GEOPHYSICAL SURVEY FOR GROUND WATER EXPLORATION NEAR KEAUHOU-KONA ISLAND OF HAWAII

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GEOPHYSICAL SURVEY
FOR
GROUND WATER EXPLORATION
NEAR KEAUHOU-KONA
ISLAND OF HAWAII

Prepared For:

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(Our Project #90001)

Table of Contents

1.0 INTRODUCTION

This report contains the results of a geophysical survey to assist the evaluation of fresh water resources near Keauhou-Kona on the Island of Hawaii. The work was performed for Kamehameha Investment Corporation (KIC) between January 9 and January 24, 1990.

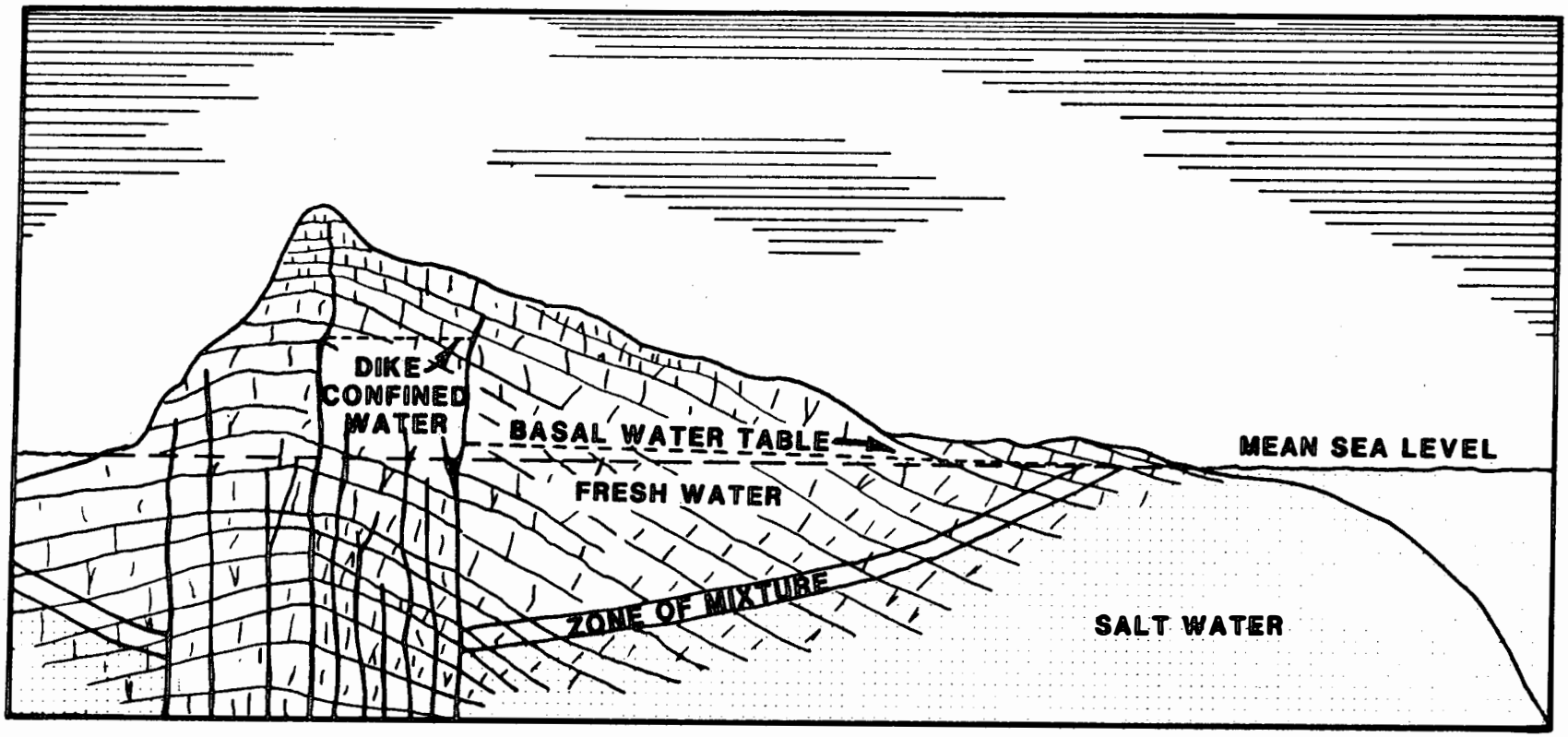
The objectives for the geophysical survey can be understood from the generalized hydrogeologic cross-section, typical of a volcanic island, shown in Figure 1-1. The volcanic rocks are generally highly permeable and rainfall rapidly infiltrates into the ground and migrates downward to the water table, and eventually discharges into the ocean. Fresh water in these settings is found in two environments.

1. Dike confined waters. Above the rift zone intrusive dikes originating from a magma source below can form ground water dams. Behind these natural dams significant quantities of ground water can be stored.

2. Basal fresh water. The high permeability of the volcanic rocks allow sea water to enter freely under the island, and a delicate balance is reached where a lens of fresh water floats on sea water. The Ghyben-Herzberg relation states that for every foot of fresh water head above sea level there will be 40 ft of fresh water below sea level.

The basal water resource was the focus in the investigations for KIC. The drilling depth to the basal fresh water lens rapidly increases with elevation, and the objective of geophysical surveys was to determine the drilling depth to fresh water and the thickness of the fresh water lens. The impetus for using geophysics is that the cost of a geophysical station is typically less than about one-five hundredth of the cost of drilling a well at elevations above 1,000 ft. Geophysical surveys are used to provide optimum locations for well placement and information about optimum well completion depths.

The geophysical method employed was time domain electromagnetic (TDEM) soundings. This method was selected because it has proven effective in prior surveys in similar settings in Hawaii.



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SCHEMATIC HYDRO-GEOLOGIC CROSS SECTION

Kamehameha Investment Corp.

PROJECT NO.: 90001 FIGURE 1-1

2.0 LOGISTICS AND DATA ACQUISITION

A brief description of the fundamentals of TDEM is given in Appendix A. Briefly, the logistics of a TDEM measurement consist of:

1. Laying out a square loop of insulated wire. A generator placed in the loop is used to drive current pulses through this closed loop. The dimensions of the square loops employed depend on the exploration depth requirements. The dimensions of the loops used for KIC varied from 100 ft by 100 ft (loop 2) to 1,500 ft by 1,500 ft (loops 8, 9 and 10).

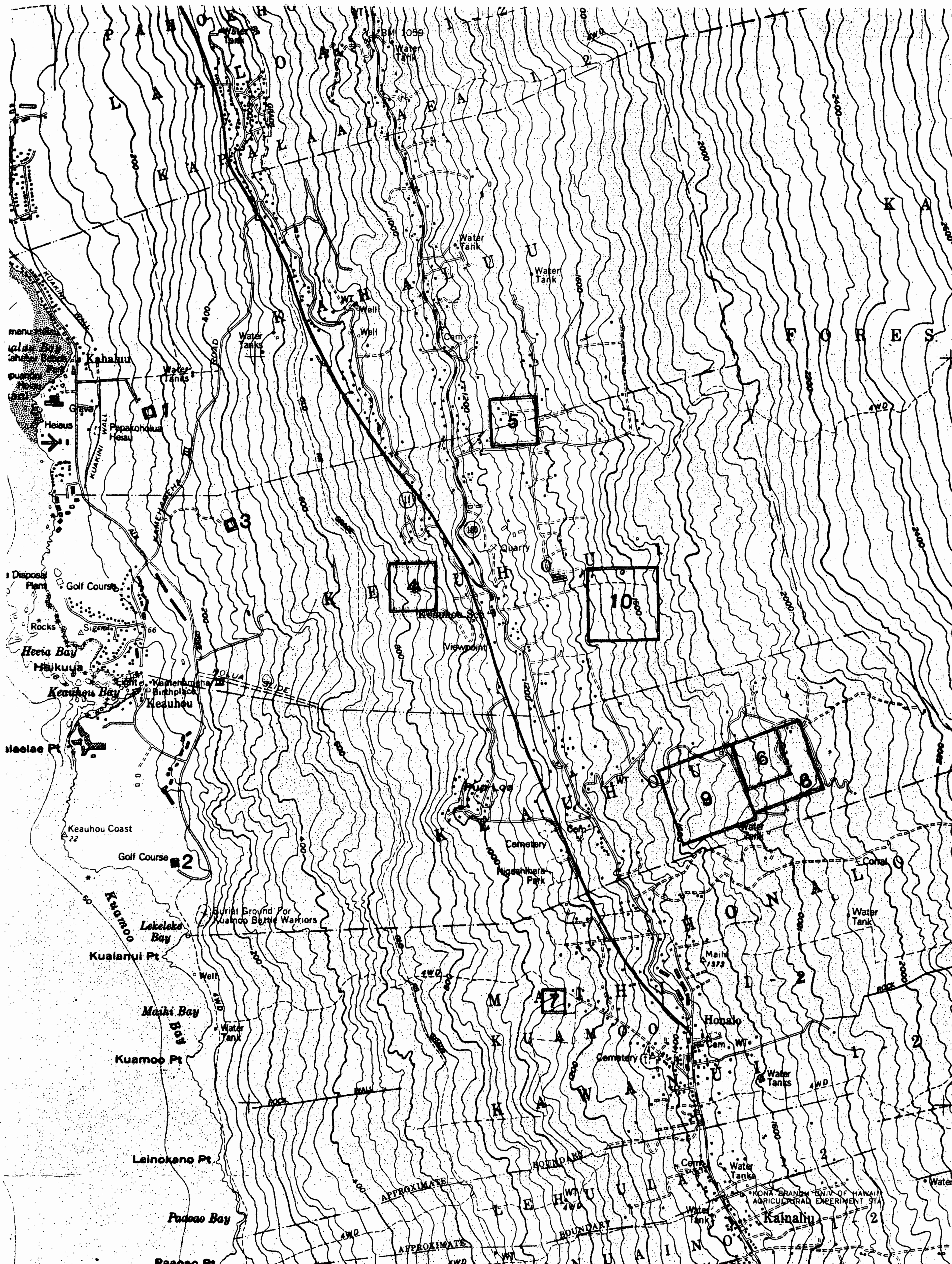
   Where possible, transmitter loop wires were positioned with at least one side along roads and trails. The terrain in many of the measurement locations is heavily vegetated and required clearing of a walking trail around the perimeter and to the center of the loop. Clearing of trails was conducted by KIC personnel.

2. Making a measurement with a receiver in the center of the loop. The data acquired at each station was stored in the field on a solid state data logger and subsequently dumped to a computer at the end of each field day. The data acquired at each station usually consisted of measurements at several receiver gain settings and transmitter frequencies in order to assure data quality and to obtain data over the largest time range possible. Data quality was generally good. At a few stations interference from power lines caused some deterioration of data quality.

During six days of field work 10 stations (soundings) were completed. A daily log of field activity is given in Table 2-1. Survey productivity was almost entirely determined by the effort required in laying out the transmitter loop wires in the heavily vegetated terrain. Figure 2-1 shows the location of the soundings conducted for KIC.

