GEOPHYSICAL SURVEYS
FOR GROUND WATER EVALUATION
NEAR KAHUKU RANCH
RIVIERA RESORT DEVELOPMENT
ISLAND OF HAWAII

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FOR GROUND WATER EVALUATION
NEAR KAHUKU RANCH
RIVIERA RESORT DEVELOPMENT
ISLAND OF HAWAII

Prepared For:

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April 24, 1990

(Our Project #90014)

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1.0 INTRODUCTION

A geophysical survey was performed for Palace Development Corporation (PDC) by Blackhawk Geosciences, Inc. (BGI) from March 27 through March 31, 1990. The purpose of this survey was to assist the evaluation of fresh water resources near Kahuku Ranch on the southern end of the Island of Hawaii, at the Riviera Resort Development.

The objectives for the geophysical survey can be understood from the hydrogeologic cross-section, typical of a volcanic island, shown in Figure 1-1. The volcanic rocks are generally highly permeable allowing rainfall to rapidly infiltrate into the ground and migrate downward to the water table, and eventually discharge 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, and behind these natural dams significant quantities of ground water can be stored.

2. Basal fresh water. The high permeability of the volcanic rocks allows 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 PDC. The drilling depth to the basal fresh water lens rapidly increases with elevation, and the objective of geophysical surveys is 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 about one-five-hundredth of the cost of drilling a well at elevations above 1,000 ft. Geophysical surveys, combined with other hydrogeologic information, are used to provide optimum locations for well placement and 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.

The specific objectives of the geophysical survey near Kuhuku Ranch at the Riviera Resort Development were (i) to calibrate the TDEM soundings near an existing well, and (ii) to derive the thickness of the basal fresh water zone to the east and north of the existing well.

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 PDC were 1,000 ft by 1,000 ft on each side for loops 1, 2 and 3, and 1,500 ft by 1,500 ft on each side for loops 4, 5, 6 and 7.

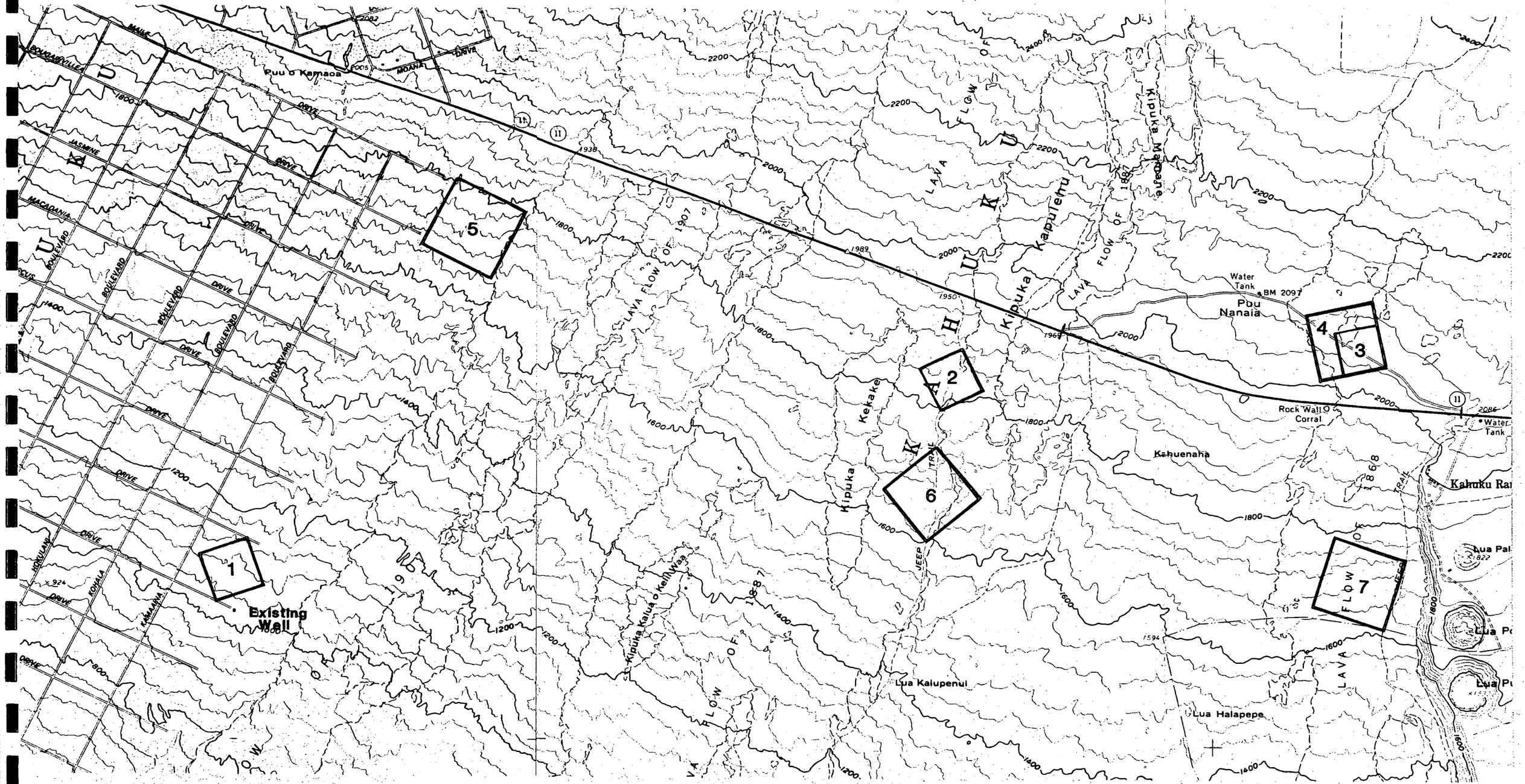
   Where possible, transmitter loop wires were positioned with at least one corner of the square loop near roads and trails. It is also important to keep the sounding position away from the power lines whenever possible. A major power line runs along Route 11. Loop 1 was positioned with the center 50 ft higher in elevation from the existing well to avoid possible interference from the borehole casing and nearby power lines.

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 very good.

During the five days of field work 7 stations (soundings) were completed. The position and number of TDEM soundings recorded was largely constrained by available road access. Additional soundings would require a means of transporting equipment away from Route 11 because of the power line along Route 11. Figure 2-1 shows the location of the soundings conducted for PDC and the locations of the existing well. A daily log of field activity is given in Table 2-1.

Table 2-1. Daily log of field activities

Date (1990)	Activity
March 26	Two BGI personnel mobilize from Golden, CO to Kailua-Kona, HI.
March 27	Set-up geophysical equipment. Record loop 1.
March 28	Recorded loop 2 and loop 3.
March 29	Recorded loop 4 and loop 5.
March 30	Recorded loop 6.
March 31	Recorded loop 7.
April 1-12	Performed other geophysical surveys.
April 12-13	BGI personnel demobilize from Kailua-Kona, HI to Golden, CO.



BLACKHAWK GEOSCIENCES, INC.

