossard, David C.	ACOUSTIC ANALYSIS/ASEPS	Wagner Associates	780726	ADA076268	U
NRLMR3832	Heitmeyer, R., et al.	PRELIMINARY RESULTS OF AN ANALYSIS OF BEAM NOISE IN THE MEDITERRANEAN (U)	Naval Research Laboratory	780901	ND ADC016 220	U
Unavailable	Watrous, B. A.	PARKA 1 OCEANOGRAPHIC DATA COMPENDIUM	Naval Ocean R&D Activity	781101	ADB115967	U
Unavailable	Dunbar, B., et al.	LAMBDA PROCESSING LABORATORY AND ENGINEERING SUPPORT, FINAL REPORT 1 JANUARY 1977 - 31 OCTOBER 1978	Texas Instruments, Inc.	781129	ND	U
Unavailable	Blumen, L. S., et al.	ASTRAL MODEL. VOLUME 2: SOFTWARE IMPLEMENTATION	Science Applications, Inc.	790101	ADA956122	U
Unavailable	Spofford, C. W.	ASTRAL MODEL. VOLUME 1: TECHNICAL DESCRIPTION	Science Applications, Inc.	790101	ADA956124	U
Unavailable	Townsend, R., et al.	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IA. OVERALL PROGRAM PERFORMANCE RESULTS WITH TEST RESULTS SUMMARY	Sanders Associates, Inc.	790101	ADC017573	U
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IB. DETAILED DESCRIPTION, TEST RESULTS	Sanders Associates, Inc.	790101	ADC017574	U
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME II. DATA ANALYSIS FACILITY AND DATA REDUCTION METHODOLOGY	Sanders Associates, Inc.	790109	ADC017575	U
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IIIA. DATA POINTS 1, 2 AND 3 RAW DATA	Sanders Associates, Inc.	790109	ADC017576	U
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IIIB. DATA POINTS 4, 5 AND 6 RAW DATA	Sanders Associates, Inc.	790109	ADC017577	U
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