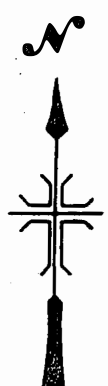
Table 2-1. Daily Log of Field Activities

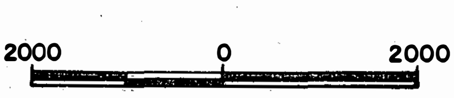
Date (1990)	Activity
January 8	Mobilization from Golden, CO to Kailua-Kona, Hawaii.
January 9	Meetings with KIC, KKRC and Tom Nance. Measurement loop 1 (near nursery, well). Measurement loop 2 (at end of Alii Drive)
January 10	Measurement loop 3 (on golf course near pond) Began clearing for loop 4 (Tanaka well).
January 11	Completed clearing for loop 4. Measurement loop 4. Measurement loop 5 (Donkey Mill Road, macadamia nut orchard).
January 12	Measurement loop 6 (approximately 1 mile East Higashihara Park).
January 13	Measurement loop 7 (approximately 1/2-mile west of Honalo). Locate areas for additional soundings.
January 14-19	KKRC employees position additional loops 8, 9 and 10.
January 22	Measurement loop 8 (approximately 1 mile E of Higashigara Park). Measurement loop 9 (approximately 1 mile E of Higashihara Park).
January 24	Measurement loop 10 (approximately 1/2-mile E of Keauhou School).
January 26-27	Demobilize from Kailua-Kona, Hawaii to Golden, CO.



POWERLINE INTERFERED WITH № 6, 7.

Kealakekua Quadrangle
Island of Hawaii





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TIME DOMAIN EM SURVEY
LOCATION MAP

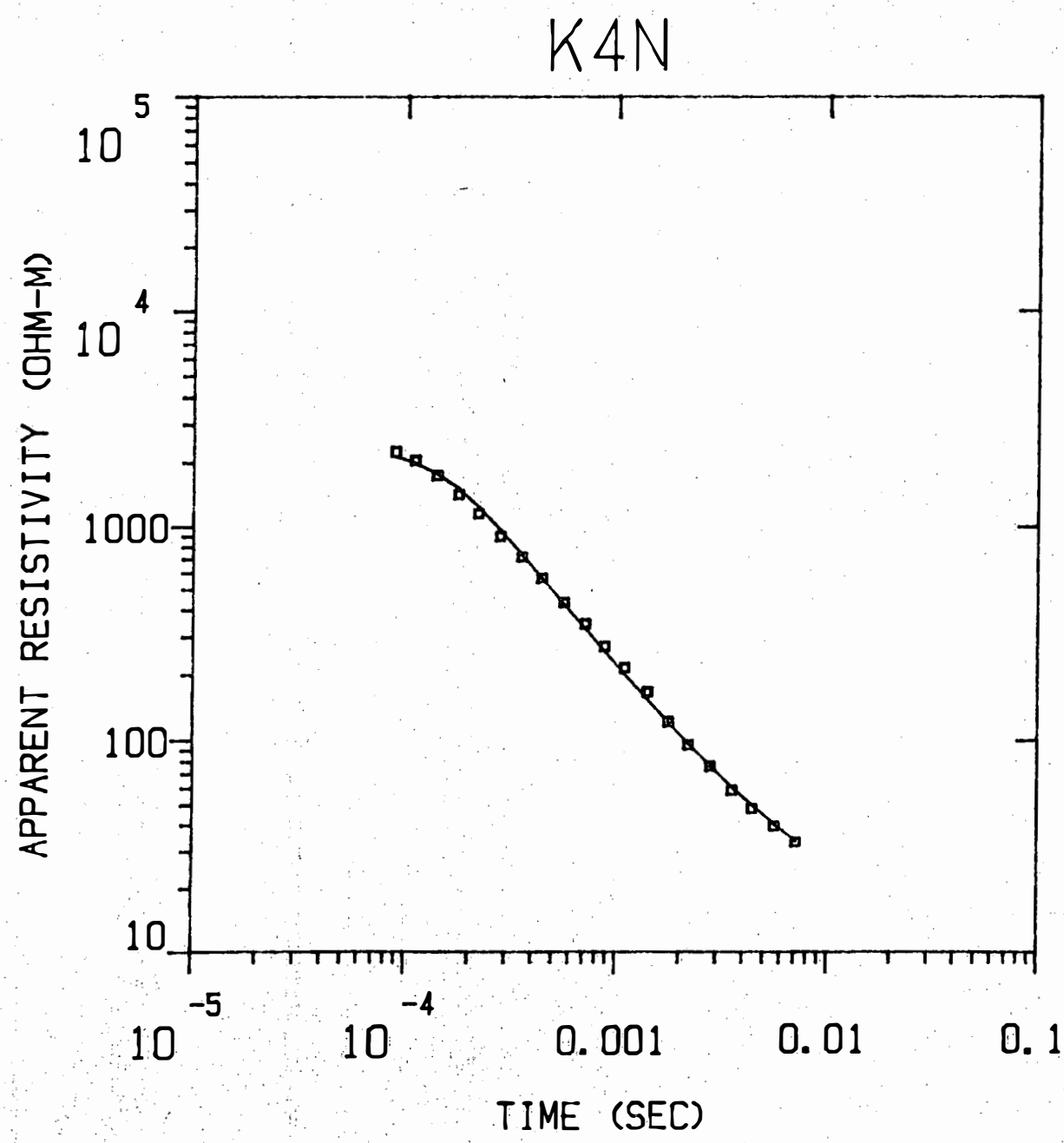
Kamehameha Investment Corp.

PROJECT NO.: 90001 **FIGURE 2-1**

3.0 DATA PROCESSING

The objective of data processing is to derive from the TDEM measurements the resistivity layering in the earth. The procedures of data processing are discussed in Appendix A. The results from data processing for each station are contained in Appendix B. A typical data set is given in Figures 3-1 and 3-2 for the station near the Tanaka well (loop #4). Figure 3-1 shows the measured data points (in terms of apparent resistivity) superimposed on a solid line. The solid line represents the computed behavior of the true resistivity layering shown on the right. It is evident that the computed behavior of the curve versus time closely corresponds to the measured behavior. Figure 3-2 lists in column 4 the error between measured and computed data in each time gate.

Figure 3-1 also shows that the resistivity layering in the upper 1,000 ft consists of two layers, - the first layer has a thickness of 285 m (934 ft) and a resistivity of 540 ohm-m, and the second layer has a resistivity of 4.10 ohm-m. At some other stations more than two layers of different resistivity were required to match the observed behavior.



MODEL:

540.
OHM-M

285. M

4.10
OHM-M

BLACKHAWK GEOSCIENCES, INC.

TANAKA WELL SOUNDING

Kamehameha Investment Corp.

PROJECT NO.: 90001 FIGURE 3-1

% ERROR: 7.31
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0
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K4N

FIGURE 3-2

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		256.0	840.0		
540.21	284.6	-28.6	-93.8	0.5	0.5
4.10					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.40E-03	1.66E+02	1.55E+02	7.260	
2	1.77E-03	1.21E+02	1.21E+02	0.250	
3	2.20E-03	9.51E+01	9.68E+01	-1.775	
4	2.80E-03	7.57E+01	7.65E+01	-1.106	
5	3.55E-03	5.84E+01	6.10E+01	-4.261	
6	4.43E-03	4.79E+01	5.01E+01	-4.261	
7	5.64E-03	3.95E+01	4.06E+01	-2.820	
8	7.13E-03	3.32E+01	3.35E+01	-1.061	
9	8.90E-05	2.25E+03	2.14E+03	5.153	
10	1.10E-04	2.05E+03	1.99E+03	2.947	
11	1.40E-04	1.74E+03	1.77E+03	-2.041	
12	1.77E-04	1.41E+03	1.51E+03	-6.539	
13	2.20E-04	1.15E+03	1.24E+03	-7.203	
14	2.80E-04	8.96E+02	9.63E+02	-6.934	
15	3.55E-04	7.13E+02	7.38E+02	-3.337	
16	4.43E-04	5.64E+02	5.67E+02	-0.391	
17	5.64E-04	4.33E+02	4.28E+02	1.342	
18	7.13E-04	3.45E+02	3.27E+02	5.323	
19	8.81E-04	2.70E+02	2.57E+02	4.961	
20	1.10E-03	2.16E+02	2.02E+02	6.964	
21	1.41E-03	1.66E+02	1.54E+02	8.291	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
CLHZ ARRAY, 21 DATA POINTS, RAMP: 200.0 MICROSEC, DATA: K4N
TANAKA WELL
BELOW SCHOOL
RMS LOG ERROR: 3.06E-02, ANTILOG YIELDS 7.3107 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	1.00		
P 2	0.00	1.00	
T 1	0.00	0.00	1.00
	P 1	P 2	T 1

4.0 INTERPRETATION RESULTS

4.1 GENERAL

The objective of KIC and its ground water consultants is not to obtain the resistivity layering of the subsurface, but to infer from the resistivities, information about the depth to salt water and the thickness of the basal fresh water lens. The translation of resistivity layering into hydrogeologic information is generally accomplished in two ways:

1. Using available knowledge about the relation between resistivity values and hydrogeology. For example, in the volcanic terrain of Hawaii, rocks saturated with sea water will have resistivities typically less than 5 ohm-m. On the other hand, dry volcanic rocks or rocks saturated with fresh water will have high resistivities (greater than 100 ohm-m). Generally, it is difficult to discriminate between fresh water saturated volcanics and brackish water (less than 1,000 ppm chlorides) saturated volcanics in the resistivity interpretations. The reason for this is that changes in porosity and degree of saturation can cause the resistivity ranges of fresh and brackish water saturated volcanics to overlap. For this reason, in the following interpretations the term "fresh/brackish" is used to refer to the water overlying the basal sea water.

2. Calibrating the geophysical interpretations at a well. In this case three wells were available for calibration.

4.2 CALIBRATION AT WELLS

The locations of the soundings conducted for KIC are given in Figure 2-1. Soundings 1, 3 and 4 were near wells. The resistivity layering measured at soundings 1 and 4 are shown in Figure 4-1. These soundings have in common that a layer of low resistivity, 3.3 ohm-m in sounding 1, 3.0 ohm-m in sounding 3, and 4.1 ohm-m in sounding 4, was measured at depth. This layer is interpreted to be the interface of fresh/brackish water and salt water. To determine the head of fresh/brackish water above sea level (water table), the Ghyben-Herzberg equation was used. Also shown on Figure 4-1 is the information from the two wells. The agreement is good, and subsequently this procedure of interpretation was used for all other soundings. The largest error is not in the TDEM measurement but in determining the surface elevation of the TDEM station. Elevation of the TDEM station was taken from the topographic map. For better accuracy, elevations would have to be surveyed.

The results of the TDEM survey are summarized in Table 4-1. Some additional comments, about the results, are given in the following paragraphs.

1. The results from sounding 5 are shown in Figure 4-2. The low resistivity at a depth of about 300 ft below surface is likely not salt water, because this layer is above sea level, but it likely is a volcanic ash or clay with a perched water table. This interpretation is supported by information from a nearby domestic well, where a perched fresh water table was reportedly encountered at less than 100 ft below surface. The depth to saline water in this sounding was beyond the effective exploration depth of the sounding (greater than 1700 ft below surface).

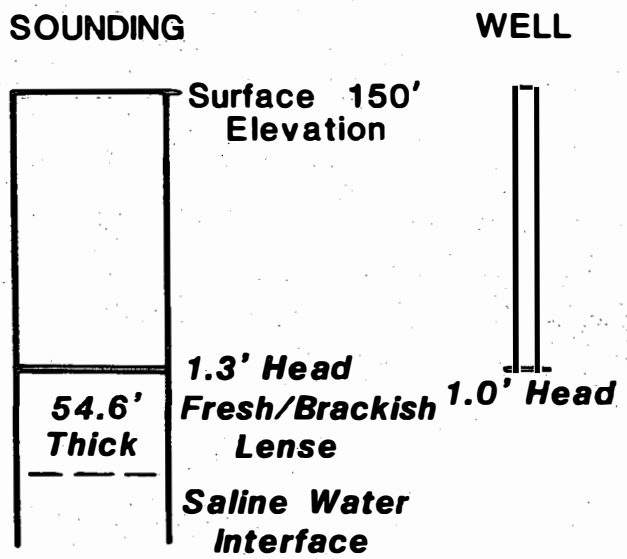
2. Power lines caused interference in sounding 6, and only a minimum head for the brackish water table above sea level was inferred from the data.

