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Distribution:
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Sandia National Laboratories
Albuquerque, New Mexico 87185

December 22, 1983

M. J. Wise
Repository Projects Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, MD 20910

Dear Ms. Wise:

Enclosed please find the results you requested of the thermal analysis for repositories in various geologic media. An additional copy was mailed to you via Federal Express yesterday (12/21/83). We hope you find this information useful.

Please contact us with any questions you have regarding this analysis.

Sincerely,

N. R. Ortiz, Manager
Nuclear Fuel Cycle Systems Safety
Department 6430

NRO:6430:jm

Enclosure

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The purpose of this analysis is to estimate the temperature rise around a high-level waste repository for various geologic media. This information could be used for the definition of a thermally "disturbed zone".

A typical repository would have an areal extent of $4x10^6 m^2$ with a height of only about 10 meters. In addition, the location of the repository would generally be between 500 meters and 1100 meters below the surface. Therefore, for the region above and within the boundary of the repository, the thermal field can be reasonably approximated by that produced by a planar heat source of infinite areal extent. We have assumed a 0^oC ambient background temperature within the entire rock mass and a 0^oC boundary condition at the surface. The temperatures calculated therefore represent the increases in temperature generated by the repository.

For our analysis, the medium is assumed to be homogeneous with constant thermophysical properties. To account for heterogeneities in the rock mass and variations in thermal conductivity with temperature, thermal profiles were determined using at least two bounding values of thermal conductivity (K) for each medium.

An analytical solution was used for a time-varying planar heat source located in a semi-infinite region. This was done by integrating the solution for the temperature field produced by an instantaneous heat source. For our analysis, the heat source was considered as piecewise linear decaying. The solution provides a time dependent temperature profile at any location around the planar source. The isotherms thus produced are horizontal lines parallel to the repository plane.

Both high-level waste and spent-fuel waste are considered. A 60kw/acre thermal loading is used for HLW, and a 30kw/acre loading is used for spent-fuel.

The parameters used for the analysis are summarized in Table 1. The results of the increases in temperature calculated for various locations above the repository are shown as a function of time for basalt, salt and tuff (Figure 1-12). Separate results for each value of thermal conductivity (K) are shown.

These data could be used to determine a thermally "disturbed zone". For example, if the "disturbed zone" is defined as that region around the repository experiencing a 10^oC rise in the surrounding media, the disturbed zone would be located at the distances indicated in Table 2.

To justify the use of this analysis, several comparison runs were performed at various distances from the heat source to compare with the thermal output from SWIFT [1]. For this comparison, a HLW thermal loading of 60kw/acre for an 1100-acre site was used. Figures 13 through 15 show three of these comparisons at distances of 0, 50, and 125 feet from the source. These figures indicate good correlation between the analytic and SWIFT thermal treatments. Branstetter et al. [2] performed thermal calculation for a HLW repository in bedded salt. In their analysis, the repository was assumed to be of rectangular dimension 2427m by 1828m, having a height of 30m. The region being modeled consisted of layers of sandstone, shale, and salt. Heat output of the buried waste was assumed to be 60kw/acre. A thermal analysis code ADINAT [3] was used to calculate the temperature field surrounding the repository.

Table 3 shows the comparison between Branstetter's results and the analytical solution at three locations above the center of the repository for times of 300 years and 1000 years. It can be seen that good agreement is obtained between the two analyses.

Table 1

INPUT PARAMETERS

MEDIUM	ROCK THERMAL CONDUCTIVITY (BTU/DAY ft ^{o}F)	ROCK DENSITY (lb/ft^3)	ROCK SPECIFIC HEAT (BTU/lb ^{o}F)	DEPTH OF REPOSITORY (ft)
BASALT	16.0 - 21.5	180.0	0.195	3609
SALT	56.4 - 84.0	133.0	0.210	2297
TUFF*	16.5 - 26.1	137.0	0.203	1641

* Thermophysical parameters are appropriate for welded tuff.

Table 2

LOCATIONS OF $\Delta 10^{o}C$ ISOTHERM IN FEET ABOVE REPOSITORY

MEDIA	SALT[a]		BASALT[b]		TUFF[c]	
WASTE TYPE	HLW	SURF	HLW	SURF	HLW	SURF
TIME (YR)						
300	700	700	450-500	450	500-550	500-600
1000	650-850	1200	700-750	750-800	800-900	900-1000

[a] K = 56.4 - 84.0

[b] K = 16.0 - 21.5

[c] K = 16.5 - 26.1

Table 3

COMPARISON OF $\Delta T(^{o}C)$ BETWEEN BRANSTETTER'S ANALYSIS AND ANALYTICAL SOLUTION

DISTANCE ABOVE REPOSITORY	426 ft		725 ft		1325 ft	
	1*	2**	1	2	1	2
TIME (YR)						
300	16.8	15-17.5	5.6	10.5-11.5	0.2	2-4
1000	14.8	11.5-14	9.6	9.5-11.5	1.7	6-7

*1 Branstetter's result [2]

