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ILS Mathematical Modeling Study of a Glide Slope Proposed for Runway 22L at Little Rock Municipal Airport, Arkansas

James D. Rambone

February 1991

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16. Abstract

This Technical Note describes the instrument landing system (ILS) math modeling performed by the Federal Aviation Administration (FAA) Technical Center at the request of the Southwest Region. Data are presented showing the computed performance of a proposed glide slope for runway 22L at Little Rock Municipal Airport, Arkansas. As requested, a sideband reference system is modeled at two proposed glide slope sites. Modeled path structure and level run plots are provided for the glide slope system installed at each proposed location. Results indicate that the sideband reference system modeled at both proposed locations should meet Category I path structure, linearity, and symmetry tolerances.

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TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	vii
INTRODUCTION	1
Purpose	1
Background	1
DISCUSSION	1
ILS Math Models	1
ILS Math Modeling Performed	3
Data Presentation	3
Data Analysis	3
CONCLUSIONS	3
REFERENCES	5

LIST OF ILLUSTRATIONS

Figure		Page
1	Little Rock Runway 22L, ILS Math Modeling Layout	6
2	Little Rock Runway 22L, Site 1 Terrain Profile	7
3	Little Rock Runway 22L, Site 2 Terrain Profile	8
4	Modeled Path Structure, Little Rock Runway 22L, Sideband Reference System, Proposed Site 1	9
5	Modeled Path Structure, Little Rock Runway 22L, Sideband Reference System, Proposed Site 2	10
6	Modeled Level Run, Little Rock Runway 22L, Sideband Reference System, Proposed Site 1	11
7	Modeled Level Run, Little Rock Runway 22L, Sideband Reference System, Proposed Site 2	12

EXECUTIVE SUMMARY

This instrument landing system (ILS) math modeling study, performed at the request of the Southwest Region, ASW-461, provides data showing the computed performance of a proposed glide slope for runway 22L at the Little Rock Municipal Airport, Arkansas. Modeled path structure and level run plots are provided for a sideband reference glide slope system installed at two proposed glide slope sites. Both proposed glide slope sites will be located 987 feet back from runway threshold. Proposed site 1 is 275 feet right offset of centerline; proposed site 2 is 275 feet left offset. Glide slope modeling computed only the effect of terrain on glide slope performance. Results indicate that the sideband reference system modeled at both proposed locations should meet Category I path structure, linearity, and symmetry tolerances.

INTRODUCTION

PURPOSE.

The purpose of this math modeling study was to provide computer modeled performance data for an instrument landing system (ILS) glide slope proposed for runway 22L at the Little Rock Municipal Airport.

BACKGROUND.

The Southwest Region, ASW-461, will be installing an ILS glide slope to serve runway 22L at the Little Rock Municipal Airport, Arkansas. In support of this project, ASW-461 has requested a math modeling study through the Navigation and Landing Division, ANN-100, which, in turn, was forwarded to the Federal Aviation Administration (FAA) Technical Center for accomplishment. The Southwest Region requested math modeling of a glide slope proposed for runway 22L. A sideband reference glide slope system was requested to be modeled at two proposed glide slope sites to determine the optimum site location. Both proposed glide slope sites are located 987 feet backset from threshold. Site 1 is located 275 feet right offset of centerline at a ground elevation of 257.25 feet mean sea level (m.s.l.), site 2 is 275 feet left offset at a ground elevation of 253.80 feet m.s.l.. The ground elevation is 259.75 feet m.s.l. at runway 22L threshold and the runway point intercept (RPI). Category I glide slope performance is required. This modeling effort was performed under project T0603S. The Technical Program Manager is Mr. Edmund A. Zyzys. Additional information regarding this study may be obtained by contacting Mr. James D. Rambone at FTS 482-5373 or (609) 484-5373.

DISCUSSION

ILS MATH MODELS.

The FAA Technical Center conducts ILS mathematical computer model studies through application of physical optics or geometric theory of diffraction techniques to compute anticipated ILS performance. The mathematical model used for this simulation was the Ohio University Geometrical Theory of Diffraction (OUGTD) model which was obtained from Ohio University under an FAA Technical Center contract. This program was written for Ohio University by Mr. Vichate Ungvichian to account for the interactions of electromagnetic waves when reflected and/or diffracted from the terrain between an ILS antenna and an aircraft (reference 1). The OUGTD program utilizes the Geometrical Theory of Diffraction (GTD) and the Uniform Theory of Diffraction (UTD) as the basic theories when computing the diffraction of the electromagnetic waves. The GTD and UTD theories both treat electromagnetic waves as rays. This is acceptable due to the localized nature of wave interactions at very high frequencies (above 100 megahertz (MHz)). This treatment allows one to include the multiple interaction (i.e., doubly diffracted, etc.) between neighboring ground plates with little computational effort. This is a very difficult task when using the Physical Optics theory. The UTD theory is used to calculate the fields in the transition areas; the GTD theory is used in all other areas.