Table 4-1. Hydrogeologic information derived from TDEM soundings

Sounding #	Surface Elevation (ft)	Head of Fresh/ Brackish Water above Sea Level (water table) (ft)	Thickness of Fresh/ Brackish Water Lens (ft)
1	150	1.3	55
2	20	0.3	10.6
3	340	<1	<3
4	840	2.3	96
5	1320	?	?
6	1800	> 8.3	> 340
7	1060	3.0	121
8	1850	12.0))	495
9	1660	50.0))	2000
10	1560	36.4	1491

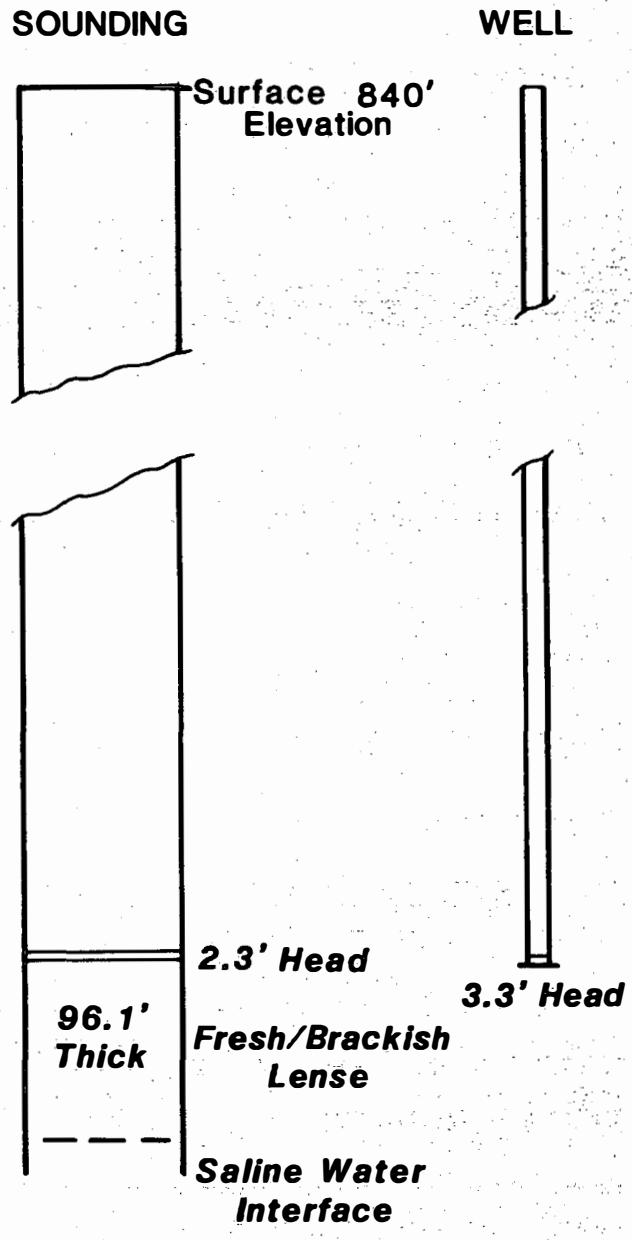
SOUNDING 1

(Near Well at Nursery)



SOUNDING 4

(Near Tanaka Well)



NOTE: Location of sounding 4 measurement approximately 100 feet lower then well elevation.

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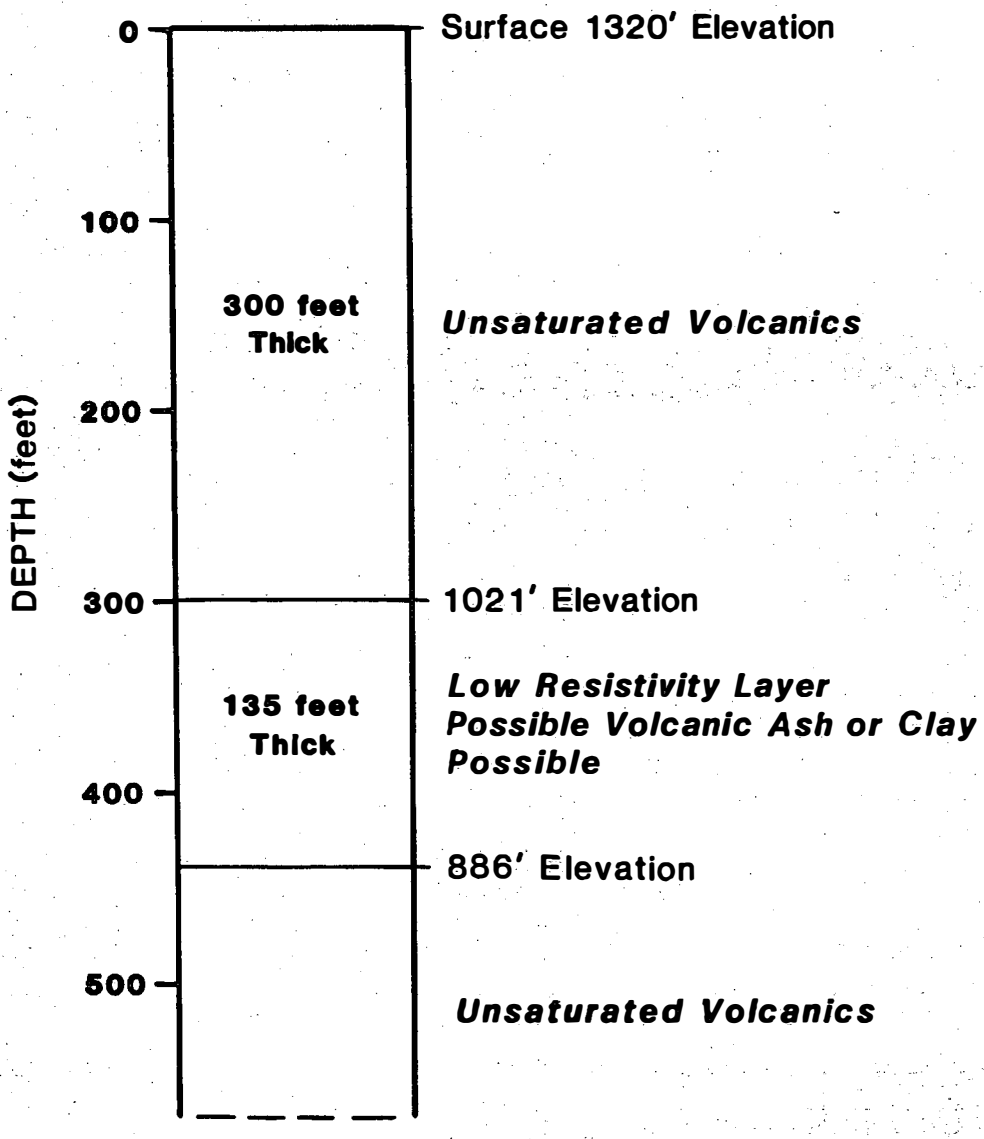
ILLUSTRATION OF TDEM CALIBRATION AT WELL LOCATIONS

Kamehameha Investment Corp.

PROJECT NO.: 90001 FIGURE 4-1

SOUNDING 5



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RESULTS FROM SOUNDING 5

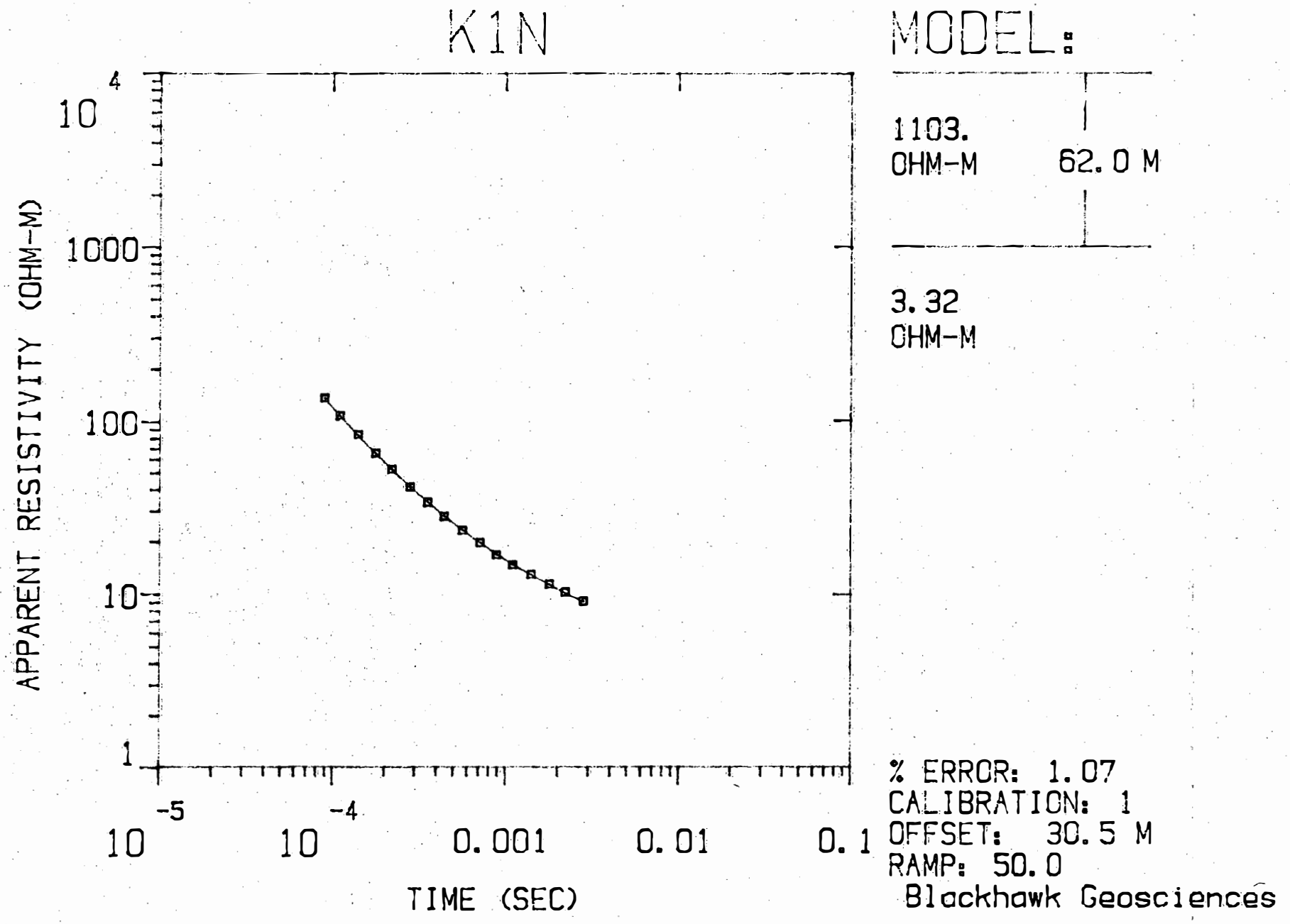
Kamehameha Investment Corp.