**2 Analytical solution for salt (HLW)

FIGURE 1

BASALT
HLW
K=15.95

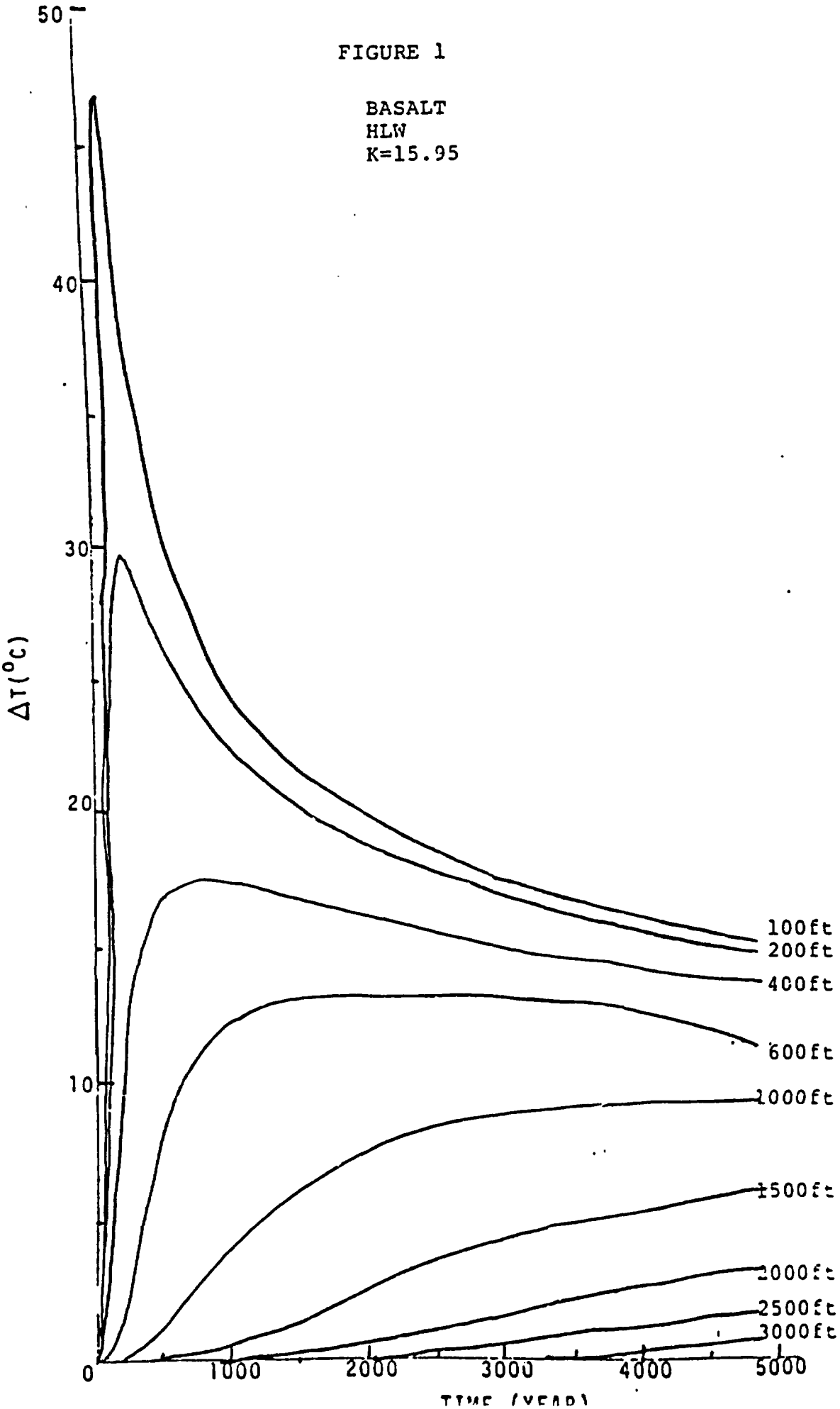
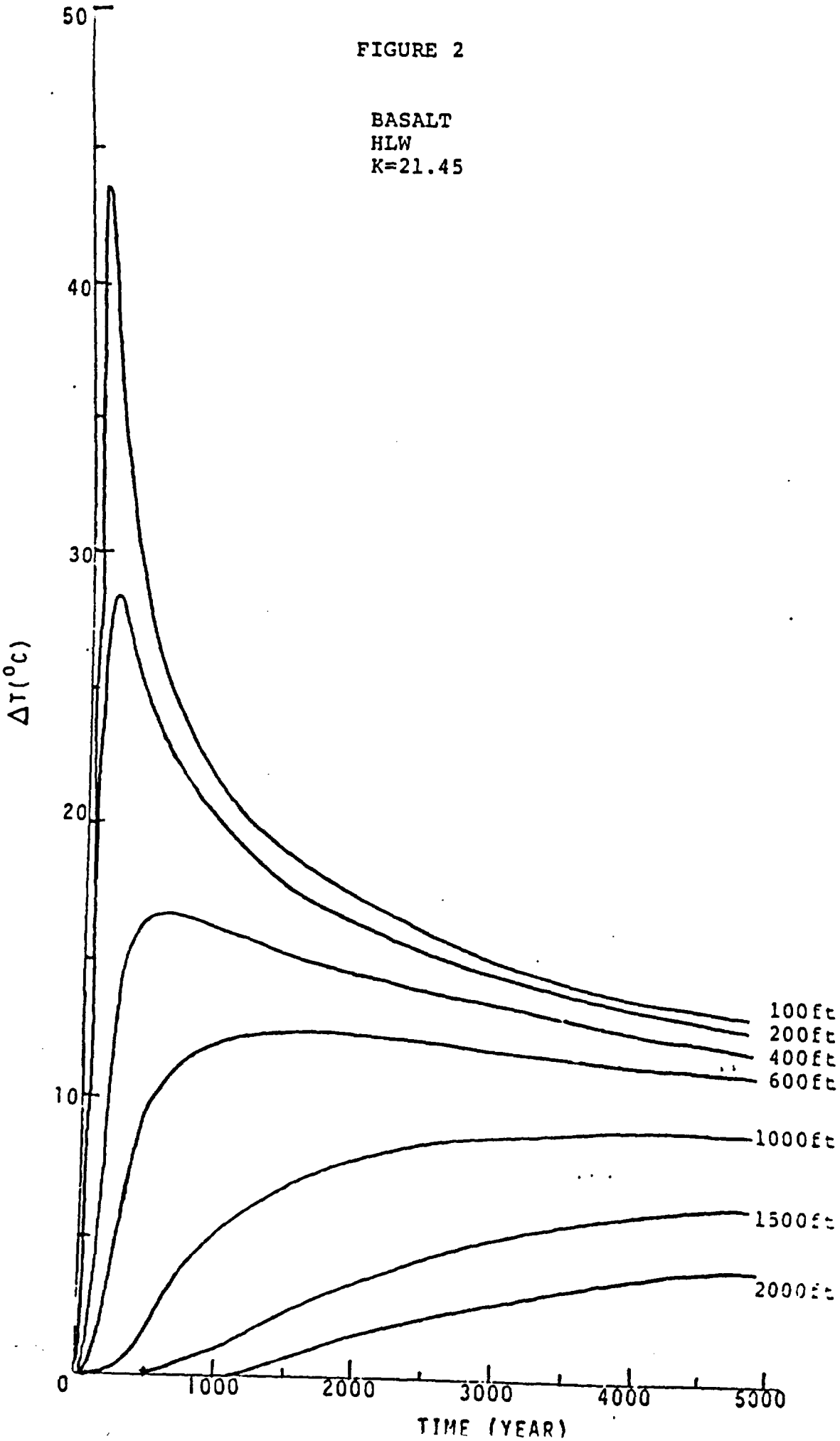


FIGURE 2

BASALT
HLW
K=21.45



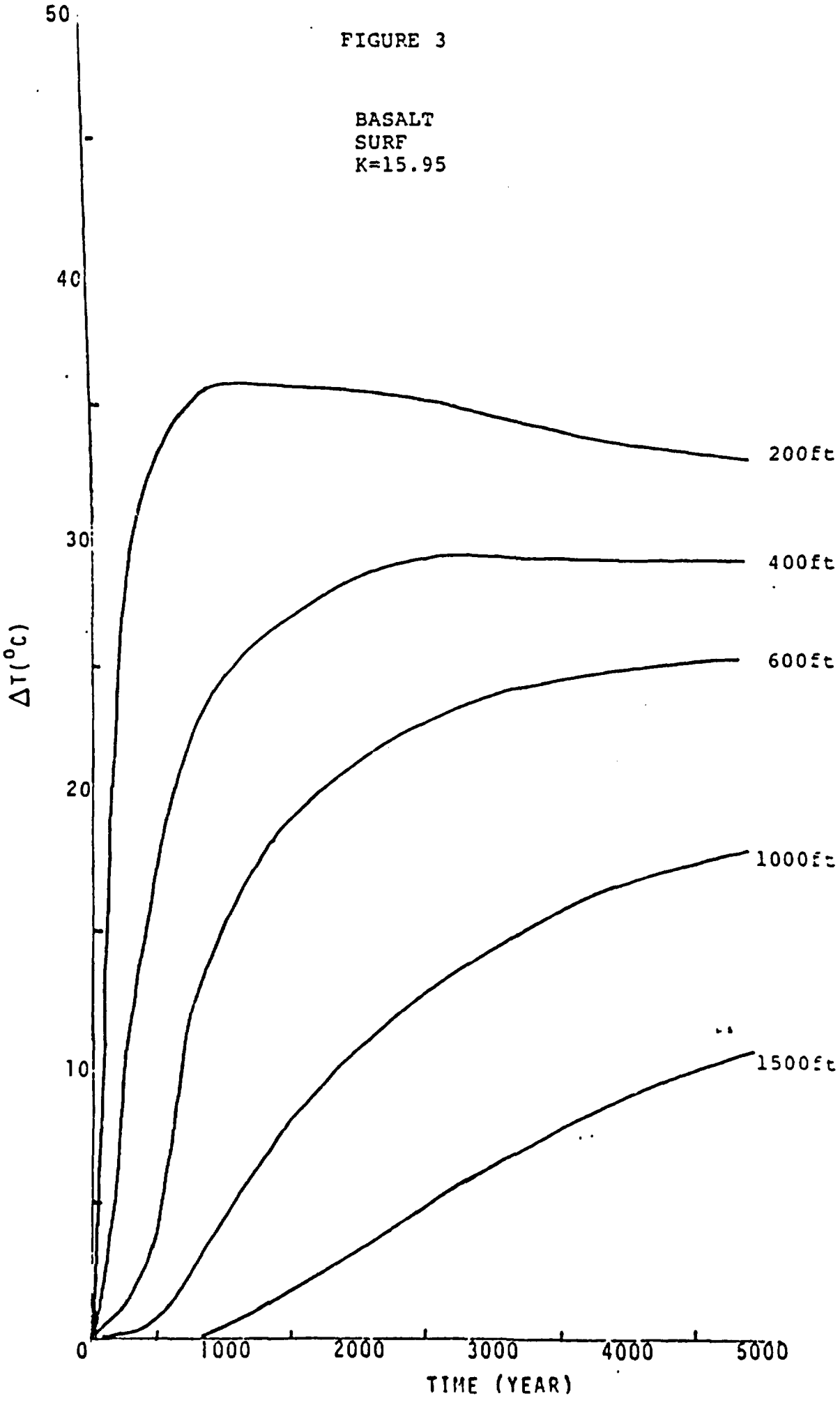


FIGURE 3
BASALT
SURF
K=15.95
50
40
30
20
10
0
ΔT(°C)
200ft
400ft
600ft
1000ft
1500ft
1000
2000
3000
4000
5000
TIME (YEAR)

