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Investigation of the Applicability of AUAMP in Shallow Water Technical Report

1 September 1992

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Prepared Under
Contract N00014-91-D-0287

for the
Office of Naval Research
Department of the Navy
Washington, D.C. 20363-5100

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U181-92-015
1 September 1992

124A

Office of Naval Research Detachment
Stennis Space Center, MS 39529-5004

Attention: Mr. Ed Chaika

Subject: Applicability of AUAMP in Shallow Water Technical Report

Reference: (a) Contract N00014-91-D-0287/001

Dear Mr. Chaika;

The enclosed document provides an investigation of the applicability of the Advanced Underwater Acoustic Modeling Project (AUAMP) version 2.6 in shallow water. This document is in response to Subtask 3 of Delivery Order #1 of the referenced contract. This document is CDRL A002 for the referenced task.

Sincerely,



D.O. Drew
ASW Project
TRW Systems Division
Systems Integration Group

Enclosure: (1) "Investigation of the Applicability of AUAMP in Shallow
Water Technical Report" 1 September 1992.

ED/adm

cc: TRW (W.F. Grattan)
Defense Technical Information Center (2)
Naval Research Laboratory (Director)
ONR Contracting Office (Code 1513) (M. Kurzius)

54482.000



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1.0 INTRODUCTION

The Office of Naval Research Detachment, Stennis Space Center tasked TRW to investigate the applicability of the Advanced Underwater Acoustic Modeling Project (AUAMP version 2.6) in shallow water and transitional (slope) ocean environments. AUAMP was developed for deep water applications and analysis was required to determine its appropriateness in shallow water environments (ref 1). This document presents preliminary results of this analysis. In addition, this report attempts to separate the environmental input dependency from the model algorithm accuracy when using AUAMP to make acoustic and system predictions. This document is an intermediate report in the process of the validation and investigation of AUAMP version 2.6 in shallow water and slope environments.

This task investigates the applicability and sufficiency of the AUAMP model algorithms, data bases, and modeling assumptions in shallow water. Initially, this evaluation addresses the sensitivity of model algorithms to environmental input parameters as well as their appropriateness for use in shallow water environments. The degree of accuracy (hence usefulness) of AUAMP predictions is then investigated with comparisons to measured data. The drastic impact of specific environmental parameters is documented in this report.

The specific scope of this document is to:

- Familiarize the reader with the philosophy and methodology used in conducting this study;
- Make the reader aware of the limitation of current data bases and other issues of using AUAMP in shallow water;
- Present results of the analysis of AUAMP algorithms and the algorithm sensitivity to environmental inputs, where appropriate.
- Present comparisons between AUAMP predictions and measured data.
- Present the results of the initial analysis of discrepancies between model and measured results.

- Point out the general obstacles in performing the evaluation of a model in shallow water, specifically the problems encountered by TRW in performing this analysis and recommend possible solutions.

The remainder of this document is divided into four sections. The second section presents the method of analysis used in this study to support model evaluation. The third section presents some general modeling and data base issues. The third section also presents model to model comparisons used in investigating a few of these issues, where applicable. The fourth section presents representative model to measured data comparisons. The fifth section summarizes this preliminary stage of the study and recommends actions that can ensure an appropriate evaluation of AUAMP in shallow water.

2.0 METHODOLOGY

The determination of whether a model is performing to a required degree of accuracy in any environment is dependent on two factors: the accuracy of the environmental inputs and; the ability of the model algorithms to correctly represent the phenomena being modeled. If the model algorithms are not appropriate, no matter what the degree of accuracy in the environmental inputs, the answer will be incorrect. Similarly, if a high fidelity, precise model exists, it will never yield useful predictions if the environmental inputs are incorrect. Thus, it is necessary in an evaluation procedure of an acoustic model to separate the inaccuracies due to non-perfect environmental data and the inaccuracies due to the model algorithms. Though it is difficult and expensive to have "accurate" environmental data, it is essential to strive for the separation of environmental and algorithm dependencies, anyway. If one piece of the environmental data is incomplete or not known to the required degree of accuracy, it can never be conclusively proven that the similarity or discrepancy of real data with a model prediction is due to faulty or incomplete environmental inputs or to the model algorithms. This procedure can be viewed as unique when compared with current deep water evaluation studies of some acoustic models. Many models (including AUAMP) were originally designed for use in deep water environments. The development of AUAMP included comparisons with PE as well as real data in its evaluation stages (ref 1). As a result, AUAMP has been well scrutinized in deep water. However, when using AUAMP in a shallow water environment, for which it was not originally intended, the results of the deep water validation may not hold. The deep water evaluation procedure is concerned with the robustness of the models as well as accuracy. The shallow water evaluation process analyzes the appropriateness of the algorithms within the model.

Using the philosophy presented above, TRW is investigating AUAMP using the following three step process:

1. Conducting a general analysis of the model algorithms and assumptions for the establishment of their correctness in shallow water.
2. Comparing models to test the implications of related algorithm issues.
3. Conducting model to measured data comparisons using both in situ

environmental inputs and Historical Ocean Profile (HOP) inputs to observe prediction differences and the effect accurate knowledge of environmental inputs has on AUAMP predictions.

The pivotal calculation in AUAMP is the ASTRAL transmission loss calculation. This transmission loss calculation is performed between the source and target and the target and receiver. In addition, ASTRAL is used to compute the transmission loss between the reverberation scatterers and the receiver as well as the transmission loss from the noise sources in the ocean to the receiver. Consequently, due to the large role ASTRAL has in the AUAMP model, this study has focused on transmission loss. The results of comparisons of signal excess data with signal excess predictions would be inconclusive because the source of discrepancy may be in any of the environmental inputs, the transmission loss calculation, the reverberation calculation, etc. It was appropriate to concentrate on transmission loss in this study since preliminary comparisons did not match well.

The initial set of test data from at-sea experiments chosen for consideration in the analysis documented in this paper is unique for a number of reasons. Since the objective of this study is to determine whether mismatches in transmission loss are due to algorithm or non-representative environmental inputs, data from tightly controlled experiments were selected for initial comparisons. This reduced the number of unknowns in the comparisons. For example, one of the experiments from which transmission loss data was used had a stationary receiver with a source moving out specified radials. This straightforward measurement technique reduces the problems and errors accrued in resolving the environment and navigation for a moving source and receiver (which is present in many current at-sea tests). In addition, AUAMP does not have the automated capability for performing multiple transmission loss runs along tracks between a moving source and receiver. It assumes the source and receiver are fixed when calculating transmission loss.

No report on an investigation in shallow water can escape without a definition of shallow water. Wherever paths are dominated by bottom bounce paths such that knowledge of the bottom becomes crucial is the working definition of shallow water used in this study, although other appropriate definitions do exist (ref 2). The bottom interaction phenomena can be due to a negative gradient sound velocity profile or just very shallow water. Within this paper the deepest shallow water environment investigated was approximately 1000 feet.

3.0 ISSUES OF USING AUAMP IN SHALLOW WATER

This section presents an overview of the capabilities of AUAMP. A summary of the data base limitations and information about the algorithms used within AUAMP and their applicability in shallow water is presented. This section also presents model to model comparisons in support of the analysis of the algorithm issues.

3.1 Background of AUAMP

The Advanced Underwater Acoustic Modeling Project (AUAMP version 2.6) is a modular system of models which utilizes the results of one model as input to another model. The ultimate output of AUAMP is range-dependent active signal excess for up to 14 receivers. AUAMP also calculates, and outputs, range-dependent transmission loss, reverberation, target echo and ambient noise. Navy standard data bases are used as the source for environmental information. The model also allows independent (synthetic, measured, etc.) data to be inserted into the model calculations rather than accessing the standard data bases inherent to AUAMP.

3.2 Algorithm and Data Base Issues with AUAMP

This section summarizes the data base restrictions currently within AUAMP and lists the algorithms within AUAMP which have been investigated for their applicability in shallow water. Reference 3 provides a detailed description of the algorithm concerns and data base restrictions.

- **Extension of the sound velocity profile with a positive pressure gradient**

ASTRAL saves time in its computations by setting up specific mathematical functions to calculate transmission loss (mode and depth functions) only once for each specific sound velocity profile. These functions are constructed by assuming the ocean to be "infinite" in depth for a specific sound velocity profile. Each sound velocity profile

is extended to an "infinite" depth of 10,000 m with a constant positive pressure gradient of .018 m/sec. Similarly, the bottom depth at the location of the SVP is considered to be the "infinite" ocean depth. Every time a new sound velocity profile is encountered, ASTRAL uses this technique to establish new functions. ASTRAL then marches out in range, renormalizing the mode functions for specific water depth changes.

The extension of the SVP with a positive pressure gradient to an infinite ocean depth is appropriate in deep water. Deep water profiles normally exhibit positive gradients near the bottom because only pressure affects the sound velocity profile at deep depths, thermal and salinity variations having ceased. For this reason, the SVP is extended in the model with a positive gradient of .018 m/s. In shallow water, this is not necessarily true. Significant salinity and thermal variations can still be taking place at or near the bottom. If in a certain environment the sound velocity profile used in TL, reverberation or noise model predictions has a negative gradient near the bottom, the extension of a positive pressure gradient on the profile could introduce a false duct near the bottom and may produce inappropriate results (ref 1,5).

- Sound Velocity Profile Data Base

The current sound velocity profile data base is limited to ocean areas deeper than 100 meters. Ongoing upgrades to AUAMP data bases will include a shallow water sound speed profile data base (ref 4).

- Bottom Interaction

Due to the multiple bottom interactions of sound energy propagating in shallow water, bottom characteristics play a significant role in the transmission loss calculation. ASTRAL uses the Bottom Loss UpGrade (BLUG) model which accesses the Low Frequency Bottom

Loss (LFBL) data base for geoacoustic parameters. Inappropriate results may occur at steep grazing angles for intermediate frequencies and thick sediments due to the way BLUG calculates a loss per bounce dependent on a reflected and refracted wave. Steep grazing angles can be encountered in upslope (transitional) environments (or at very short ranges, i.e., less than a mile in 200 feet of water) (ref 5, 8).

Additionally, there is a lack of empirical bottom loss data at shallow grazing angles. In flat bottomed shallow water environments the energy from the shallow grazing angle rays contributes significantly to the transmission loss at a given range. Multiple bottom interactions are accentuated by the characteristically negative gradient shallow water sound velocity profile, which is refracting an increased number of rays to the bottom. Bottom loss information at shallow angles is pivotal for calculating transmission loss in shallow water environments.

Representative model to model comparisons are presented in this next section (3.3) to investigate the sensitivity of AUAMP to bottom loss at shallow grazing angles relative to other models.

- Low Frequency Bottom Loss Data Base (LFBL)

This data base, until recently, supplied nine geoacoustic parameters to ASTRAL. These parameters characterized specific areas of the ocean and include sediment thickness values in two-way travel time. Recently, a tenth parameter, an attenuation exponent that adjusts the bottom loss in shallow water, has been added to the LFBL data base. This tenth parameter is not used within AUAMP version 2.6. Upgrades to AUAMP will include the use of this parameter. Thus, bottom interaction in shallow water is treated similarly to bottom interaction in deep water (ref 10).

- **Scattering Strength**

In shallow water small grazing angle rays dominate the transmission loss. The scattering strength models implemented in AUAMP, Mackenzie-Lambert to calculate bottom scattering strength and Chapman-Harris to calculate surface scattering strength, may produce inappropriate results for grazing angles less than a few degrees (as compared with measured data) (ref 9).

Additionally, AUAMP does not handle forward scattering in its modeling of reverberation. The model assumes all scattering is back in the direction of the source (ref 9).

- **Total energy versus Peak energy transmission loss**

AUAMP version 2.6 uses the total energy for calculating transmission loss. Peak energy is sometimes measured during sea tests. Upgrades (version 2.8) to AUAMP will employ the option of peak energy to represent transmission loss (ref 4). It is the investigators decision as to which prediction technique is appropriate for a specific study.

Selected issues above were investigated further with model to model comparisons for analysis purposes. A summary of these analyses are presented in the next subsection.

3.3 Model to Model Comparisons

3.3.1 SVP Extension Algorithm

One of the initial algorithms investigated for its appropriateness in shallow water was the extension of the sound velocity profile with a positive pressure gradient within ASTRAL (ref 1, 5). This is done to conserve time within ASTRAL. Initial depth functions are constructed for each watermass assuming an ocean depth of 10,000 m. The SVP for a specific area of

ocean is extended to the "infinite" ocean depth of 10,000 m with a positive pressure gradient. This technique can introduce discontinuities (in the first derivative) that may skew transmission loss results when a negative gradient exists at the bottom. To investigate the severity of the effect of extending the SVP with a positive gradient when a negative gradient exists near the bottom (as is characteristic in shallow water) three shallow water cases with a constant depth of 328 feet were defined:

- A) A range-independent environment with an isovelocity profile to the bottom;
- B) A range-independent environment with an isovelocity profile to 60 feet then a positive gradient to the bottom;
- C) A range-independent environment with an isovelocity profile to 60 feet then a negative gradient to the bottom;

Figure 3-1 (a) through (c) show each of the sound velocity profiles described above. Model runs were conducted for each of the three cases using ASTRAL within AUAMP (ref 1, 6), the Fast Asymptotic Multipath Expansion (FAME) model of GSM (ref 11), and the Navy Standard Parabolic Equation (PE) (ref 12). The hypothesis used in conducting this

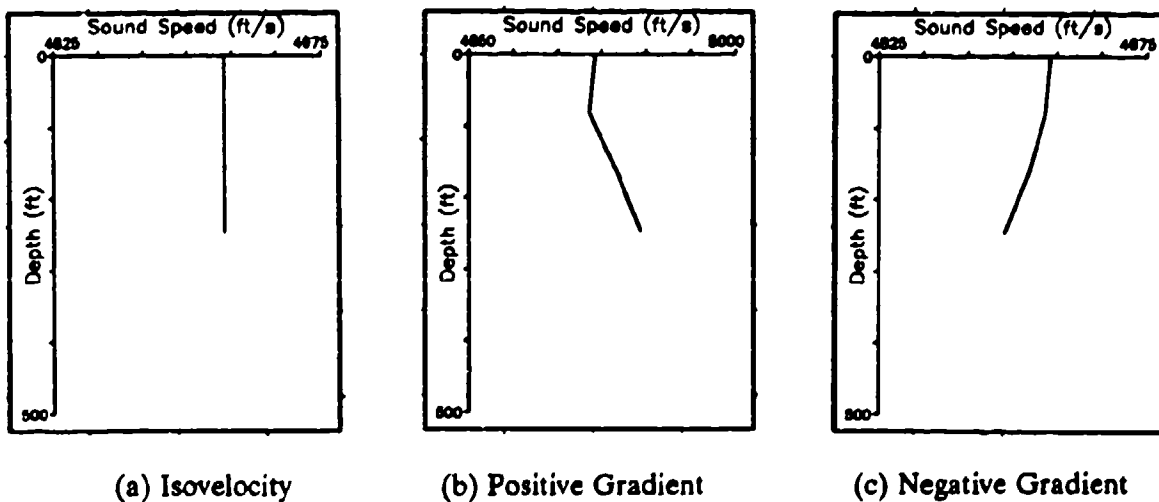


Figure 3-1. Sound Velocity Profiles Used in Algorithm Investigation

investigation, was that ASTRAL was computing transmission loss correctly for the isovelocity (Case A) and positive gradient (Case B) environments, yet may not be calculating it correctly in the negative gradient environment due to the SVP positive gradient extension (Case C). If this hypothesis were true, the results of the comparisons would have the three different models agreeing fairly well in the isovelocity and positive gradient cases. In the negative gradient case PE and FAME would agree, but with ASTRAL results going notably askew.

Figure 3-2 gives the environmental parameters used in these model runs.

Parameter	Value
Water Depth	328 feet
Source Depth	60 feet
Receiver Depth	90 feet
Frequency	200 Hz

Figure 3-2. Parameters Used in SVP Extension Model Comparison

Figure 3-3 presents the LFBL parameters used for this run. Figure 3-4 presents a plot of the bottom loss versus grazing angle curve for this environment derived from the LFBL parameters.

The three models were run range-independently with the above parameters. Thus, the three separate runs for each model were characterized uniquely by only a change in the sound velocity profile.

Figures 3-5 through 3-7 present three curves to a graph representing the results of each of the models for a specific environment (SVP Cases A through C, respectively).

As expected, the FAME, PE and ASTRAL results for the isovelocity and positive gradients all tend to behave similarly. In the positive gradient case, FAME tends to underpredict, yet a general agreement is seen. This is in accordance with the hypothesis stated above. In the negative gradient case, the models tend to agree as well. This does not demonstrate the

LFBL Parameter	Value
Ratio of SVP sediment to SVP water	.991
Gradient of SVP in sediment	1.3 /s
Sediment profile curvature	-.5 /s
Attenuation at interface	.0070 dB/m/kHz
Attenuation gradient	.00005 dB/m/kHz/m
Sediment surface density	2.66 gm/cc
Thin layer density	3.69 gm/cc
Thin layer thickness	.48 m
Sediment two way travel time	1.29 s

Figure 3-3. LFBL Parameters Used for this Run (absorbing bottom)

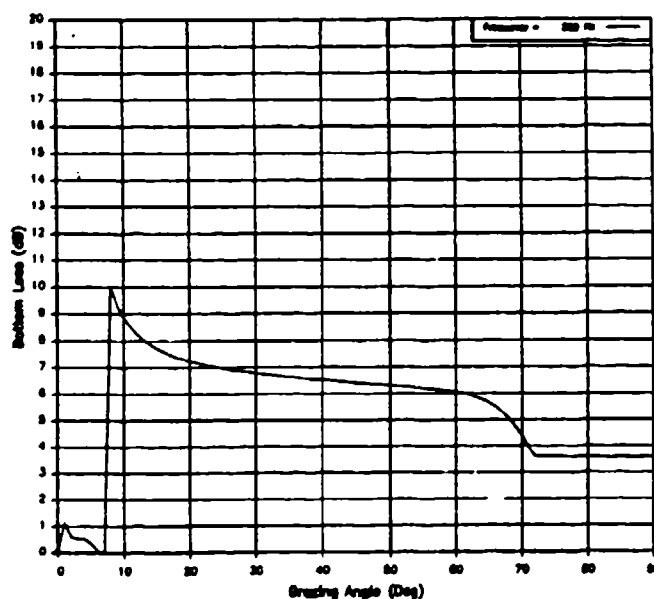
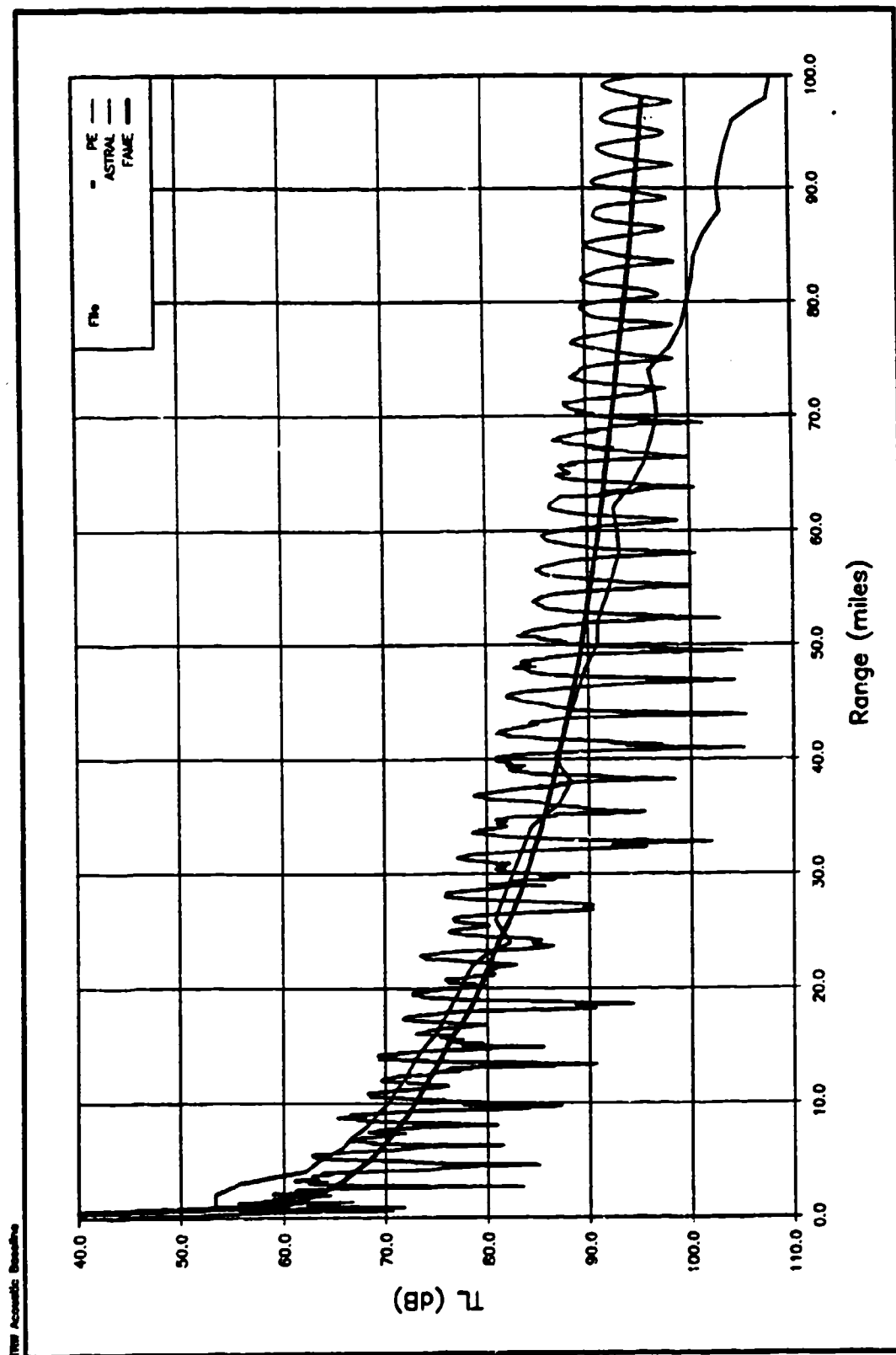
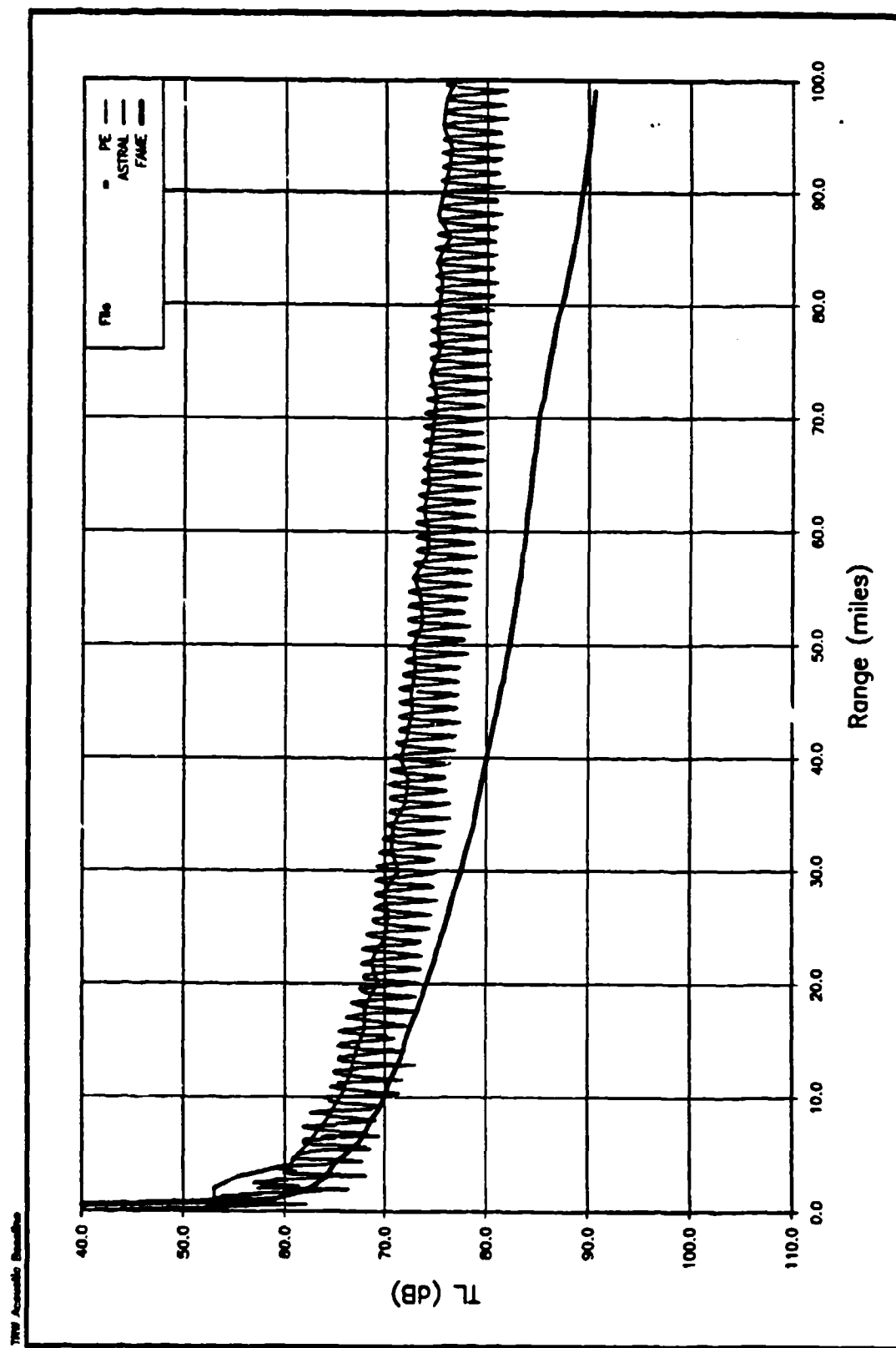


Figure 3-4. Bottom Loss (absorbing bottom) for SVP Extension Analysis



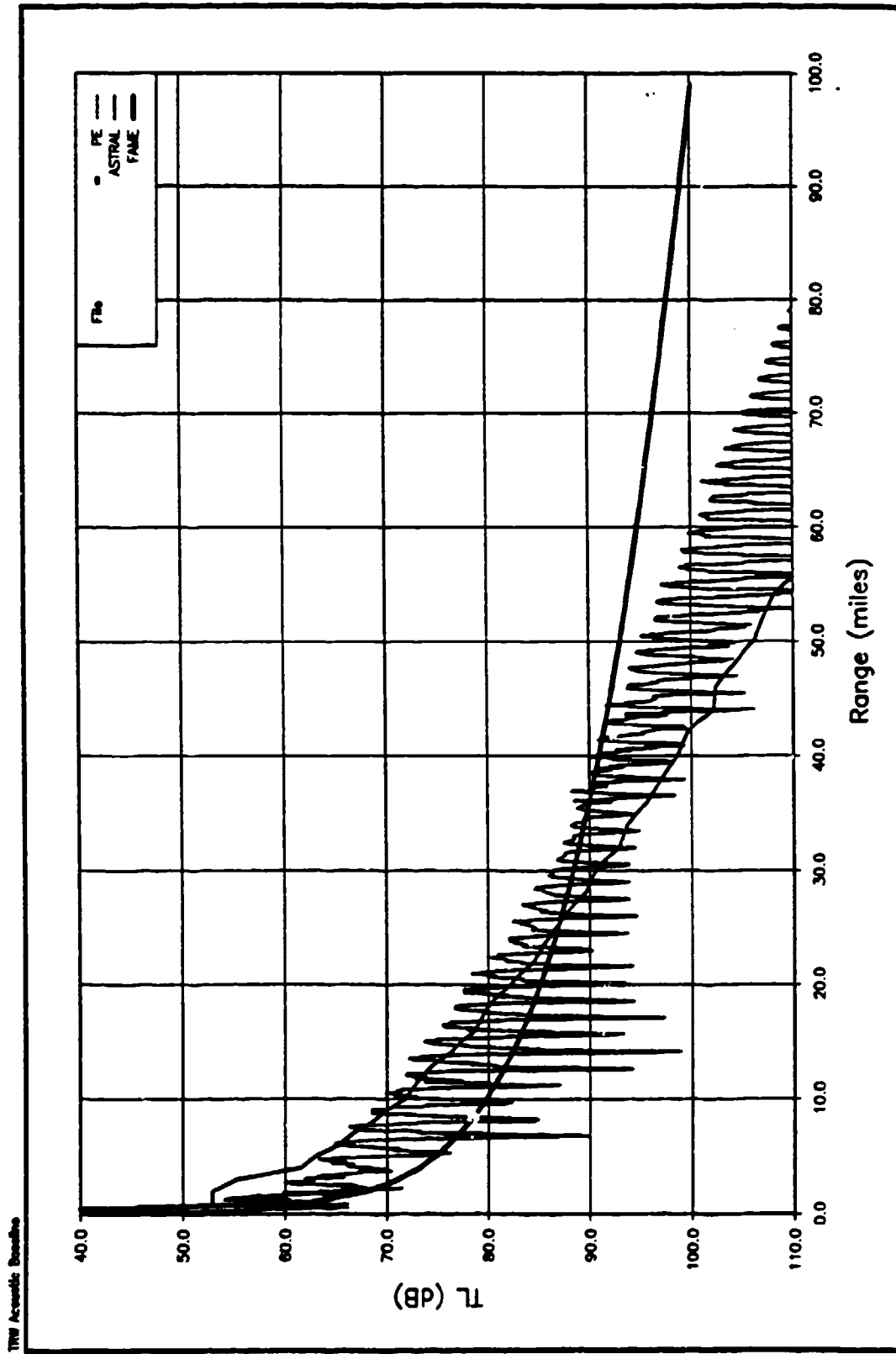
FAME/PE/ASTRAL Comparisons Isovelocity

Figure 3.5. ASTRAL, FAME, and PE Comparisons for Case A (Isovelocity)



FAME/PE/ASTRAL Comparisons Positive Gradient

Figure 3-6. ASTRAL, FAME, and PE Comparisons for Case B (Positive Gradient)



FAME/PE/ASTRAL Comparisons

Figure 3-7. ASTRAL, FAME, and PE Comparisons for Case C (Negative Gradient)

drastic behavior the hypothesis proposed. One possible cause for this is the fact that the sediment sound speed for this run was taken to be slower than the sound speed in the water column (absorbing bottom). Thus, all energy in the bottom tended to be captured by the bottom and did not reemerge into the water column. This possibly could disguise the extension algorithm effects, since the bottom paths are not playing into the waterborne transmission loss paths significantly.