PROJECT NO.: 90001 FIGURE 4-2

5.0 CONCLUSIONS

The TDEM survey indicates that the optimum well locations are at soundings 6, 8, 9 and 10. At these locations the head of fresh/brackish water is expected to be in excess of 8 ft above sea level, and the thickness of the fresh/brackish water lens is in excess of 340 ft. A shallow perched water table may exist at sounding 5, but long term water production would likely be limited. The large difference in interpreted head between sounding 4 and sounding 10 (2.3 ft to 36.4 ft, respectively) over a relatively short horizontal distance (about 4,000 ft) may infer that some type of ground water damming structure exists between these two soundings.

Interference from power lines and utilities caused some deterioration in data quality in soundings 6 and 8. Calibration of TDEM interpretations near wells showed good agreement.


K1N
MODEL:
1103.
OHM-M
62.0 M
3.32
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
% ERROR: 1.07
CALIBRATION: 1
OFFSET: 30.5 M
RAMP: 50.0
Blackhawk Geosciences

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	(FEET)	CONDUCTANCE (S) LAYER	TOTAL
		45.7	150.0		
1103.40	62.0	-16.3	-53.5	0.1	0.1
3.32					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.36E+02	1.36E+02	0.122	
2	1.10E-04	1.07E+02	1.07E+02	0.169	
3	1.40E-04	8.34E+01	8.26E+01	1.052	
4	1.77E-04	6.51E+01	6.49E+01	0.376	
5	2.20E-04	5.26E+01	5.24E+01	0.376	
6	2.80E-04	4.16E+01	4.19E+01	-0.577	
7	3.55E-04	3.38E+01	3.40E+01	-0.368	
8	4.43E-04	2.80E+01	2.82E+01	-0.711	
9	5.64E-04	2.32E+01	2.34E+01	-0.650	
10	7.13E-04	1.98E+01	1.97E+01	0.347	
11	8.85E-04	1.68E+01	1.70E+01	-1.405	
12	1.10E-03	1.47E+01	1.49E+01	-1.099	
13	1.41E-03	1.29E+01	1.29E+01	0.563	
14	1.78E-03	1.14E+01	1.13E+01	0.715	
15	2.21E-03	1.03E+01	1.02E+01	1.051	
16	2.83E-03	9.14E+00	9.12E+00	0.175	

R: 30. X: 0. Y: 30. DL: 61. REQ: 33. CF: 1.0000
CLHZ ARRAY, 16 DATA POINTS, RAMP: 50.0 MICROSEC, DATA: K1N
1N NEAR NURSERY

RMS LOG ERROR: 4.64E-03, ANTILOG YIELDS 1.0742 %
LATE TIME PARAMETERS

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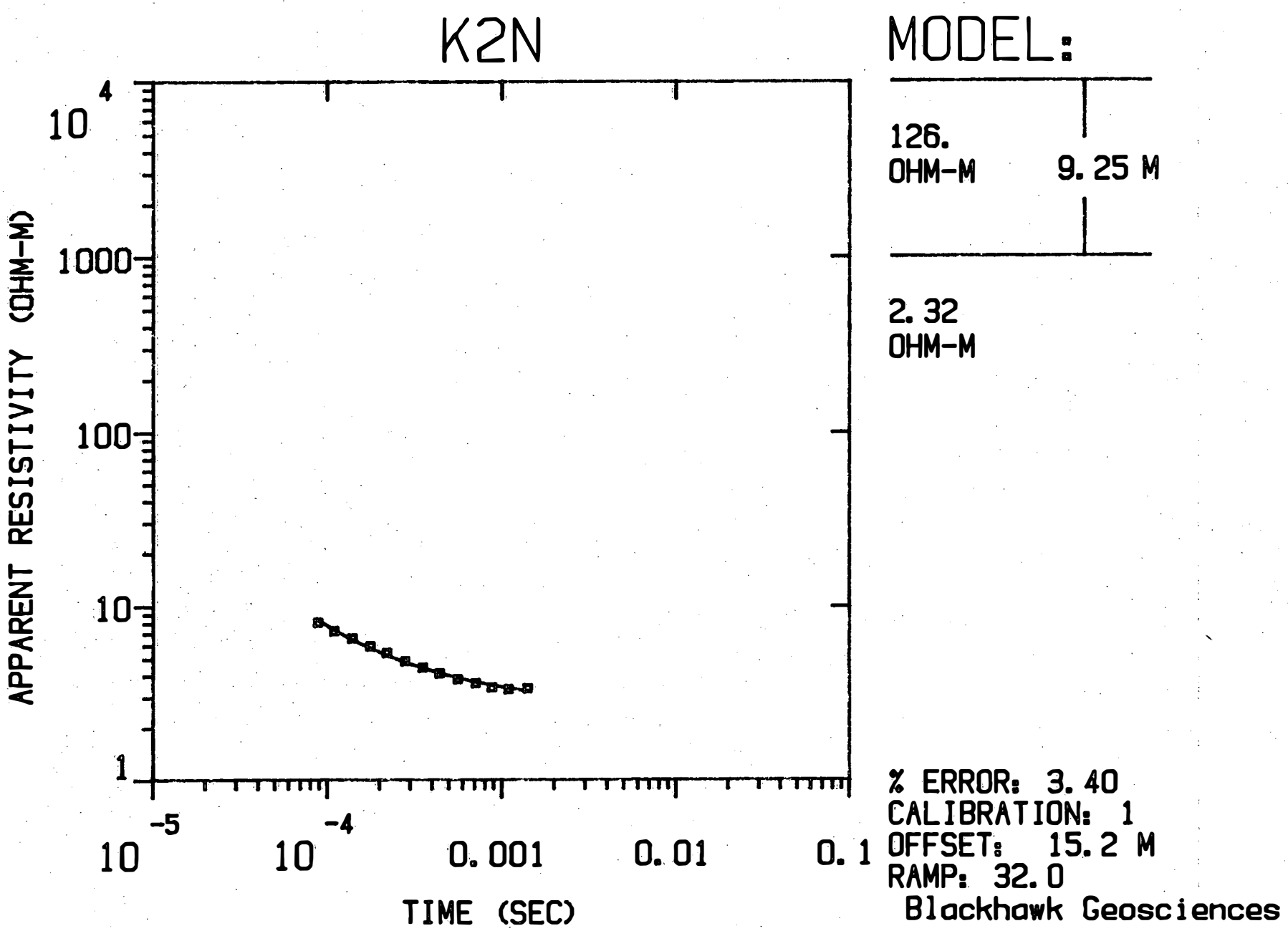
PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.07		
P 2	-0.01	1.00	
T 1	0.01	0.00	1.00


K2N
MODEL:
126.
OHM-M
9.25 M
2.32
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
% ERROR: 3.40
CALIBRATION: 1
OFFSET: 15.2 M
RAMP: 32.0
Blackhawk Geosciences

K2N

MODEL: 2 LAYERS

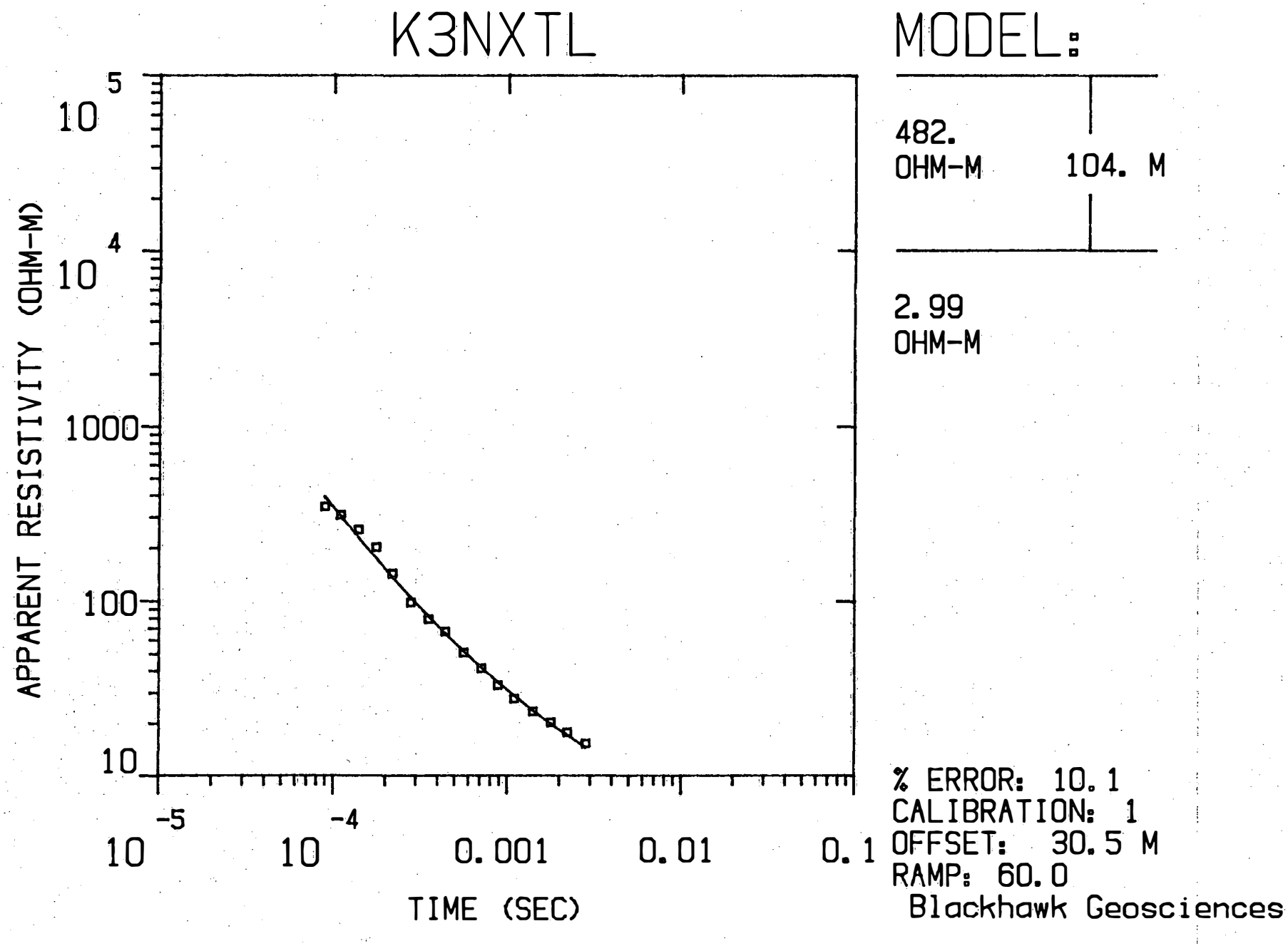
RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		6.1	20.0		
126.02	9.3	-3.2	-10.3	0.1	0.1
2.32					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	8.13E+00	8.39E+00	-3.037	
2	1.10E-04	7.25E+00	7.38E+00	-1.752	
3	1.40E-04	6.60E+00	6.47E+00	1.895	
4	1.77E-04	5.94E+00	5.78E+00	2.737	
5	2.20E-04	5.42E+00	5.26E+00	3.084	
6	2.80E-04	4.85E+00	4.80E+00	1.121	
7	3.55E-04	4.46E+00	4.42E+00	0.727	
8	4.43E-04	4.12E+00	4.14E+00	-0.449	
9	5.64E-04	3.82E+00	3.88E+00	-1.753	
10	7.13E-04	3.62E+00	3.68E+00	-1.613	
11	8.81E-04	3.42E+00	3.52E+00	-2.982	
12	1.10E-03	3.34E+00	3.38E+00	-1.310	
13	1.41E-03	3.37E+00	3.25E+00	3.684	