FIGURE 4

BASALT
SURF
K=21.45

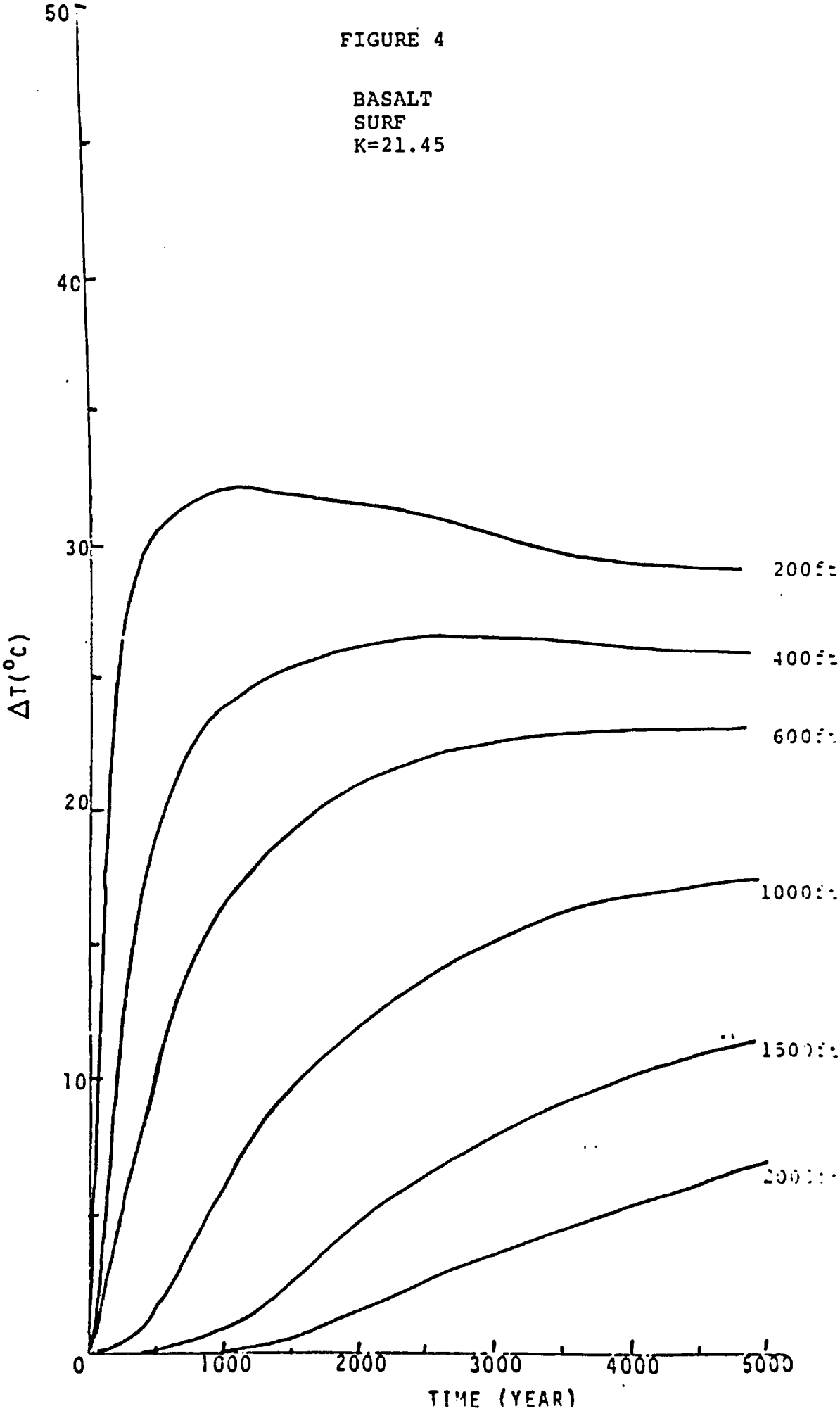


FIGURE 5

SALT
HLW
K=56.38

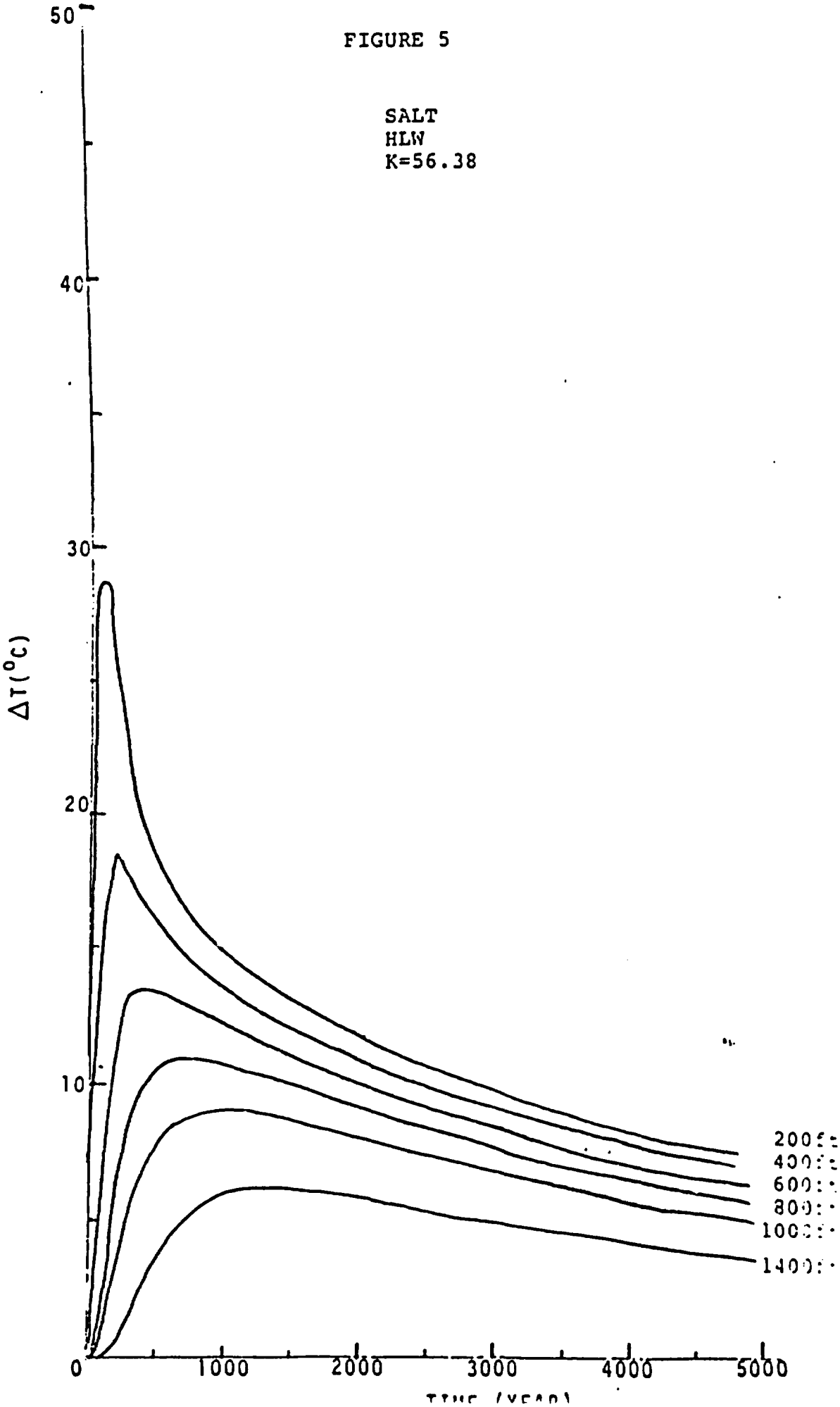


FIGURE 6

SALT
HLW
K=84.01