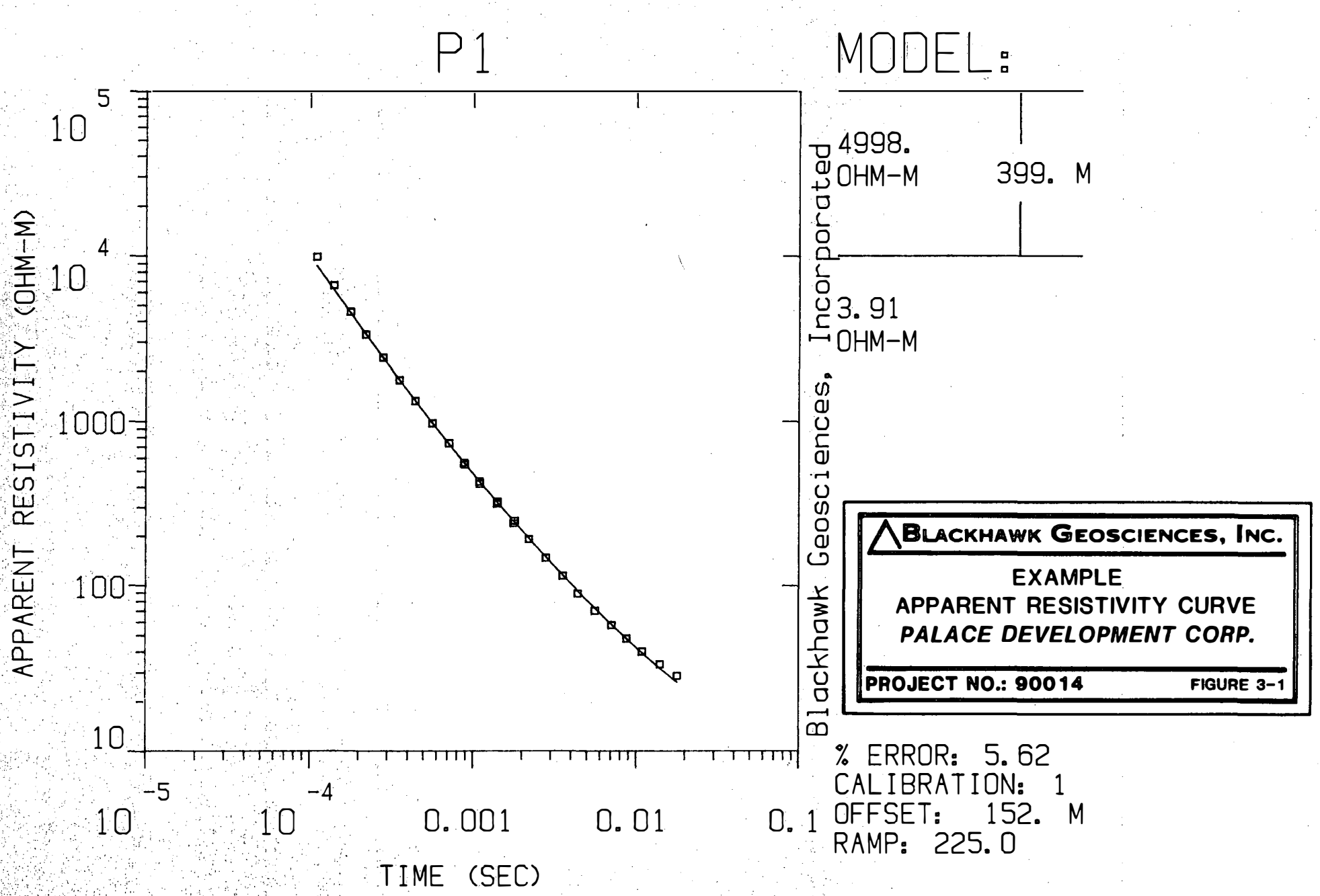
TIME DOMAIN EM SURVEY
LOCATION MAP
PALACE DEVELOPMENT CORP.

PROJECT NO.: 90014 **FIGURE 2-1**

3.0 DATA PROCESSING

The objective of data processing is to derive from the TDEM measurements in the center of the loop 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. An example data set is given in Figures 3-1 and 3-2 for the station near the existing well site (loop 1). 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. Figure 3-2 lists in column 4 the error between measured and computed data in each time gate.

Figure 3-1 shows that the resistivity layering in the upper 1,400 ft consists of two layers, - the first layer has a thickness of 399 m (1,310 ft) with a resistivity of greater than 1,000 ohm-m, and the second layer has a resistivity of 3.9 ohm-m. Stations 1 and 5 were both interpreted with two layer models. At the other stations the data was interpreted with three layer models.


P1
MODEL:
4998.
OHM-M
399. M
3.91
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)
Blackhawk Geosciences, Incorporated
% ERROR: 5.62
CALIBRATION: 1
OFFSET: 152. M
RAMP: 225.0
BLACKHAWK GEOSCIENCES, INC.
EXAMPLE
APPARENT RESISTIVITY CURVE
PALACE DEVELOPMENT CORP.
PROJECT NO.: 90014
FIGURE 3-1

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		326.1	1070.0		
4998.44	399.4	-73.3	-240.2	0.1	0.1
3.91					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.10E-04	9.85E+03	8.70E+03	13.256	
2	1.40E-04	6.59E+03	6.22E+03	5.975	
3	1.77E-04	4.54E+03	4.50E+03	0.981	
4	2.20E-04	3.31E+03	3.34E+03	-0.871	
5	2.80E-04	2.40E+03	2.42E+03	-0.753	
6	3.55E-04	1.76E+03	1.77E+03	-0.791	
7	4.43E-04	1.32E+03	1.33E+03	-0.953	
8	5.64E-04	9.69E+02	9.77E+02	-0.868	
9	7.13E-04	7.34E+02	7.29E+02	0.682	
10	8.81E-04	5.57E+02	5.62E+02	-0.881	
11	8.90E-04	5.47E+02	5.56E+02	-1.515	
12	1.10E-03	4.30E+02	4.32E+02	-0.349	
13	1.10E-03	4.18E+02	4.30E+02	-2.806	
14	1.40E-03	3.16E+02	3.24E+02	-2.402	
15	1.41E-03	3.24E+02	3.21E+02	1.079	
16	1.77E-03	2.39E+02	2.47E+02	-3.138	
17	1.80E-03	2.47E+02	2.43E+02	1.579	
18	2.20E-03	1.91E+02	1.93E+02	-1.238	
19	2.80E-03	1.47E+02	1.49E+02	-1.457	
20	3.55E-03	1.14E+02	1.15E+02	-1.097	
21	4.43E-03	8.89E+01	9.20E+01	-3.360	
22	5.64E-03	7.01E+01	7.25E+01	-3.266	
23	7.13E-03	5.75E+01	5.78E+01	-0.615	
24	8.81E-03	4.78E+01	4.78E+01	0.110	
25	1.10E-02	4.00E+01	3.94E+01	1.690	
26	1.41E-02	3.36E+01	3.18E+01	5.690	
27	1.80E-02	2.86E+01	2.63E+01	8.904	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 27 DATA POINTS, RAMP: 225.0 MICROSEC, DATA: P1
2703 0001 0001 Z OPR XTL L 7 10+100
Ch.21 = 0.225 Ch.22 = 0.89 Ch.23 = 20 Ch.24 = 9
RMS LOG ERROR: 2.37E-02, ANTILOG YIELDS 5.6207 %
LATE TIME PARAMETERS

+ Blackhawk Geosciences, Incorporated +

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.27
P 2 -0.29 0.80
T 1 -0.02 -0.01 1.00
P 1 P 2 T 1

BLACKHAWK GEOSCIENCES, INC.

EXAMPLE DATA SHEET FOR SOUNDING #1

PALACE DEVELOPMENT CORP.

PROJECT NO.: 90014 **FIGURE 3-2**

4.0 INTERPRETATION RESULTS

4.1 GENERAL

The objective of PDC and its ground water consultants is not to obtain the resistivity layering of the subsurface, but to infer from the resistivity 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 rocks of Hawaii rocks saturated with salt water will generally have resistivities of less than 5 ohm-m. On the other hand, dry volcanic rocks can have very high resistivities (greater than 1,000 ohm-m).

2. Calibrating the geophysical interpretation at a well. In this case one well was available for comparison. The approximate location of this well is shown in Figure 2-1. The head information is useful as an approximate range for general comparisons. Sounding 1, located about 50 ft higher in elevation and about 800 ft northwest of the well shows a computed head of 6 ft. This value is in general agreement with the head value of 3.5 ft from the well 50 ft lower in elevation (Fig. 4-1).

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

Table 4-1. Results of TDEM Survey

Sounding #	Surface Elevation (ft)	Head of Fresh/Brackish Water Above Sea Level (Water Table) (ft)	Minimum Thickness of Fresh/Brackish Water Lens (ft)
1	1070	6	246
2	1820	--	--
3	2050	--	--
4	2050	--	--
5	1750	6.1	252
6	1670	12.4	507
7	1680	--	--

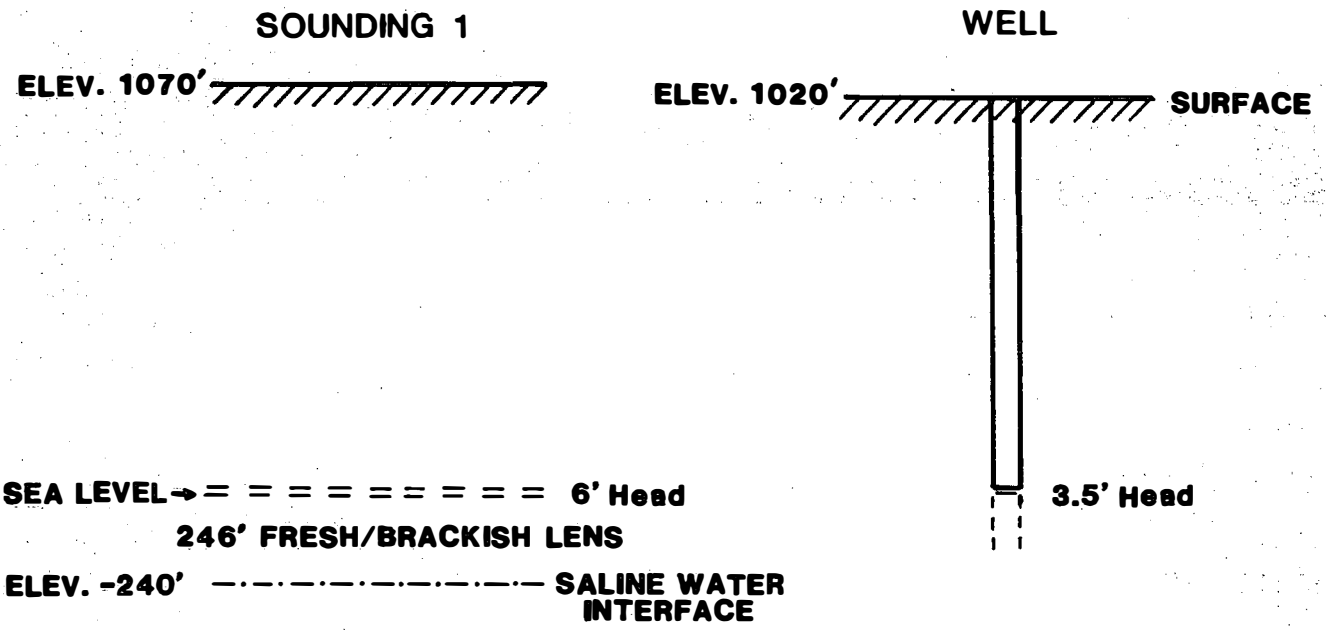
(1) In sounding 1 near the well, sounding 5 approximately one mile north of sounding 1, and sounding 6 near the middle of the survey area, the results indicate a saline water interface present within the effective exploration depth of the sounding measurement. In sounding 2, located approximately one-half mile north of sounding 6, the saline water interface was beyond the effective exploration depth of the sounding measurement (1,000 ft by 1,000 ft transmitter loops vs 1,500 ft by 1,500 ft transmitter loops for sounding 6).