To investigate whether the bottom profile coupled with the water column profile has a significant effect on the SVP extension algorithm, the same comparisons were done, for a reflective bottom (sound speed in bottom is greater than that in the water column). Figure 3-8 presents the LFBL parameters used for this situation. Figure 3-9 shows the bottom loss versus grazing angle curve derived from the LFBL parameters. Figures 3-10 through 3-12 present the comparisons of AUAMP, PE, and FAME for the reflective bottom.

The gradient used to create the negative and positive sound velocity profiles was $.16 /s$. The effect of the algorithm when the sound velocity profile exhibits a much steeper gradient, either positive or negative was investigated. A gradient of $.5 /s$ was used for this investigation. Figure 3-13 through 3-14 present the transmission loss predictions from AUAMP, PE and FAME when using a sharp positive gradient and a sharp negative gradient with an absorbing bottom as shown in Figure 3-4.

LFBL Parameter	Value
Ratio of SVP sediment to SVP water	1.061
Gradient of SVP in sediment	1.3 /s
Sediment profile curvature	-.5 /s
Attenuation at interface	.0010 dB/m/kHz
Attenuation gradient	.0001 dB/m/kHz/m
Sediment surface density	2.79 gm/cc
Thin layer density	4.03 gm/cc
Thin layer thickness	.47 m
Sediment two way travel time	1. s

Figure 3-8. LFBL Parameters Used for this Run (reflecting bottom)

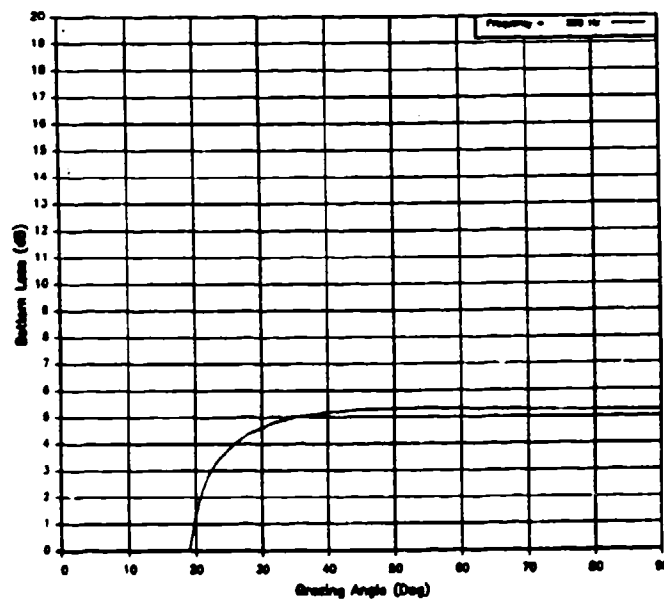
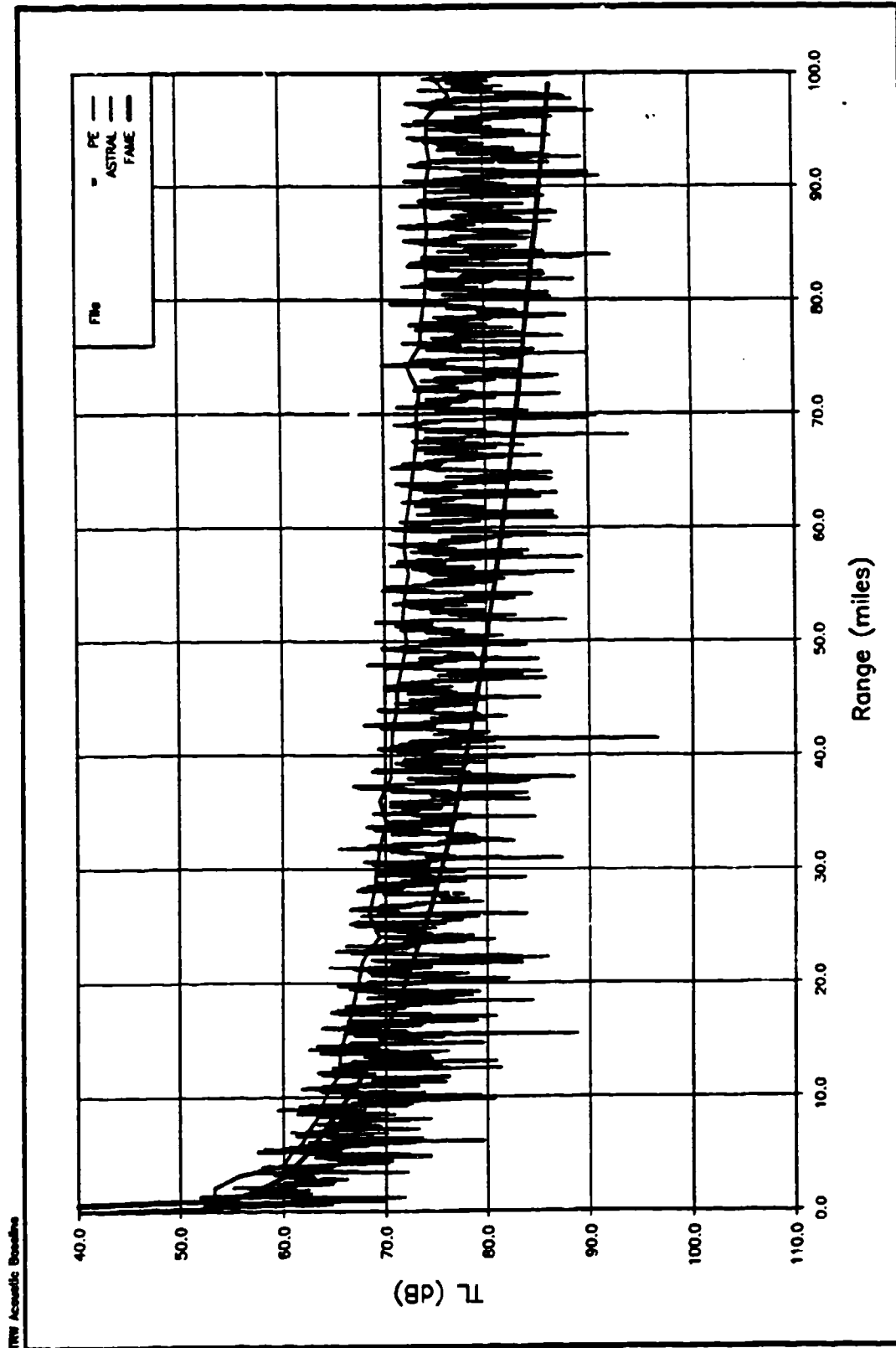
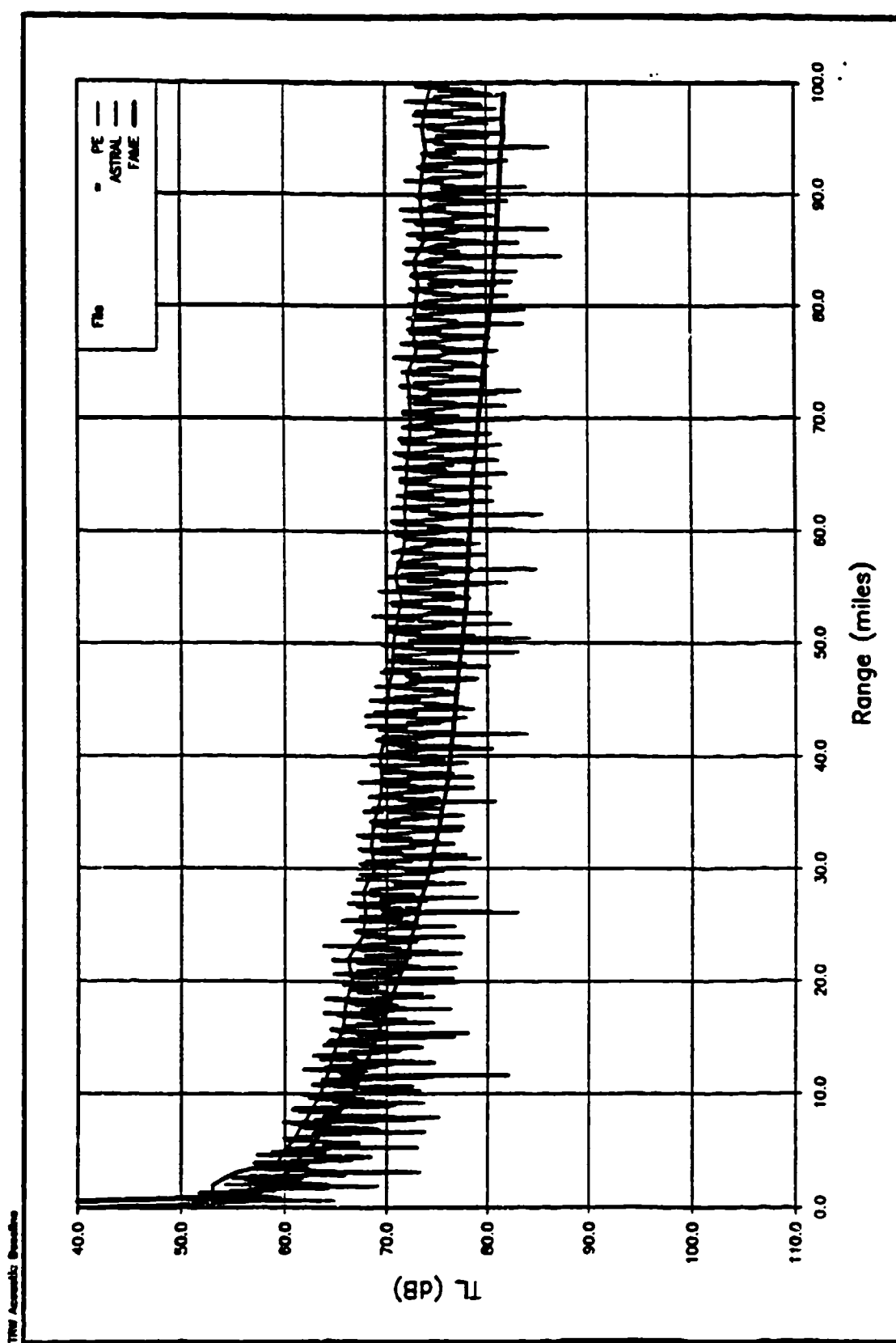


Figure 3-9. Bottom Loss (reflecting bottom) for SVP Extension Analysis



FAME/PE/ASTRAL Comparisons Isovelocity

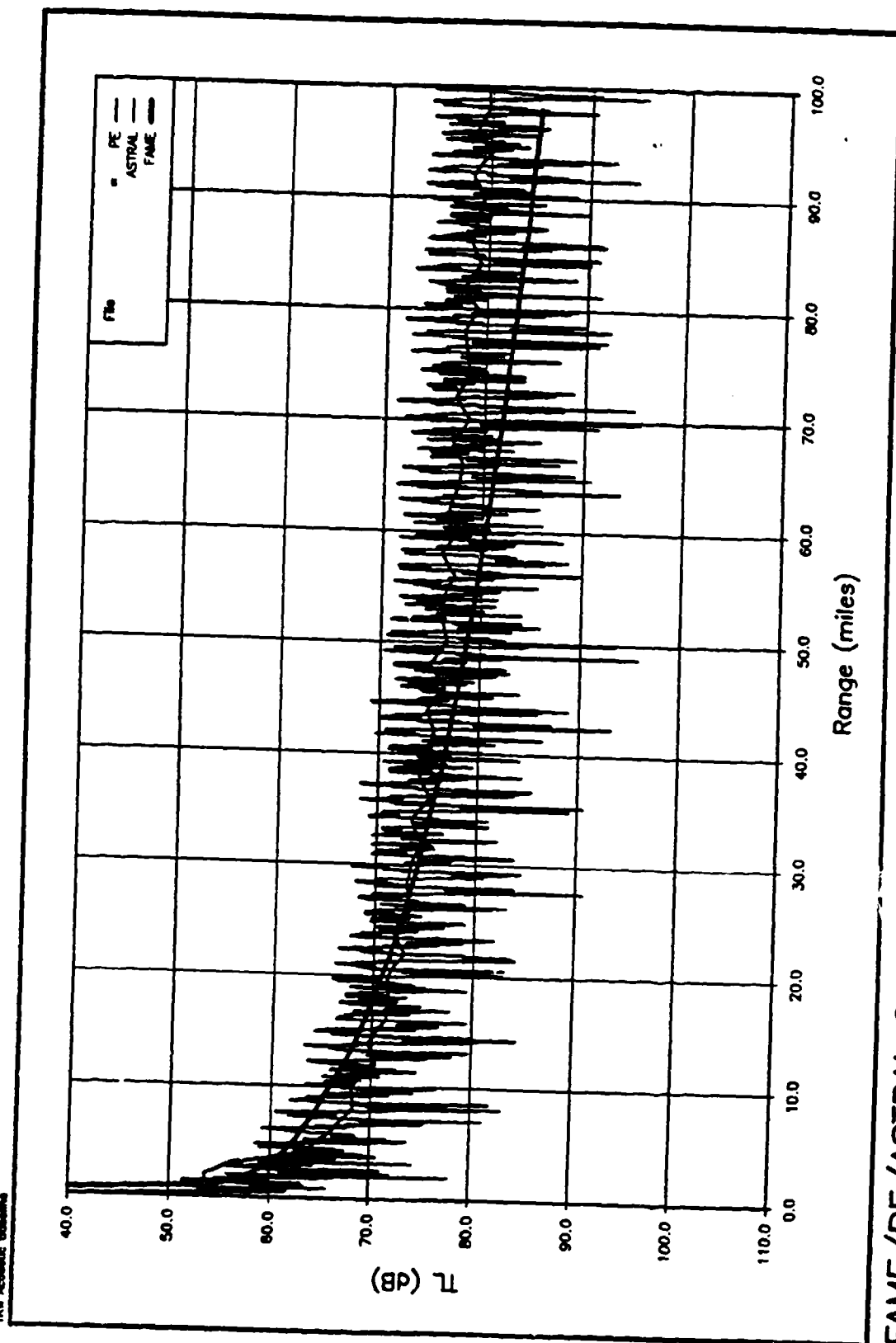
Figure 3-10. ASTRAL, FAME, and PE Comparisons for Case A (Isovelocity)



FAME/PE/ASTRAL Comparisons Positive Gradient

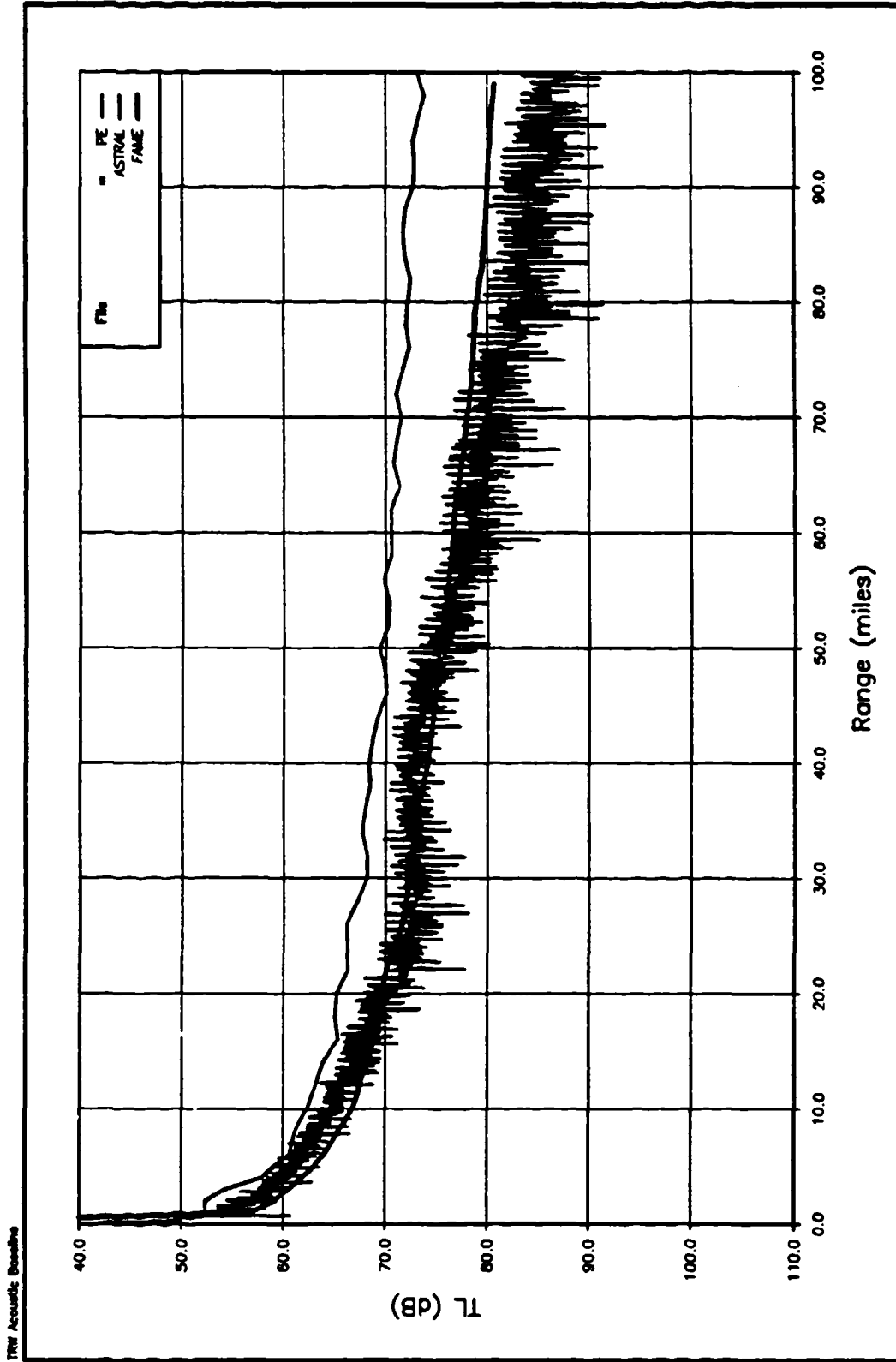
Figure 3-11. ASTRAL, FAME, and PE Comparisons for Case B (Positive Gradient)

True Acoustic Baseline



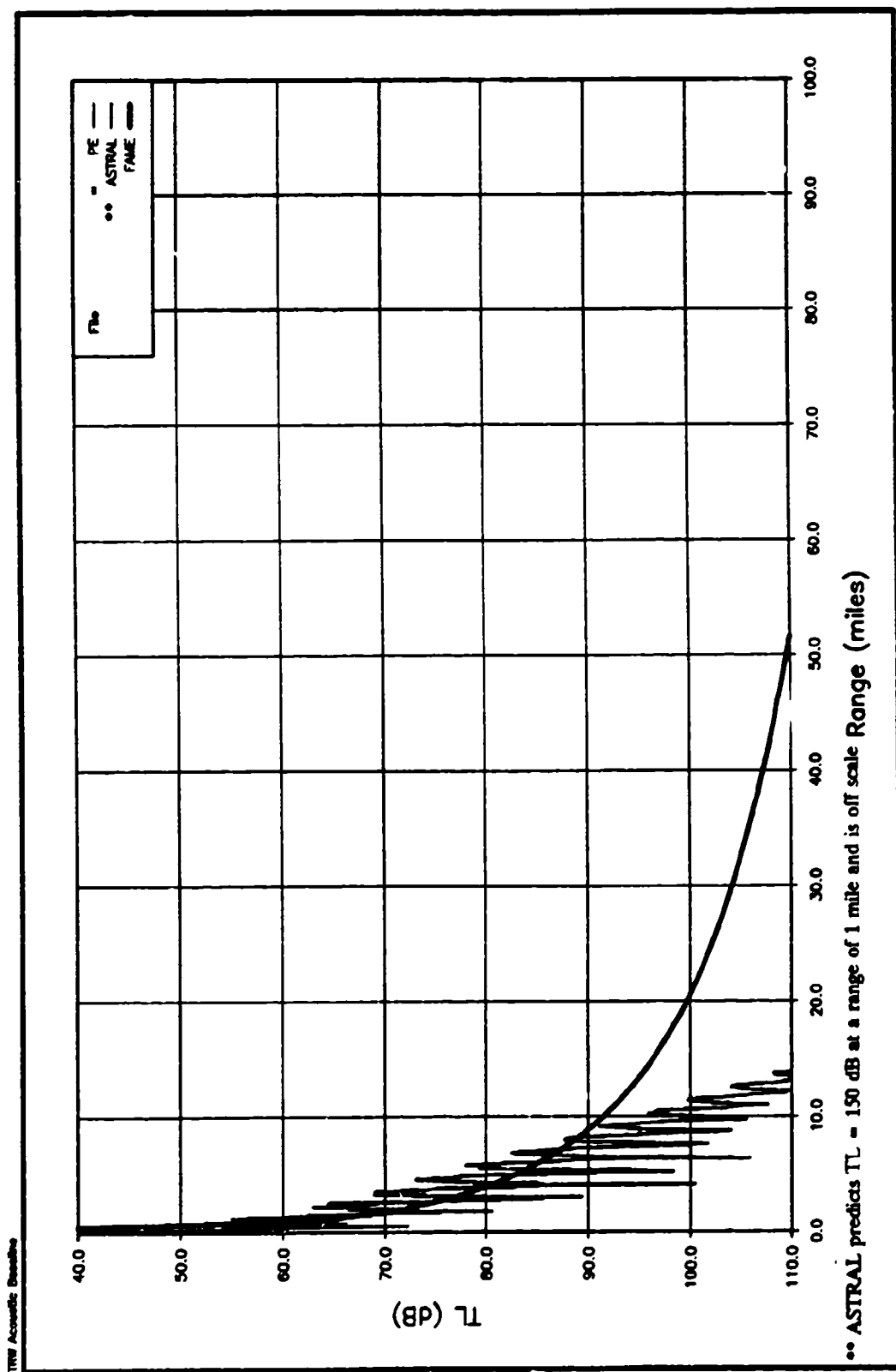
FAME/PE/ASTRAL Comparisons Negative Gradient

Figure 3-12. ASTRAL, FAME, and PE Comparisons for Case C (Negative Gradient)



FAME/PE/ASTRAL Comparisons Sharp positive grad

Figure 3-13. ASTRAL, FAME, and PE Comparisons for Sharp Positive Gradient



FAME/PE/ASTRAL Comparisons Sharp negative grad

Figure 3-14. ASTRAL, FAME, and PE Comparisons for Sharp Negative Gradient

- **Observations**

- **Absorbing Bottom**

ASTRAL, FAME, and PE agree well in the isovelocity case. ASTRAL tends to underpredict transmission loss for the .16 /s positive gradient case. In the .16 /s negative gradient case ASTRAL is seen to underpredict at short ranges and overpredict significantly at long ranges. When moving to a steeper gradient (.5 /s) for both the positive and negative gradient cases, ASTRAL is seen to significantly underpredict TL relative to FAME and PE. In the sharp negative gradient case, ASTRAL predicts 150 dB worth of transmission loss at 1 nm.