The model considers the direct ray plus 13 additional rays. Each ray is determined by the various terrain irregularities encountered in front of the ILS antenna system. These rays are:

1. Direct
2. Reflected
3. Diffracted
4. Reflected-reflected
5. Reflected-diffracted
6. Diffracted-reflected
7. Diffracted-diffracted
8. Reflected-reflected-diffracted
9. Reflected-reflected-reflected
10. Reflected-diffracted-reflected
11. Diffracted-diffracted-reflected
12. Reflected-diffracted-diffracted
13. Diffracted-reflected-reflected
14. Diffracted-reflected-diffracted

The pseudo-3D version of the model was used for this modeling effort. This version uses a matrix of X, Y, and Z coordinates for the terrain to compute a new terrain profile for each observation point (simulated aircraft position). The term "pseudo-3D" is used to emphasize the fact that the model is not truly 3-dimensional, but rather an enhancement of the 2D version which uses a single terrain profile for all observation points.

The subroutine that determines the profile was modified by FAA Technical Center engineers to eliminate some restrictions on establishing the origin and selection of coordinates. For each observation point and its associated terrain profile, the simulated course deviation indicator (CDI) deflection is computed from the various combinations of rays.

Input data required by the model consists of two data files: the terrain matrix file and the input/control file. The terrain matrix file consists of X (distance perpendicular to the runway), Y (distance along the runway centerline extended), and Z (elevation values referenced to the base of the antenna mast). The computer model applies an interpolation process to the terrain matrix file to determine a new terrain profile for each observation point (simulated aircraft position) along the flightpath. The new profile is that of the terrain directly below a line drawn from the ILS antenna to the observation point. This profile is the surface used in the computation of the glide slope radio frequency (RF) energy at the observation point. The input/control file consists of data describing the antenna system (location, amplitude, and phase of each antenna element), along with other pertinent site and flightpath data. Antenna heights were computed to produce actual path angles of approximately 3.0 degrees. Antenna current phasing for all simulations were computed using a simulation of the airborne phasing techniques detailed in the Flight Inspection Manual OAP 8200.1 (reference 2). In the simulation, samples of antenna current phase are recorded while flying the simulated aircraft along an approach angle of 1.5 degrees from 8 to 4 nautical miles (nmi) with respect to the site. Ten samples of antenna current phase are recorded for each antenna. Using average phase values, the phase of the upper antenna is adjusted for zero phase difference with respect to the lower antenna for sideband reference or null reference systems. For the capture effect system, the phases of the lower and upper antennas are adjusted to result in zero phase difference with respect to the middle antenna. This technique is similar to the method originated by the Ohio University Avionics Center for their modeling applications.

ILS MATH MODELING PERFORMED.

Figure 1 shows the location of the proposed glide slope sites with respect to runway 22L. The GTD-3D glide slope model was used to model the effects of terrain on glide slope performance. Figures 2 and 3 show a composite of terrain profiles for simulated aircraft positions in the distance interval from 35,000 to 1,000 feet from runway RPI in increments of 1,000 feet. Figure 2 shows the terrain profile for site 1 and figure 3 shows the terrain profile for site 2. As requested, a sideband reference system was modeled at the two proposed glide slope sites. A summary of the model input data describing the glide slope antenna system at the proposed sites is provided in table 1. Glide slope level and path structure computer runs were made with this data.

DATA PRESENTATION.

Glide slope modeling results are presented in the form of course structure and level run plots. The reference flightpath for a structure plot is the hyperbolic path formed by the intersection of a cone originating at the base of the antenna and a vertical plane located along runway centerline. In the model, this path is determined by the location of the eyepiece of the theodolite. For the data presented, the theodolite eyepiece is positioned at the X and Y coordinates of the glide slope antenna mast, but at the elevation (Z coordinate) of the RPI. Modeled results are given in figures 4 through 7. Path structure run results are given in figures 4 and 5. Sideband reference system performance modeled at site 1 is shown in figure 4 and system performance modeled at site 2 in figure 5. Figures 6 and 7 are the modeled level run results for the sideband reference system modeled at sites 1 and 2, respectively.

DATA ANALYSIS.

Glide slope modeled path structure results for the sideband reference system modeled at site 1 (figure 4) and modeled at site 2 (figure 5) both provide similar results with a path structure within Category I tolerance limits. The level run results for the sideband reference system (figures 6 and 7) show a linear crossover and near symmetrical glidepath which meet Category I tolerances.

CONCLUSIONS

Modeled results indicate that satisfactory Category I path structure performance should be obtained with the sideband reference system installed at either of the proposed glide slope sites. Level run performance meets Category I linearity and symmetry tolerances for the sideband reference system modeled at both sites.