R: 15. X: 0. Y: 15. DL: 30. REQ: 17. CF: 1.0000
CLHZ ARRAY, 13 DATA POINTS, RAMP: 32.0 MICROSEC, DATA: K2N
K2N AT END OF ROAD WEST OF GULF COURSE
NEAR THE SHORE
RMS LOG ERROR: 1.45E-02, ANTILOG YIELDS 3.3952 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.02
P 2 0.00 1.00
T 1 0.02 0.00 1.00
P 1 P 2 T 1


K3NXTL
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
482.
OHM-M
104. M
2.99
OHM-M
% ERROR: 10.1
CALIBRATION: 1
OFFSET: 30.5 M
RAMP: 60.0
Blackhawk Geosciences

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		103.6	340.0		
481.75	104.4	-0.8	-2.7	0.2	0.2
2.99					

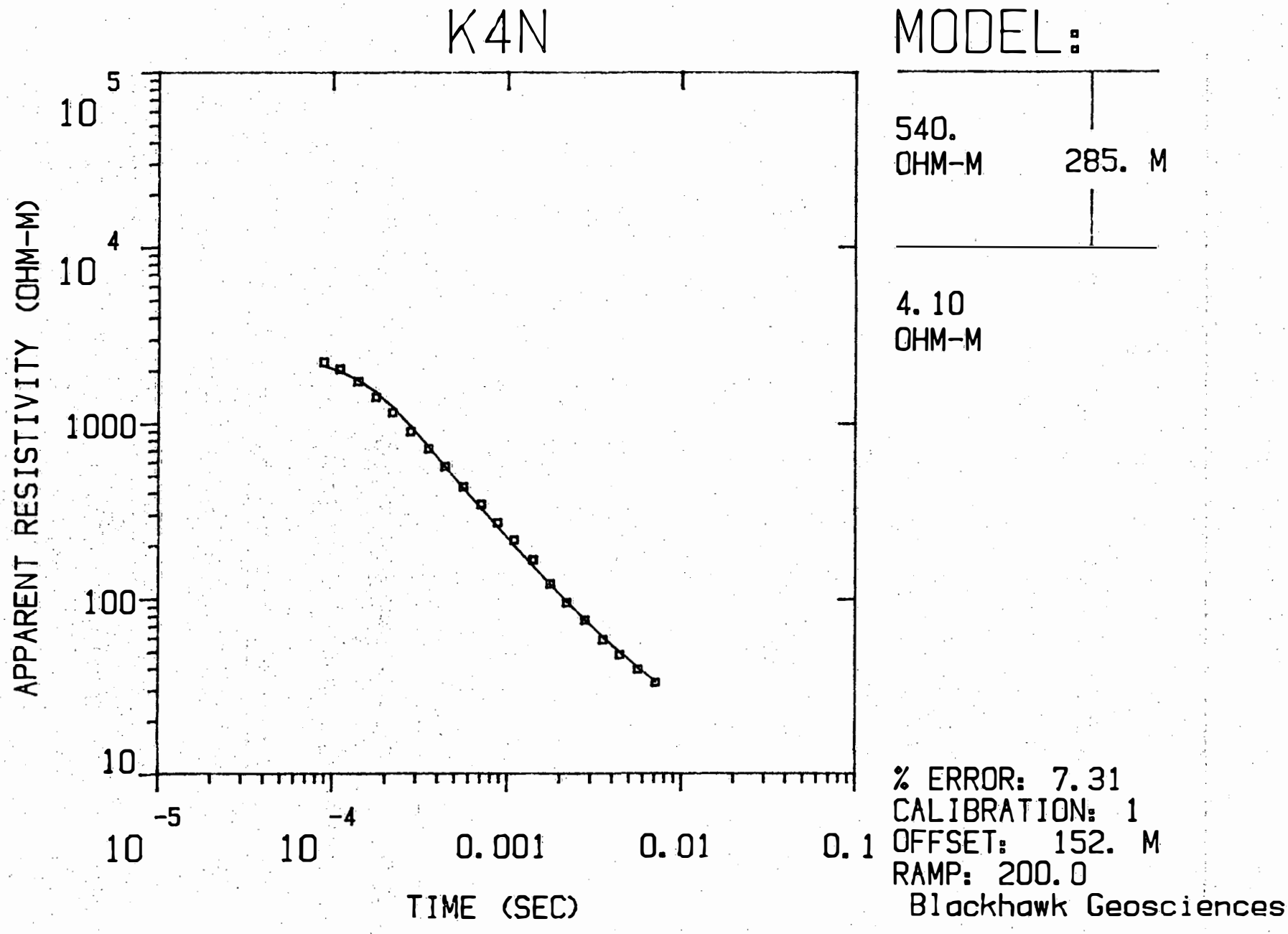
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	3.44E+02	3.92E+02	-12.208	
2	1.10E-04	3.08E+02	3.03E+02	1.447	
3	1.40E-04	2.53E+02	2.28E+02	10.933	
4	1.77E-04	2.01E+02	1.75E+02	15.019	
5	2.20E-04	1.43E+02	1.37E+02	4.549	
6	2.80E-04	9.83E+01	1.05E+02	-6.674	
7	3.55E-04	7.91E+01	8.24E+01	-3.977	
8	4.43E-04	6.71E+01	6.57E+01	2.001	
9	5.64E-04	5.09E+01	5.21E+01	-2.183	
10	7.13E-04	4.14E+01	4.20E+01	-1.346	
11	8.85E-04	3.31E+01	3.46E+01	-4.218	
12	1.10E-03	2.77E+01	2.89E+01	-4.247	
13	1.41E-03	2.34E+01	2.38E+01	-1.492	
14	1.78E-03	2.02E+01	1.99E+01	1.885	
15	2.21E-03	1.78E+01	1.71E+01	3.588	
16	2.83E-03	1.53E+01	1.45E+01	5.362	

R: 30. X: 0. Y: 30. DL: 61. REQ: 33. CF: 1.0000
CLHZ ARRAY, 16 DATA POINTS, RAMP: 60.0 MICROSEC, DATA: K3NXTL
NEAR WELL ON GOLF COURSE
BELOW TEE
RMS LOG ERROR: 4.16E-02, ANTILOG YIELDS 10.0526 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.79		
P 2	-0.02	1.00	
T 1	0.00	0.00	1.00
	P 1	P 2	T 1



MODEL:

540.
OHM-M

285. M

4.10
OHM-M

% ERROR: 7.31
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0

Blackhawk Geosciences

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		256.0	840.0		
540.21	284.6	-28.6	-93.8	0.5	0.5
4.10					

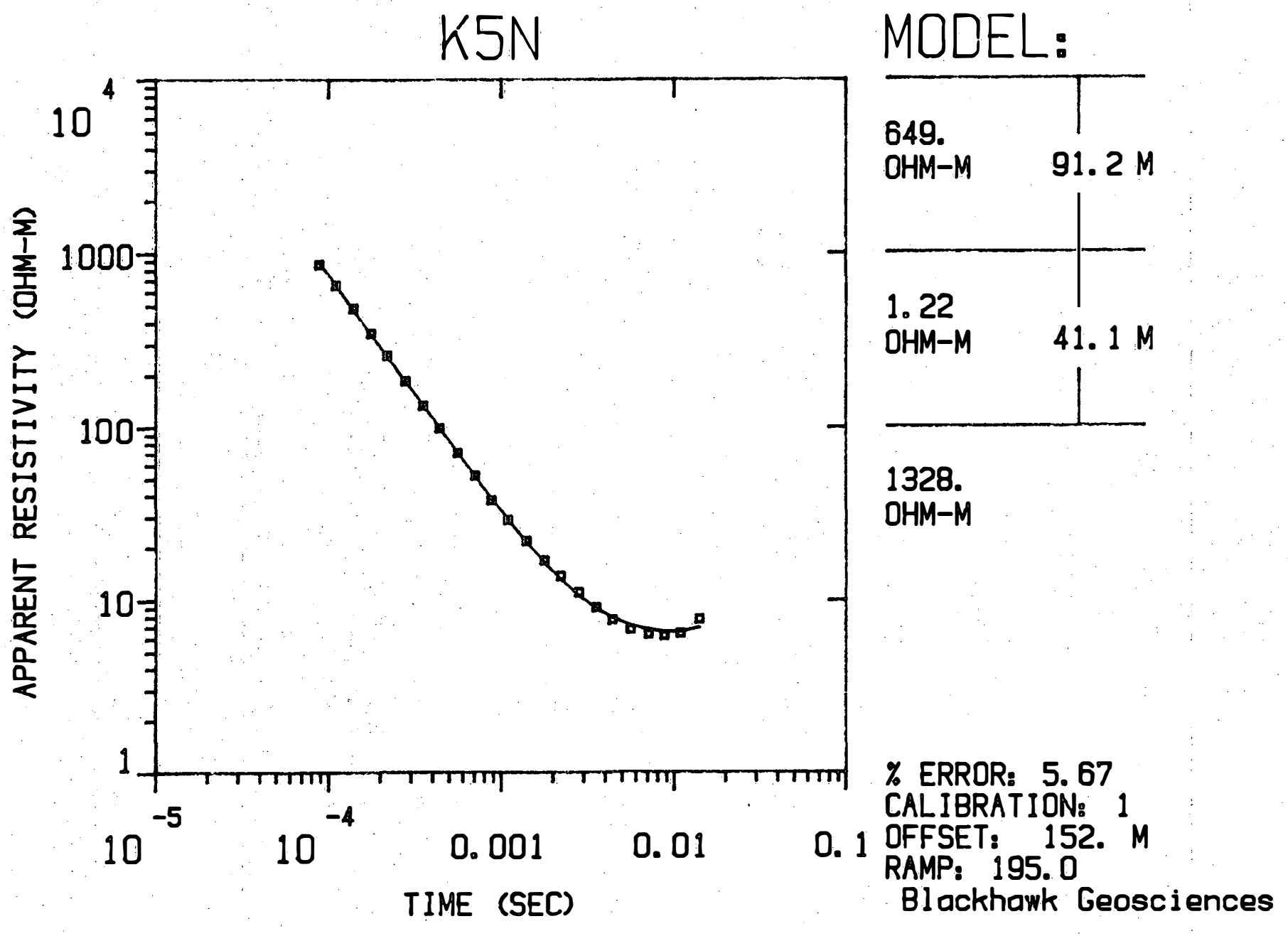
	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.40E-03	1.66E+02	1.55E+02	7.260	
2	1.77E-03	1.21E+02	1.21E+02	0.250	
3	2.20E-03	9.51E+01	9.68E+01	-1.775	
4	2.80E-03	7.57E+01	7.65E+01	-1.106	
5	3.55E-03	5.84E+01	6.10E+01	-4.261	
6	4.43E-03	4.79E+01	5.01E+01	-4.261	
7	5.64E-03	3.95E+01	4.06E+01	-2.820	
8	7.13E-03	3.32E+01	3.35E+01	-1.061	
9	8.90E-05	2.25E+03	2.14E+03	5.153	
10	1.10E-04	2.05E+03	1.99E+03	2.947	
11	1.40E-04	1.74E+03	1.77E+03	-2.041	
12	1.77E-04	1.41E+03	1.51E+03	-6.539	
13	2.20E-04	1.15E+03	1.24E+03	-7.203	
14	2.80E-04	8.96E+02	9.63E+02	-6.934	
15	3.55E-04	7.13E+02	7.38E+02	-3.337	
16	4.43E-04	5.64E+02	5.67E+02	-0.391	
17	5.64E-04	4.33E+02	4.28E+02	1.342	
18	7.13E-04	3.45E+02	3.27E+02	5.323	
19	8.81E-04	2.70E+02	2.57E+02	4.961	
20	1.10E-03	2.16E+02	2.02E+02	6.964	
21	1.41E-03	1.66E+02	1.54E+02	8.291	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
CLHZ ARRAY, 21 DATA POINTS, RAMP: 200.0 MICROSEC, DATA: K4N
TANAKA WELL
BELOW SCHOOL
RMS LOG ERROR: 3.06E-02, ANTILOG YIELDS 7.3107 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	1.00		
P 2	0.00	1.00	
T 1	0.00	0.00	1.00
	P 1	P 2	T 1