- **Reflecting Bottom**

ASTRAL, FAME and PE agree much better for both gradient cases (at .16 /s gradient) and the isovelocity case. ASTRAL does tend to underpredict relative to PE on the isovelocity and positive gradient profile cases. ASTRAL and PE agree well for the negative gradient case with a reflective bottom.

- **Conclusions**

Comparing both bottoms against all three sound velocity profiles does not show ASTRAL results behaving significantly different relative to the PE and FAME results for the reflective bottom case. In the absorbing bottom case, the steeper the gradient (either positive or negative) results in ASTRAL disagreeing with PE. In the negative gradient case, the difference between models is much more pronounced. Given the test cases presented here with the environmental data used, the SVP extension algorithm within AUAMP does appear to significantly affect transmission loss prediction capability in steep negative gradient environments with an absorbing bottom. In less steep gradient environments, the problem does not manifest itself as clearly. Though the results here leave suspect the SVP extension algorithm, the treatment of the bottom between PE and ASTRAL may be different enough to result in the discrepancies seen in this section, regardless of the extension algorithm.

3.3.2 Bottom Loss Dependence in Shallow Water and in Slope environments

Due to the significant role of the bottom in shallow water, an analysis was conducted to determine AUAMP's sensitivity to bottom loss as compared to other models. This analysis aids in understanding the BLUG treatment of bottom loss within ASTRAL in shallow water. It is noted that ASTRAL, as incorporated into version 2.6, does not use the tenth shallow water attenuation parameter included in the new LFBL data base (see Section 3.2).

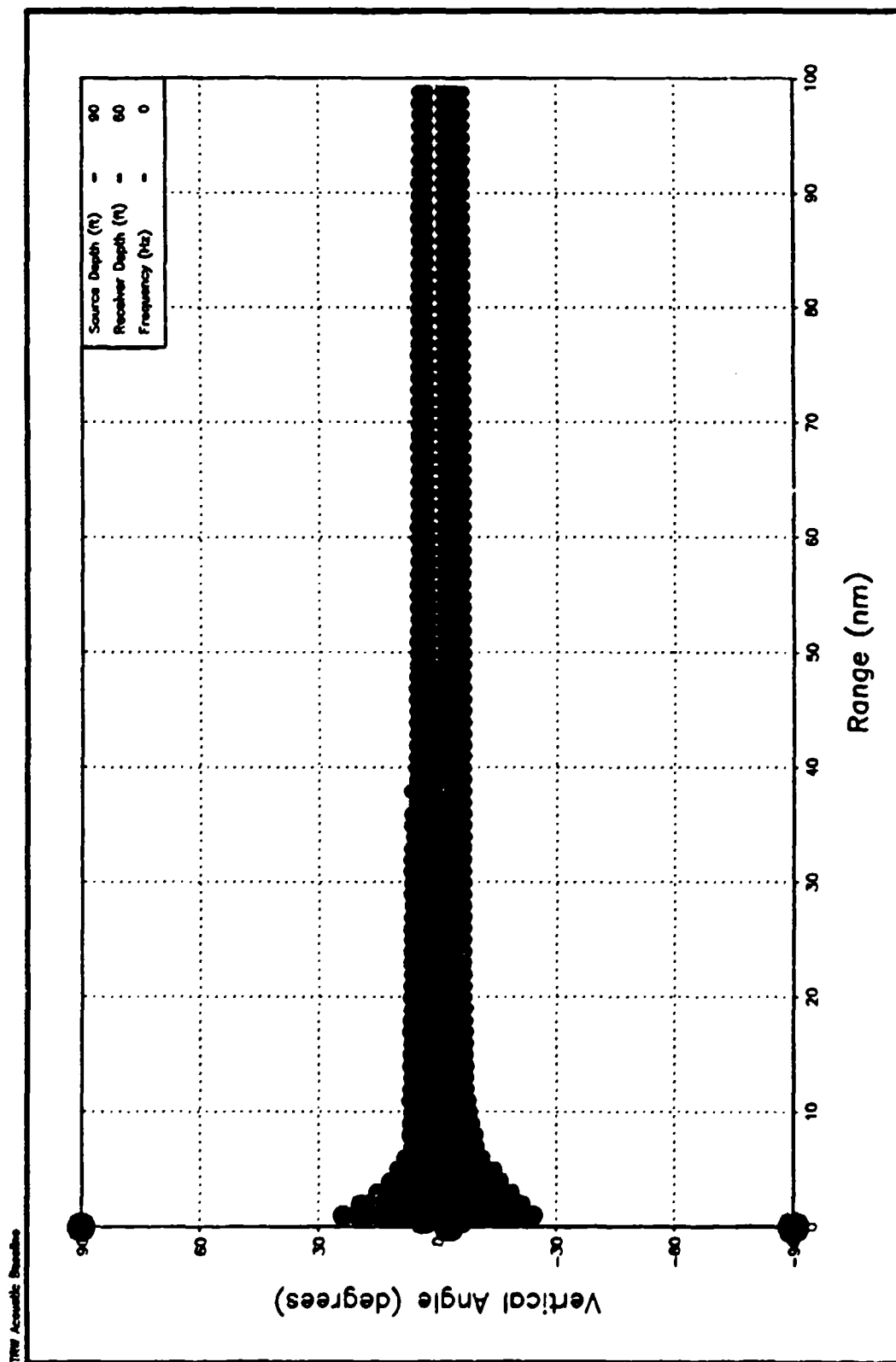
AUAMP, PE and FAME were run in a range-independent environment with the same parameters shown in Figure 3-2 above, except at a frequency of 600 Hz, for the same positive gradient sound velocity profile as shown in Figure 3-1(b). Three separate cases were run:

- A) High Loss below grazing angles of 20 degrees;
- B) Low Loss below grazing angles of 20 degrees;
- C) Medium Loss below grazing angles of 20 degrees.

The qualifier of below 20 degrees was used because of the depth of the water relative to the range. With a water depth of 200 feet, one would expect grazing angles to be less than 20 degrees beyond .014 miles in this environment. The dominance of low grazing angles is further reinforced with a plot of the grazing angles versus arrival angle curves for this environment using the low loss case. Figure 3-15 shows the arrival angle as a function of range for Case C from FAME.

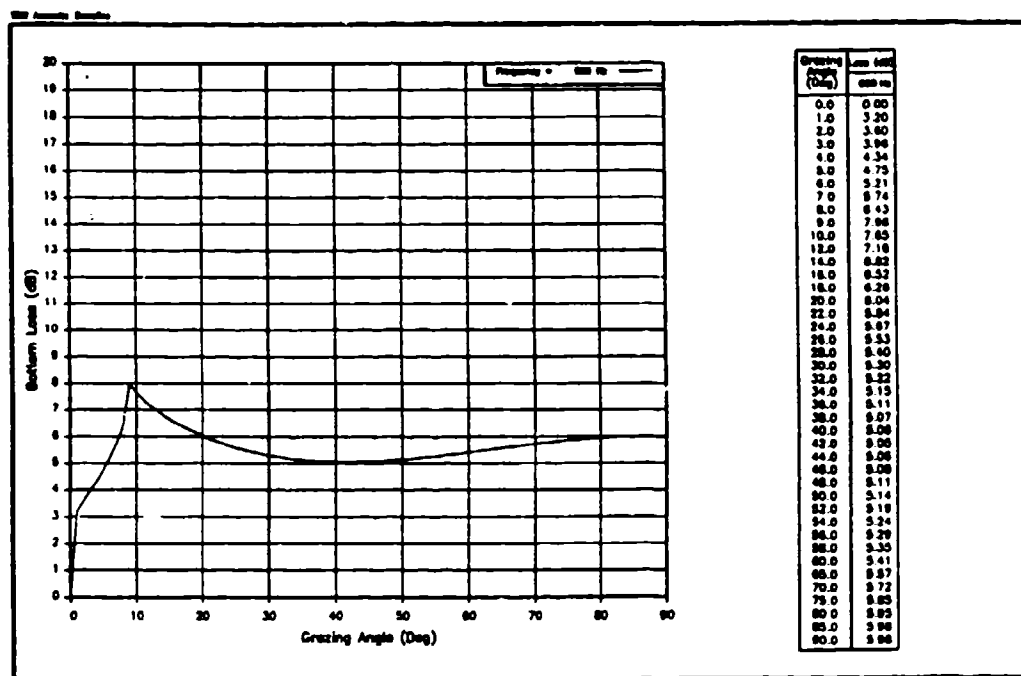
Figures 3-16 through 3-21 present the bottom loss versus grazing angle and appropriate model comparisons for Cases A through C, respectively.

The bottom loss at low angles does not have a significant effect on the transmission loss for this positive gradient environment. Changing the bottom loss a few dB at the low angles had only a small effect on the final transmission loss in all the model cases. This appeared to be a mild reaction to bottom loss. To model the SVP closer to an approximation of shallow water environments, the same test cases were run with the negative gradient profile shown in Figure 3-1(c). Figures 3-22 through 3-27 present the applicable bottom loss versus grazing



FAME Arrival Structure

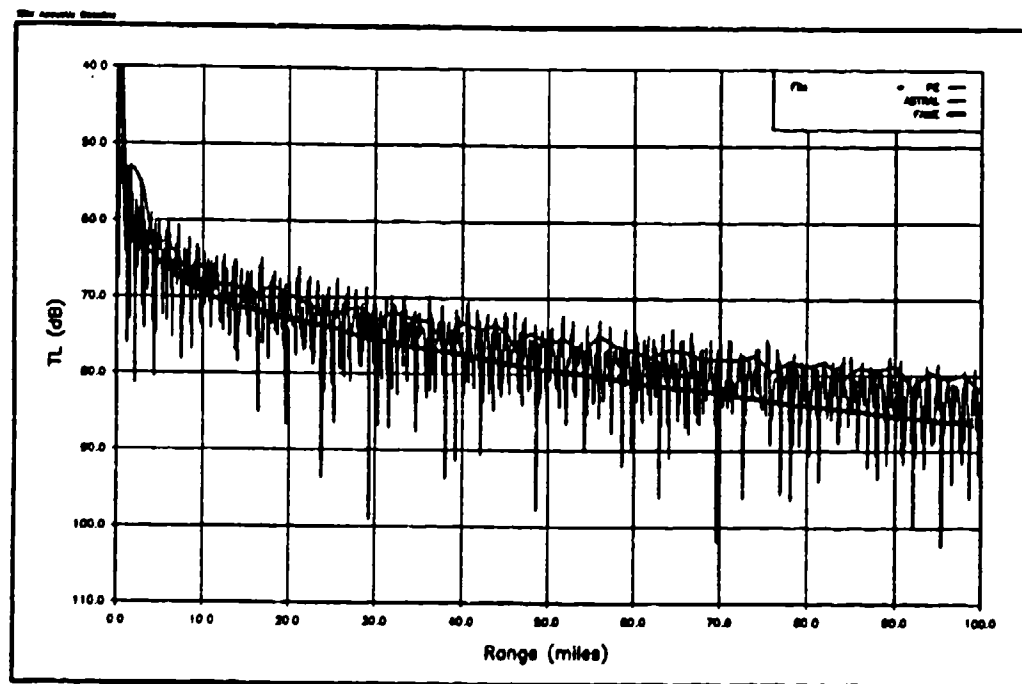
Figure 3-15. Arrival Angle as a Function of Range (w/ bottom loss from Case C)



BLUG-Derived Bottom Loss

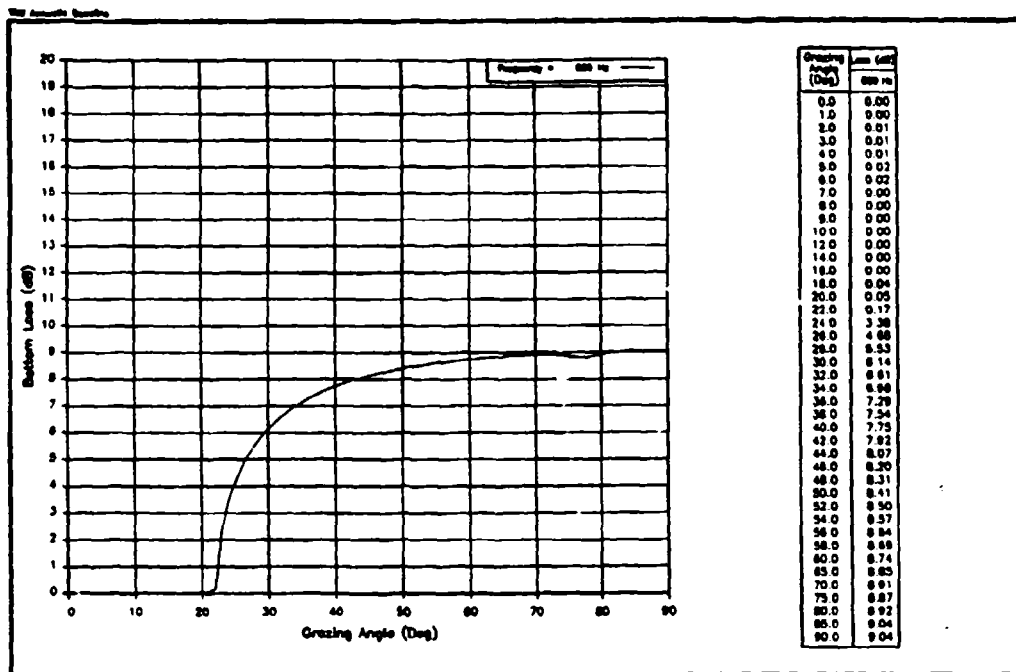
FALL, 0.0N - 0.0W
High Loss

Figure 3-16. Bottom Loss versus Grazing Angle - High Loss



FAME/PE/ASTRAL Comparisons (+) High Loss Bottom

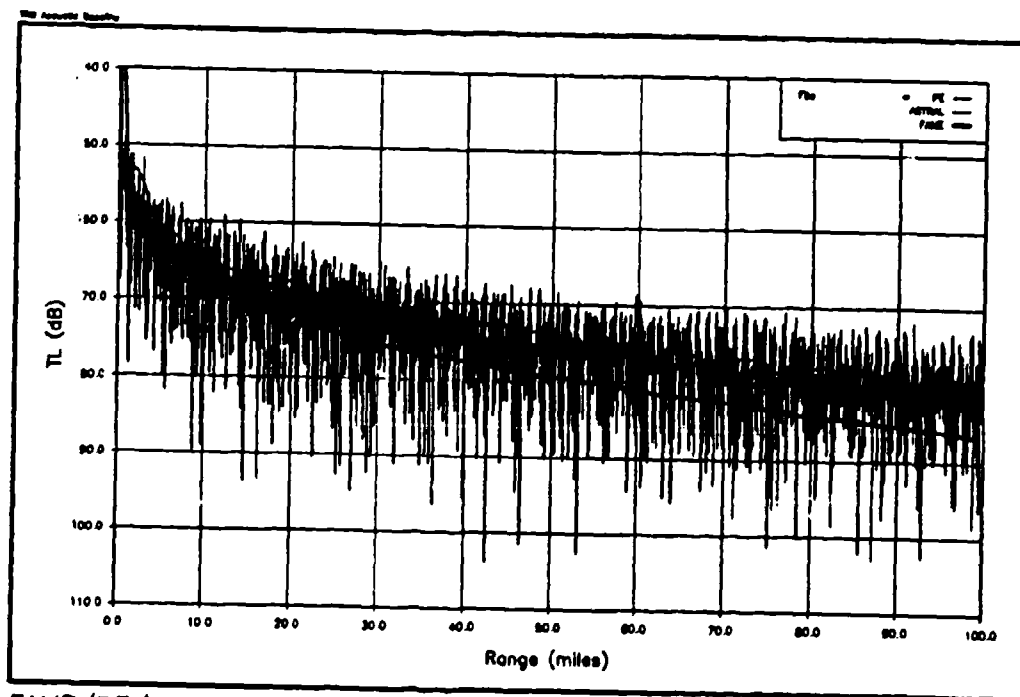
Figure 3-17. ASTRAL, FAME, and PE Comparisons - positive gradient (High Loss)



BLUG-Derived Bottom Loss

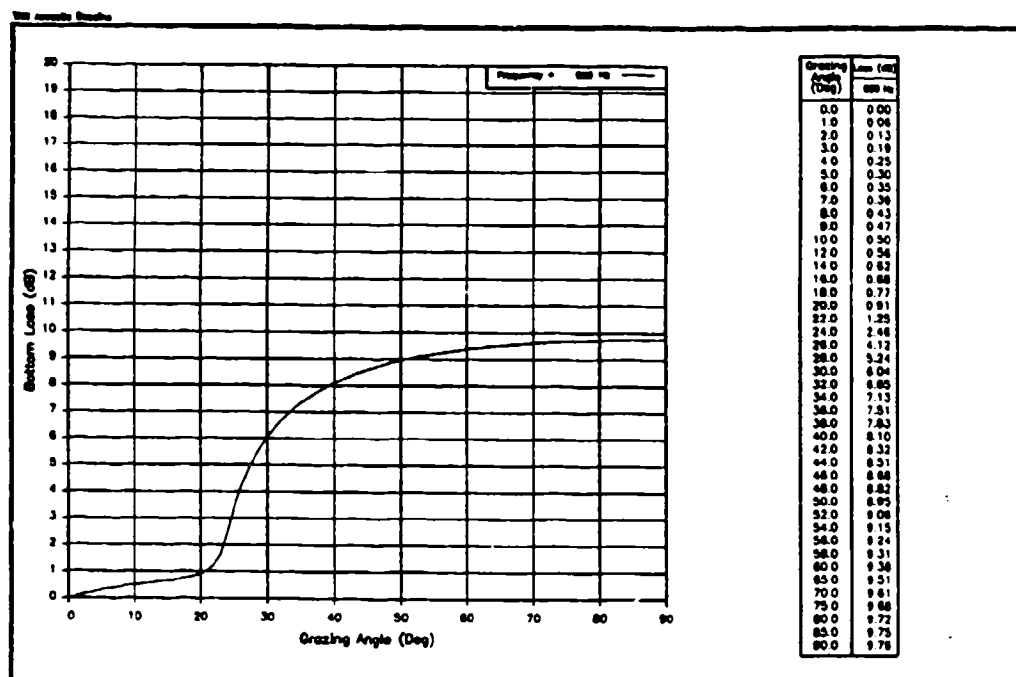
FALL, 0.0N - 0.0W
Low Loss

Figure 3-18. Bottom Loss versus Grazing Angle - Low Loss



FAME/PE/ASTRAL Comparisons (+) Low Loss Bottom

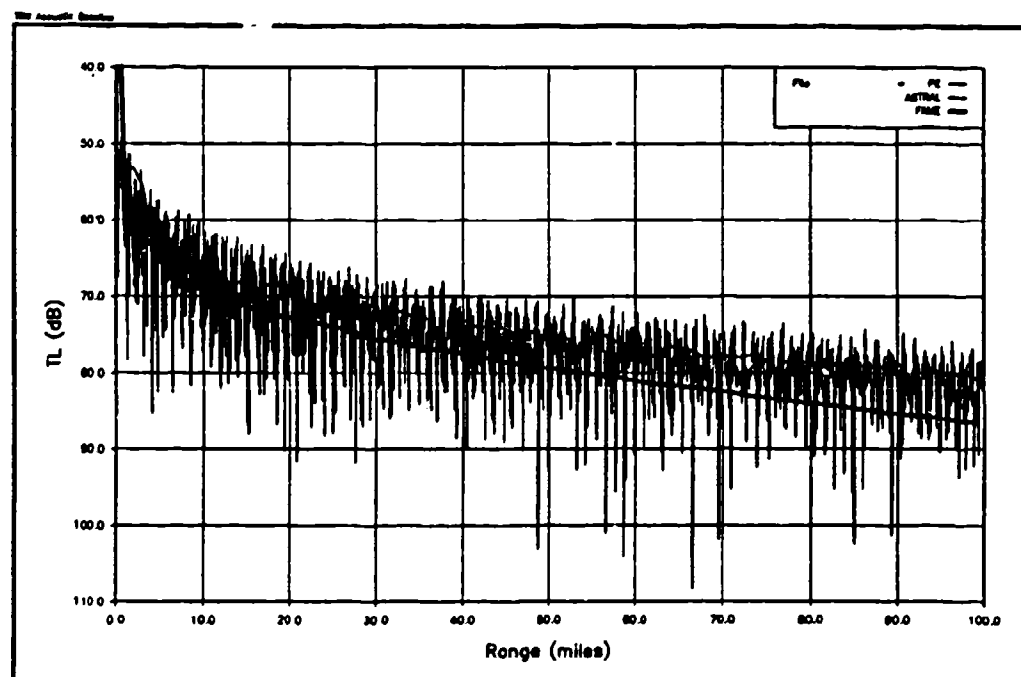
Figure 3-19. ASTRAL, FAME, and PE Comparisons - positive gradient (Low Loss)



BLUG-Derived Bottom Loss

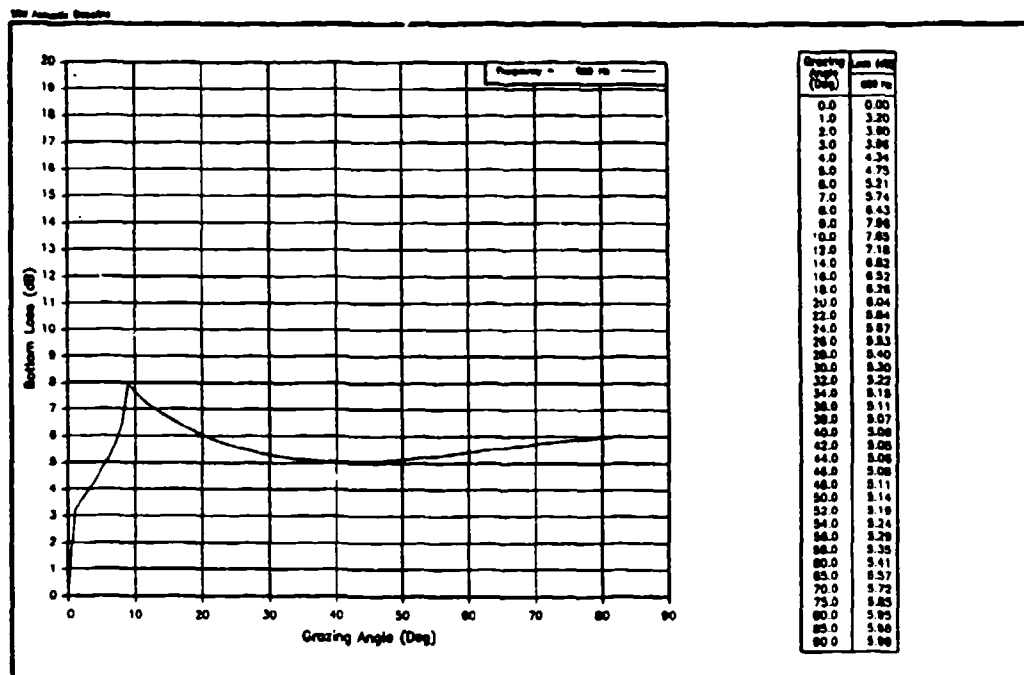
FALL, 0.0N - C.0W
Medium Loss

Figure 3-20. Bottom Loss versus Grazing Angle - Medium Loss



FAME/PE/ASTRAL Comparisons (+) Med Loss Bottom

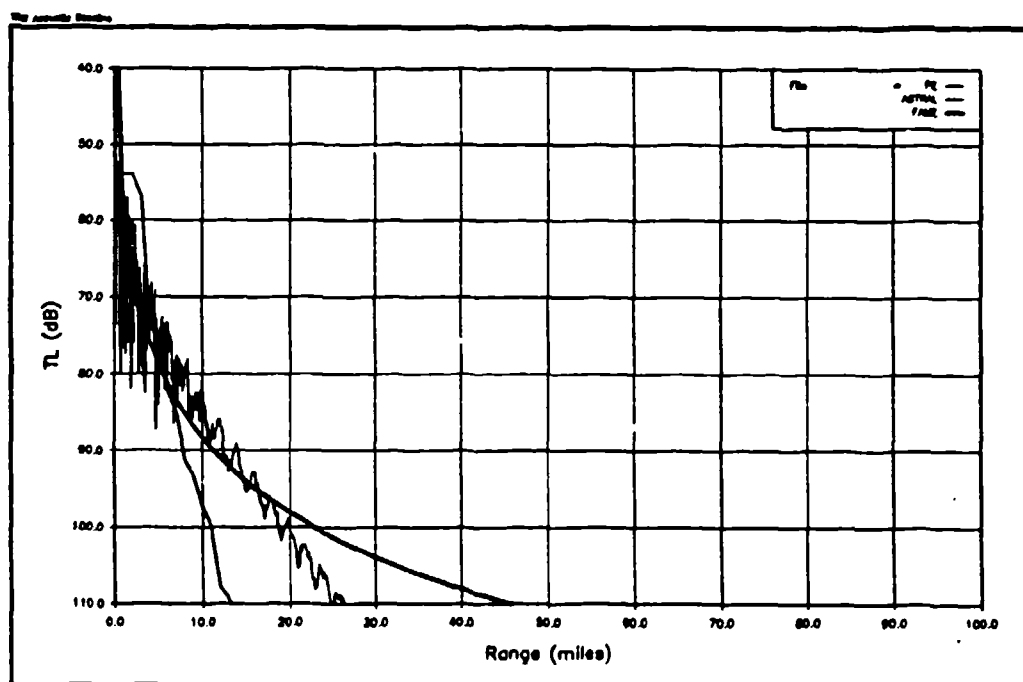
Figure 3-21. ASTRAL, FAME, and PE Comparisons - positive gradient (Medium Loss)