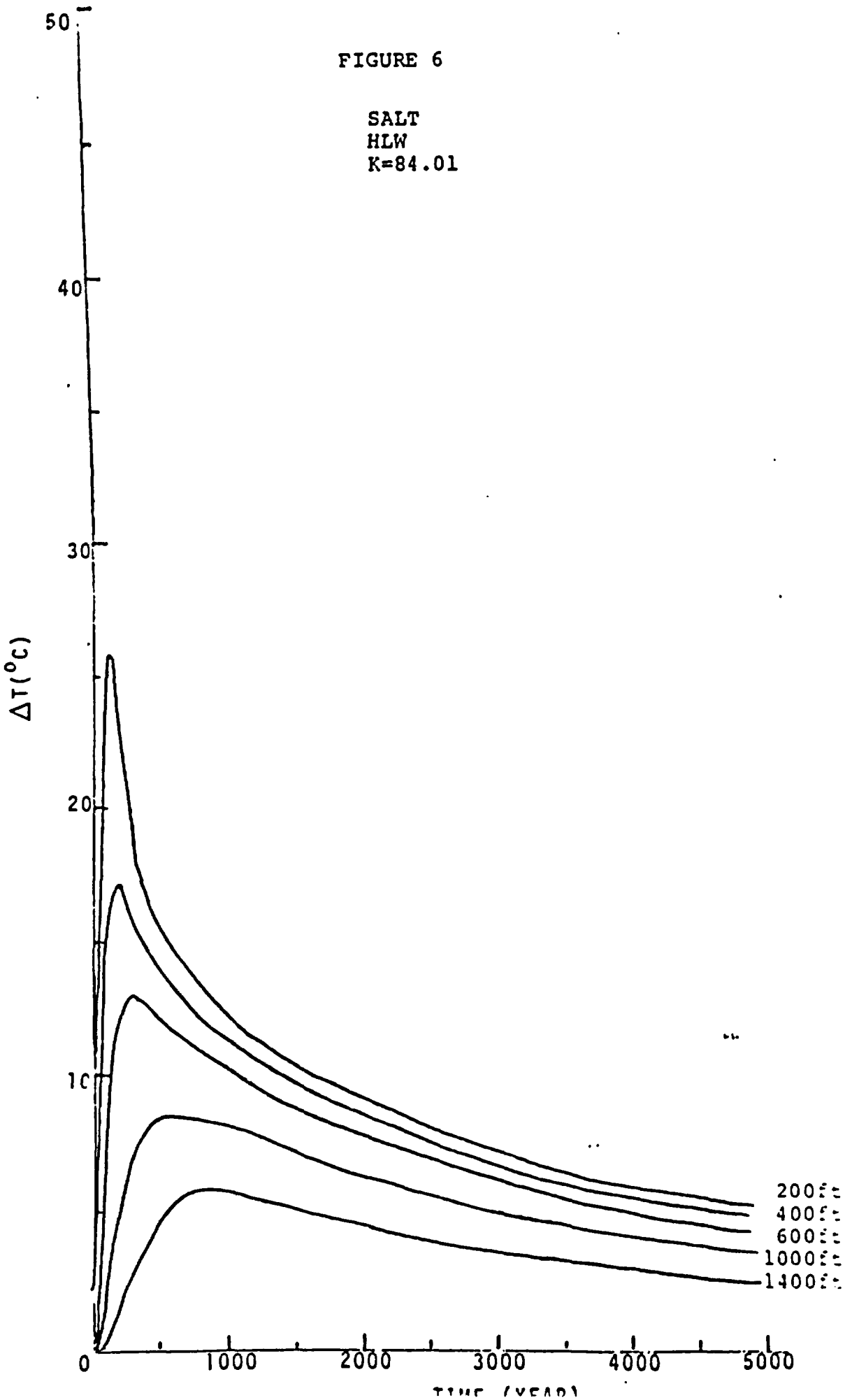
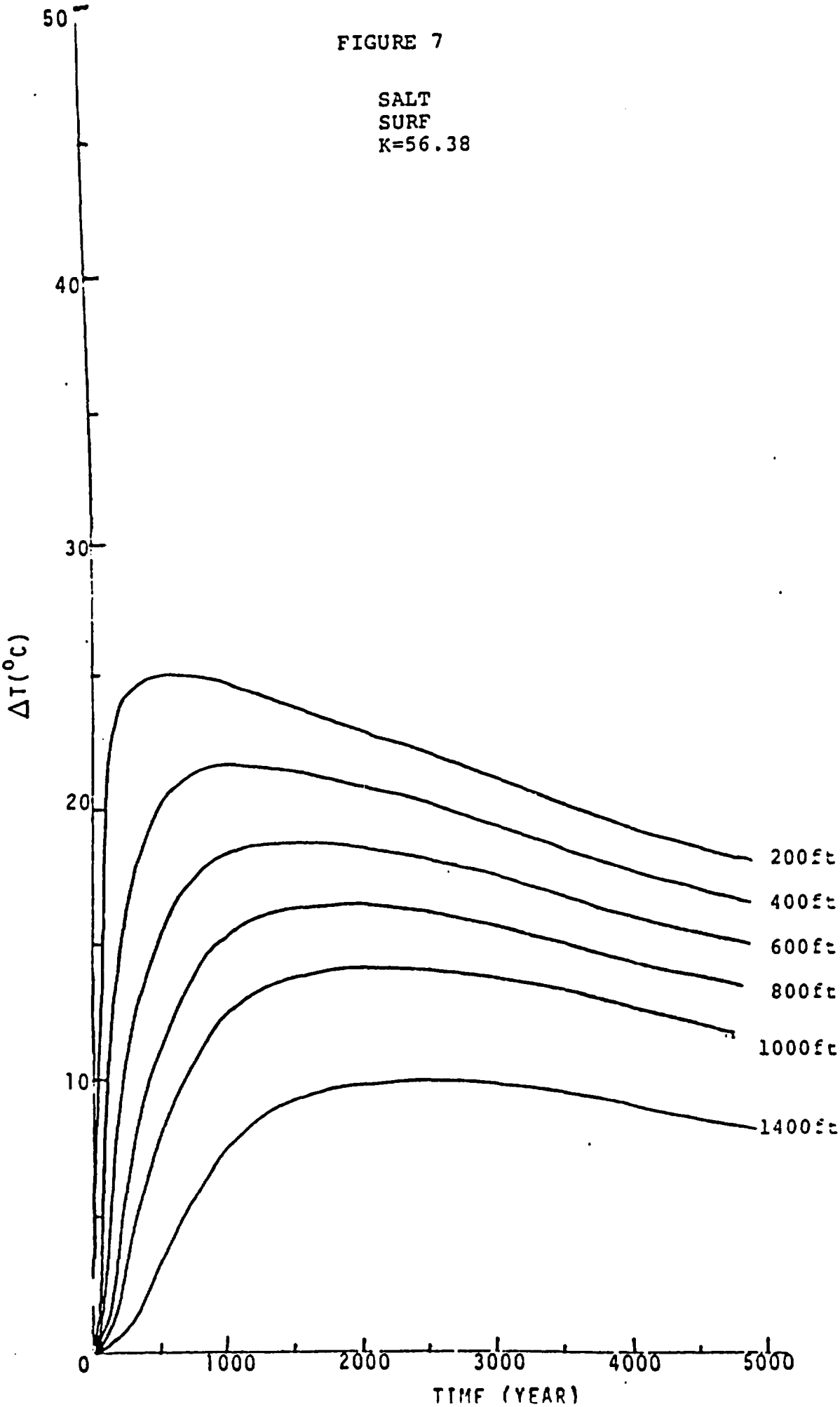


FIGURE 7


SALT
SURF
K=56.38
50
40
30
20
10
0
ΔT(°C)
1000
2000
3000
4000
5000
TIME (YEAR)
200ft
400ft
600ft
800ft
1000ft
1400ft