(2) Soundings 3, 4 and 7 did not detect a saline water interface. There are two possible reasons that may explain the results:

(a) The depth to the saline water interface is beyond the effective exploration depth of the sounding (> 2,800 ft below the surface).

(b) The proximity of the rift and fault zone, as well as nearby flow sources (Fig. 4-2), may have a great effect on the measurement. A magma body could inhibit infiltration of saline and or fresh/brackish water.

SOUNDING 1
AT WELL AT EAST END OF POHA DRIVE

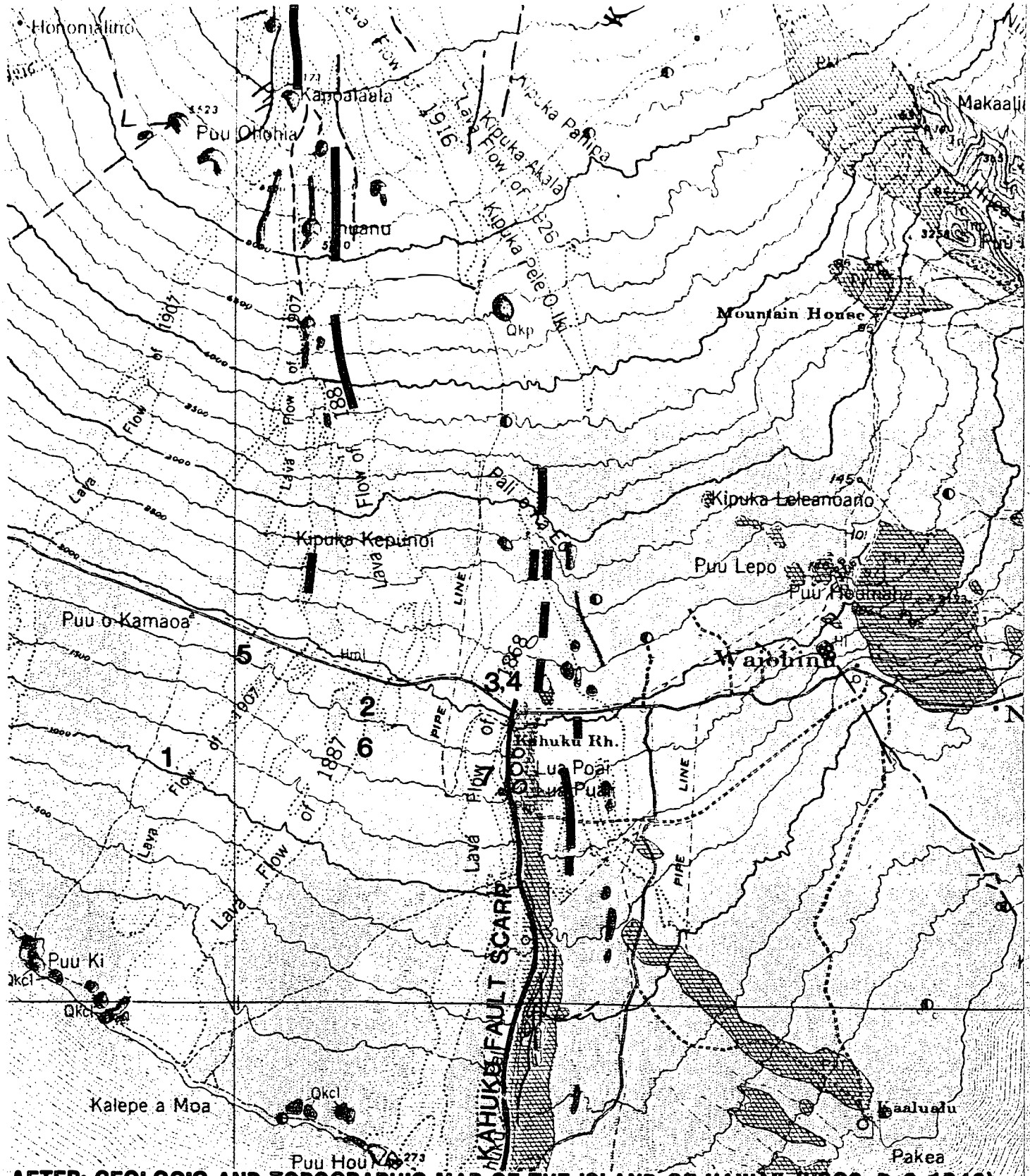


NOTE: Location of sounding 1 measurement is approximately 50 feet higher than well location.

BLACKHAWK GEOSCIENCES, INC.

ILLUSTRATION OF TDEM COMPARISON AT WELL
PALACE DEVELOPMENT CORP.

PROJECT NO.: 90014 FIGURE 4-1



AFTER: GEOLOGIC AND TOPOGRAPHIC MAP OF THE ISLAND OF HAWAII (USGS, B-9, 1946).

Historic and Prehistoric fissure vents at source of flows.

2 Approximate TDEM sounding locations Palace Development Corp.

10,000 0 10,000

SCALE - FEET

BLACKHAWK GEOSCIENCES, INC.

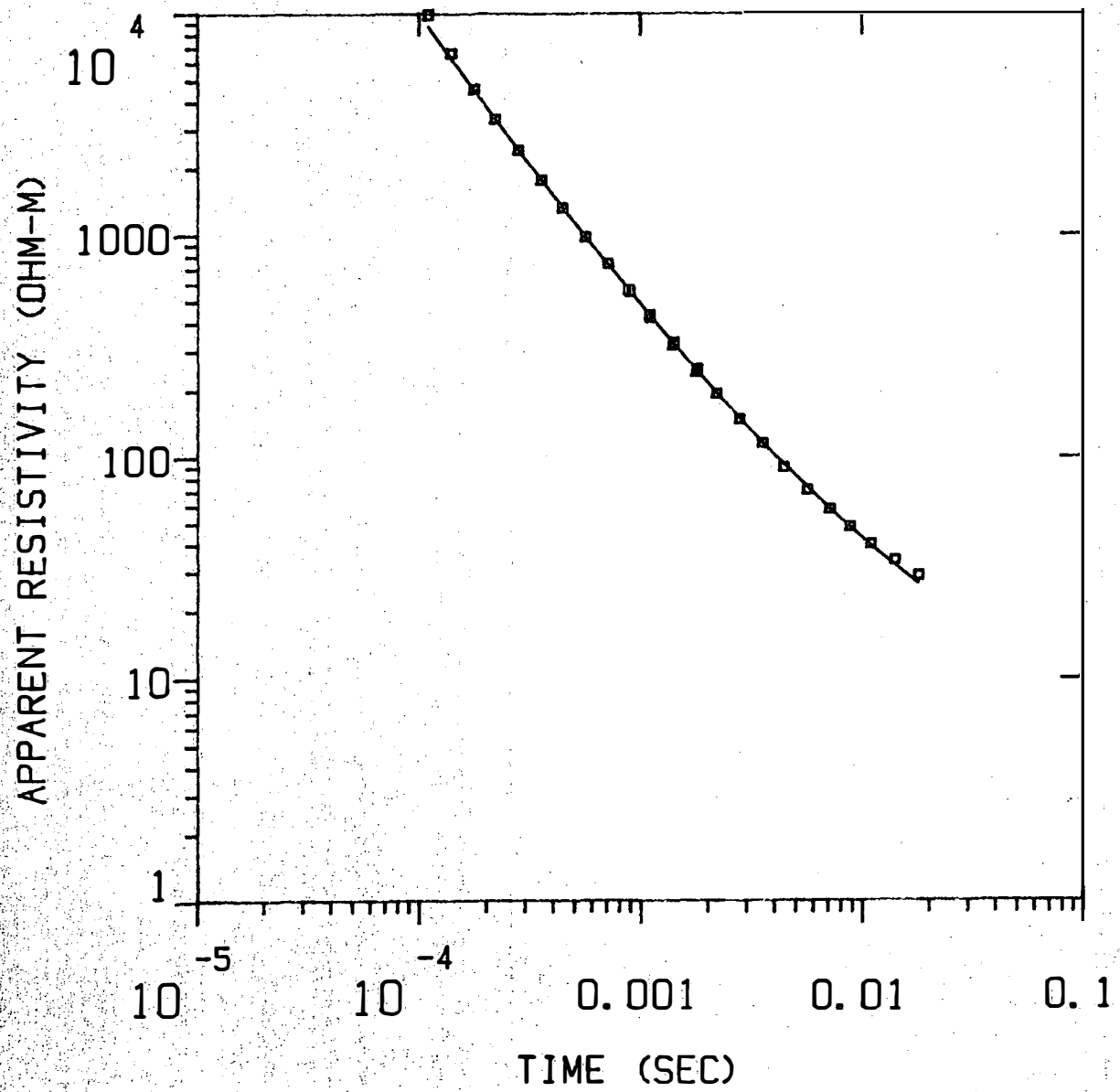
ILLUSTRATION MAP SHOWING PROXIMITY OF FISSURE VENT LAVA SOURCES AND FAULT ZONE *PALACE DEVELOPMENT CORP.*