K5N
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
MODEL:
649.
OHM-M
91.2 M
1.22
OHM-M
41.1 M
1328.
OHM-M
% ERROR: 5.67
CALIBRATION: 1
OFFSET: 152. M
RAMP: 195.0
Blackhawk Geosciences

K5N

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		402.3	1320.0		
648.97	91.2	311.1	1020.7	0.1	0.1
1.22	41.1	270.0	885.7	33.7	33.9
1327.87					

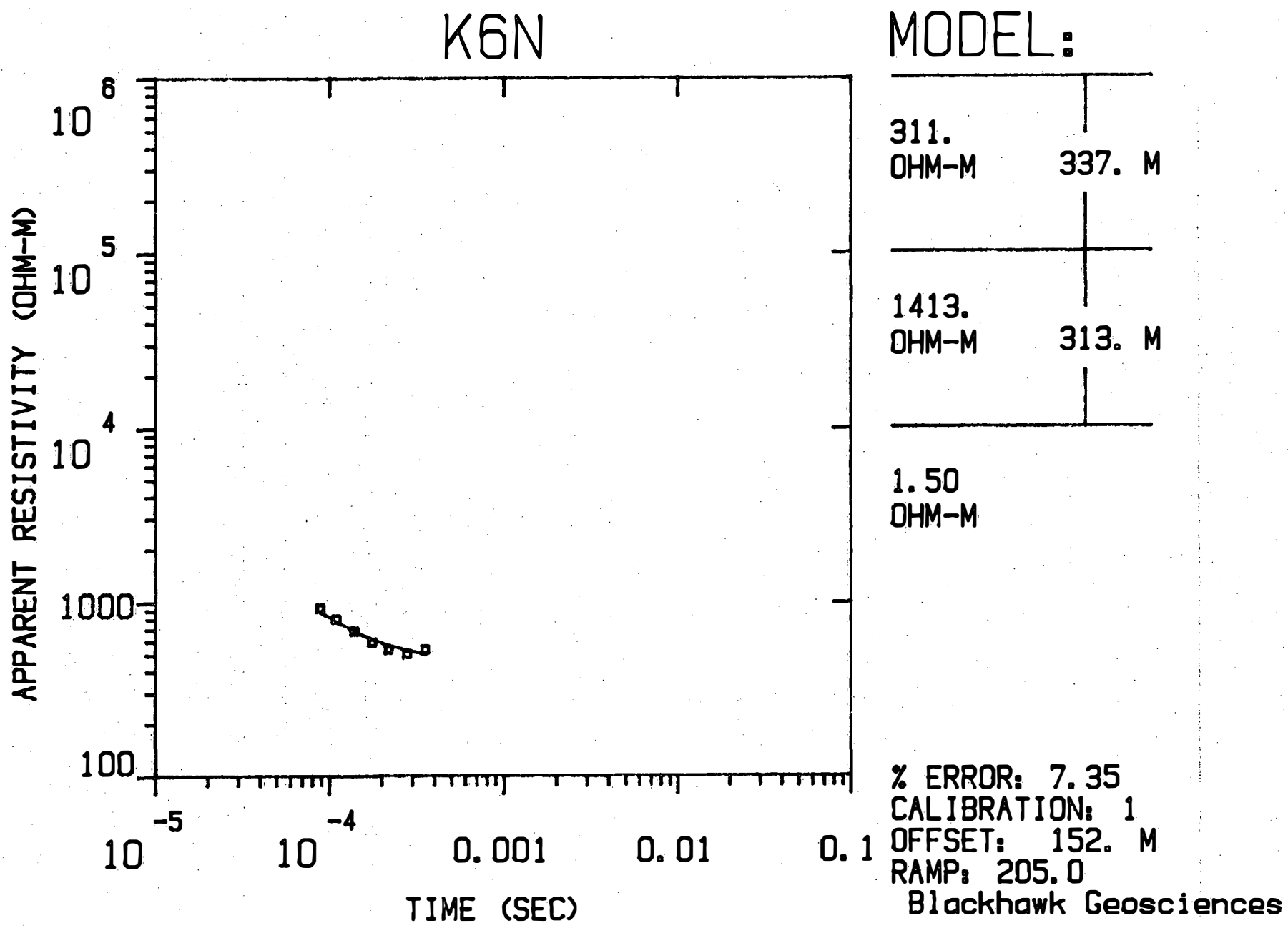
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	8.59E+02	8.92E+02	-3.701	
2	1.10E-04	6.55E+02	6.61E+02	-0.973	
3	1.40E-04	4.83E+02	4.73E+02	2.253	
4	1.77E-04	3.48E+02	3.43E+02	1.694	
5	2.20E-04	2.59E+02	2.55E+02	1.378	
6	2.80E-04	1.85E+02	1.85E+02	0.086	
7	3.55E-04	1.34E+02	1.34E+02	-0.441	
8	4.43E-04	9.84E+01	9.92E+01	-0.735	
9	5.64E-04	7.08E+01	7.13E+01	-0.650	
10	7.13E-04	5.22E+01	5.17E+01	0.925	
11	8.85E-04	3.75E+01	3.86E+01	-2.677	
12	1.10E-03	2.89E+01	2.91E+01	-0.867	
13	1.41E-03	2.18E+01	2.15E+01	1.583	
14	1.78E-03	1.69E+01	1.64E+01	2.633	
15	2.21E-03	1.37E+01	1.32E+01	3.837	
16	2.83E-03	1.11E+01	1.06E+01	4.058	
17	3.57E-03	9.09E+00	8.99E+00	1.050	
18	4.43E-03	7.68E+00	7.94E+00	-3.285	
19	5.64E-03	6.79E+00	7.12E+00	-4.694	
20	7.13E-03	6.35E+00	6.77E+00	-6.268	
21	8.81E-03	6.22E+00	6.57E+00	-5.222	
22	1.10E-02	6.44E+00	6.55E+00	-1.652	
23	1.41E-02	7.80E+00	6.97E+00	11.952	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
CLHZ ARRAY, 23 DATA POINTS, RAMP: 195.0 MICROSEC, DATA: K5N
MAC NUT LOOP
NE CORNER NEAR ROBINSON GATE
RMS LOG ERROR: 2.39E-02, ANTILOG YIELDS 5.6656 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.98				
P 2	0.00	1.00			
P 3	0.00	0.00	0.00		
T 1	0.00	0.00	0.00	1.00	
T 2	0.00	0.00	0.00	0.00	1.00
	P 1	P 2	P 3	T 1	T 2


K6N
MODEL:
311.
OHM-M
337. M
1413.
OHM-M
313. M
1.50
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^6
10^5
10^4
1000
100
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
% ERROR: 7.35
CALIBRATION: 1
OFFSET: 152. M
RAMP: 205.0
Blackhawk Geosciences

K6N

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		548.6	1800.0		
310.60	336.7	212.0	695.4	1.1	1.1
1413.50	312.8	-100.8	-330.8	0.2	1.3
1.50					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	9.32E+02	8.87E+02	5.121	
2	1.10E-04	8.07E+02	7.81E+02	3.314	
3	1.40E-04	6.86E+02	6.86E+02	0.103	
4	1.77E-04	5.92E+02	6.16E+02	-3.989	
5	2.20E-04	5.39E+02	5.69E+02	-5.409	
6	2.80E-04	5.08E+02	5.36E+02	-5.140	
7	3.55E-04	5.40E+02	5.05E+02	6.996	

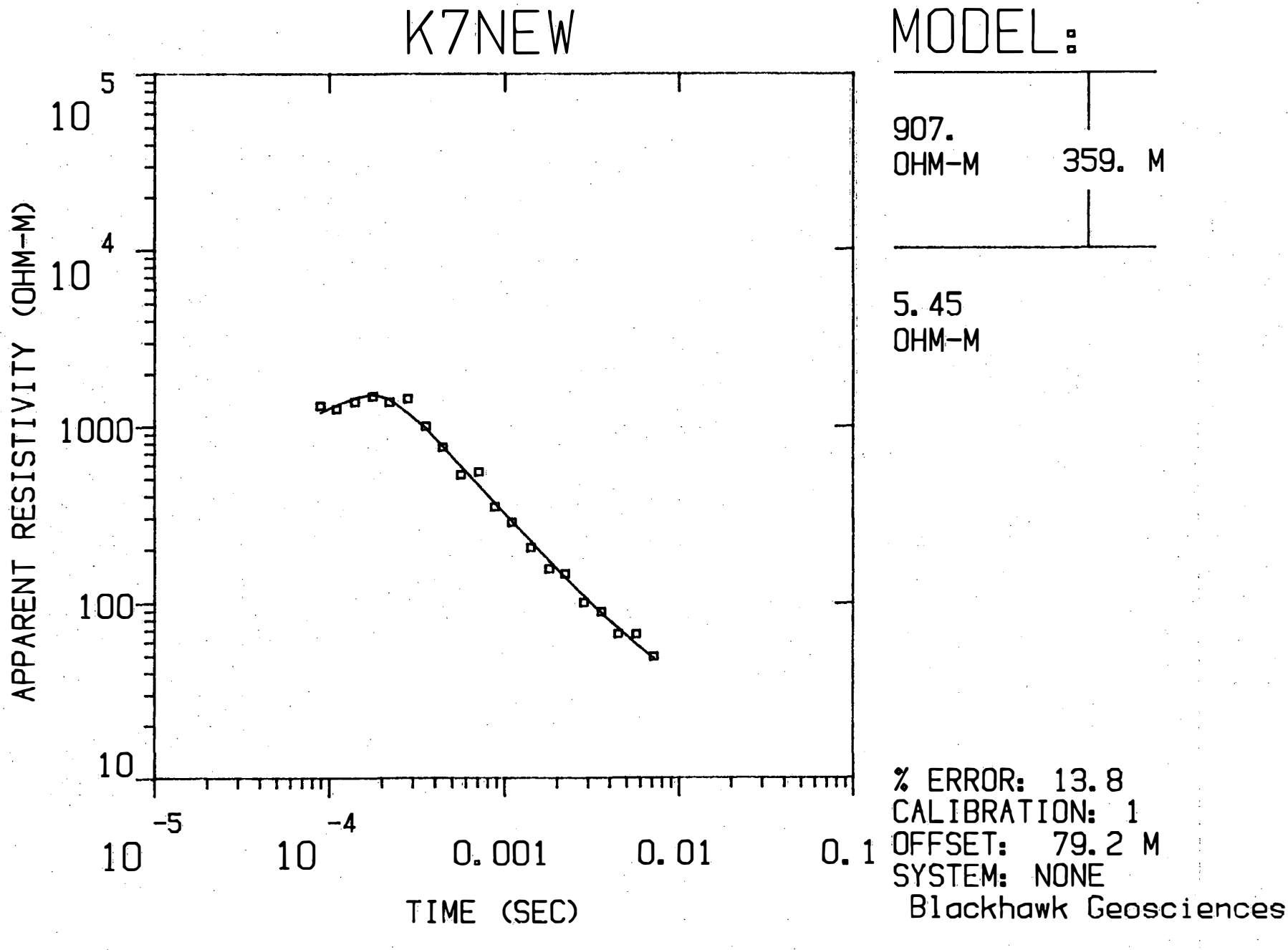
R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
CLHZ ARRAY, 7 DATA POINTS, RAMP: 205.0 MICROSEC, DATA: K6N