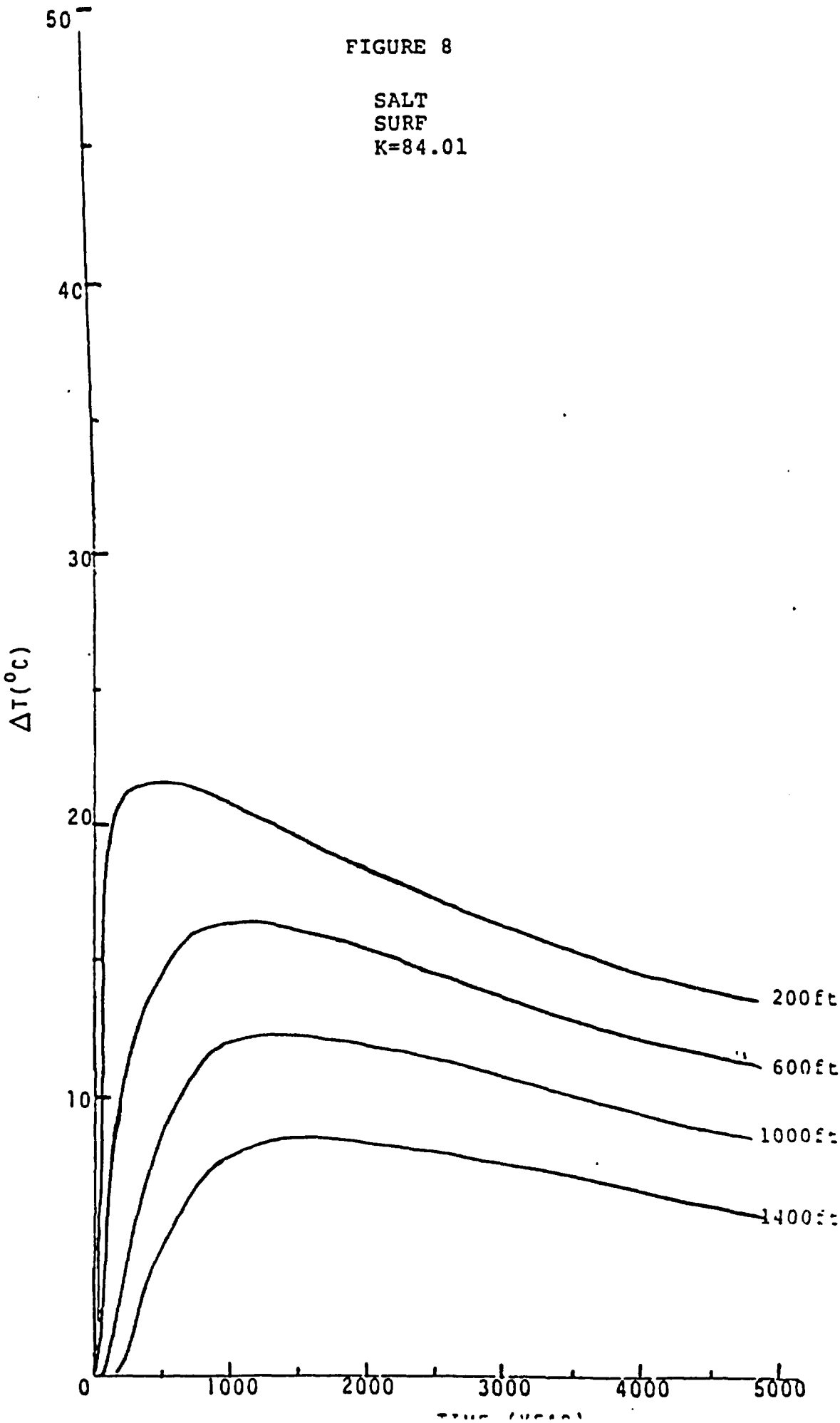


FIGURE 8
SALT
SURF
K=84.01
50
40
30
20
10
0
ΔT(°C)
1000
2000
3000
4000
5000
200ft
600ft
1000ft
1400ft

FIGURE 9

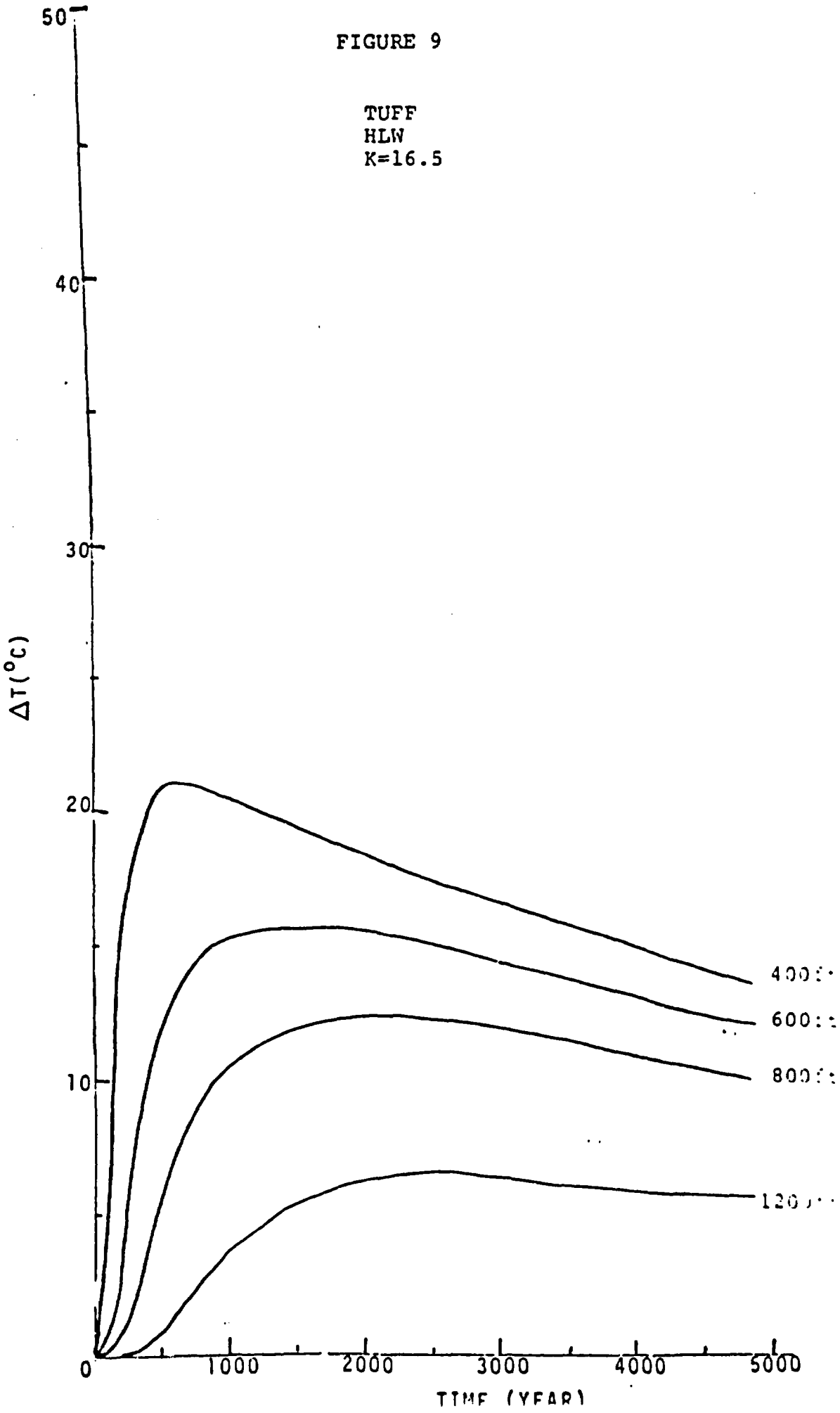
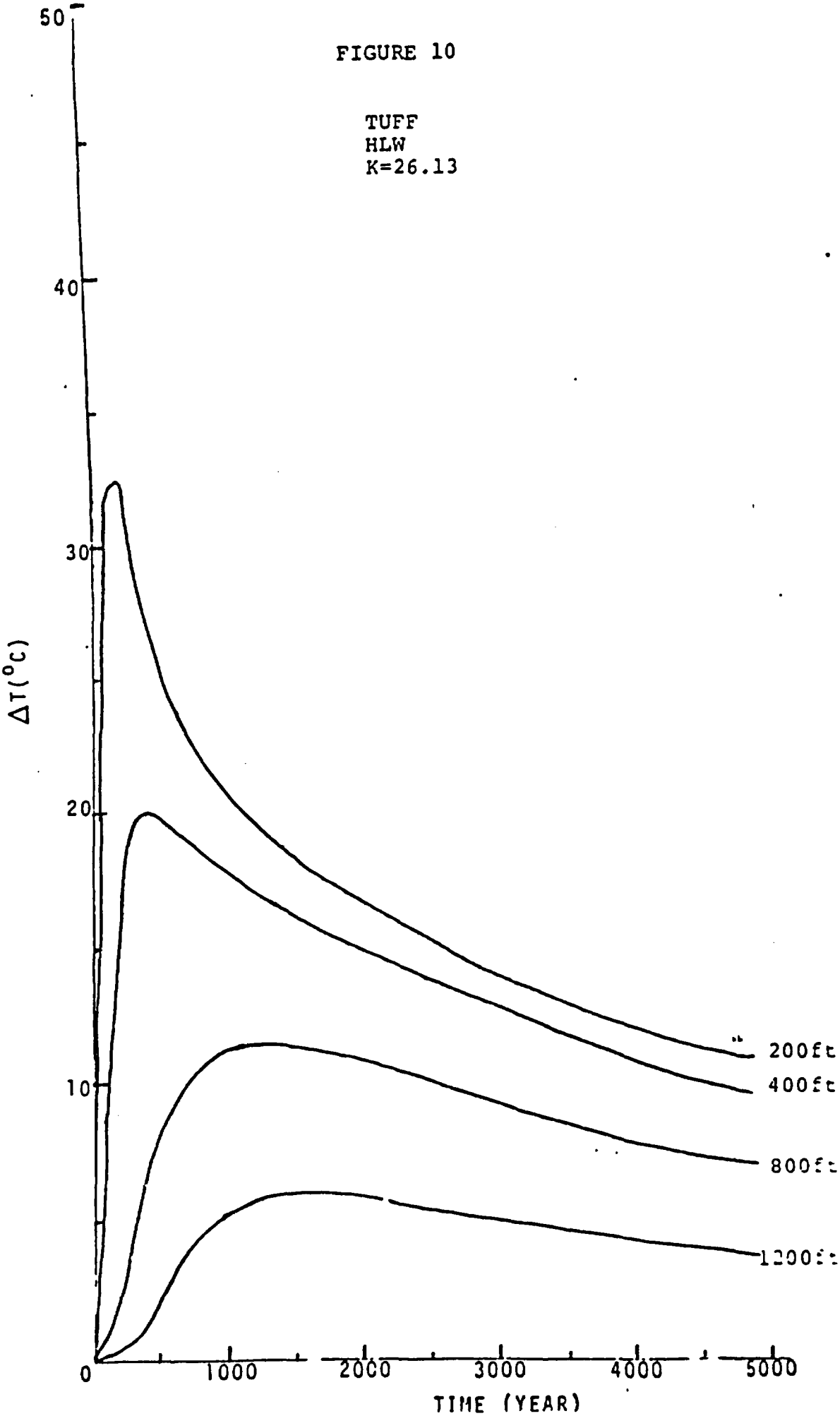