PROJECT NO.: 90014 FIGURE 4-2

5.0 CONCLUSIONS

The TDEM survey indicates that with the available data the optimum location for an additional well would be near sounding 6. At this location the head of fresh/brackish water is expected to be approximately 12 ft with a fresh/brackish water lens of approximately 500 ft in thickness.

A minimum of two additional soundings between soundings 5 and 6 would better define the aquifer in the proposed Riviera Resort area. This would require additional effort using helicopter support or considerable manpower efforts to transport equipment away from the power line along Route 11.



MODEL:

4998.
OHM-M

399. M

3.91
OHM-M

% ERROR: 5.62
CALIBRATION: 1
OFFSET: 152. M
RAMP: 225.0

Blackhawk Geosciences

P1

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		326.1	1070.0		
4998.44	399.4	-73.2	-240.2	0.1	0.1
3.91					

	TIMES	DATA	CALC	% ERROR	STD ERR
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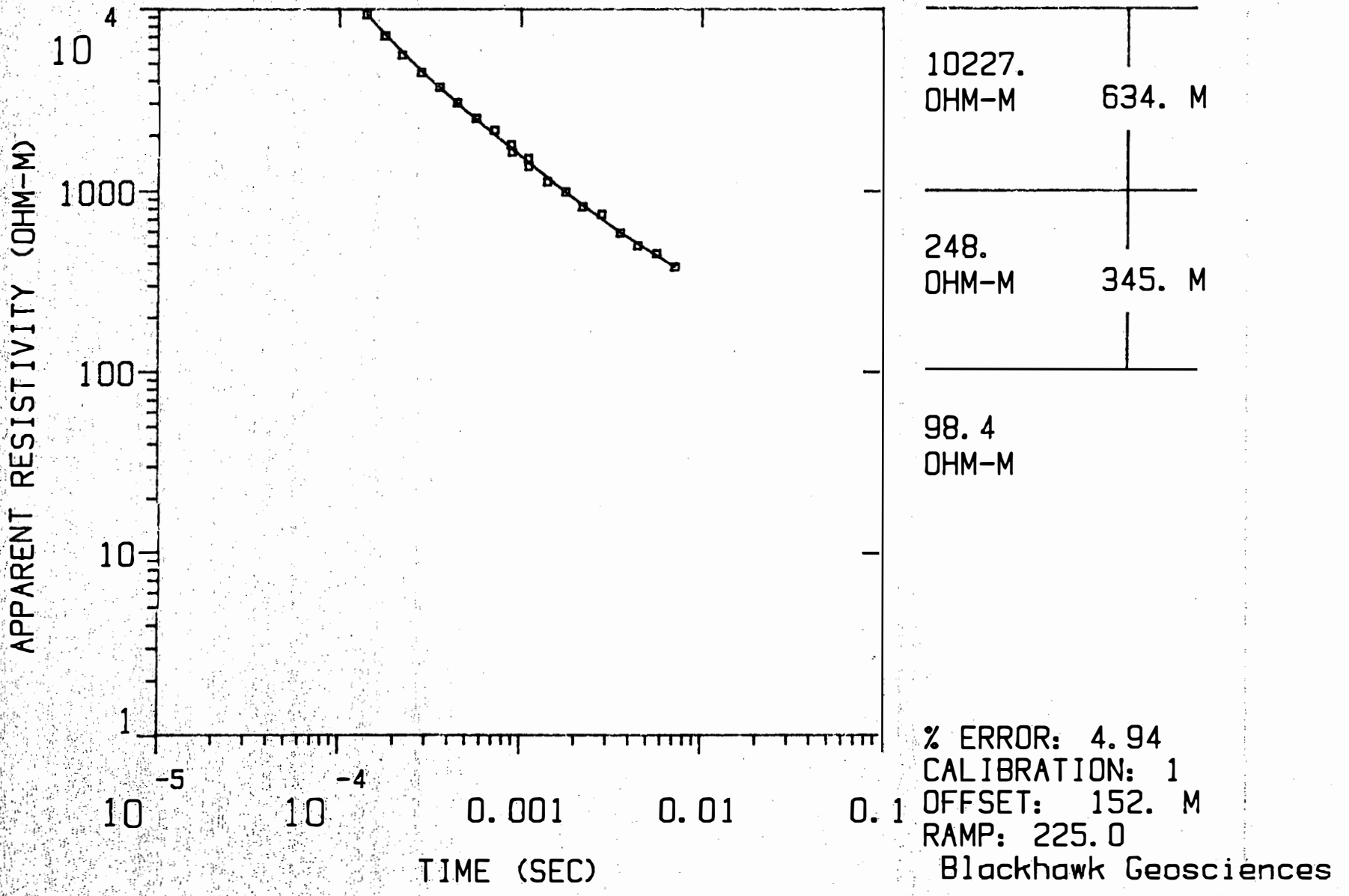
2	1.40E-04	6.59E+03	6.22E+03	5.975	
3	1.77E-04	4.54E+03	4.50E+03	0.931	
4	2.20E-04	3.31E+03	3.34E+03	-0.871	
5	2.80E-04	2.40E+03	2.42E+03	-0.753	
6	3.55E-04	1.76E+03	1.77E+03	-0.791	
7	4.43E-04	1.32E+03	1.33E+03	-0.953	
8	5.64E-04	9.69E+02	9.77E+02	-0.869	
9	7.13E-04	7.34E+02	7.29E+02	0.682	
10	8.81E-04	5.57E+02	5.62E+02	-0.881	
11	8.90E-04	5.47E+02	5.56E+02	-1.515	
12	1.10E-03	4.30E+02	4.32E+02	-0.349	
13	1.10E-03	4.18E+02	4.30E+02	-2.806	
14	1.40E-03	3.16E+02	3.24E+02	-2.402	
15	1.41E-03	3.24E+02	3.21E+02	1.079	
16	1.77E-03	2.39E+02	2.47E+02	-3.138	
17	1.80E-03	2.47E+02	2.43E+02	1.579	
18	2.20E-03	1.91E+02	1.93E+02	-1.238	
19	2.80E-03	1.47E+02	1.49E+02	-1.457	
20	3.55E-03	1.14E+02	1.15E+02	-1.097	
21	4.43E-03	8.89E+01	9.20E+01	-3.360	
22	5.64E-03	7.01E+01	7.25E+01	-3.266	
23	7.13E-03	5.75E+01	5.78E+01	-0.615	
24	8.81E-03	4.78E+01	4.78E+01	0.110	
25	1.10E-02	4.00E+01	3.94E+01	1.690	
26	1.41E-02	3.36E+01	3.18E+01	5.690	
27	1.80E-02	2.86E+01	2.63E+01	8.904	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 27 DATA POINTS, RAMP: 225.0 MICROSEC, DATA: P1
2703 0001 0001 Z OPR XTL L 7.10+100
Ch.21 = 0.225 Ch.22 = 0.89 Ch.23 = 20 Ch.24 = 9
RMS LOG ERROR: 2.37E-02, ANTILOG YIELDS 5.6207 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.27
P 2 -0.29 0.80