TABLE 1. GLIDE SLOPE DATA SUMMARY

Sideband Reference Antenna	Proposed Site 1 Height/Offset (ft/ft)	Proposed Site 2 Height/Offset (ft/ft)
Lower	7.36/0.0	7.23/0.000
Upper	22.08/-0.788	21.70/-0.761
Average Path Angle (deg)	3.0	3.0
Path Width (deg)	0.70	0.70
Path Symmetry (percent)	54/46	53/47
A-Ratio (*)	0.299	0.265
Phase (deg)	-0.895	-5.418
Backset from threshold (ft)	987.0	987.0
Offset from centerline(ft)	-275.0	275.0
Elevation (ft m.s.l.)	257.25	253.80
Frequency (Mhz)	332.9	332.9

(*) A-Ratio - Ratio of separate sideband signal amplitude to carrier sideband signal amplitude.

REFERENCES

1. User's Manual for the Ohio University Geometric Theory of Diffraction Glide Slope Model, Ohio University Technical Report Number OU/AEC/ERR 47-7, February 1982.

2. United States Flight Inspection Manual, FAA Handbook OAP 8200.1, Change 32, Section 217.

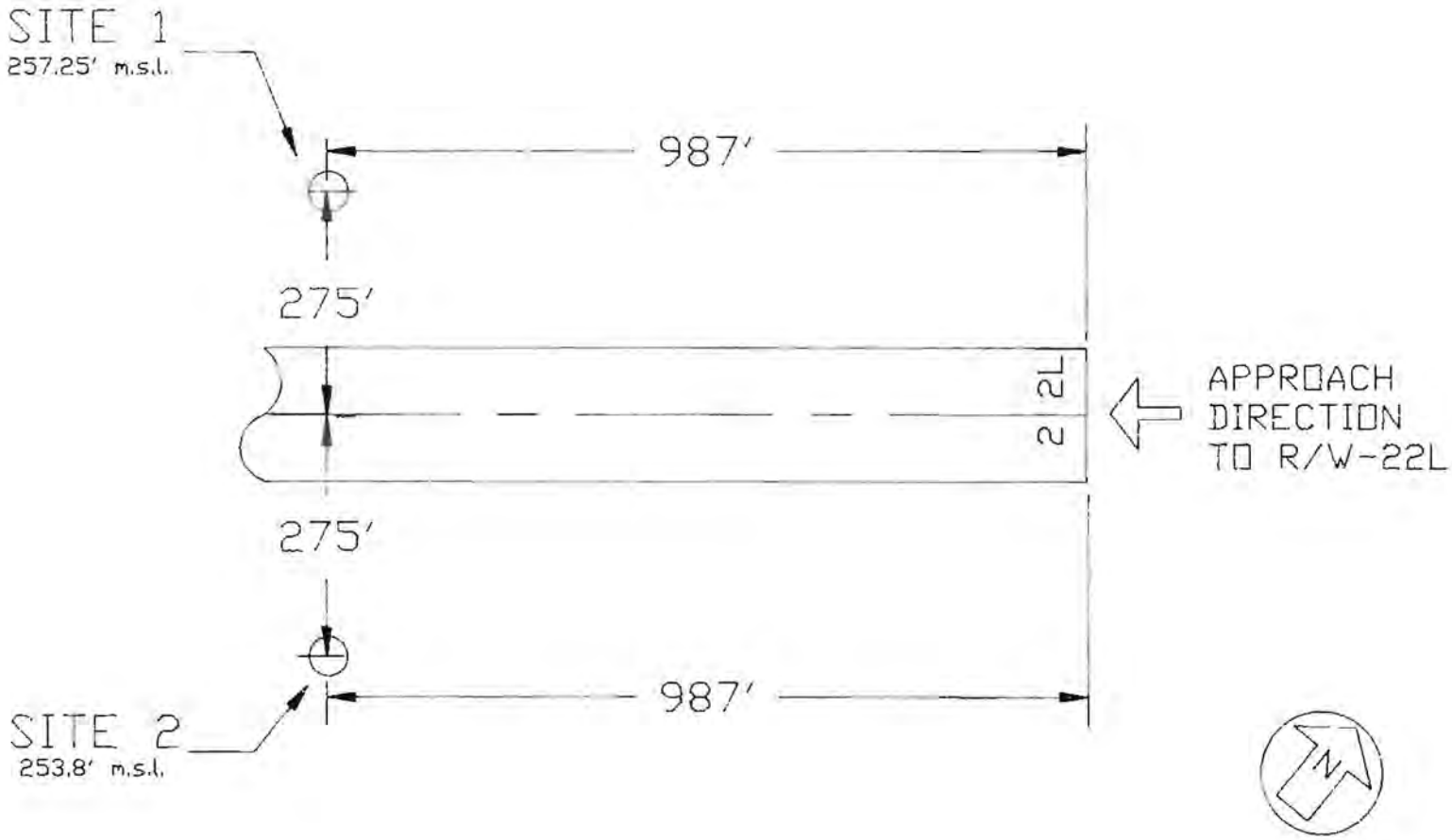

FIGURE 1. LITTLE ROCK RUNWAY 22L, ILS MATH MODELING LAYOUT

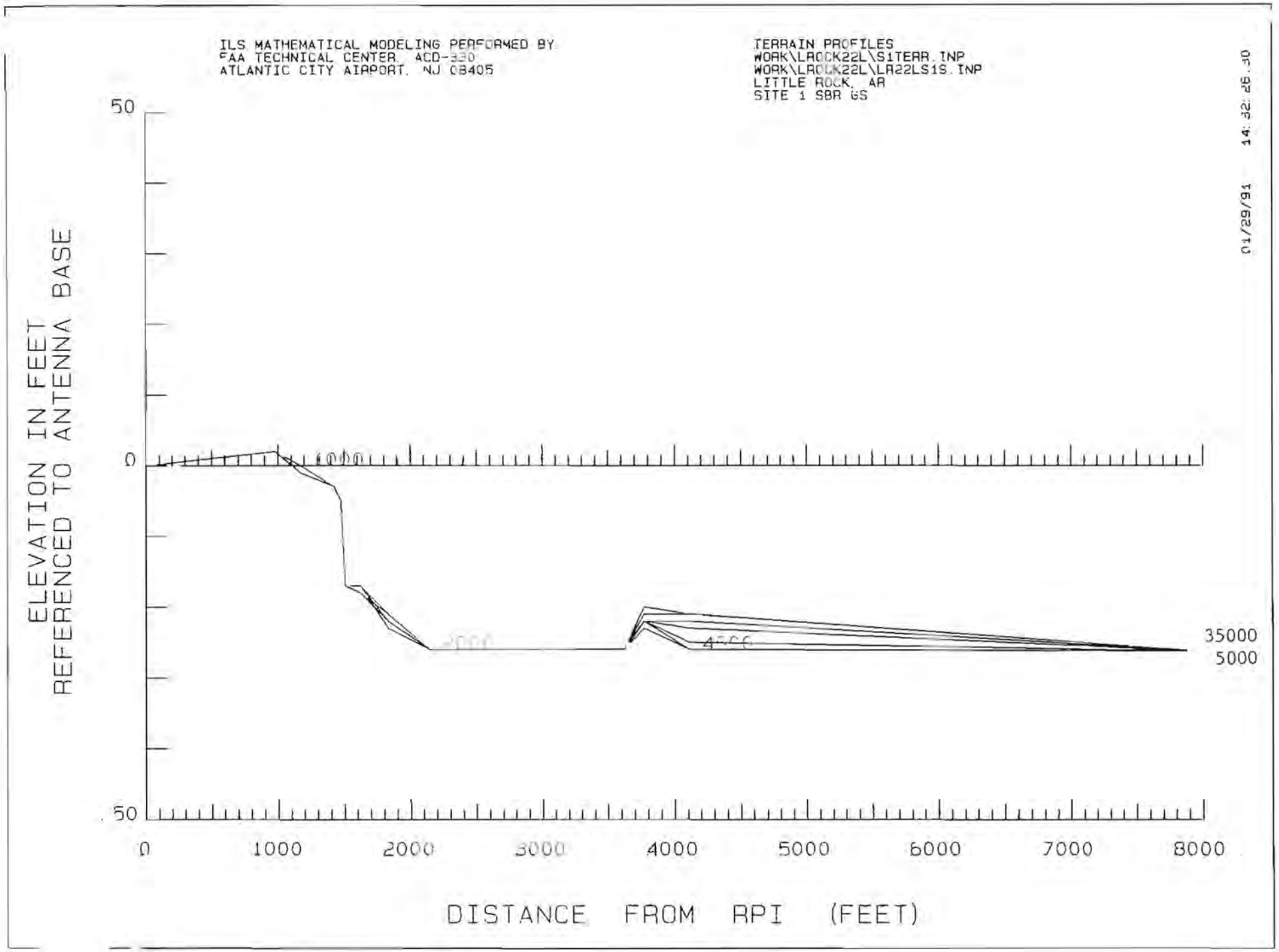

FIGURE 2. LITTLE ROCK RUNWAY 22L, SITE 1 TERRAIN PROFILE

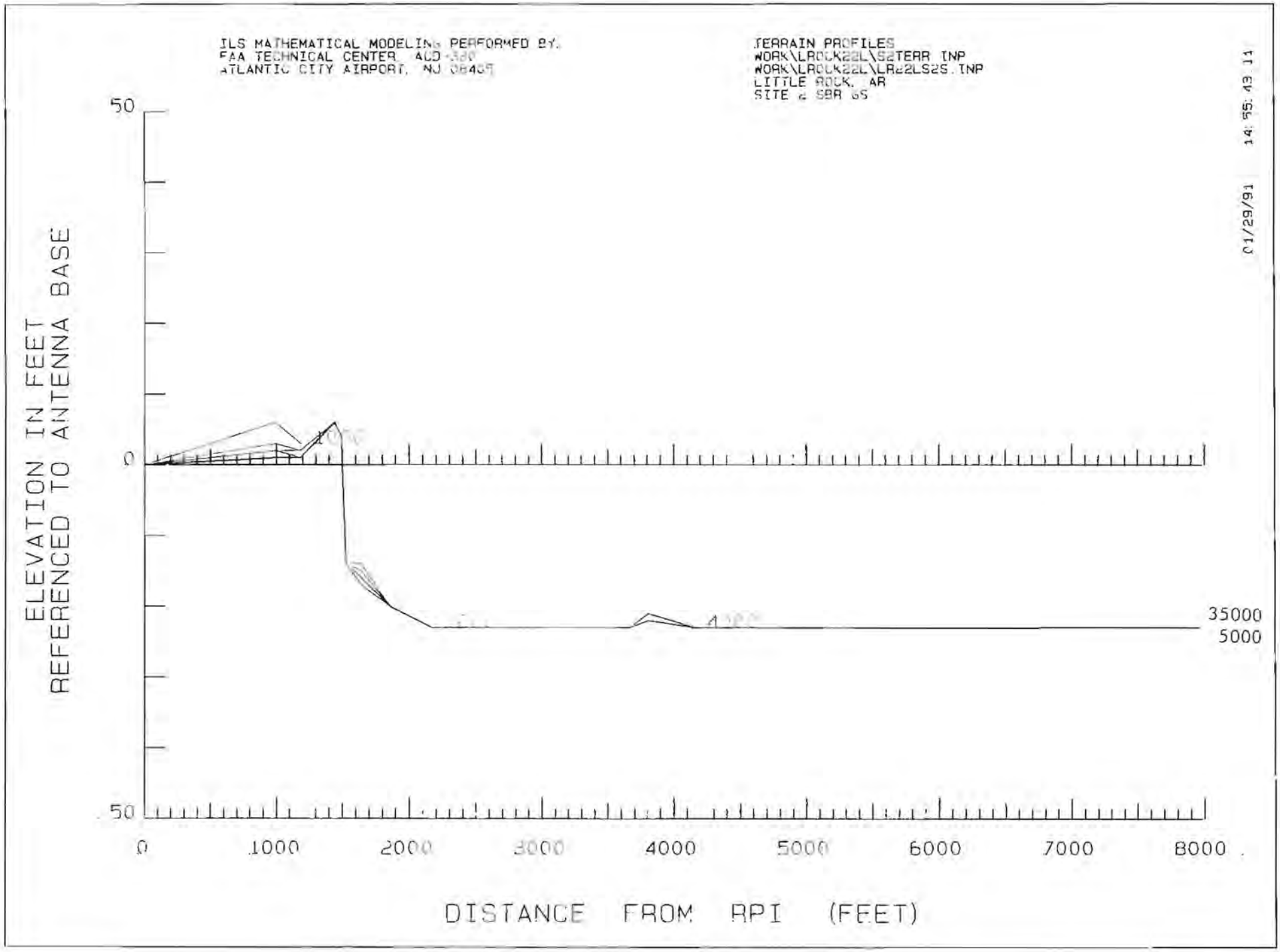

FIGURE 3. LITTLE ROCK RUNWAY 22L, SITE 2 TERRAIN PROFILE