TUFF
HLW
K=16.5
50
40
30
20
10
0
ΔT(°C)
1000
2000
3000
4000
5000
TIME (YEAR)

FIGURE 10


TUFF
HLW
K=26.13
50
40
30
20
10
0
ΔT(°C)
1000
2000
3000
4000
5000
TIME (YEAR)
200ft
400ft
800ft
1200ft

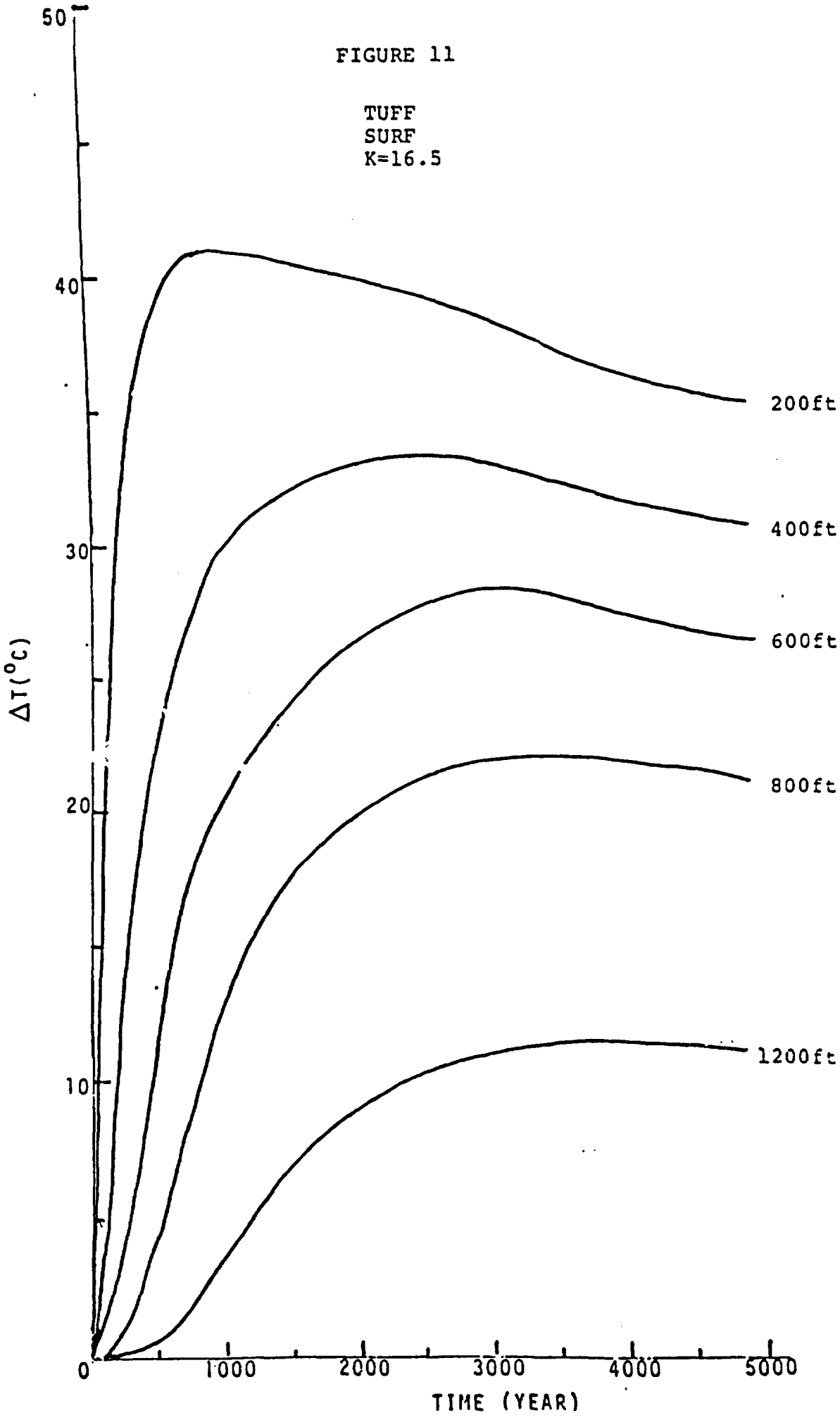


FIGURE 11
TUFF
SURF
K=16.5
50
40
30
20
10
0
ΔT(°C)
200ft
400ft
600ft
800ft
1200ft
1000
2000
3000
4000
5000
TIME (YEAR)

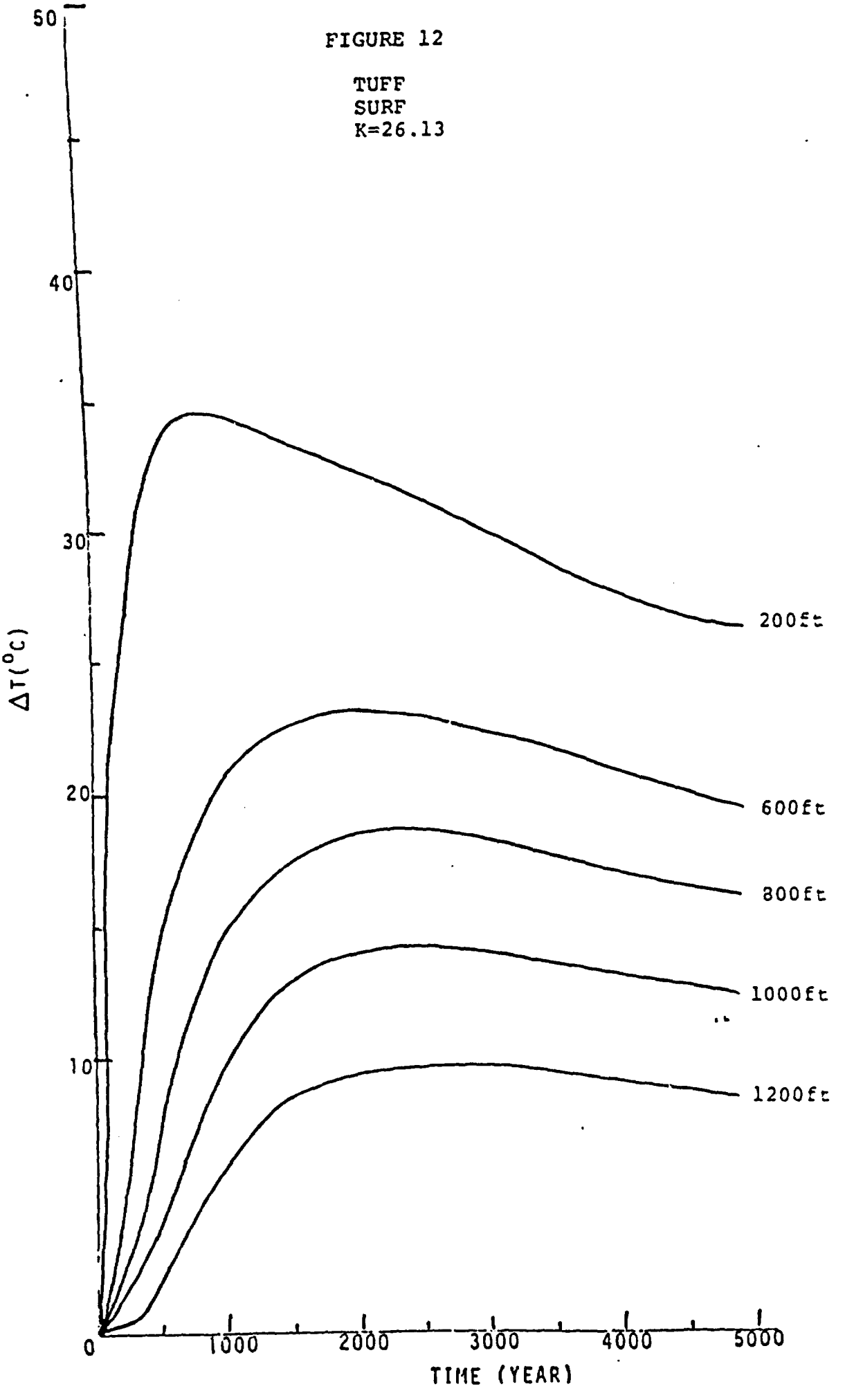


FIGURE 12
TUFF
SURF
K=26.13
50
40
30
20
10
0
ΔT(°C)
200ft
600ft
800ft
1000ft
1200ft
1000
2000
3000
4000
5000
TIME (YEAR)

FIGURE 13

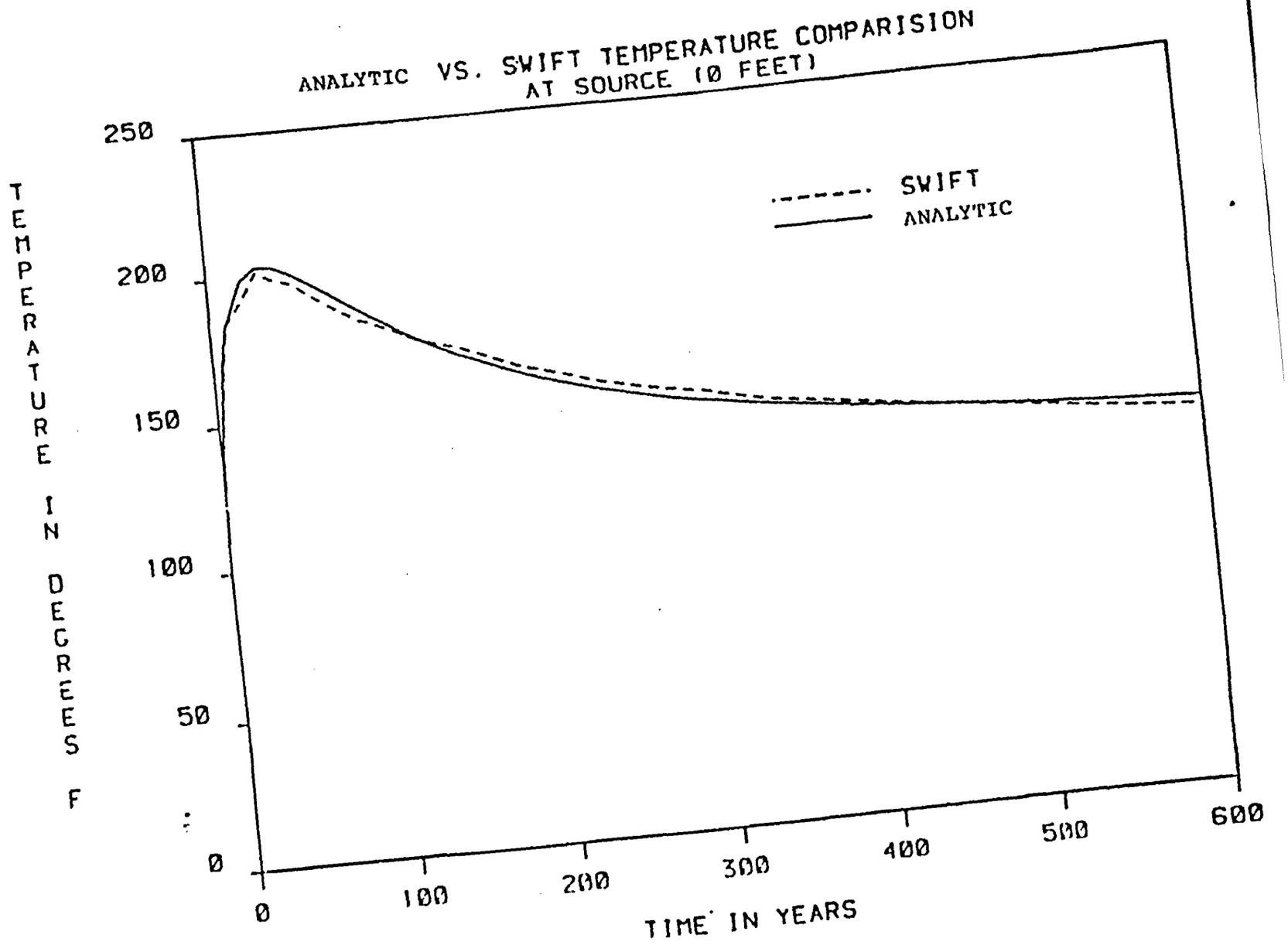

ANALYTIC VS. SWIFT TEMPERATURE COMPARISION
AT SOURCE (0 FEET)
SWIFT
ANALYTIC
TEMPERATURE IN DEGREES F
250
200
150
100
50
0
0
100
200
300
400
500
600
TIME IN YEARS

FIGURE 14

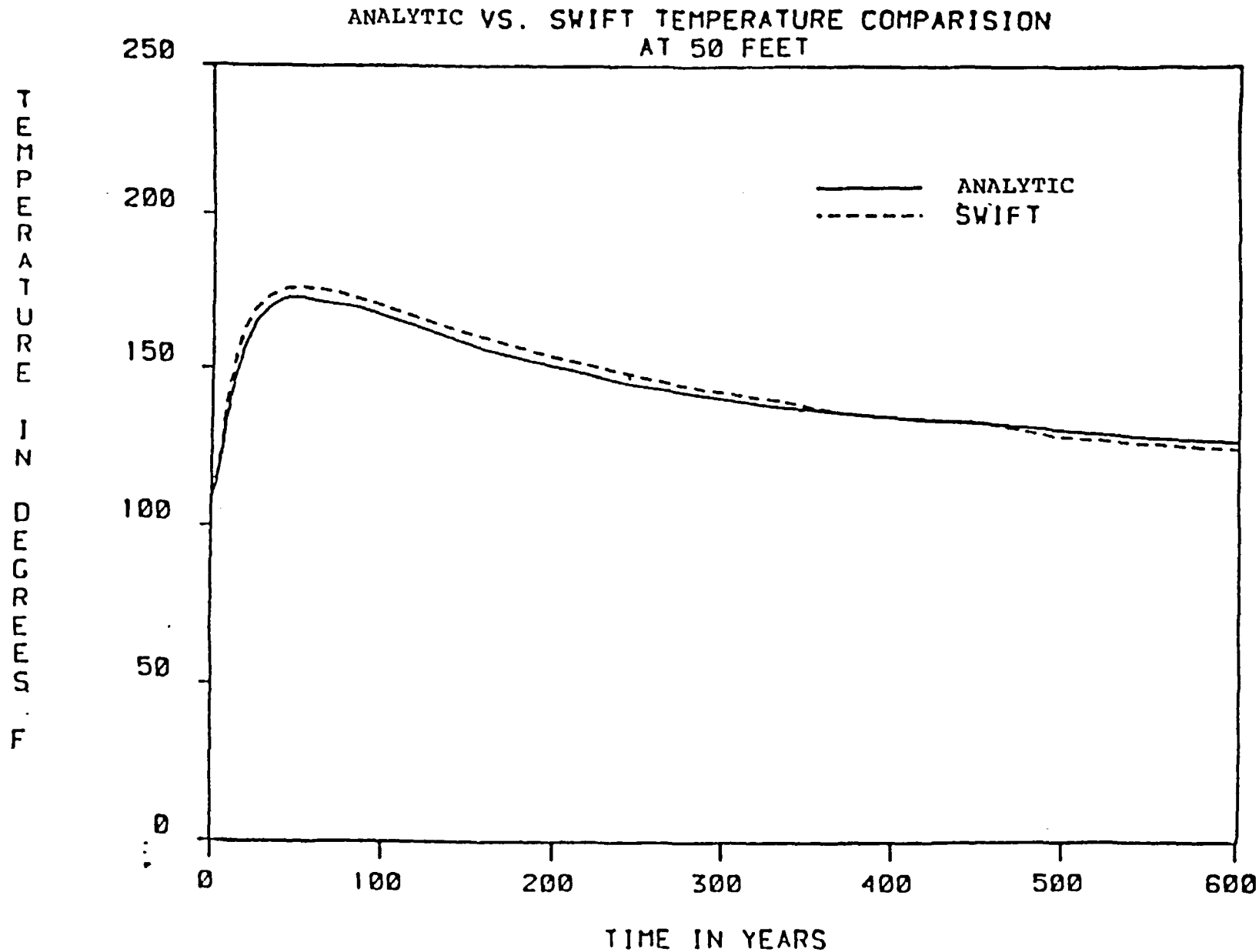
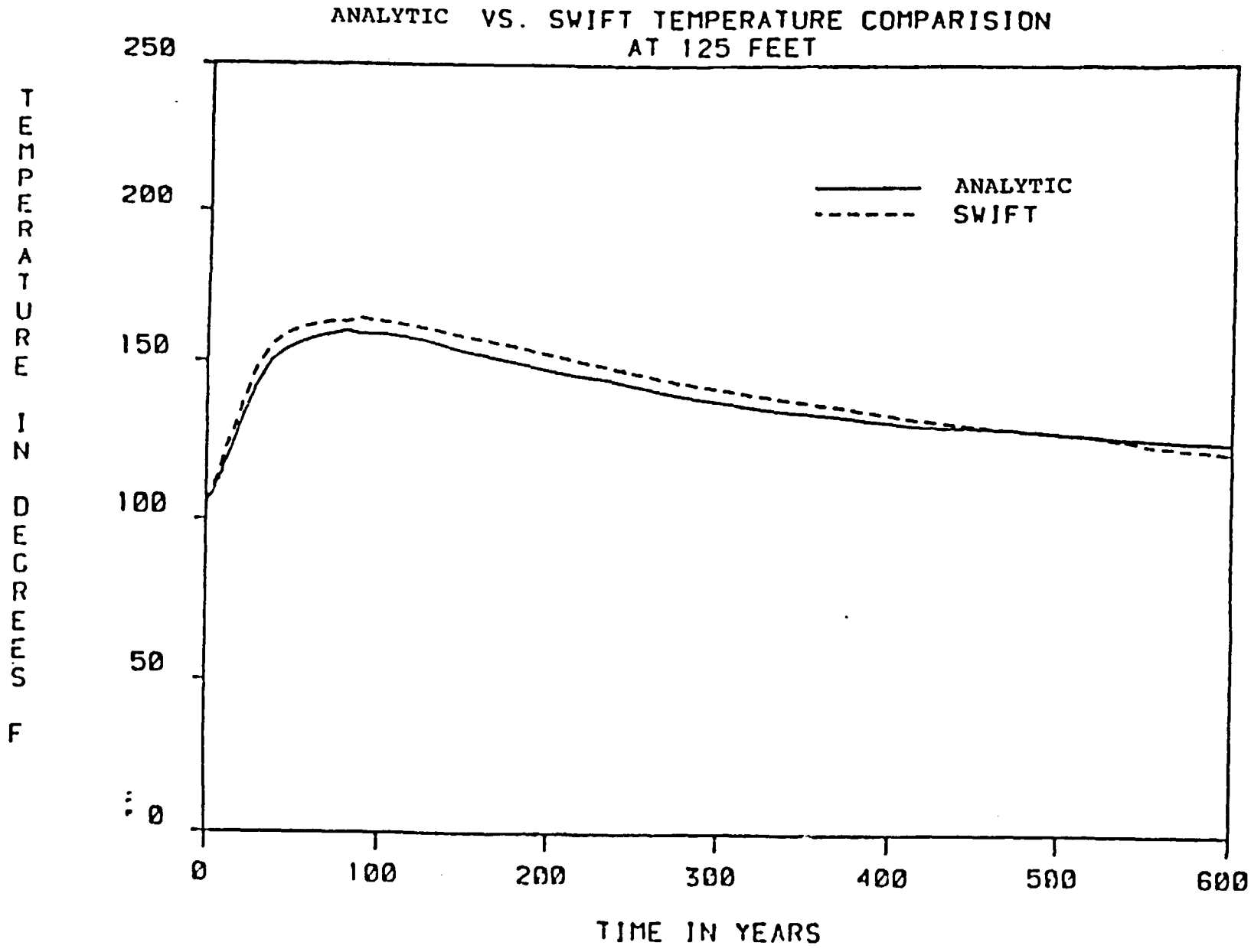

ANALYTIC VS. SWIFT TEMPERATURE COMPARISION
AT 50 FEET
TEMPERATURE IN DEGREES F
250
200
150
100
50
0
0
100
200
300
400
500
600
TIME IN YEARS
ANALYTIC
SWIFT

FIGURE 15


ANALYTIC VS. SWIFT TEMPERATURE COMPARISION
AT 125 FEET
TEMPERATURE IN DEGREES F
250
200
150
100
50
0
ANALYTIC
SWIFT
0
100
200
300
400
500
600
TIME IN YEARS

References

[1] Reeves, M., and Cranwell, R. M., "User's Manual for the Sandia Waste-Isoltion Flow and Transport Model (SWIFT)", NUREG/CR-2324, SAND81-2516, 1981.

[2] Branstetter, L. J., Krieg, R. D., and Stone, C. M., "A Method for Modeling Regional Scale Deformation and Stresses Around Radioactive Waste Depositories in Bedded Salt," NUREG/CR-2339, SAND81-0237, 1981.

[3] Klaus-Jurgen Bathe, "ADINAT: A Finite Element Program for Automatic Dynamic Incremental Nonlinear Analysis of Temperatures," Report No. 82448-5, Massachusetts Institute of Technology, Cambridge, Massachusetts, May 1977.