BLUG-Derived Bottom Loss

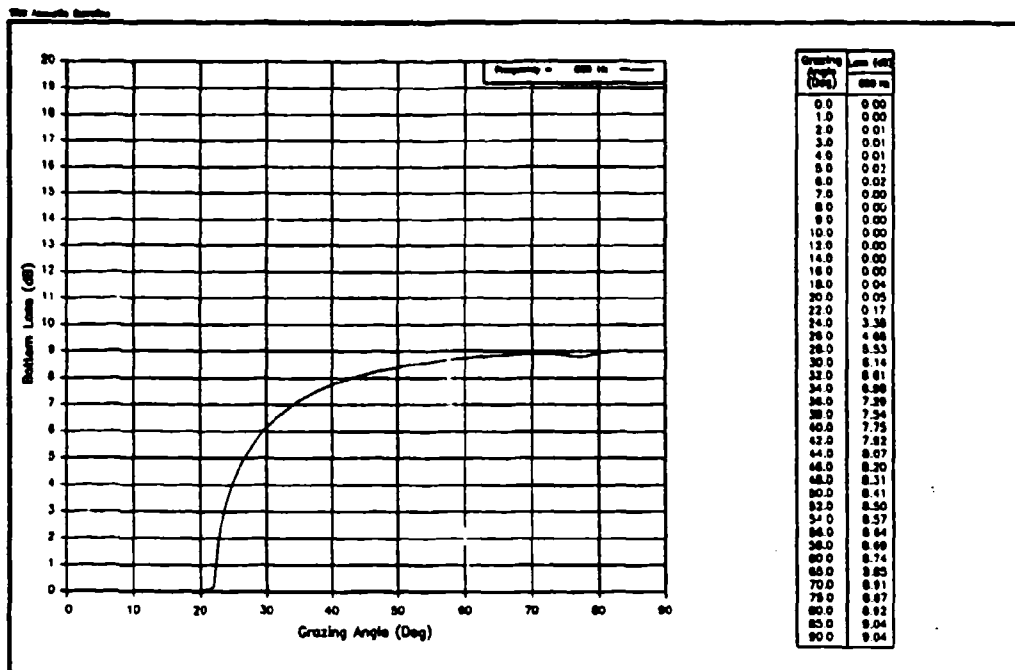
FALL, 0.0N - 0.0W
High Loss

Figure 3-22. Bottom Loss versus Grazing Angle - High Loss



FAME/PE/ASTRAL Comparisons (-) High Loss Bottom

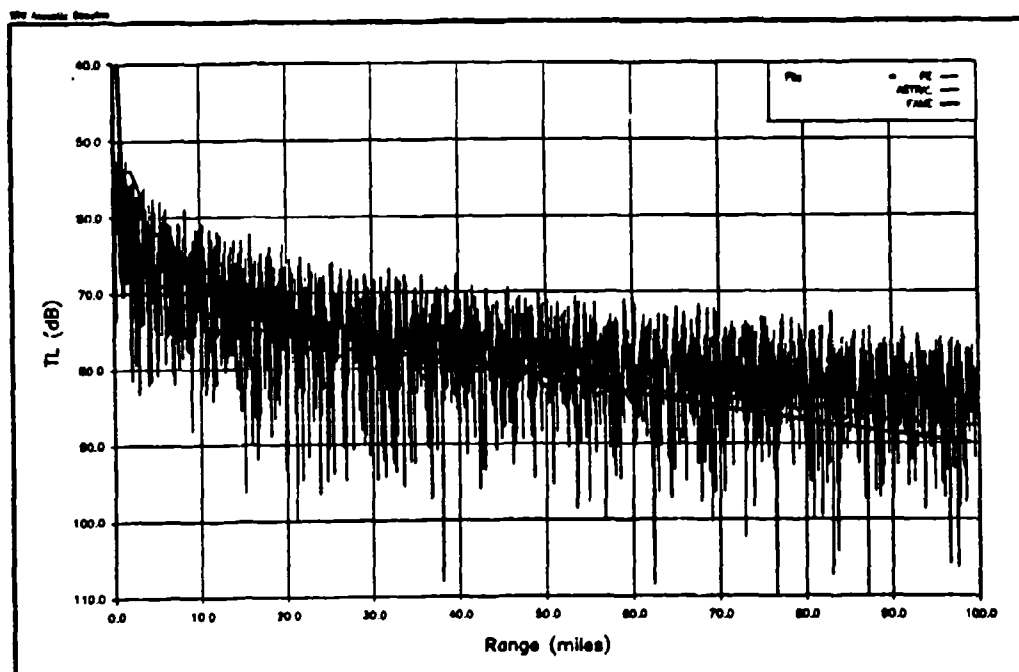
Figure 3-23. ASTRAL, FAME, and PE Comparisons - negative gradient (High Loss)



BLUG-Derived Bottom Loss

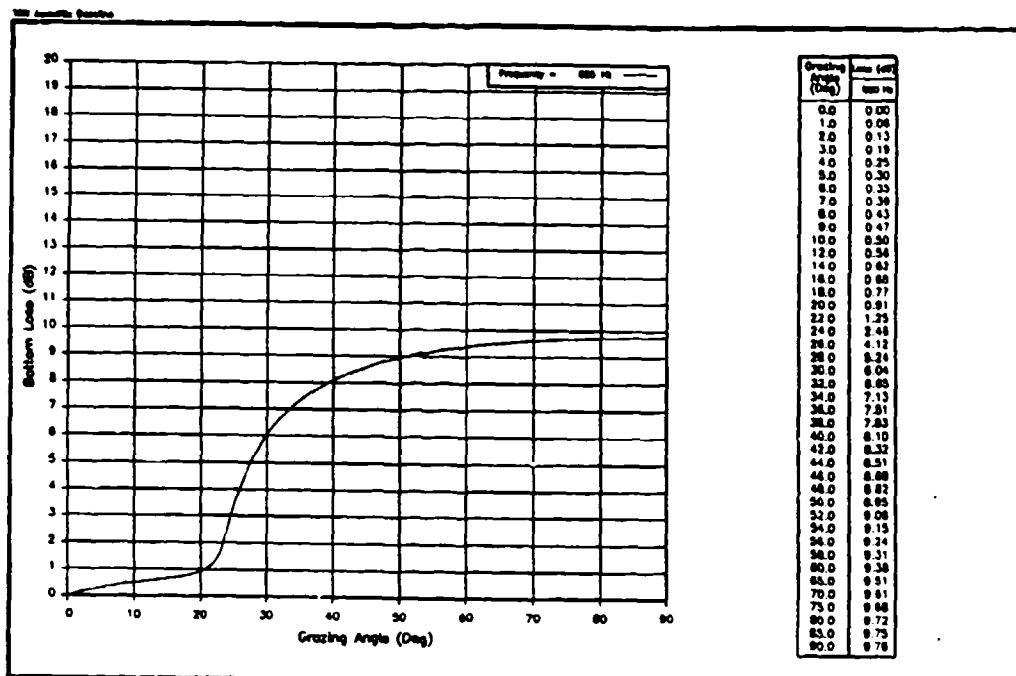
FALL, 0.0N - 0.0W
Low Loss

Figure 3-24. Bottom Loss versus Grazing Angle - Low Loss



FAME/PE/ASTRAL Comparisons (-) Low Loss Bottom

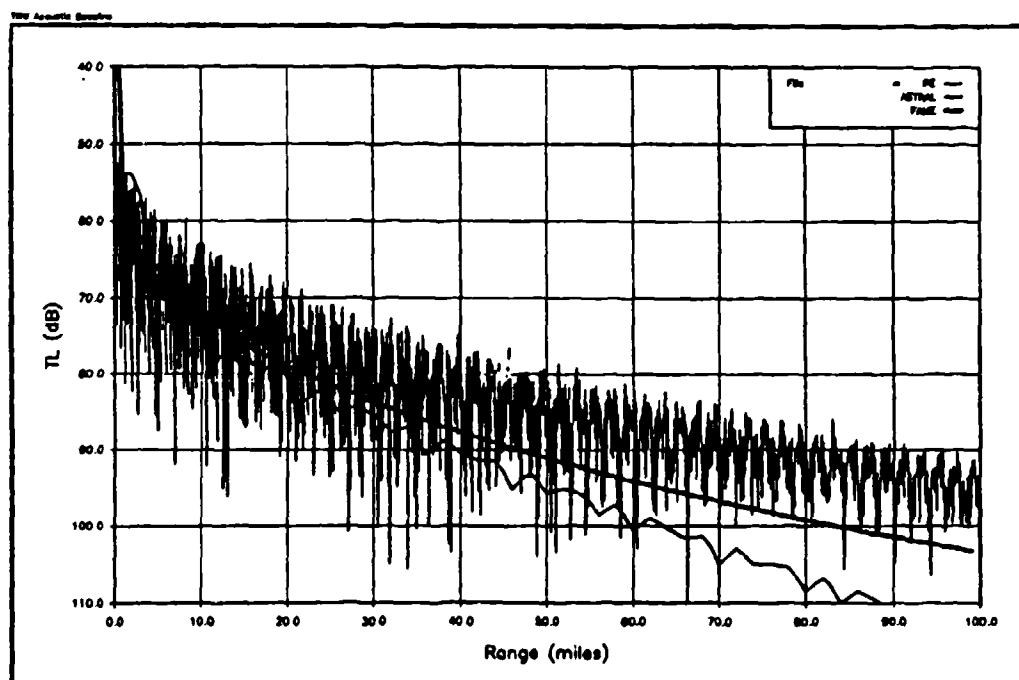
Figure 3-25. ASTRAL, FAME, and PE Comparisons - negative gradient (Low Loss)



BLUG-Derived Bottom Loss

FALL, 0.0N - 0.0W
Medium Loss

Figure 3-26. Bottom Loss versus Grazing Angle - Medium Loss

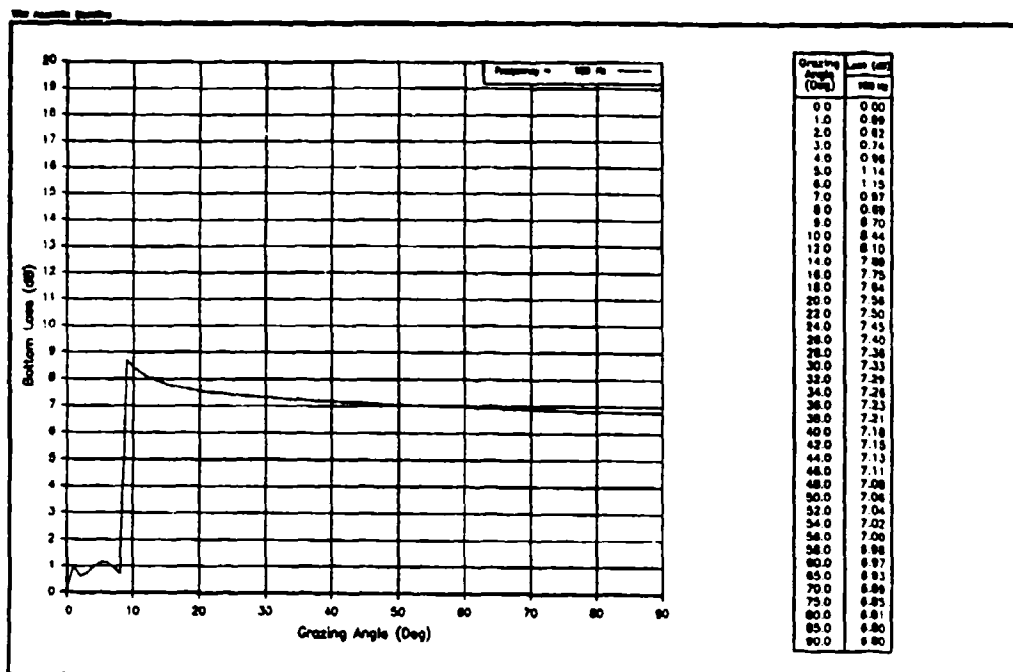


FAME/PE/ASTRAL Comparisons (-) Med Loss Bottom

Figure 3-27. ASTRAL, FAME, and PE Comparisons - negative gradient (Medium Loss)

angle curves and the comparisons of the model runs using that specific curve and associated LFBL parameters.

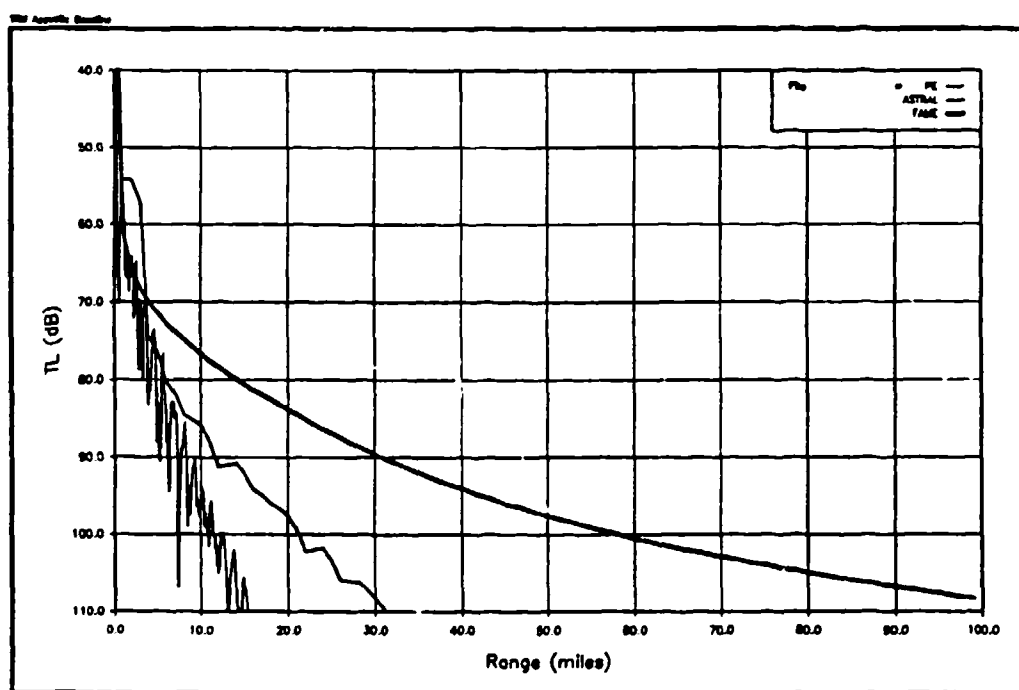
To observe the frequency dependence of the results transmission loss results were generated from AUAMP at a frequency of 100 Hz for a negative gradient SVP characterized environment for the three loss cases given above. Figures 3-28 through 3-33 presents the bottom loss versus grazing angle curve with results of the comparisons for this frequency.



BLUG-Derived Bottom Loss

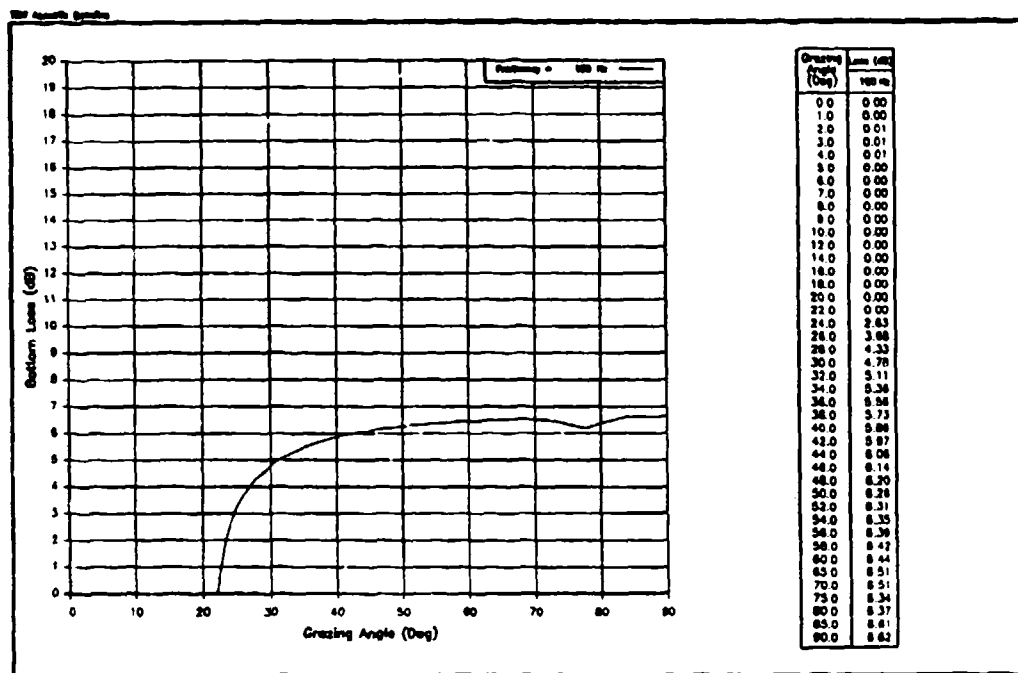
FALL, 0.0N - 0.0W
High Loss

Figure 3-28. Bottom Loss versus Grazing Angle - High Loss



FAME/PE/ASTRAL 100 Hz High loss (-)grad

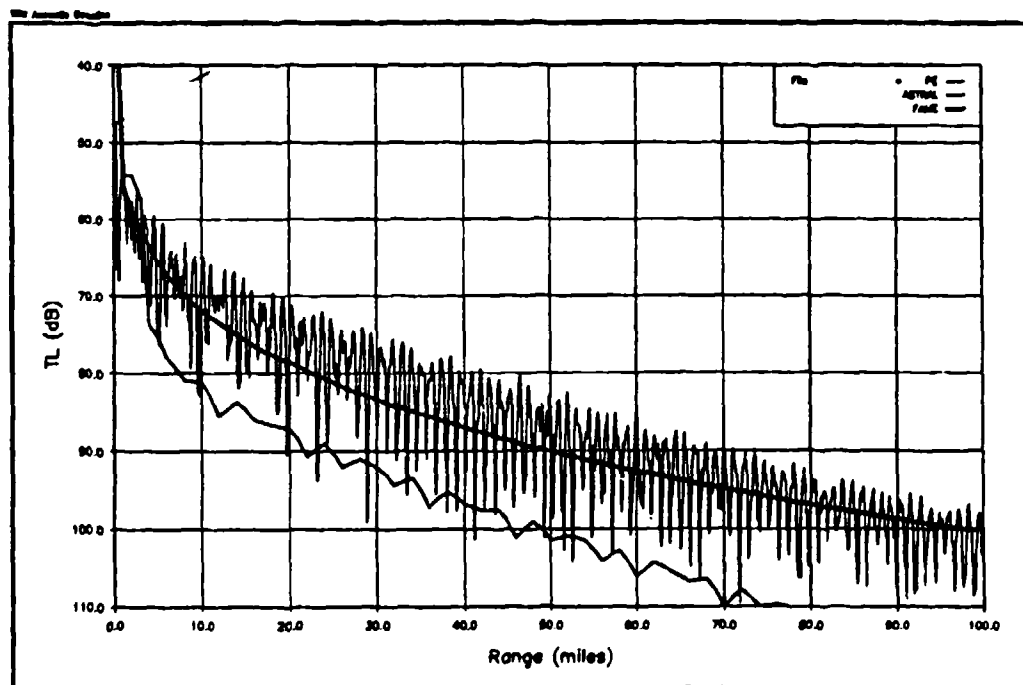
Figure 3-29. ASTRAL, FAME, and PE Comparisons 100 Hz - negative gradient (High Loss)



BLUG-Derived Bottom Loss

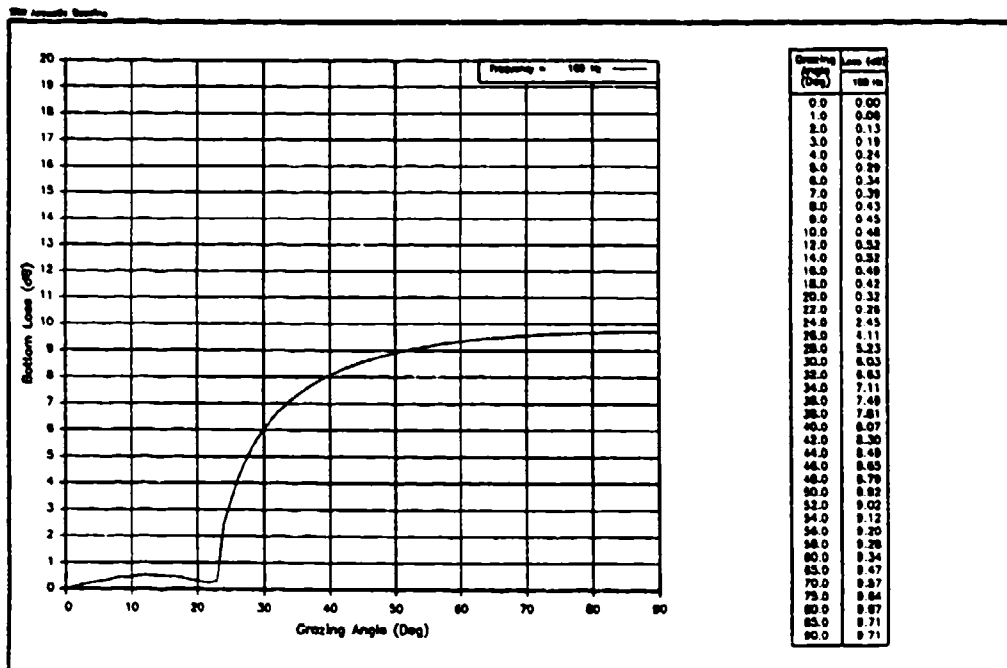
FALL, 0.0N - 0.0W
Low Loss

Figure 3-30. Bottom Loss versus Grazing Angle - Low Loss



FAME/PE/ASTRAL 100 Hz Low loss (-)grad

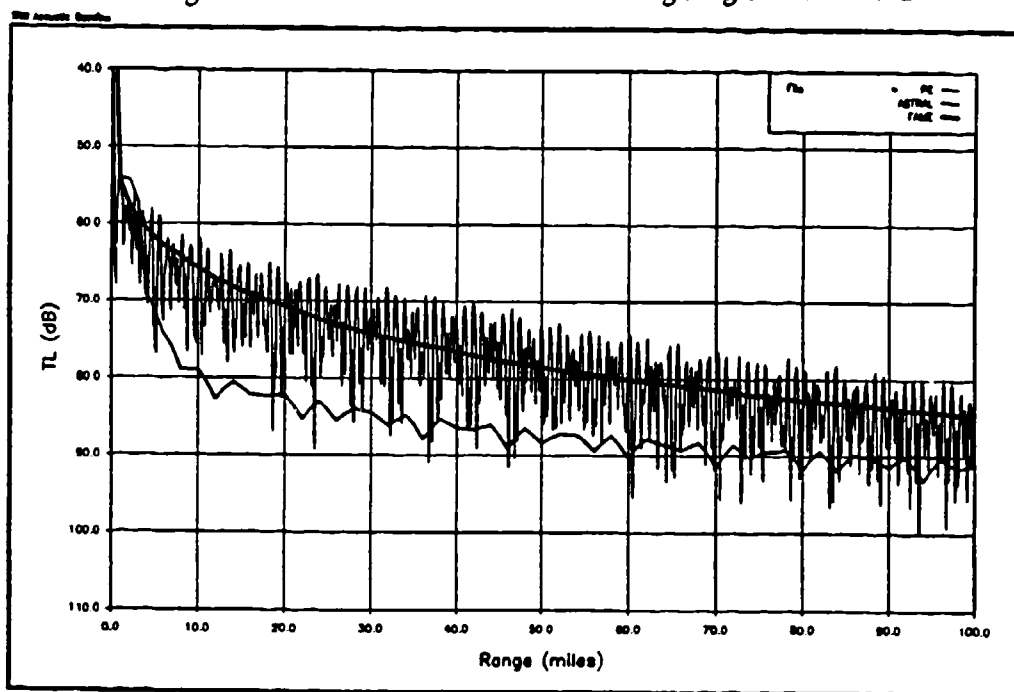
Figure 3-31. ASTRAL, FAME, and PE Comparisons 100 Hz - negative gradient (Low Loss)



BLUG-Derived Bottom Loss

FALL, 0.0N - 0.0W
Medium Loss

Figure 3-32. Bottom Loss versus Grazing Angle - Medium Loss



FAME/PE/ASTRAL 100 Hz Med loss (-)grad

Figure 3-33. ASTRAL, FAME, and PE Comparisons 100 Hz - negative gradient (Medium Loss)

- **Observations**

- **Positive Gradient**

In the high, medium, and low loss case there exists a good agreement between ASTRAL, FAME, and PE. This is because the positive gradient SVP is refracting energy away from the bottom. As a result the bottom loss does not play a significant role in the water borne transmission loss.

- **Negative Gradient**

In the low loss case ASTRAL, FAME and PE tend to behave similarly. When a medium loss bottom exists ASTRAL tends to increasingly overpredict TL as range increases. In the high loss case ASTRAL is overpredicting transmission loss significantly relative to PE and FAME.

- **Frequency Dependence**

In the 100 Hz case, ASTRAL overpredicts TL significantly in the low loss and medium loss case relative to PE. ASTRAL is underpredicting TL relative to PE in the high loss case. This is the opposite effect than seen at 600 Hz, in which ASTRAL was overpredicting TL relative to PE.

- **Conclusions**

In positive gradient characterized environments, regardless of the bottom type, ASTRAL and PE agree well. In negative gradient characterized environments, a small change (about 4-6 dB) in the bottom loss (from Case B to Case A) at the shallow angles results in differences in transmission loss of 15 dB or more at ranges of 20 miles. There are significant discrepancies between the models when a negative gradient and an absorbing bottom exist. This could be due to the SVP extension algorithm or the treatment of the bottom in specific models. At lower frequencies the problems appear significantly worse, notably for a negative gradient environment with a high bottom loss.

Knowledge of the bottom loss in environments having negative gradient characteristic profiles is crucial in determining the transmission loss. Precise and accurate knowledge of the bottom loss at shallow grazing angles is absolutely necessary; an error of only a few dB can result in considerable transmission loss variance. The arrival angles shown in Figure 3-15 demonstrate that all significant grazing angles are less than 10 degrees at ranges greater than 1 mile. In so far as PE is to be believed in shallow water environments, ASTRAL is not predicting the same transmission loss results in negative gradient environments for any of the loss cases, with the most significantly affected environment being the high loss case. There should be caution exercised when using ASTRAL in negative gradient environments especially with high loss bottoms.

4.0 MODEL TO MEASURED COMPARISONS

Comparing model predictions with measured transmission loss is the ultimate method of ensuring the accuracy of the model. However, because of the detailed work involved in collecting measurements and associated environmental and navigation data, finding an experiment with all the precise data and resolution (time, space) necessary to perform a rigorous analysis is often difficult. For this reason two very straightforward cases were analyzed initially. Only initial comparisons of representative data sets have been made. No attempt was made to conduct an exhaustive and comprehensive set of runs within an experiment.

Two comparisons for each run in an experiment were completed:

- 1) Comparison of AUAMP-generated transmission loss accessing existing data bases with measured transmission loss.
- 2) Comparison of AUAMP-generated transmission loss using every piece of measured environmental data available with measured transmission loss.