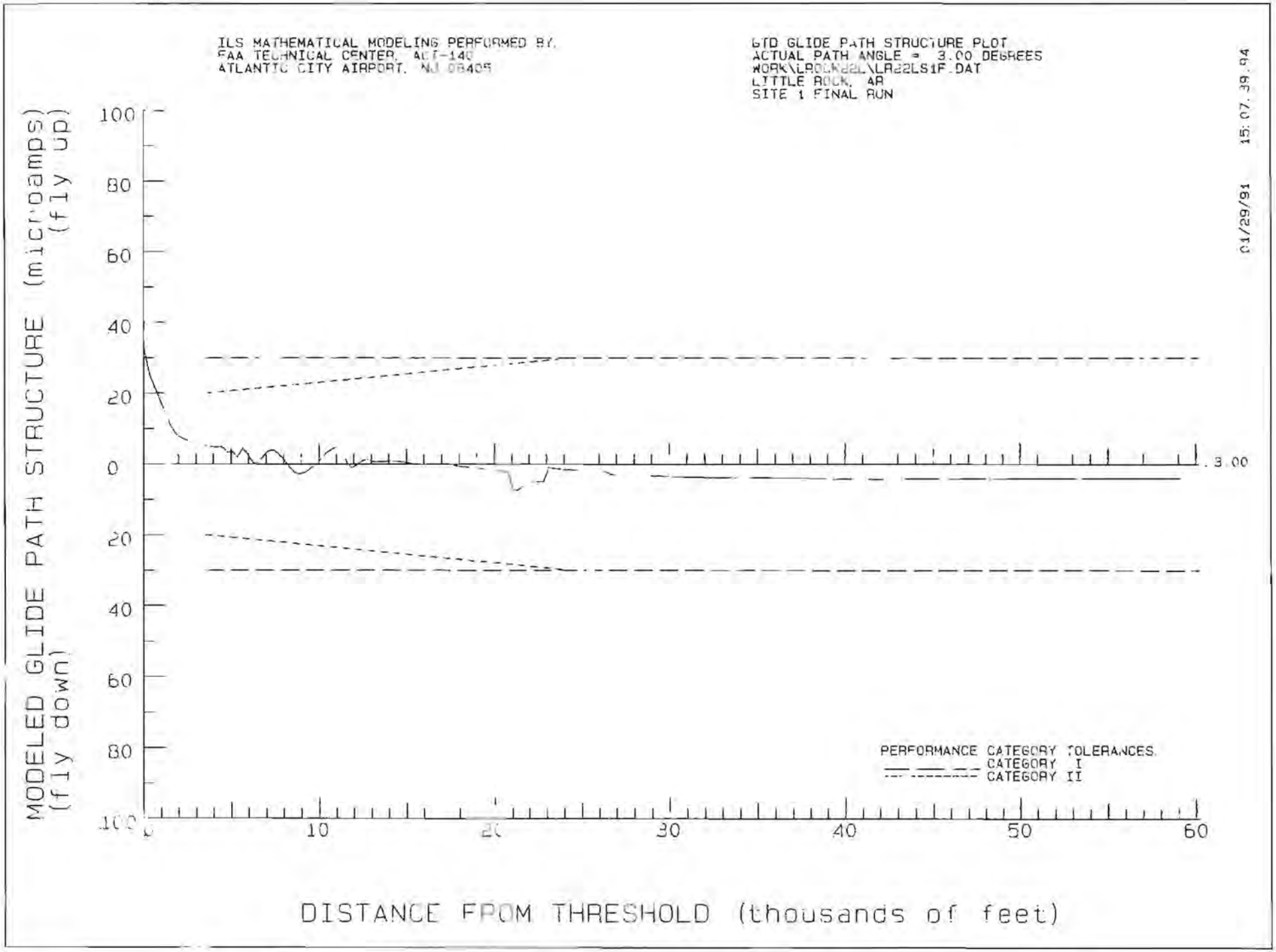

FIGURE 4. MODELED PATH STRUCTURE, LITTLE ROCK RUNWAY 22L, SIDEBAND REFERENCE SYSTEM, PROPOSED SITE 1

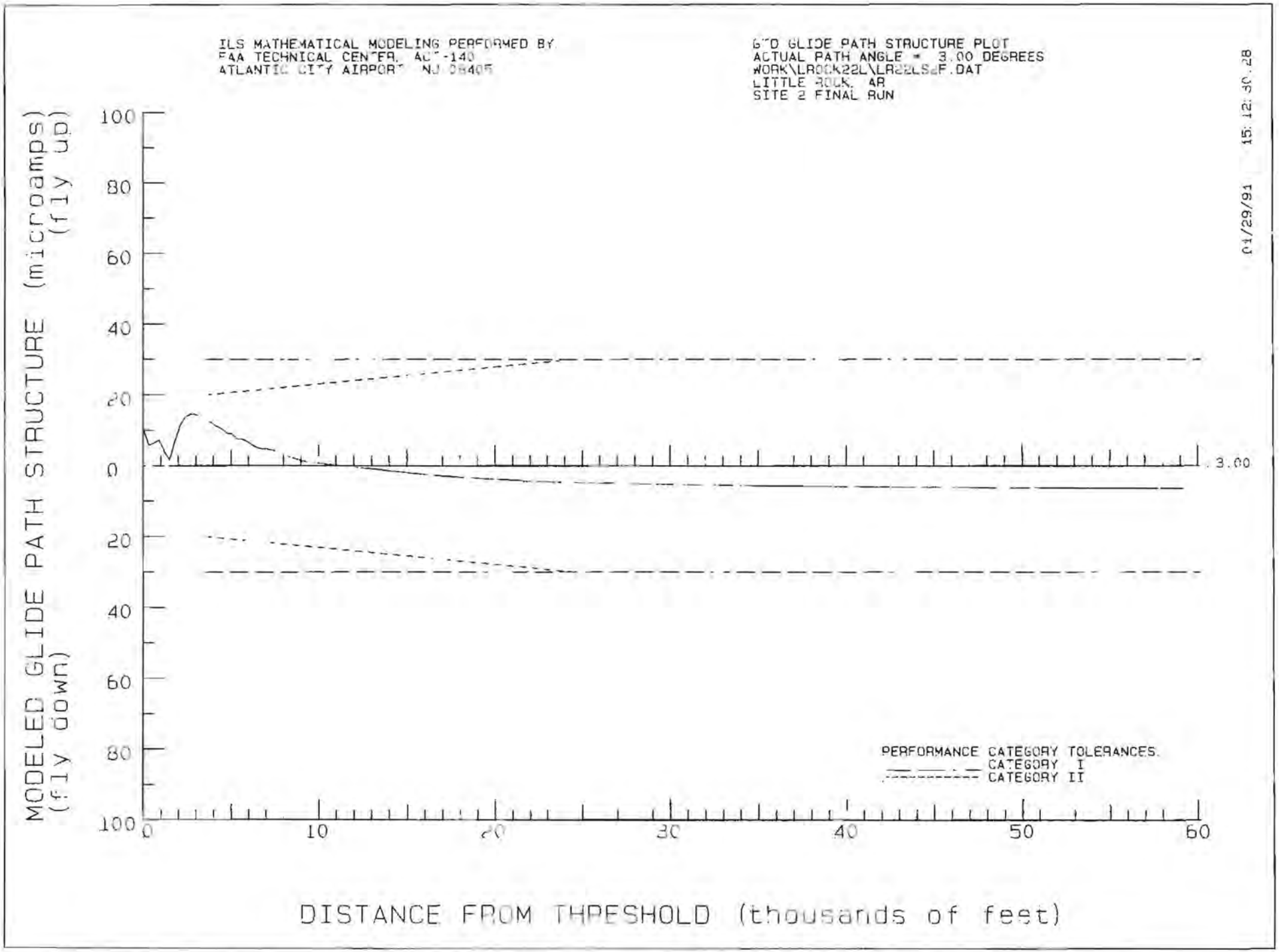

FIGURE 5. MODELED PATH STRUCTURE, LITTLE ROCK RUNWAY 22L, SIDEBAND REFERENCE SYSTEM, PROPOSED SITE 2