P2
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
MODEL:
10227.
OHM-M
634. M
248.
OHM-M
345. M
98.4
OHM-M
% ERROR: 4.94
CALIBRATION: 1
OFFSET: 152. M
RAMP: 225.0
Blackhawk Geosciences

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		554.7	1820.0		
10227.39	633.9	-79.2	-259.7	0.1	0.1
248.20	344.5	-423.7	-1390.1	1.4	1.5
98.36					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.61E+04	1.57E+04	2.358	
2	1.10E-04	1.24E+04	1.22E+04	1.469	
3	1.40E-04	9.32E+03	9.28E+03	0.475	
4	1.77E-04	7.03E+03	7.17E+03	-1.978	
5	2.20E-04	5.52E+03	5.72E+03	-3.594	
6	2.80E-04	4.41E+03	4.52E+03	-2.549	
7	3.55E-04	3.66E+03	3.63E+03	0.586	
8	4.43E-04	3.00E+03	2.99E+03	0.392	
9	5.64E-04	2.46E+03	2.44E+03	1.215	
10	7.13E-04	2.12E+03	2.02E+03	5.421	
11	8.81E-04	1.77E+03	1.70E+03	4.494	
12	8.90E-04	1.61E+03	1.68E+03	-4.193	
13	1.10E-03	1.49E+03	1.42E+03	4.798	
14	1.10E-03	1.35E+03	1.42E+03	-4.578	
15	1.40E-03	1.11E+03	1.18E+03	-5.385	
16	1.77E-03	9.80E+02	9.78E+02	0.202	
17	2.20E-03	8.13E+02	8.30E+02	-2.129	
18	2.80E-03	7.37E+02	6.97E+02	5.804	
19	3.55E-03	5.81E+02	5.89E+02	-1.291	
20	4.43E-03	4.94E+02	5.09E+02	-3.010	
21	5.64E-03	4.47E+02	4.36E+02	2.437	
22	7.13E-03	3.78E+02	3.79E+02	-0.143	

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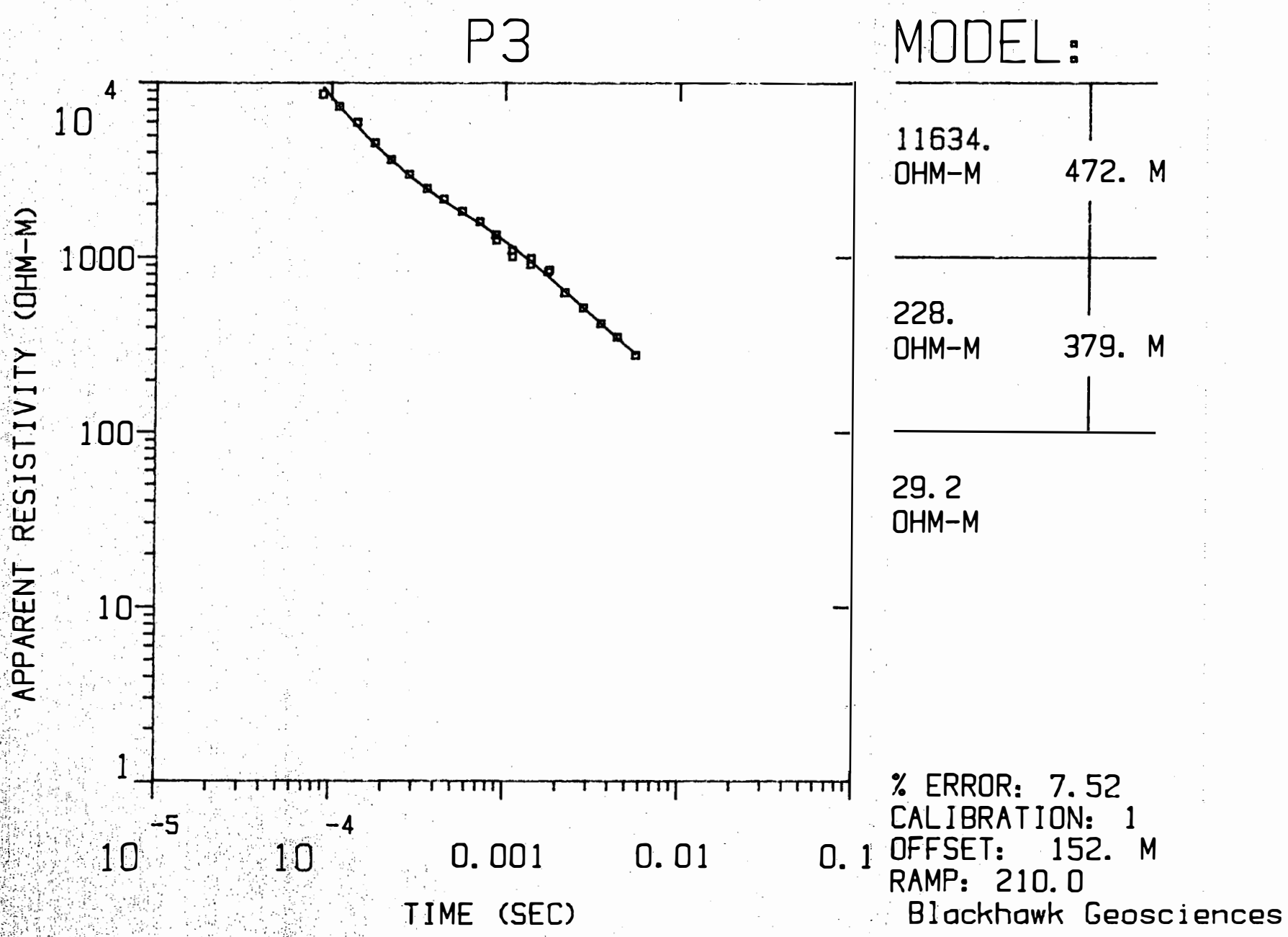
2803 0002 0002 Z OPR XTL L 7 10+100
Ch.21 = 0.225 Ch.22 = 0.89 Ch.23 = 20 Ch.24 = 9
RMS LOG ERROR: 2.09E-02, ANTILOG YIELDS 4.9387 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	P 3	T 1	T 2
P 1	0.90				
P 2	-0.02	0.99			
P 3	0.00	0.00	1.00		
T 1	0.01	0.00	0.00	1.00	
T 2	-0.01	0.00	0.00	0.00	1.00


P3
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
11634.
OHM-M
472. M
228.
OHM-M
379. M
29.2
OHM-M
% ERROR: 7.52
CALIBRATION: 1
OFFSET: 152. M
RAMP: 210.0
Blackhawk Geosciences

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		624.8	2050.0		
11633.77	472.2	152.6	500.7	0.0	0.0
228.45	379.2	-226.5	-743.2	1.7	1.7
29.22					