These two comparisons aid in the determination of the effect the environmental information used from the data bases versus the in situ environmental data has on the calculation. Comparisons of measured data and AUAMP predictions from three experiments are presented in this document:

- 1) Acoustic Observations at a Shallow Water Location off The Coast of Florida (ref 13)
- 2) Airborne Measurements of Shallow Water Acoustics at Various Locations off the Eastern and Gulf Coasts of the United States (ref 14)
- 3) LFA-7 (ref 15, 16)

The first two experiments from which data was used represent very straightforward, non-complicated measurements. The sources were stationary and the environment was described fairly well with in situ SVP, bottom depths, etc. These two test exercises were analyzed extensively. The third experiment listed above represented a challenge in the correlation of

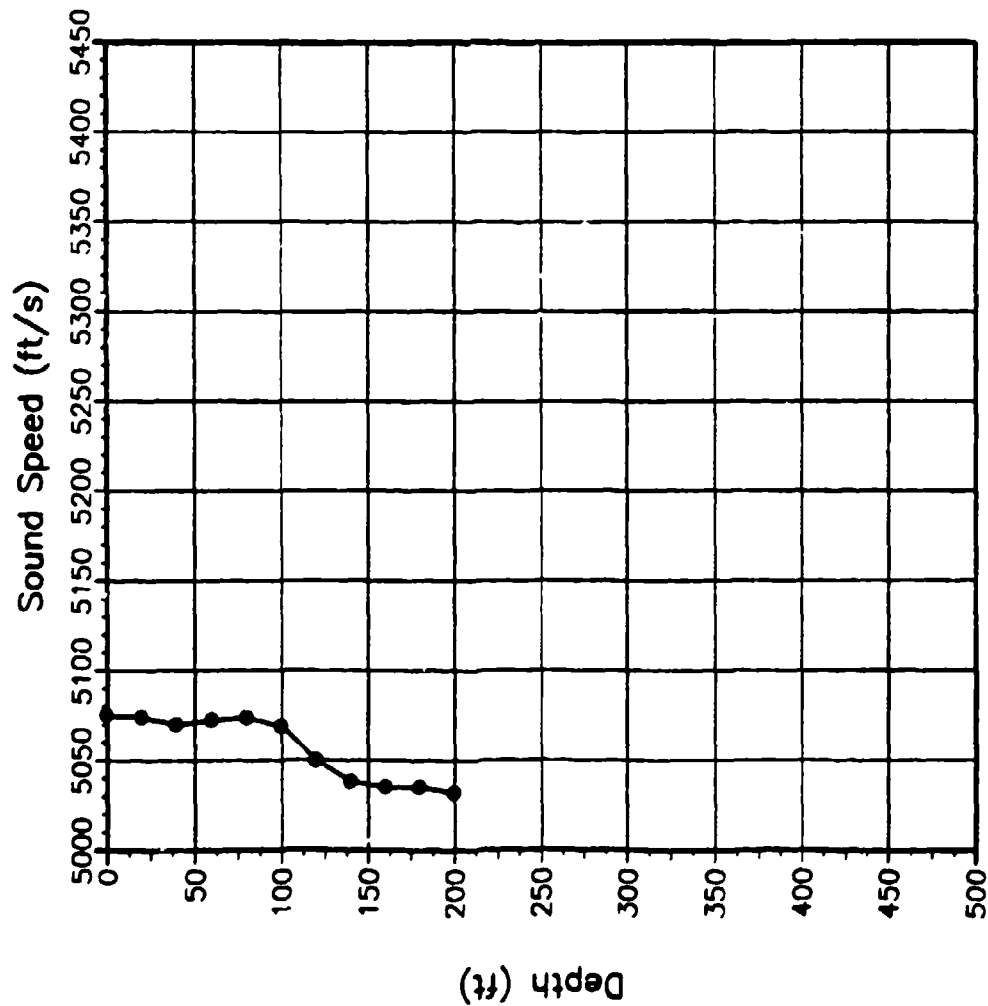
all navigation, environmental and transmission loss data. Preliminary comparisons of measured transmission loss from this experiment and AUAMP predictions are presented. The lack of some navigation data at the time this document was written, demonstrates clearly some of the problems that can arise with non-precise navigation data.

The following three subsections, address each experiment listed above, in turn. Each subsection contains an overview of the experiment, parameters of the experiment, and the results of actual comparisons made. The last part of each subsection includes the description of the methods used in the analysis and its results with illustrations stressing important observations.

4.1 Urlick-68, Acoustic Observations At A Shallow Water Location Off The Coast of Florida

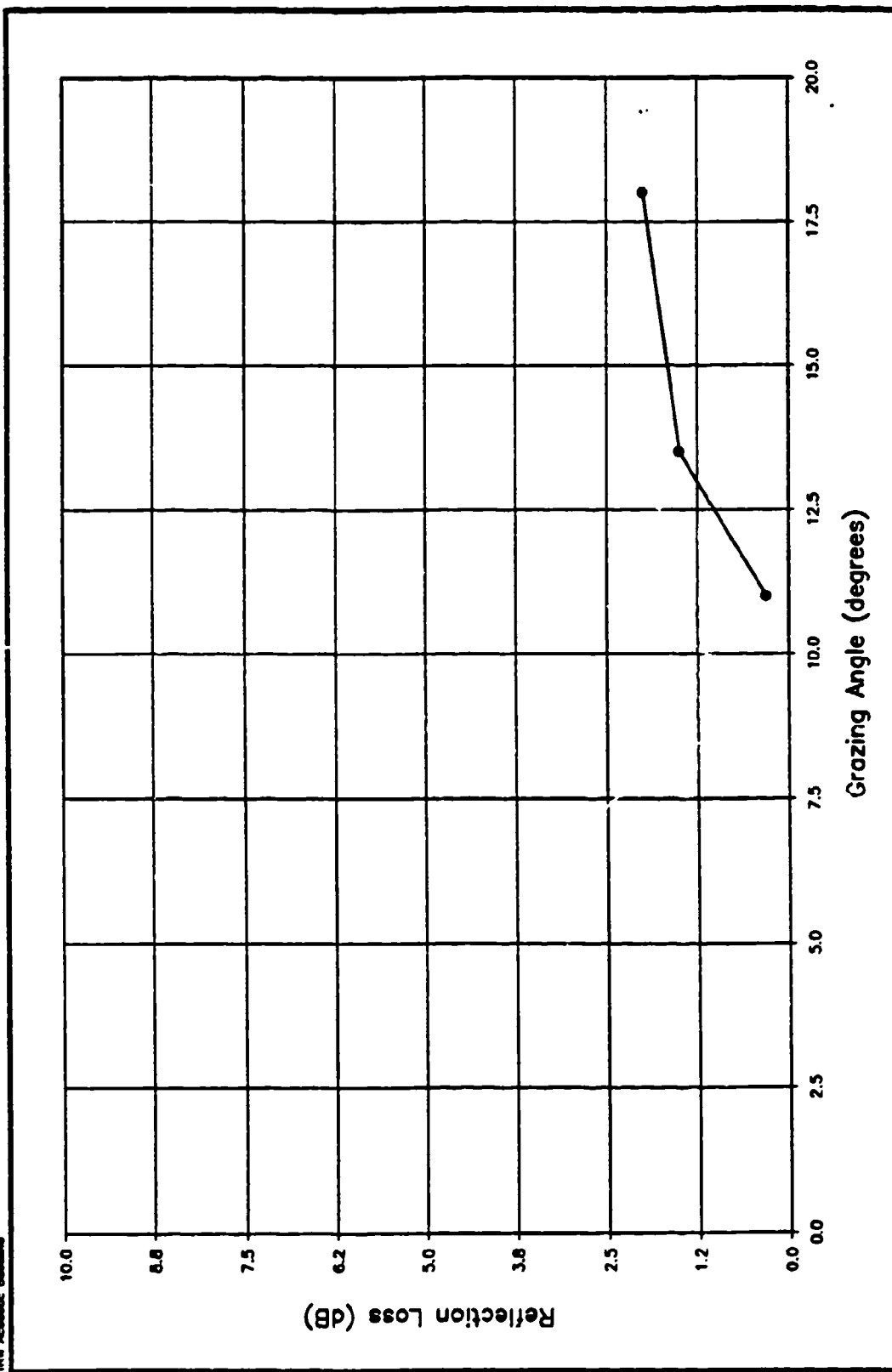
This experiment was conducted under the leadership of Robert Urlick (NOL) in October of 1968 off the coast of Florida over a period of 36 hours. The receiver remained stationary while aircraft dropped standard explosive sources along radials at various bearings from the receiver. The primary measurements taken were transmission loss out to a range of 50 miles, reverberation level, reverberation coherence, bottom loss and bottom scattering strength. The advantage of this experiment is in its stationary receiver and measured transmission loss over a range of frequencies, as well as bottom loss measurements. In addition, the receiver was positioned in such a place that one radial run consisted of a flat bottom run, while two other radial runs encountered upslope and downslope bathymetry conditions. This analysis addresses two separate sections covering the flat and upslope runs; the downslope run is not included in this report.

The receiver environment was characterized by a bottom depth of 200 feet at 26-00-N, 83-30-W. The measured sound velocity profile at the receiver is given in Figure 4-1. Two omni receivers at depths of 80 and 180 feet were suspended from the ship. The windspeed was modeled at a constant 7 knots (measured) for all comparisons in this section. The measured bottom loss marked by three measured data points is shown in Figure 4-2 and is the bottom loss for a frequency band of 800-1600 Hz.



FALL, 0.0N - 0.0E
Measure SVP at Receiver Site

Figure 4-1. Measured Sound Velocity Profile at Receiver



Measured Bottom Loss

Figure 4-2. Measured Bottom Loss

The following two subsections covering flat and upslope runs present comparisons of AUAMP predictions and measured transmission loss for two frequencies (150 and 600 Hz), and two receiver depths (80 and 180 ft). The source depth throughout this exercise was 60 feet. Two frequencies were analyzed to observe AUAMP's dependence on frequency. Two AUAMP predictions are presented for each measured run. One of the predictions is AUAMP-generated transmission loss, calculated accessing the HOP data bases resident within AUAMP. The second prediction presents AUAMP-generated transmission loss calculated using all available measured data. This measured data consisted of bottom depth, SVP, bottom loss, and windspeed. AUAMP was modified to allow input of in situ measurements for bottom loss, SVP, bathymetry, etc. It is noted that ASTRAL is confined to using BLUG provinces and subsequently LFBL parameters. Thus, to input in situ bottom loss, the set of LFBL parameters which resulted in the best fit to the bottom loss versus measured grazing angle curve was used as the in situ LFBL parameters.

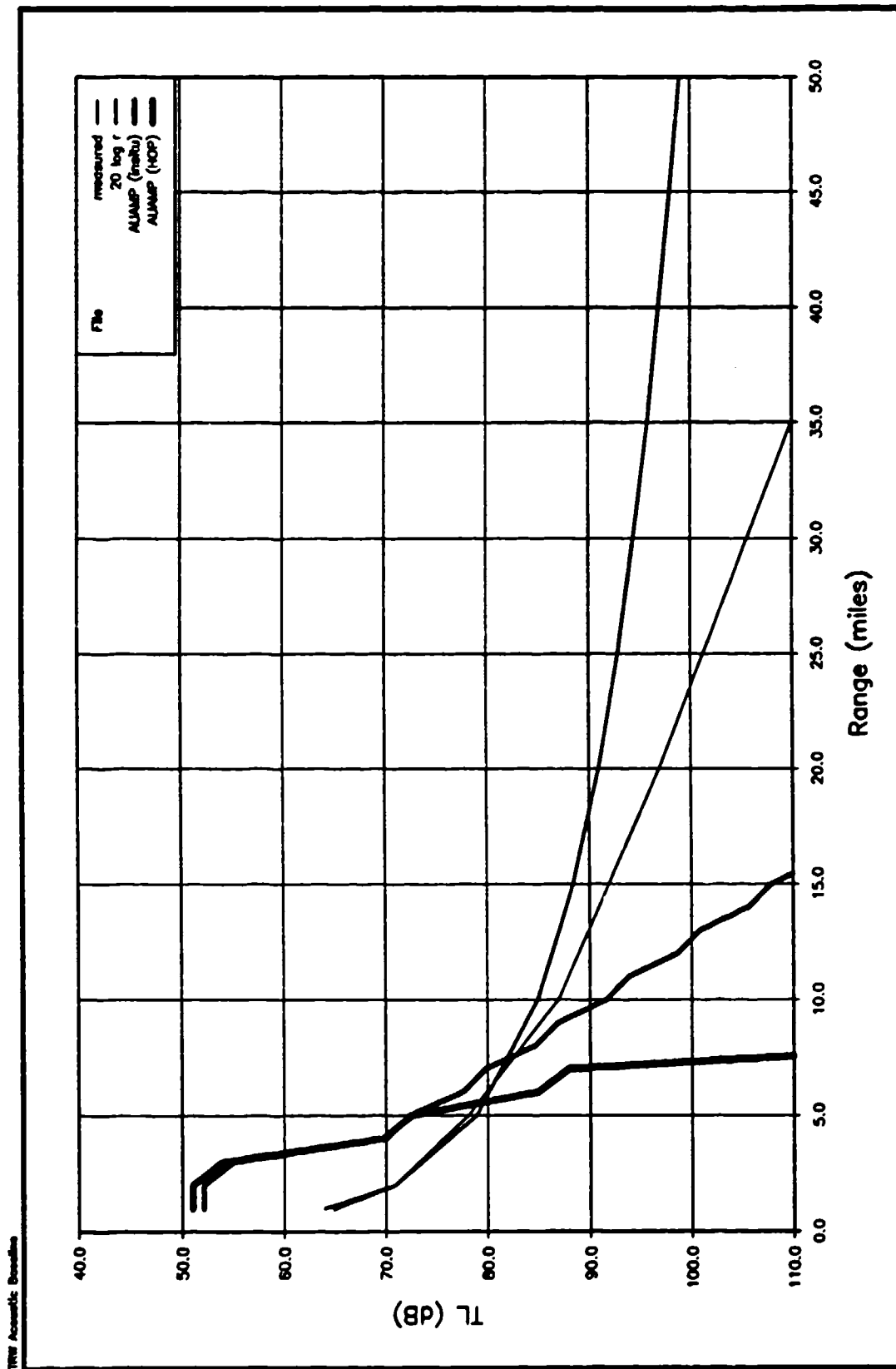
4.1.1 Flat Environment, Run A

Comparisons between the transmission loss for four cases are presented in this section for Run A. They consist of:

- 1) Receiver at 80 ft at 150 Hz;
- 2) Receiver at 80 ft at 600 Hz;
- 3) Receiver at 180 ft at 150 Hz;
- 4) Receiver at 180 ft at 600 Hz.

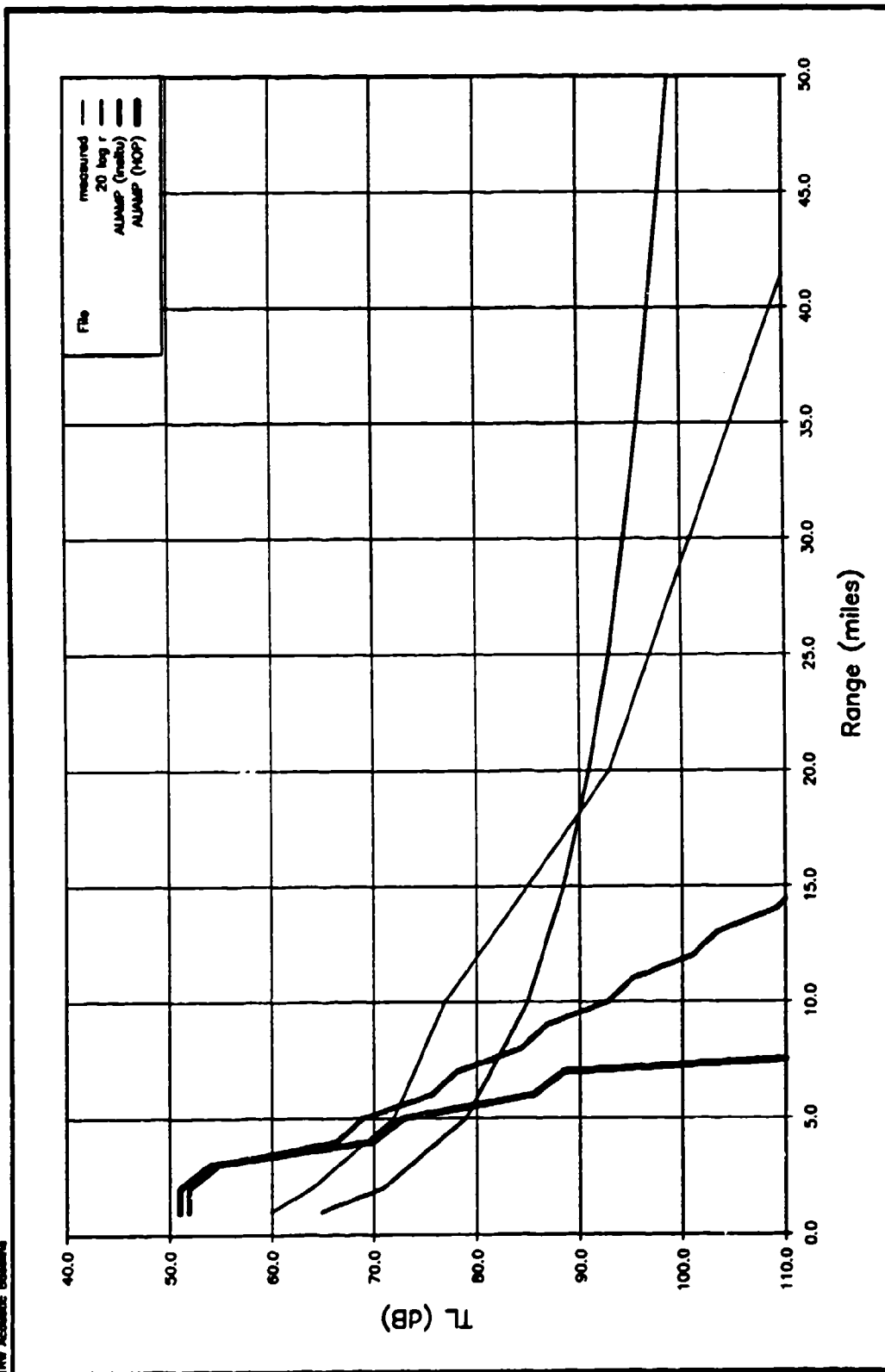
Figures 4-3 through 4-6 present the comparisons between AUAMP and measured data for each of the above cases. Each figure consists of 4 curves:

- 1) AUAMP transmission loss generated with HOP environmental data;
- 2) AUAMP transmission loss generated with measured environmental data;
- 3) Measured transmission loss;
- 4) $20 \log(r)$ for reference.



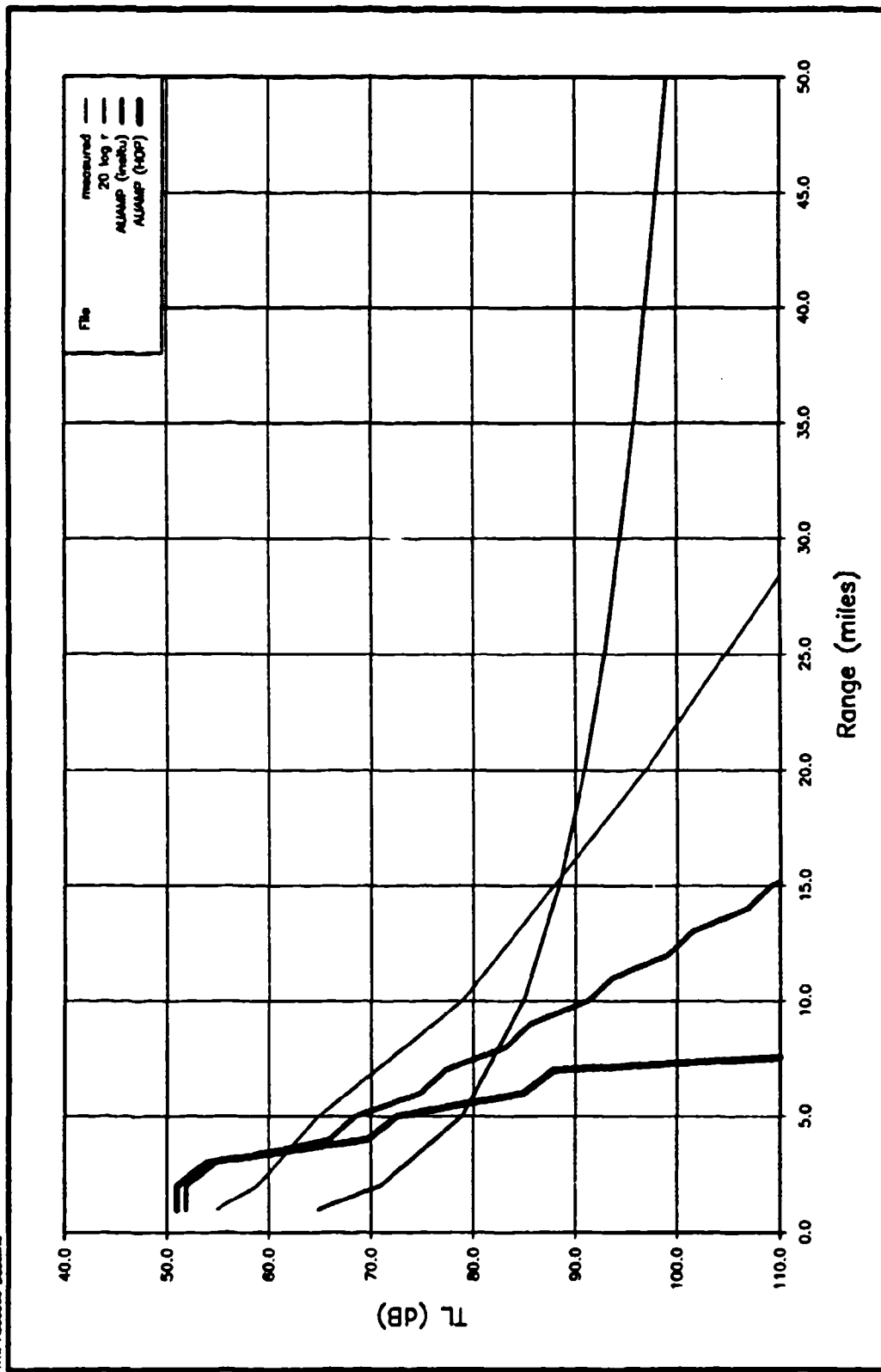
Rec 180 ft, 150 Hz Flat

Figure 4-3. ASTRAL and Measured Data Comparison; 150 Hz, Receiver at 80 ft (Flat)



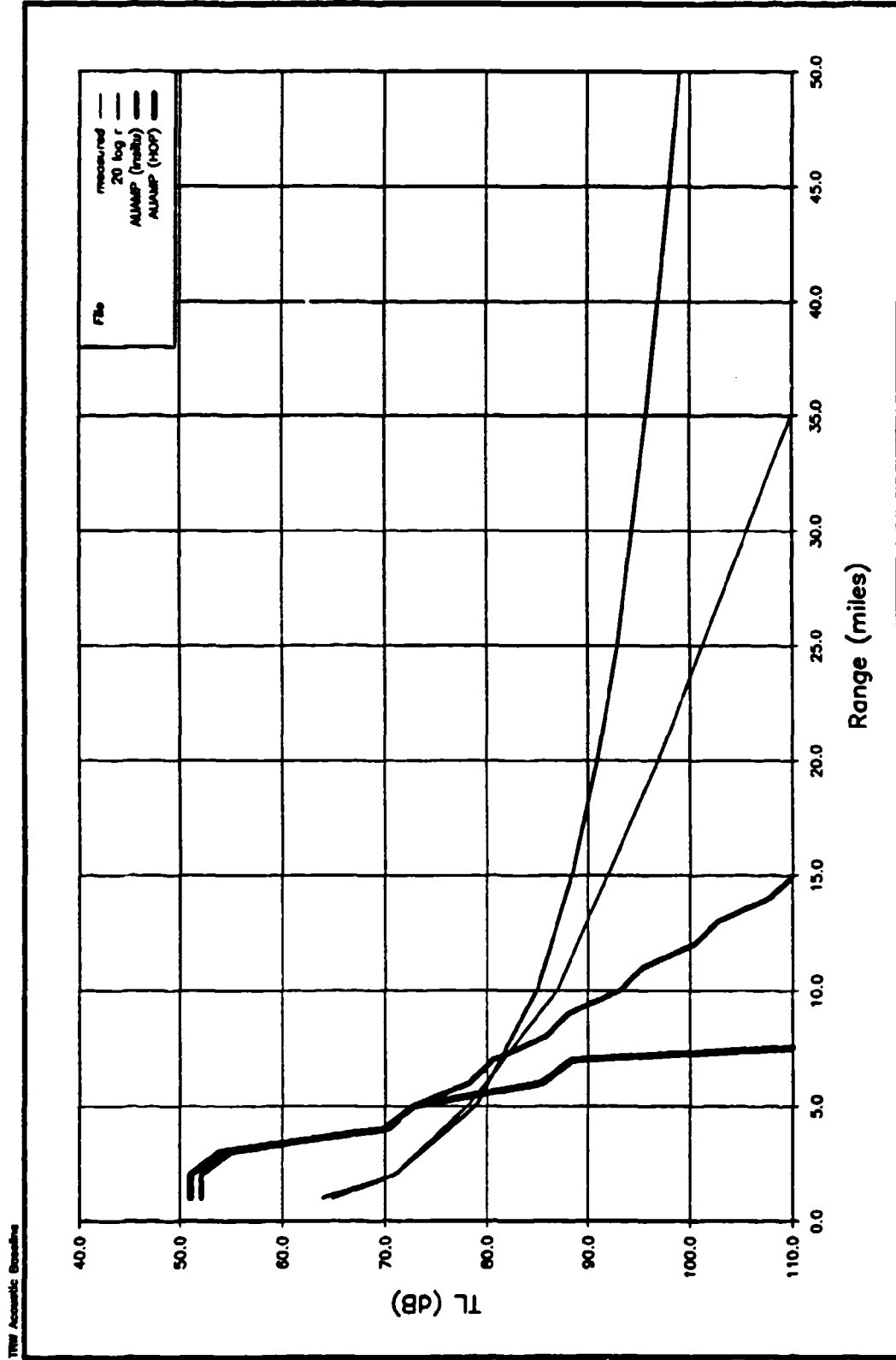
Rec 80 ft, 600 Hz Flat

Figure 4-4. ASTRAL and Measured Data Comparison; 600 Hz, Receiver at 80 ft (Flat)



Rec 80 ft, 150 Hz Flat

Figure 4-5. ASTRAL and Measured Data Comparison; 150 Hz, Receiver at 180 ft (Flat)



Rec 180 ft, 600 Hz Flat

Figure 4-6. ASTRAL and Measured Data Comparison; 600 Hz, Receiver at 180 ft (Flat)

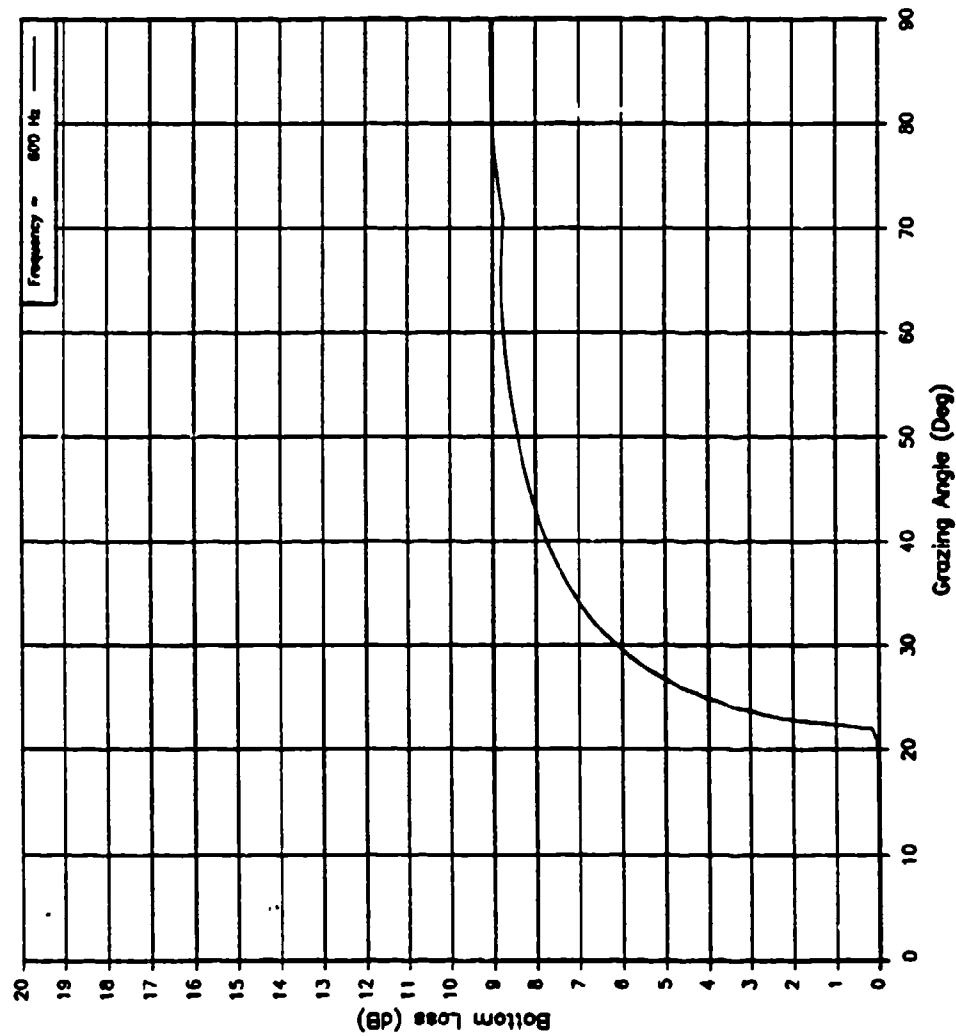
- **Observations**

As one can see in these four figures, there is no significant similarity in the comparisons. Predictions generated with in situ data do tend to predict the trend of the measured transmission loss data mildly better. The large discrepancies between any of the comparisons can be due to a number of reasons, the most significant is discussed below.

- **The bottom loss**

As seen in our test case (Section 3.2) ASTRAL is very sensitive to bottom loss in shallow water at the low angles. To determine what the LFBL parameters should be to represent the measured bottom loss versus grazing angle curve, an analysis of the bottom loss of many environments was conducted. These bottom loss curves were correlated with the measured bottom loss curve to obtain the best match. We were essentially correlating three measured data points in the wrong frequency band. Because we did not have bottom loss versus grazing angle information below 11 degrees we assumed the bottom loss below 11 degrees was constant at the 11 degree value which was less than 1 dB. With this assumption the model was run. The resultant predictions are those shown in the above plots. If the bottom loss was assumed to be 0 dB at low angles or, conversely assumed to increase at the low angles, different LFBL parameters would have been fed into AUAMP and different transmission loss predictions generated.

To investigate the sensitivity and the extent to which the bottom loss affects a correlation between measured data and AUAMP predictions, the following analysis was completed. Three different sets of bottom loss parameters were fed into the model with all other environmental inputs remaining constant at the measured value. Figures 4-7 through 4-9 demonstrate the 3 bottom loss cases tried. The bottom loss shown in Figure 4-8 is the bottom loss that AUAMP extracted automatically out of the receiver location for this run and used to generate the transmission loss predictions shown above. Figure 4-10 presents the AUAMP predictions of transmission loss generated using each of these bottom loss cases as well as the measured transmission loss for this

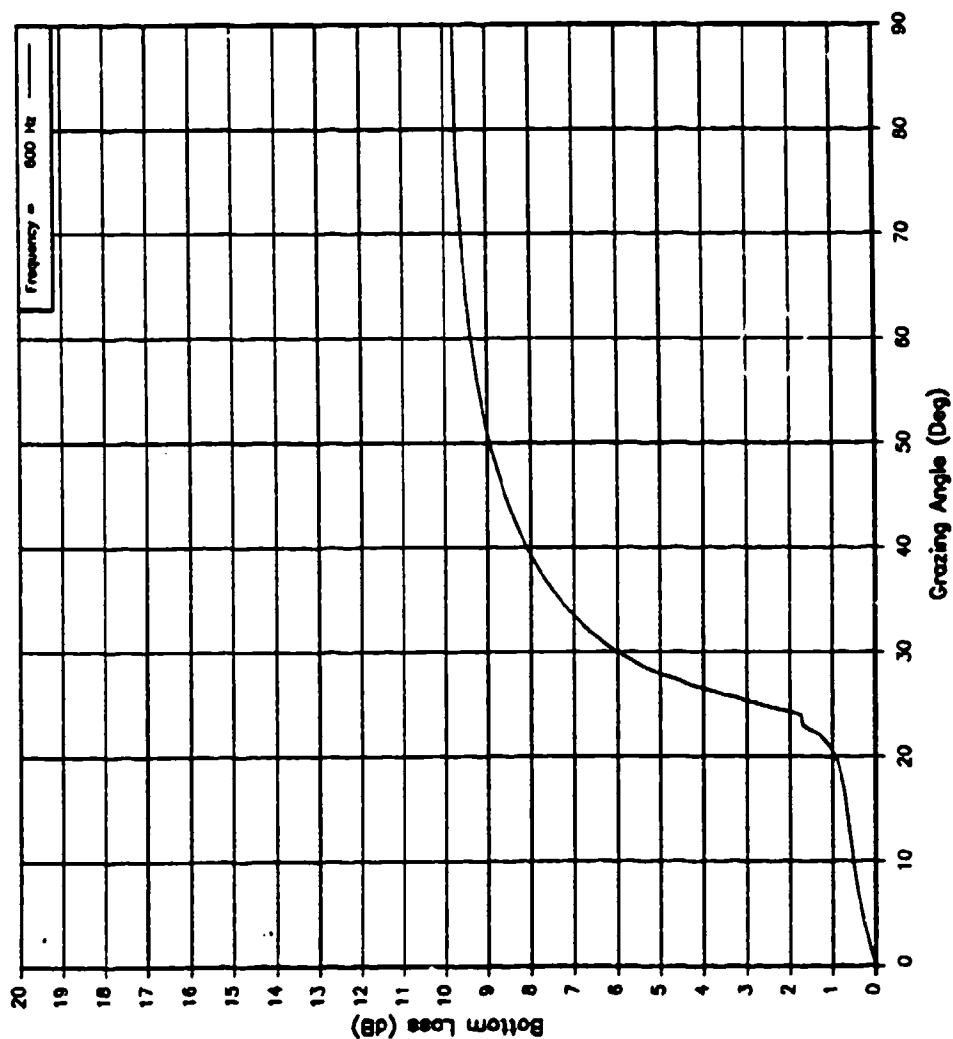


BLUG--Derived Bottom Loss

FALL, 0.0N - 0.0W

Figure 4-7. Bottom Loss versus Grazing Angle (Low Loss)

TIME Acoustic Baseline



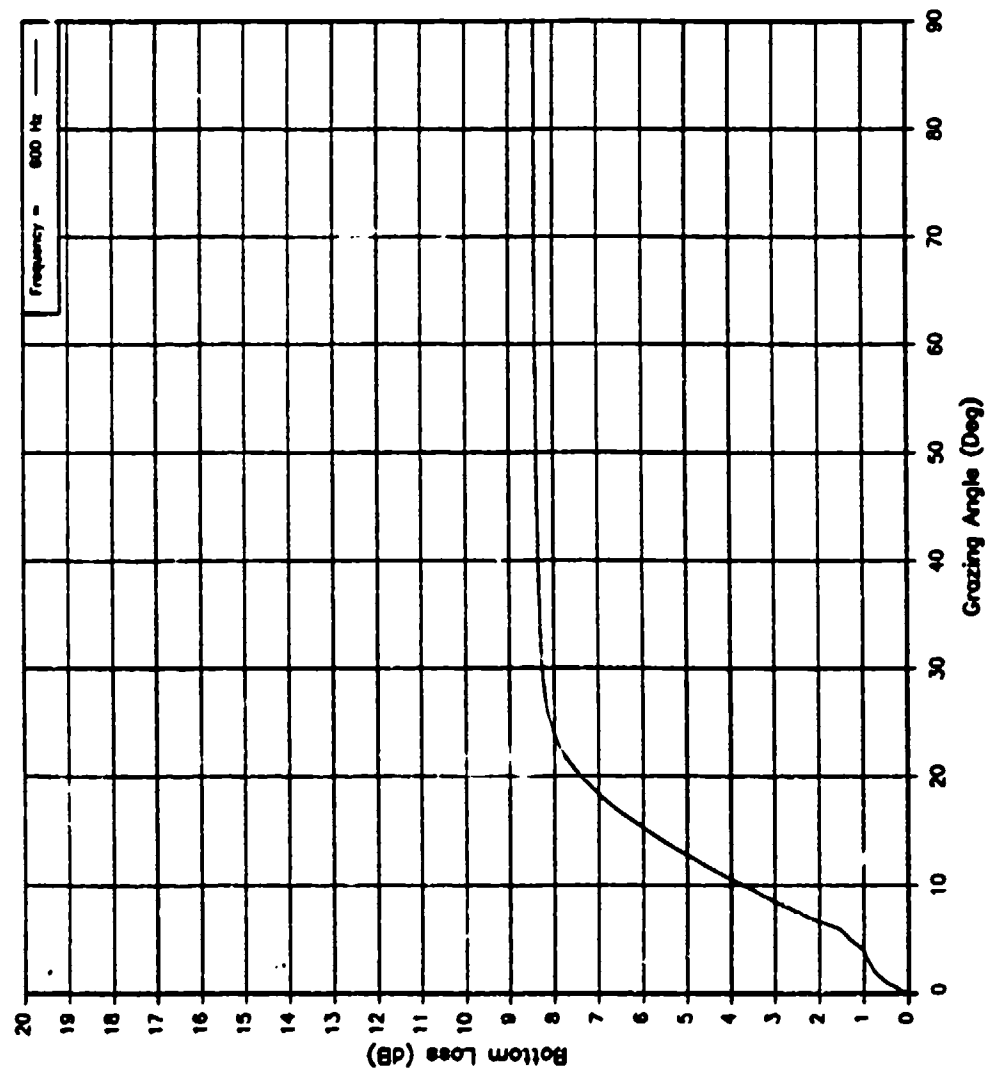
Grazing Angle (Deg)	Loss (dB)
0.0	0.00
1.0	0.07
2.0	0.13
3.0	0.19
4.0	0.25
5.0	0.30
6.0	0.35
7.0	0.40
8.0	0.44
9.0	0.48
10.0	0.51
12.0	0.57
14.0	0.63
16.0	0.69
18.0	0.78
20.0	0.93
22.0	1.27
24.0	1.74
26.0	3.61
28.0	5.07
30.0	6.01
32.0	6.84
34.0	7.13
36.0	7.51
38.0	7.83
40.0	8.10
42.0	8.32
44.0	8.51
46.0	8.68
48.0	8.82
50.0	8.95
52.0	9.06
54.0	9.15
56.0	9.24
58.0	9.31
60.0	9.38
65.0	9.51
70.0	9.61
75.0	9.68
80.0	9.72
85.0	9.75
90.0	9.76

BLUG-Derived Bottom Loss

FALL, 25.5N - 76.5W
AC Medium Loss

Figure 4-8. Bottom Loss versus Grazing Angle (Medium Loss)

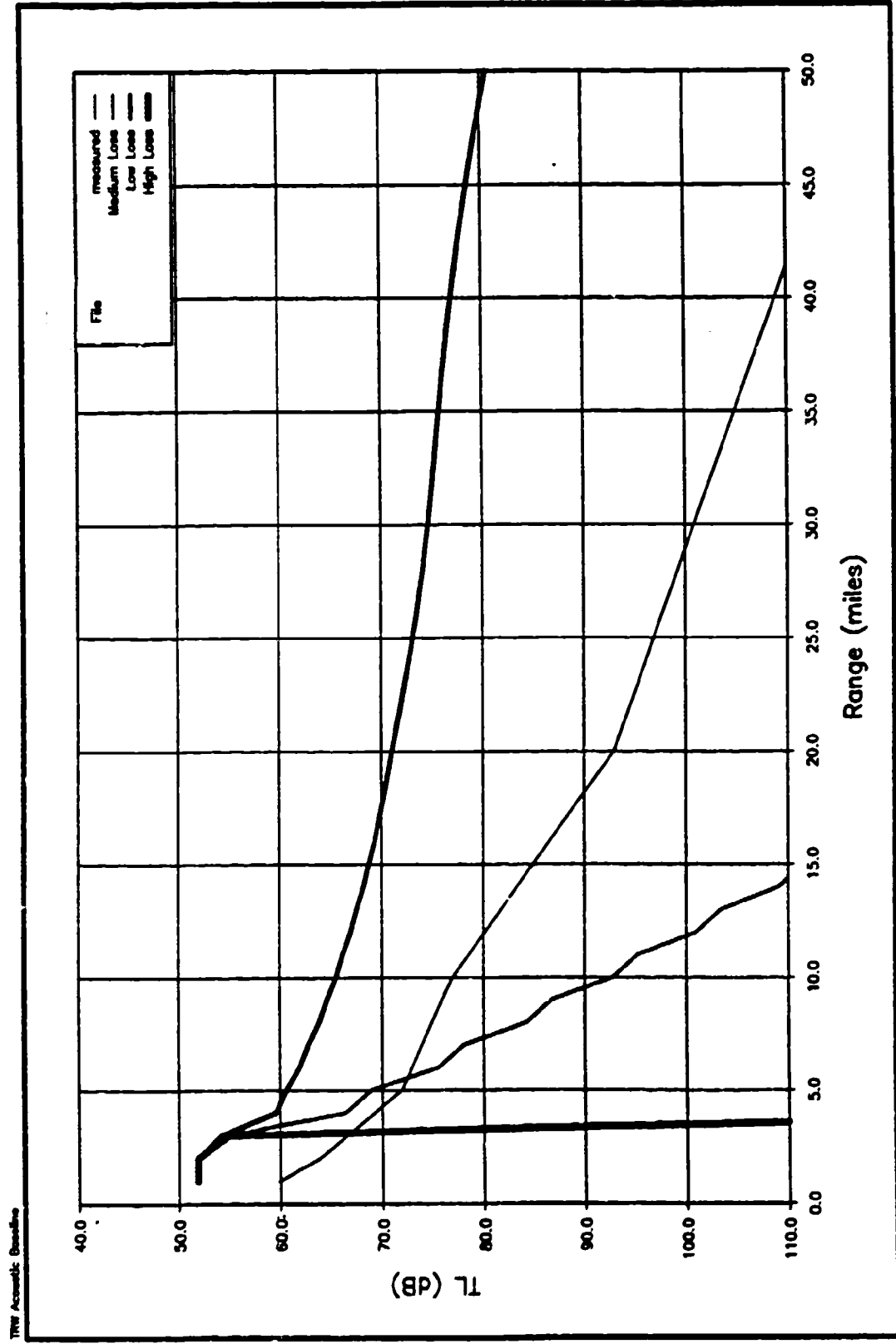
TRE Acoustic Solutions



BLUG-Derived Bottom Loss

FALL, 26.0N - 76.5W
AA High Loss

Figure 4-9. Bottom Loss versus Grazing Angle (High Loss)



Rec 80 ft, 600 Hz Flat TL Bottom Loss Comparisons

Figure 4-10. Comparisons Between AUAMP with Different Bottom Types and Measured Data

run again. It is obvious that the bottom loss at very shallow angles is playing a very significant role in the transmission loss predictions within ASTRAL. The only significant difference between the bottom loss versus grazing angle curves shown in Figure 4-7 through 4-8 is at the shallow grazing angles. In addition, from Section 2 we see that all grazing angle rays that contribute to the transmission loss at a specific range are the shallow angles (below 20 degrees). The measured transmission loss can be matched perfectly with an AUAMP prediction, given a slightly different bottom loss versus grazing angle curve. This clearly illustrates that no longer is it sufficient to have knowledge of the bottom loss within 2 or 3 dB for a shallow water run. It is crucial to have accurate and precise low grazing angle bottom loss information. Again, the importance of shallow grazing angle bottom loss is emphasized.

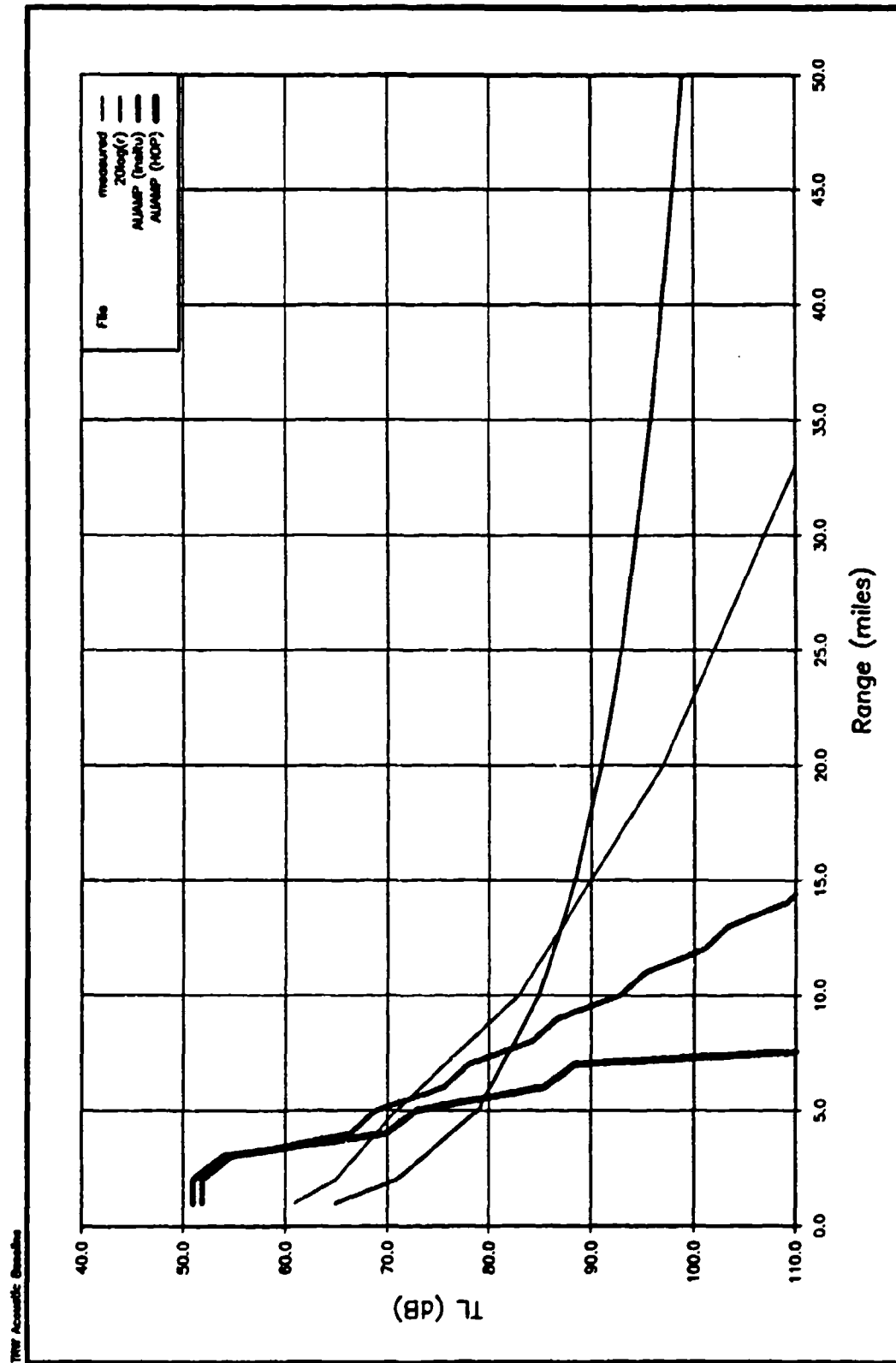
4.1.2 Upslope Environment

This part of the experiment was characterized by the sources moving from the receiver on a radial with a bearing 260 degrees from the receiver. There is a gradual slope over 30 miles from 400 feet at the source uphill to 200 feet at the receiver. The transitional environment is an environment of present concern, and the intent of these comparisons are to note AUAMP's capabilities in predicting transmission loss in upslope runs.

Two representative cases are presented to illustrate the results of comparisons:

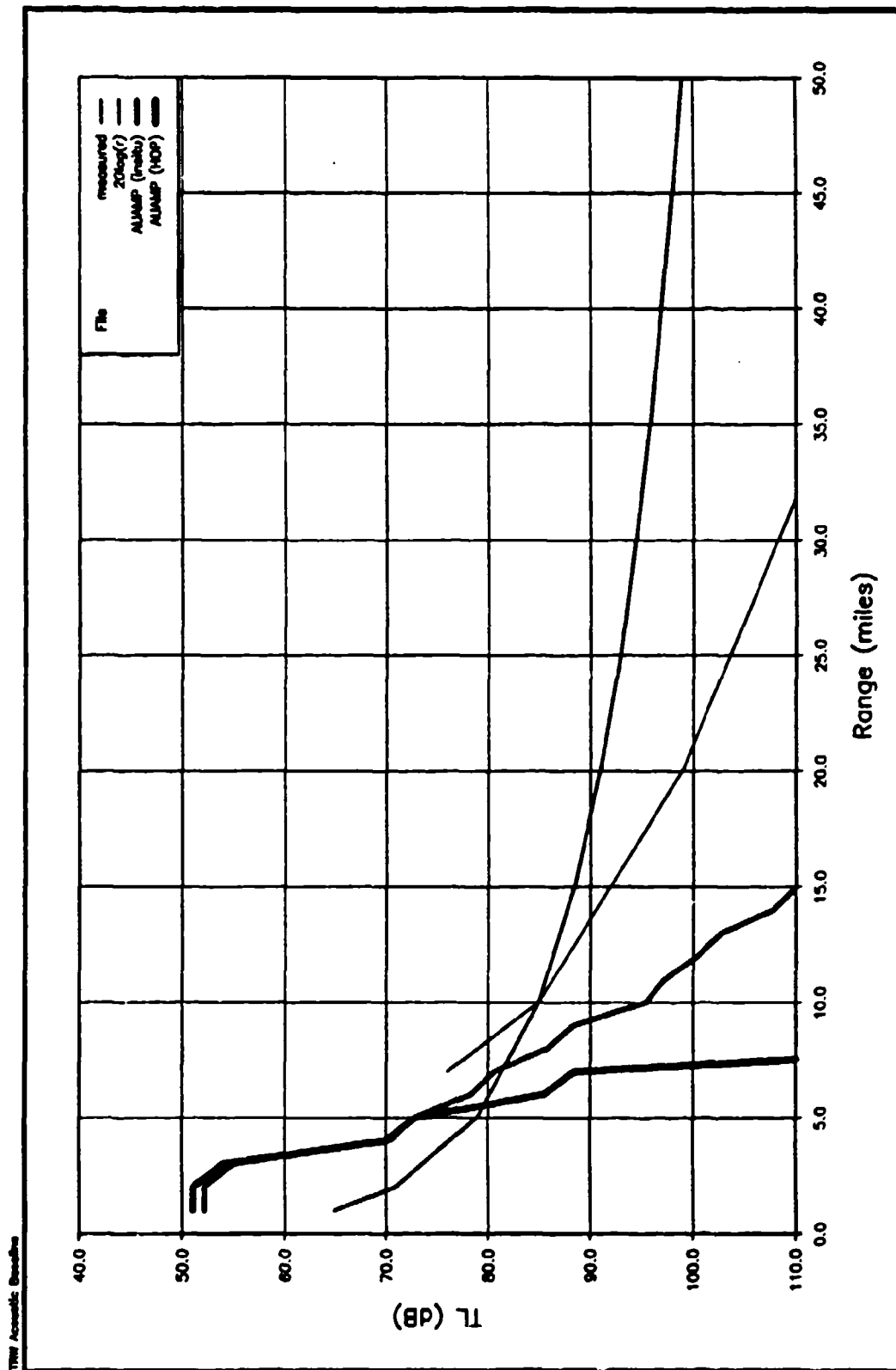
- A) Receiver at 80 feet at 600 Hz;
- B) Receiver at 180 feet at 600 Hz.

Four transmission loss plots are presented on each of the following figures as described in Section 4.1.1. Figures 4-11 and 4-12 present the results of the comparisons.



Rec 80 ft, 600 Hz Upslope

Figure 4-11. ASTRAL and Measured Data Comparison; Receiver at 80 ft, 600 Hz (Upslope)



Rec 180 ft, 600 Hz Upslope

Figure 4-12. ASTRAL and Measured Data Comparison; Receiver at 180 ft, 600 Hz (Upslope)

- **Observations**

The comparison of measured data with AUAMP predictions generated with in situ environmental information or even with HOP environmental data does not correlate significantly well. A small improvement is seen when moving from HOP generated predictions to in situ generated predictions. The culprit for the large order mismatch is probably, once again, the lack of precise bottom loss information.

4.2 Urlick-71, Airborne Measurements of Shallow Water Acoustics at Various Locations off the Eastern and Gulf Coasts of the United States

Urlick collected transmission loss data out to 30 miles for eight locations extending from Cape Cod to the Mississippi Delta in 1971. The transmission loss was collected by a stationary receiver at each site while explosives were dropped along 8 different radials from each receiver. This experiment highlights the range-dependence of typical shallow water sites off the east coast of the U.S. In this report representative comparisons are presented. Specifically, comparisons of data measured in Site 1 (Gulf of Mexico) and Site 5 (off the Delaware shore) with AUAMP predictions are given. Measured range-dependent sound velocity profiles and bottom depth exist for some radials as well as at the receiver site. Measured windspeed is available as well. No bottom loss information was collected for this experiment. The characteristic SVP for Site 1 was a negative gradient near the bottom. The characteristic SVP in Site 5 was an isovelocity or very small positive or negative gradient near the bottom depending on the exact range from the receiver. The bottom province extracted out of LFBL was constant across all environments. The province reflected an absorbing bottom (sound speed in sediment is less than sound speed in water column). The remainder of this section is divided into two subsections for each of the sites of interest (1 and 5).

4.2.1 Gulf of Mexico, Site 1

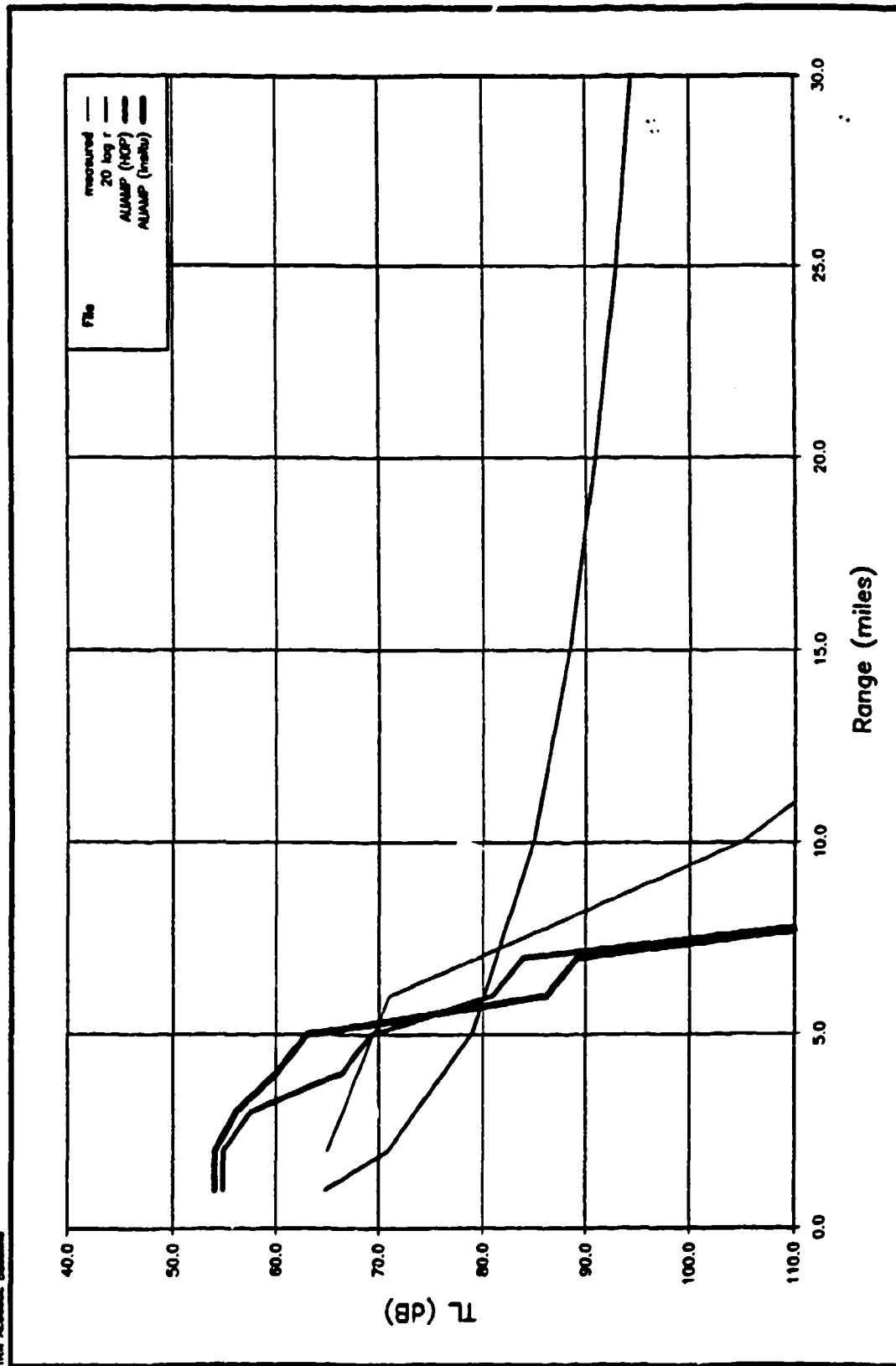
In Site 1, the Gulf of Mexico, aircraft dropped explosive sources set to detonate at a depth of 60 ft. The receiver was a sonobouy deployed at the center of the 8 radial arms receiving at a depth of 90 ft. Various frequencies were processed with the explosive source. The transmission loss in octave bands centered at 125 and 500 Hz are the two presented in this section. For Site 1 two radials are presented (165 degrees and 345 degrees). These two

radials were chosen because they had a higher amount of measured environmental data than other radials. For each of the areas, one figure is given with four plots on each of them which represent:

- 1) AUAMP transmission loss generated accessing HOP data bases;
- 2) AUAMP transmission loss generated accessing in situ environmental data (range-dependent SVP, bottom depth);
- 3) Measured transmission loss;
- 4) $20 \log(r)$ (for reference).

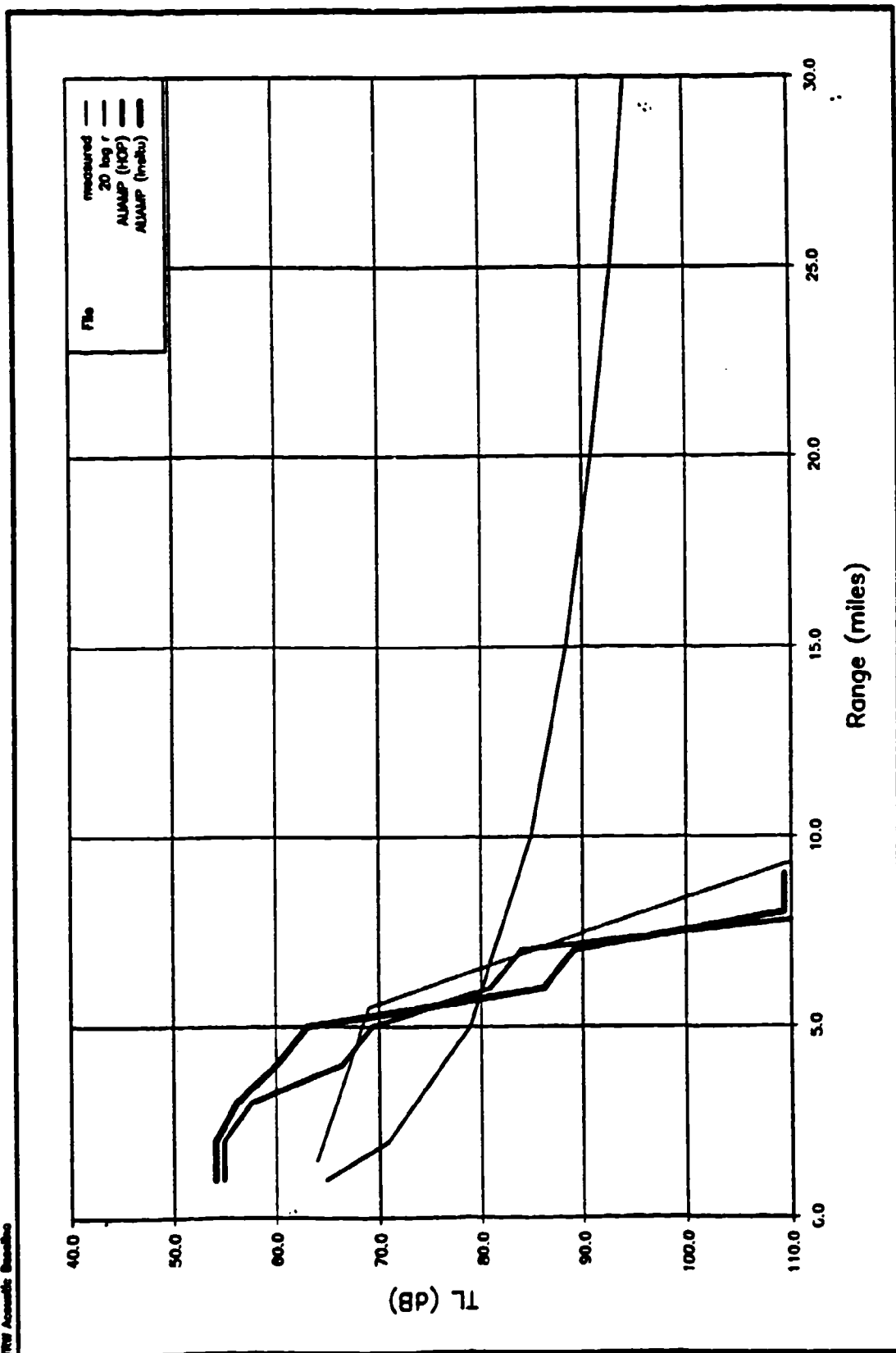
This site was too shallow to use the standard SVP data bases within AUAMP. The HOP designated SVP's for this site were extracted from the ADI shallow water SVP data base for CONUS (ref 18).

Figures 4-13 and 4-14 present comparisons of transmission loss for the 125 Hz case for radials 1 and 2, respectively (165 and 345 degrees). Figures 4-15 and 4-16 present comparisons for transmission loss for the 500 Hz case for radials 1 and 2 respectively.



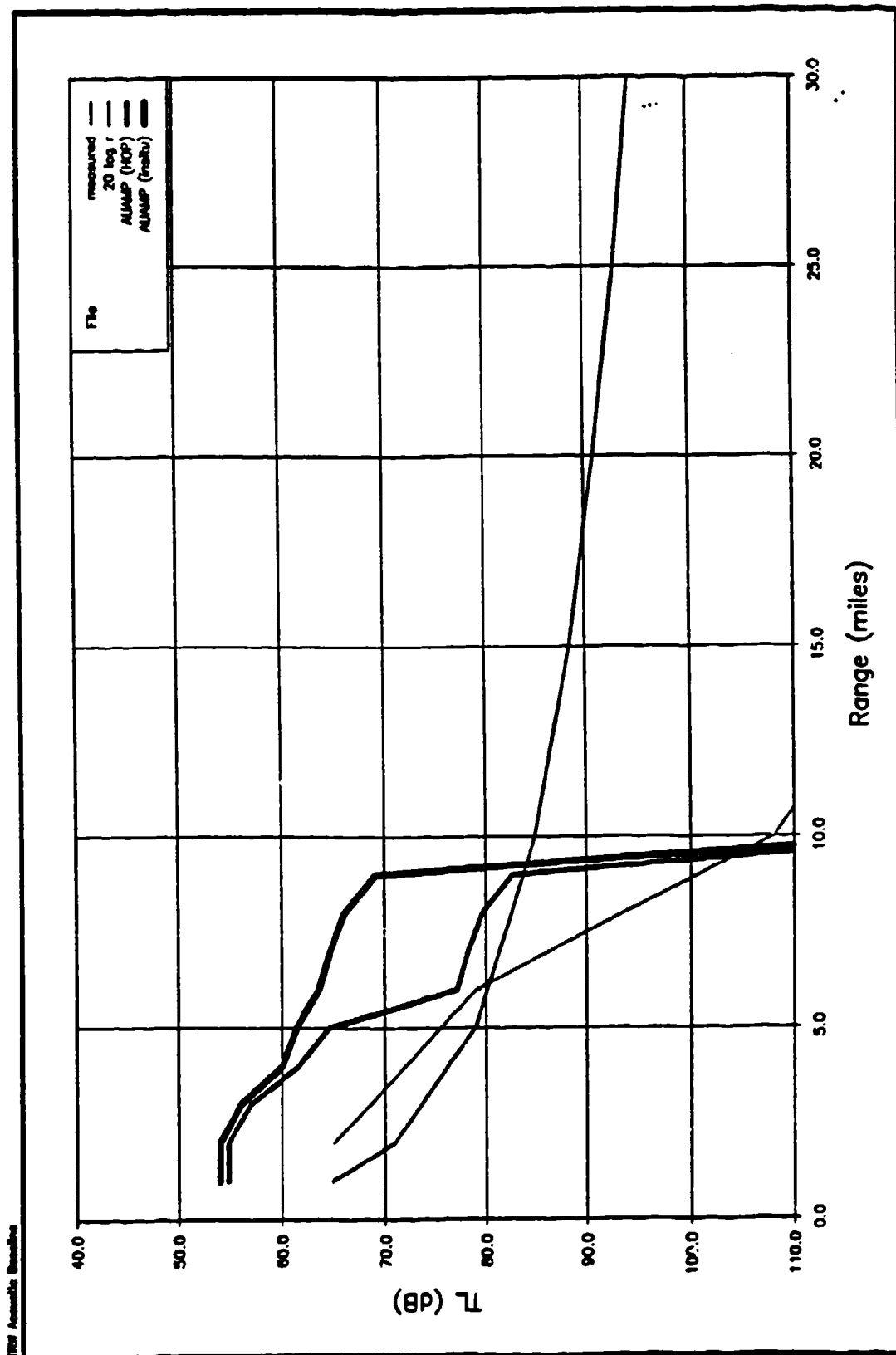
Site 1 Radial = 165 deg 125 Hz

Figure 4-13. ASTRAL Comparison with Measured Data, Site 1; 165 deg Radial; 125 Hz



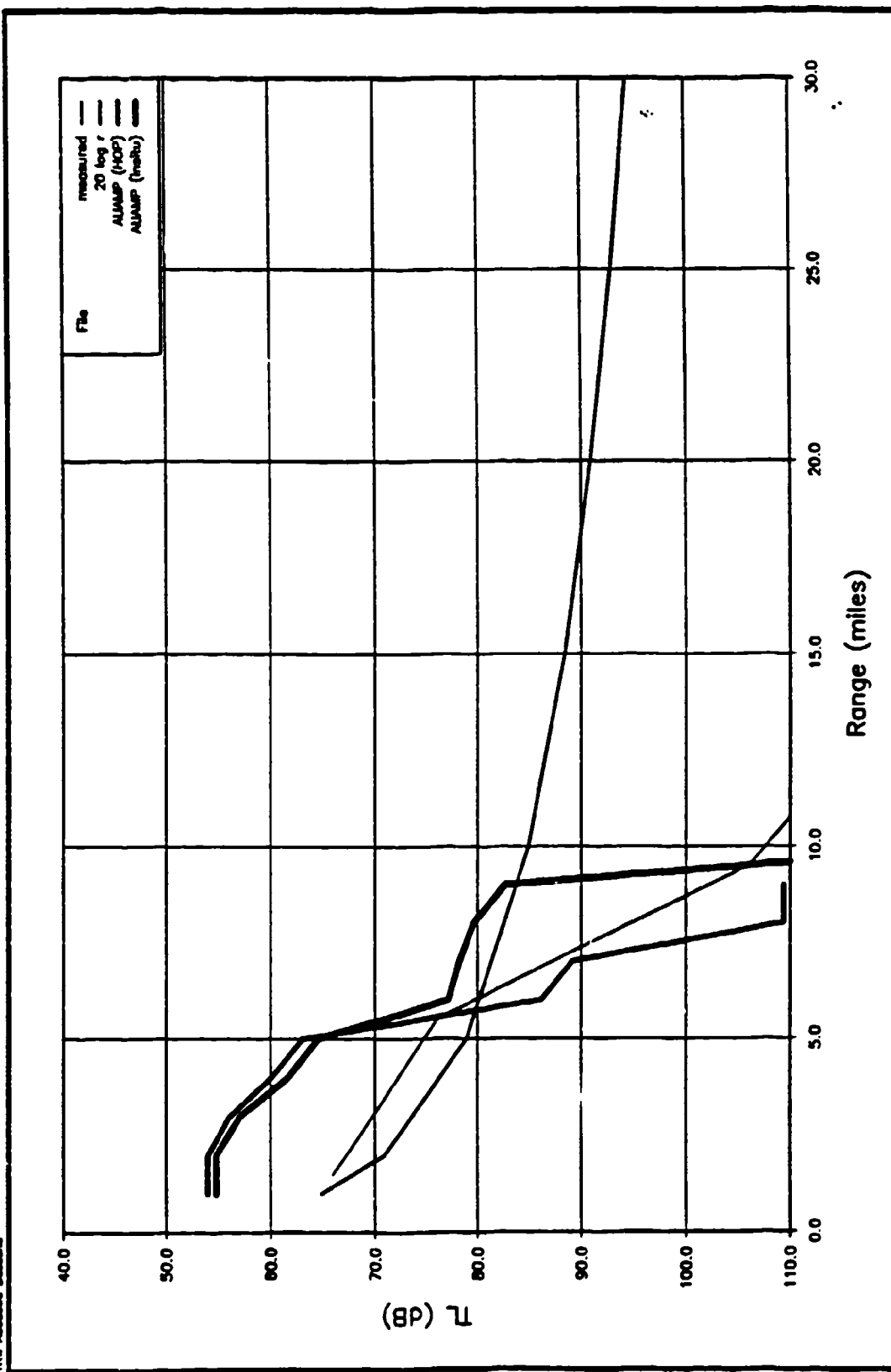
Site 1 Radial = 345 deg 125 Hz

Figure 4-14. ASTRAL Comparison with Measured Data, Site 1; 345 deg Radial; 125 Hz



Site 1 Radial = 165 deg 500 Hz

Figure 4-15. ASTRAL Comparison with Measured Data, Site 1; 165 deg Radial; 500 Hz



Site 1 Radial = 345 deg 500 Hz

Figure 4-16. ASTRAL Comparison with Measured Data, Site 1; 345 deg Radial; 500 Hz

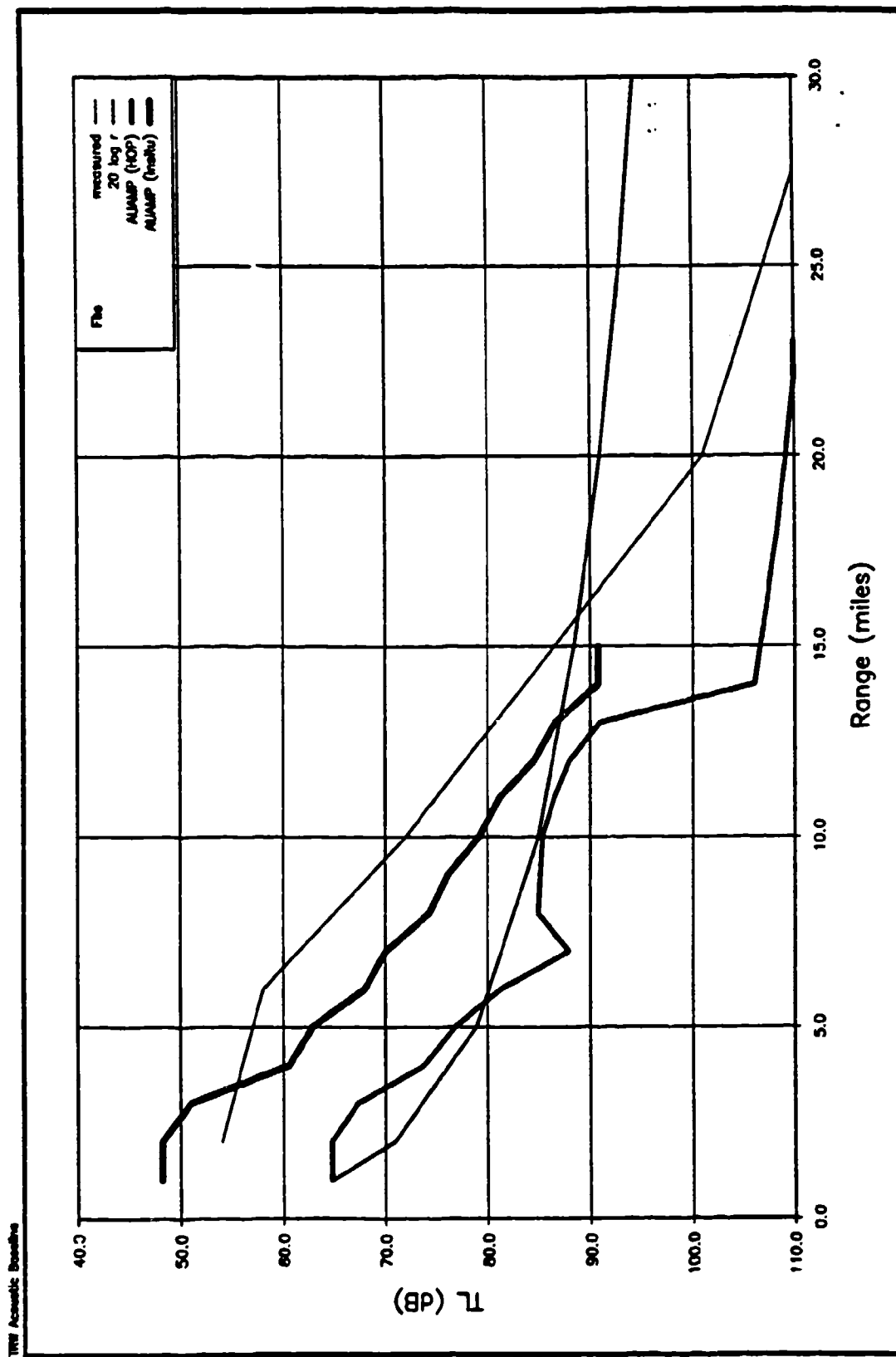
- **Observations**

A relatively good match exists between the measured transmission loss and the AUAMP generated transmission loss for both the in situ environmental data as well as the HOP generated data. No significant improvement is seen from moving from AUAMP HOP generated predictions to AUAMP in situ generated predictions.

There exists a slight offset in slope (i.e., in range) between the measured transmission loss and the AUAMP generated transmission loss for both the 125 and 500 Hz frequencies. This offset could be to a very small mismatch in the bottom loss. This type of slope offset was seen much more drastically in the results of the effect of bottom loss at shallow grazing angles for the Urick-68 experiment (Figure 4-10). This small offset is minimal and may be due to a very small change in bottom loss.

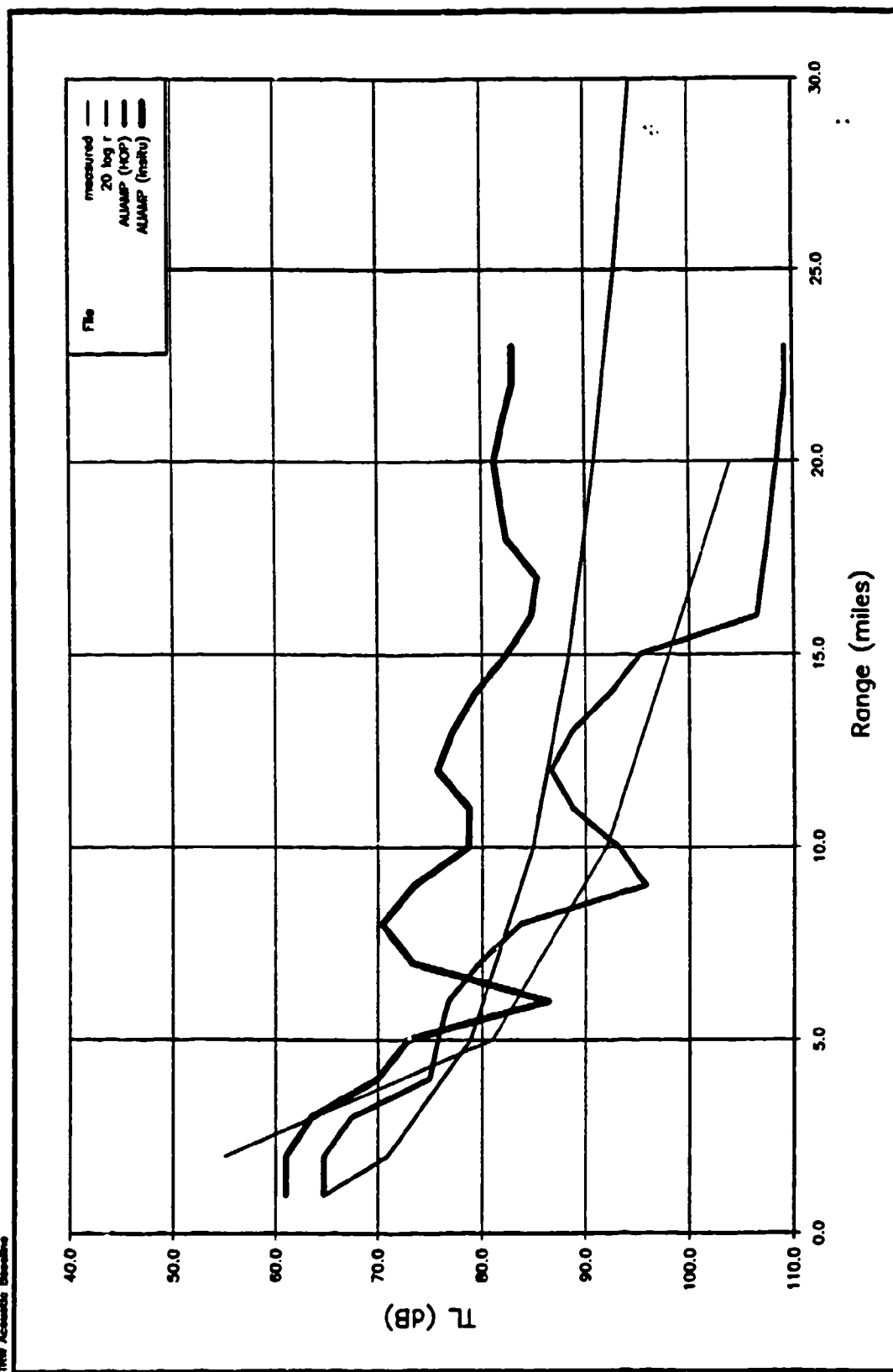
4.2.2 Area 5, Off the Delaware Shore

Comparisons of transmission losses in this location were done for two radials (255 and 365 deg), representing vastly different environments. There are 4 curves to a page as explained in Section 4.2.1. Figures 4-17 and 4-18 present comparisons of transmission loss for a frequency of 125 Hz for radials, 1 and 2 respectively. Figures 4-19 and 4-20 present comparisons of transmission loss for a frequency of 500 Hz for radials 1 and 2, respectively.