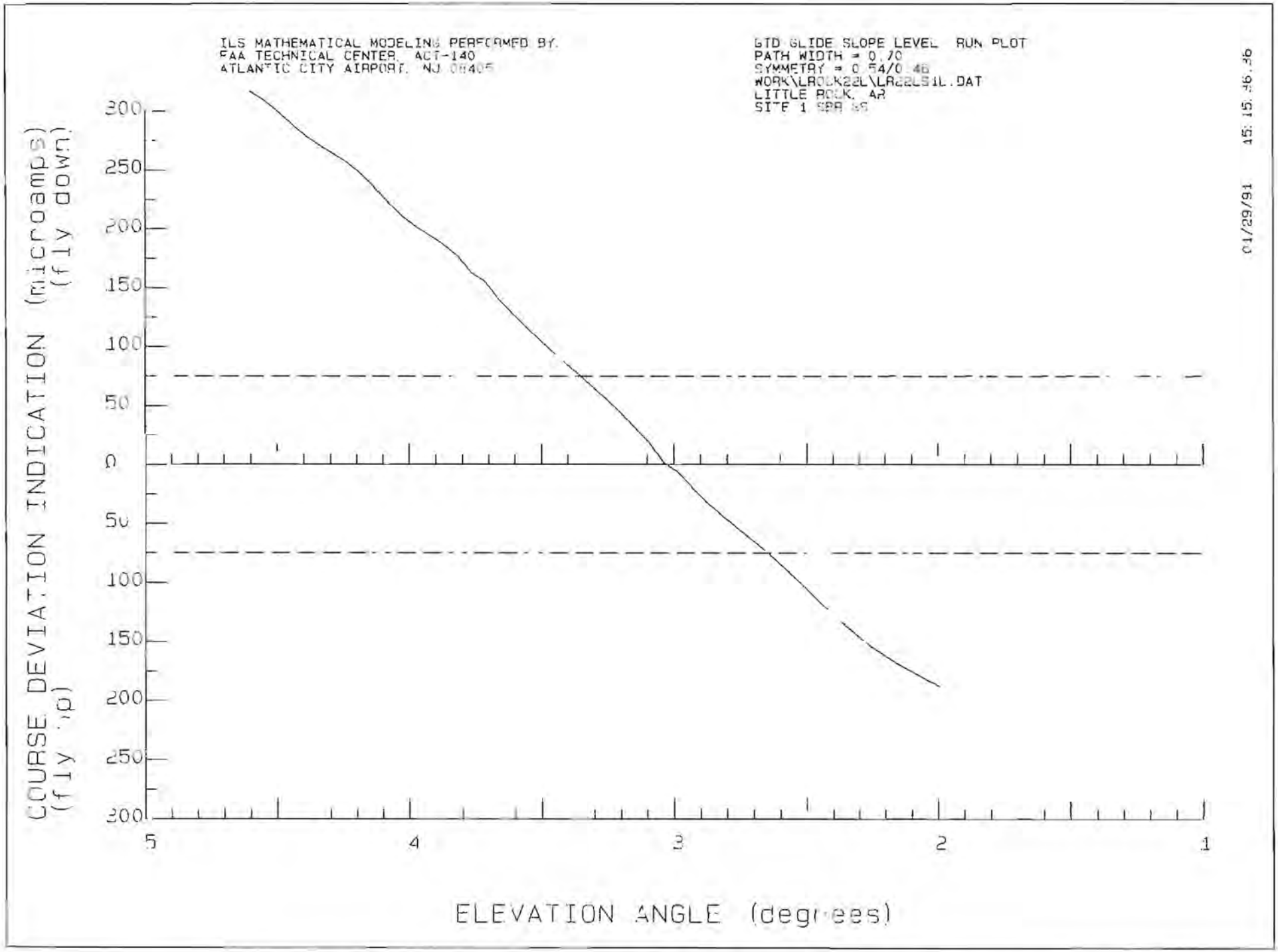

FIGURE 6. MODELED LEVEL RUN, LITTLE ROCK RUNWAY 22L, SIDEBAND REFERENCE SYSTEM, PROPOSED SITE 1

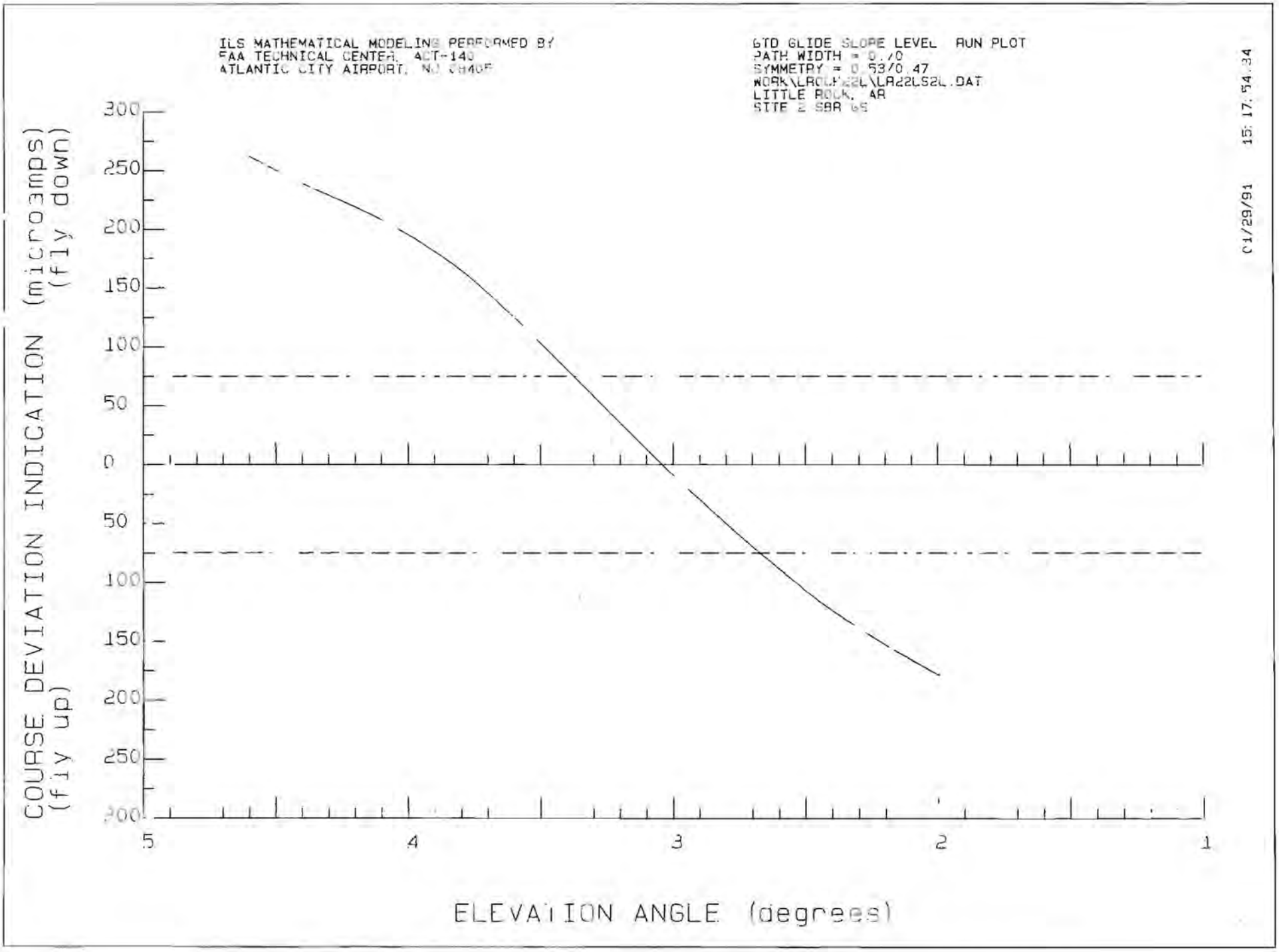

FIGURE 7. MODELED LEVEL RUN, LITTLE ROCK RUNWAY 22L, SIDEBAND REFERENCE SYSTEM, PROPOSED SITE 2