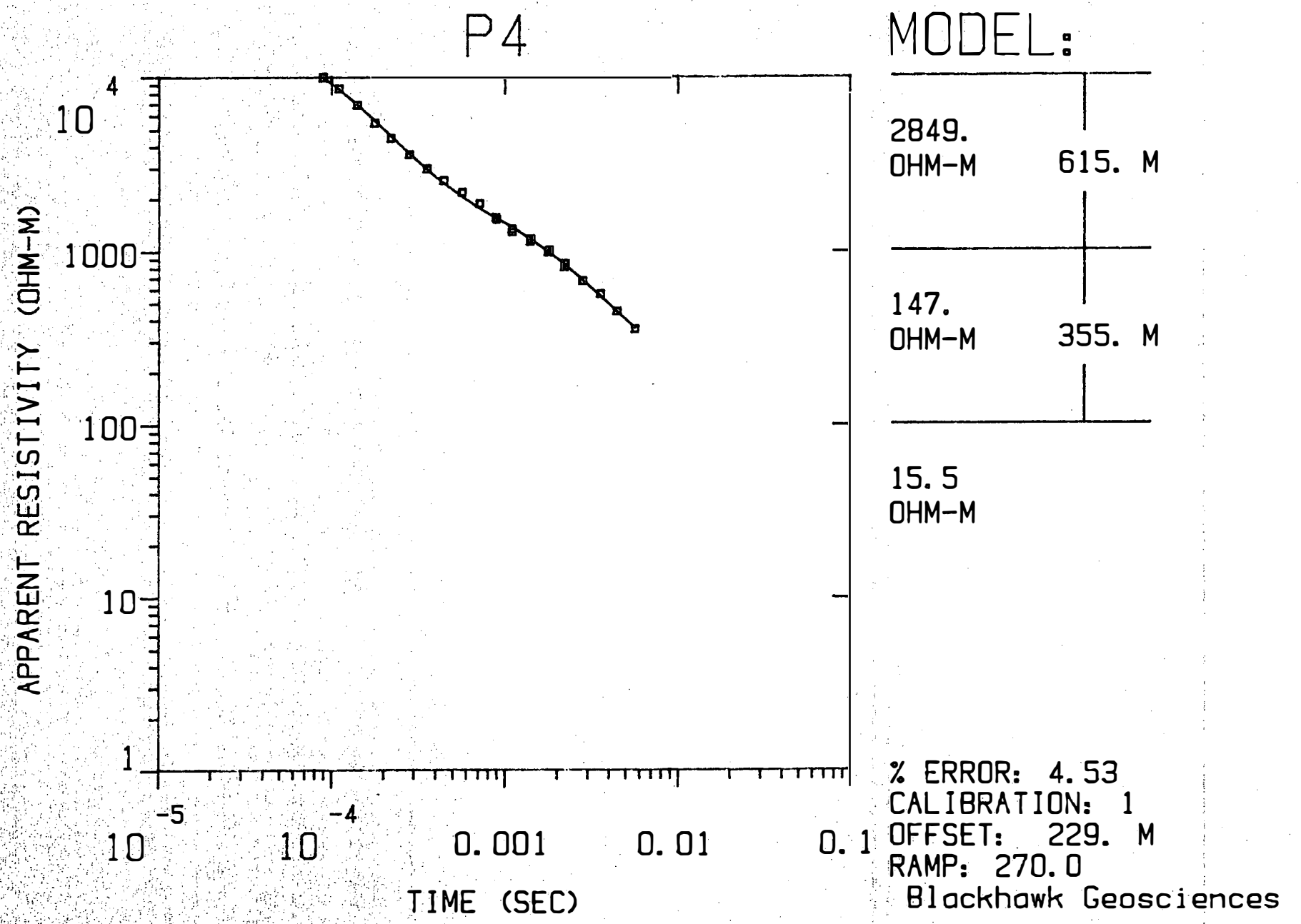
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	8.60E+03	9.34E+03	-7.944	
2	1.10E-04	7.27E+03	7.30E+03	-0.465	
3	1.40E-04	5.92E+03	5.59E+03	5.915	
4	1.77E-04	4.50E+03	4.39E+03	2.560	
5	2.20E-04	3.60E+03	3.57E+03	0.728	
6	2.80E-04	2.97E+03	2.91E+03	2.323	
7	3.55E-04	2.46E+03	2.42E+03	1.446	
8	4.43E-04	2.14E+03	2.07E+03	3.024	
9	5.64E-04	1.82E+03	1.78E+03	1.962	
10	7.13E-04	1.58E+03	1.54E+03	2.609	
11	8.81E-04	1.33E+03	1.33E+03	-0.263	
12	8.90E-04	1.24E+03	1.32E+03	-6.301	
13	1.10E-03	1.09E+03	1.14E+03	-4.547	
14	1.10E-03	9.99E+02	1.13E+03	-11.922	
15	1.40E-03	9.03E+02	9.43E+02	-4.253	
16	1.41E-03	9.80E+02	9.37E+02	4.594	
17	1.77E-03	8.24E+02	7.73E+02	6.660	
18	1.80E-03	8.38E+02	7.63E+02	9.766	
19	2.20E-03	6.25E+02	6.38E+02	-2.034	
20	2.80E-03	5.12E+02	5.15E+02	-0.651	
21	3.55E-03	4.18E+02	4.19E+02	-0.235	
22	4.43E-03	3.50E+02	3.45E+02	1.337	
23	5.64E-03	2.77E+02	2.81E+02	-1.606	

R: 152. X: 0. Y: 153. DL: 305. REQ: 170. CF: 1.0000
TDHZ ARRAY, 23 DATA POINTS, RAMP: 210.0 MICROSEC, DATA: P3
2803 0003 0003 Z OPR XTL H 6 8+100
Ch.21 = 0.21 Ch.22 = 0.089 Ch.23 = 19.5 Ch.24 =
RMS LOG ERROR: 3.15E-02, ANTILOG YIELDS 7.5177 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.01				
P 2	-0.01	0.39			
P 3	0.01	-0.12	0.09		
T 1	0.03	0.15	-0.02	0.93	
T 2	-0.03	-0.09	0.00	0.03	0.73
	P 1	P 2	P 3	T 1	T 2



MODEL:

2849.
OHM-M

615. M

147.
OHM-M

355. M

15.5
OHM-M

% ERROR: 4.53
CALIBRATION: 1
OFFSET: 229. M
RAMP: 270.0

Blackhawk Geosciences

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		624.8	2050.0		
2848.93	614.5	10.3	33.8	0.2	0.2
146.63	354.7	-344.4	-1129.8	2.4	2.6
15.52					

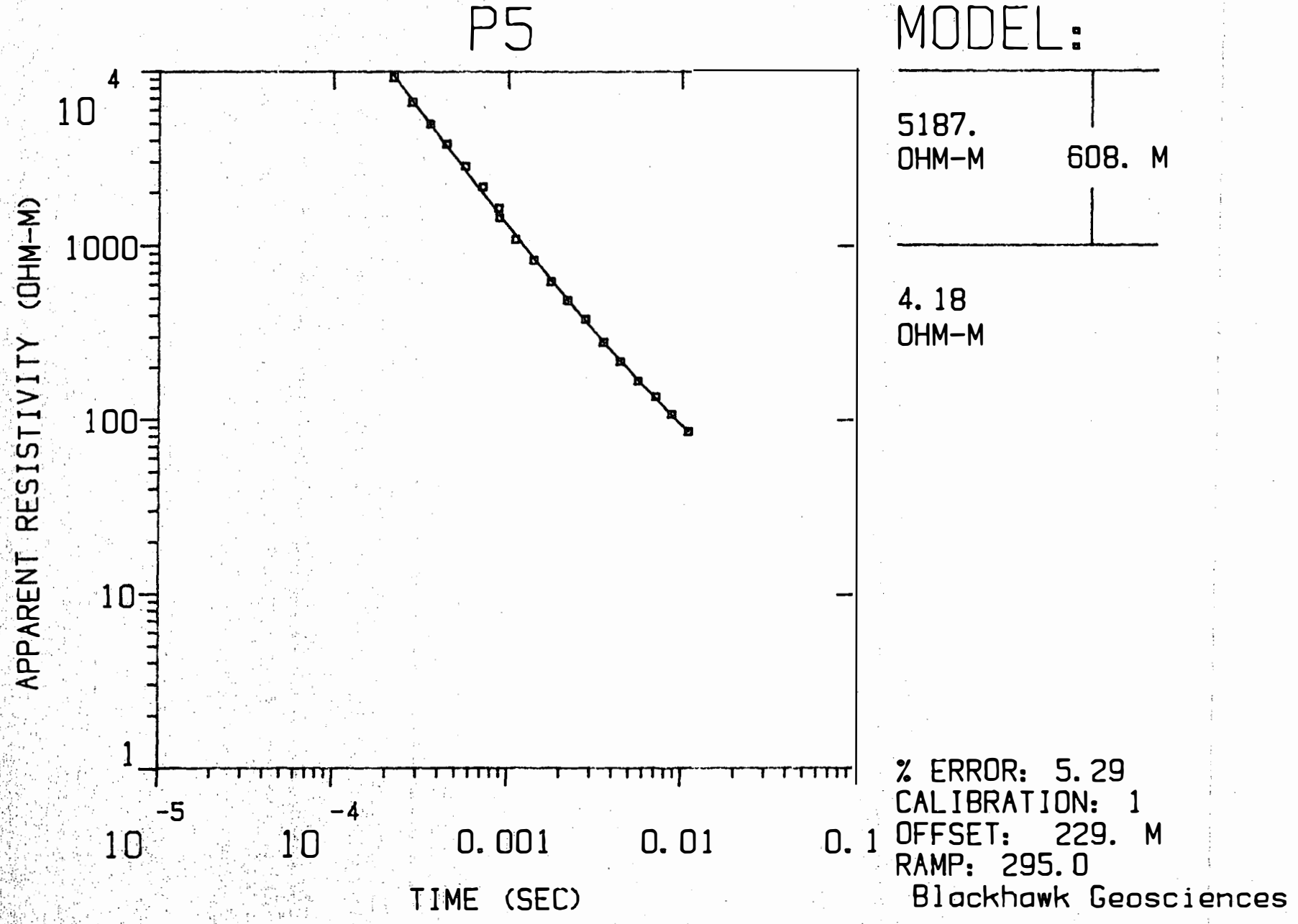
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	9.94E+03	9.83E+03	1.101	
2	1.10E-04	8.53E+03	8.44E+03	1.062	
3	1.40E-04	6.88E+03	6.92E+03	-0.653	
4	1.77E-04	5.41E+03	5.59E+03	-3.167	
5	2.20E-04	4.43E+03	4.55E+03	-2.625	
6	2.80E-04	3.57E+03	3.63E+03	-1.556	
7	3.55E-04	2.96E+03	2.93E+03	1.125	
8	4.43E-04	2.54E+03	2.45E+03	3.698	
9	5.64E-04	2.17E+03	2.05E+03	5.751	
10	7.13E-04	1.87E+03	1.75E+03	6.430	
11	8.81E-04	1.56E+03	1.55E+03	0.650	
12	8.90E-04	1.51E+03	1.54E+03	-1.527	
13	1.10E-03	1.33E+03	1.37E+03	-3.090	
14	1.10E-03	1.28E+03	1.37E+03	-6.167	
15	1.40E-03	1.13E+03	1.17E+03	-3.321	
16	1.41E-03	1.17E+03	1.16E+03	0.443	
17	1.77E-03	9.78E+02	9.87E+02	-0.918	
18	1.80E-03	1.00E+03	9.77E+02	2.802	
19	2.20E-03	8.04E+02	8.35E+02	-3.722	
20	2.22E-03	8.42E+02	8.27E+02	1.816	
21	2.80E-03	6.67E+02	6.76E+02	-1.395	
22	3.55E-03	5.60E+02	5.44E+02	2.965	
23	4.43E-03	4.43E+02	4.42E+02	0.092	
24	5.64E-03	3.50E+02	3.54E+02	-1.110	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000
TDHZ ARRAY, 24 DATA POINTS, RAMP: 270.0 MICROSEC, DATA: P4
2903 0004 0004 Z OPR XTL H 6 8+100
Ch.21 = 0.27 Ch.22 = 0.089 Ch.23 = 18.5 Ch.24 =
RMS LOG ERROR: 1.93E-02, ANTILOG YIELDS 4.5350 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.97				
P 2	-0.04	0.83			
P 3	-0.03	-0.22	0.49		
T 1	0.01	0.02	0.00	1.00	
T 2	-0.02	-0.07	-0.09	0.01	0.96
	P 1	P 2	P 3	T 1	T 2