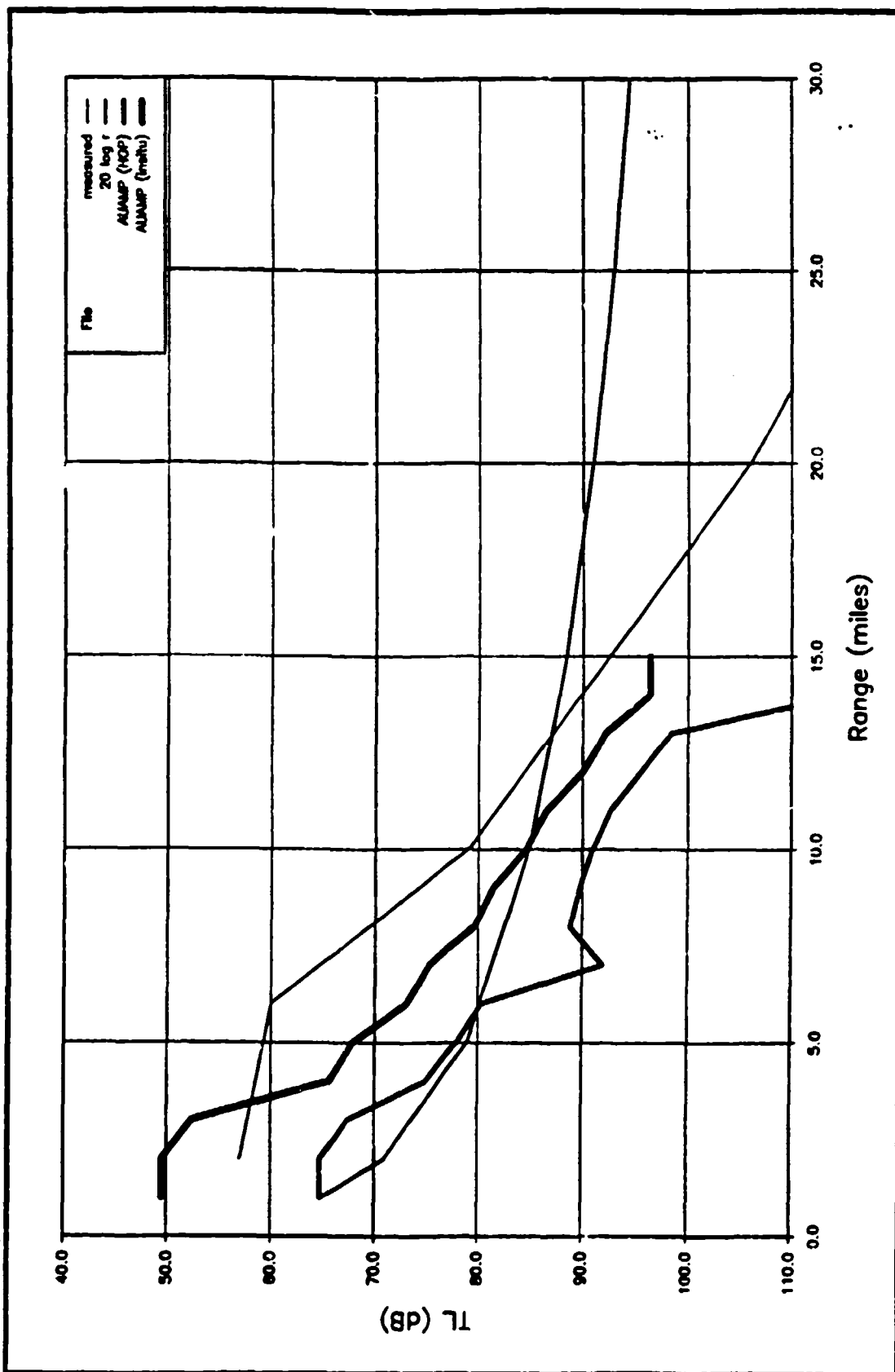
Site 5 Radial = 255 deg 125 Hz

Figure 4-17. ASTRAL Comparison with Measured Data, Site 5; 255 deg Radial; 125 Hz



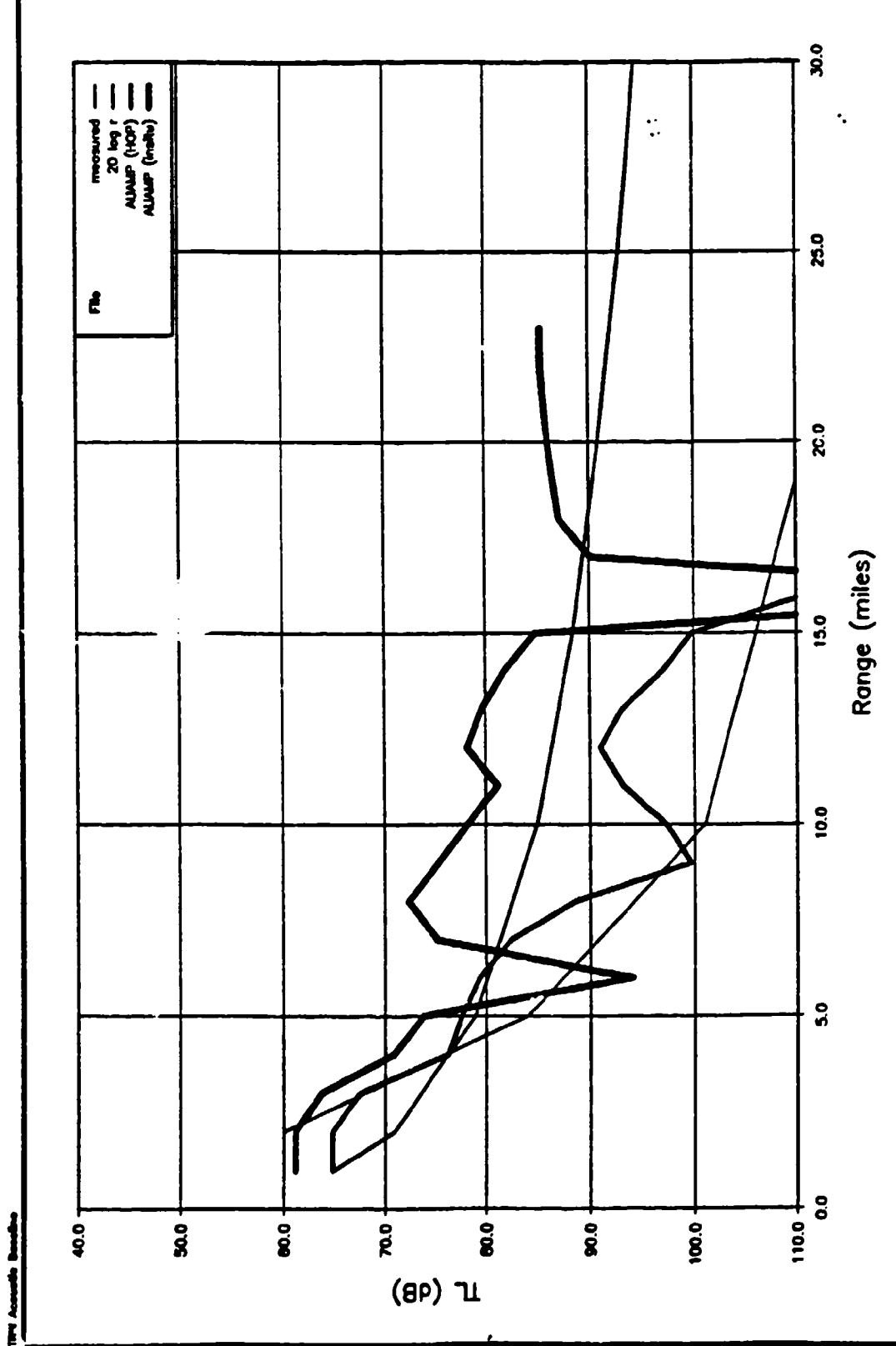
Site 5 Radial = 365 deg 125 Hz

Figure 4-18. ASTRAL Comparison with Measured Data, Site 5; 365 deg Radial; 125 Hz



Site 5 Radial = 255 deg 500 Hz

Figure 4-19. ASTRAL Comparison with Measured Data, Site 5; 255 deg Radial; 500 Hz



Site 5 Radial = 365 deg 500 Hz

Figure 4-20. ASTRAL Comparison with Measured Data, Site 5; 365 deg Radial; 500 Hz

• Observations

The comparisons are improved at this site for the 255 degree radial relative to the 365 degree radial. This is possibly because the water depth is deeper than the previous site. The water depth at the receiver was approximately 700 feet and stayed essentially constant. In situ environmental data predictions result in an improved comparison over HOP generated predictions. The characteristic SVP at the receiver site had a slight positive gradient. This could have downplayed the importance of knowing the bottom information, since sound was refracting away from the bottom.

A constant offset in transmission loss is seen between the measured transmission loss and the AUAMP generated transmission loss with the in-situ data for the 255 degree radial. The slope of the two curves appear the same. The reason for this type of offset in transmission loss will be investigated further.

The transmission loss predictions out radial 365 did not correlate well with measured data. This is possibly because this radial was characterized as a steep downslope. No detailed bathymetry data was available to accurately map this.

4.3 LFA-7

The LFA-7 experiment, conducted in July of 1991 in the Mediterranean, was unique as compared to the two other experiments in this study. It consisted of a moving source as well as a moving receiver. The environment for the transmission loss runs presented here was primarily an upslope environment. For the transmission loss comparisons presented, the only in situ data used were SVP and windspeed. The comparisons shown below compare a static TL run generated from AUAMP with measured transmission loss from a moving source and receiver. To accurately model the measured transmission loss, with the motion of the assets included, multiple transmission loss runs would have to be completed. This was not done in this analysis. For the transmission loss runs received, detailed navigation data was missing at the point where it was most crucial. Thus, all navigational information is relatively crude, having been extracted from the XBT drop points and the sparse truth data available at those times. Determining which of the transmission loss runs actually were venturing up the slope was difficult. The runs investigated initially were at the start of the experiment and no truth

data existed. The run in which truth data may have been available, by coincidence, was missing the times associated with the run. Yet, using information from the environmental measurements and what truth data was available for the times of interest, two transmission loss run measurements were compared with AUAMP predictions.

Figure 4-21 reflects transmission loss generated and measured for a source at 60 feet. The three curves plotted are:

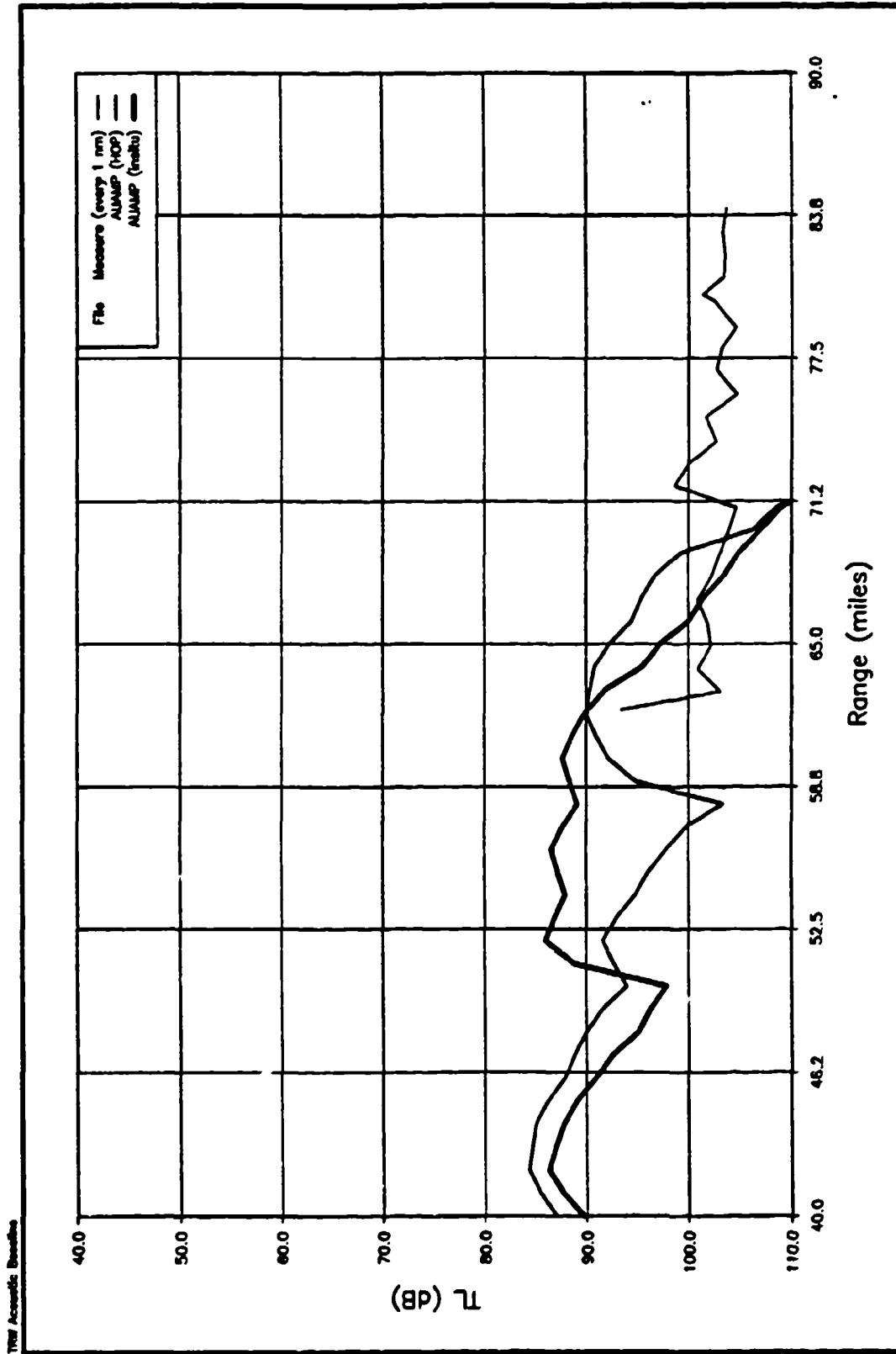
- 1) AUAMP predictions with HOP data;
- 2) AUAMP predictions with in situ SVP;
- 3) Measured data.

Case 2 is a best guess as to the asset locations and the location for the in situ SVP relative to these assets. The measured data is the data received from reference 16, yet only one value every mile was plotted. With the range resolution of 2 nm presently within AUAMP, as well as with the data base resolution, the fine structure of the measured TL would not be seen. Smaller range intervals do not have enough of a significant effect to explain the differences shown (ref 17).

Figure 4-22 reflects transmission loss generated and measured for a source at 350 feet. The two curves plotted are:

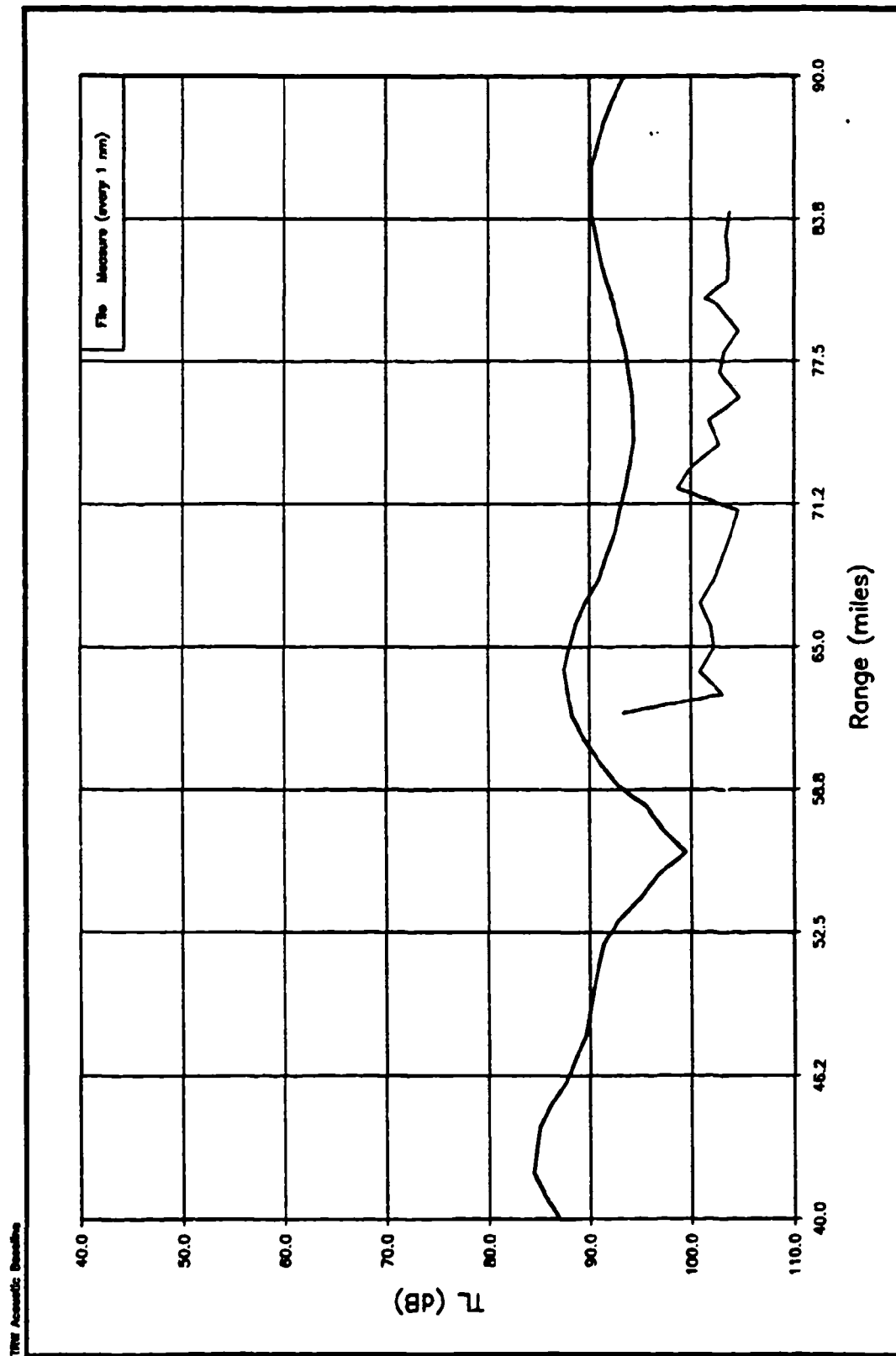
- 1) AUAMP predictions with HOP data
- 2) Measured data

In situ SVP is not presented in this plot as it was inconclusive as to the location of the assets relative to the XBT drop.



Area 2 Source at 60 ft

Figure 4-21. LFA-7 Transmission Loss Comparison 1 (60 ft receiver)



Area 1 Source at 350 ft

Figure 4-22. LFA-7 Transmission Loss Comparison (350 ft source)

- **Observations**

There is very poor agreement with modeled data. Imprecise navigation data clearly results in inconclusive results. This complex experiment with the motion of all the assets involved make it difficult to determine a result in a specific area. Even if precise navigational data had been available for all assets, the speed and direction of the source and receiver may throw the results off, or not having bottom loss information may be the culprit for the poor results. This experiment emphasizes the difficulties in validating a model. If the validation is to be a robustness analysis (i.e., how well do you have to know the navigational position to get an accurate answer or, given a system, what is the most appropriate way to model it with the model) this may be the experiment to pursue. To determine whether a model can accurately model an ocean environment, this experiment is entirely too complex. This experiment will be investigated further as more precise navigational data is received to attempt to pinpoint the culprit parameter for the mismatch.

There exists a constant offset in transmission loss between the measured and modeled data in Figure 4-22, as in the previous experiment. The reason for this type of offset will be further investigated.

5.0 PRELIMINARY CONCLUSIONS, RESULTS, RECOMMENDATIONS

These comparisons have generated some initial observations and results which follow.

- ASTRAL predictions agree with PE and FAME for positive gradient environments.

Though the comparisons presented in Section 2 are not exhaustive, it appears that ASTRAL is not behaving significantly different than FAME and PE in shallow water environments where a positive gradient exists, no matter what the bottom. ASTRAL is useful in shallow water environments characterized by a positive gradient.

- ASTRAL predictions disagree with PE and FAME for negative gradient environments.

The negative gradient environment is accentuating the bottom interaction. FAME, PE and ASTRAL do not agree well for these environments. The disagreement between PE and ASTRAL is greatest when an absorbing bottom exists in the presence of a negative gradient SVP. As the negative gradient increases, the disagreement between PE and ASTRAL grows for both the reflective and absorbing bottom. Caution should be exercised when using AUAMP for negative gradient environments.

- All models predict a marked sensitivity to bottom loss at shallow grazing angles.

Though this is physically predictive, the present data bases and techniques of modeling the bottom loss may not be sufficiently comprehensive. The high sensitivity of a few tenths of a dB in bottom loss which significantly affects transmission loss dictates the knowledge of bottom loss characteristics (i.e., reflectivity, bottom scattering strength) with a resolution which will support useful model predictions in shallow water. PE, FAME and ASTRAL do differ significantly when the bottom plays an important role in the transmission loss calculation (negative gradient, absorbing bottom), ASTRAL demonstrates the most significant effect due to these environmental conditions.

- The transmission loss comparisons do not consistently correlate with measurements.

This is seen throughout the comparisons. In cases where the correlation was better the sound velocity profile usually had a positive gradient. The positive gradient situation minimized bottom interactions, such that accurate bottom information or data was not as significant as in the negative gradient cases. This again seems to be highlighting a data base problem and possibly a bottom modeling problem. The distinction between bottom modeling and a data base problem cannot be resolved until precise bottom loss measurements are available.

- Bottom loss knowledge is crucial.

Bottom loss is the most significant environmental parameter, especially at very low grazing angles. Even a small difference (less than 1 dB) at the low angles can result in a 10 dB difference in transmission loss at 10 miles (as seen in the analysis cases presented at the end of Section 4.1).

- Knowledge of the asset locations and environment are crucial.

This can be seen clearly in the LFA-7 experiment. Movement of the source position in an upslope environment can affect the transmission loss significantly.

- In some cases a constant offset in transmission loss is seen.

This is evident in the Urick-71 and LFA-7 experiments. This kind of phenomena is not as easily explained with bottom loss differences since bottom loss variances tend to result in significant differences in the slope of the transmission loss curve. Constant offsets between measured and modeled data in shallow water will be investigated further.

- Preliminary Recommendations

Conduct an experiment specifically designed to measure bottom loss, especially at the

low grazing angles. There is no sufficient amount of bottom loss measurements at low grazing angles for low frequencies (less than 1kHz) in shallow water. Conclusive evaluation of shallow water transmission loss modeling capability requires the input of proper bottom characteristics with appropriate resolution. This is demonstrated through the ASTRAL transmission loss predictions shown in Section 3. Small variations in bottom loss at shallow angles significantly affect the transmission loss.

Conclusive studies into the applicability of a model in shallow water dictate controlled experiments with minimal possibilities of error. Navigation errors can be reduced greatly by designing an experiment to have a stationary receiver and moving source (or vice versa). Bottom loss measurements, SVP along the TL track, wind data, and scattering strength data as well as detailed bathymetry data should then be taken. Then, with this nearly precise environmental information, comparisons with model predictions should be performed. In the absence of this type of experiment, available parameters can be appropriately (or inappropriately) adjusted to obtain a good correlation.

The same needs that exist for bottom loss are present for bottom scattering strength modeling. In the active arena of current efforts, these two parameters need to be better understood and characterized.

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SUPPLEMENTARY

INFORMATION



DEPARTMENT OF THE ARMY
HEALTH CARE STUDIES AND CLINICAL INVESTIGATION ACTIVITY
FORT SAM HOUSTON, TEXAS 78234-8000



REPLY TO
ATTENTION OF

ERRATA AD-B167 935

HSNN-R (5-5)

8 November 93

MEMORANDUM FOR Defense Technical Information Center, ATTN: DTIC-
OCC, Catalog Branch, Building 5, Cameron Station,
Alexandria, VA 22304-6145

SUBJECT: Release of Limited Reports in DTIC

1. Enclosed is a list of reports submitted by Health Care Studies and Clinical Investigation. At the time of submission we requested these documents be limited to DOD agencies only. This limitation no longer applies. **'Please remove the limitation on all the listed reports (enclosed). 'These reports should now be "Unlimited, Available for Public Use."**

2. By lifting the limitation on this reports, will they now be provided to National Technical Information Service? This agency would like these documents placed with NTIS for a wider audience.

3. Point of contact is Beverly Rakowitz DSN 471-0047/9610 or commercial 210-221-0047/9610. Mailing address is Directorate of Health Care Studies and Analyses, Cdr, AMEDDC&S, ATTN: HSHN-R, 1608 Stanley Road, Fort Sam Houston, TX 78234-6125.

ERRATA AD-B167 935

Encl

BEVERLY RAKOWITZ
Technical Information Specialist
D/HCS&A

48 this pgs

CHANGE FROM LIMITED TO UNLIMITED:

AD B166231L CHAMPUS Substance Abuse Treatment Costs & Utilization for Adolescent Beneficiaries in Health Services Command Catchment Areas Fiscal Years 1990-1991, RP92-016

AD B167229 Outpatient Nonavailability Statement Procedures Health Services Command Catchment Areas: Third Quarter Fiscal Year 1991, RP92-018

AD B166262L Coordinated Care Data Dictionaries, RP92-019

AD B166187L Financial Analysis Support System (FASS) Training Manual Version 2.1a, RP92-020

AD B167764 Partnership Provider Audit Report for Fort Drum MEDDAC, Fort Carson MEDDAC, & Eisenhower AMC Gateway Catchment Areas, Fiscal Year 1991, RP92-021

AD B167595 Partnership Provider Audit Report for Fort Benning MEDDAC and Fort Riley MEDDAC Gateway Catchment Areas, RP92-022

AD B167766 Partnership Provider Audit Report for Fort Leavenworth MEDDAC and Fort Campbell MEDDAC Gateway Catchment Areas, RP92-023

AD B167552 Partnership Provider Audit Report for Fort Leonard Wood MEDDAC, West Point MEDDAC, Fort Bragg MEDDAC and Fort Sill MEDDAC Gateway Catchment Areas, RP92-024

✓ AD B167935 Partnership Provider Audit Report for William Beaumont
* AMC Gateway Catchment Areas, RP92-025

AD B167509 Partnership Provider Audit Report for Fort Hood MEDDAC Gateway Catchment Areas, RP92-026

AD B167821 Partnership Provider Audit Report for Letterman, Tripler, & Madigan Medical Center Catchment Areas, RP92-027

Start AD B167819 Partnership Provider Audit Report for Fitzsimmons, Walter Reed and Brooke Medical Center Catchment Areas, RP92-028

AD B167765 Partnership Provider Audit Report for Redstone Arsenal, Fort McClellan, Fort Rucker, & Fort Wainwright Medical Department Activity Catchment Areas, RP92-029

AD B167852 Partnership Provider Audit Report for Fort Huachuca, Fort Ord, & Fort Stewart Medical Department Activity Catchment Areas, RP92-030

AD B167594 Partnership Provider Audit Report for Fort Knox, Fort Polk, Fort Meade, Fort Devens, Fort Monmouth, Fort Dix, & Fort Jackson Medical Department Activity Catchment Areas, RP92-031