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REPORT**



**MEASUREMENTS AND PREDICTIONS OF
TRANSMISSION LOSS AT TWO SITES
IN THE SOUTHWEST APPROACHES
TO THE ENGLISH CHANNEL**

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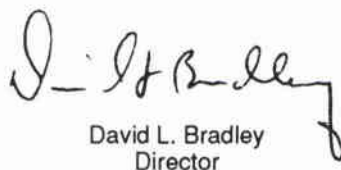
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Measurements and predictions of
transmission loss at two sites in the
Southwest Approaches to the
English Channel

A. Caiti F. Ingenito, A. Kristensen
and M. D. Max

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Measurements and predictions of transmission loss at two sites in the Southwest Approaches to The English Channel

A. Caiti F. Ingenito, A. Kristensen and M. D. Max

Executive Summary: There has been an increasing emphasis on shallow water areas as likely sites of naval operations. Sonar performance prediction models for shallow water must perform well in the wide variety of environments normally found there. Transmission loss is a fundamental quantity for performance prediction, and of the environmental factors which affect transmission loss, the bottom, often the controlling factor, is most difficult to characterize.

The Seafloor Acoustics Group has conducted a series of exercises in representative shallow-water areas with the objectives of testing and evaluating techniques for determining bottom parameters and acoustically characterizing 'reference sites' for model development and evaluation. This work reports on an experiment conducted at two sites in the southwest approaches to the English Channel. At one site there were long NE-SW trending 'ridges', while at the other site the bottom was chalk, with little or no sediment cover. Both sites were surveyed using uniboom, sparker, and side-scan sonar. Cores and grab samples were taken in both areas. Transmission loss was measured along two tracks at the first site, one along and the other perpendicular to the crest of the ridges. At the second site measurements were made along a single track. At both sites explosive sources and a four element receiving array were used. The transmission loss data were processed in 1/3 octave bands and analysed at frequencies of 100, 200, 400, 800, and 1600Hz.

Except for the compressional velocity profile at the second site, attempts to make direct measurements of bottom acoustic parameters were unsuccessful. Instead-geoacoustic models of both areas were constructed by adjusting the bottom acoustic parameters in the SAFARI prediction model until a good fit to the measured transmission loss data was obtained. The resulting models, in addition to giving good agreement between measured and predicted transmission loss, are reasonably consistent with our knowledge obtained from coring and geological studies.

The measured data show no significant difference between transmission loss along and perpendicular to the ridge crest at the first site. Unusually high loss was measured on the shallow receiver at the second site. This can be understood in terms of the characteristics of the structure of the acoustic field determined by the environment. Comparing the two sites, the transmission loss at the second site is much higher for all the frequencies and source-receiver combinations. This is probably due the highly absorbing chalk bottom.



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Measurements and predictions of transmission loss at two sites in the Southwest Approaches to The English Channel

A. Caiti F. Ingenito, A. Kristensen and M. D. Max

Abstract: As part of a continuing series of measurements being made by SACLANTCEN in representative shallow water areas an experiment was conducted in the southwest approaches to the English Channel. Measurements were made at two sites with different bottom characteristics. At one site there were long NE-SW trending ridges while at the other site the nearly flat bottom was chalk, with little or no sediment cover. Transmission loss was measured along two tracks at the first site, one along and the other perpendicular to the line of crests and troughs of the sand waves. At the other site, measurements were made along a single track. At both sites explosive sources and a four element receiving array were used. The transmission loss data were processed in 1/3 octave bands and analysed at frequencies of 100, 200, 400, 800, and 1600Hz. Attempts to make direct measurements of bottom acoustic parameters were largely unsuccessful; instead the bottom acoustic parameters were adjusted to obtain a good fit to the transmission loss data with the SAFARI prediction model. The resulting geoacoustic models were reasonably consistent with knowledge of the bottom obtained from other sources. It was found that there was no significant difference in transmission loss measured along and perpendicular to the crests and troughs of the ridges at the first site. Transmission loss was much higher at the second site due to the highly absorbing chalk bottom. Unusually high loss was measured at the second site for the shallow receiver. This can be understood in terms of the characteristics of the modal structure of the acoustic field.

Keywords: Bottom properties – SWAP – Southwest Approaches to the English Channel – transmission loss

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Introduction

The Seafloor Acoustics Group has been conducting a series of measurements in representative shallow water areas with the objectives of testing and evaluating techniques for determining bottom parameters and of acoustically characterizing 'reference' sites for model development and evaluation. To characterize an area, the acoustic properties of the bottom are measured and these measured results are supplemented by acoustic parameters inferred from physical properties of the sediments. A geoacoustic model of the bottom is then developed. Broadband transmission loss is measured simultaneously with the bottom measurements and compared with predictions of a transmission loss model using the bottom geoacoustic model as input. The degree of agreement between the transmission loss measurements and the predictions is a measure of the validity of the geoacoustic model.

The work reported here is based on an experiment conducted in the southwest approaches to the English Channel (SWAP) in July–August 1992 (Fig. 1). Measurements were made at two sites with different bottom characteristics. At the first site there were long NE–SW trending ridges while at the second site the bottom was chalk, with little or no sediment cover. The work was done in collaboration with scientists from the U.S. Naval Research Laboratory, who tested a remote sensing technique for determining acoustic bottom parameters. Their results will be reported elsewhere: this report is devoted to the SACLANT Centre results.

2

General description of the area

The inner areas of the continental shelf to the west of Britain and France are, for the most part, only thinly covered by recent sediments. Because of the history of sea level rises and falls during the last 100,000 years were caused by ice cap formation and melting, this shelf has been subjected to subaerial, rather than submarine, conditions for much of the time. As a result, compaction of the sediments and the replacement of sea water brines by fresh water in interstitial spaces have introduced a set of physical properties not usually found in marine sediments, even though most of the sediment was originally deposited under shallow marine conditions. Sediments on continental shelves which dry, develop properties more characteristic of dry land sediments and weakly lithified sedimentary rocks. Fine-grained and calcareous sediments especially, show alteration. Although coarser grained sands and gravels tend to maintain their porosity because the grain structure is self-supporting, finer grained sands, silts, and especially muds and clays may undergo great compaction upon drying or losing a significant amount of water. These fine-grain sediments are only partially grain supported and the grains can always be more tightly packed than their marine depositional state. Both increased pressures, introduced through burial, and drying or introduction of lighter density pore water, can cause collapse of the marine sediment structure. Marine clays, for instance, are known to compact into one-quarter of their depositional wet volume with normal compaction.

Between 9,000 and 12,000 years ago a major transgression of the sea flooded the continental shelf and strongly eroded it. Sea level has risen about 130 m. Much of the continental shelf is very flat and the rocks exposed at or near the sea bed are relatively fresh as a result of this recent transgression. The sea bottom tends to be somewhat rougher and shallower over some of the older rock types. Sediments on this inner continental shelf consist of thin carbonate-rich sands with a low mud content over a gravel layer left behind during the transgression. Sediments rarely exceed 1 m in thickness over the entire area. Sediment on the outer shelf is thicker, but most of it was deposited during the last sea level rise when large continuous asymmetrical sandwaves were formed. These are now relic features below the general wave base, and different from smaller sandwaves in shallow water that are presently moving in response to modern sedimentation patterns. These sandwaves were subject to some deflation and erosion as sea level rose, but their shape is retained. However, they have a gravel surface that may be in part carbonate-cemented and a locally thin covering of recent, finer-grained sediment.

3

Description of sites

Two sites on the shelf were selected for study. An extensive geophysical survey was conducted and has been reported in [1].

Site 1. This site is on the outer shelf where the prevailing bottom morphology is of long NE–SW trending, asymmetric ridges, with the steeper side toward the NW. These are relic, having been formed when the sea level was lower, over 11,000 years ago. The sediment surface of these large dunes is probably somewhat coarser than when they were originally deposited because of erosion. Gravel pediments, coarse sand, and carbonates may be common on the tops of the sandwaves. Troughs and lower areas will probably have recent, fine-grained sediment, but there may be only shallowly buried more coarse grained patches. Beneath the sandwaves is upper Tertiary and Plio-Pleistocene sands and gravels, often with thin limestone partings and beds. Troughs between the ridge crests may be entirely unlithified sediment.

Site 2. This site has a chalk bottom formed from Cretaceous marls that were buried, lithified, and exhumed during weak tectonic activity. The bottom is virtually flat. The upper surface of the chalk bottom has relief of the order of less than a metre, with some upstanding chalk bedding often not completely covered by sediment. Resting immediately on the chalk is an older, somewhat acoustically strongly scattering, rippled sediment, formed from coarse sand and gravel, which is locally buried by an acoustically transparent infilling sand disposed in long streaks and irregular shaped patches. The younger sands also lay directly on chalk.

4

Measurement techniques

The measurement techniques used in the experiment are briefly described below. For more details, see the references.

4.1. WIDE ANGLE MEASUREMENTS

This is a standard method [2] for measuring compressional velocities of the bottom layers. A broadband source emits pulses which are received by a vertical hydrophone array suspended from a float which is allowed to drift away from the source ship. The received signals are the direct arrival and the various reflections from the surface and the interfaces between the bottom layers. From the arrival times of the signals the thicknesses and the compressional velocities of the layers can be calculated.

4.2. INTERFACE WAVE INVERSION

The shear-wave velocity estimation method using interface waves is described by Akal *et al.* [3]. The method is based on the dispersion characteristics of interface waves, which are related to the bottom shear velocity, propagating at the water-sediment interface. Explosive sources are detonated endfire to an array of geophones sensitive to the vertical component of the ground motion. Analysis of the recorded interface wave produces a group velocity *vs.* frequency curve. An inversion algorithm is then applied which gives the best fit to the group velocity curve in the least squares sense. The result is an estimated shear-velocity profile *vs.* depth in the bottom.

4.3. COMPRESSIONAL VELOCITY FROM THE REFRACTED WAVE

The compressional velocity as a function of depth in the bottom can be obtained with the same experimental configuration as the interface-wave inversion method described in 4.2. Small seismic charges are fired endfire to the array at short ranges and the first refracted arrival is identified. Compressional velocity as a function of depth is computed by inversion of the first refracted arrival using the Wiechert-Hergloz-Bateman integral [4]. A smooth curve of compressional velocity *vs.* depth that best fits the refracted data in the least squares sense is obtained.

4.4. OTHER BOTTOM MEASUREMENTS

Cores and grab samples were taken in both areas. Both sites were surveyed using uniboom, sparker, and side-scan sonar.

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4.5. TRANSMISSION LOSS MEASUREMENTS

The transmission loss tracks at Site 1 are shown in Fig. 2. A four-element vertical hydrophone array with elements at depths of 10, 50, 90, and 130 m was deployed and anchored at point A. The array was connected via a radio link to the NRV *Alliance* which detonated charges at depths of 50 and 100 m approximately every kilometre along the track. Runs were made along two tracks, A-B, from southeast to northwest, and A-C, from southwest to northeast. The received signals were telemetered to the *Alliance* where they were recorded and subsequently processed in 1/3 octave bands and subtracted from source levels to obtain transmission loss. Low sea state conditions (0-1) prevailed during the measurements.

At Site 2 a vertical array was deployed at point D (Fig. 3) with four hydrophones at depths of 10, 35, 65, and 98 m. The 65 m hydrophone failed. A single track, D-E, was run with explosive charges detonated at 50 and 100 m depth. The data were recorded and processed as for Site 1. The wind speed was 15 knots (sea state 3) during the measurements.

5

The geoacoustic models

5.1. SITE 1

At this site both the Wide Angle and Interface Wave Inversion methods failed to produce useful results. For the Wide Angle method no returns from layer boundaries were observed while for the Interface Wave Inversion method, it was not possible to identify the interface wave. A core taken at the array site was only 40 cm long with fine sand at the surface and coarser sand as depth increased. Given the lack of bottom data, a geoacoustic model for this site was constructed by fitting the transmission loss data, starting with a sandy first layer. The resulting simple geoacoustic model (Table 1), when applied using the range-independent algorithm SAFARI [7], provided an excellent fit of model results to experimental data. The water level at this site was 150 m. The first 150 m of Table 1 give the sound velocity profile in the water column when the transmission loss measurements were made.