P5
MODEL:
5187.
OHM-M
608. M
4.18
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: 5.29
CALIBRATION: 1
OFFSET: 229. M
RAMP: 295.0
Blackhawk Geosciences

MODEL: 2 LAYERS

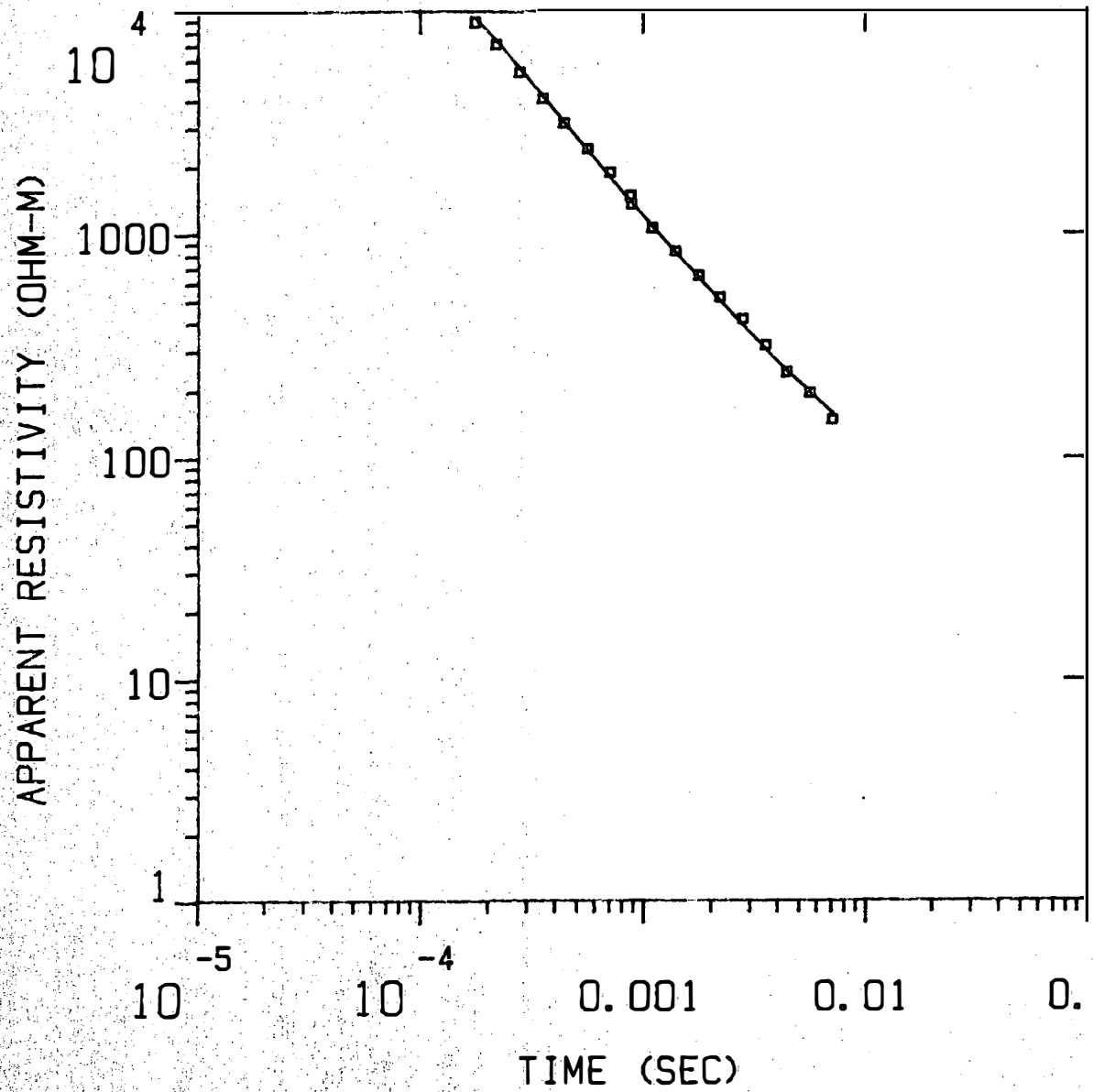
RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		533.4	1750.0		
5186.95	608.4	-75.0	-246.2	0.1	0.1
4.18					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.10E-04	2.37E+04	2.36E+04	0.558	
2	1.40E-04	1.74E+04	1.75E+04	-0.403	
3	1.77E-04	1.23E+04	1.27E+04	-3.317	
4	2.20E-04	9.26E+03	9.41E+03	-1.596	
5	2.80E-04	6.63E+03	6.80E+03	-2.451	
6	3.55E-04	4.95E+03	4.94E+03	0.250	
7	4.43E-04	3.79E+03	3.68E+03	3.029	
8	5.64E-04	2.82E+03	2.68E+03	5.157	
9	7.13E-04	2.15E+03	1.98E+03	8.468	
10	8.81E-04	1.62E+03	1.51E+03	7.213	
11	8.90E-04	1.43E+03	1.49E+03	-4.108	
12	1.10E-03	1.08E+03	1.14E+03	-5.743	
13	1.40E-03	8.20E+02	8.46E+02	-3.179	
14	1.77E-03	6.19E+02	6.37E+02	-2.733	
15	2.20E-03	4.84E+02	4.91E+02	-1.372	
16	2.80E-03	3.77E+02	3.69E+02	2.124	
17	3.55E-03	2.79E+02	2.81E+02	-0.960	
18	4.43E-03	2.15E+02	2.19E+02	-1.953	
19	5.64E-03	1.66E+02	1.68E+02	-1.329	
20	7.13E-03	1.34E+02	1.31E+02	2.393	
21	8.81E-03	1.06E+02	1.05E+02	1.192	
22	1.10E-02	8.46E+01	8.47E+01	-0.090	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000
TDHZ ARRAY, 22 DATA POINTS, RAMP: 295.0 MICROSEC, DATA: P5
2903 0005 0005 Z OPR XTL H 6 8+100
Ch.21 = 0.295 Ch.22 = 0.089 Ch.23 = 19 Ch.24 =
RMS LOG ERROR: 2.24E-02, ANTILOG YIELDS 5.2925 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER
P 1 0.59
P 2 -0.13 0.75
T 1 0.00 -0.02 1.00
P 1 P 2 T 1



MODEL:

10497.
OHM-M
428. M

572.
OHM-M
232. M

12.9
OHM-M

% ERROR: 5.46
CALIBRATION: 1
OFFSET: 229. M
RAMP: 280.0

Blackhawk Geosciences

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		509.0	1670.0		
10496.71	427.7	81.3	266.7	0.0	0.0
571.62	232.0	-150.7	-494.5	0.4	0.4
12.86					