RMS LOG ERROR: 3.08E-02, ANTILOG YIELDS 7.3538 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	1.00				
P 2	0.00	0.02			
P 3	0.00	0.02	0.02		
T 1	0.00	-0.06	0.00	0.89	
T 2	-0.02	-0.01	0.01	0.27	0.09
	P 1	P 2	P 3	T 1	T 2


K7NEW
MODEL:
907.
OHM-M
359. M
5.45
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
% ERROR: 13.8
CALIBRATION: 1
OFFSET: 79.2 M
SYSTEM: NONE
Blackhawk Geosciences

K7NEW

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		323.1	1060.0		
906.80	359.2	-36.1	-118.4	0.4	0.4
5.45					

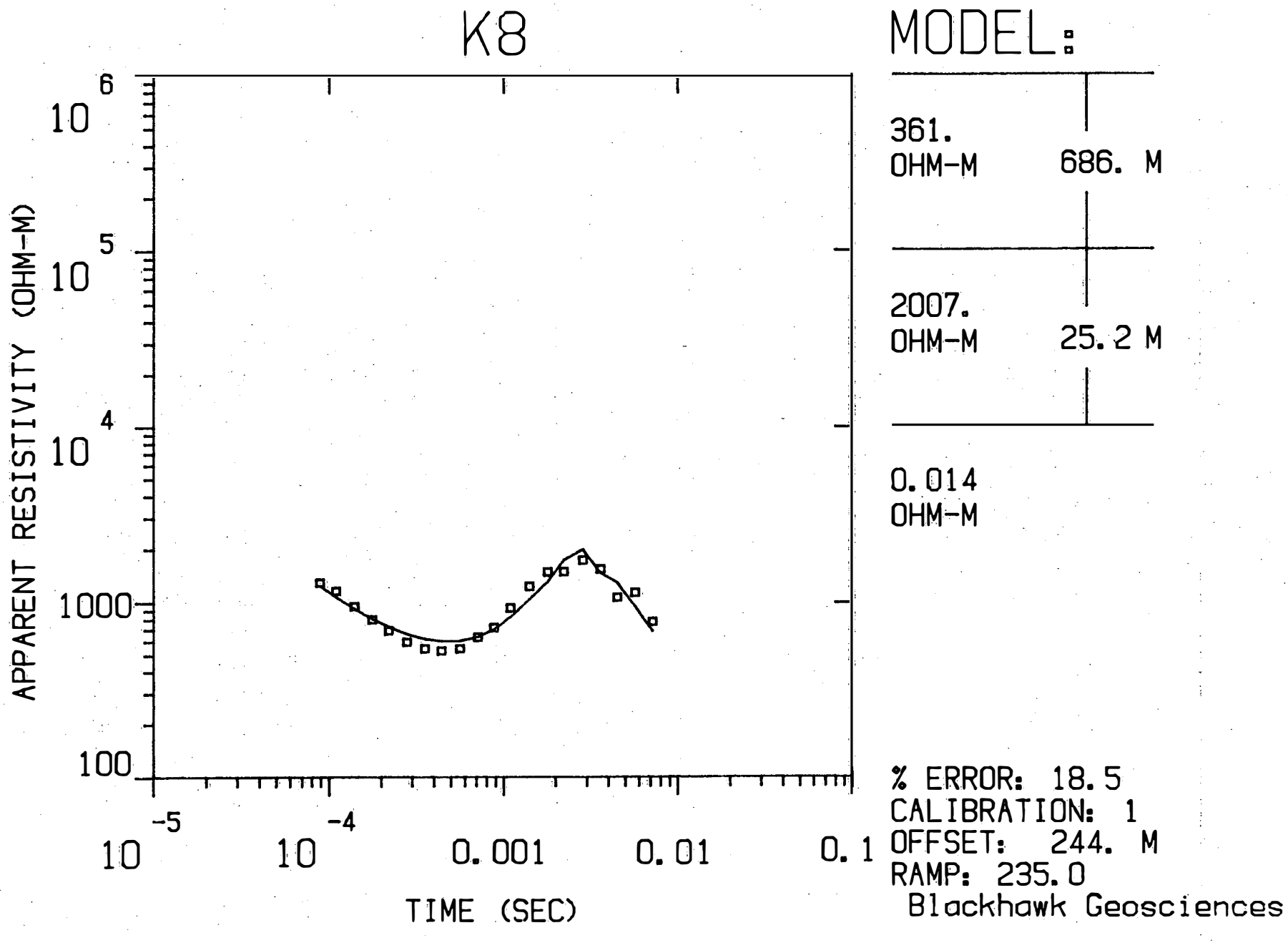
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.31E+03	1.21E+03	8.654	
2	1.10E-04	1.26E+03	1.33E+03	-5.269	
3	1.40E-04	1.38E+03	1.45E+03	-4.868	
4	1.77E-04	1.49E+03	1.53E+03	-2.878	
5	2.20E-04	1.37E+03	1.43E+03	-3.882	
6	2.80E-04	1.44E+03	1.20E+03	20.809	
7	3.55E-04	1.00E+03	9.81E+02	2.259	
8	4.43E-04	7.60E+02	7.69E+02	-1.173	
9	5.64E-04	5.27E+02	5.90E+02	-10.644	
10	7.13E-04	5.49E+02	4.59E+02	19.461	
11	8.81E-04	3.47E+02	3.65E+02	-4.890	
12	1.10E-03	2.83E+02	2.88E+02	-1.685	
13	1.41E-03	2.04E+02	2.21E+02	-7.677	
14	1.80E-03	1.55E+02	1.72E+02	-9.758	
15	2.22E-03	1.46E+02	1.39E+02	4.810	
16	2.85E-03	1.01E+02	1.09E+02	-7.975	
17	3.60E-03	8.93E+01	8.77E+01	1.876	
18	4.49E-03	6.66E+01	7.21E+01	-7.571	
19	5.70E-03	6.65E+01	5.85E+01	13.629	
20	7.19E-03	4.96E+01	4.84E+01	2.327	

R: 79. X: 0. Y: 79. DL: 158. REQ: 88. CF: 1.0000
CLHZ ARRAY, 20 DATA POINTS, SYSTEM: NONE DATA: K7NEW
K7N
PASTURE AREA
RMS LOG ERROR: 5.60E-02, ANTILOG YIELDS 13.7546 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	1.00		
P 2	0.00	1.00	
T 1	0.00	0.00	1.00
	P 1	P 2	T 1



MODEL:

361.
OHM-M

686. M

2007.
OHM-M

25.2 M

0.014
OHM-M

% ERROR: 18.5
CALIBRATION: 1
OFFSET: 244. M
RAMP: 235.0

Blackhawk Geosciences

K8

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		563.9	1850.0		
361.28	686.0	-122.1	-400.7	1.9	1.9
2007.27	25.2	-147.3	-483.3	0.0	1.9
0.01					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.30E+03	1.25E+03	4.184	
2	1.10E-04	1.17E+03	1.08E+03	8.243	
3	1.40E-04	9.54E+02	9.25E+02	3.161	
4	1.77E-04	8.01E+02	8.10E+02	-1.125	
5	2.20E-04	6.91E+02	7.28E+02	-5.064	
6	2.80E-04	5.95E+02	6.61E+02	-10.069	
7	3.55E-04	5.45E+02	6.19E+02	-11.921	
8	4.43E-04	5.29E+02	6.00E+02	-11.830	
9	5.64E-04	5.44E+02	6.04E+02	-9.903	
10	7.13E-04	6.35E+02	6.36E+02	-0.173	
11	8.81E-04	7.21E+02	7.02E+02	2.740	
12	1.10E-03	9.36E+02	8.27E+02	13.186	
13	1.41E-03	1.24E+03	1.05E+03	18.136	
14	1.80E-03	1.49E+03	1.31E+03	14.060	
15	2.22E-03	1.50E+03	1.74E+03	-13.776	
16	2.85E-03	1.74E+03	1.99E+03	-12.636	
17	3.60E-03	1.55E+03	1.47E+03	4.901	
18	4.49E-03	1.07E+03	1.30E+03	-17.695	
19	5.70E-03	1.14E+03	9.49E+02	20.192	
20	7.19E-03	7.75E+02	6.88E+02	12.587	

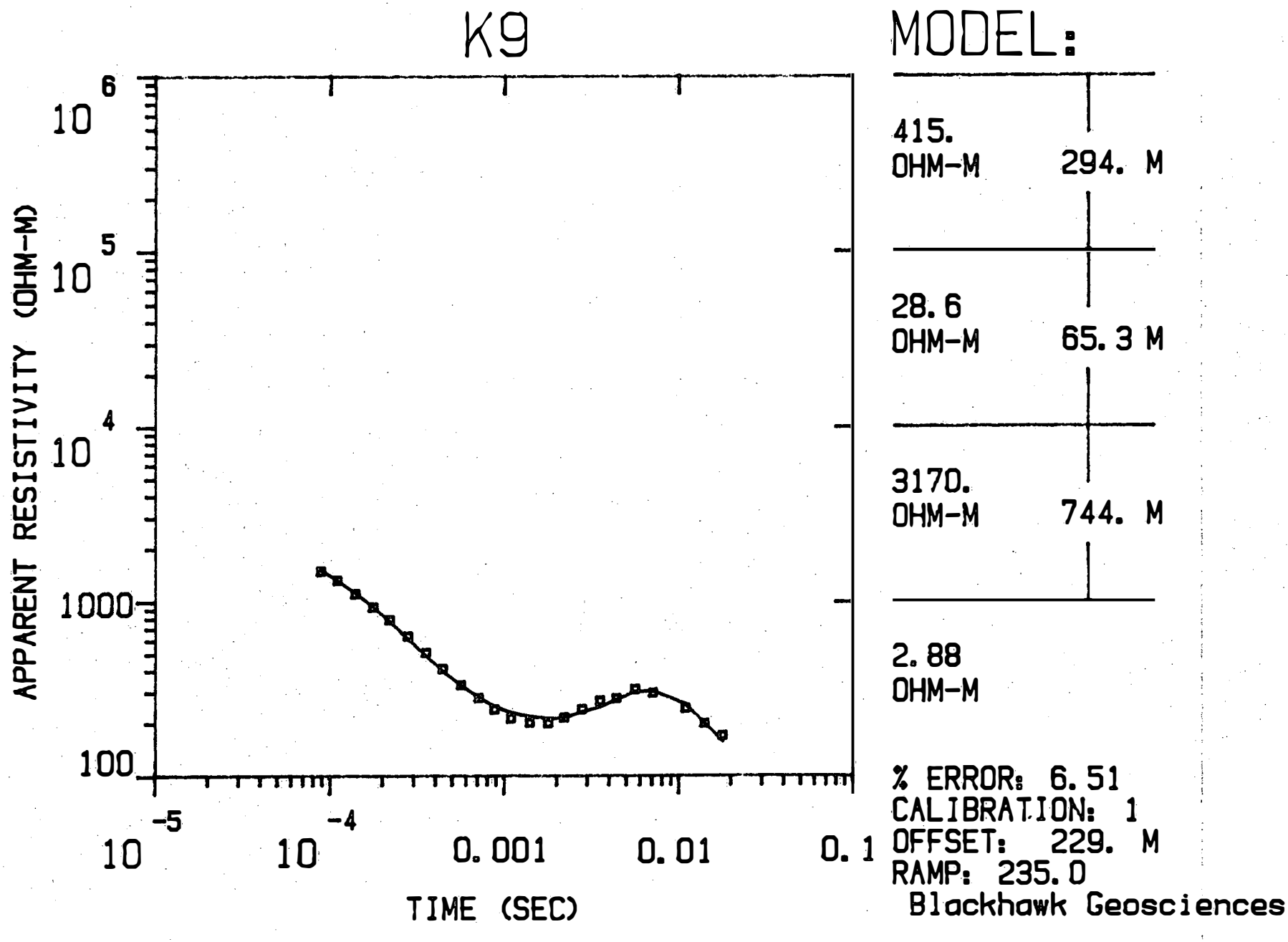
R: 244. X: 0. Y: 244. DL: 488. REQ: 271. CF: 1.0000
CLHZ ARRAY, 20 DATA POINTS, RAMP: 235.0 MICROSEC, DATA: K8

RMS LOG ERROR: 7.36E-02, ANTILOG YIELDS 18.4693 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	1.00				
P 2	0.00	0.00			
P 3	-0.01	0.00	0.86		
T 1	0.00	0.00	-0.01	1.00	
T 2	-0.01	0.00	-0.08	0.04	0.04
	P 1	P 2	P 3	T 1	T 2


K9
APPARENT RESISTIVITY (OHM-M)
10^6
10^5
10^4
1000
100
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
MODEL:
415.
OHM-M
294. M
28.6
OHM-M
65.3 M
3170.
OHM-M
744. M
2.88
OHM-M
% ERROR: 6.51
CALIBRATION: 1
OFFSET: 229. M
RAMP: 235.0
Blackhawk Geosciences

MODEL: 4 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		506.0	1660.0		
414.97	293.6	212.3	696.7	0.7	0.7
28.58	65.3	147.1	482.5	2.3	3.0
3170.42	743.9	-596.8	-1958.1	0.2	3.2
2.88					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.49E+03	1.52E+03	-1.661	
2	1.10E-04	1.33E+03	1.33E+03	-0.206	
3	1.40E-04	1.11E+03	1.13E+03	-1.400	
4	1.77E-04	9.33E+02	9.38E+02	-0.591	
5	2.20E-04	7.89E+02	7.74E+02	1.881	
6	2.80E-04	6.34E+02	6.16E+02	2.976	
7	3.55E-04	5.10E+02	4.89E+02	4.324	
8	4.43E-04	4.11E+02	3.99E+02	2.847	
9	5.64E-04	3.31E+02	3.30E+02	0.162	
10	7.13E-04	2.79E+02	2.82E+02	-0.889	
11	8.81E-04	2.39E+02	2.50E+02	-4.352	
12	1.10E-03	2.13E+02	2.29E+02	-7.056	
13	1.41E-03	2.01E+02	2.18E+02	-7.677	
14	1.78E-03	2.00E+02	2.11E+02	-5.554	
15	2.21E-03	2.16E+02	2.15E+02	0.210	
16	2.80E-03	2.40E+02	2.32E+02	3.775	
17	3.55E-03	2.70E+02	2.47E+02	9.043	
18	4.43E-03	2.78E+02	2.73E+02	1.798	
19	5.64E-03	3.14E+02	3.05E+02	3.063	
20	7.13E-03	2.99E+02	3.07E+02	-2.715	
21	1.10E-02	2.42E+02	2.57E+02	-5.626	
22	1.41E-02	1.99E+02	1.99E+02	0.076	
23	1.80E-02	1.69E+02	1.57E+02	7.412	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000
CLHZ ARRAY, 23 DATA POINTS, RAMP: 235.0 MICROSEC, DATA: K9

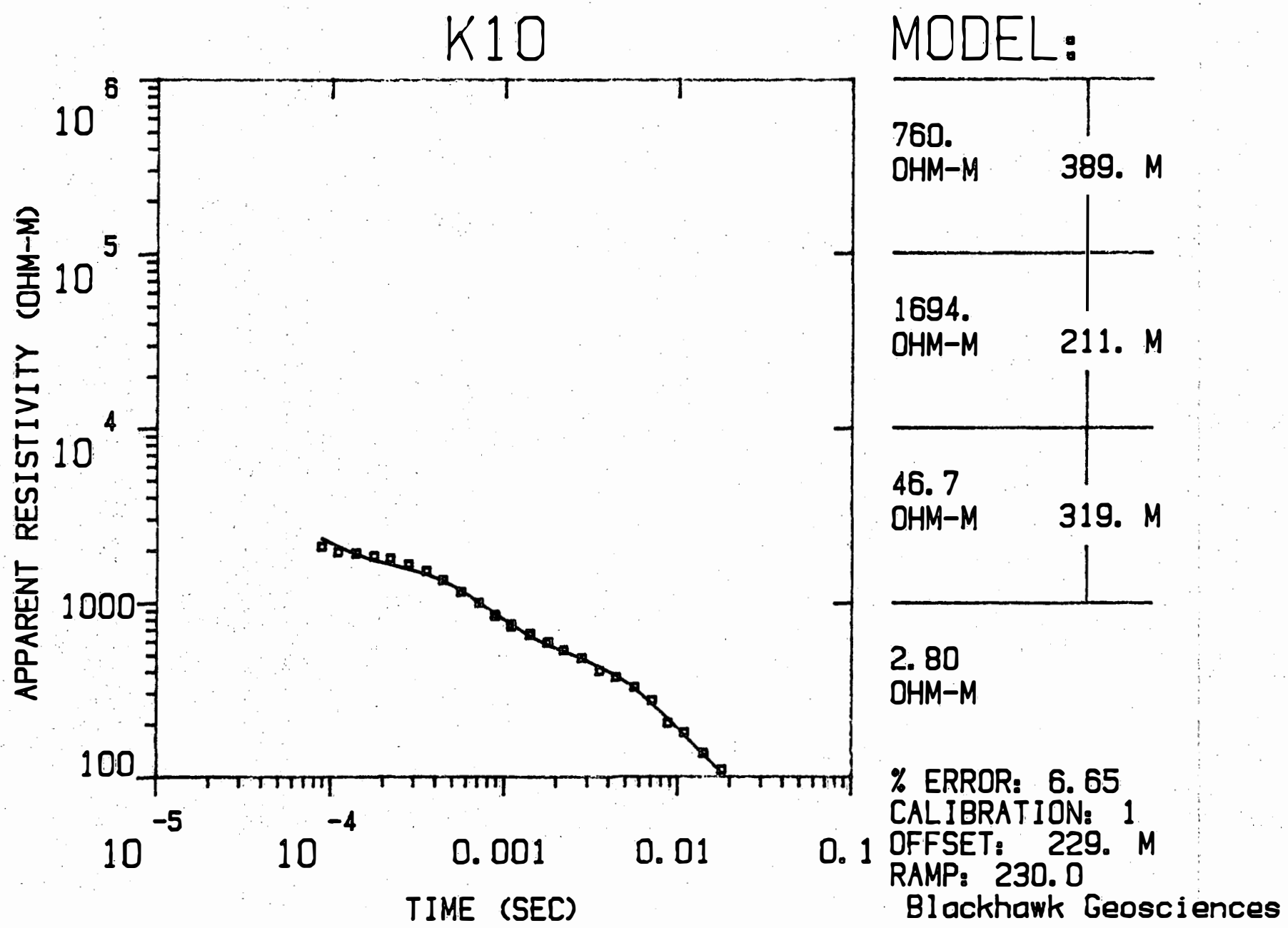
RMS LOG ERROR: 2.74E-02, ANTILOG YIELDS 6.5125 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	P 3	P 4	T 1	T 2	T 3
P 1	0.99						
P 2	-0.01	0.69					
P 3	0.00	-0.01	0.01				
P 4	0.00	0.16	-0.03	0.28			
T 1	0.00	0.05	0.00	-0.02	0.99		
T 2	-0.01	-0.34	-0.04	0.22	0.05	0.62	
T 3	0.00	0.02	0.00	-0.09	0.00	0.03	0.99

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS


K10
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^6
10^5
10^4
1000
100
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
760.
OHM-M
389. M
1694.
OHM-M
211. M
46.7
OHM-M
319. M
2.80
OHM-M
% ERROR: 6.65
CALIBRATION: 1
OFFSET: 229. M
RAMP: 230.0
Blackhawk Geosciences

K10

MODEL: 4 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		475.5	1560.0		
759.53	389.3	86.2	282.9	0.5	0.5
1693.98	210.6	-124.3	-408.0	0.1	0.6
46.67	319.4	-443.7	-1455.8	6.8	7.5
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	2.11E+03	2.35E+03	-10.293	
2	1.10E-04	1.97E+03	2.12E+03	-7.134	
3	1.40E-04	1.93E+03	1.91E+03	1.009	
4	1.77E-04	1.87E+03	1.77E+03	5.508	
5	2.20E-04	1.80E+03	1.67E+03	7.938	
6	2.80E-04	1.67E+03	1.57E+03	6.156	
7	3.55E-04	1.53E+03	1.46E+03	4.548	
8	4.43E-04	1.36E+03	1.35E+03	0.655	
9	5.64E-04	1.16E+03	1.19E+03	-2.476	
10	7.13E-04	1.01E+03	1.01E+03	-0.813	
11	8.81E-04	8.61E+02	8.78E+02	-1.869	
12	8.90E-04	8.44E+02	8.72E+02	-3.204	
13	1.10E-03	7.58E+02	7.61E+02	-0.487	
14	1.10E-03	7.34E+02	7.59E+02	-3.292	
15	1.40E-03	6.56E+02	6.50E+02	0.931	
16	1.41E-03	6.68E+02	6.46E+02	3.333	
17	1.77E-03	5.93E+02	5.76E+02	3.027	
18	1.80E-03	5.97E+02	5.72E+02	4.399	
19	2.20E-03	5.36E+02	5.30E+02	1.273	
20	2.80E-03	4.82E+02	4.81E+02	0.219	
21	3.55E-03	4.05E+02	4.28E+02	-5.319	
22	4.43E-03	3.73E+02	3.84E+02	-2.824	
23	5.64E-03	3.27E+02	3.22E+02	1.429	
24	7.13E-03	2.73E+02	2.62E+02	4.226	
25	8.81E-03	2.03E+02	2.15E+02	-5.772	
26	1.10E-02	1.79E+02	1.74E+02	3.376	
27	1.41E-02	1.37E+02	1.34E+02	1.642	
28	1.80E-02	1.10E+02	1.05E+02	4.442	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000
TDHZ ARRAY, 28 DATA POINTS, RAMP: 230.0 MICROSEC, DATA: K10
2401 001N 010N Z OPR XTL H 6 8+100
Ch.21 = 0.23 Ch.22 = 0.089 Ch.23 = 15 Ch.24 = 2
RMS LOG ERROR: 2.79E-02, ANTILOG YIELDS 6.6452 %
LATE TIME PARAMETERS

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PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.93
P 2 0.02 0.00
P 3 -0.02 -0.01 0.34

F 4	0.00	0.00	0.00	0.00			
T 1	-0.03	0.01	0.16	0.00	0.70		
T 2	0.06	0.02	0.03	0.00	0.38	0.27	
T 3	-0.02	-0.02	-0.18	0.00	0.04	-0.03	0.76
	P 1	P 2	P 3	F 4	T 1	T 2	T 3