Table 1 *Geoacoustic model for Site 1, the 'Sand Ridge Area'. Depth is measured from the sea surface; the first 150 meters are the water column values.*

Depth (m)	C_p (m/s)*	C_s (m/s)*	α_p (dB/ λ)*	α_s (dB/ λ)*
0.0	1515.0	0.0	0.0	0.0
25.0	1515.0	0.0	0.0	0.0
39.0	1492.0	0.0	0.0	0.0
150.0	1492.0	0.0	0.0	0.0
150.0	1800.0	700.0	0.4	1.0
152.0	1800.0	700.0	0.4	1.0
152.0	3000.0	1700.0	0.11	2.6

* C_p and C_s are the compressional and shear velocities, respectively, α_p and α_s are the compressional and shear attenuations.

The sub-bottom values, i.e. for depths greater than 152 m, are approximate. Sensitivity tests using a wide range of values did not substantially alter the model results.

5.2 SITE 2

At this site the compressional velocity profile was obtained by the method described in Section 4.3. The interface wave method again failed to produce a useful shear velocity profile. Therefore the shear velocity in the first bottom layer was adjusted to produce the best fit to the 1600 Hz transmission loss data. Then the shear velocity was allowed to increase with depth, to approach the ratio 1.9 of compressional to shear velocity recommended by Hamilton [6] for chalk. The compressional and shear

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attenuations, assumed to vary as the $-1/6$ power of depth [7], were adjusted for the best fit to the transmission loss data at the lower frequencies. The resulting geacoustic model for this area is given in Table 2. [N.B. The water level at this site was 112 m. The first 112 m of Table 2 give the sound velocity profile in the water column when the transmission loss measurements were made.]

Table 2 - *Geoacoustic model for Site 2, the Chalk Area. Depth is measured from the sea surface; the first 112 meters are the water column values.*

Depth (m)	C_p (m/s)*	C_s (m/s)*	α_p (dB/ λ)*	α_s (dB/ λ)*
0.0	1515.0	0.0	0.0	0.0
24.0	1515.0	0.0	0.0	0.0
40.0	1494.0	0.0	0.0	0.0
112.0	1494.0	0.0	0.0	0.0
112.0	1720.0	700.0	0.75	1.38
115.0	1768.0	785.0	0.56	1.13
122.0	1815.0	873.0	0.51	1.10
132.0	1862.0	939.0	0.47	1.07
143.0	1910.0	997.0	0.46	1.08
156.0	1957.0	1030.0	0.44	1.06
170.0	2004.0	1055.0	0.42	1.00
212.0	2004.0	1055.0	0.42	1.00
212.0	5500.0	3000.0	0.11	0.06

* C_p and C_s are the compressional and shear velocities, respectively, α_p and α_s are the compressional and shear attenuations.

The sub-bottom values, i.e. for depths greater than 212 m, are approximate. Sensitivity tests using a wide range of values did not substantially alter the model results.

6

Comparison of measured and predicted transmission loss

6.1 SITE 1

Transmission loss measurements were made along two tracks at this site, one along and the other perpendicular to the line of the crest and trough of the sand wave. The objective was to determine the effect of the sea-Bottom geometry on propagation. Inspection of the data showed no significant difference between the transmission loss measured along the two tracks, hence only the results of track A-B, the SE to NW track, will be given here. These are shown in Figs. 4-43. Also shown in the figures is the predicted transmission loss obtained from the SAFARI model [5] with the geoacoustic model of Table 1 as input. The agreement between the measurements and the predictions, for the two source depths, four receiver depths, and over four octaves of frequency, is reasonable. The geoacoustic model of Table 1 represents a thin attenuating layer over a hard subbottom which results in lower loss at lower frequencies.

6.2 SITE 2

The transmission loss measured along Track D-E of Site 2 is shown in Figs. 44-73. Also shown are the predictions made with SAFARI using the geoacoustic model of Table 2 as input. The agreement between measurements and predictions is quite variable.

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7

Conclusions

With the failure to obtain useful direct measurements of bottom parameters at both sites, geoacoustic models were constructed by adjusting the bottom parameters to fit the measured transmission loss data. The resulting models are reasonably consistent with our knowledge of the bottoms at the two sites obtained from coring and geological studies.

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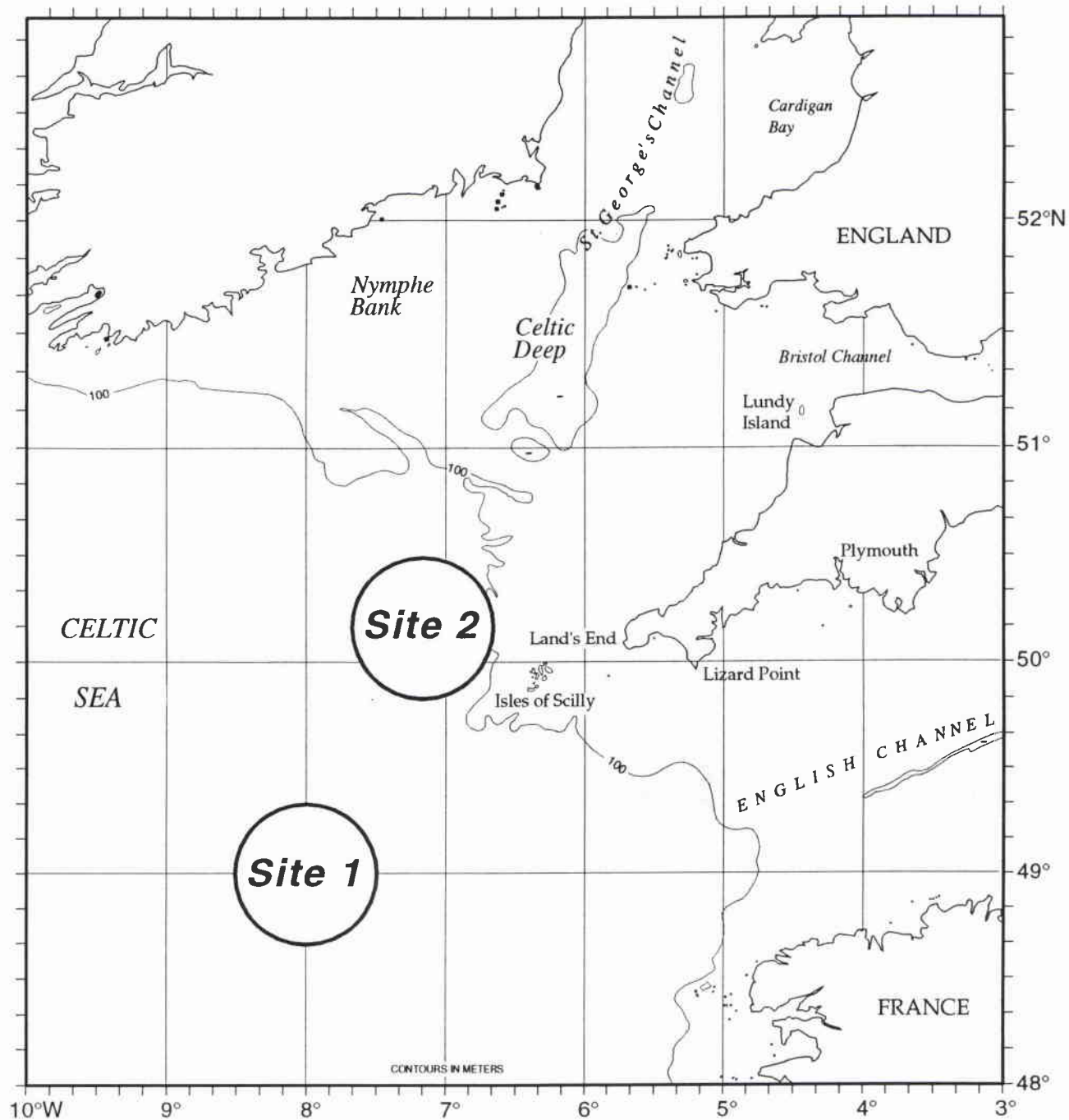


Figure 1 The Southwest Approaches to the English Channel showing the two experimental sites.

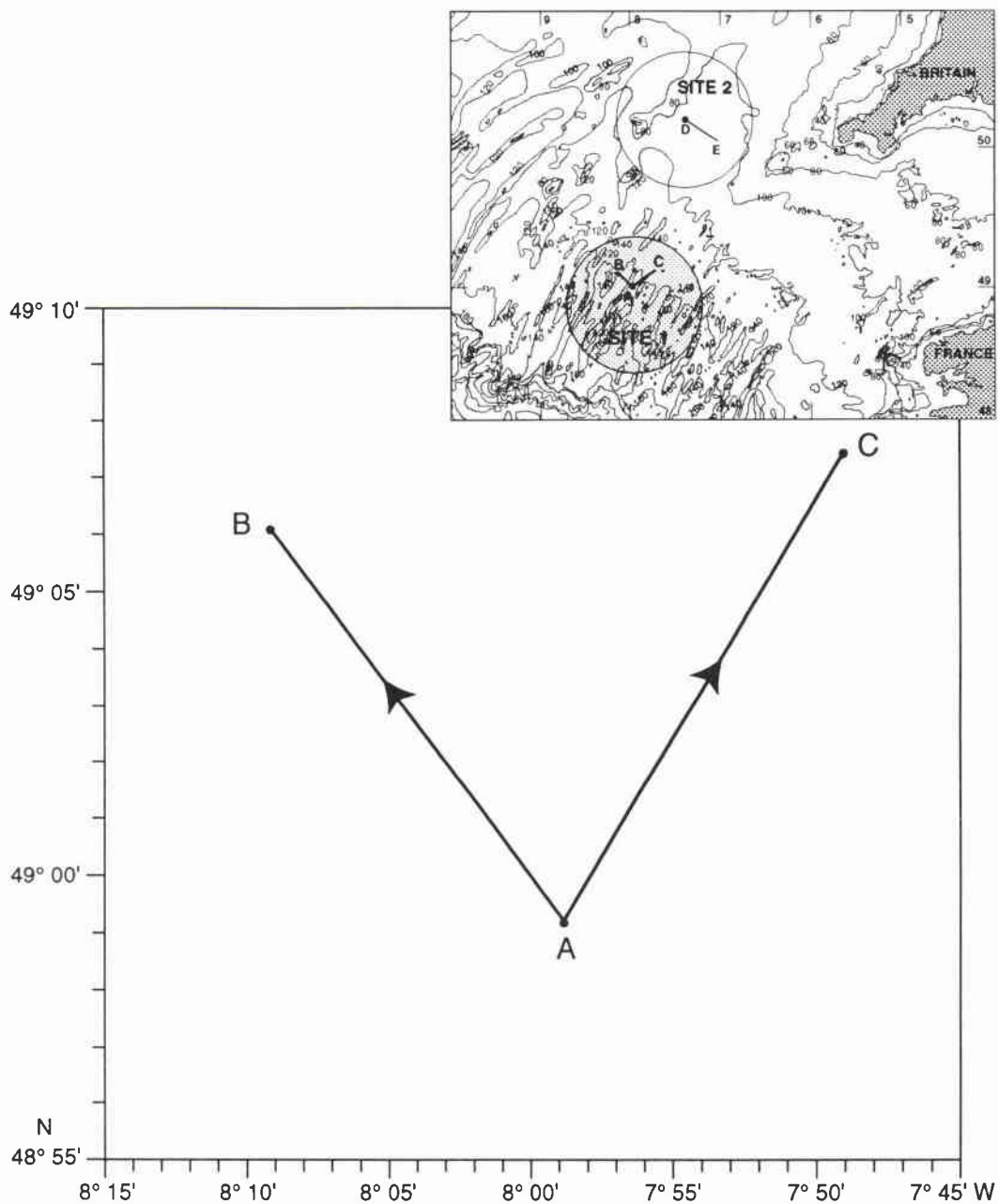


Figure 2 The two tracks A-B and A-C at Site 1 along which transmission loss runs were made. The receiving array was at point A.

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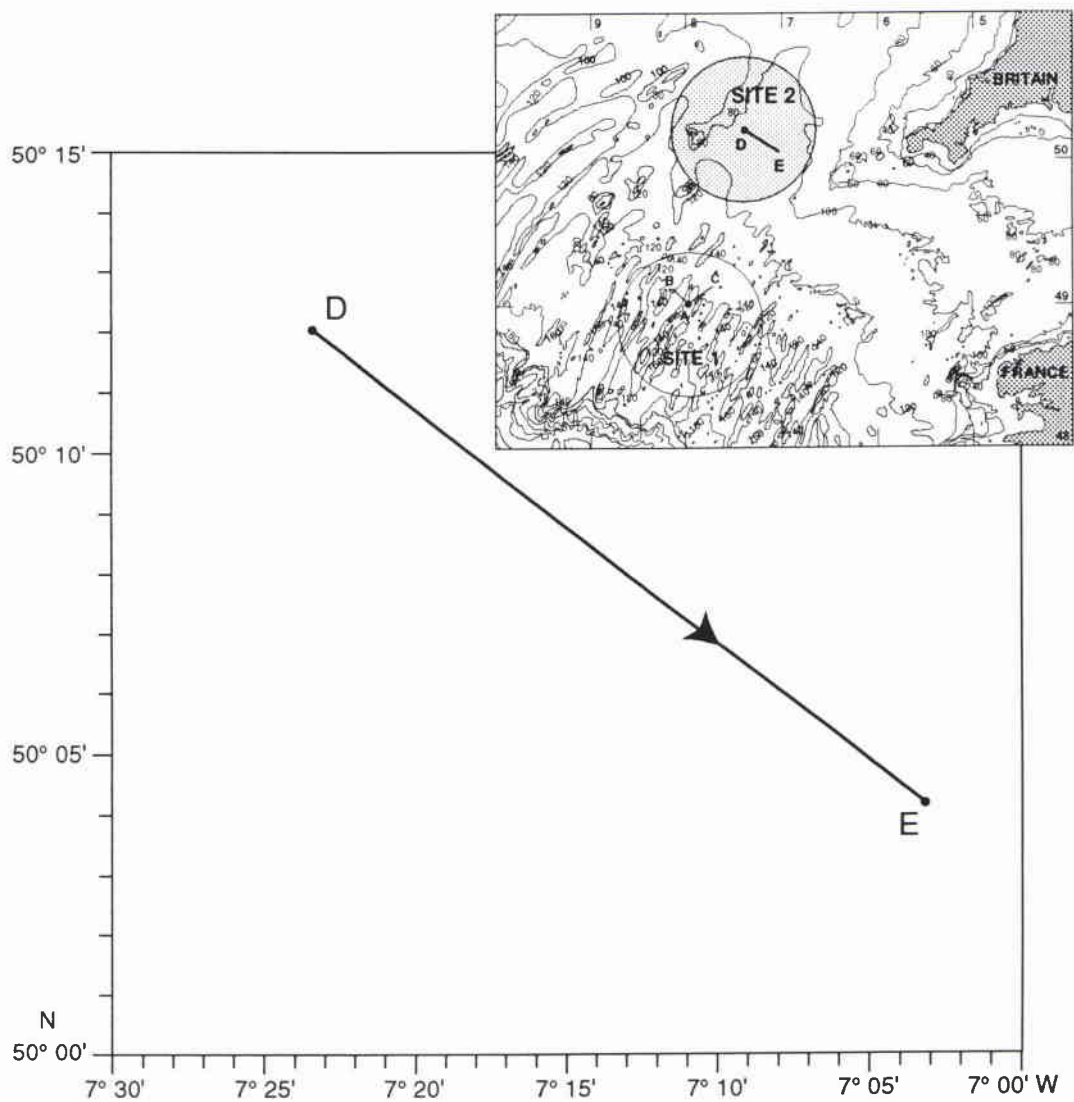
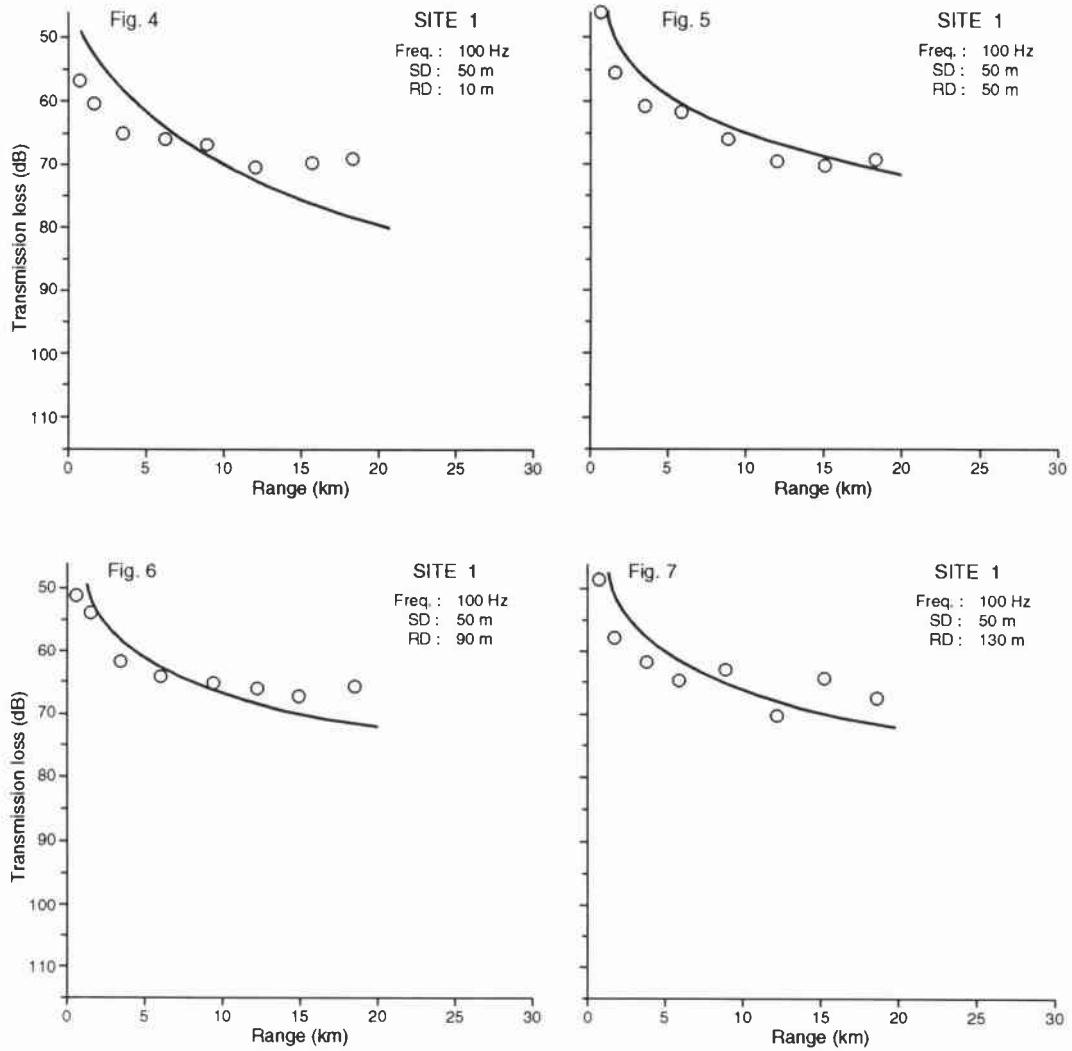
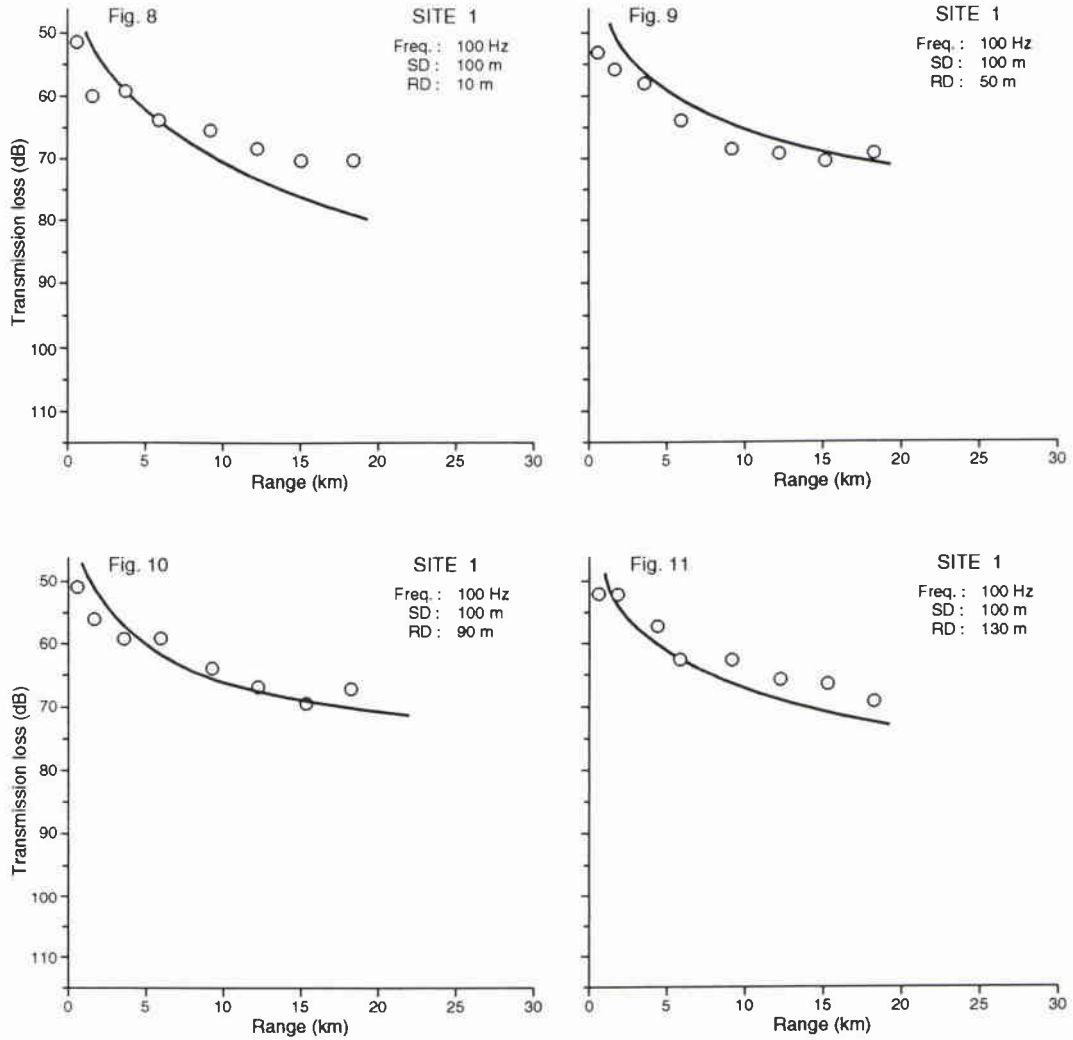


Figure 3 The track D-E at Site 2 along which a transmission loss run was made. The receiving array was at point D.

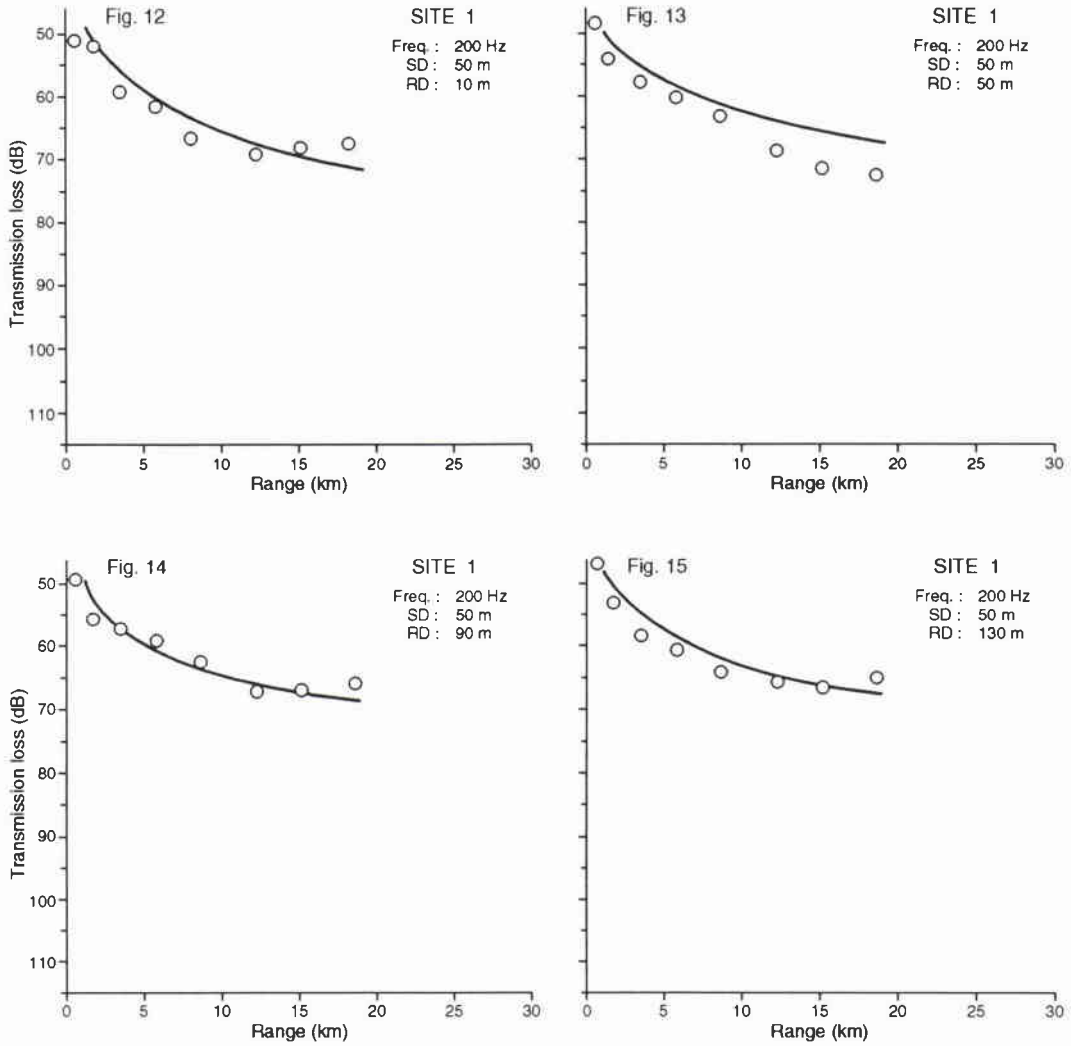


Figures 4–7 Comparison between measured and predicted transmission loss for Track A–B of Site 1. The points are the measurements and the solid curves are the predictions. Frequency=100 Hz; SD=50 m; RD=10, 50, 90, 130 m respectively

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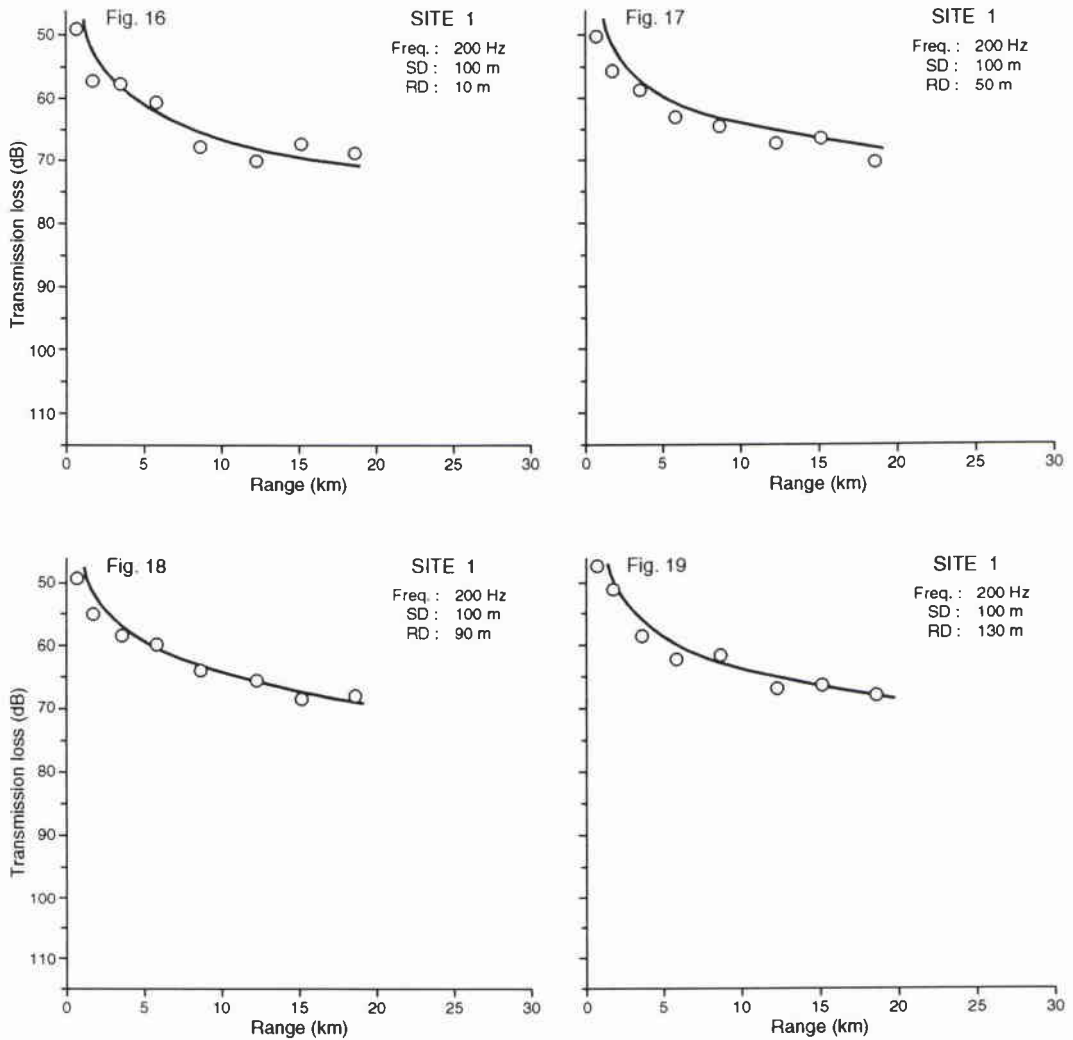


Figures 8–11 Comparison between measured and predicted transmission loss for Track A–B off Site 1. The points are the measurements and the solid curves are the predictions. Frequency=100 Hz ; SD=100 m; RD=10, 50, 90, 130 m respectively

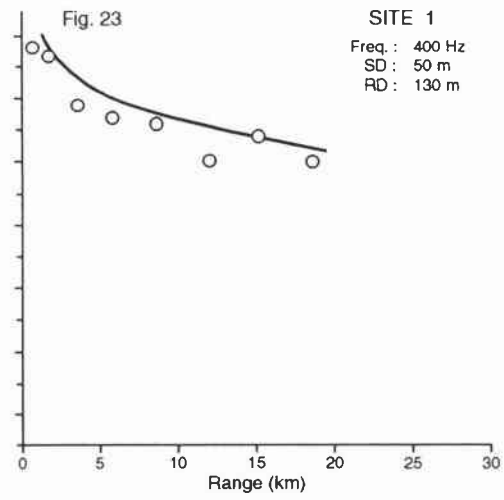
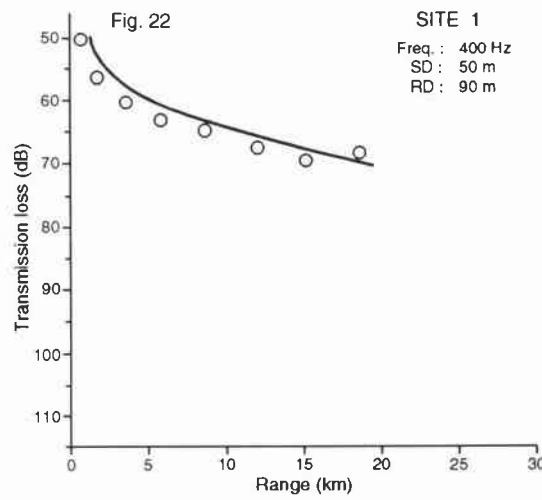
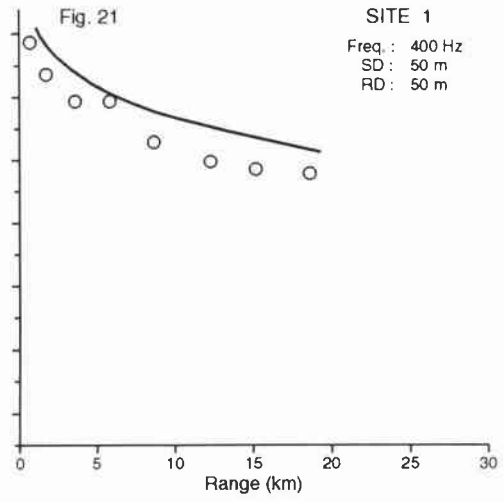
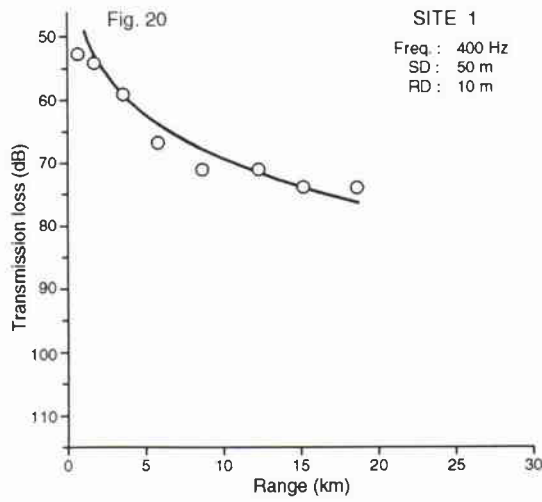


Figures 12–15 Comparison between measured and predicted transmission loss for Track A–B of Site 1. The points are the measurements and the solid curves are the predictions. Frequency=200 Hz ; SD=50 m; RD=10, 50, 90, 130 m respectively

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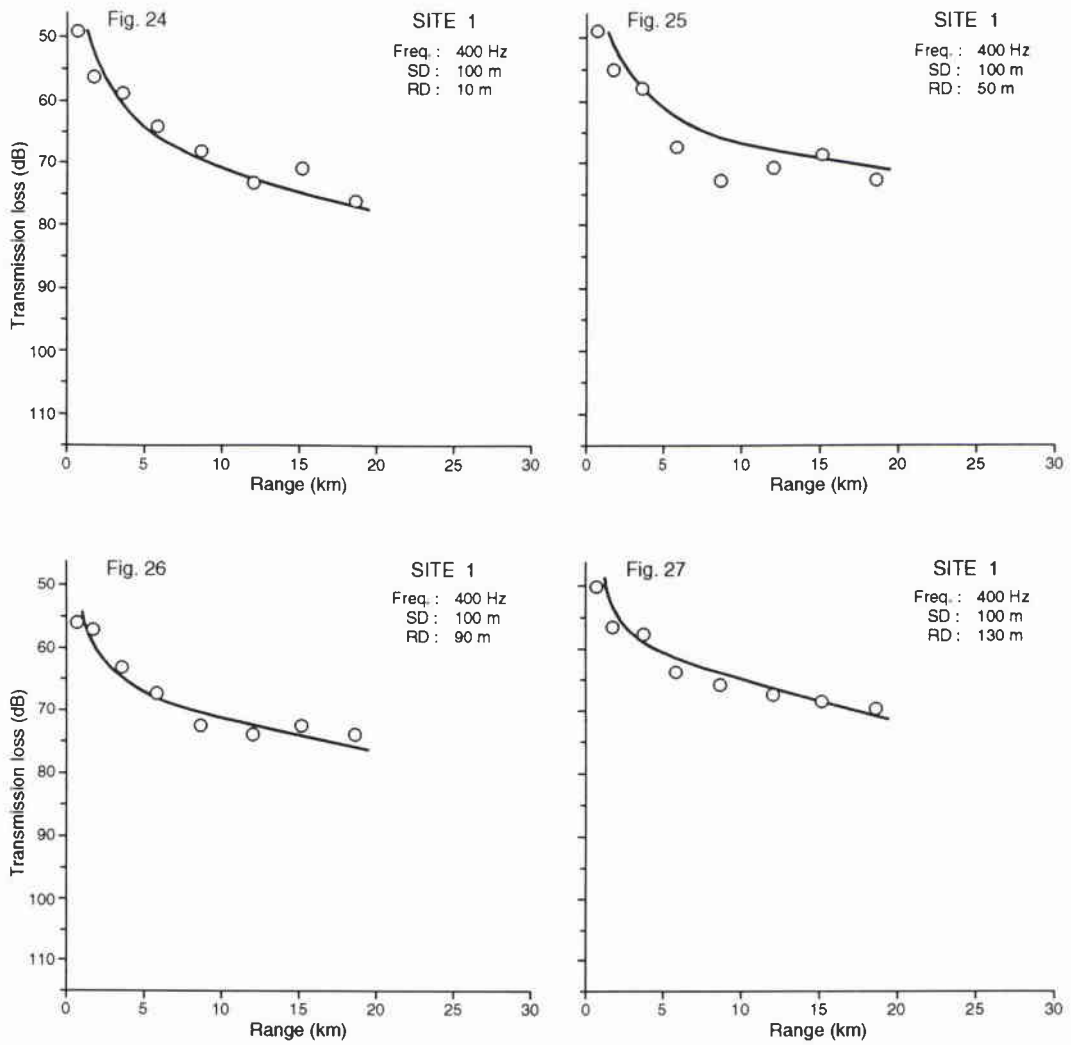


Figures 16–19 Comparison between measured and predicted transmission loss for Track A–B of Site 1. The points are the measurements and the solid curves are the predictions. Frequency=200 Hz ; SD=100 m; RD=10, 50, 90, 130 m respectively

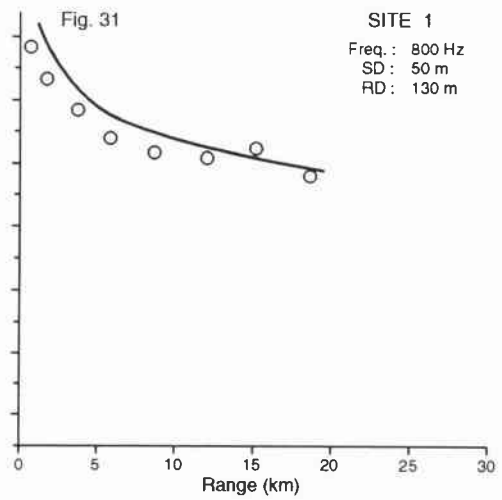
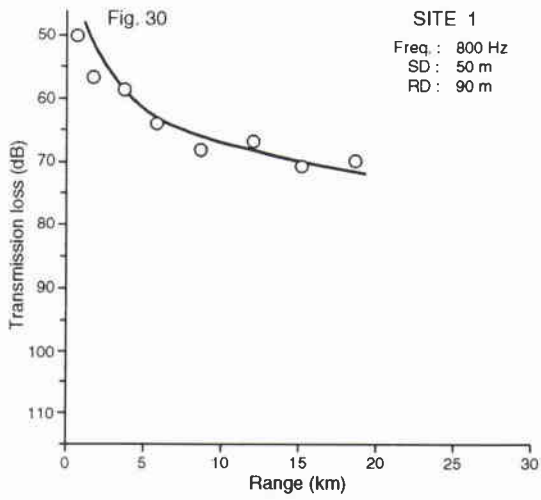
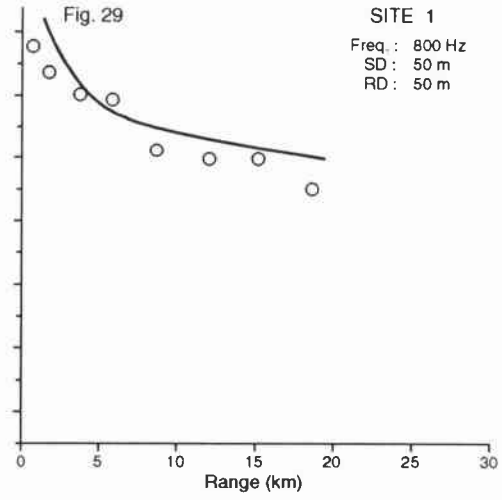
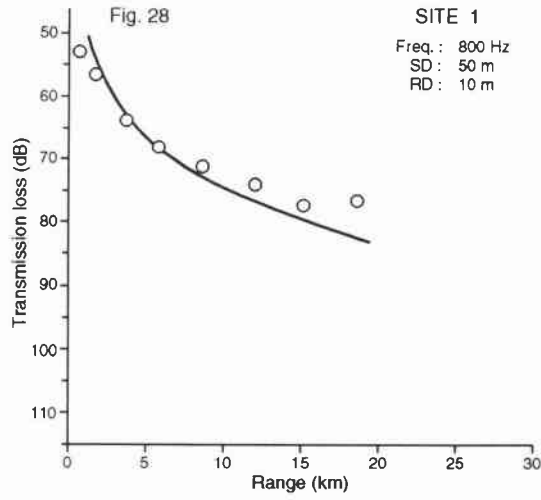


Figures 20–23 Comparison between measured and predicted transmission loss for Track A–B of Site 1. The points are the measurements and the solid curves are the predictions. Frequency=400 Hz ; SD=50 m; RD=10, 50, 90, 130 m respectively

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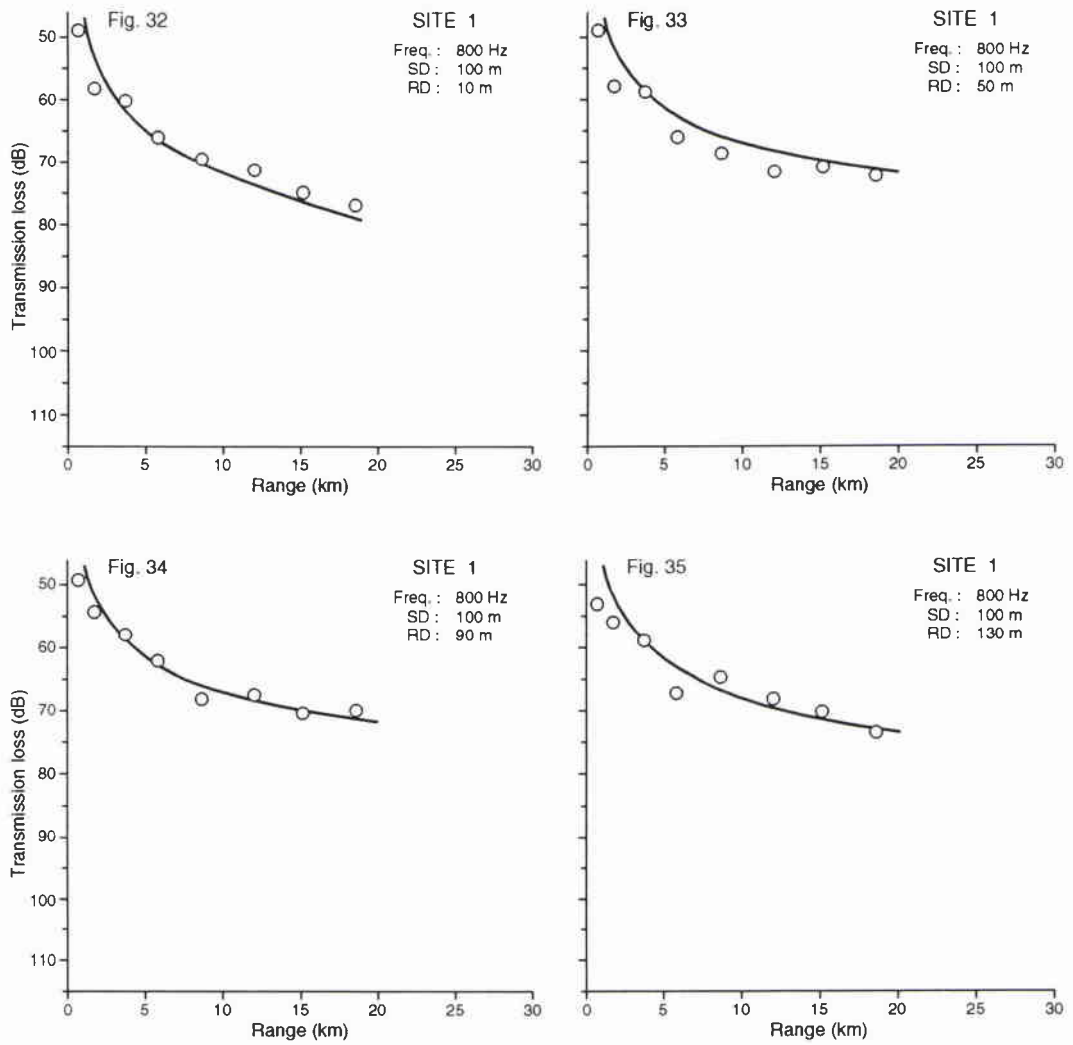


Figures 24–27 Comparison between measured and predicted transmission loss for Track A–B of Site 1. The points are the measurements and the solid curves are the predictions. Frequency=400 Hz ; SD=100 m; RD=10, 50, 90, 130 m respectively

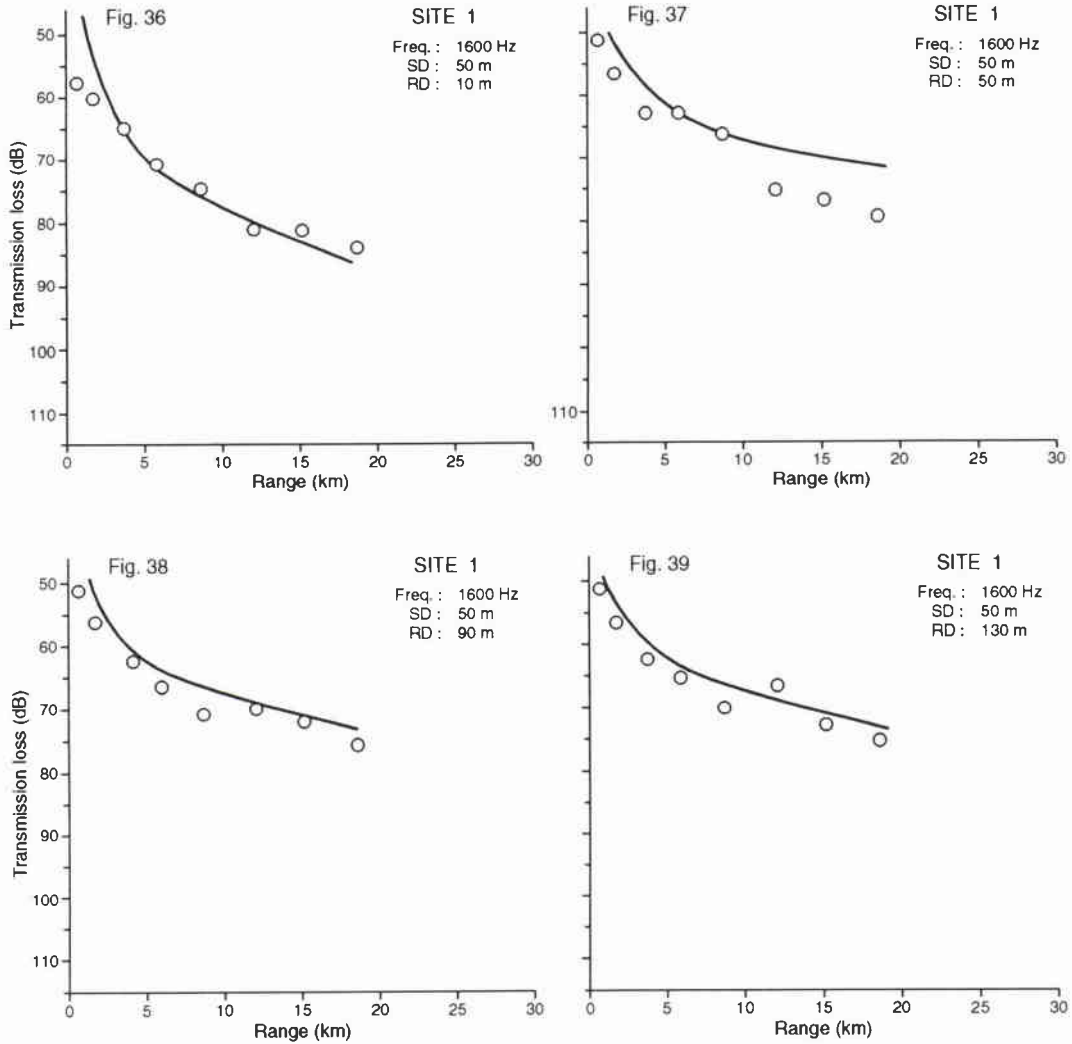


Figures 28–31 Comparison between measured and predicted transmission loss for Track A–B of Site 1. The points are the measurements and the solid curves are the predictions. Frequency=800 Hz ; SD=50 m; RD=10, 50, 90, 130 m respectively

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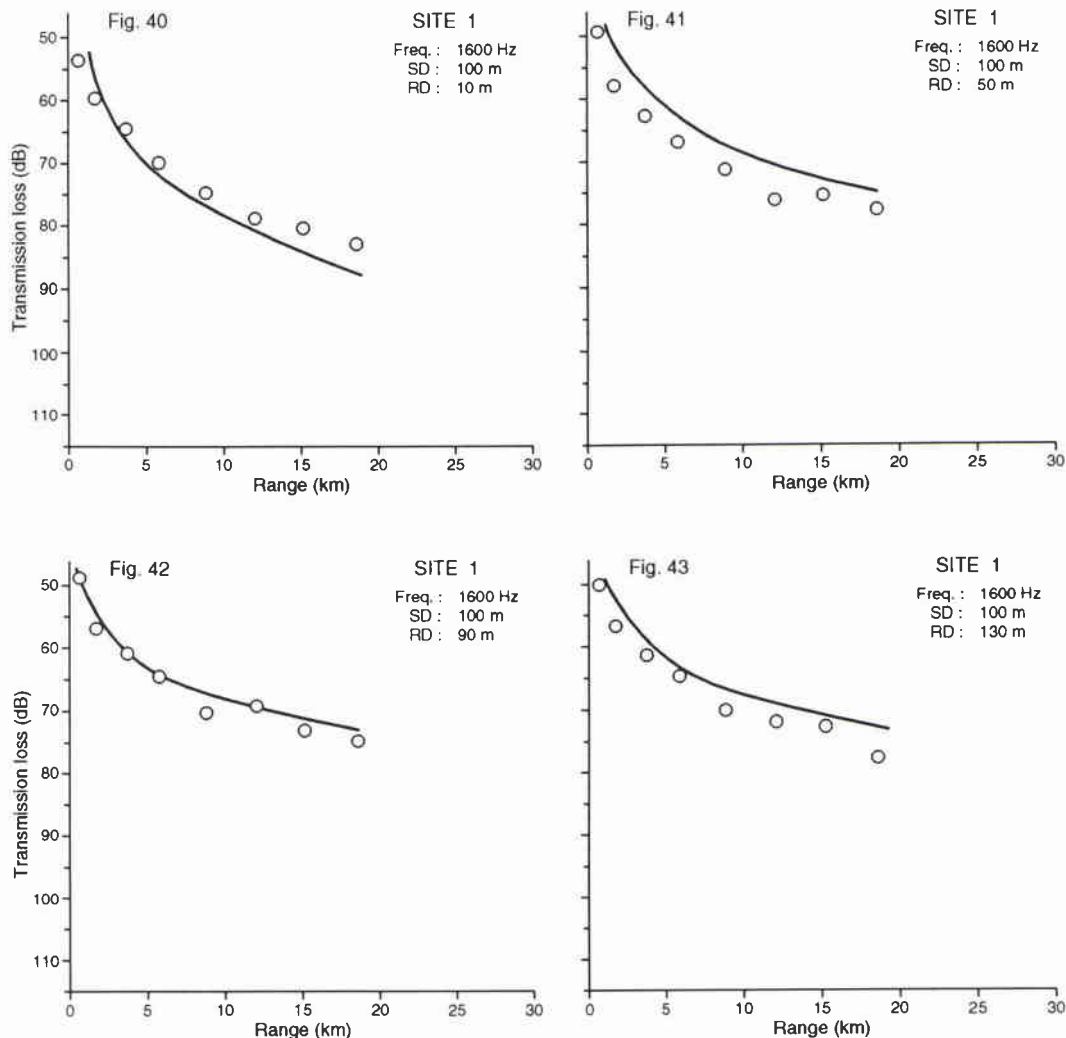


Figures 32–35 Comparison between measured and predicted transmission loss for Track A–B of Site 1. The points are the measurements and the solid curves are the predictions. Frequency=800 Hz; SD=100 m; RD=10, 50, 90, 130 m respectively

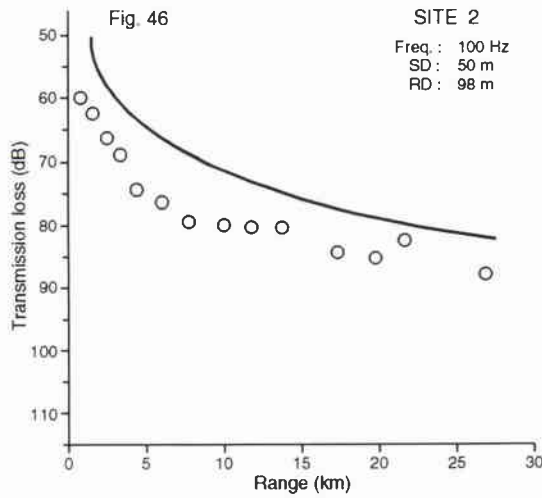
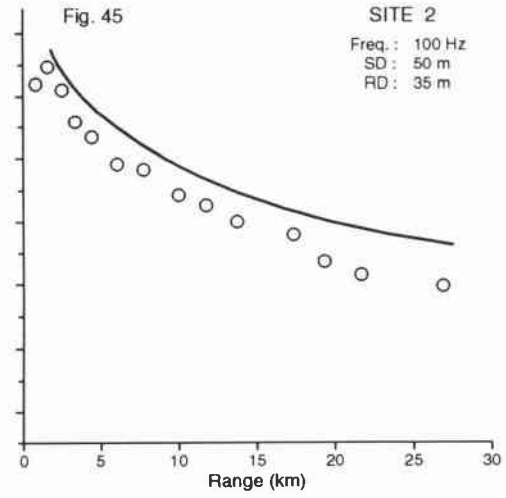
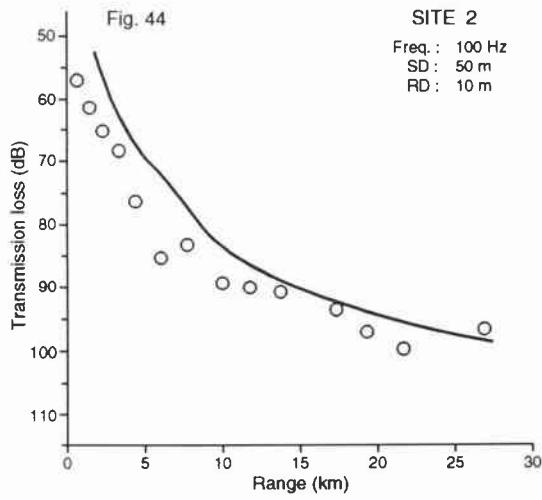


Figures 36–39 Comparison between measured and predicted transmission loss for Track A–B of Site 1. The points are the measurements and the solid curves are the predictions. Frequency=1600 Hz ; SD=50 m; RD=10, 50, 90, 130 m respectively

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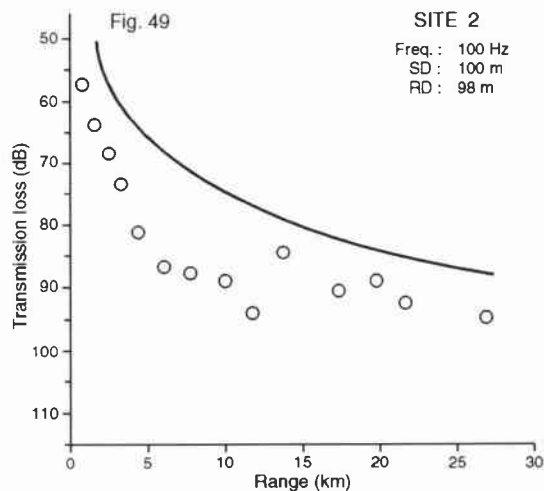
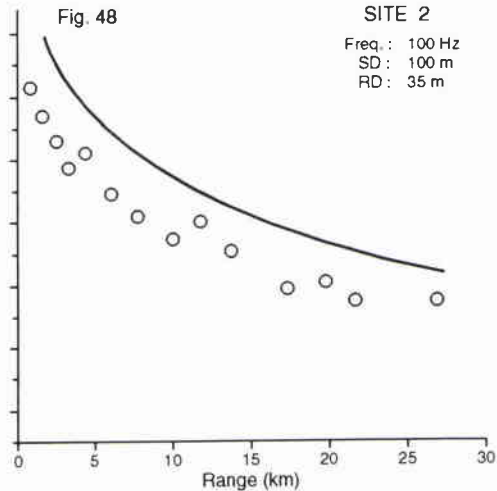
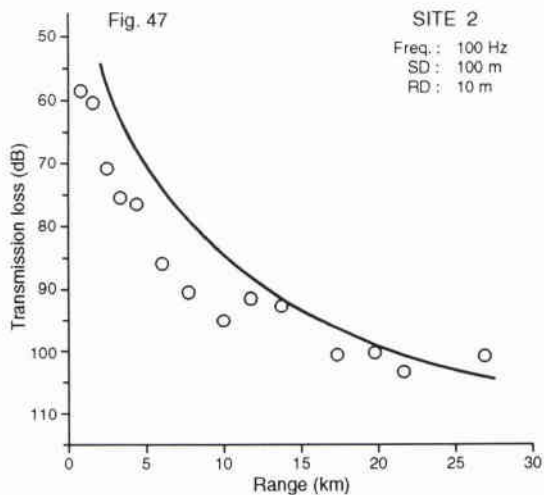


Figures 40–43 Comparison between measured and predicted transmission loss for Track A–B of Site 1. The points are the measurements and the solid curves are the predictions. Frequency=1600 Hz ; SD=100 m; RD=10, 50, 90, 130 m respectively

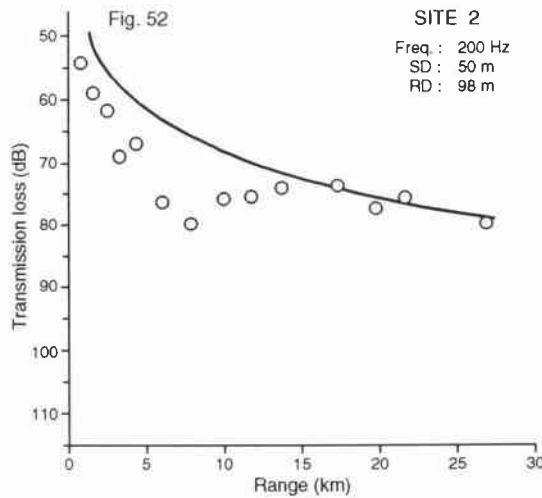
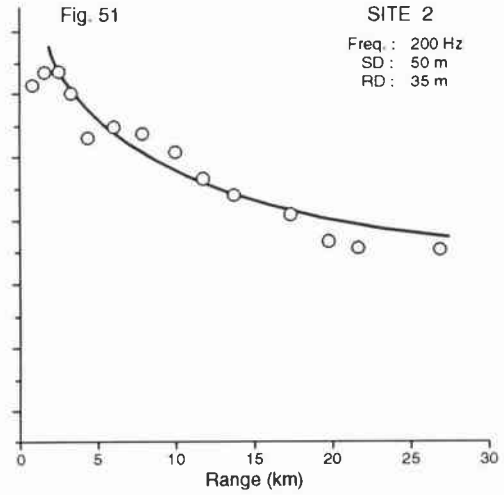
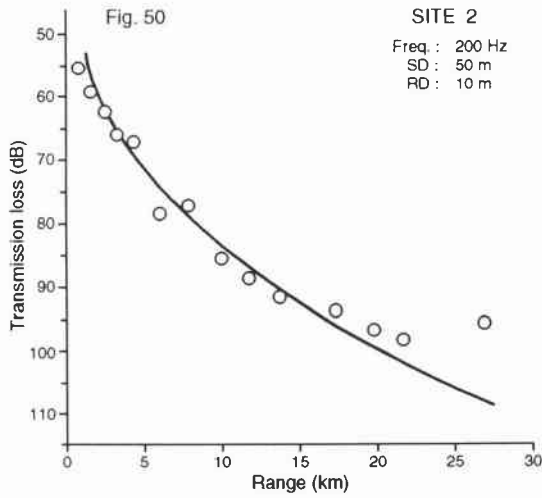


Figures 44–46 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=100 Hz ; SD=50 m; RD=10, 35, 98 m respectively

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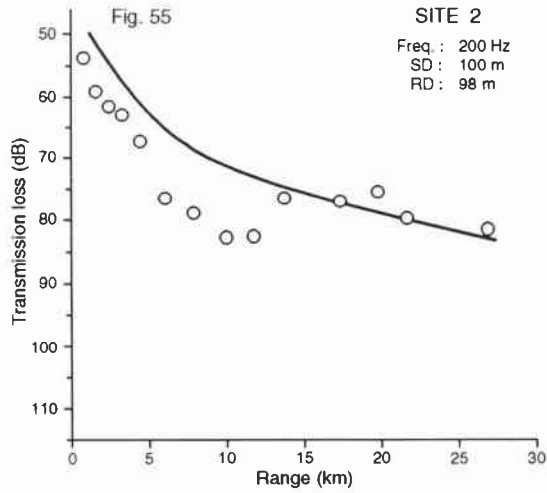
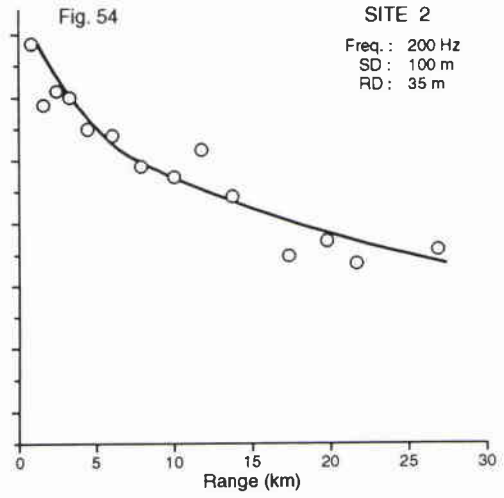
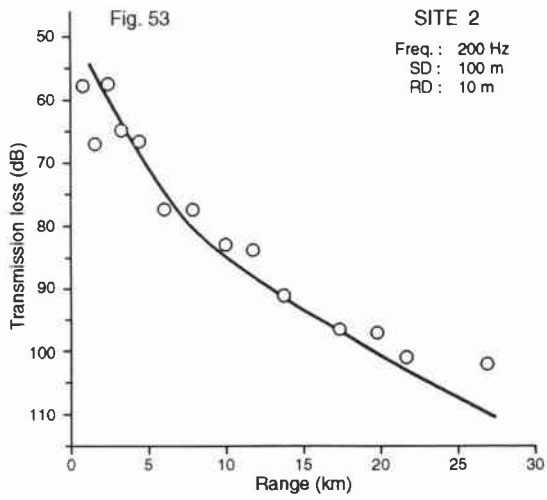


Figures 47–49 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=100 Hz; SD=100 m; RD=10, 35, 98 m respectively

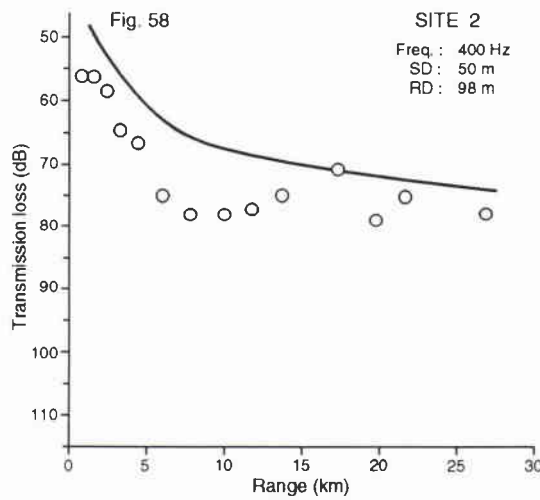
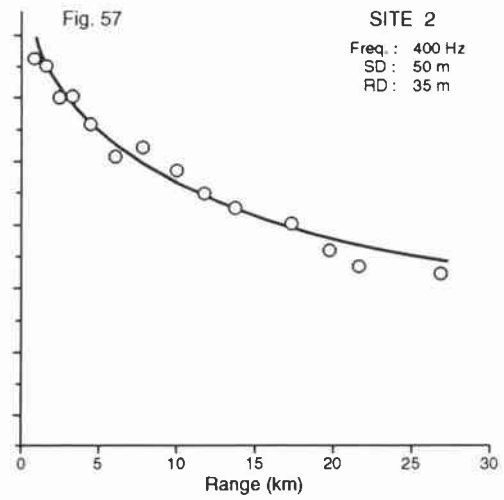
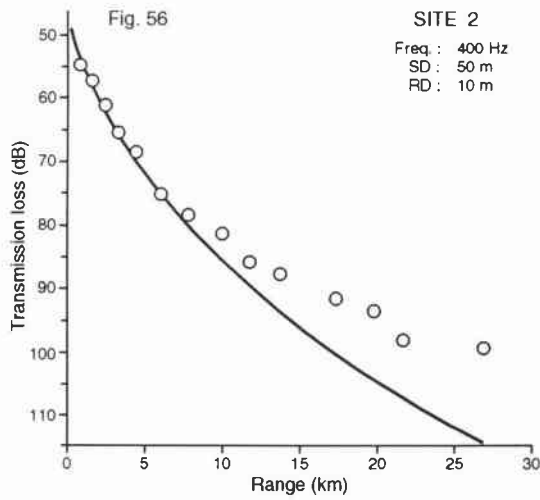


Figures 50–52 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=200 Hz; SD=50 m; RD=10, 35, 98 m respectively

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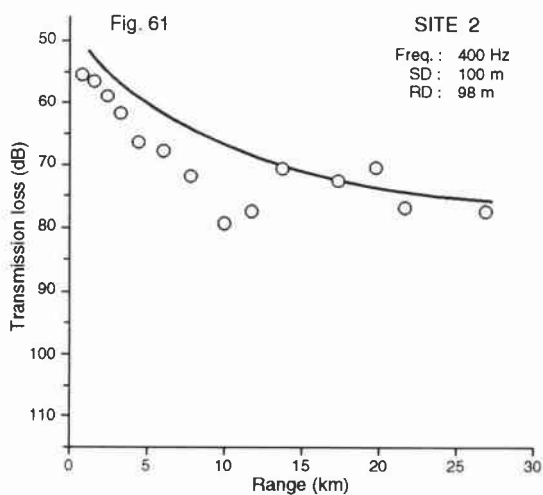
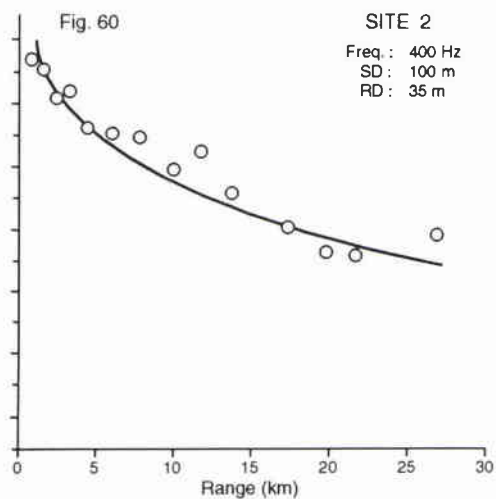
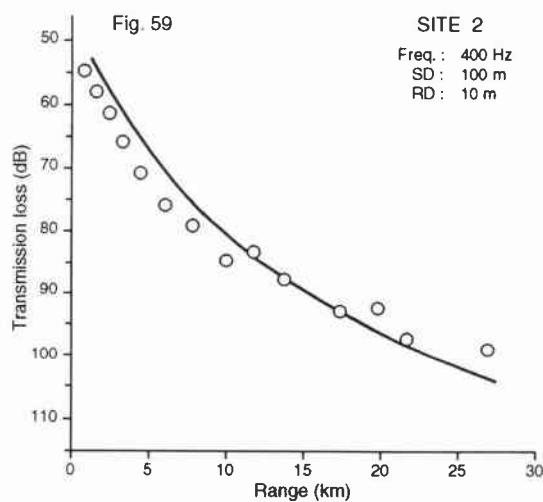


Figures 53–55 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=200 Hz; SD=100 m; RD=10, 35, 98 m respectively

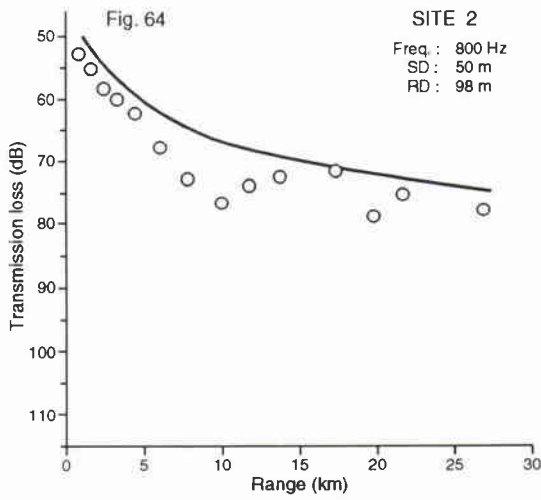
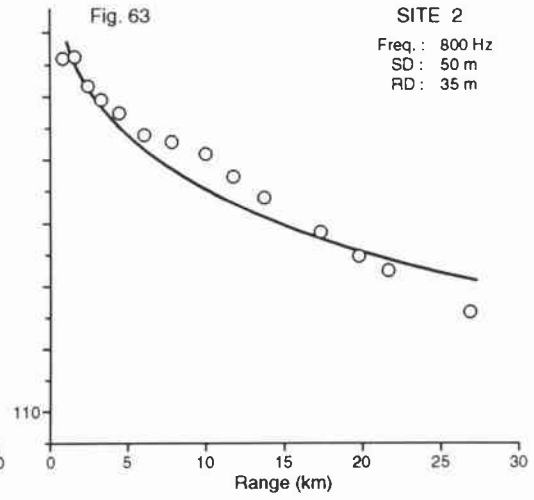
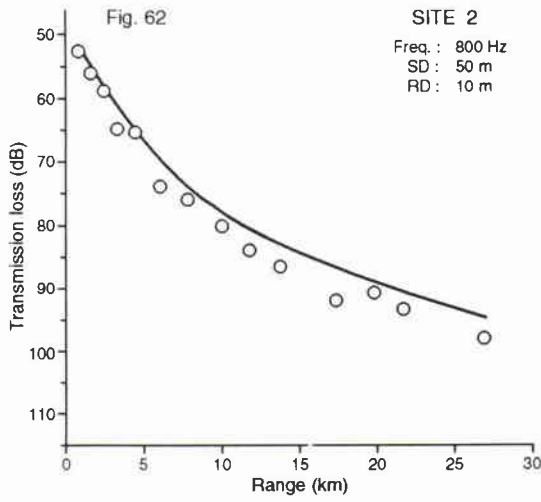


Figures 56–58 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=400 Hz; SD=50 m; RD=10, 35, 98 m respectively

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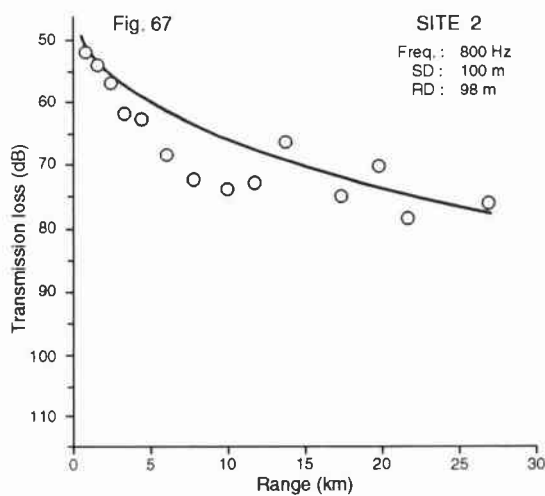
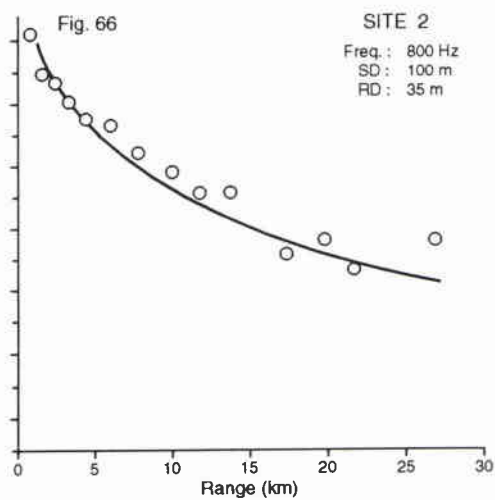
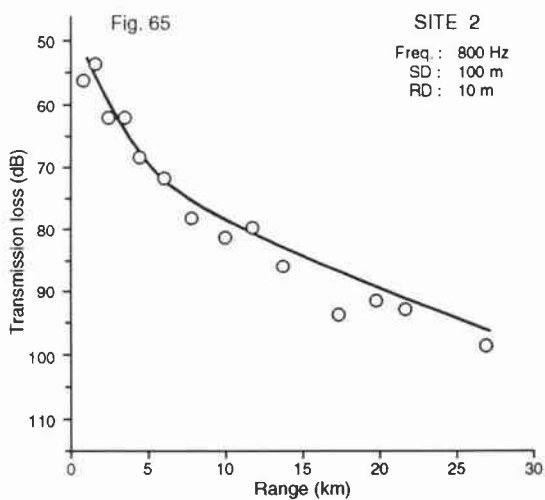


Figures 59–61 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=400 Hz; SD=100 m; RD=10, 35, 98 m respectively

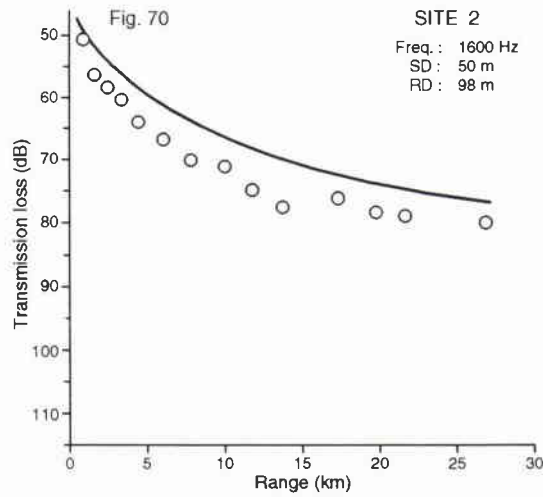
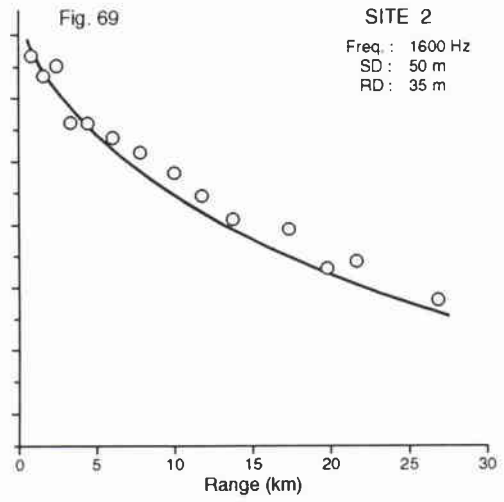
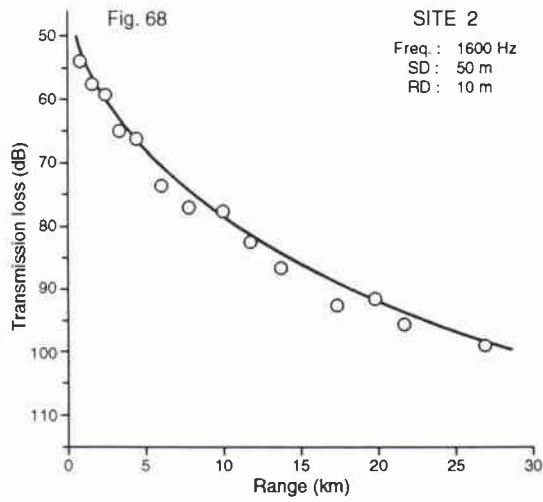


Figures 62–64 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=800 Hz; SD=50 m; RD=10, 35, 98 m respectively

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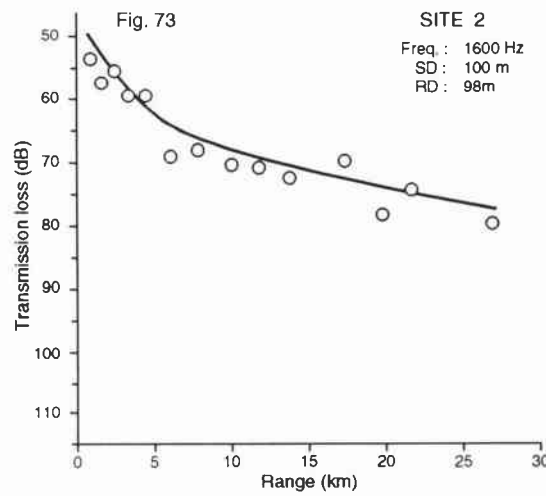
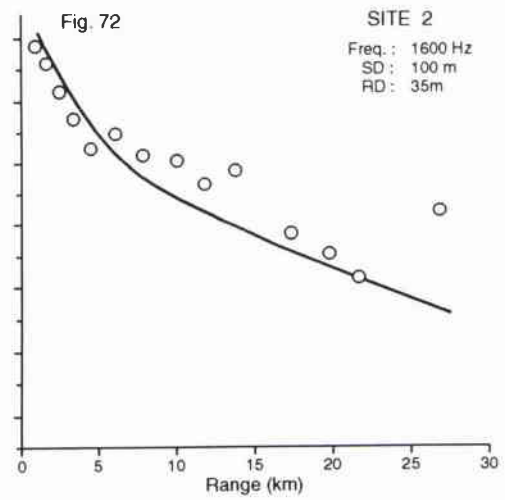
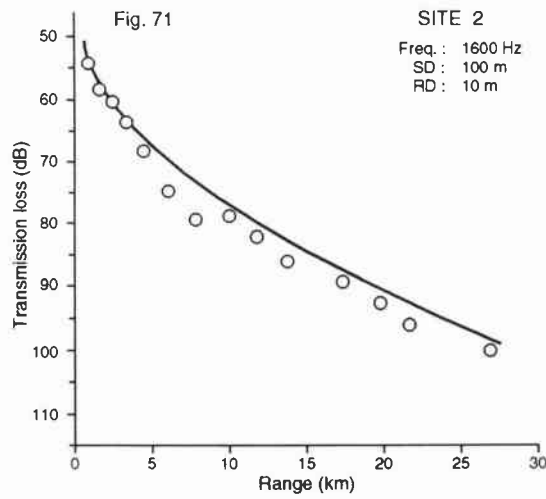


Figures 65–67 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=800 Hz; SD=100 m; RD=10, 35, 98 m respectively



Figures 68–70 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=1600 Hz; SD=50 m; RD=10, 35, 98 m respectively

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Figures 71–73 Comparison between measured and predicted transmission loss for Track D–E of Site 2. The points are the measurements and the solid curves are the predictions. Frequency=1600 Hz; SD=100 m; RD=10, 35, 98 m respectively

Document Data Sheet

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<i>Document Serial No.</i> SR-242	<i>Date of Issue</i> December 1995	<i>Total Pages</i> 39 pp.
<i>Author(s)</i> A. Caiti F. Ingenito, A. Kristensen and M. D. Max		
<i>Title</i> Measurements and predictions of transmission loss at two sites in the Southwest Approaches to The English Channel		
<i>Abstract</i> As part of a continuing series of measurements being made by SACLANTCEN in representative shallow water areas an experiment was conducted in the southwest approaches to the English Channel. Measurements were made at two sites with different bottom characteristics. At one site there were long NE-SW trending ridges while at the other site the nearly flat bottom was chalk, with little or no sediment cover. Transmission loss was measured along two tracks at the first site, one along and the other perpendicular to the line of crests and troughs of the sand waves. At the other site, measurements were made along a single track. At both sites explosive sources and a four element receiving array were used. The transmission loss data were processed in 1/3 octave bands and analysed at frequencies of 100, 200, 400, 800, and 1600Hz. Attempts to make direct measurements of bottom acoustic parameters were largely unsuccessful; instead the bottom acoustic parameters were adjusted to obtain a good fit to the transmission loss data with the SAFARI prediction model. The resulting geoacoustic models were reasonably consistent with knowledge of the bottom obtained from other sources. It was found that there was no significant difference in transmission loss measured along and perpendicular to the crests and troughs of the ridges at the first site. Transmission loss was much higher at the second site due to the highly absorbing chalk bottom. Unusually high loss was measured at the second site for the shallow receiver. This can be understood in terms of the characteristics of the modal structure of the acoustic field.		
<i>Keywords</i> Bottom properties – SWAP – Southwest Approaches to the English Channel – transmission loss		
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