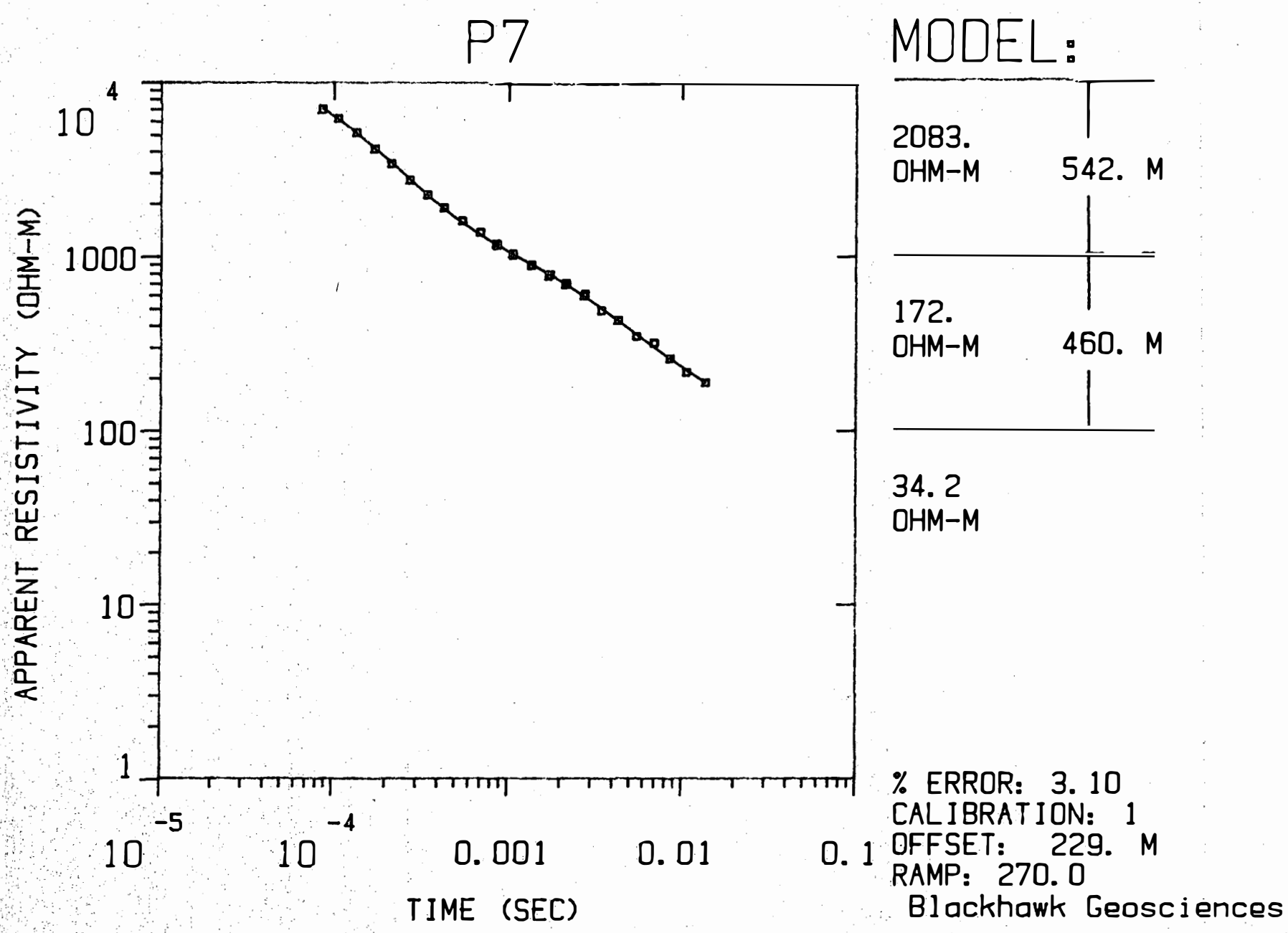
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.76E+04	1.74E+04	1.350	
2	1.10E-04	1.50E+04	1.45E+04	2.896	
3	1.40E-04	1.18E+04	1.17E+04	0.689	
4	1.77E-04	8.95E+03	9.33E+03	-4.090	
5	2.20E-04	7.03E+03	7.35E+03	-4.326	
6	2.80E-04	5.30E+03	5.55E+03	-4.440	
7	3.55E-04	4.05E+03	4.18E+03	-2.956	
8	4.43E-04	3.14E+03	3.19E+03	-1.546	
9	5.64E-04	2.41E+03	2.38E+03	1.305	
10	7.13E-04	1.88E+03	1.80E+03	4.839	
11	8.81E-04	1.48E+03	1.40E+03	5.563	
12	8.90E-04	1.35E+03	1.39E+03	-2.525	
13	1.10E-03	1.06E+03	1.08E+03	-2.456	
14	1.40E-03	8.28E+02	8.22E+02	0.697	
15	1.77E-03	6.45E+02	6.34E+02	1.839	
16	2.20E-03	5.14E+02	4.99E+02	2.980	
17	2.80E-03	4.12E+02	3.88E+02	6.264	
18	3.55E-03	3.16E+02	3.04E+02	3.801	
19	4.43E-03	2.39E+02	2.44E+02	-2.030	
20	5.64E-03	1.93E+02	1.95E+02	-0.878	
21	7.13E-03	1.46E+02	1.57E+02	-6.825	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000
R: 229. X: 0. Y: 229. DL: 457. REQ: 0. CF: 0.9970
TDHZ ARRAY, 11 DATA POINTS, RAMP: 280.0 MICROSEC, DATA: P6
TDHZ ARRAY, 10 DATA POINTS, RAMP: 280.0 MICROSEC, DATA: PALP0002
3003 0006 0006 Z OPR XTL H 6 8+100
Ch.21 = 0.28 Ch.22 = 0.089 Ch.23 = 18.5 Ch.24 =
RMS LOG ERROR: 2.31E-02, ANTILOG YIELDS 5.4585 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.11						
P 2	0.05	0.19					
P 3	0.00	-0.02	0.74				
T 1	0.05	0.19	-0.04	0.95			
T 2	-0.10	-0.33	0.00	0.09	0.84		
F 1	0.00	0.00	0.00	0.00	0.00	0.00	
C 2	0.00	-0.04	0.02	-0.06	0.00	-0.06	0.64
	P 1	P 2	P 3	T 1	T 2	F 1	C 2


P7
MODEL:
2083.
OHM-M
542. M
172.
OHM-M
460. M
34.2
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: 3.10
CALIBRATION: 1
OFFSET: 229. M
RAMP: 270.0
Blackhawk Geosciences

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		512.1	1680.0		
2083.37	542.5	-30.4	-99.9	0.3	0.3
172.21	459.5	-490.0	-1607.5	2.7	2.9
34.16					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	2.39E-01	2.36E-01	0.991	
2	1.10E-04	1.71E-01	1.74E-01	-1.509	
3	1.40E-04	1.25E-01	1.26E-01	-1.083	
4	1.77E-04	9.61E-02	9.42E-02	2.013	
5	2.20E-04	7.50E-02	7.31E-02	2.589	
6	2.80E-04	5.68E-02	5.56E-02	2.252	
7	3.55E-04	4.19E-02	4.20E-02	-0.103	
8	4.43E-04	3.14E-02	3.19E-02	-1.448	
9	5.64E-04	2.22E-02	2.30E-02	-3.454	
10	7.13E-04	1.54E-02	1.62E-02	-4.929	
11	8.81E-04	1.16E-02	1.16E-02	-0.584	
12	8.90E-04	1.16E-02	1.14E-02	1.219	
13	1.10E-03	8.13E-03	8.19E-03	-0.777	
14	1.10E-03	8.30E-03	8.14E-03	1.898	
15	1.40E-03	5.52E-03	5.39E-03	2.580	
16	1.41E-03	5.37E-03	5.31E-03	0.998	
17	1.77E-03	3.81E-03	3.64E-03	4.738	
18	1.80E-03	3.56E-03	3.56E-03	-0.050	
19	2.20E-03	2.62E-03	2.60E-03	0.849	
20	2.22E-03	2.48E-03	2.56E-03	-2.989	
21	2.80E-03	1.80E-03	1.79E-03	0.278	
22	2.85E-03	1.65E-03	1.75E-03	-5.702	
23	3.55E-03	1.33E-03	1.27E-03	4.598	
24	4.43E-03	9.31E-04	9.37E-04	-0.585	
25	5.64E-03	6.99E-04	6.71E-04	4.044	
26	7.13E-03	4.45E-04	4.84E-04	-8.173	
27	8.81E-03	3.58E-04	3.57E-04	0.110	
28	1.10E-02	2.73E-04	2.61E-04	4.761	
29	1.41E-02	1.78E-04	1.78E-04	-0.026	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000
TDHZ ARRAY, 29 DATA POINTS, RAMP: 270.0 MICROSEC, DATA: P7
3103 0007 0007 Z OPR XTL H 6 8+100
Ch.21 = 0.27 Ch.22 = 0.089 Ch.23 = 18.5 Ch.24 =
RMS LOG ERROR: 1.32E-02, ANTILOG YIELDS 3.0978 %
EARLY TIME PARAMETERS

PARAMETER RESOLUTION MATRIX: